Water Control Manual

Yellowtail Dam and Bighorn Reservoir

Bighorn River
Montana

U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

October 2022

Yellowtail Dam

Yellowtail's Afterbay Dam and Bighorn Canal

NOTICE TO USERS OF THIS MANUAL

Regulations specify this Water Control Manual be published in a hard copy binder with loose leaf form, and only those sections, or parts thereof, requiring changes will be revised and printed. Therefore, this copy should be preserved in good condition so that inserts can be made to keep the manual current. Changes to individual pages must carry the date of revision, which is the Division's approval date. A digital copy is published at the following link: https://water.usace.army.mil/

REGULATION ASSISTANCE PROCEDURES

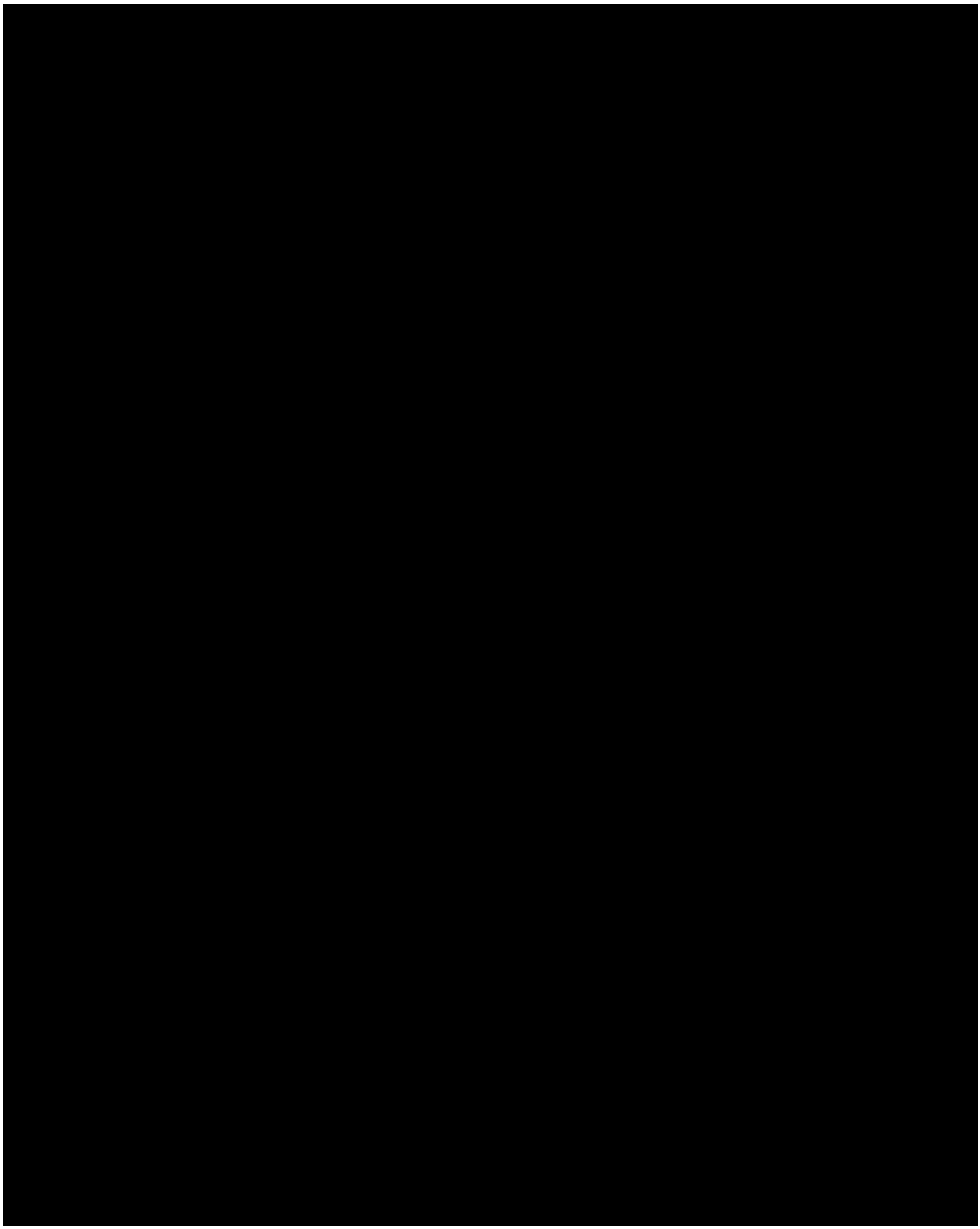

Table of Contents

TABLES

PLATES

EXHIBITS

Yellowtail Dam and Bighorn Reservoir Pertinent Data

GENERAL	
Location of Dam	22 miles north of Montana-Wyoming State Line, and 45 miles southwest of Hardin, Montana.
County	Big Horn
Drainage area, Bighorn River above Boysen Dam	7,710 sq. mi.
Drainage area, Shoshone River above Buffalo Bill Dam	1,498 sq. mi.
Drainage area, Bighorn River above Yellowtail Dam	19,626 sq. mi.
Drainage area, Bighorn River above mouth	22,940 sq. mi.
Authorization	Flood Control Act approved December 22, 1944 (Public Law 534, 78th Congress, 2nd Session)
Purpose of Project	Power production, irrigation, industrial water, flood control, fish & wildlife, and recreation.

DAM	
Type	Concrete Arch
Crest elevation	3660.0 feet
Crest Width	22 feet
Base thickness at center of arch	145 feet
Crest length	1,450 feet
Height above streambed	494 feet
Height above foundation excavation	525 feet
Date of completion	December 1966
Date of closure	Water storage began November 3, 1965
SPILLWAY	
Location	Left abutment
Type	Gated intake with concrete lined tunnel
Crest Elevation	3593.0 feet
Number of crest gates	2
Type of crest gates	Radial
Width of crest gates	25 feet
Height of crest gates	64.4
Type of gate operating machinery hoist	Motor driven with counterweighted gate hoists
Discharge capacity at max. water surface elev. 3660.0 ft	92,000 cfs
Length of spillway tunnel	1,890 feet
Minimum diameter of spillway tunnel	32 feet
OUTLET WORKS	
Evacuation and irrigation outlet	2 – 84 inch inside diameter
Location	Center of dam to right of power penstocks
Length of pipe	289 feet (irrigation outlet), 216 feet (evacuation outlet)
Control	Ring-follower gate, hollow jet valve, and bulkhead
Maximum allowable discharge	2,500 cfs each
Intake elevation C.L.	3400.0 feet (irrigation outlet) 3300.0 feet (evacuation outlet)
Grapevine tunnel (future irrigation)	1 – 9.5 foot inside diameter
Location	Left abutment of dam
Length of tunnel	305 feet
Control	Bulkhead gate (fixed wheel in future)
Discharge capacity at top of inactive elev 3547 ft.	862 cfs
Intake elevation C.L.	3535.0 feet
POWERPLANT	
Power Penstocks	4 – 12 feet inside diameter
Location	Center of dam
Length of penstocks	2 – 396 feet, 2 – 398 feet
Control	Fixed wheel gates on upstream face of dam and turbine wicket gates.
Discharge capacity (at design head)	2,000 cfs per unit
Intake elevation C.L.	3450.0 feet NGVD29
Turbines	4-Francis Type @ 87,500 HP
Generators	4-Vertical Shaft @ 72,000 kW
Plant Capacity	288,000 kW
AFTERBAY DAM	
Location	2.3 miles downstream from Yellowtail Dam
Storage	3,141 acre-feet
Top of dam elevation	3204.6 feet
Maximum operating water surface	3192.0 feet – 2,877 acre-feet
Discharge capacity	
Overflow weir (5 – 30x13.5 foot radial gates)	15,500 cfs
Sluiceway (3 – 10x8 foot slide gates)	4,500 cfs
Bighorn Canal (2 – 10x8 foot slide gates)	750 cfs

RESERVOIR USE	Elevation Limits (feet)	Capacity (acre-feet)
Surcharge Storage Zone	3657.0 – 3660.0	48,708
Flood Control Storage Zone	3640.0 – 3657.0	252,630
Joint Use Storage Zone	3614.0 – 3640.0	232,735
Conservation Storage Zone	3547.0 – 3614.0	310,844
Inactive Storage Zone	3296.5 - 3547.0	449,118
Dead Storage Zone	3166.0 - 3296.5	18,355

RESERVOIR POOLS	Elevation Storage (feet)	Gross Area (acres)	Gross (acre-feet)
Maximum Water Surface	3660.0	16,446	1,312,390
Top of Flood Control Storage (Top of Spillway Gates)	3657.0	16,026	1,263,682
Top of Joint Use Storage	3640.0	13,627	1,011,052
Top of Conservation Storage	3614.0	5,979	778,317
Top of Inactive Storage	3547.0	4,002	467,473
Top of Dead Storage (River Outlet Invert)	3296.5	398	18,355
Streambed Elevation at Dam Axis	3166.0	0	0

DESIGN FLOODS	Max. Flood Inflow (cfs)	Max. Flood Outflow (cfs)	Peak Pool Elev. (feet)	Flood Inflow Volume (acre-feet)
Reservoir Design Flood (52-day volume)	37,500	21,000	3656.2	2,044,000
Original Spillway Design Flood (10-day volume)	126,000	99,000	3659.1	1,070,000
Updated Spillway Design Flood (19-day volume)	887,000	630,600	overtopped	4,700,000

ABBREVIATIONS

af	acre-feet
CCC	Casper Control Center
cfs	cubic feet per second
CFR	Code of Federal Regulations
Corps	Corps of Engineers
Co-op	Cooperative stream gaging program
CWMS	Corps Water Management System
EAP	Emergency Action Plan
EM	Engineering Manual
ER	Engineering Regulation
FWA	Field Working Agreement
HEC	Hydrologic Engineering Center
HEC-ResSim	Reservoir Simulation Software
HEC-HMS	Hydrologic Modeling System Software
kW	Kilowatt
MDNRC	Montana Department of Natural Resources and Conservation
System	Missouri River Mainstem Reservoir System
MRBWM	Missouri River Basin Water Management
MTAO	Montana Area Office
MW	Mega Watts
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWD	Northwestern Division
NWS	National Weather Service
PMF	Probable Maximum Flood
Reclamation	United States Bureau of Reclamation
SNOTEL	Snow Telemetry
SWE	Snow Water Equivalent
USGS	United States Geological Survey
WYAO	Wyoming Area Office
WCWQS	Water Control and Water Quality Section
WDEQ	Wyoming Department of Environmental Quality

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CHAPTER 1—INTRODUCTION

1-01 AUTHORIZATION

This manual was prepared in compliance with the following authorities and directives:

- Engineering Regulation (ER) 1110-2-240, "Water Control Management", May 30, 2016
- Section 7 of the Flood Control Act, Dec 22, 1944
- 33 Code of Federal Regulations (CFR) Chapter II Part 208, Flood Control Regulations, Section 208.11.
- ER 1110-2-8156 "Preparation of Water Control Manuals", Sep 30, 2018

1-02 PURPOSE AND SCOPE

Yellowtail Dam and Bighorn Lake was constructed by the Bureau of Reclamation (Reclamation) on the Bighorn River and was completed in 1966. This water control manual covers the regulation of the reservoir only for flood control purposes as designated in legislation and regulations identified in Section 1-01. This manual also contains current information about the dam and reservoir as well as descriptions of the project and its history, watershed characteristics, the data collection and communications network, and the organizations responsible for collecting data and regulating the reservoir.

1-03 RELATED MANUALS AND REPORTS

a. Senate Document 191, 78th Congress, 2nd Session, "Missouri River Basin, Conservation, Control and Use of Water Resources, April, 1944."

b. U.S. Department of the Interior, Bureau of Reclamation, "Definite Plan Report on Yellowtail Unit, January, 1950."

c. U.S. Department of the Interior, Bureau of Reclamation, "Report on Yellowtail Unit, Lower Bighorn Division, Missouri River Basin Project, June, 1962."

d. Field Working Agreement (FWA) between U.S. Bureau of Reclamation and U.S. Army Corps of Engineers governing the regulation of Yellowtail Dam and Bighorn Lake, June 2023.

e. Bureau of Reclamation, "Standing Operating Procedures – Yellowtail Dam and Yellowtail Afterbay Dam, Montana, August 2000."

f. Bureau of Reclamation, "Emergency Action Plan, Yellowtail Dam, Montana, September 2014."

g. Yellowtail Dam Reallocation Study, Omaha District, Corps of Engineers, April 2010.

h. U.S. Department of the Interior, Bureau of Reclamation, “Final Draft Report, Yellowtail Unit Operating Criteria Evaluation Study and Report, April 9, 2012”.

1-04 PROJECT OWNER

Yellowtail Dam was constructed by Reclamation.

1-05 OPERATING AGENCY

Reclamation’s Montana Area Office (MTAO) is responsible for the operation and maintenance of the Yellowtail Dam Facility. Forecasting reservoir inflows and directing water releases associated with the reservoir during normal operations is performed by the Reservoir and River Operations Group of the MTAO. The Casper Control Center (CCC) is responsible for the remote daily operation of the generating units, and for monitoring and reporting reservoir level, inflow, river releases, and power generation. The CCC is responsible for most of the gate changes which are scheduled and directed by the Reservoir and River Operations Group of the MTAO. The spillway gates and river outlet gates cannot be remotely operated from the CCC and must be manually operated from the dam. All releases for power generation and river flows are closely coordinated with Western Area Power Administration.

1-06 REGULATING AGENCIES

The organization for Yellowtail Dam and Reservoir is based on a division of regulating responsibility between Reclamation and the U.S. Army Corps of Engineers (Corps). In accordance with the Flood Control Act of 1944, the Corps is responsible for the regulation of storage allocated to flood control as described in the Water Control Plan. All other regulatory functions are the responsibility of Reclamation’s MTAO. Personnel from these offices are listed in the directory of regulation personnel on page v, Regulation Assistance Procedures, at the beginning of this water control manual.

1-07 VERTICAL DATUM

In the original design and construction of Yellowtail Dam, elevations on design drawings and reservoir levels referenced the Sea Level Datum of 1929. This was based on measured water levels at 26 tide stations in the United States and Canada, and commonly referred to as "feet above mean sea level”. In 1973 the Sea Level Datum of 1929 was renamed the National Geodetic Vertical Datum of 1929 (NGVD29). **Unless specifically noted, all elevations in this manual are referenced to NGVD29**. The NGVD29 datum was subsequently replaced by the North American Vertical Datum of 1988 (NAVD88) as the current vertical reference datum used by the National Oceanic and Atmospheric Administration. The NAVD88 is based on a single point as the reference point from which all other elevations are measured. As such, the conversion from the NGVD29 to the NAVD88 varies depending on location. As specified in ER 1110-2-8160, long-term efforts shall be programmed to transition from older datums to NAVD88.

In this water control manual, elevations for reservoir levels and project drawings are based upon the National Geodetic Vertical Datum of 1929 (NGVD29) and have not been converted to the North American Vertical Datum of 1988 (NAVD88) because of the desire to provide elevation data that is consistent with historical events and the original design drawings for the project. If elevations referenced to the NAVD88 datum are needed, at Yellowtail Dam to convert from NGVD29 datum to NAVD88 add 2.92 feet.

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CHAPTER 2—DESCRIPTION OF PROJECT

2-01 LOCATION

Yellowtail Dam is located on the Bighorn River, 22 miles north of the Montana-Wyoming state line and 45 miles southwest of Hardin, Montana. The dam is located in Big Horn County. Plate 2-1 shows the location of Yellowtail Dam and Bighorn Reservoir within the Yellowstone River basin.

2-02 PURPOSE

Yellowtail Dam was constructed by Reclamation on the Bighorn River as a multi-use project. The reservoir is regulated to provide a flood risk mitigation to the Bighorn River downstream from the dam and to the Yellowstone River downstream from its confluence with the Bighorn River. Listed below are the other purposes.

a. Purposes Assigned by Congress

1) Irrigation

2) Hydropower

3) Flood control

4) Recreation

5) Fish and wildlife

6) Industrial

7) Sediment retention

b. Purposes Subsequently Assigned by Congress

None.

c. Purposes Derived from General Congressional Acts

1) Endangered Species Act of 1973, as amended (16 U.S.C 1531 et seq.)

d. Incidental Benefits

The major benefits provided by Yellowtail Dam are attributed to the authorized purposes.

2-03 PHYSICAL COMPONENTS

The physical components of Yellowtail Dam and afterbay are shown on Plate 2-2 to 2-6 and are described below.

a. Embankment

Yellowtail Dam is a variable thickness concrete arch-type structure with an axis radius of 800 feet. The height of the dam is 525 feet above the lowest point in the foundation, and the length of the roadway crest is approximately 1,450 feet. Embankment drawings are shown on Plates 2-2 and 2-3.

b. Spillway

An inclined spillway tunnel is located through the left abutment rock and is capable of discharging 92,000 cubic feet per second (cfs). The spillway crest is controlled by two 25 by 64.4 foot radial gates operated by motor-driven counterweighted gate hoists. Spillway drawings are shown on Plate 2-4. Spillway discharge rating curves are shown on Plate 2-7.

c. Outlet Works

Two river outlets, having a combined allowable capacity of 5,000 cfs, provide bypass releases and can be used to augment the spillway discharge if needed. Each outlet is controlled by an 84-inch ring-follower gate and an 84-inch hollow-jet valve. For maintenance of the outlet conduits and ring-follower gates, a bulkhead gate is provided on the upstream face of the dam for closure of either outlet. Provision for future irrigation requirements is made through the Grapevine Tunnel intake, located through the left abutment of the dam. Outlet works drawings are shown on Plate 2-5. Outlet works discharge rating curves are shown on Plate 2-8.

d. Hydroelectric Power Facilities

Four 12-foot diameter penstocks extend through the dam to the powerplant located at the toe of the dam. The powerplant is an indoor-type structure with four generating units having a combined capacity of 288,000 kilowatts. The turbines are of the Francis type, and are rated at 87,500 horsepower each under an effective head of 440 feet. The discharge capacity of each turbine ranges from 1,710 cfs to 2,090 cfs for the operating levels of 355 feet at minimum head to 466 feet at maximum head, respectively. Powerplant drawings are shown on Plates 2-2 and 2-3.

e. Afterbay and Bighorn Canal

Yellowtail Afterbay Dam is located approximately 2.3 miles downstream from Yellowtail Dam. The aerial photograph on page iii shows the location of the Afterbay Dam relative to Yellowtail Dam. It is used to smooth out fluctuating discharges from Yellowtail Powerplant downstream and to supply the necessary water for irrigation requirements in the Bighorn Canal. The dam consists of five concrete overflow weir sections (regulated by five 30 by 13.5 feet radial gates) and three concrete sluiceway sections (regulated by three 120 by 96 inch slide gates) used to control flow on the river. The combination overflow weir (design capacity 15,500 cfs) and sluiceway (design capacity 4,500 cfs) is capable of discharging the safe river channel capacity of 20,000 cfs. In event of a flood whereby these design discharges would be exceeded, Reclamation will monitor the Afterbay structure for its safety. Plate 2-6 shows the plan, elevation and sections of the

Afterbay Dam. Afterbay sluiceway discharge rating curves are shown on Plate 2-9, Afterbay area-capacity curves are shown on Plate 2-11.

f. Reservoir

Bighorn Lake is about 71 miles long, 47 miles of which is in Bighorn Canyon. The canyon ends about 4.5 miles south of the Montana-Wyoming boundary, and there the reservoir increases to a maximum width of 2 miles. The maximum depth of the reservoir is about 500 feet. The storage allocations for the reservoir are shown in Table 7-1. New hydrographic and topographic surveys were conducted and a new elevation-area-capacity table and curve were developed and approved in 2020. The updated area-capacity curves are shown on Plate 2-10 and similar information is shown in the Pertinent Data Section and on Plate 7-1. Exhibit IV shows the area and capacity tables in one-foot increments and Exhibit V shows a more detailed version of the capacity table in tenth-foot increments. Plate 2-14 shows the reservoir inundated areas for the pool elevations of 3640.0 feet (top of joint use control zone) and 3657.0 (top of flood control zone). Additional information concerning sediment accumulation in the reservoir is contained in Section 4-04.

g. Water Supply Facilities

There are numerous diversions for irrigation located upstream and downstream of Yellowtail. See Section 3-04 for more information regarding upstream and downstream irrigation and facilities.

The Bighorn Canal intake is regulated by two 120 by 96 inch slide gates installed in the canal headworks at the right end of the concrete section of the dam. It is designed to discharge up to 750 cfs. Earth embankments at each end of the dam connect the concrete section to high ground at each abutment.

2-04 RELATED CONTROL FACILITIES

A number of reservoirs have been constructed in the Yellowstone Basin by Federal, State and private agencies. The primary purpose of most of these projects is irrigation with flood control storage space allocated only in the Boysen and Yellowtail projects. Powerplants have also been incorporated in several of the projects to develop hydroelectric potential. Section 3-04 contains additional information on related control facilities and Table 3-1 lists reservoirs in the Bighorn and Yellowstone River Basins having a storage capacity of more than 10,000 acre-feet (af).

2-05 REAL ESTATE ACQUISITION

The Crow Indian Reservation, spreading over about 3,500 square miles, encompasses the damsite and a portion of the reservoir area. Relocations necessary for Bighorn Lake were confined to the upper end of the lake. The town of Kane (population 20), 5 miles of railroad, 5 miles of rural electric transmission line, 3.5 miles of telephone line and a county bridge with connecting roads were relocated as part of the project. Also, in 1956 the Wyoming Highway Department rebuilt the bridge on State Highway 14 (now designated as Alternate U.S. Highway No. 14) across the Bighorn River. At that time, in anticipation of reservoir

backwater, the Bureau of Reclamation entered into an agreement with the highway department to pay the additional cost necessary to build the bridge 17 feet higher.

2-06 PUBLIC FACILITIES

Bighorn Lake and its environs provides outstanding recreational opportunities of local, regional, and national interest. Congress has designated the reservoir surface and some of the surrounding area as the Bighorn Canyon National Recreational Area. This area, comprising about 63,000 acres, is administered by the National Park Service. The reservoir has 12,700 surface acres of lake and 191 shoreline miles, and offers good fishing opportunity for walleye, brown trout, and ling. Information on the Bighorn Canyon National Recreation area can be found on the National Park Service website at http://www.nps.gov/bica.

The Bighorn River downstream of Yellowtail Afterbay Dam boasts a blue-ribbon trout fishery. There are numerous river access points that allow fisherman to wade in or utilize a boat ramp.

CHAPTER 3—HISTORY OF PROJECT

3-01 AUTHORIZATION

The Definite Plan Report on the Yellowtail Unit (which consists of a dam and reservoir, a powerplant and switchyard, and an afterbay and dam), dated January 1950, was approved by the Bureau of Reclamation Commissioner in November 1950. Congress did not approve construction, however, until 1961. Yellowtail Unit is a part of the Missouri River Basin Project as authorized by Section 9 of the Act of Congress approved December 22, 1944 (58 Stat. 887), referred to as the Flood Control Act of 1944.

3-02 PLANNING AND DESIGN

First investigations by Reclamation were made during 1903-1905 to study the feasibility of making a gravity diversion near the Yellowtail damsite to a canal system along the west side of the river. Investigations started in 1913, and a detailed report dated October 24, 1917, recommended construction of a gravity arch dam of rubble concrete about 480 feet high, a powerplant with 500 miles of transmission lines, and 62 miles of highline canals to irrigate 60,000 acres of benchland. Reclamation investigations of the Yellowtail Dam and Bighorn Lake sites in 1939-1942 were later summarized and published in Senate Document 191, 78th Congress, 2nd session, in which a low dam at the Yellowtail site and one at the Kane site were proposed to be operated in conjunction with a total installed capacity of 105,000 kilowatts. The Definite Plan Report, dated January 1950, was approved by the Commissioner of Reclamation on November 10, 1950. The report substantiated conclusions that a single high dam at the Yellowtail site would be more economical than the two smaller dams.

3-03 CONSTRUCTION

Initial excavation of the dam abutments started in the summer of 1961. The river diversion was made January 22, 1963. Deliberate fill of Bighorn Lake began in November 1965 and fill of the inactive space was completed during June 1966. The first power unit was placed in service in August 1966, while the last of the four units was on the line in November 1966. The conservation storage space was first filled on June 13, 1967, after which exceptionally large inflows filled the joint use storage space and encroached upon the exclusive flood control storage space on June 23, 1967. A maximum pool level of 3656.4 feet occurred on July 6, 1967, only 0.6 feet below the reservoir surcharge level. These high levels necessitated reservoir releases of about 25,000 cfs, a major portion of which was through the spillway. Subsequent examination indicated damage to the spillway structure as a result of these releases. Spillway rehabilitation required a substantial lowering of the reservoir level in 1968, and in May of that year a minimum reservoir level of 3585.7 feet was recorded. Completion of this rehabilitation allowed the resumption of normal operation in 1969.

3-04 RELATED PROJECTS

A number of reservoirs have been constructed in the Bighorn River basin upstream from Yellowtail Dam by Federal, State and private agencies. The primary purpose of most of these projects is irrigation, with flood control storage space allocated only in the Boysen and Yellowtail projects. Powerplants have also been incorporated in several of the projects to

take advantage of hydroelectric potential. Table 3-1 lists reservoirs in the Bighorn and Yellowstone River Basins having a storage capacity of more than 10,000 af. Numerous smaller irrigation storage reservoirs and ponds are also present in the watershed.

Table 3-1 Reservoirs in Bighorn and Yellowstone River Basin

Reservoir	Stream	Total Capacity (af)	Year Dam Closed	Operated by
Bull Lake	Bull Lake Creek	152,000	1938	USBR
Pilot Butte	Wyoming Canal	34,000	1926	USBR
Boysen	Wind River	892,000[1]	1951	USBR
Anchor	Owl Creek	17,200	1960	USBR
Sunshine	Greybull River	53,000	1942	GVID
Buffalo Bill	Shoshone River	646,565	1903	USBR
Bighorn Lake	Bighorn River	1,263,682	1965	USBR
Mystic Lake	Stillwater River	20,800	1925	NWE
Cooney	Clarks Fork	27,500	1936	MWCB
Tongue River	Tongue River	69,400	1939	MWCB

USBR – U.S. Bureau of Reclamation
GVID – Greybull Valley Irrigation District
NWE – Northwestern Energy
MWCB - Montana Water Conservation Board
[1] Contains 150,600 af of exclusive flood control zone which can be partially controlled.

All these reservoirs along with many natural lakes in the basin have some effect on streamflow; however, except for Boysen and Buffalo Bill, the reservoirs are usually full before the peaks from large floods occur and offer little reduction in the yearly peak flow. Additional information on Boysen and Buffalo Bill Reservoirs is given below:

a. Boysen Dam and Reservoir

Boysen Dam controls a major portion of the inflows to Bighorn Lake. The Corps of Engineers is responsible for regulation of the Exclusive Flood Control Zone and has shared responsibility with Reclamation for regulation of the joint use storage zone. May-July runoff forecasts made by the Corps are used to set the pool elevation of responsibility. When the pool elevation of responsibility is exceeded or the downstream flood targets are exceeded the Corps is responsible for release decisions. When the pool elevation is below the pool elevation of responsibility and the downstream flood targets are not exceeded, Reclamation is responsible for release decisions. Boysen has flood targets at Kane, WY, Bighorn, MT and Miles City, MT. Operations at Boysen will be modified to avoid exceeding the targets whenever doing so will not result in more damaging releases to the Bighorn reach later in the snowmelt season. Reclamation has the responsibility for hydropower, irrigation, recreation, fish and wildlife and other conservation purposes as well as for maintenance of the project. Normal regulation is made through the powerplant or a bypass valve, which have capacities of 2,400 cfs and 1,400 cfs, respectively. The spillway has two radial gates, 30 x 25 feet, through which larger releases are made. Reference the Boysen Reservoir Water Control Manual for further details relating to this project. The area-capacity curves for Boysen Reservoir are shown on Plate 2-12.

b. Buffalo Bill Reservoir

This reservoir is part of Reclamation's Shoshone Project which includes the Shoshone powerplant and Heart Mountain powerplant. The reservoir is located on the Shoshone River above Cody, WY and controls a major portion of Bighorn Lake inflow. The Corps has no operational authority at Buffalo Bill. Buffalo Bill provides flood control benefits to downstream reaches, but no storage is specifically allocated for this purpose. A dam modification project began in 1985 and was completed in 1993. The dam was raised nearly 25 feet and added 260,000 af of additional storage. Its current maximum storage capacity is 646,565 af. The area-capacity curves for Buffalo Bill Reservoir are shown on Plate 2-13. The project is designed to serve the irrigation needs for about 88,000 acres, and releases to provide this service may be made through the following:

1) The Canyon Conduit, which obtains its water from a high-level outlet at Buffalo Bill Dam, has a capacity of 1,200 cfs. This feeds the Heart Mountain powerplant (nameplate capacity, 5,000 kW) with a maximum discharge capacity of about 350 cfs and the Heart Mountain canal, which has a 900 cfs capacity.

2) The Shoshone powerplant (nameplate capacity, 6,000 kW) has a maximum discharge capacity of about 600 cfs and is located at the toe of Buffalo Bill Dam.

3) The river outlet has a maximum capacity of about 3,000 cfs at full pool.

4) The spillway has a maximum capacity of 25,000 cfs.

5) The dam was redesigned to safely overtop during an extremely large runoff event.

Normal operation consists of scheduling releases to attain a minimum elevation prior to the May-July mountain snowmelt runoff period. This minimum level will be dependent on the water supply, both past and anticipated, but with normal events a drawdown of 5365 feet, or about 432,000 af can be expected. The reservoir draft is often increased in years with above average mountain snowpack. The maximum flow of the Shoshone River since construction was 18,700 cfs in 1918. Since the construction of Yellowtail Dam the maximum flow of 16,400 cfs occurred in June 1981.

c. Bull Lake

Bull Lake, with a capacity of 152,000 af, is the largest reservoir above Boysen. Bull Lake is part of Reclamation’s Riverton Unit. The Corps has no operational authority at Bull Lake.

d. Pilot Butte

With a capacity of 34,000 af, Pillot Butte is one of the larger reservoirs above Boysen. Pilot Butte is part of Reclamation’s Riverton Unit. Pilot Butte is an off-stream storage

project whose inflows are fed via Midvale Irrigation District's Wyoming Canal on the Wind River. The Corps has no operational authority over this reservoir.

e. Sunshine Reservoir

Sunshine Reservoir is on the Wood River below Boysen Dam. The Wood River is a tributary of the Greybull River. Sunshine Reservoir is operated by Greybull Valley Irrigation District. The Corps has no operational authority.

f. Garrison Dam and Lake Sakakawea

Garrison Dam is on the Missouri River downstream of the mouth of the Yellowstone River. Releases from Yellowtail Dam take 4-5 days to reach Garrison Dam.

g. Irrigation Projects

Due to the arid climate of interior portions of the Bighorn basin, irrigation is extensively practiced throughout the basin. It is estimated the total irrigated area in the Bighorn basin now approximates 465,000 acres. Over 300,000 acres are irrigated in the drainage area above Yellowtail Dam.

Irrigation occurs along most of the Bighorn tributaries between Boysen and Yellowtail. These tributary diversions remove water and consume the water before it reaches the Bighorn River. These tributaries include Nowood River, Owl Creek, Greybull River, Shell Creek, and Shoshone River.

The Shoshone River has a large irrigated area. Buffalo Bill Reservoir supplements the irrigation needs of the Shoshone Valley. About 15 miles and 25 miles downstream from Buffalo Bill on the Shoshone River are the Corbett and Willwood diversion dams and their associated irrigation canals. The Corbett canal has a capacity of 1,000 cfs and the Willwood canal's capacity is 300 cfs. These full channel capacities would be used only at times of maximum irrigation demands.

Irrigation from the vicinity of the present Yellowtail damsite started with development of the Reno Unit in 1885 by the Indian Service (now Bureau of Indian Affairs) to the benefit of the Crow Indians. At present, the Bighorn Canal can divert 750 cfs from the Yellowtail project. The Bighorn Canal is located at the Afterbay Dam. Two-Leggings Canal and Victory Canal also divert water downstream of Yellowtail.

Table 3-2 is a list of the irrigation projects in the Bighorn watershed. The average monthly diversions from April-September are shown. These diversions occur regularly and cyclically, except after large rainfall events. Heavy winter snowpack can also delay and decrease diversions. The effects of diversions should be taken into account during runoff events.

Table 3-2. Irrigation Projects and Average Diversions in the Bighorn River Basin

Diversion Name			Average Monthly Diversion, cfs					
Wind River	lat	long	Apr	May	Jun	Jul	Aug	Sep
Dinwoody Canal	43.382	109.367	70	49	55	66	59	50
LeClair Canal at Headworks	43.108	108.663	25	147	263	321	265	192
Upper Wind River A Canal at Headworks, near Burris, WY	43.408	109.312	3	54	64	55	58	52
Riverton Valley Irrigation District Canal at Headworks	43.026	108.495	19	92	116	136	104	77
Midvale Irrigation District (Wyoming Canal)	43.226	108.950	279	828	1262	1380	1080	815
Johnstown Ditch near Kinnear	43.150	108.728	0	13	23	26	25	20
Aragon Ditch at Headworks	43.191	108.784	-	22	39	29	28	21
Winchester Ditch at Headworks	43.231	109.025	4	8	15	16	23	20
Coolidge Canal, Little Wind Res	43.018	108.833	0	94	133	108	64	46
Ray Canal, Little Wind Res	43.001	108.932	13	104	198	234	174	107
Sub-Agency Canal Res	42.993	108.616	8	99	81	116	100	72
Bighorn River above Shoshone River								
Upper Lucerne Canal	43.697	108.178	3	27	5	38	36	29
Highland Hanover	43.932	107.964	22	81	96	122	114	66
Lower Hanover Canal	43.974	107.991	67	135	159	178	157	101
Lower Lucerne Canal	43.688	-108.186	4	31	41	46	39	24
Upper Hanover Canal	43.853	108.174	192	415	34	496	456	381
Bighorn Canal near Worland	43.945	108.016	203	415	452	491	446	382
Kirby Canal at Headworks	43.679	108.182	5	51	65	68	61	50
Bench Canal (Greybull)	44.403	-108.554	21	138	195	237	184	121
Bluff Canal	43.871	108.136	42	93	105	111	103	83
Shoshone River								
Cody Canal	44.472	109.182	31	172	240	252	203	147
Deaver-Frannie Canal	44.833	108.696	68	243	255	263	264	249
Elk Lovell Canal	44.710	108.704	83	265	313	338	317	276
Frannie Canal	44.731	108.826	127	721	786	868	825	633
Garland Canal	44.637	108.943	285	742	808	872	793	651
Globe Canal	44.792	108.495	11	42	46	54	51	45
Heart Mountain Canal	44.518	109.127	128	458	724	782	653	459
Hunt Canal	44.842	108.427	27	89	101	114	108	92
Lakeview Canal	44.321	109.417	20	130	214	218	179	123
Sidon Canal	44.740	108.597	96	227	260	287	275	235
Willwood Canal	44.672	108.909	103	256	264	351	324	256

1973-2003 average flows provided by “Bighorn Wind Water Plan 2003” produced by the State of Wyoming

3-05 DAM SAFETY HISTORY AND ISSUES

Reclamation is responsible for dam safety at Yellowtail Dam. To date no significant dam safety issues have occurred at Yellowtail Dam.

The Yellowtail Afterbay Dam is designed to be breached above flows of 20,000 cfs. In 1967 approximately 25,000 cfs was released through the afterbay with some complications. Reclamation is responsible for the operation of the Yellowtail Afterbay Dam.

3-06 PRINCIPAL REGULATION PROBLEMS

One problem associated with Yellowtail Dam regulation is the inability to pass the revised Probable Maximum Flood (PMF), discussed in further detail in Section 8-02.a. Failure of Yellowtail Dam as result of overtopping is unlikely due to the remote probability of the overtopping flood events and the low estimated probability of erosion of the foundation rock necessary to fail the dam. Other operational issues are discussed in Section 7-02, Constraints.

3-07 MODIFICATION TO REGULATIONS

a. Field Working Agreement For Water Control Between Bureau of Reclamation And U.S. Army Corps of Engineers, 21 Sep 1971

The original FWA set elevation and storage volumes of exclusive flood control and joint use storage as well as the other pool zones. It also outlines flood control operations and release responsibility in the Joint Use Zone as it pertains to flood control and conservation.

b. Current Field Working Agreement

The current FWA modifies the 1971 agreement to further outline Missouri River System Flood Control Operations as seen in Section 7-05.

CHAPTER 4—WATERSHED CHARACTERISTICS

4-01 GENERAL CHARACTERISTICS

The Bighorn River is a tributary of the Yellowstone River, which in turn is a tributary of the Missouri River. The Missouri River has a drainage area of 529,350 square miles, the Yellowstone River has a drainage area of 70,400 square miles, and the Bighorn River has a drainage area of 22,940 square miles.

The Yellowstone River Basin is located in north-central Wyoming, southeastern Montana, and extreme western North Dakota. The basin is roughly pear-shaped, with a length of about 440 miles and a maximum width of about 310 miles. Of the total drainage area, 70,400 square miles, roughly half is in Montana and half is in Wyoming, with 740 square miles in North Dakota.

The Yellowstone River originates in Yellowstone National Park and flows in a northeasterly direction to its confluence with the Missouri River near Williston, North Dakota. There are four main tributaries, all of which flow from the south: Clarks Fork, entering near Laurel, MT; Bighorn River, entering near Custer, MT; Tongue River, entering at Miles City, MT; and the Powder River entering near Terry, MT. Drainage areas, lengths, and slopes of the main stem and the principal tributaries are shown in Table 4-1.

Table 4-1. Main Stem and Principal Tributaries

Stream	Drainage Area Square Miles	Length Miles	Average Slope Feet per Mile
Yellowstone	70,400	671	13
Clarks Fork	2,850	151	28
Wind	7,750	160	17
Bighorn	22,940	461	15
Tongue	5,440	265	27

The main stem of the Yellowstone River below the mouth of the Bighorn River flows in a meandering channel through an alluvial flood plain 1.5 to 7 miles in width. The flood plain is mostly farmland, with a large part of it irrigated.

The Bighorn River drains an oval-shaped area between the Wind River and the Absaroka Mountain Ranges on the west and the Bighorn Mountains on the east. The basin is about 260 miles long in a north-south direction and 160 miles in maximum width, and is 22,940 square miles in area, of which 18,880 square miles are in Wyoming and 4,060 square miles in Montana.

The Bighorn River from the headwaters near Togwotee Pass to the mouth of the Wind River Canyon is named the Wind River. As the river leaves the Wind River Canyon its name changes to the Bighorn River, which continues to flow northward through the arid high plains of north central Wyoming. Near the Wyoming-Montana state line the river enters the deep

and narrow Bighorn Canyon, at the mouth of which Yellowtail Dam has been constructed. Below the dam, the Bighorn River continues to flow northward through the rolling plains area of eastern Montana to its junction with the Yellowstone River, about 280 river miles above the Yellowstone's confluence with the Missouri River.

Major tributaries to the Bighorn River between Boysen and Yellowtail Dams are the Greybull and Shoshone Rivers, whose headwaters are in the Absaroka mountain range. Nowood Creek and Shell Creek are the largest tributaries draining the Bighorn Mountains entering in this reach, while below Yellowtail Dam the Little Bighorn River, which also drains portions of the Bighorn mountain range, is the only major downstream tributary. Plate 4-2 outlines the major subbasins above Yellowtail Dam.

4-02 TOPOGRAPHY

Elevations in the Bighorn basin range from 13,785 feet on Gannet Peak in the Wind River Range and 5,000 feet in the Wind River valley near Riverton to less than 3,000 feet near the Yellowstone River. Slopes of the river and all its major tributaries are characteristically steep in the mountainous headwater regions, becoming flatter as the river progresses downstream, with the least slope generally being experienced near the mouths. Natural vegetative cover ranges from coniferous forests in the higher mountain areas to essentially a desert culture of sage brush in interior portions of the basin. Outside of the higher elevations, trees are in abundance only along stream channels. In the Wyoming portion of the basin most lands are used for grazing except where irrigation is practiced and intensive farming is possible. Dryland wheat farming is practiced in the plains areas of Montana.

4-03 GEOLOGY AND SOILS

a. Geology

Yellowtail Dam is located on the Bighorn River near the mouth of the Bighorn Canyon, about 21 miles directly north of the Montana-Wyoming State line and 45 miles by road south and west of the city of Hardin, Montana. Bighorn Reservoir extends the full length of the canyon and onto the valley floor in the Bighorn Basin, Wyoming.

The Bighorn Mountains and adjacent Pryor Mountains, though separate structural units, are parts of a large anticlinal arch which extends northward from central Wyoming into southern Montana. During the process of uplift and erosion, the top and younger rock formations were removed. The remnants of the more resistant members form tilted and conspicuous hogbacks or long narrow ridges paralleling the mountains and marking the transition from the plains. The Bighorn River maintained its course by erosion during the period of uplift. The resulting canyon has a maximum depth of about 2,000 feet. At the Yellowtail Dam site, it is about 2,500 feet wide and 800 feet deep, exposing (in downward succession) the Tensleep sandstone, the Amsden formation, and the Madison limestone. A geological description of the area above Boysen Dam can be found in the Boysen Water Control Manual.

b. Soils

Central Wyoming is ecologically diverse and contains a wide range of environments; including shrub and grassland plains, alluvial valleys, volcanic plateaus, forested mountains, woodland and shrub land hills, glacial peaks, lava fields, and wetlands. These environments coupled with topographic gradients largely influence overall water flow, rates of infiltration, runoff response, and flow velocity in the region. The headwaters of the mountainous regions should be expected to be largely influenced by steep topographic gradients owing to high velocity flow rates of stormwater runoff and snow melt. Although the mountainous regions are predominantly forested and heavily vegetated, data gathered by the Wyoming Department of Environmental Quality (WDEQ) in the mountainous watersheds indicates that sedimentation in the mountainous streams may be caused by high flow velocities and uncontrolled erosion (WDEQ, 2010). As the smaller tributary creeks transition from the headwaters of the mountainous areas, they converge into the major tributaries culminating in larger flow volumes but with shallower topographic gradients. The Bighorn Valley is primarily an arid zone sparsely vegetated with sage brush except for the areas of major streams and rivers where trees line the banks. Based on the description of the Wind River Formation, infiltration from streams or rivers into the surrounding formation would be limited, thus confining stormwater runoff or snow melt to the topographic drainage features. Because vegetation is sparse and infiltration rates are anticipated to be low within the Wind River Valley, stormwater runoff response times would be relatively quick with the potential for flash flooding or high volume flows. Similar runoff behavior is expected through the Bighorn basin from the headwaters to Yellowtail Dam. Downstream of Yellowtail Dam an alluvial floodplain is bordered by high country hills. Plant growth in unirrigated areas is limited to pasture and sage brush.

4-04 SEDIMENT

The sediment storage allowance at Bighorn Lake is 315,000 af below elevation 3660.0 feet. The original sediment study for Bighorn Lake (took place in 1949), with an estimated allowance for the effect of Boysen Dam, estimated an average annual storage depletion at 4,570 af. This indicated the space would be filled in 69 years. A later study for the period 1952-1958, after the closure of Boysen Dam, estimated the average annual storage depletion as 3,660 af. This indicates the space would be filled in 86 years.

The most recent hydrographic survey determined that Bighorn Lake has a storage capacity of 1,312,390 af and a surface area of 16,450 acres at reservoir elevation 3660.0 feet. Table 1 in Exhibit IV shows the capacity table in one-foot increments and Table 2 in Exhibit IV shows the area table in one-foot increments. Exhibit V shows a more detailed capacity table in tenth-foot increments. The updated area-capacity curve is found on Plate 2-10. Based on the most recent survey, actual sediment accumulation rate has been 2,281 af per year.

4-05 CLIMATE

The Bighorn River drainage area is characterized by climate extremes, both by area and from season to season. Table 4-2 gives period of record values for temperature, snowfall and precipitation at Yellowtail Dam.

Table 4 2. Normal Climate Values at Yellowtail Dam Jul 1948 – Jun 2016

Month	Average Max Temperature (°F)	Average Min Temperature (°F)	Average Precipitation (inches)	Snowfall Depth (inches)
January	38.3	16.8	0.9	9.0
February	43.4	21.6	0.7	6.5
March	51.1	27.3	1.3	6.2
April	61.3	36.3	2.1	2.9
May	70.7	44.6	2.9	0.2
June	80	52.5	2.6	0.0
July	90.2	58.6	1.3	0.0
August	89.5	57.1	1.0	0.0
September	77.6	47.7	1.8	0.1
October	64.5	38.8	1.7	1.0
November	49.5	28.4	0.9	3.4
December	40.6	19.8	0.8	7.0
Annual	**63.1**	**37.5**	**17.8**	**36.2**

Source: Western Regional Climate Center Temperature and Precipitation data recorded at Yellowtail Dam station, whose last record was in 2016. http://www.wrcc.dri.edu/summary/Climsmwy.html

a. Evaporation

Evaporation was historically estimated using a 4-foot Class A evaporation pan. Evaporation is now calculated using a bulk flux evaporation estimate. This estimate uses real-time hydrometeorological data collected at the Billings Logan International Airport along with Yellowtail's physical properties to calculate an evaporated volume. Table 4-3 lists the input and output parameters needed to calculate evaporation.

Table 4-3. Bighorn Lake Evaporation Estimate Input and Output

Inputs	Unit	Parameter Name
Percentage of sky covered by high level clouds	%	%-Cloud-High
Percentage of sky covered by mid-level clouds	%	%-Cloud-Mid
Percentage of sky covered by low level clouds	%	%-Cloud-Low
Relative Humidity	%	%-Rel-Hum
Elevation of high-level clouds	meters	Elev-Cloud-High
Elevation of mid-level clouds	meters	Elev-Cloud-Mid
Elevation of low-level clouds	meters	Elev-Cloud-Low
Air pressure	kPa	Pres-Air
Wind Speed	m/s	Speed-Wind
Air Temperature	C	Temp-Air
Reservoir Area	meters	Area
Reservoir Elevation	meters	Elev
Outputs	**Unit**	**Parameter Name**
Irrad Sensible Heat	W/m^2	Irrad-Heat-Sensible
Irrad Latent Heat	W/m^2	Irrad-Heat-Latent
Short Wave Radiation Flux	W/m^2	Irrad-Flux-Solar
Long Wave Radiation Flux in	W/m^2	Irrad-Flux-IR
Long Wave Radiation Flux out	W/m^2	Irrad-Flux-IR-Out
Water Temperature (estimated at every half meter)	C	Temp-Water-Surface or Temp-Water-x,xm
Hourly Evaporation	mm	Evap
Daily Evaporation	mm	Evap
Daily Evaporated Volume	cms	Flow-Evap

b. Temperature

Temperatures during the winter season over the interior portions of the basin are typical of a continental area where downslope winds often occur. With an arctic outbreak, minimums of as low as 40 degrees below zero may occur while within a few days' maximums may reach as high as 60 degrees above zero. Summer temperatures of over 100 degrees often occur; however, with the low humidities common over the interior, diurnal temperature variations are usually large, resulting in cool nights with the hot days. A growing season of about 135 days occurs in the milder interior areas while at higher elevations this season may be shorter.

c. Precipitation

The high mountain ranges are relatively humid with normal annual precipitation of 30 inches or more. Interior regions sheltered by the mountains are desert in nature with some locations averaging 5 inches of precipitation annually. Large amounts of snow accumulate in the mountains during the winter months, of which most melts during the succeeding summer season; however, in the Wind River Range, glaciers exist. Snow also occurs over the interior plains during the winter season, but usually melts soon after it occurs, limiting significant accumulations. Warm season precipitation is usually in the

form of convective showers, originating over the mountains then drifting with the prevailing westerly winds over the interior plains. Rain showers will occur, but rainfall is often part of intense thunderstorm activity.

d. Wind

Severe windstorms of a general nature are not frequent but can occur several times per year, particularly during the late winter and spring. Prevailing winds are predominately from the southwest. However, the area is in or near the path of principal storms from the northwest. Between cold waves in the winter there are periods, sometimes longer than 10 days, of mild but often windy weather. These occasional warm, downslope winds are known as "chinooks", and tend to prevent deep accumulation of snow in the more open country. “Chinook” winds frequently reach speeds of 25 to 50 miles per hour or more and can persist with little interruption for several days.

4-06 STORMS AND FLOODS

Floods in the Yellowstone River Basin fall into three distinct types: floods caused by ice jams, accompanied by runoff from snowmelt in the lower areas of the basin; floods caused by the melting of the mountain snow cover, frequently in combination with rain in the foothills or plains areas; and floods caused by intense rains, which usually occur as summer thunderstorms.

a. Flood of 1918

The open-water flood of 1918, which is one of the greatest general floods of record in the Yellowstone River Basin, caused significant damage in both rural areas and river communities. Floodwaters along the Yellowstone River inundated nearly all the business and residential property in Forsyth, MT.

b. Flood of 1923

The greatest rainfall flood of record on the lower Bighorn River resulted from the storm of September 27 to October 1, 1923. This storm had a total duration of 108 hours, starting at 1 a.m. on September 27 and lasting until 1 p.m. on October 1. However, most of the rainfall occurred in the first two days. Some total rainfall reports from this storm were: Basin – 1.50”, Buffalo Bill Dam – 3.22”, Cody – 2.26”, Lander- 3.80", Lovell - 0.74", Riverton - 4.25", and Worland - 2 .64". At Hardin, this flood had a peak flow of 42,300 cfs and a 10-day volume of 380,000 af.

c. Flood of 1967

The natural May-July flow for 1967 was the highest of record to date at the St. Xavier stream gaging station. The June precipitation was 385 percent of average for 12 stations in the drainage area above Boysen, and 280 percent of average for 20 stations between Boysen and Yellowtail. About one third of these stations reported a monthly precipitation of near 6 inches or better. This rainfall and melting snowpack produced record daily inflows of 29,700 cfs on July 1. These inflows drove the reservoir elevation to a record 3656.4 feet. Releases were increased as the pool rose and reached a record 24,700 cfs on July 7. The Yellowtail Afterbay Dam design discharge is 20,000 cfs. The Afterbay

Dam was able to pass these flows without major damage to the Afterbay structure. Routing of this flood is shown on Plate 4-3.

d. Flood of 1997

The winter of 1997 brought near record snowpack. In preparation for the large runoff Yellowtail Dam was drafted to 3593.2 feet elevation on May 8. On June 10, Reclamation's MTAO notified the Corps Yellowtail's pool level was climbing fast and was close to the Exclusive Flood Control Zone. Reclamation also reported flooding in the upper Yellowstone River basin, and they planned to hold Yellowtail releases at 6,500 cfs for two more days until the Yellowstone River peaks at Livingston, MT and Corwin Springs, MT had passed Billings, MT. On June 11, higher than expected inflows into Yellowtail prompted Reclamation to incrementally increase Yellowtail releases from 6,500 cfs to 11,000 cfs over a three-day period. On June 13, Yellowtail releases were 11,400 cfs (including a 400 cfs release diverted by the Bighorn Canal). The Yellowstone River at Billings, MT peaked at approximately 82,000 cfs on June 12 and was at 77,000 cfs on June 13.

On June 16, Yellowtail Dam entered the Exclusive Flood Control Pool with releases of 11,400 cfs, and inflows of 19,000 cfs. Missouri River Basin Water Management (MRBWM) requested that releases be held at 11,400 cfs until Garrison's pool elevation peaked. The Corps' Yellowtail elevation forecast peaked at 3644.5 feet (24% of flood control pool occupied) on June 28. By June 17, Boysen Reservoir was close to entering its Exclusive Flood Control Zone. The Corps requested the Wyoming Area Office (WYAO) hold Boysen releases at 4,000 cfs to give relief to Yellowtail and Reclamation agreed to the request. Reclamation's Regional Office called to express concerns regarding Yellowtail and suggested that Corps make release reductions from Tiber Dam to reduce Fort Peck and Garrison inflows as an alternative to reducing Yellowtail releases. On June 18, a conference call involving MRBWM, the Omaha District Water Control and Water Quality Section (WCWQS), MTAO, WYAO, and Reclamation's Regional Office resulted in the decision to cut Tiber releases from 4,000 cfs to 1,000 cfs. This reduction over a 16-day period would decrease Garrison storage by 110,000 ac-ft (approximately 0.3 feet of elevation).

On June 19, Boysen Reservoir entered its Exclusive Flood Control Zone. The Corps increased releases from 4,000 cfs to 5,000 cfs on June 19 and from 5,000 cfs to 6,500 cfs by June 23. Concerns regarding the Garrison Reservoir possibly exceeding the top of the spillway gates resulted in a decision to cut Yellowtail releases from 11,500 cfs to 6,000 cfs at a reduction rate of 1,000 cfs per day. Yellowtail inflows were expected to drop from 14,000 cfs to 11,000 cfs over the same period. The updated Corps' forecasts had Yellowtail peaking at 3654.6 feet, filling 88% of the flood control pool. On July 2, large rainstorms dumped 5 inches of rain over the Garrison project area. High northwest winds pushed the Garrison pool level to 1854.7 feet and caused splashing over the spillway gates. The Corps cut Yellowtail releases from 6,000 cfs to 4,000 cfs to further relieve Garrison project inflows. On July 6, the Garrison project peaked and began passing inflows. From June 23 to July 7, the reduction from 11,500 cfs to 4,000 cfs from Yellowtail held back 142,600 af from the Garrison project (approximately 0.4 feet of Garrison pool elevation).

On July 11, the Corps reduced Boysen releases from 4,000 cfs to 3,000 cfs which was held until Boysen's Exclusive Flood Control Zone was evacuated. The Corps also increased Yellowtail releases from 4,000 cfs to 6,000 cfs. On July 14, Yellowtail pool peaked at 3651.6 feet with 68% of the Exclusive Flood Control Zone filled. On July 15, the Corps increased Yellowtail releases to full powerplant capacity (approximately 7,300 cfs) and held that release until Bighorn Reservoir left the Exclusive Flood Control Zone.

Table 4-4 shows discharge peaks for the event for streamgaging stations that are in the vicinity of Boysen and Yellowtail Dams and Plate 4-4 depicts the 1997 flood hydrograph.

Table 4-4

1997 Peak Flows near Yellowtail Dam

Location	Peak Flow (cfs) and Date
Bighorn River at Kane, WY	18,400 - June 11, 1997
Bighorn River at Basin, WY	16,900 - June 15, 1997
Wind River at Riverton, WY	10,100 - June 11, 1997
Wind River below Boysen Dam, WY	6,650 - June 22, 1997
Yellowstone River at Sidney, MT	87,400 - June 17, 1997

e. Flood of 2011

Snowpack in the Bighorn Mountains accumulated at approximately 120% of normal through April. Snowpack in April and May increased dramatically as numerous snowstorms hit the Bighorns. The Bighorns' snowpack usually peaks in mid-April, but the snowpack did not peak until late May. The snowpack reached record levels on May 31, peaking at over 175% of normal. Figure 4-1 shows the 2011 Bighorn Mountain snow water equivalent (SWE) compared to the 30-year average. Snowpack above Boysen Reservoir was near the 30-year average from December 2010 through April 2011. Large snowstorms in April and May increased the snowpack to over 170% of normal. The snow began to melt in mid-May, but as the low elevation snow melted new snow continued to fall. The Shoshone River snowpack was near normal through April 1. Repeated snowstorms in April and May increased the snowpack to a peak on May 1 of 130% of normal.

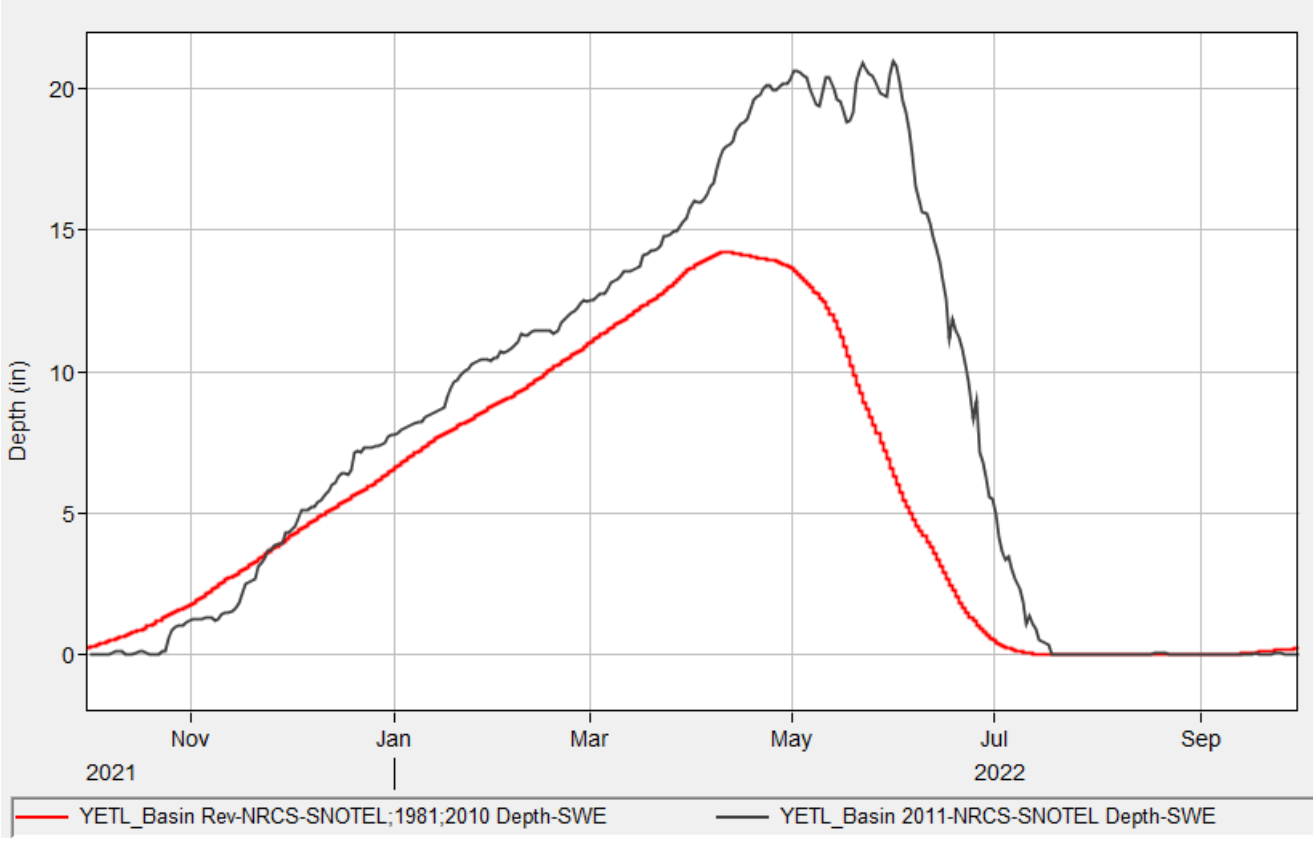

Figure 4-1. 2011 Yellowtail Basin SWE.

Yellowtail Regulation. In early May, Yellowtail, Boysen, and Buffalo Bill Dams were positioned to capture the high snowpack without using large portions of the Exclusive Flood Control Zones. The Water Control Manual required Yellowtail's pool elevation be drawn down to 3614.0 feet. Reclamation's operations of the conservation pool evacuated an additional 7.5 feet of storage in expectation of the high snowmelt runoff. However, heavy rainfall over the entire Bighorn Basin from May 19 through June 1 created ravaging floods downstream of Yellowtail Dam and deposited snow and rain upstream of all three reservoirs. By May 22, the Bighorn River downstream of Yellowtail had swallowed towns and property along the river. High flows also threatened the Interstate 90 bridges at Hardin, MT. The MT HWY 384 Bridge at Hardin, MT is 100 feet upstream of the Interstate 90 bridges at Hardin. The Montana Department of Transportation (MTDOT) was concerned the 384 bridge would fail because it had not been designed to handle the forces from these high flows. A failure of the 384 bridge could have a cascading effect and fail the Interstate 90 bridges along with it. MTDOT asked Reclamation to reduce flows to minimize stress on the 384 bridge. MRBWM also requested release cuts to reduce inflows into Garrison. Reclamation cut releases from 8,000 cfs to 3,500 cfs to maximize benefits to downstream flooding. These release cuts, along with rainfall runoff into Yellowtail, brought the pool from 3606.6 feet up to 3632.3 feet by the end of May.

After the late May storm, it became apparent the Exclusive Flood Control Storage Zones at Yellowtail and Boysen would be utilized. The rainstorm forced Yellowtail to use 183,000 af of storage space that had been vacated for snowmelt runoff, leaving less available storage space to manage a larger snowpack brought by the storms.

In response to historic late May rainfall in eastern Montana, MRBWM requested the immediate utilization of all available storage at Section 7 projects. The WCWQS and Reclamation determined Yellowtail Dam could not immediately utilize its Exclusive Flood Control Zone as it would be needed to mitigate Yellowtail surcharge operations and provide flood benefits during the peak snowpack inflow. Reclamation and the WCWQS agreed Yellowtail would most effectively benefit the Missouri River Flood Control System by storing water during the peak snowmelt runoff. Early June reservoir forecasts showed Yellowtail in surcharge operations and setting a record pool elevation. Releases were ramped up to 15,000 cfs by June 4. 15,000 cfs was the second highest release on record (24,700 cfs is record) and caused damages downstream to residential and agricultural property. Even with a 15,000 cfs release, the pool elevation was forecasted to reach 3657.2 feet during the peak snowmelt runoff. Releases were increased to 15,500 cfs on June 11. The Bighorn Canal was also damaged by the heavy downstream rainfall and would not divert its normal 300 to 500 cfs away from the Bighorn River.

Peak snowpack runoff into Yellowtail, Boysen and Buffalo Bill usually occurs in the last week in June. In mid-June, Reclamation forecasted peak inflows during the first 10 days in July due to unusually cool temperatures in May and June. This cool pattern persisted through the end of June. The mild temperatures melted much of the snowpack in the Bighorn Mountains during this period, but did not have the energy necessary to melt the higher elevation snow upstream of Boysen and Buffalo Bill. This melt pattern decreased peak inflows into Yellowtail because much of the snow in the Bighorn Mountains melted before the snowmelt runoff upstream of Boysen and Buffalo Bill increased. The prolonged melt also allowed for the evacuation of more water and helped decrease the chances of surcharge operations.

Regulation Related to Missouri River Mainstem Reservoirs. A favorable June-July water supply outlook in late June diminished concerns of surcharge operations at Yellowtail. Releases were decreased from 15,500 cfs to 14,500 cfs on June 23. The Bighorn Canal also started consumptively removing water from the Bighorn River. But record flooding along the Missouri River had pushed Fort Peck and Garrison into their surcharge storage zones. Mainstem reservoir releases doubled their previous record releases from all projects. Flooding along the Missouri River had shut down Interstate highways and threatened major metropolitan areas along with countless other damages. A special request to store significant floodwaters to benefit the Missouri River flooding was made to Reclamation by the WCWQS and MRBWM. The WCWQS, Reclamation, and MRBWM coordinated release plans to balance local flood risk and benefits to downstream flooding. The most immediate need was to decrease flows on the Missouri River near Williston, ND. A federal levee protects Williston, ND from high Garrison pool levels and high Missouri River flows. The Williston levee had experienced record stages for over a month and was showing serious stress. Large boils and other seepage issues continued to worsen as high stages persisted. While reductions from Yellowtail would not decrease Missouri River stages dramatically, it was determined even the slightest decreases in stages would have profound benefits on levee seepage. Cutting releases would also hold more water out of the river while Garrison was surcharged. Reclamation was concerned about cutting releases before the snowpack runoff started to recede, which would increase the risk of higher releases and surcharge operations. It was decided to cut releases to 8,500 cfs for a short period to improve the situation at Williston and Garrison. A target maximum elevation of 3652.0 feet to 3655.0 feet

was also set for Yellowtail. Releases would be increased when necessary to hold Yellowtail's pool elevation below the target level.

Yellowtail Dam releases were decreased from 14,000 cfs to 8,500 cfs between June 30 and July 2 to benefit the Williston levee and Garrison. This release was held from July 2 through July 11. Releases were then increased to hold the pool elevation below 3655 feet. Yellowtail peaked at elevation 3655.0 feet on July 24. At the peak pool elevation, river releases reached 12,000 cfs, and the peak total release was 12,425 cfs. Evacuation releases were set to maximize downstream flooding benefits and minimize bank sloughing. All floodwaters were evacuated by mid-October. At the peak, Yellowtail stored 225,000 af in the Exclusive Flood Control Zone, occupying 87% of the Exclusive Flood Control Zone. Plate 4-5 depicts Yellowtail's 2011 flood hydrograph.

Buffalo Bill Regulation. While Buffalo Bill has no authorized flood control storage and Reclamation makes all regulation decisions, its operations greatly impact the Bighorn system and must be factored into all flood control decisions.

The WYAO April-July runoff forecast on June 1 was approximately 1,110,000 af. A peak release of 6,300 cfs was needed to manage the forecasted inflows. The WYAO planned to store water through the peak inflow, limiting downstream peak inflows into Yellowtail. This plan would leave available only a small amount of local flood protection in the event of a large rainfall upstream of Buffalo Bill. Releases were increased throughout June to prepare for the peak snowmelt inflow. Inflows peaked on June 30 at over 16,200 cfs. The WYAO July 1 runoff forecast was increased to 1,220,000 af, increasing planned peak releases to over 9,000 cfs to hold pool elevations below 5391.5 feet. Inflows remained high through the first two weeks of July. Temperatures cooled in mid-July and inflows began to recede. Releases from Buffalo Bill were then cut to minimize flow into Yellowtail. The total April-July runoff was 1,230,000 af.

f. Flood of 2017

Yellowtail entered December with a nearly full conservation zone after a large fall rainfall event increased the pool almost 10 feet. Repeated snowstorms from December through April produced a record snowpack in the Wind River basin and near record snowpack in the Shoshone and Bighorn basins.

Yellowtail's pool was slowly drawn down until late February when snowpack exceeded 140% of normal. Releases were increased from approximately 2,500 cfs in mid-February to 4,500 cfs on March 1. The March 1 May-July runoff forecast (natural) was 2,206,000 af, 161% of normal. Reclamation's Most Probable Operation joint-use drawdown and releases exceeded the Corps' requirement.

Additional coordination with Reclamation began in mid-March. The Corps, the WYAO, the Regional Office, and the MTAO began having ad-hoc conference calls to discuss different runoff and release scenarios. This elevated coordination continued through the remainder of the event.

March brought additional snowfall and increased the runoff forecast. April 1 May-July runoff forecast (natural) was 2,402,000 af, 175% of normal. Reclamation's Most Probable Operation Plan exceeded the Corps' joint-use drawdown and release requirement. Reclamation continued to increase releases to evacuate storage ahead of the runoff season. Releases began March at approximately 4,500 cfs and reached approximately 8,900 cfs by early April. The joint use storage zone was evacuated by March 28.

Snowpack continued to accumulate in April. May 1 May-July runoff forecast (natural) was increased to 3,025,000 af, 220% of normal. Based on this high runoff, the entire joint use storage was to be evacuated. Reclamation's Most Probable Operation Plan met and exceeded the Corps' joint-use drawdown and release requirement. Releases on April 1 were approximately 8,900 cfs and reached approximately 12,000 cfs by May 1.

Snowmelt between Boysen and Yellowtail ramped up in May. Yellowtail pool elevation reached a minimum of 3603.4 feet on May 11 before inflows increased causing the pool to rise. Releases were held near 13,000 cfs through much of May and were increased to approximately 14,300 cfs by the end of the month. The June 1 May-July runoff forecast (natural) dropped to 2,993,000 af. Based on this high runoff, the entire joint use storage was to be evacuated. Reclamation's Most Probable Operation Plan met and exceeded the Corps' joint-use drawdown and release requirement. The pool elevation ended the month at 3605.8 feet, 34.2 feet below the base of exclusive flood control.

Yellowtail's inflow was highest in June peaking over 18,000 cfs on June 12. Releases were cut in early June to fill the conservation storage. Releases reached 9,500 cfs on June 20 and stayed between 9,000 cfs and 10,000 cfs through the remainder of June and most of July.

Inflows were above 10,000 cfs for the first 14 days of July as water continued to be stored in Yellowtail. Floodwaters entered the Exclusive Flood Control Zone on July 2 and the Corps assumed the release responsibility. Yellowtail peaked at 3647.0 feet on July 16. Release cuts were coordinated between the Corps and Reclamation's Wyoming and Montana Area Offices to best evacuate water from Yellowtail and Boysen. Yellowtail exited the Exclusive Flood Control Zone on August 10. Plate 4-6 depicts the 2017 flood hydrograph.

g. Flood of 2018

Yellowtail's storage consistently dropped through the winter. In mid-February 2018 releases were increased to approximately 4,500 cfs to continue evacuating storage ahead of the runoff season.

The March 1 May-Jul runoff forecast was 1,862,000 af. Reclamation's Most Probable Operation Plan exceeded the Corps' joint use storage requirement. Snowpack in March continued to accumulate at above average rates in the Shoshone and Bighorn ranges and near average above Boysen. Releases were increased throughout the month as Reclamation continued to draft the reservoir.

The April 1 May-July runoff forecast was 1,835,000 af. Reclamation's Most Probable Operation Plan exceeded the Corps' joint use requirement. Releases were held near 7,500 cfs for most of April as the reservoir reached 3603.9 feet, its lowest level of the year, on April 30.

May 1 May-July runoff forecast was 1,784 af. Reclamation's Most Probable Operation Plan met and exceeded the Corps' joint-use drawdown and release requirement for both May 1 and June 1. After below normal April temperatures delayed the snowmelt season, May temperatures were above normal and quickly increased inflows into the projects. Repeated rainstorms across Montana and Wyoming May 22-27 combined with high snowmelt runoff dramatically increased Yellowstone River flows. Ahead of these events the Corps and Reclamation's Wyoming and Montana Area Offices began coordinating operations from Boysen, Buffalo Bill, and Yellowtail. This coordination occurred daily and continued into mid-July to assure optimal operation was achieved. Flows at Miles City were forecast to exceed 70,000 cfs in late May. In response to above flood target flows at Miles City, releases were cut from Yellowtail and Boysen. Releases were cut starting May 23 from near 8,000 cfs to near 6,000 cfs while flows near Miles City receded. The pool rose 18 feet during this cut and finished May at 3633.0 feet.

Releases were increased beginning on June 1. During this time large inflows from snowmelt and rainfall also accumulated in Bighorn Lake.

The large May precipitation totals increased the June runoff forecast. June 1 May-July runoff forecast (natural) was increased to 2,109,000 af. The June 1 joint use storage requirements for this runoff and the expected releases were 160,000 af below the top of the Joint Use Storage Zone. Providing flood risk reduction at Miles City superseded the joint use evacuation requirement. Releases in June increased from near 6,000 cfs to approximately 14,000 cfs by June 18. Inflows fluctuated between 13,000 to nearly 18,000 cfs during this period. Additional heavy rains in Montana, Wyoming, and North Dakota brought excessive runoff into the Missouri River Mainstem Flood Control System. MRBWM requested Yellowtail and other Section 7 projects delay release increases or cut releases to curtail inflows to the Mainstem reservoirs. Releases were held near 14,000 cfs and the pool rose from 3642.5 feet to 3645.3 feet as a result of this operation.

Following the peak pool elevation, releases were quickly cut to closely match inflows to minimize Yellowtail's contribution to downstream inflows. These cuts were made starting June 30 and the cuts continued through most of July. The reservoir exited the flood pool on August 3 and release responsibility was returned to Reclamation. It should be noted without MRBMWD's request to reduce releases, releases would likely have been held near higher levels already experienced this year and for longer durations. This would have resulted in a quicker evacuation of the flood pool. But the operation as implemented provided additional flood risk reduction benefits to the Missouri River Mainstem Flood Control System. Plate 4-7 depicts the 2018 flood hydrograph.

h. Flood of 2019

Yellowtail's storage consistently dropped through winter. Releases were held between 3,000-4,000 cfs from November to mid-May.

The Corps' March 1 May-Jul runoff forecast was 1,296,000 af. Reclamation's Most Probable Operation Plan exceeded the Corps' joint use drawdown requirement.

The Corps' April 1 May-July runoff forecast was 1,111,000 af. Reclamation's Most Probable Operation Plan exceeded the Corps' joint-use drawdown requirement.

The Corps' May 1 May-July runoff forecast was 1,235,000 af. Reclamation's Most Probable Operation Plan met and exceeded the Corps' joint-use drawdown and release requirement for both May 1 and June 1. Near record precipitation in the Bighorn Basin was experienced in May 2019. The Bighorn and Wind National Weather Service (NWS) Climate Districts received 5" of precipitation, more than doubling the average May precipitation. This precipitation increased actual flow volumes well above those forecasted.

On May 30 MRBWM requested efforts be taken to reduce releases from Boysen, Canyon Ferry, Tiber, and Yellowtail. Inflows into the Missouri River were at record levels through much of March, April, and May due to heavy plains snowmelt and heavy rainfall on fully saturated soils. Storage in the four lower mainstem projects was especially taxed and required relief from upstream projects. MRBWM requested immediate reductions in releases to minimize inflows into Fort Peck and Garrison. It was determined the optimal storage target at Yellowtail was to fill 25%-40% of the Exclusive Flood Control Zone.

Reclamation and the Corps began holding daily conference calls to coordinate Bighorn River operations. Yellowtail releases were cut from 6,500 cfs to 5,600 cfs between June 1-5. Releases were held at this level as long as possible. By June 11 the Joint Use Zone was nearly full with substantial runoff remaining. Releases were increased as part of the plan to fill 25%-40% of the Exclusive Flood Control Zone. Releases peaked at 11,300 cfs on June 23. The pool elevation peaked on July 10 at 3648.1 feet, with 44% of the Exclusive Flood Control Zone full. The stored floodwater was slowly evacuated in July and early August.

It should be noted without MRBWM's request to reduce flows, releases would likely have been held at higher levels already experienced and for longer durations. This would have resulted in a quicker evacuation of the flood pool. But the operation as implemented provided additional flood risk reduction benefits to the Missouri River flood control system. Plate 4-8 depicts the 2019 flood hydrograph.

4-07 RUNOFF CHARACTERISTICS

A major portion of the runoff to the Bighorn River originates from the winter's snow accumulation in the higher elevations of the basin. Plate 4-9 shows a graph of Yellowtail's historical monthly inflow volume and Plates 4-10a and 4-10b present this data in tabular form. The historic annual inflow volume for the period of record is graphically represented in Plate 4-11.

Flow of the uncontrolled streams in the Bighorn Basin reflects the seasonal distribution of runoff previously described. However, irrigation is extensively practiced in the basin and has a marked effect upon the runoff appearing as streamflow. It is estimated that between the years 1910 and 1970 average annual depletions above Boysen Dam increased by about 200,000 af. Between Boysen Dam and Yellowtail Dam, the corresponding increase in depletions approximates 170,000 af annually. Most of these depletions to streamflow result from irrigation practices, although watershed treatment, stock ponds and reservoir evaporation also affects streamflow.

From 1910 to present the maximum recorded daily average flow at Bighorn River near St. Xavier was 37,400 cfs in June 1935, while a minimum daily average flow of 228 cfs was observed in December 1937. Both the peak maximum and minimum pre-date Boysen and Yellowtail construction. Annual crest flows usually occur during the May-July mountain snowmelt period.

Seasonal streamflow variations on the Yellowstone River at its confluence with the Bighorn River are similar to those described for St. Xavier and are due to similar causes. The maximum discharge recorded at Billings, Montana (upstream from the Bighorn's mouth) is 84,000 cfs, occurring on June 12, 2022. A minimum flow of 430 cfs was recorded in December 1932.

Plates 4-12 through 4-21 show stream rating curves for important gages upstream and downstream of Yellowtail Dam.

4-08 WATER QUALITY

The primary water quality concern in the Bighorn River is the cold-water fishery downstream of Yellowtail. Water temperature, total gas saturation (PSAT), and ideal fishing flow rates are all factors when Reclamation is operating Yellowtail under normal operating conditions. During flood operations water quality needs are always taken into consideration, but worsening flooding can force their subordination. Reclamation is responsible for coordinating water quality at Yellowtail.

4-09 CHANNEL AND FLOODWAY CHARACTERISTICS

Channel capacity or bankfull flow varies on the river downstream from Yellowtail Dam. This manual’s flood control targets are 20,000 cfs and 25,000 cfs at St. Xavier and Bighorn, respectively, on the Bighorn River and 65,000 cfs and 100,000 cfs on the Yellowstone River at Miles City and Sidney respectively. Flooding at these levels is for the most part confined to the lowland areas immediate and adjacent to the main river channel. The largest flooding concern along the Bighorn River is between Yellowtail and the mouth. Lowland and pasture impacts begin near 11,000 cfs. Outbuildings and road access are impacted near 13,000 cfs, and permanent residential structures are impacted above 15,000 cfs. Since Yellowtail releases exceeded 25,000 cfs in 1967, 15,000 cfs in 2011, and Yellowtail has a total release capacity of nearly 100,000 cfs, impacts to areas adjacent to the river channel will continue to be impacted at an undetermined frequency. Plate 4-22 shows the travel times to important downstream locations.

4-10 UPSTREAM STRUCTURES

See Section 3-04, Related Projects.

4-11 DOWNSTREAM STRUCTURES

See Section 3-04, Related Projects.

4-12 ECONOMIC DATA

a. Population

In the area downstream from Yellowtail Dam, the majority of towns and areas having the greatest population density are located along the larger rivers and streams. The populations of the larger towns downstream from Yellowtail Dam are displayed in Table 4-5.

Table 4-5

Population and Growth of Towns Below Yellowtail Dam

Town	1960	1970	1990	2000	2010	2020
Hardin, MT	2,789	2,733	3,010	3,405	3,667	3,705
Hysham, MT	494	373	368	327	312	307
Forsyth, MT	2,032	1,873	2,174	1,918	1,866	1,752
Miles City, MT	9,800	9,023	8,610	8,473	8,405	8,181
Terry, MT	1,140	870	653	604	609	550
Glendive, MT	7,058	6,305	4,770	4,865	4,927	4,924
Sidney, MT	4,564	4,543	5,184	5,044	4,843	6,255

Population growth in the last ten years has been driven by shale oil production in eastern Montana. The increases in consumptive use of water due to increased populations is small and has not affected operations of Yellowtail Dam.

b. Agriculture

Major crops are alfalfa, small grains, and sugar beets. Alfalfa production dominates in terms of acreage and value, and also requires the most water. Sugar beets are important in some areas, and also demand considerable water. Spring grains (oats, barley) require less water. Table 4-6 shows agricultural data for Big Horn County, MT from the 2007 and 2012 Census of Agriculture.

Table 4-6

Agricultural Data below Bighorn Reservoir

	2007	2012
Land in farms (acres)	2,899,620	3,148,871
No. of farms	695	527
Total Cropland (acres)	383,588	268,114
No. of cropland farms	441	310
Irrigated land (acres)	59,681	46,292
No. of irrigated farms	231	150
Market Value of Agriculture Products Sold	$94,853,000	$108,747,000
% Crops	44	49
% Livestock, Poultry, and their products	56	51

Data from 2007, 2012 Census of Agriculture, USDA, National Agriculture Statistics Service for Big Horn County, MT.

See Section 3-04, Related Structures for more information on irrigation diversions.

c. Industry

Employment by industry in the areas above and below Yellowtail Dam are found in Table 4-7.

Table 4-7 Employment by Industry near Yellowtail Dam

	Big Horn County, WY	Big Horn County, MT
Agriculture, Forestry, Fishing, & Hunting	3.3%	6.9%
Mining, Quarrying, & Oil & Gas Extraction	14.4%	3%
Construction	6.6%	4%
Manufacturing	6.5%	2%
Wholesale Trade	2.9%	4%
Retail Trade	6.8%	11%
Transportation & Warehousing	2.0%	0%
Information	1.8%	1%
Finance & Insurance	2.2%	3%
Real Estate & Rental & Leasing	0.3%	5%
Professional & Technical Services	2.2%	2%
Administrative & Waste Services	6.1%	1%
Health Care & Social Assistance	2.8%	14%
Arts, Entertainment, & Recreation	0.5%	1%
Accommodation & Food Services	4.4%	13%
Other Services, Except Public Admin.	1.9%	3%
Total Government	34.5%	26%

Data from 2012 Quarterly Census of Employment and Wages, Montana Dept of Labor and Industry, 2014 Wyoming Quarterly Census of Employment and Wages.

The cities of Billings, Miles City, Glendive, and Sidney constitute the center of the manufacturing industries in the basin. Oil is an important product of the Yellowstone and Bighorn Basins. Recent developments in eastern Montana, which includes the lower part of the Yellowstone River, has become one of the largest oil-producing areas in the country. The production of oil in this region consumes large amounts of water. No operational changes at Yellowtail Dam have been needed to meet this consumptive

demand. Coal is the principal mineral resource and is mined extensively in Rosebud County, Montana, and in most of the counties of Wyoming.

d. Flood Damages

Historically, flood damages occurred in the larger communities primarily of Hardin, Forsyth, Miles City, Terry, and Glendive. The potential damage areas downstream from Yellowtail Dam has been divided into five reaches for computation of flood damages. Discharge-damage curves are shown on Plate 4-23.

Annual flood damages prevented by Yellowtail Dam are shown in Table 4-8. Total damages prevented by Yellowtail Dam/Bighorn Reservoir since its construction is $371,773,000 in 2019 dollars.

Table 4-8

Flood Damages Prevented by Yellowtail Dam (x $1,000)

	Unadjusted (x$1,000)			Adjusted to 2019 $ (x$1,000)		
Year	Local	Mainstem	Total	Local	Mainstem	Total
1967	122.0	1,320.0	1,442.0	1,109.3	12,002.6	13,112.0
1968	0.0	0.0	0.0	0.0	0.0	0.0
1969	15.0	597.0	612.0	116.7	4,645.1	4,761.8
1970	90.0	253.0	343.0	661.7	1,860.2	2,522.0
1971	40.0	80.5	120.5	259.4	522.0	781.3
1972	106.0	871.3	977.3	621.7	5,110.4	5,732.1
1973	16.2	108.3	124.5	87.5	585.0	672.5
1974	463.0	1,759.0	2,222.0	2,361.8	8,972.8	11,334.6
1975	170.0	3,578.0	3,748.0	800.1	16,840.2	17,640.3
1976	0.0	754.0	754.0	0.0	3,252.4	3,252.4
1977	0.0	0.0	0.0	0.0	0.0	0.0
1978	2,380.0	4,680.0	7,060.0	8,844.9	17,392.4	26,237.3
1979	0.0	1.4	1.4	0.0	4.5	4.5
1980	0.0	202.0	202.0	0.0	639.7	639.7
1981	105.0	3,514.0	3,619.0	307.8	10,300.4	10,608.2
1982	125.0	1,299.4	1,424.4	343.9	3,575.3	3,919.2
1983	0.0	1,404.0	1,404.0	0.0	3,620.0	3,620.0
1984	0.0	4,250.0	4,250.0	0.0	10,808.4	10,808.4
1985	0.0	0.0	0.0	0.0	0.0	0.0
1986	2,826.7	0.0	2,826.7	6,997.7	0.0	6,997.7
1987	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0
1990	1,425.0	0.0	1,425.0	3,225.0	0.0	3,225.0
1991	268.9	9,890.6	10,159.5	592.0	21,774.6	22,366.6
1992	0.0	856.2	856.2	0.0	1,842.4	1,842.4
1993	0.0	8,048.5	8,048.5	0.0	16,440.6	16,440.6
1994	0.0	34.4	34.4	0.0	67.9	67.9
1995	239.2	1,816.0	2,055.2	471.1	3,576.9	4,048.0
1996	113.1	4,312.9	4,426.0	214.2	8,167.2	8,381.3
1997	717.9	26,833.2	27,551.1	1,303.6	48,726.5	50,030.1
1998	0.0	4,678.5	4,678.5	0.0	8,479.8	8,479.8
1999	23.6	3,597.8	3,621.4	41.4	6,311.4	6,352.8
2000	0.0	613.3	613.3	0.0	1,063.1	1,063.1
2001	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	412.3	412.3	0.0	693.4	693.4
2003	0.0	6,239.5	6,239.5	0.0	10,317.8	10,317.8
2004	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.0	10,480.9	10,480.9	0.0	15,188.8	15,188.8
2006	0.0	13.3	13.3	0.0	18.7	18.7
2007	0.0	1,652.3	1,652.3	0.0	2,240.7	2,240.7

	Unadjusted (x$1,000)			Adjusted to 2019 $ (x$1,000)		
Year	Local	Mainstem	Total	Local	Mainstem	Total
2008	85.5	14,717.9	14,803.4	108.9	18,741.8	18,850.6
2009	67.0	2,410.2	2,477.2	86.4	3,109.5	3,195.9
2010	0.0	9,215.6	9,215.6	0.0	11,536.0	11,536.0
2011	2,035.6	10,143.0	12,178.6	2,454.5	12,230.2	14,684.7
2012	0.0	2,405.5	2,405.5	0.0	2,846.4	2,846.4
2013	0.0	1,171.7	1,171.7	0.0	1,362.7	1,362.7
2014	270.8	9,361.3	9,632.1	307.8	10,639.2	10,947.0
2015	56.8	5,216.0	5,272.8	63.0	5,786.2	5,849.2
2016	0.0	202.9	202.9	0.0	220.5	220.5
2017	248.2	8,192.9	8,441.1	259.8	8,575.2	8,834.9
2018	1,050.7	17,459.4	18,510.1	1,062.0	17,647.4	18,709.4
2019	381.8	953.3	1,335.1	381.8	953.3	1,335.1
TOTAL	13,443.0	185,601.3	199,044.3	33,084.1	338,689.2	371,773.3

Source: USACE Omaha District, Environmental, Economics, and Cultural

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CHAPTER 5—DATA COLLECTION AND COMMUNICATION NETWORKS

5-01 HYDROMETEOROLOGICAL STATIONS

a. Facilities

A map of stream gaging stations upstream and downstream of Yellowtail Dam is presented on Plate 5-1.

The Cooperative Stream Gaging (Co-op) Program is a joint effort between the Corps, Reclamation, and the United States Geological Survey (USGS) providing remote site, satellite data transmissions utilized for water management. Plate 5-2 displays a table of streamgage stations relevant to Yellowtail Dam with various organization's identification names, drainage areas, mean values, and periods of record.

Since 1964 the National Resources Conservation Service (NRCS) has established automated Snow Telemetry (SNOTEL) stations or snow pillows in the mountain areas. The locations of these SNOTEL stations are shown on Plate 5-3. Plate 5-4 contains a table of average bi-weekly SWE values for SNOTEL stations located in the upstream basin of Yellowtail Dam. It can be used to track the progress of the snowpack accumulation, as well as precipitation.

Real-time rainfall gages located in area are shown on a map in Plate 5-3. The monthly precipitation totals are shown in Plate 5-5.

b. Reporting

Data from hydrologic gages for water management are obtained from various sources including contract observers, project offices, NWS, USGS, Reclamation, and state offices. The NWS provides current weather conditions, temperature, stage and flow forecasts, observed precipitation reports, river level data, and special hydrologic forecasts including flood warnings.

There are many websites that provide a variety of weather products including universities, NWS, and commercial vendors of weather products.

Periodic discharge measurements made by the USGS are normally furnished to the WCWQS through automated computer exchange but can also be obtained by email, or telephone for various stations. These are used to maintain current stage-discharge relationships. Collection and publication of data such as stage, discharge, sediment, and water quality are the primary functions of the Co-op program.

The NRCS publishes real-time SNOTEL updates to the NRCS website.

c. Maintenance

The Corps and Reclamation support individual hydrologic database systems by contributing personnel, funds, and equipment. Streamgaging sites are maintained by Reclamation and the USGS. SNOTEL sites are maintained by the NRCS.

Omaha District personnel complete the District's streamgaging program with assistance from the USGS. The USGS' activities are funded through the Co-op Program (FC-33). The Co-op Program provides financial support for operation and maintenance of multiple streamgaging stations.

Data Collection Platforms are installed and maintained by the USGS, Reclamation, and the Corps WCWQS personnel.

5-02 WATER QUALITY STATIONS

a. Facilities

Reclamation funds and maintains numerous water quality sensors at reservoirs and streamgages throughout the basin. See Section 4-08 for details about Water Quality.

b. Reporting

Water Quality data is collected, stored, and reported by Reclamation and the USGS.

c. Maintenance

Maintenance is performed by Reclamation and the USGS at their respective sites.

5-03 SEDIMENT STATIONS

No sedimentation stations are operated by Reclamation relative to Yellowtail's operation.

5-04 RECORDING HYDROLOGIC DATA

The Corps Water Management System (CWMS) is the Omaha District's primary data management system and modeling suite. CWMS was developed by the Hydrologic Engineering Center (HEC) and utilizes an Oracle database to store river, reservoir and weather data.

Reclamation's HydroMet database provides current runoff conditions for river and reservoir operations. Reclamation shares streamflow, canal diversion, and reservoir data with the Corps that is used to determine flood control requirements. Real-time provisional data is accessible on Reclamation's website.

5-05 COMMUNICATION NETWORK

According to Yellowtail's Standing Operating Procedure (Reclamation's primary project document), Yellowtail Powerplant is equipped with telephone service. Other Reclamation telephone services connect by microwave to the CCC. Most Reclamation management personnel are also equipped with cellular phones.

There is also a Western Area Power Administration PBX extension at the powerplant. Western Area Power Administration can also be contacted with radios via relay repeater stations. Radio communications for National Park Service Law enforcement and Western Area Power Administration can be found in Reclamation's Emergency Action Plan (EAP).

a. Emergency Warning

The MTAO, Yellowtail Dam operating personnel, and/or the CCC is responsible for emergency notification. These Reclamation entities will follow the warning response detailed in Reclamation's EAP. If emergency operations occur that may impact flood control, notification must be made to the Corps. In the event flood forecasts are required, the NWS is federally mandated to issue flood warnings.

b. Emergency Situations

Section 7-15 describes deviations from normal regulation during emergency situations. When these or any other emergency situations arise, the MTAO Area Manager and the Reservoir and River Operations Group should be immediately notified and informed of all information pertaining to the incident. If the incident should occur after normal office hours, individuals listed as emergency contacts for MTAO in the Communications Directory on page V shall be contacted by calling their cell or home telephone numbers. The local county sheriff and state emergency offices shall also be immediately notified. Additional local contact information is available in Reclamation's Yellowtail Standing Operating Procedures. Should an emergency require a deviation from the flood control guidelines in this Water Control Manual, the WCWQS will inform the MRBWM of its activities as soon as possible. Written confirmation of the deviation, including a description of the cause of the emergency, will be furnished to the MRBWM.

c. Remote Control

The remote supervision of the Yellowtail powerplant and the outlet works is normally performed by the CCC in Mills, WY. This has resulted in the powerplant being completely unattended most of the time, with the exception of Monday through Thursday when the dam operating personnel are on duty between 0700 and 1730 hours Mountain Time. If the CCC is unable to make changes at the project, local plant operators are on-call to make changes as needed.

5-06 COMMUNICATION WITH PROJECT

a. Corps of Engineers with Bureau of Reclamation

Telephone and email are available for communication between the Yellowtail powerplant, the MTAO in Billings, MT, and the Omaha District WCWQS.

Except for emergency conditions outlined in the Standing Instructions to Dam Operator in Exhibit III, issuance of regulation orders during flood control operations is the function of the Corps' Omaha District WCWQS. Verbal regulation orders issued by the Omaha District WCWQS to Reclamation's MTAO or Yellowtail's Facility Manager will be confirmed in writing as soon as practicable. The written orders will be sent via email to the MTAO Reservoir and River Operations Group who shares the information with the Facility Manager and the Regional Office. During the runoff season, release forecasts are shared with the MRBWM.

Dam operating personnel are required to report rapidly rising pool levels and heavy rainfall to the MTAO Reservoir and River Operations Group. In the event the MTAO

cannot be reached, the Dam Operator will notify the Omaha District WCWQS or the Corps' Garrison Project Manager. The method, time, and items to be reported are detailed in the Standing Instructions to the Dam Operator in Exhibit III.

b. Reclamation with Other

Reclamation communicates with state and local agencies regarding water supply, fish and wildlife, and other items of concern.

5-07 PROJECT REPORTING INSTRUCTIONS

The Yellowtail staff collects data as requested by the MTAO. Generally current pool elevation, recent precipitation, discharge amounts through the various gates and tunnels and any other information pertinent to the operation of the project is shared with the MTAO who relays this information as needed to the Corps via computer exchange.

5-08 WARNINGS

The procedure for the dissemination of Emergency Public Information is detailed in Reclamation's Yellowtail Dam and Reservoir EAP.

The NWS is federally mandated to issue flood warnings.

CHAPTER 6—HYDROLOGIC FORECASTS

6-01 ROLE OF DIFFERENT AGENCIES

a. Role of Corps

The Corps will make forecasts when river flows at St. Xavier, Bighorn, Miles City, or Sidney are at risk of exceeding their flood targets and whenever water is stored in the Exclusive Flood Control Zone. The Corps also makes seasonal inflow volume forecasts to determine the needed evacuation of the joint use storage zone.

b. Role of Other Agencies

Reclamation makes both short-term and long-term reservoir inflow forecasts, which are used to make release decisions. Reclamation also makes seasonal inflow volume forecasts to better inform their reservoir inflow forecasts.

The NWS releases short-term inflow forecasts as part of their mission as official forecaster. This forecast is generally limited to an inflow forecast with a less than two week forecast window. The NWS also produces long-term inflow ensemble forecasts, which provide a range of possible inflows based on possible weather scenarios. Both Reclamation and the Corps use this information as a guide when forecasting inflow and making operational decisions.

6-02 FLOOD CONDITION FORECASTS

a. Requirements

Yellowtail Dam requires short range, event based forecasting as well as long range runoff forecasts. The seasonal May-Jul runoff forecasts are further described in Section 6-04.

b. Methods

The Corps has a HEC Hydrologic Modeling System (HEC-HMS) runoff model to aid in Bighorn runoff forecasting. The HMS model uses observed precipitation, snowpack conditions, streamflow and predicted precipitation and predicted temperatures to forecast runoff. This information feeds a HEC Reservoir Simulation Software (HEC-ResSim) model which aids the Corps' in making release decisions.

Plate 6-1 can aid in quickly determining the storage volume required for a specific inflow and release scenario. Historic inflow recessions of previous floods have decayed at a rate of 0.9 to 0.96 per day. Plate 6-2 shows the comparison of these historic inflow recessions.

6-03 CONSERVATION PURPOSE FORECASTS

Reclamation has responsibility for preparing water conservation forecasts, which are sometimes referred to as drought contingency forecasts.

6-04 LONG RANGE FORECASTS

a. Requirements

A major portion of the annual inflow into Yellowtail Dam results from the mountain snowmelt. On a monthly basis from March through July, the Corps prepares an inflow forecast for the May-July 3-month period. The May-July forecast is used to determine the required joint use storage evacuation volume.

b. Methods

The long-range runoff volume forecast method, which is presented in Exhibit VI, utilizes historical and current SNOTEL station data, daily precipitation data (see Section 5-01), and historical May-July and October-November Yellowtail inflow. Similar long-range runoff forecasts are independently prepared by Reclamation and the NRCS, which the Corps takes into consideration. A more detailed explanation of how to calculate the required evacuation is in Exhibit VII.

The Corps' HEC-HMS runoff model can also be used to perform long-term runoff forecasts. This requires large amounts of historic and forecasted air temperature, precipitation, and snowpack gridded data sets. The Corps is working with Reclamation and the NWS to utilize the HMS model to improve long-term runoff forecasting.

6-05 DROUGHT FORECAST

Reclamation has responsibility for preparing water conservation forecasts, which are sometimes referred to as drought contingency forecasts.

6-06 WATER QUALITY FORECAST

Any water quality forecasting at Yellowtail will be the responsibility of Reclamation.

CHAPTER 7—WATER CONTROL PLAN

7-01 GENERAL OBJECTIVES

The operating objectives at Yellowtail Dam are to regulate river flow to mitigate downstream flood risk; to maximize the power generation benefit; provide water for irrigation, municipal, and industrial use; provide desired river flow conditions to meet the needs of the downstream river fishery; and provide desired conditions for fish, wildlife, and recreational use in the reservoir. Flood regulation will be coordinated between Reclamation and the Corps as specified in this manual.

7-02 CONSTRAINTS

a. Reservoir Area Upstream of Dam.

See Section 7-06 for Recreation constraints.

b. Near Dam and Outlet Works Facilities.

1) The release through the river outlet works should be limited to about 2,500 cfs to prevent damage to the riverbank.
2) The minimum release through the spillway depends on reservoir head. The minimum gate opening is 6 inches.
3) Releases through the spillway and river outlet gates can only be made by operation personnel at the Yellowtail Dam site. Remote operation is performed by the CCC in Mills, WY. All changes in releases through the powerplant can be made by the CCC.
4) To lessen the possibility of slides or cave-ins of the Bighorn Canyon walls, the Reclamation has recommended that drawdown of the pool level not to exceed one foot per day.

c. Downstream Locations and Fishery Flow Targets.

1) The minimum preferred fishery target below Yellowtail Dam is discussed in Section 7-08. Reclamation's conservation operations meet these minimums whenever practicable. Flood control operations should attempt to meet these minimums whenever practicable.
2) The maximum design discharge from the downstream Afterbay Dam is 20,000 cfs. The maximum recorded release was 24,700 cfs. To consider releases higher than this, it is recommended the Afterbay Dam left abutment be breached to pass the releases around the Afterbay Dam itself. Reclamation will make the final decision to breach the Afterbay Dam should this situation ever arise.
3) CCC remotely operates the Bighorn Canal sluice gates, Afterbay Dam sluice gates, and three of the five After Bay Dam radial gates. Two of the Afterbay Dam radial gates are operated locally by Yellowtail staff.
4) Rural residences in the Bighorn River floodplain between Yellowtail and the mouth can be impacted by discharges below 20,000 cfs.

7-03 OVERALL PLAN FOR WATER CONTROL

a. Storage Allocations

The storage space in Yellowtail has been allocated as shown in Table 7-1. The storage capacities shown are based upon 2017 sediment surveys. Plate 7-1 contains a schematic of reservoir allocations. See Plate 7-2 for a graphical depiction of Corps and Reclamation release responsibilities at different storage levels and operating conditions. The individual storage zones are discussed in the following paragraphs.

Table 7-1

Bighorn Reservoir Storage Allocations (based on 2017 survey)

Reservoir Use	Elev Limits (feet)	Incremental Capacity (af)	Total Capacity (af)
Surcharge Storage	3657.0-3660.0	48,708	1,312,390
Exclusive Flood Control Storage	3640.0-3657.0	252,630	1,263,682
Joint Use Storage	3614.0-3640.0	232,735	1,011,052
Active Conservation Storage	3547.0-3614.0	310,844	778,317
Inactive Storage	3296.5-3547.0	449,118	467,473
Dead Storage	3166.0-3296.5	18,355	18,355

1) **Total Flood Control Allocation**. The total flood control allocation at Yellowtail includes capacity between elevation 3614.0 feet and 3657.0 feet and amounts to 485,365 af of storage. This includes the Exclusive Flood Control Zone and the Joint Use Zone.

2) **Exclusive Flood Control Allocation**. The Exclusive Flood Control Zone includes the storage between elevation 3640.0 feet and 3657.0 feet and amounts to 252,630 af of storage. This storage is reserved and regulated exclusively for flood control to reduce downstream flood damages.

3) **Joint Use Allocation**. The Joint Use Zone is 232,735 af of storage between 3614.0 feet and 3640.0 feet. The Joint Use Zone is vacated seasonally to maximize flood risk reduction during high snowpack years. This space can also remain full during the spring if water supply is forecasted to be less than needed to meet the conservation requirement as described in Exhibit VII. If the discharges exceed the downstream flood targets described in this manual, the Joint Use Zone can also be filled to maximize flood risk reduction, so long as filling the Joint Use Zone is not forecasted to exceed discharge thresholds

at the control points later in the runoff year.

4) **Active Conservation Storage**. Active conservation storage capacity allocation includes the storage capacity between elevation 3547.0 and elevation 3614.0 feet and amounts to 310,844 af of storage.

5) **Inactive Storage.** Inactive storage capacity allocation includes the storage capacity between elevation 3296.5 feet and elevation 3547.0 feet and amounts to 449,118 af of storage.

6) **Dead Storage.** Dead storage capacity allocation shall include the storage capacity between streambed elevation and elevation 3296.5 feet (currently 18,355 af). This capacity is established by the elevation of the invert of the river outlet which is the lowest outlet on the dam.

b. Afterbay Storage Allocation.

The storage allocations for the Afterbay are shown in the following Table 7-2. Except for a minimum 3175.0 feet elevation during the irrigation season, the storage in the Afterbay is used to vary Yellowtail Powerplant releases, which maximizes hydropower value, while maintaining constant downstream river levels. Elevation 3175.0 feet is the minimum level required to release the maximum discharge to the Bureau of Indian Affairs Canal through the headworks in the Afterbay Dam. The maximum discharge capacity of the sluiceway gates is 4,500 cfs. The Afterbay was originally designed to pass all flows up to 4,500 cfs through the sluiceway and any flows in excess of 4,500 cfs through the spillway gates. In an effort to reduce Nitrogen supersaturation in the Bighorn River, it is now generally preferred to mix flows at a ratio of 75% through the afterbay spillway and 25% through the sluiceway whenever possible. The top of the active storage capacity (elevation 3192.0 feet) is the elevation that provides the designed optimum operation of the powerplant. This level provides the maximum possible fluctuation of the Afterbay needed to meet peak generation demands.

Table 7-2

Afterbay Reservoir Storage Allocations

Use	Elev Limits (feet)	Total Capacity (af)
Top of Dam	3204.6	n/a
Operating Deck. (5.5 ft freeboard)	3197.5	n/a
Active Conservation	3157.0-3192.0	2,887
Spillway Crest	3179.5	n/a
Invert of Canal Slide Gates	3167.0	n/a
Invert of Sluice Gates - Dead Storage	3157.0	n/a

nr – Afterbay Reservoir only has specified active conservation storage.

7-04 STANDING INSTRUCTIONS TO DAM OPERATOR

a. Flood Control Operation

When the pool is in the Exclusive Flood Control Zone, or when the vacated Joint Use Zone is encroached, or when downstream flood targets are exceeded, instructions for releases will be issued by the Corps to the MTAO, who will transmit the instructions to the Dam Operator. If communications cannot be made between the Corps and the MTAO, the Corps will communicate instructions directly to the Dam Operator.

b. Emergency Instructions

Refer to Exhibit III for definition of emergency regulation and emergency flood control regulation procedures. If all normal means of communication fail, the dam operating personnel shall regulate releases for flood control as explained by the Emergency Release Schedule in Exhibit III.

7-05 FLOOD RISK MANAGEMENT

Bighorn Lake will be regulated for flood control primarily for the reduction and prevention of flooding downstream from the project, on both the Bighorn and Yellowstone Rivers. In general, the developed method of flood control regulation of Bighorn Lake may be classified as Method C, defined in Engineering Manual EM 1110-2-3600 October 10, 2017. This represents a combination of the concepts. First, reducing downstream damaging stages as much as possible during each flood with the currently available storage space, while at the same time considering operations for floods of project design magnitude.

a. Plan of Regulation.

Project releases will be made as necessary to prevent the discharge from exceeding the flows outlined in Table 7-3:

Table 7-3

Target Discharges During Flood Control Regulation

20,000 cfs	near St. Xavier, MT
25,000 cfs	at Bighorn, MT
65,000 cfs	at Miles City, MT
100,000 cfs	at Sidney, MT

The only exception to this would be in the event of occurrence of high inflows in combination with pool elevations exceeding 3649.0 feet as discussed below. Travel times from the dam to the above listed stations are shown on Plate 4-22. The flow will be forecasted as described in Section 6-02.

b. Integrated Regulation of All Flood Control Reservoirs In Missouri River Basin

Releases from Yellowtail Dam eventually flow into Lake Sakakawea (Garrison) of the Missouri River Mainstem Reservoir System (System). As per the Missouri River Mainstem Reservoir System Master Manual, Section 7-04.25, “When tributary reservoir regulation affects Missouri River flood flows or navigation on the Missouri River, tributary reservoir regulation will, however, become a direct concern of the MRBWM office. During such periods, the MRBWM office will issue pertinent tributary reservoir regulating instructions so that flood damages may be held to a minimum through integrated regulation of all flood control reservoirs in the Missouri River basin.” Additionally, as per Section 208.11 of 33 CFR Chapter II, “The water control plan is subject to temporary modification by the Corps of Engineers if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communication available. The action taken shall be confirmed in writing the same day to the project owner and shall include justification for the action.” As a result of these requirements, during large floods affecting the System, releases of flood storage from Yellowtail may be adjusted in order to meet basin-wide flood control goals of the System. Requests for modification will be made to the MTAO Reservoir and River Operations Group in Billings, MT, which is part of the Missouri Basin Region. Requests should be made via telephone call or email and confirmed via an official reservoir regulation order the same day.

c. Regulation Curves

Regulation curves on Plate 7-3 were developed by the methods described in Section 4-5 of EM 111-2-3600, primarily for use during large floods or during emergency regulation. They will serve as a basis for regulation when other information may not be available. They are based on a flood hydrograph with an approximate 25-day recession, which is representative of a mountain snowmelt recession above Bighorn Lake, and give the minimum releases for any combination of pool elevation and inflow. If the actual flood event is characterized by the normal flood hydrograph shape upon which the curves are based, the criteria assures effective use of the flood control storage space by (1) filling the flood control storage space (2) maintaining the maximum flood release at the lowest practical level, and (3) reducing the magnitude of changes in release rates. Inflows are normally computed daily (from release volume plus change in storage for the previous 24-hour period) and hourly based on a 6-hour moving average. When the pool elevation is above 3649.0 feet and the inflow is more than 30,000 cfs inflows, the adjustment in release rates can be increased.

Regulation curves on Plate 7-4 were developed by Reclamation using methods like those used to create Plate 7-3. They were utilized in the design of the spillway and are based on a flood hydrograph with an approximate 2-day recession which tends to be representative of a rainfall flood. Because of the safety factor element involved, in choosing a short recession for design purposes, these curves represent limiting regulation criteria and are not recommended for normal snowmelt flood control use in that normal flood events have a significant snowmelt component with long recessions. Compared to the operational curves referenced in the above paragraph, these design curves would delay increasing flood releases, thereby usually resulting in a higher peak pool elevation and peak flood release for snowmelt floods. In the spillway design routing, inflows were computed for one hour intervals; however, in actual practice, because the accuracy of computing inflows during short time periods for large reservoirs can be questionable, inflows normally will be computed on a daily timestep and a 6 hour moving average. In the spillway design routing, if inflows had been computed over longer time periods, a larger spillway discharge would have resulted. The design curves are included in this report as limiting criteria which specify minimum releases irrespective of other considerations.

d. Evacuation and Refill of Joint Use Zone

Filling of the Joint Use Zone in Bighorn Lake prior to the end of the flood season is a prime requisite for regulation of the reservoir. The Joint Use Zone is evacuated each year to a level that balances flood control and conservation. Monthly seasonal forecasts, as described in Exhibit VII of this manual, define the pool elevation of responsibility. Reclamation is required to maintain flood control capacity by keeping the pool elevation at or below the pool elevation of responsibility. If the pool elevation of responsibility is exceeded before the end of the runoff season, the Corps will notify Reclamation and Reclamation will increase releases to non-damaging levels and return the pool to the pool elevation of responsibility. Table 4 in Exhibit VII is an aid in establishing and maintaining the pool elevation of responsibility. See Plate 7-2 for a graphical depiction of the Corps' and Reclamation's release responsibility at various pool elevations.

e. Coordination with Other Projects

As discussed in Section 3-04, there are several reservoir projects above Bighorn Lake which influence Yellowtail inflows and regulation. Boysen Reservoir is the only Yellowstone Basin project containing flood control storage space. Boysen and Buffalo Bill are the major projects whose regulation could materially alter inflows into Bighorn Lake. The amount and duration of joint-use storage evacuation in Bighorn Lake and the magnitude of flood control releases must consider the effects of all upstream reservoirs upon anticipated runoff. It is possible that vacant space in all upstream reservoirs (other than Boysen) will be filled prior to the release of any water at rates substantially in excess of irrigation requirements. It also follows that when this upstream storage is filled, these upstream reservoirs will have little effect if large inflows still occur. At times it may become desirable to reduce Boysen releases based on accumulated storage in Bighorn Lake or to increase Yellowtail releases on the basis of events occurring in Boysen or other upstream reservoirs.

f. Ice Jams

Control of streamflow during the period of ice breakup and prevention of ice jams is an important flood control function of the project. Releases will be scheduled to minimize impacts of ice jam flooding. This usually requires a temporary reduction in project releases upon reports of downstream ice problems. Normally, fluctuation of project releases should be avoided during periods of ice breakup, as this tends to speed up the process.

g. Surcharge Operations

When it becomes apparent the pool elevation will exceed the top of the Exclusive Flood Control Zone (elevation 3657.0 feet), the Regional Director will be notified. Operation of the reservoir is the responsibility of Reclamation when the reservoir level is in the surcharge zone. A total of 3.0 feet of surcharge with a capacity of 48,708 af has been provided above the Exclusive Flood Control Zone. When the pool level is above the Exclusive Flood Control Zone, the District Engineer may make recommendations to the Regional Director for operation in interest of flood control, but such recommendations shall not be considered mandatory.

7-06 RECREATION

The information below describes recreation impacts taken into operational consideration under normal conditions. All the recreation facilities within the boundaries of the Bighorn Canyon Recreation Area are under the administration of the National Park Service through cooperative agreement No. 98-AA-60-10390.

An optimum lake level at or above elevation 3630.0 feet provides full flat-water recreational use from the upper end of the lake at Lovell, Wyoming down to the dam at Fort Smith, Montana. Below elevation 3617.0 feet, the use of the boat ramp at Horseshoe Bend becomes questionable. If the elevation is drawn below 3580.0 feet, all the boat ramps and marinas serving the lake are severely impacted. Recreational use on Bighorn Lake is also affected when the lake exceeds elevation 3642.0 feet. The Black Canyon recreation area is

affected at this level and many of the campground facilities become affected if the water level exceeds this elevation. During the period between Memorial Day and Labor Day, it is most desirable to operate the lake at or above elevation 3620.0 feet, to provide recreation at all the lake's boat ramps.

There are some restrictions on specific water surface levels in the Afterbay Reservoir for recreation. During the irrigation season, the minimum operating level of the Afterbay should be set no lower than elevation 3175.0 feet to provide appropriate diversions for irrigation. For flat water recreation on the Afterbay Reservoir, the minimum desirable operating level of the Afterbay should be no lower than elevation 3176.0 feet.

7-07 WATER QUALITY

The Corps does not have specific water quality responsibilities at Yellowtail Dam and Bighorn Reservoir. Reclamation will continue its water quality monitoring program for the reservoir. See Section 4-08 for more information on Reclamation's Water Quality monitoring efforts.

7-08 FISH AND WILDLIFE

The Corps does not have specific Fish and Wildlife responsibilities at Yellowtail Dam and Bighorn Reservoir.

The following desired fishery flows should be considered and provided, when possible, based on available water supply and the need to meet other operating goals and reservoir needs.

1) **Preferred Flow Range:** 2,500 cfs to 8,000 cfs is the preferred target range for flows when conditions allow.

2) Optimum Fishery Flow: A minimum of 2,500 cfs provides good spawning, rearing and cover conditions in all major side channels.

3) **Standard Fishery Flow:** A minimum of 2,000 cfs provides adequate spawning and rearing conditions in most side channels but cover for juvenile and adult fish is limited.

4) Minimum Fishery Flow: A minimum flow of 1,500 cfs protects main channel habitat but not important side channels. Fish population will likely be impacted at this flow rate.

5) Absolute Minimum Fishery Flow: During the planning stage for the Yellowtail Unit, the U.S. Fish and Wildlife Service recommended a minimum instantaneous river flow of 1,000 cfs. In the 1962 Yellowtail Unit Definite Plan Report, Reclamation accepted this recommendation and stated: "Downstream releases from the Yellowtail Afterbay are planned to exceed 1,000 cubic feet per second which is the minimum instantaneous flow recommended by the U.S. Fish and Wildlife Service." Releases

below 1,500 cfs should only be considered when necessary to prevent the active conservation storage from being fully depleted during a drought and as required for necessary emergency situations and dam safety concerns. During the irrigation season a minimum river flow of about 1,400 cfs is required to satisfy downstream irrigation use while maintaining a minimum river flow of 1,000 cfs below the irrigation diversions.

Management of the Bighorn Lake area for wildlife purposes was established between Reclamation and the Wyoming Game and Fish Department under Contract No. 14-06-600-9160 dated May 11, 1967.

7-09 WATER SUPPLY

The MDNRC adjudicates water rights by setting minimum release rates from reservoirs or at diversion dams, especially during the irrigation season when water shortages occur. During flood control operations, Reclamation will notify the Corps if any operations would jeopardize water supply.

7-10 HYDROELECTRIC POWER

Hydroelectric power generation is dependent upon turbine discharge and head. At the rated nameplate capacity, Yellowtail Powerplant generates 288 Megawatts (MW). At reservoir elevations above 3615.0 feet, sufficient head is available to operate Yellowtail Powerplant at its full capability of 288 MW. At elevations below 3615.0, capability is restricted to less than 288 MW, and if significant amounts of reactive power are required, loss of capability below 250 MW can start at elevation 3610.0 feet. It is generally desirable to maintain reservoir storage above elevation 3600.0 feet whenever there is a sufficient water supply and additional evacuation is not needed in the spring for flood control. The operating head at which the powerplant becomes inefficient to operate is at elevation 3547.0 feet.

If there is an unscheduled complete powerplant outage, stored water within the Afterbay will be released to the Bighorn River until Yellowtail personnel respond to the power failure and manually restore flows to the Afterbay and Bighorn River to pre-outage levels. Further adjustments to this release rate will be based on other water supply needs.

7-11 NAVIGATION

Yellowtail Dam and Reservoir is not regulated for navigation.

7-12 DROUGHT CONTINGENCY PLANS

Reclamation will conduct drought contingency planning.

7-13 FLOOD EMERGENCY ACTION PLANS

Reclamation maintains an EAP that is distributed among state, county and local emergency officials. The Corps will maintain communications with the MTAO during flood control operations. If communications with the MTAO are lost, the Corps will communicate release decisions directly with the Yellowtail Dam Operator.

7-14 DEVIATION FROM NORMAL REGULATION

a. Emergencies

An emergency situation is defined as a circumstance where failure to act immediately could result in loss of life or significant property damage. Occasional non-flood emergencies can occur where deviation from the normal operating procedures would assist other interests in managing the emergency. Examples of these types of emergencies include dam safety emergencies, downstream chemical spills, drowning, and/or facility failures. The EAP for Yellowtail was prepared by the MTAO. Copies of this plan are maintained at Reclamation offices and in the WCWQS. If the water control actions taken during an emergency are not covered in this manual, the WCWQS must inform MRBWM as soon as practicable. Written confirmation of the deviation and a description of the cause must be furnished to MRBWM.

b. Unplanned Minor Deviations

In some instances, activities of other interests create the potential need for unplanned deviations from normal operations. These activities usually require temporary deviations, usually from a few hours to a few days. A typical example of activities that would create the potential for unplanned minor deviations would be modifications of bridge and utility crossings or maintenance and inspection of reservoir project facilities. Each request should be analyzed on its own merits to determine if it is covered by this manual. If the proposed action is not covered by this manual, a deviation will be required. An evaluation of the proposed action should be included in the deviation request, including consideration of upstream watershed conditions, potential flood threats, the amount of water in storage in Bighorn Lake, and whether any alternative measures could be taken that would not require a deviation. Each deviation request will be evaluated to ensure that any potential adverse impacts to authorized project purposes are identified and considered prior to implementation. Approval for these minor deviations normally will be obtained from MRBWM by email. Post-deviation written documentation to MRBWM should contain an explanation of the deviation and its cause. In turn, a written response to the deviation request will be provided by MRBWM.

c. Planned Deviations

In accordance with Northwestern Division (NWD) Regulation1110-2-6, the Chief of MRBWM at NWD is the responsible approving official for all deviation requests for Yellowtail Dam. All deviation requests involving controversial regional or nationally significant actions shall be coordinated with the Chief of MRBWM prior to approval. The Chief of MRBWM retains authority to approve or disapprove all deviation requests. Prior approval is required for deviations from this Water Control Manual that do not meet the requirements of Sections 7-14.a and 7-14.b. Pre-coordination of a potential deviation request should occur between the requesting office and the approving authority to ensure a deviation is necessary. Deviation requests should be submitted to the Chief of MRBWM as appropriate. MRBWM will coordinate with the appropriate district or districts for all division-originated deviation requests. All deviations shall be documented in order to respond to any public concerns raised by those deviations. Coordination with federal, state, tribal, local, and private interests should be undertaken as appropriate. At a

minimum, deviation requests should discuss the need for coordination and present a plan for that coordination. Informal coordination prior to a deviation request may also be appropriate.

7-15 RATE OF RELEASE CHANGE

Release rates will not be changed more than 1,000 cfs in 6 hours when downstream channel is ice covered. During open water conditions, changes are limited to 5,000 cfs in 6 hours. Reclamation notifies all interested downstream stakeholders of all changes by email through water orders.

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CHAPTER 8—EFFECT OF WATER CONTROL PLAN

8-01 GENERAL

The following regulation objectives can be met at Yellowtail Dam by following the water control plan: a) regulate river flow to mitigate downstream flood risk; b) provide water for irrigation, municipal, and industrial use; c) provide desired river flow conditions to meet the needs of the downstream river fishery; d) provide desired conditions for fish, wildlife, and recreational use in the reservoir; and e) provide desired river and reservoir regulation to maximize the power generation benefit at Yellowtail powerplant. Plates 8-1 through 8-7 show plots of elevation, inflow and outflow for the period of record.

8-02 FLOOD RISK MANAGEMENT

a. Probable Maximum Flood

The spillway design flood or inflow design flood was reviewed and updated by Reclamation in a 1988 study. The updated spillway design flood is based upon the PMF. The PMF was determined to result from a probable maximum rainstorm over the entire basin on top of a 100-year snowpack event. Runoff from this flood event was routed downstream through Boysen Reservoir on the Wind River, Buffalo Bill Reservoir on the Shoshone River, and combined with runoff from the drainage basin below these two upstream reservoirs. The total rain-on-snow inflow flood for Boysen Reservoir has a peak discharge of 523,300 cfs and a volume of 2,098,000 af. The total rain on snow inflow flood for Buffalo Bill Reservoir has a peak discharge of 176,700 cfs and a volume of 647,900 af. The total flood runoff from the intervening area between these two upstream reservoirs and Bighorn Lake has a peak discharge of 823,900 cfs and a volume of 2,795,000 af. The resulting PMF has a peak discharge of 887,000 cfs and a 450 hour volume of 4,700,000 af.

Because there is authorized flood control space in Bighorn Lake and the flood occurred near the time that maximum snow conditions still existed in the basin, the PMF was routed through the lake using the assumption that the initial lake level would be at elevation 3620.0 feet, 6 feet above the top of the active conservation pool. This flood routing resulted in a peak discharge of 630,600 cfs and Yellowtail Dam being overtopped by 25.6 feet. Overtopping of the dam occurs before peak inflow of the PMF, but the failure potential from overtopping during the PMF is judged to be low. The routing studies also determined that floods greater than 31 percent of the PMF will overtop the dam. Plate 8-8 shows the PMF flood routing.

b. Reservoir Design Flood

The reservoir design flood for Yellowtail Dam was based on an analysis of past floods. The peak discharge was obtained from a curve enveloping a plot of recorded peak discharges versus drainage areas in the Bighorn Basin. The ratios of peak to volume for various periods of time were determined for several floods. The values were plotted on appropriate graph paper and curves were used to determine the shape and volume of the basic flood hydrograph. A hydrograph similar to that of the greatest rainstorm flood of record was superimposed upon the basic hydrograph so that the desired peak

discharge was obtained. A peak flow of 37,500 cfs, and a 52-day volume of 2,044,000 af resulted from this analysis. Routing of this project flood through Yellowtail Dam using regulation curves described in Section 7-05.c, and after it has been modified to show the effect of the operation of Boysen Reservoir (assuming 50% of the flood volume would come from the area above Boysen Reservoir as indicated from study of past floods), is shown on Plate 8-9.

c. Original Spillway Design Flood

The original spillway or inflow design flood as developed by Reclamation has a peak discharge of 126,000 cfs and a 10-day volume of 1,070,000 af. Routing of the original inflow design flood using regulation curves (Plate 7-3) is shown on Plate 8-10. The beginning pool elevation used in the routing (3648.9 feet) was that used by Reclamation in designing the spillway capacity. This represents the point where the Exclusive Flood Control Zone is approximately half full. The peak pool and release achieved in the routing were elevation 3659.1 feet and 99,000 cfs.

The magnitude (volume and peak inflow) of the design floods are compared with actual floods in Table 8-1 as follows:

Table 8-1

Comparison of Design Floods and Observed Floods

Flood	Station	Days	Volume ac-ft	Peak inflow (cfs)
PMF	Yellowtail	19	4,700,000	887,000
SDF (Original)	Yellowtail	10	1,070,000	126,000
RDF	Yellowtail	52	2,044,000	55,900
2017	Yellowtail	52	1,542,600	18,400
2011	St. Xavier	52	1,629,700	20,400
1967	Yellowtail	52	1,813,000	29,800
1965	St. Xavier	52	1,467,000	26,400
1957	St. Xavier	52	1,266,000	19,400
1947	St. Xavier	52	1,620,000	28,300
1943	St. Xavier	52	1,667,000	25,800

8-03 RECREATION

The Corps does not have specific recreation responsibilities at Yellowtail Dam, Bighorn Lake, or on the Bighorn River. See Section 2-06 for more information about public facilities above and below Yellowtail Dam.

8-04 WATER QUALITY

The Corps does not have specific water quality responsibilities above or below Yellowtail Dam. Reclamation will continue its water quality monitoring program for the reservoir and will make recommendations during flood control operations. The Corps will attempt to meet water quality requirements whenever the water quality requirements do not conflict with flood control operations.

8-05 FISH AND WILDLIFE

The Corps does not have any specific fish and wildlife responsibilities at Yellowtail Dam, Bighorn Lake, or on the Bighorn River. Reclamation will continue to coordinate fish and wildlife interests with state, local and other interested parties.

8-06 WATER SUPPLY

See Section 7-09 for more information on water supply.

8-07 HYDROELECTRIC POWER

See Section 7-10 for hydropower details.

8-08 NAVIGATION

Yellowtail Dam is not regulated for navigation.

8-09 DROUGHT CONTINGENCY PLAN

See Section 7-12 for Drought Contingency details.

8-10 FLOOD EMERGENCY ACTION PLAN

See Section 7-13 for Emergency Action Plan details.

8-11 FREQUENCIES

An analysis of historic peak pool elevations at Yellowtail Dam is shown in Plate 8-11.

8-12 OTHER STUDIES

No studies affecting Yellowtail flood control regulation are currently underway.

As forecast methods are used, possible improvements will be studied.

a. Examples of Regulation

Plates 4-3 through 4-8 show the regulation of several floods that occurred during Yellowtail's period of record. Exhibit VII provides an example of producing the May-July runoff forecast and setting the pool elevation of responsibility. These examples along with the regulation criteria specified in this manual will assist the water manager in making release decisions.

Reclamation has done numerous studies to improve conservation and joint use pool operations. These studies are available from the MTAO or Reclamation's Technical Services Center.

The Corps has developed a HEC-CWMS model for the Bighorn basin. This includes a direct runoff hydrologic model, reservoir simulation model, hydraulic model, and economic damages model. The model can be used by the WCWQS to aid in regulation.

b. Channel and Floodway Improvement

See Section 4-09 for a description of the downstream channel.

CHAPTER 9—WATER CONTROL MANAGEMENT

9-01 RESPONSIBILITIES AND ORGANIZATION

The organization for regulation of Yellowtail Dam and Bighorn Lake is based on a division of regulating responsibilities between the Bureau of Reclamation and the Corps of Engineers. In accordance with the Flood Control Act of 1944, the Corps of Engineers is responsible for prescribing regulations for the use of storage allocated to flood control. All other regulatory functions are the responsibility of Reclamation.

a. Corps of Engineers

ER 1110-2-1400, May 30 , 2016, assigns the Corps' reservoir regulation responsibility in the Missouri River Basin to the NWD Engineer. The regulations permit delegation of certain reservoir regulation functions to the District Engineer in the project area. The responsibility for assembly and interpretation of data affecting current reservoir regulation and for carrying out flood control regulation of Yellowtail Dam, according to plans agreed on in advance, has been delegated to the Omaha District Engineer. The WCWQS of the Omaha District has been assigned this District responsibility. In addition, the NWD Engineer, through NWD's MRBWM, monitors and reviews the overall regulation procedures performed by the Omaha District. An organization chart for the Omaha District is shown on Plate 9-1.

b. Bureau of Reclamation

Reclamation is the construction agency for Yellowtail Dam and is responsible for coordinating all matters pertaining to the operation and regulation of the project. Reclamation is solely responsible for regulation of the reservoir when the pool elevation is below 3614.0 feet or above 3657.0 feet. Between elevations 3614.0 feet and 3640.0 feet, the Joint Use Storage Zone, Reclamation and the Corps are jointly responsible.

The Reservoir and River Operations Group, MTAO, Missouri Basin Region, Reclamation in Billings, MT is responsible for water regulation at Yellowtail Dam and Bighorn Lake for all purposes except flood control. Within limits for the use of water and storage set by the Reservoir and River Operations Group, power generation is scheduled by Western Area Power Administration in Montrose, CO. Operation and maintenance of the project are under the immediate supervision of the Yellowtail Dam Facility Manager. The Facility Manager's duties for flood control operation are given in Exhibit III, Standing Instructions to Dam Operator. The Reservoir and River Operations Group will operate the outlet facilities and collect and report reservoir and hydrologic data. Exhibit III also lists Reclamation's Reservoir and River Operations Group personnel. An organization chart for Reclamation is shown on Plate 9-2.

c. National Weather Service

The NWS works closely with the Corps and Reclamation in providing forecasts of reservoir inflows and flood warnings to the public. An organization chart for the NWS is shown on Plate 9-3.

9-02 INTERAGENCY COORDINATION

a. Local Press and Corps Bulletins

Reclamation is responsible for coordination with the press when Yellowtail is not in a flood control operation. When flood control operations are occurring, Reclamation will remain the leader in coordination and the Corps will assist as needed.

b. National Weather Service

The Corps and Reclamation each have working relationships with the National Weather Service and these existing lines of communication will be used during a flood event.

c. U.S. Geological Survey

The Corps and Reclamation each have working relationships with the USGS and these existing lines of communication will be used during a flood event.

d. Power Marketing Agency

Reclamation routinely communicates with WAPA. This existing line of communication will be used during a flood event.

e. Other Federal, State, or Local Agencies

Reclamation is responsible for coordination with other federal, state and local agencies when Yellowtail is not in a flood control operation. When flood control operations are occurring, Reclamation will remain the leader in coordination and the Corps will assist as needed.

9-03 INTERAGENCY AGREEMENTS

The FWA between Reclamation and the Corps is in Exhibit II.

9-04 COMMISIONS, RIVER AUTHORITIES, COMPACTS AND COMMITTEES

There are committees and interest groups who provide operation suggestions in the Bighorn Basin. The responses and studies required by these groups are generally the responsibility of Reclamation. Reclamation will involve the Corps if any impacts to flood risk reduction from Yellowtail Dam are possible.

9-05 NON-FEDERAL HYDROPOWER

There is minimal non-federal hydropower that affects the regulation of Yellowtail Dam.

9-06 REPORTS

The Omaha District WCWQS publishes an Annual Report that describes operation and flood regulation for each project in the Omaha District. Reclamation's Reservoir and River Operations Group of the MTAO also publishes an Annual Operations Report each year that describes the operation for Yellowtail Dam.

EXHIBIT I

33 CFR Chapter II Part 208, Flood Control Regulations, Section 208.11

This exhibit contains text and table from 33 CFR Chapter II, Part 208, Flood Control Regulations, Section 208.11, Regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to prescription of rules and regulations by the Secretary of the Army in the interest of flood control and navigation (7-1-12 Edition). In this document, the text of Section 208.11 has been reformatted (indented) for clarity, and the List of Projects table at the end of document has been shortened to only include reservoirs within the Missouri River basin. Note that all elevation references for Yellowtail Dam in this document are based upon the National Geodetic Vertical Datum of 1929 (NGVD29). See paragraph 1-03 of Water Control Manual for additional information on elevation datum for Yellowtail Dam. Section 208.11 should be reviewed on an annual basis to identify any changes and these changes should be included in an updated exhibit to this manual. Updated editions of Section 208.11 can be found at the following website: http://www.ecfr.gov.

Exhibit I

33 CFR Chapter II Part 208 Flood Control Regulations, Section 208.11 (7-1-12 Edition),
Regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to prescription of rules and regulations by the Secretary of the Army in the interest of flood control and navigation.

(a) *Purpose.* This regulation prescribes the responsibilities and general procedures for regulating reservoir projects capable of regulation for flood control or navigation and the use of storage allocated for such purposes and provided on the basis of flood control and navigation, except projects owned and operated by the Corps of Engineers; the International Boundary and Water Commission, United States and Mexico; and those under the jurisdiction of the International Joint Commission, United States, and Canada, and the Columbia River Treaty. The intent of this regulation is to establish an understanding between project owners, operating agencies, and the Corps of Engineers.

(b) *Responsibilities.* The basic responsibilities of the Corps of Engineers regarding project operation are set out in the cited authority and described in the following paragraphs:

(1) Section 7 of the Flood Control Act of 1944 (58 Stat. 890, 33 U.S.C. 709) directs the Secretary of the Army to prescribe regulations for flood control and navigation in the following manner:

> Hereafter, it shall be the duty of the Secretary of War to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds provided on the basis of such purposes, and the operation of any such project shall be in accordance with such regulations: Provided, That this section shall not apply to the Tennessee Valley Authority, except that in case of danger from floods on the lower Ohio and Mississippi Rivers the Tennessee Valley Authority is directed to regulate the release of water from the Tennessee River into the Ohio River in accordance with such instructions as may be issued by the War Department

(2) Section 9 of Public Law 436–83d Congress (68 Stat. 303) provides for the development of the Coosa River, Alabama and Georgia, and directs the Secretary of the Army to prescribe rules and regulations for project operation in the interest of flood control and navigation as follows:

> The operation and maintenance of the dams shall be subject to reasonable rules and regulations of the Secretary of the Army in the interest of flood control and navigation. NOTE: This Regulation will also be applicable to dam and reservoir projects operated under provisions of future legislative acts wherein the Secretary of the Army is directed to prescribe rules and regulations in the interest of flood control and navigation. The Chief of Engineers, U.S. Army Corps of Engineers, is

designated the duly authorized representative of the Secretary of the Army to exercise the authority set out in the Congressional Acts. This Regulation will normally be implemented by letters of understanding between the Corps of Engineers and project owner and will incorporate the provisions of such letters of understanding prior to the time construction renders the project capable of significant impoundment of water. A water control agreement signed by both parties will follow when deliberate impoundment first begins or at such time as the responsibilities of any Corps-owned projects may be transferred to another entity. Promulgation of this Regulation for a given project will occur at such time as the name of the project appears in the FEDERAL REGISTER in accordance with the requirements of paragraph 6k. When agreement on a water control plan cannot be reached between the Corps and the project owner after coordination with all interested parties, the project name will be entered in the FEDERAL REGISTER and the Corps of Engineers plan will be the official water control plan until such time as differences can be resolved.

(3) Federal Energy Regulatory Commission (FERC), formerly Federal Power Commission (FPC), Licenses.

(i) Responsibilities of the Secretary of the Army and/or the Chief of Engineers in FERC licensing actions are set forth in reference 3c above and pertinent sections are cited herein. The Commission may further stipulate as a licensing condition, that a licensee enter into an agreement with the Department of the Army providing for operation of the project during flood times, in accordance with rules and regulations prescribed by the Secretary of the Army.

(A) Section 4(e) of the Federal Power Act requires approval by the Chief of Engineers and the Secretary of the Army of plans of dams or other structures affecting the navigable capacity of any navigable waters of the United States, prior to issuance of a license by the Commission as follows:

The Commission is hereby authorized and empowered to issue licenses to citizens * * * for the purpose of constructing, operating and maintaining dams, water conduits, reservoirs, powerhouses, transmission lines, or other project works necessary or convenient for the development and improvement of navigation and for the development, transmission, and utilization of power across, along, from or in any of the streams or other bodies of water over which Congress has jurisdiction * * * Provided further, That no license affecting the navigable capacity of any navigable waters of the United States shall be issued until the plans of the dam or other structures affecting navigation have been approved by the Chief of Engineers and the Secretary of the Army.

(B) Sections 10(a) and 10(c) of the Federal Power Act specify conditions of project licenses including the following:

> (1) Section 10(a). ‘‘That the project adopted * * * shall be such as in the judgment of the Commission will be best adapted to a comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce, for the improvement and utilization of waterpower development, and for other beneficial public uses * * *.’’
>
> (2) Section 10(c). ‘‘That the licensee shall * * * so maintain and operate said works as not to impair navigation, and shall conform to such rules and regulations as the Commission may from time to time prescribe for the protection of life, health, and property * * *.’’

(C) Section 18 of the Federal Power Act directs the operation of any navigation facilities built under the provision of that Act, be controlled by rules and regulations prescribed by the Secretary of the Army as follows:

> The operation of any navigation facilities which may be constructed as part of or in connection with any dam or diversion structure built under the provisions of this Act, whether at the expense of a licensee hereunder or of the United States, shall at all times be controlled by such reasonable rules and regulations in the interest of navigation; including the control of the pool caused by such dam or diversion structure as may be made from time to time by the Secretary of the Army, * * *.

(ii) Federal Power Commission Order No. 540 issued October 31, 1975, and published November 7, 1975 (40 FR 51998), amending § 2.9 of the Commission’s General Policy and Interpretations prescribed Standardized Conditions (Forms) for Inclusion in Preliminary Permits and Licenses Issued Under part I of the Federal Power Act. As an example, Article 12 of Standard Form L–3, titled: ‘‘Terms and Conditions of License for Constructed Major Projects Affecting Navigable Waters of the United States,’’ sets forth the Commission’s interpretation of appropriate sections of the Act, which deal with navigation aspects, and attendant responsibilities of the Secretary of the Army in licensing actions as follows:

> The United States specifically retains and safeguards the right to use water in such amount, to be determined by the Secretary of the Army, as may be necessary for the purposes of navigation on the navigable waterway affected; and the operations of the Licensee, so far as they affect the use, storage and discharge from storage of waters affected by the license, shall at all times be controlled by such reasonable rules and regulations as the Secretary of the

> Army may prescribe in the interest of navigation, and as the Commission may prescribe for the protection of life, health, and property, * * * and the Licensee shall release water from the project reservoir at such rate * * * as the Secretary of the Army may prescribe in the interest of navigation, or as the Commission may prescribe for the other purposes hereinbefore mentioned.

(c) *Scope and terminology.* This regulation applies to Federal authorized flood control and/or navigation storage projects, and to non-Federal projects which require the Secretary of the Army to prescribe regulations as a condition of the license, permit or legislation, during the planning, design and construction phases, and throughout the life of the project. In compliance with the authority cited above, this regulation defines certain activities and responsibilities concerning water control management throughout the Nation in the interest of flood control and navigation. In carrying out the conditions of this regulation, the owner and/or operating agency will comply with applicable provisions of Pub. L. 85–624, the Fish and Wildlife Coordination Act of 1958, and Pub. L. 92–500, the Federal Water Pollution Control Act Amendments of 1972. This regulation does not apply to local flood protection works governed by § 208.10, or to navigation facilities and associated structures which are otherwise covered by part 207 (Navigation Regulations) of title 33 of the code. Small reservoirs, containing less than 12,500 acre-feet of flood control or navigation storage, may be excluded from this regulation and covered under § 208.10, unless specifically required by law or conditions of the license or permit.

(1) The terms *reservoir* and *project* as used herein include all water resource impoundment projects constructed or modified, including natural lakes, that are subject to this regulation.

(2) The term *project owner* refers to the entity responsible for maintenance, physical operation, and safety of the project, and for carrying out the water control plan in the interest of flood control and/or navigation as prescribed by the Corps of Engineers. Special arrangements may be made by the project owner for ‘‘operating agencies’’ to perform these tasks.

(3) The term *letter of understanding* as used herein includes statements which consummate this regulation for any given project and define the general provisions or conditions of the local sponsor, or owner, cooperation agreed to in the authorizing legislative document, and the requirements for compliance with section 7 of the 1944 Flood Control Act, the Federal Power Act or other special congressional act. This information will be specified in the water control plan and manual. The letter of understanding will be signed by a duly authorized representative of the Chief of Engineers and the project owner. A ‘‘field working agreement’’ may be substituted for a letter of understanding, provided that the specified minimum requirements of the latter, as stated above, are met.

(4) The term *water control agreement* refers to a compilation of water control criteria, guidelines, diagrams, release schedules, rule curves and specifications that basically govern

the use of reservoir storage space allocated for flood control or navigation and/or release functions of a water control project for these purposes. In general, they indicate controlling or limiting rates of discharge and storage space required for flood control and/or navigation, based on the runoff potential during various seasons of the year.

(5) For the purpose of this regulation, the term *water control plan* is limited to the plan of regulation for a water resources project in the interest of flood control and/or navigation. The water control plan must conform with proposed allocations of storage capacity and downstream conditions or other requirements to meet all functional objectives of the particular project, acting separately or in combination with other projects in a system.

(6) The term *real-time* denotes the processing of current information or data in a sufficiently timely manner to influence a physical response in the system being monitored and controlled. As used herein the term connotes * * * the analyses for and execution of water control decisions for both minor and major flood events and for navigation, based on prevailing hydrometeorological and other conditions and constraints, to achieve efficient management of water resource systems.

(d) *Procedures—*

(1) *Conditions during project formulation.* During the planning and design phases, the project owner should consult with the Corps of Engineers regarding the quantity and value of space to reserve in the reservoir for flood control and/or navigation purposes, and for utilization of the space, and other requirements of the license, permit or conditions of the law. Relevant matters that bear upon flood control and navigation accomplishment include: Runoff potential, reservoir discharge capability, downstream channel characteristics, hydrometeorological data collection, flood hazard, flood damage characteristics, real estate acquisition for flowage requirements (fee and easement), and resources required to carry out the water control plan. Advice may also be sought on determination of and regulation for the probable maximum or other design flood under consideration by the project owner to establish the quantity of surcharge storage space, and freeboard elevation of top of dam or embankment for safety of the project.

(2) *Corps of Engineers involvement.* If the project owner is responsible for real-time implementation of the water control plan, consultation and assistance will be provided by the Corps of Engineers when appropriate and to the extent possible. During any emergency that affects flood control and/or navigation, the Corps of Engineers may temporarily prescribe regulation of flood control or navigation storage space on a day-to-day (real-time) basis without request of the project owner. Appropriate consideration will be given for other authorized project functions. Upon refusal of the project owner to comply with regulations prescribed by the Corps of Engineers, a letter will be sent to the project owner by the Chief of Engineers or his duly authorized representative describing the reason for the regulations prescribed, events that have transpired, and notification that the project owner is in violation

of the Code of Federal Regulations. Should an impasse arise, in that the project owner or the designated operating entity persists in noncompliance with regulations prescribed by the Corps of Engineers, measures may be taken to assure compliance.

(3) *Corps of Engineers implementation of real-time water control decisions.* The Corps of Engineers may prescribe the continuing regulation of flood control storage space for any project subject to this regulation on a day-to-day (real-time) basis. When this is the case, consultation and assistance from the project owner to the extent possible will be expected. Special requests by the project owner, or appropriate operating entity, are preferred before the Corps of Engineers offers advice on real-time regulation during surcharge storage utilization.

(4) *Water control plan and manual.* Prior to project completion, water control managers from the Corps of Engineers will visit the project and the area served by the project to become familiar with the water control facilities, and to insure sound formulation of the water control plan. The formal plan of regulation for flood control and/or navigation, referred to herein as the water control plan, will be developed and documented in a water control manual prepared by the Corps of Engineers. Development of the manual will be coordinated with the project owner to obtain the necessary pertinent information, and to insure compatibility with other project purposes and with surcharge regulation. Major topics in the manual will include: Authorization and description of the project, hydrometeorology, data collection and communication networks, hydrologic forecasting, the water control plan, and water resource management functions, including responsibilities and coordination for water control decision-making. Special instructions to the dam tender or reservoir manager on data collection, reporting to higher Federal authority, and on procedures to be followed in the event of a communication outage under emergency conditions, will be prepared as an exhibit in the manual. Other exhibits will include copies of this regulation, letters of understanding consummating this regulation, and the water control agreements. After approval by the Chief of Engineers or his duly authorized representative, the manual will be furnished the project owner.

(5) *Water control agreement.*

(i) A water control diagram (graphical) will be prepared by the Corps of Engineers for each project having variable space reservation for flood control and/or navigation during the year; e.g., variable seasonal storage, joint-use space, or other rule curve designation. Reservoir inflow parameters will be included on the diagrams when appropriate. Concise notes will be included on the diagrams prescribing the use of storage space in terms of release schedules, runoff, nondamaging or other controlling flow rates downstream of the damsite, and other major factors as appropriate. A water control release schedule will be prepared in tabular form for projects that do not have variable space reservation for flood control and/or navigation. The water control diagram or release schedule will be signed by a duly authorized

representative of the Chief of Engineers, the project owner, and the designated operating agency, and will be used as the basis for carrying out this regulation. Each diagram or schedule will contain a reference to this regulation.

(ii) When deemed necessary by the Corps of Engineers, information given on the water control diagram or release schedule will be supplemented by appropriate text to assure mutual understanding on certain details or other important aspects of the water control plan not covered in this regulation, on the water control diagram or in the release schedule. This material will include clarification of any aspects that might otherwise result in unsatisfactory project performance in the interest of flood control and/or navigation. Supplementation of the agreement will be necessary for each project where the Corps of Engineers exercises the discretionary authority to prescribe the flood control regulation on a day-today (real-time) basis. The agreement will include delegation of the responsibility. The document should also cite, as appropriate, section 7 of the 1944 Flood Control Act, the Federal Power Act and/or other congressional legislation authorizing construction and/or directing operation of the project.

(iii) All flood control regulations published in the FEDERAL REGISTER under this section (part 208) of the code prior to the date of this publication which are listed in § 208.11(e) are hereby superseded.

(iv) Nothing in this regulation prohibits the promulgation of specific regulations for a project in compliance with the authorizing acts, when agreement on acceptable regulations cannot be reached between the Corps of Engineers and the owner.

(6) *Hydrometeorological instrumentation.* The project owner will provide instrumentation in the vicinity of the damsite and will provide communication equipment necessary to record and transmit hydrometeorological and reservoir data to all appropriate Federal authorities on a real-time basis unless there are extenuating circumstances or are otherwise provided for as a condition of the license or permit. For those projects where the owner retains responsibility for real-time implementation of the water control plan, the owner will also provide or arrange for the measurement and reporting of hydrometeorological parameters required within and adjacent to the watershed and downstream of the damsite, sufficient to regulate the project for flood control and/or navigation in an efficient manner. When data collection stations outside the immediate vicinity of the damsite are required, and funds for installation, observation, and maintenance are not available from other sources, the Corps of Engineers may agree to share the costs for such stations with the project owner. Availability of funds and urgency of data needs are factors which will be considered in reaching decisions on cost sharing.

(7) *Project safety.* The project owner is responsible for the safety of the dam and appurtenant facilities and for regulation of the project during surcharge storage utilization.

Emphasis upon the safety of the dam is especially important in the event surcharge storage is utilized, which results when the total storage space reserved for flood control is exceeded. Any assistance provided by the Corps of Engineers concerning surcharge regulation is to be utilized at the discretion of the project owner, and does not relieve the owner of the responsibility for safety of the project.

(8) *Notification of the general public.* The Corps of Engineers and other interested Federal and State agencies, and the project owner will jointly sponsor public involvement activities, as appropriate, to fully apprise the general public of the water control plan. Public meetings or other effective means of notification and involvement will be held, with the initial meeting being conducted as early as practicable but not later than the time the project first becomes operational. Notice of the initial public meeting shall be published once a week for 3 consecutive weeks in one or more newspapers of general circulation published in each county covered by the water control plan. Such notice shall also be used when appropriate to inform the public of modifications in the water control plan. If no newspaper is published in a county, the notice shall be published in one or more newspapers of general circulation within that county. For the purposes of this section a newspaper is one qualified to publish public notices under applicable State law. Notice shall be given in the event significant problems are anticipated or experienced that will prevent carrying out the approved water control plan or in the event that an extreme water condition is expected that could produce severe damage to property or loss of life. The means for conveying this information shall be commensurate with the urgency of the situation. The water control manual will be made available for examination by the general public upon request at the appropriate office of the Corps of Engineers, project owner or designated operating agency.

(9) *Other generalized requirements for flood control and navigation.*

(i) Storage space in the reservoirs allocated for flood control and navigation purposes shall be kept available for those purposes in accordance with the water control agreement, and the plan of regulation in the water control manual.

(ii) Any water impounded in the flood control space defined by the water control agreement shall be evacuated as rapidly as can be safely accomplished without causing downstream flows to exceed the controlling rates; i.e., releases from reservoirs shall be restricted insofar as practicable to quantities which, in conjunction with uncontrolled runoff downstream of the dam, will not cause water levels to exceed the controlling stages currently in force. Although conflicts may arise with other purposes, such as hydropower, the plan or regulation may require releases to be completely curtailed in the interest of flood control or safety of the project.

(iii) Nothing in the plan of regulation for flood control shall be construed to require or allow dangerously rapid changes in magnitudes of releases. Releases will be made

in a manner consistent with requirements for protecting the dam and reservoir from major damage during passage of the maximum design flood for the project.

(iv) The project owner shall monitor current reservoir and hydro- meteorological conditions in and adjacent to the watershed and downstream of the damsite, as necessary. This and any other pertinent information shall be reported to the Corps of Engineers on a timely basis, in accordance with standing instructions to the damtender or other means requested by the Corps of Engineers.

(v) In all cases where the project owner retains responsibility for real-time implementation of the water control plan, he shall make current determinations of: Reservoir inflow, flood control storage utilized, and scheduled releases. He shall also determine storage space and releases required to comply with the water control plan prescribed by the Corps of Engineers. The owner shall report this information on a timely basis as requested by the Corps of Engineers.

(vi) The water control plan is subject to temporary modification by the Corps of Engineers if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communication available. The action taken shall be confirmed in writing the same day to the project owner and shall include justification for the action.

(vii) The project owner may temporarily deviate from the water control plan in the event an immediate short-term departure is deemed necessary for emergency reasons to protect the safety of the dam, or to avoid other serious hazards. Such actions shall be immediately reported by the fastest means of communication available. Actions shall be confirmed in writing the same day to the Corps of Engineers and shall include justification for the action. Continuation of the deviation will require the express approval of the Chief of Engineers, or his duly authorized representative.

(viii) Advance approval of the Chief of Engineers, or his duly authorized representative, is required prior to any deviation from the plan of regulation prescribed or approved by the Corps of Engineers in the interest of flood control and/or navigation, except in emergency situations provided for in paragraph (d)(9)(vii) of this section. When conditions appear to warrant a prolonged deviation from the approved plan, the project owner and the Corps of Engineers will jointly investigate and evaluate the proposed deviation to insure that the overall integrity of the plan would not be unduly compromised. Approval of prolonged deviations will not be granted unless such investigations and evaluations have been conducted to the extent deemed necessary by the Chief of Engineers, or his designated representatives, to fully substantiate the deviation.

(10) *Revisions.* The water control plan and all associated documents will be revised by the Corps of Engineers as necessary, to reflect changed conditions that come to bear upon flood

control and navigation, e.g., reallocation of reservoir storage space due to sedimentation or transfer of storage space to a neighboring project. Revision of the water control plan, water control agreement, water control diagram, or release schedule requires approval of the Chief of Engineers or his duly authorized representative. Each such revision shall be effective upon the date specified in the approval. The original (signed document) water control agreement shall be kept on file in the respective Office the Division Engineer, Corps of Engineers, Department of the Army, located at division offices throughout the continental USA. Copies of these agreements may be obtained from the office of the project owner, or from the office of the appropriate Division Engineer, Corps of Engineers.

(11) *Federal Register.* The following information for each project subject to section 7 of the 1944 Flood Control Act and other applicable congressional acts shall be published in the FEDERAL REGISTER prior to the time the projects becomes operational and prior to any significant impoundment before project completion or * * * at such time as the responsibility for physical operation and maintenance of the Corps of Engineers owned projects is transferred to another entity:

(i) Reservoir, dam, and lake names,

(ii) Stream, county, and State corresponding to the damsite location,

(iii) The maximum current storage space in acre-feet to be reserved exclusively for flood control and/or navigation purposes, or any multiple-use space (intermingled) when flood control or navigation is one of the purposes, with corresponding elevations in feet above mean sea level, and area in acres, at the upper and lower limits of said space,

(iv) The name of the project owner, and (v) Congressional legislation authorizing the project for Federal participation.

(e) *List of projects.* The following tables, ‘‘Pertinent Project Data—Section 208.11 Regulation,’’ show the pertinent data for projects which are subject to this regulation. Note that the following tables show only those projects within the Missouri River basin, which includes the Omaha District and Kansas City District of the Northwestern Division, Corps of Engineers.

LIST OF PROJECTS

[Missouri River Basin Non-Corps projects with Corps Regulation Requirements]

Project name[1] (1)	State (2)	County (3)	Stream[1] (4)	Project purpose[2] (5)	Storage 1000 AF (6)	Elev limits feet M.S.L.		Area in acres		Authorizing legis.[3] (11)	Proj. owner[4] (12)
						Upper (7)	Lower (8)	Upper (9)	Lower (10)		
Omaha District Projects											
Boysen Dam & Res	WY	Fremont	Wild R	F FEIQ EIQ	150.4 146.1 403.8	4732.2 4725.0 4717.0	4725.0 4717.0 4685.0	22170 19560 16960	19560 16960 9280	PL 78–534	USBR.
Canyon Ferry Dam & Lk	MT	Lewis Clark	Missouri R	F FEI EI	99.5 795.1 711.5	3800.0 3797.0 3770.0	3797.0 3770.0 3728.0	33535 32800 24125	32800 24125 11480	PL 78–534	USBR.
Clark Canyon Dam & Res	MT	Beaverhead	Beaverhead R	F FI I	79.1 50.4 126.1	5560.4 5546.1 5535.7	5546.1 5535.7 5470.6	5900 5160 4495	5160 4495 220	PL 78–534	USBR.
Glendo Dam & Res	WY	Platte	N Platte R	F EIM	271.9 454.3	4653.0 4635.0	4635.0 4570.0	17990 12370	12370 3130	PL 78–534	USBR.
Heart Butte Dm & Lk Tschida	ND	Grant	Heart R	F IQ	147.9 69.0	2094.5 2064.5	2064.5 2030.0	6580 3400	3400 810	PL 78–534	USBR.
Jamestown Dam & Res	ND	Stutsman	James R	F IQ	185.4 28.1	1454.0 1429.8	1429.8 1400.0	13210 2090	2090 160	PL 78–534	USBR.
Keyhole Dam & Res	WY	Crook	Belle Fourche R	F IQ	140.5 185.8	4111.5 4099.3	4099.3 4051.0	13730 9410	9410 820	PL 78–534	USBR.
Pactola Dam & Res	SD	Pennington	Rapid Cr	F IM	43.1 55.0	4621.5 4580.2	4580.2 4456.1	1230 860	860 100	PL 78–534	USBR.
Shadehill Dam & Res	SD	Perkins	Grand R	F IQ	218.3 80.9	2302.0 2271.9	2271.9 2250.8	9900 4800	4800 2800	PL 78–534	USBR.
Tiber Dam & Res	MT	Libert Toole	Marias R	F FIQ IQ	400.9 268.0 121.7	3012.5 2993.0 2976.0	2993.0 2976.0 2966.4	23150 17890 13790	17890 13790 11710	PL 78–534	USBR.
Yellowtail Dam & Bighorn Lk	MT	Big Horn	Bighorn R	F FEIQ EIQ	258.3 240.3 336.1	3657.0 3640.0 3614.0	3640.0 3614.0 3547.0	17280 12600 6915	12600 6915 4150	PL 78–534	USBR PUD
Kansas City District Projects											
Bonny Dam & Res	CO	Yuma	S Fork Republic R	F ICR	128.2 39.2	3710.0 3672.0	3672.0 3638.0	5036 2042	2042 331	PL 78–534 PL 79–732	USBR.
Cedar Bluff Dam & Res	KS	Trego	Smoky Hill R	F IMCR	191.9 149.8	2166.0 2144.0	2144.0 2107.8	10790 6869	6869 2086	PL 78–534	USBR.
Enders Dam & Res	NE	Chase	Frenchman Cr	F ICR	30.0 34.5	3127.0 3112.3	3112.3 3082.4	2405 1707	1707 658	PL 78–534 PL 84–505	USBR.
Glen Elder Dam & Waconda Lk	KS	Mitchel	Solomon R	F IM	722.3 204.8	1488.3 1455.6	1455.6 1428.0	33682 12602	12602 3341	PL 78–534 PL 79–526	USBR.
Kirwin Dam & Res	KS	Phillips	N Fork Solomon R	F ICR	215.1 89.6	1757.3 1729.2	1729.3 1697.0	10640 5080	5080 1010	PL 78–534 PL 79–732; PL 79–526	USBR.
Lovewell Dam & Res	KS	Jewell	White Rock Cr	F ICR	50.5 24.9	1595.3 1582.6	1582.6 1571.7	5025 2986	2986 1704	PL 78–534 PL 79–732	USBR.
Medicine Cr Dam Harry Strunk Lk	NE	Frontier	Medicine Cr	F ICR	52.7 26.8	2386.2 2366.1	2366.1 2343.0	3483 1840	1840 701	PL 78–534 PL 84–505	USBR.
Norton Dam & Kieth Sebelius Lk	KS	Norton	Prairie Dog Cr	F IMRC	98.8 30.7	2331.4 2304.3	2304.3 2280.4	5316 2181	2181 587	PL 78–534 PL 79–526 PL 79–732	USBR.
Red Willow Dam Hugh Butler Lk	NE	Frontier	Red Willow Cr	F IRC	48.9 27.3	2604.9 2581.8	2581.8 2558.0	2682 1629	1629 787	PL 78–534 PL 85–783 PL 84–505	USBR.
Trenton Dam & Res	NB	Hitchcock	Republican R	F IRC	134.1 99.8	2773.0 2752.0	2752.0 2720.0	7940 4922	4922 1572	PL 78–534 PL 84–505	USBR.
Webster Dam & Res	KS	Rocks	S Fork Solomon R	F IRC	183.4 72.1	1923.7 1892.5	1892.5 1860.0	8480 3772	3772 906	PL 78–534 PL 79–526 PL 79–732	USBR

[1]Cr—Creek; CS—Control Structure; Div—Diversion; DS—Drainage Structure; FG—Floodgate; Fk—Fork; GIWW—Gulf Intercoastal Waterway; Lk—Lake; L&D—Lock & Dam; PS—Pump Station; R—River; Res—Reservoir
[2]F—Flood Control; N—Navigation; P—Corps Hydropower; E—Non Corps Hydropower; I—Irrigation; M—Municipal and/or Industrial Water Supply; C—Fish and Wildlife Conservation; A—Low Flow Augmentation or Pollution Abatement; R—Recreation; Q—Water Quality or Silt Control
[3]FCA—Flood Control Act; FERC—Federal Energy Regulatory Comm; HD—House Document; PL—Public Law; PW—Public Works; RHA—River & Harbor Act; SD—Senate Document; WSA—Water Supply Act
[4]Appl Pwr—Appalachian Power; Chln PUD—Chelan Cnty PUD 1; CLPC—CT Light & Power Co; Dgls PUD—Douglas Cnty PUD 1; DWR—Department of Water Resources; EB-MUD—East Bay Municipal Utility Dist; GRD—Grand River Dam Auth; Grnt PUD—Grant Cnty PUD 2; Hnbl—city of Hannibal; M&T Irr—Modesto & Turlock Irr; Mrcd Irr—Merced Irr; NEPC—New England Power Co; Pgnt P&L—Pugent Sound Power & Light; Ptmc Comm—Upper Potomac R Comm; Rclm B—Reclamation Board; Rkfd—city of Rockford; Sttl—city of Seattle; Tac—City of Tacoma; Vale USBR—50% Vale Irr 50% USBR; WF&CWID—City of Wichita Falls and Wichita Cnty Water Improvement District No. 2; WMEC—Western MA Electric Co; YCWA—Yuba City Water Auth; Yolo FC&W—Yolo Flood Control & Water Conserv Dist

(Sec. 7, Pub. L. 78–534, 58 Stat. 890 (33 U.S.C. 709); the Federal Power Act, 41 Stat. 1063 (16 U.S.C. 791(A)); and sec. 9, Pub. L. 83–436, 68 Stat. 303)

[43 FR 47184, Oct. 13, 1978, as amended at 46 FR 58075, Nov. 30, 1981; 55 FR 21508, May 24, 1990]

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EXHIBIT II

MEMORANDUM OF AGREEMENT BETWEEN U.S. ARMY CORPS OF ENGINEERS, OMAHA DISTRICT AND U.S. BUREAU OF RECLAMATION, MISSOURI BASIN REGION

YELLOWTAIL DAM AND BIGHORN RESERVOIR

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MEMORANDUM OF AGREEMENT
BETWEEN
U.S. ARMY CORPS OF ENGINEERS, OMAHA DISTRICT
AND
U.S. BUREAU OF RECLAMATION, MISSOURI BASIN REGION

SUBJECT: Yellowtail Dam Field Working Agreement

Flood Control Regulations governing the regulation of Yellowtail Dam and Bighorn Lake, Bighorn River, in Big Horn County, Montana, having been completed and published in the Federal Register, at Page 17996, Volume 36, issue of September 9, 1971, it is agreed that the dam and reservoir will be regulated under the following rules, unless and until such rules shall be amended by mutual agreement. This Field Working Agreement supersedes all previously signed agreements:

a. Storage Capacity Allocations. The storage capacity allocations of Bighorn Lake, exclusive of surcharge storage capacity above elevation 3657.0 feet, are defined in the following subparagraphs:

(1) Exclusive Flood Control Storage. Exclusive flood control storage capacity allocation shall include the storage capacity between elevation 3640.0 feet and 3657.0 feet, for which there have been constructed suitable outlet works to provide discharges as expressly indicated herein.

(2) Joint Use Storage. Joint use storage capacity allocation shall include the storage capacity between elevation 3614.0 feet and 3640.0 feet. Joint use storage capacity shall normally be available for conservation usage but may be vacated for seasonal flood control between 1 May and 31 July as provided hereinafter. The joint use storage may also be filled if downstream flood targets are exceeded.

(3) Conservation Storage. Active conservation storage capacity allocation shall include the storage capacity between elevation 3547.0 and elevation 3614.0 feet.

(4) Inactive Storage. Inactive storage capacity allocation shall include the storage capacity between elevation 3296.5 and elevation 3547.0 feet.

(5) Dead Storage. Dead storage capacity allocation shall include the storage capacity between streambed elevation and elevation 3296.5 feet. This capacity is established by the elevation of the invert of the river outlet.

b. Storage Reallocations. The Regional Director shall at reasonable intervals make necessary field surveys and office studies to prepare estimates of volume and location of sediment deposits in the reservoir. If the results of these studies show the total storage available for exclusive flood control, joint use, or active conservation (currently amounting to 252,630 acre-feet, 232,735 acre-feet, and 310,844 acre-feet respectively) is reduced by an amount exceeding 10 percent of the allocation for such purpose, the regulation plan described herein with respect to the elevation limits of the storage allocation shall be reviewed with the view of equitably distributing the loss of reservoir capacity between the primary reservoir uses. Any redistribution of storage capacity allocations is to be contingent on subparagraph h.

c. Plan of Operation. The Regional Director shall regulate Yellowtail Dam and Bighorn Lake in the interest of flood control in accordance with the Part 208, Flood Control Regulations, and the Standing Instructions to the Dam Tender. Regulation of the reservoir when the pool level is in the exclusive flood control zone or in the portion of the joint use storage when required for flood control, or when flows at downstream flood targets are exceeded as described in paragraphs below, shall be construed as a flood control operation and releases shall be determined by the District Engineer. At all other pool levels, the District Engineer may make recommendations to the Regional Director for regulating in the interest of flood control, but such recommendations shall not be considered mandatory (however, the Regional Director shall regulate to maintain non-damaging releases insofar as possible consistent with criteria given in subparagraph f and the Standing Instructions to Dam Tender).

1. Joint Use Operation. Responsibility for operation of storage in the joint use space between elevations 3614.0 feet and 3640.0 feet shall be established by the pool elevation of responsibility. Filling of the joint use zone in Bighorn Lake prior to the end of the flood season is a prime requisite for regulation of the reservoir. The joint use zone is evacuated each year to a level that balances flood control and conservation. Monthly seasonal forecasts, as described in Exhibit VII, define the pool elevation of responsibility. Reclamation is required to maintain flood control capacity by keeping the pool elevation at or below the pool elevation of responsibility. If pool elevation of responsibility is exceeded before the end of the runoff season the Corps will notify Reclamation and Reclamation will increase releases to non-damaging levels and return the pool elevation to the pool elevation of responsibility. Table 4 in Exhibit VII is an aid in establishing and maintaining the pool elevation of responsibility. During these periods whenever the reservoir is above the elevations so defined, operation of the reservoir shall be construed as a flood control operation, and releases shall be determined by the District Engineer, except for minimum releases needed for power, irrigation, and other downstream conservation requirements. Whenever the reservoir is below the elevation of responsibility and stages at downstream flood points are below target levels, releases will be determined by the Regional Director.

The Regional Director and the District Engineer may, by mutual agreement, recommend change in the plan of operation set forth herein for consideration and approval by higher echelons of their respective organizations.

2. Flood Targets. Regulation of storage of Yellowtail Dam will be made to prevent exceeding the values below, insofar as possible. The only exception to this would be in the event of occurrence of high inflows in combination with pool elevations above 3649.0 feet. The Corps will have release responsibility if the flood targets are exceeded while the reservoir is in the conservation or joint use storage zone. The flood targets and their locations are listed below.

Flood Target Discharge	Target Locations
20,000 cfs	near St. Xavier
25,000 cfs	at Bighorn
65,000 cfs	at Miles City
100,000 cfs	at Sidney

d. Integrated Regulation of All Flood Control Reservoirs in Missouri River Basin. Releases from Yellowtail Dam eventually flow into Garrison Reservoir of the Missouri River Mainstem Reservoirs. In the quotes below, the USACE Northwestern Division's Missouri River Basin Water Management is abbreviated MRBWM. As per the Missouri River Mainstem Reservoir System Master Water Control Manual, November 2018, paragraph 7-04.25, "When tributary reservoir regulation affects Missouri River flood flows or navigation on the Missouri River, tributary reservoir regulation will, however, become a direct concern of the MRBWM office. During such periods, the MRBWM office will issue pertinent tributary reservoir regulating instructions so that flood damages may be held to a minimum through integrated regulation of all flood control reservoirs in the Missouri River basin." Additionally, as per Section 208.11 of 33 CFR Chapter II, "The water control plan is subject to temporary modification by the Corps of Engineers if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communication available. The action taken shall be confirmed in writing the same day to the project owner and shall include justification for the action." As a result of these requirements, during large floods affecting the Missouri River Mainstem Reservoirs, releases of flood storage in Bighorn Reservoir may be adjusted in order to meet basin-wide flood control goals of the Missouri River System. In the case of Yellowtail Dam, requests for modification will be made to the Montana Area Office Reservoir and River Operations Group, Bureau of Reclamation in Billings, MT, which is part of the Missouri Basin Region. Requests should be made via telephone call or email and confirmed via an official reservoir regulation order the same day.

e. Conservation and Dam Safety Release Priorities. Nothing in this agreement shall prohibit the Regional Director from making such releases as are required to meet irrigation, power, or other downstream conservation requirements or as may be required to protect the dam and reservoir from major damage.

f. Instructions issued by the District Engineer. Flood control operations shall be issued to the Regional Director. The operating personnel at the dam shall act upon the order of the District Engineer after receipt of the order by the Regional Director. In the absence of communication between the operating personnel and the Regional Director, the District Engineer will issue flood control operations directly to the operating personnel.

g. Collection and assembly of Hydrologic Data and Reporting Arrangements. Available reports from precipitation and streamflow stations pertinent to flood control regulation of the reservoir which are collected by either the Regional Director or District Engineer will be relayed to the other by the most expeditious means of communication, under such detailed arrangements as may be made from time to time.

h. Design Limitations. It is recognized that any changes in the discharge characteristics of the spillway structures resulting from reallocation of storage capacities, or for any other reason, which otherwise are mutually acceptable to the Corps of Engineers and the Bureau of Reclamation, must be approved by the Regional Director.

[redacted]

Mark R. Himes, P.E.
Colonel, Corps of Engineers
District Commander

[redacted]

(Date)

BRENT ESPLIN

Digitally signed by BRENT ESPLIN
Date: 2023.06.06 13:09:46 -06'00'

Brent C Esplin
Regional Director
Missouri Basin Region

(Date)

EXHIBIT III

STANDING INSTRUCTIONS TO DAM OPERATOR FOR FLOOD CONTROL OPERATIONS

YELLOWTAIL DAM AND BIGHORN RESERVOIR

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POST IN A CONSPICUOUS PLACE

STANDING INSTRUCTIONS TO DAM OPERATOR FOR FLOOD CONTROL OPERATIONS AT YELLOWTAIL DAM

1. Routine Reports. The Water Control & Water Quality Section of the Office of the District Engineer, U.S. Army Corps of Engineers (Corps), Omaha, Nebraska, is the unit of the Corps designated to prepare and issue regulation orders concerning flood control operation of Yellowtail Dam. Regulation orders are prepared by the Corps and normally telephoned or emailed to Reclamation's Montana Area Office (MTAO). Normally hydrologic data is obtained from Reclamation's Hydromet database. Should this data be unavailable the Dam Tender will furnish the Corps through the MTAO or directly by 8 a.m. daily, reports of pertinent reservoir data (pool and tailwater, elevations, storage, outflow, inflow, precipitation, etc.).

2. Special Reports. The dam tender will notify the District Engineer's regulation personnel through the MTAO's Reservoir and River Operations Group, immediately whenever the following conditions occur between 7:45 a.m. and 4:30 p.m. and will report by 9 a.m. the following day whenever they occur between 4:30 p.m. and 7:45 a.m., weekends and holidays included. In the event the Reservoir and River Operations Group cannot be reached, the dam tender will telephone the data to the Area Engineer at Corps' Garrison Project Office in Riverdale, ND, for further transmittal to the District Engineer.

a. The dam operator has knowledge of flooding downstream.

b. The pool has risen 0.5 foot or more in 6 hours. (A rise in pool which, in the opinion of the dam tender, reaches this limit only as a result of wind effects, need not be reported).

c. The pool is above elevation 3614.0 feet and has risen 2.0 feet or more since the last report to these offices.

d. The pool is above elevation 3614.0 feet and the average inflow for the day is more than 5,000 cfs greater than the latest report.

3. Emergency Regulation. Instructions for flood control operations will normally be issued to the MTAO. If the MTAO cannot be contacted, the District Engineer will issue flood control operations directly to the dam tender. If there is a communications failure and the dam tender cannot transmit the Special Reports required in paragraph 2, the dam tender, while remaining at his post, will continue every possible effort to re-establish communication with the District Engineer or the MTAO including use of any available Federal, commercial, or private means of communication or transportation media. In the meantime, he will regulate releases for flood control as shown in the attached Emergency Release Schedule.

4. Safety of Dam. The foregoing regulation procedures are not intended to restrict the dam tender from taking such additional measures as are necessary to ensure safety of the dam.

5. Reports of Emergency Regulation. The dam tender shall report all details of emergency regulation to the District Engineer regulation personnel and/or Regional Director office personnel as promptly as practicable when communications are restored.

EMERGENCY FLOOD CONTROL RELEASE SCHEDULE

For use in the event the Corps and MTAO personnel cannot be reached.

A. FOR A RISING POOL.

1. There is reported flooding downstream.

Reservoir Elev. (NGVD29)	Release Schedule
3614-3648	Immediately reduce release to conservation requirement. Hold for 3 days and then follow last Regulation Order.
3648-3660	Release greater of: conservation requirement, last Regulation Order, or as indicated on Plate A.

2. There is no reported flooding downstream.

Reservoir Elev. (NGVD29)	Release Schedule
3614-3645	Follow last Regulation Order.
3645-3660	Release greater of: conservation requirement, last Regulation Order, or as indicated on Plate A.

B. FOR A STATIONARY OR FALLING POOL.

1. There is reported flooding downstream.

Reservoir Elev. (NGVD29)	Release Schedule
3614-3660	Follow above schedule under A.1.

2. There is no reported flooding downstream.

Reservoir Elev. (NGVD29)	Release Schedule
3614-3640	Release between the range of 12,000 cfs and conservation requirement to maintain the pool elevation at 3640.
3640-3660	Maintain maximum gate opening attained.

C. FURTHER INSTRUCTIONS.

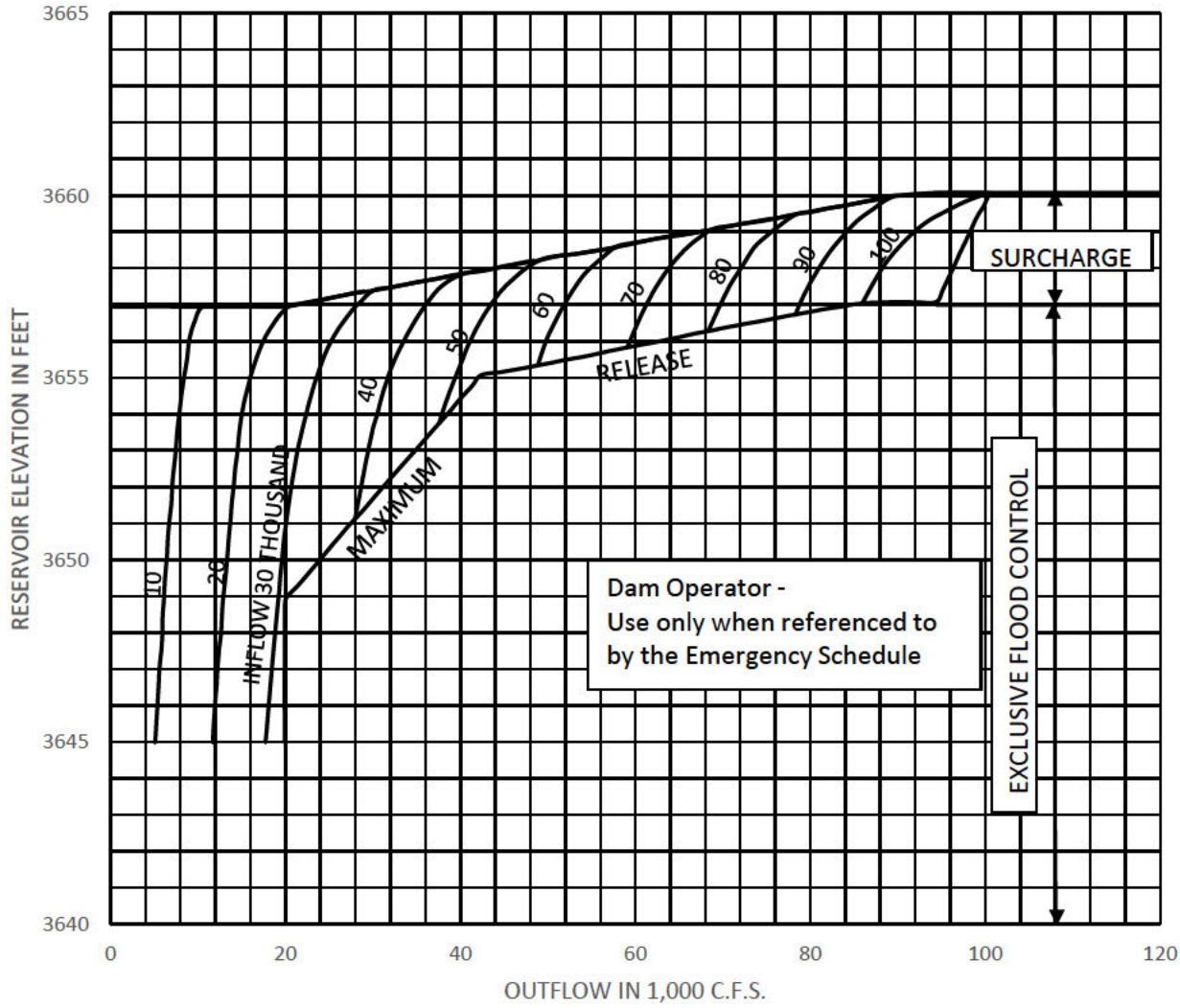
1. Releases need not be reduced below conservation requirements for flood control purposes.

2. Inflows will be computed (from the release volume plus change in storage) from periods of at least 6 hours.

3. Flood control releases will normally not be adjusted more often than at 6-hour intervals. However, when the river is open and a change of more than 4,000 cfs is required, the total change shall be made at a rate of 4,000 cfs every half-hour.

4. Incremental 6-hour release changes shall not exceed 500 cfs when the river downstream is frozen.

5. The maximum rate of pool drawdown shall not exceed 1.0 feet in 24 hours. This limitation takes precedence over all other instructions.



Operating Instructions:

1. Follow Emergency Release Schedule until larger releases are required by these curves.
2. When curves indicate a lesser release than the current release, maintain maximum gate openings attained until pool falls to elevation 3640.0 feet, but limit maximum rate of reservoir drawdown to 1.0 foot in 24 hours.
3. When elevation is below 3640.0 feet release as indicated by the Emergency Release Schedule.

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Yellowtail Regulation Curves Standing Instructions to Dam Operator

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate A

EXHIBIT IV

AREA - CAPACITY TABLES IN ONE FOOT INCREMENTS

YELLOWTAIL DAM AND BIGHORN RESERVOIR

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Capacity Table at 1-Foot Increments

The capacity table is in acre-feet. The elevation increment is one foot.

ELEV. FEET	0	1	2	3	4	5	6	7	8	9
3190						0.	0.	0.	0.	0.
3200	0.	0.	0.	0.	1.	1.	3.	9.	18.	31.
3210	48.	70.	100.	138.	184.	237.	296.	359.	426.	496.
3220	570.	648.	731.	819.	913.	1011.	1114.	1223.	1336.	1455.
3230	1579.	1707.	1840.	1977.	2117.	2262.	2411.	2562.	2717.	2876.
3240	3037.	3202.	3370.	3541.	3716.	3894.	4076.	4261.	4451.	4644.
3250	4841.	5041.	5246.	5455.	5668.	5885.	6106.	6330.	6558.	6789.
3260	7023.	7261.	7502.	7747.	7994.	8245.	8500.	8758.	9020.	9285.
3270	9555.	9828.	10105.	10387.	10674.	10965.	11261.	11562.	11868.	12180.
3280	12498.	12820.	13146.	13475.	13809.	14146.	14488.	14833.	15183.	15536.
3290	15894.	16256.	16624.	16999.	17379.	17765.	18156.	18554.	18958.	19367.
3300	19783.	20204.	20630.	21060.	21497.	21938.	22383.	22833.	23287.	23745.
3310	24208.	24675.	25145.	25620.	26099.	26582.	27068.	27559.	28054.	28552.
3320	29055.	29561.	30072.	30586.	31104.	31627.	32153.	32686.	33225.	33769.
3330	34318.	34876.	35442.	36017.	36601.	37193.	37793.	38399.	39011.	39628.
3340	40251.	40881.	41520.	42168.	42824.	43489.	44161.	44840.	45525.	46217.
3350	46915.	47619.	48329.	49045.	49767.	50494.	51228.	51967.	52713.	53466.
3360	54224.	54989.	55761.	56540.	57325.	58117.	58915.	59721.	60533.	61352.
3370	62177.	63009.	63848.	64694.	65547.	66407.	67273.	68146.	69025.	69912.
3380	70804.	71704.	72610.	73522.	74442.	75367.	76299.	77238.	78183.	79135.
3390	80093.	81058.	82029.	83006.	83990.	84980.	85976.	86979.	87988.	89004.
3400	90026.	91055.	92090.	93131.	94180.	95234.	96295.	97363.	98438.	99520.
3410	100608.	101704.	102807.	103918.	105037.	106163.	107307.	108482.	109685.	110918.
3420	112181.	113483.	114835.	116237.	117688.	119190.	120733.	122308.	123916.	125557.
3430	127230.	128933.	130663.	132421.	134205.	136016.	137853.	139714.	141599.	143507.
3440	145440.	147395.	149373.	151372.	153393.	155437.	157502.	159590.	161700.	163832.
3450	165987.	168163.	170360.	172579.	174819.	177080.	179362.	181664.	183987.	186331.
3460	188696.	191081.	193487.	195913.	198359.	200826.	203313.	205818.	208343.	210887.
3470	213449.	216030.	218631.	221250.	223888.	226546.	229221.	231914.	234625.	237353.
3480	240100.	242864.	245648.	248451.	251274.	254116.	256976.	259855.	262751.	265666.
3490	268598.	271550.	274522.	277514.	280526.	283558.	286611.	289683.	292775.	295887.

ELEV. FEET	0	1	2	3	4	5	6	7	8	9
3500	299019.	302170.	305341.	308530.	311739.	314966.	318213.	321479.	324763.	328067.
3510	331390.	334731.	338093.	341473.	344874.	348294.	351733.	355193.	358672.	362171.
3520	365690.	369228.	372785.	376360.	379953.	383565.	387194.	390842.	394507.	398190.
3530	401891.	405609.	409344.	413098.	416869.	420658.	424464.	428287.	432128.	435987.
3540	439864.	443757.	447668.	451596.	455540.	459501.	463479.	467473.	471483.	475509.
3550	479550.	483608.	487682.	491771.	495876.	499998.	504134.	508287.	512456.	516642.
3560	520843.	525061.	529296.	533546.	537814.	542097.	546396.	550711.	555041.	559387.
3570	563748.	568124.	572515.	576922.	581344.	585782.	590235.	594704.	599189.	603690.
3580	608207.	612740.	617289.	621856.	626439.	631039.	635658.	640299.	644961.	649644.
3590	654348.	659076.	663832.	668615.	673426.	678263.	683130.	688030.	692962.	697927.
3600	702924.	707959.	713037.	718159.	723324.	728533.	733791.	739102.	744467.	749886.
3610	755359.	760919.	766598.	772398.	778317.	784356.	790527.	796842.	803300.	809902.
3620	816647.	823570.	830706.	838055.	845617.	853392.	861418.	869734.	878340.	887235.
3630	896420.	905962.	915928.	926317.	937129.	948365.	960030.	972132.	984669.	997643.
3640	1011052.	1024758.	1038622.	1052644.	1066823.	1081160.	1095642.	1110254.	1124996.	1139870.
3650	1154873.	1170010.	1185282.	1200689.	1216232.	1231910.	1247726.	1263682.	1279778.	1296014.
3660	1312390.									

Area Tables at 1-Foot Increments

The area table is in acres. The elevation increment is one foot.

ELEV. FEET	0	1	2	3	4	5	6	7	8	9
3190						0.	0.	0.	0.	0.
3200	0.	0.	0.	0.	0.	0.	4.	8.	11.	15.
3210	19.	26.	34.	42.	49.	57.	61.	65.	68.	72.
3220	76.	81.	86.	91.	96.	101.	106.	111.	116.	121.
3230	126.	131.	135.	139.	143.	147.	150.	153.	157.	160.
3240	163.	166.	170.	173.	176.	180.	184.	187.	191.	195.
3250	199.	203.	207.	211.	215.	219.	222.	226.	229.	233.
3260	236.	239.	243.	246.	249.	253.	256.	260.	264.	267.
3270	271.	275.	280.	284.	289.	293.	298.	304.	309.	315.
3280	320.	324.	328.	332.	335.	339.	343.	347.	351.	355.
3290	360.	365.	371.	377.	383.	389.	395.	401.	407.	412.
3300	418.	423.	428.	434.	439.	444.	448.	452.	456.	460.
3310	465.	469.	473.	477.	481.	485.	489.	493.	497.	501.
3320	505.	508.	512.	516.	520.	524.	530.	536.	541.	547.
3330	553.	562.	571.	579.	588.	597.	603.	609.	614.	620.
3340	626.	635.	643.	652.	660.	669.	676.	682.	688.	695.
3350	701.	707.	713.	719.	725.	730.	737.	743.	749.	755.
3360	762.	768.	775.	782.	789.	795.	802.	809.	815.	822.
3370	829.	836.	842.	849.	856.	863.	870.	876.	883.	890.
3380	896.	903.	909.	916.	922.	929.	935.	942.	948.	955.
3390	961.	968.	974.	981.	987.	993.	1000.	1006.	1012.	1019.
3400	1025.	1032.	1038.	1045.	1051.	1058.	1065.	1071.	1078.	1085.
3410	1092.	1099.	1107.	1115.	1122.	1130.	1159.	1189.	1218.	1248.
3420	1277.	1327.	1377.	1427.	1477.	1527.	1559.	1592.	1624.	1657.
3430	1690.	1717.	1744.	1771.	1798.	1825.	1849.	1873.	1897.	1920.
3440	1944.	1966.	1988.	2010.	2032.	2054.	2077.	2099.	2121.	2143.
3450	2166.	2187.	2208.	2229.	2250.	2271.	2292.	2313.	2334.	2354.
3460	2375.	2395.	2416.	2436.	2457.	2477.	2496.	2515.	2534.	2553.
3470	2572.	2591.	2610.	2629.	2648.	2667.	2684.	2702.	2720.	2737.
3480	2755.	2774.	2794.	2813.	2832.	2851.	2870.	2888.	2906.	2924.
3490	2942.	2962.	2982.	3002.	3022.	3042.	3062.	3082.	3102.	3122.

ELEV. FEET	0	1	2	3	4	5	6	7	8	9
3500	3142.	3161.	3180.	3199.	3218.	3237.	3256.	3275.	3294.	3313.
3510	3332.	3351.	3371.	3391.	3410.	3430.	3450.	3469.	3489.	3509.
3520	3529.	3547.	3566.	3584.	3602.	3621.	3639.	3656.	3674.	3692.
3530	3709.	3727.	3745.	3762.	3780.	3798.	3815.	3832.	3850.	3868.
3540	3885.	3902.	3919.	3936.	3953.	3970.	3986.	4002.	4018.	4034.
3550	4050.	4066.	4081.	4097.	4113.	4129.	4145.	4161.	4177.	4194.
3560	4210.	4226.	4243.	4259.	4275.	4291.	4307.	4322.	4338.	4353.
3570	4368.	4384.	4399.	4415.	4430.	4445.	4461.	4477.	4493.	4509.
3580	4525.	4541.	4558.	4575.	4592.	4609.	4630.	4651.	4672.	4694.
3590	4715.	4742.	4769.	4797.	4824.	4851.	4884.	4916.	4948.	4981.
3600	5013.	5057.	5100.	5144.	5187.	5231.	5284.	5338.	5392.	5446.
3610	5500.	5620.	5740.	5859.	5979.	6099.	6243.	6386.	6530.	6673.
3620	6817.	7030.	7243.	7455.	7668.	7881.	8171.	8461.	8751.	9040.
3630	9330.	9754.	10177.	10601.	11024.	11447.	11883.	12319.	12755.	13191.
3640	13627.	13785.	13943.	14101.	14258.	14416.	14547.	14677.	14808.	14938.
3650	15069.	15204.	15340.	15475.	15610.	15746.	15886.	16026.	16166.	16306.
3660	16446.									

EXHIBIT V

CAPACITY TABLES IN 0.1 FOOT INCREMENTS

YELLOWTAIL DAM AND BIGHORN RESERVOIR

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Capacity Table at 0.1-Foot Increments

The capacity table is in acre-feet. The elevation increment is one tenth of one foot.

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3195	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3196	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3197	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3198	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
3199	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3200	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
3201	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
3202	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
3203	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
3204	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9
3205	0.9	1.0	1.0	1.2	1.3	1.5	1.7	2.0	2.3	2.6
3206	3.0	3.4	3.9	4.4	4.9	5.4	6.0	6.7	7.3	8.0
3207	8.8	9.6	10.4	11.2	12.1	13.0	14.0	15.0	16.0	17.1
3208	18.2	19.3	20.5	21.7	23.0	24.3	25.6	26.9	28.3	29.8
3209	31.2	32.7	34.3	35.9	37.5	39.1	40.8	42.5	44.3	46.1
3210	47.9	49.8	51.8	53.8	55.9	58.1	60.4	62.8	65.2	67.7
3211	70.3	73.0	75.7	78.5	81.4	84.4	87.5	90.6	93.8	97.1
3212	100.4	103.9	107.4	111.0	114.7	118.4	122.2	126.1	130.1	134.2
3213	138.3	142.5	146.8	151.2	155.6	160.1	164.7	169.4	174.2	179.0
3214	183.9	188.9	193.9	199.1	204.3	209.6	215.0	220.4	226.0	231.6
3215	237.2	243.0	248.8	254.6	260.4	266.3	272.2	278.2	284.2	290.2
3216	296.3	302.4	308.6	314.7	321.0	327.2	333.5	339.9	346.2	352.6
3217	359.1	365.6	372.1	378.6	385.2	391.9	398.5	405.2	412.0	418.7
3218	425.6	432.4	439.3	446.2	453.2	460.2	467.2	474.3	481.4	488.6
3219	495.7	503.0	510.2	517.5	524.9	532.2	539.6	547.1	554.6	562.1
3220	569.6	577.2	584.9	592.6	600.3	608.1	616.0	623.9	631.8	639.8
3221	647.9	656.0	664.1	672.3	680.6	688.9	697.2	705.6	714.1	722.6
3222	731.1	739.7	748.4	757.1	765.8	774.6	783.5	792.4	801.3	810.3
3223	819.4	828.5	837.6	846.8	856.1	865.4	874.7	884.1	893.6	903.0
3224	912.6	922.2	931.8	941.5	951.3	961.1	970.9	980.8	990.8	1000.8
3225	1010.8	1020.9	1031.1	1041.3	1051.5	1061.8	1072.2	1082.6	1093.0	1103.6
3226	1114.1	1124.7	1135.4	1146.1	1156.9	1167.7	1178.6	1189.5	1200.5	1211.5
3227	1222.6	1233.7	1244.9	1256.1	1267.4	1278.7	1290.1	1301.5	1313.0	1324.6
3228	1336.2	1347.8	1359.5	1371.2	1383.0	1394.9	1406.8	1418.7	1430.7	1442.8
3229	1454.9	1467.1	1479.3	1491.5	1503.9	1516.2	1528.6	1541.1	1553.6	1566.2

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3230	1578.8	1591.5	1604.2	1616.9	1629.7	1642.6	1655.4	1668.3	1681.3	1694.3
3231	1707.3	1720.4	1733.5	1746.7	1759.9	1773.1	1786.4	1799.7	1813.1	1826.5
3232	1839.9	1853.4	1866.9	1880.5	1894.1	1907.8	1921.4	1935.2	1948.9	1962.7
3233	1976.6	1990.5	2004.4	2018.4	2032.4	2046.5	2060.6	2074.7	2088.9	2103.1
3234	2117.4	2131.7	2146.0	2160.4	2174.8	2189.3	2203.8	2218.3	2232.9	2247.5
3235	2262.2	2276.9	2291.7	2306.4	2321.2	2336.1	2350.9	2365.8	2380.8	2395.7
3236	2410.7	2425.7	2440.8	2455.9	2471.0	2486.2	2501.4	2516.6	2531.8	2547.1
3237	2562.4	2577.8	2593.2	2608.6	2624.0	2639.5	2655.0	2670.6	2686.1	2701.7
3238	2717.4	2733.0	2748.7	2764.5	2780.3	2796.1	2811.9	2827.7	2843.6	2859.6
3239	2875.5	2891.5	2907.5	2923.6	2939.7	2955.8	2972.0	2988.2	3004.4	3020.6
3240	3036.9	3053.2	3069.6	3086.0	3102.4	3118.8	3135.3	3151.8	3168.4	3185.0
3241	3201.6	3218.2	3234.9	3251.6	3268.4	3285.2	3302.0	3318.9	3335.7	3352.7
3242	3369.6	3386.6	3403.6	3420.7	3437.8	3454.9	3472.1	3489.3	3506.5	3523.7
3243	3541.0	3558.4	3575.7	3593.1	3610.5	3628.0	3645.5	3663.0	3680.6	3698.2
3244	3715.8	3733.5	3751.2	3768.9	3786.7	3804.5	3822.3	3840.2	3858.1	3876.0
3245	3894.0	3912.0	3930.0	3948.1	3966.2	3984.4	4002.6	4020.8	4039.1	4057.4
3246	4075.7	4094.1	4112.5	4131.0	4149.5	4168.0	4186.6	4205.2	4223.9	4242.6
3247	4261.3	4280.0	4298.8	4317.7	4336.5	4355.5	4374.4	4393.4	4412.4	4431.5
3248	4450.6	4469.7	4488.9	4508.1	4527.4	4546.7	4566.0	4585.4	4604.8	4624.2
3249	4643.7	4663.2	4682.8	4702.4	4722.0	4741.7	4761.4	4781.1	4800.9	4820.7
3250	4840.6	4860.5	4880.4	4900.4	4920.4	4940.5	4960.6	4980.7	5000.9	5021.1
3251	5041.4	5061.7	5082.1	5102.4	5122.9	5143.3	5163.8	5184.4	5205.0	5225.6
3252	5246.3	5267.0	5287.7	5308.5	5329.3	5350.2	5371.1	5392.1	5413.1	5434.1
3253	5455.2	5476.3	5497.4	5518.6	5539.9	5561.1	5582.5	5603.8	5625.2	5646.6
3254	5668.1	5689.6	5711.2	5732.8	5754.4	5776.1	5797.8	5819.6	5841.4	5863.2
3255	5885.1	5907.0	5929.0	5951.0	5973.0	5995.1	6017.2	6039.3	6061.5	6083.6
3256	6105.9	6128.1	6150.4	6172.8	6195.1	6217.5	6240.0	6262.4	6284.9	6307.5
3257	6330.0	6352.7	6375.3	6398.0	6420.7	6443.4	6466.2	6489.0	6511.9	6534.7
3258	6557.7	6580.6	6603.6	6626.6	6649.7	6672.7	6695.9	6719.0	6742.2	6765.4
3259	6788.7	6812.0	6835.3	6858.7	6882.1	6905.5	6929.0	6952.5	6976.0	6999.6
3260	7023.2	7046.8	7070.5	7094.2	7117.9	7141.7	7165.5	7189.3	7213.2	7237.1
3261	7261.0	7285.0	7308.9	7333.0	7357.0	7381.1	7405.3	7429.4	7453.6	7477.8
3262	7502.1	7526.4	7550.7	7575.1	7599.5	7623.9	7648.4	7672.9	7697.4	7721.9
3263	7746.5	7771.2	7795.8	7820.5	7845.2	7870.0	7894.8	7919.6	7944.4	7969.3
3264	7994.2	8019.2	8044.2	8069.2	8094.3	8119.3	8144.5	8169.6	8194.8	8220.0

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3265	8245.3	8270.5	8295.9	8321.2	8346.6	8372.0	8397.5	8423.0	8448.6	8474.1
3266	8499.7	8525.4	8551.1	8576.8	8602.6	8628.4	8654.2	8680.1	8706.0	8731.9
3267	8757.9	8783.9	8810.0	8836.1	8862.2	8888.4	8914.6	8940.8	8967.1	8993.4
3268	9019.8	9046.2	9072.6	9099.1	9125.6	9152.1	9178.7	9205.3	9231.9	9258.6
3269	9285.3	9312.1	9338.9	9365.7	9392.6	9419.5	9446.4	9473.4	9500.4	9527.4
3270	9554.5	9581.7	9608.8	9636.0	9663.3	9690.6	9718.0	9745.3	9772.8	9800.3
3271	9827.8	9855.3	9883.0	9910.6	9938.3	9966.1	9993.8	10021.7	10049.5	10077.5
3272	10105.4	10133.4	10161.5	10189.6	10217.7	10245.9	10274.1	10302.4	10330.7	10359.1
3273	10387.5	10415.9	10444.4	10472.9	10501.5	10530.1	10558.8	10587.5	10616.3	10645.1
3274	10673.9	10702.8	10731.7	10760.7	10789.7	10818.8	10847.9	10877.0	10906.2	10935.5
3275	10964.8	10994.1	11023.5	11052.9	11082.4	11111.9	11141.6	11171.2	11200.9	11230.7
3276	11260.5	11290.4	11320.3	11350.3	11380.3	11410.4	11440.6	11470.8	11501.0	11531.3
3277	11561.7	11592.1	11622.6	11653.1	11683.7	11714.3	11745.0	11775.7	11806.5	11837.4
3278	11868.3	11899.2	11930.2	11961.3	11992.4	12023.6	12054.8	12086.1	12117.5	12148.8
3279	12180.3	12211.8	12243.4	12275.0	12306.6	12338.3	12370.1	12401.9	12433.8	12465.8
3280	12497.7	12529.8	12561.9	12594.0	12626.1	12658.3	12690.5	12722.8	12755.1	12787.4
3281	12819.8	12852.2	12884.7	12917.2	12949.7	12982.3	13014.9	13047.6	13080.2	13113.0
3282	13145.7	13178.5	13211.4	13244.2	13277.2	13310.1	13343.1	13376.1	13409.2	13442.3
3283	13475.5	13508.6	13541.9	13575.1	13608.4	13641.8	13675.1	13708.5	13742.0	13775.5
3284	13809.0	13842.6	13876.2	13909.8	13943.5	13977.2	14011.0	14044.8	14078.6	14112.5
3285	14146.4	14180.4	14214.3	14248.4	14282.5	14316.6	14350.7	14384.9	14419.1	14453.4
3286	14487.7	14522.1	14556.5	14590.9	14625.4	14659.9	14694.5	14729.1	14763.7	14798.4
3287	14833.1	14867.9	14902.7	14937.5	14972.4	15007.3	15042.3	15077.3	15112.3	15147.4
3288	15182.5	15217.7	15252.9	15288.1	15323.4	15358.8	15394.1	15429.5	15465.0	15500.5
3289	15536.0	15571.6	15607.2	15642.8	15678.5	15714.3	15750.0	15785.8	15821.7	15857.6
3290	15893.5	15929.5	15965.5	16001.6	16037.8	16074.0	16110.3	16146.6	16183.0	16219.5
3291	16256.0	16292.6	16329.2	16365.9	16402.6	16439.4	16476.3	16513.2	16550.2	16587.2
3292	16624.3	16661.5	16698.7	16736.0	16773.3	16810.7	16848.2	16885.7	16923.2	16960.9
3293	16998.5	17036.3	17074.1	17111.9	17149.9	17187.8	17225.9	17264.0	17302.1	17340.3
3294	17378.6	17416.9	17455.3	17493.8	17532.3	17570.9	17609.5	17648.2	17686.9	17725.7
3295	17764.6	17803.5	17842.5	17881.5	17920.6	17959.7	17998.9	18038.2	18077.5	18116.9
3296	18156.4	18195.9	18235.5	18275.1	18314.8	18354.5	18394.3	18434.2	18474.1	18514.1
3297	18554.1	18594.2	18634.4	18674.6	18714.8	18755.2	18795.6	18836.0	18876.5	18917.1
3298	18957.7	18998.4	19039.2	19080.0	19120.8	19161.8	19202.7	19243.8	19284.9	19326.0
3299	19367.3	19408.5	19449.9	19491.3	19532.7	19574.2	19615.8	19657.4	19699.1	19740.9

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3300	19782.7	19824.5	19866.4	19908.4	19950.4	19992.5	20034.6	20076.8	20119.0	20161.2
3301	20203.6	20245.9	20288.3	20330.8	20373.3	20415.9	20458.5	20501.2	20543.9	20586.7
3302	20629.5	20672.4	20715.3	20758.3	20801.3	20844.4	20887.5	20930.7	20973.9	21017.2
3303	21060.5	21103.9	21147.3	21190.8	21234.3	21277.9	21321.5	21365.2	21408.9	21452.7
3304	21496.5	21540.4	21584.3	21628.3	21672.3	21716.4	21760.6	21804.7	21849.0	21893.3
3305	21937.6	21982.0	22026.4	22070.9	22115.4	22159.9	22204.5	22249.1	22293.8	22338.5
3306	22383.3	22428.1	22472.9	22517.8	22562.7	22607.7	22652.7	22697.8	22742.8	22788.0
3307	22833.2	22878.4	22923.6	22968.9	23014.3	23059.7	23105.1	23150.6	23196.1	23241.6
3308	23287.2	23332.9	23378.6	23424.3	23470.0	23515.8	23561.7	23607.6	23653.5	23699.5
3309	23745.5	23791.6	23837.7	23883.8	23930.0	23976.2	24022.5	24068.8	24115.1	24161.5
3310	24208.0	24254.4	24300.9	24347.5	24394.1	24440.7	24487.4	24534.1	24580.9	24627.7
3311	24674.5	24721.4	24768.3	24815.3	24862.3	24909.4	24956.4	25003.6	25050.7	25097.9
3312	25145.2	25192.5	25239.8	25287.2	25334.6	25382.0	25429.5	25477.1	25524.6	25572.2
3313	25619.9	25667.6	25715.3	25763.1	25810.9	25858.8	25906.7	25954.6	26002.6	26050.6
3314	26098.7	26146.8	26194.9	26243.1	26291.3	26339.6	26387.9	26436.2	26484.6	26533.0
3315	26581.5	26630.0	26678.5	26727.1	26775.8	26824.4	26873.1	26921.9	26970.7	27019.5
3316	27068.3	27117.2	27166.2	27215.2	27264.2	27313.2	27362.3	27411.5	27460.6	27509.9
3317	27559.1	27608.4	27657.7	27707.1	27756.5	27806.0	27855.5	27905.0	27954.6	28004.2
3318	28053.8	28103.5	28153.2	28203.0	28252.8	28302.6	28352.5	28402.4	28452.4	28502.4
3319	28552.4	28602.5	28652.6	28702.8	28753.0	28803.2	28853.5	28903.8	28954.2	29004.5
3320	29055.0	29105.4	29156.0	29206.5	29257.1	29307.7	29358.4	29409.1	29459.8	29510.6
3321	29561.4	29612.3	29663.2	29714.2	29765.1	29816.2	29867.2	29918.3	29969.4	30020.6
3322	30071.8	30123.1	30174.4	30225.7	30277.1	30328.5	30380.0	30431.4	30483.0	30534.5
3323	30586.2	30637.8	30689.5	30741.2	30793.0	30844.8	30896.6	30948.5	31000.4	31052.4
3324	31104.4	31156.4	31208.5	31260.6	31312.8	31365.0	31417.2	31469.5	31521.8	31574.2
3325	31626.6	31679.0	31731.5	31784.0	31836.6	31889.3	31942.0	31994.8	32047.6	32100.5
3326	32153.5	32206.5	32259.6	32312.7	32365.9	32419.1	32472.4	32525.8	32579.2	32632.6
3327	32686.2	32739.8	32793.4	32847.1	32900.8	32954.6	33008.5	33062.4	33116.4	33170.5
3328	33224.6	33278.7	33332.9	33387.2	33441.5	33495.9	33550.3	33604.8	33659.4	33714.0
3329	33768.7	33823.4	33878.2	33933.0	33987.9	34042.8	34097.9	34152.9	34208.0	34263.2
3330	34318.5	34373.8	34429.2	34484.7	34540.2	34595.9	34651.7	34707.5	34763.5	34819.5
3331	34875.6	34931.8	34988.1	35044.5	35100.9	35157.5	35214.2	35270.9	35327.7	35384.6
3332	35441.6	35498.7	35555.9	35613.2	35670.6	35728.0	35785.6	35843.2	35900.9	35958.7
3333	36016.6	36074.6	36132.7	36190.8	36249.1	36307.4	36365.9	36424.4	36483.0	36541.7
3334	36600.5	36659.4	36718.4	36777.4	36836.6	36895.8	36955.1	37014.5	37074.0	37133.6

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3335	37193.3	37253.1	37312.9	37372.8	37432.7	37492.7	37552.7	37612.8	37673.0	37733.2
3336	37793.4	37853.8	37914.2	37974.6	38035.1	38095.7	38156.3	38216.9	38277.7	38338.5
3337	38399.3	38460.2	38521.2	38582.2	38643.2	38704.4	38765.6	38826.8	38888.1	38949.5
3338	39010.9	39072.3	39133.9	39195.5	39257.1	39318.8	39380.6	39442.4	39504.3	39566.2
3339	39628.2	39690.2	39752.3	39814.5	39876.7	39939.0	40001.3	40063.7	40126.1	40188.6
3340	40251.2	40313.8	40376.5	40439.3	40502.2	40565.2	40628.3	40691.4	40754.7	40818.0
3341	40881.4	40944.9	41008.5	41072.1	41135.9	41199.7	41263.7	41327.7	41391.8	41456.0
3342	41520.2	41584.6	41649.1	41713.6	41778.2	41842.9	41907.7	41972.6	42037.5	42102.6
3343	42167.7	42233.0	42298.3	42363.7	42429.2	42494.7	42560.4	42626.1	42692.0	42757.9
3344	42823.9	42890.0	42956.1	43022.4	43088.8	43155.2	43221.7	43288.3	43355.0	43421.8
3345	43488.7	43555.6	43622.6	43689.7	43756.8	43824.0	43891.3	43958.6	44026.0	44093.5
3346	44161.0	44228.6	44296.3	44364.0	44431.8	44499.6	44567.5	44635.5	44703.5	44771.6
3347	44839.8	44908.0	44976.3	45044.7	45113.1	45181.6	45250.2	45318.8	45387.5	45456.2
3348	45525.0	45593.9	45662.8	45731.8	45800.9	45870.0	45939.2	46008.5	46077.8	46147.2
3349	46216.7	46286.2	46355.8	46425.4	46495.1	46564.9	46634.8	46704.7	46774.6	46844.7
3350	46914.8	46984.9	47055.2	47125.4	47195.8	47266.2	47336.6	47407.1	47477.7	47548.3
3351	47619.0	47689.8	47760.6	47831.4	47902.3	47973.3	48044.3	48115.4	48186.6	48257.8
3352	48329.1	48400.4	48471.8	48543.2	48614.7	48686.2	48757.9	48829.5	48901.3	48973.1
3353	49044.9	49116.8	49188.8	49260.8	49332.9	49405.0	49477.2	49549.4	49621.8	49694.1
3354	49766.5	49839.0	49911.6	49984.2	50056.8	50129.5	50202.3	50275.2	50348.0	50421.0
3355	50494.0	50567.1	50640.2	50713.4	50786.6	50860.0	50933.4	51006.8	51080.3	51153.9
3356	51227.5	51301.2	51375.0	51448.8	51522.7	51596.6	51670.6	51744.7	51818.8	51893.0
3357	51967.3	52041.6	52116.0	52190.4	52265.0	52339.5	52414.2	52488.9	52563.6	52638.5
3358	52713.3	52788.3	52863.3	52938.4	53013.5	53088.7	53164.0	53239.3	53314.7	53390.2
3359	53465.7	53541.3	53616.9	53692.6	53768.4	53844.2	53920.1	53996.1	54072.1	54148.2
3360	54224.3	54300.6	54376.8	54453.2	54529.6	54606.0	54682.6	54759.2	54835.9	54912.6
3361	54989.4	55066.3	55143.2	55220.2	55297.3	55374.5	55451.7	55529.0	55606.3	55683.7
3362	55761.2	55838.8	55916.4	55994.0	56071.8	56149.6	56227.5	56305.4	56383.5	56461.5
3363	56539.7	56617.9	56696.2	56774.6	56853.0	56931.5	57010.0	57088.6	57167.3	57246.1
3364	57324.9	57403.8	57482.7	57561.8	57640.9	57720.0	57799.2	57878.5	57957.9	58037.3
3365	58116.8	58196.4	58276.0	58355.7	58435.5	58515.3	58595.2	58675.1	58755.2	58835.3
3366	58915.4	58995.7	59076.0	59156.3	59236.8	59317.3	59397.8	59478.5	59559.2	59639.9
3367	59720.8	59801.7	59882.7	59963.7	60044.8	60126.0	60207.2	60288.5	60369.9	60451.3
3368	60532.8	60614.4	60696.0	60777.8	60859.5	60941.4	61023.3	61105.3	61187.3	61269.4
3369	61351.6	61433.8	61516.1	61598.5	61681.0	61763.5	61846.1	61928.7	62011.4	62094.2
3370	62177.1	62260.0	62343.0	62426.1	62509.2	62592.4	62675.7	62759.0	62842.4	62925.9
3371	63009.4	63093.0	63176.7	63260.4	63344.2	63428.1	63512.0	63596.0	63680.1	63764.3
3372	63848.5	63932.8	64017.1	64101.5	64186.0	64270.6	64355.2	64439.9	64524.6	64609.5
3373	64694.4	64779.3	64864.4	64949.5	65034.6	65119.9	65205.2	65290.5	65376.0	65461.5
3374	65547.1	65632.7	65718.4	65804.2	65890.0	65975.9	66061.9	66148.0	66234.1	66320.3

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3375	66406.5	66492.9	66579.3	66665.7	66752.2	66838.8	66925.5	67012.2	67099.0	67185.9
3376	67272.8	67359.8	67446.8	67533.9	67621.1	67708.4	67795.7	67883.1	67970.6	68058.1
3377	68145.7	68233.3	68321.1	68408.9	68496.7	68584.6	68672.6	68760.7	68848.8	68937.0
3378	69025.3	69113.6	69202.0	69290.4	69379.0	69467.5	69556.2	69644.9	69733.7	69822.6
3379	69911.5	70000.5	70089.5	70178.7	70267.9	70357.1	70446.4	70535.8	70625.3	70714.8
3380	70804.4	70894.1	70983.8	71073.6	71163.5	71253.4	71343.4	71433.4	71523.5	71613.7
3381	71703.9	71794.2	71884.6	71975.0	72065.5	72156.1	72246.8	72337.4	72428.2	72519.0
3382	72609.9	72700.9	72791.9	72883.0	72974.2	73065.4	73156.7	73248.0	73339.4	73430.9
3383	73522.5	73614.1	73705.8	73797.5	73889.3	73981.2	74073.1	74165.1	74257.2	74349.3
3384	74441.5	74533.8	74626.1	74718.5	74811.0	74903.5	74996.1	75088.7	75181.5	75274.2
3385	75367.1	75460.0	75553.0	75646.0	75739.2	75832.3	75925.6	76018.9	76112.3	76205.7
3386	76299.2	76392.8	76486.4	76580.1	76673.9	76767.7	76861.6	76955.6	77049.6	77143.7
3387	77237.8	77332.1	77426.4	77520.7	77615.1	77709.6	77804.1	77898.8	77993.4	78088.2
3388	78183.0	78277.9	78372.8	78467.8	78562.9	78658.0	78753.2	78848.5	78943.8	79039.2
3389	79134.7	79230.2	79325.8	79421.5	79517.2	79613.0	79708.8	79804.7	79900.7	79996.8
3390	80092.9	80189.1	80285.4	80381.7	80478.0	80574.5	80671.0	80767.5	80864.2	80960.8
3391	81057.6	81154.4	81251.3	81348.2	81445.2	81542.3	81639.4	81736.6	81833.9	81931.2
3392	82028.6	82126.1	82223.6	82321.2	82418.8	82516.5	82614.3	82712.1	82810.0	82907.9
3393	83006.0	83104.1	83202.2	83300.4	83398.7	83497.0	83595.4	83693.9	83792.4	83891.0
3394	83989.7	84088.4	84187.2	84286.0	84384.9	84483.9	84582.9	84682.0	84781.2	84880.4
3395	84979.7	85079.0	85178.5	85278.0	85377.5	85477.1	85576.8	85676.5	85776.3	85876.2
3396	85976.1	86076.1	86176.2	86276.3	86376.5	86476.8	86577.1	86677.5	86777.9	86878.4
3397	86979.0	87079.6	87180.3	87281.1	87381.9	87482.8	87583.8	87684.8	87785.9	87887.0
3398	87988.3	88089.5	88190.9	88292.3	88393.8	88495.3	88596.9	88698.6	88800.3	88902.1
3399	89004.0	89105.9	89207.9	89310.0	89412.1	89514.2	89616.5	89718.8	89821.2	89923.6
3400	90026.1	90128.7	90231.3	90334.0	90436.8	90539.6	90642.5	90745.5	90848.5	90951.6
3401	91054.7	91158.0	91261.2	91364.6	91468.0	91571.5	91675.0	91778.6	91882.3	91986.0
3402	92089.8	92193.7	92297.6	92401.6	92505.7	92609.8	92714.0	92818.3	92922.6	93027.0
3403	93131.5	93236.0	93340.5	93445.2	93549.9	93654.7	93759.5	93864.4	93969.4	94074.5
3404	94179.5	94284.7	94390.0	94495.2	94600.6	94706.0	94811.5	94917.1	95022.7	95128.4
3405	95234.1	95340.0	95445.9	95551.8	95657.8	95763.9	95870.1	95976.3	96082.6	96189.0
3406	96295.4	96401.9	96508.5	96615.1	96721.8	96828.6	96935.4	97042.3	97149.3	97256.3
3407	97363.5	97470.6	97577.9	97685.2	97792.6	97900.0	98007.5	98115.1	98222.8	98330.5
3408	98438.3	98546.2	98654.1	98762.1	98870.2	98978.3	99086.5	99194.8	99303.1	99411.5
3409	99520.0	99628.5	99737.1	99845.8	99954.5	100063.3	100172.2	100281.2	100390.2	100499.3

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3410	100608.4	100717.6	100827.0	100936.3	101045.8	101155.3	101264.9	101374.6	101484.3	101594.2
3411	101704.1	101814.1	101924.1	102034.3	102144.5	102254.8	102365.1	102475.6	102586.1	102696.7
3412	102807.4	102918.1	103028.9	103139.8	103250.8	103361.8	103473.0	103584.2	103695.5	103806.8
3413	103918.2	104029.7	104141.3	104253.0	104364.7	104476.5	104588.4	104700.4	104812.4	104924.5
3414	105036.7	105149.0	105261.3	105373.8	105486.2	105598.8	105711.5	105824.2	105937.0	106049.9
3415	106162.8	106276.0	106389.4	106503.1	106617.1	106731.5	106846.1	106961.0	107076.2	107191.7
3416	107307.5	107423.5	107539.9	107656.6	107773.5	107890.8	108008.4	108126.2	108244.4	108362.8
3417	108481.5	108600.6	108719.9	108839.5	108959.4	109079.6	109200.1	109320.9	109442.0	109563.4
3418	109685.1	109807.1	109929.3	110051.9	110174.8	110297.9	110421.4	110545.1	110669.1	110793.5
3419	110918.1	111043.0	111168.2	111293.8	111419.5	111545.7	111672.0	111798.7	111925.7	112053.0
3420	112180.6	112308.5	112437.0	112566.0	112695.4	112825.4	112955.9	113086.8	113218.3	113350.2
3421	113482.7	113615.7	113749.1	113883.1	114017.5	114152.5	114287.9	114423.9	114560.3	114697.3
3422	114834.7	114972.7	115111.1	115250.0	115389.5	115529.4	115669.9	115810.8	115952.2	116094.2
3423	116236.6	116379.5	116523.0	116666.9	116811.3	116956.3	117101.7	117247.6	117394.0	117541.0
3424	117688.4	117836.3	117984.7	118133.6	118283.0	118433.0	118583.4	118734.3	118885.7	119037.6
3425	119190.0	119342.8	119496.0	119649.5	119803.3	119957.4	120111.8	120266.6	120421.7	120577.1
3426	120732.9	120889.0	121045.4	121202.1	121359.2	121516.5	121674.3	121832.3	121990.7	122149.3
3427	122308.4	122467.7	122627.4	122787.4	122947.7	123108.3	123269.3	123430.6	123592.2	123754.1
3428	123916.4	124079.0	124241.9	124405.2	124568.8	124732.7	124896.9	125061.4	125226.3	125391.5
3429	125557.0	125722.9	125889.1	126055.6	126222.4	126389.6	126557.1	126724.9	126893.0	127061.5
3430	127230.3	127399.4	127568.7	127738.4	127908.2	128078.4	128248.9	128419.6	128590.5	128761.8
3431	128933.3	129105.1	129277.2	129449.5	129622.1	129795.0	129968.2	130141.6	130315.3	130489.3
3432	130663.5	130838.0	131012.8	131187.8	131363.1	131538.7	131714.6	131890.7	132067.1	132243.8
3433	132420.7	132598.0	132775.4	132953.2	133131.2	133309.5	133488.1	133666.9	133846.0	134025.4
3434	134205.1	134385.0	134565.2	134745.7	134926.4	135107.4	135288.7	135470.2	135652.0	135834.1
3435	136016.5	136199.1	136382.0	136565.1	136748.4	136932.0	137115.8	137299.8	137484.1	137668.6
3436	137853.4	138038.4	138223.7	138409.1	138594.9	138780.8	138967.0	139153.5	139340.1	139527.0
3437	139714.2	139901.6	140089.2	140277.1	140465.2	140653.6	140842.1	141031.0	141220.0	141409.3
3438	141598.9	141788.7	141978.7	142168.9	142359.4	142550.2	142741.1	142932.4	143123.8	143315.5
3439	143507.4	143699.6	143892.0	144084.7	144277.5	144470.7	144664.0	144857.6	145051.5	145245.6
3440	145439.9	145634.4	145829.2	146024.2	146219.4	146414.8	146610.5	146806.3	147002.4	147198.7
3441	147395.2	147592.0	147789.0	147986.2	148183.6	148381.2	148579.0	148777.1	148975.4	149173.9
3442	149372.6	149571.6	149770.7	149970.1	150169.7	150369.5	150569.6	150769.8	150970.3	151171.0
3443	151372.0	151573.1	151774.5	151976.0	152177.9	152379.9	152582.1	152784.6	152987.3	153190.2
3444	153393.3	153596.6	153800.2	154004.0	154208.0	154412.2	154616.7	154821.3	155026.2	155231.3
3445	155436.6	155642.2	155847.9	156053.9	156260.1	156466.6	156673.2	156880.1	157087.2	157294.5
3446	157502.1	157709.9	157917.8	158126.1	158334.5	158543.2	158752.0	158961.2	159170.5	159380.0
3447	159589.8	159799.8	160010.0	160220.5	160431.2	160642.0	160853.2	161064.5	161276.1	161487.8
3448	161699.8	161912.1	162124.5	162337.2	162550.1	162763.2	162976.5	163190.1	163403.9	163617.9
3449	163832.1	164046.6	164261.3	164476.2	164691.3	164906.7	165122.2	165338.0	165554.0	165770.3

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3450	165986.7	166203.4	166420.3	166637.4	166854.7	167072.2	167290.0	167507.9	167726.1	167944.4
3451	168163.0	168381.8	168600.8	168820.0	169039.5	169259.1	169479.0	169699.0	169919.3	170139.8
3452	170360.5	170581.4	170802.5	171023.8	171245.4	171467.1	171689.1	171911.3	172133.7	172356.3
3453	172579.1	172802.1	173025.3	173248.8	173472.4	173696.3	173920.4	174144.7	174369.2	174593.9
3454	174818.8	175044.0	175269.3	175494.9	175720.7	175946.6	176172.8	176399.2	176625.9	176852.7
3455	177079.8	177307.0	177534.5	177762.1	177990.0	178218.1	178446.4	178674.9	178903.6	179132.5
3456	179361.6	179590.9	179820.4	180050.2	180280.1	180510.3	180740.6	180971.2	181202.0	181433.0
3457	181664.1	181895.5	182127.1	182358.9	182591.0	182823.2	183055.6	183288.2	183521.1	183754.1
3458	183987.4	184220.8	184454.5	184688.4	184922.5	185156.8	185391.3	185626.0	185860.9	186096.0
3459	186331.3	186566.9	186802.6	187038.5	187274.7	187511.1	187747.6	187984.4	188221.4	188458.6
3460	188696.0	188933.6	189171.4	189409.4	189647.6	189886.0	190124.6	190363.5	190602.5	190841.7
3461	191081.2	191320.8	191560.7	191800.7	192041.0	192281.5	192522.1	192763.0	193004.1	193245.3
3462	193486.8	193728.5	193970.4	194212.5	194454.8	194697.3	194940.0	195182.9	195426.0	195669.3
3463	195912.9	196156.6	196400.5	196644.7	196889.0	197133.6	197378.3	197623.3	197868.4	198113.8
3464	198359.4	198605.1	198851.1	199097.3	199343.7	199590.3	199837.0	200084.0	200331.2	200578.7
3465	200826.3	201074.0	201322.0	201570.2	201818.6	202067.2	202315.9	202564.9	202814.0	203063.3
3466	203312.9	203562.6	203812.5	204062.5	204312.8	204563.3	204814.0	205064.8	205315.8	205567.0
3467	205818.5	206070.1	206321.9	206573.8	206826.0	207078.4	207330.9	207583.7	207836.6	208089.7
3468	208343.0	208596.5	208850.2	209104.1	209358.1	209612.4	209866.8	210121.5	210376.3	210631.3
3469	210886.5	211141.9	211397.5	211653.2	211909.2	212165.4	212421.7	212678.2	212935.0	213191.9
3470	213449.0	213706.2	213963.7	214221.4	214479.2	214737.3	214995.5	215254.0	215512.6	215771.4
3471	216030.4	216289.6	216548.9	216808.5	217068.2	217328.2	217588.3	217848.6	218109.2	218369.9
3472	218630.8	218891.8	219153.1	219414.5	219676.2	219938.0	220200.1	220462.3	220724.7	220987.3
3473	221250.1	221513.0	221776.2	222039.5	222303.1	222566.8	222830.8	223094.9	223359.2	223623.7
3474	223888.3	224153.2	224418.3	224683.5	224949.0	225214.6	225480.4	225746.4	226012.6	226279.0
3475	226545.6	226812.3	227079.2	227346.3	227613.6	227881.0	228148.7	228416.5	228684.5	228952.7
3476	229221.0	229489.5	229758.2	230027.1	230296.1	230565.4	230834.8	231104.4	231374.1	231644.0
3477	231914.2	232184.4	232454.9	232725.5	232996.4	233267.4	233538.5	233809.9	234081.4	234353.1
3478	234625.0	234897.0	235169.2	235441.7	235714.2	235987.0	236259.9	236533.0	236806.3	237079.8
3479	237353.4	237627.2	237901.2	238175.4	238449.8	238724.3	238999.0	239273.9	239548.9	239824.2
3480	240099.6	240375.2	240650.9	240926.9	241203.1	241479.5	241756.0	242032.8	242309.7	242586.8
3481	242864.2	243141.7	243419.4	243697.3	243975.4	244253.7	244532.2	244810.9	245089.8	245368.8
3482	245648.1	245927.5	246207.2	246487.0	246767.1	247047.3	247327.7	247608.3	247889.1	248170.1
3483	248451.3	248732.7	249014.3	249296.0	249578.0	249860.2	250142.5	250425.0	250707.8	250990.7
3484	251273.8	251557.1	251840.6	252124.3	252408.2	252692.3	252976.6	253261.1	253545.7	253830.6

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3485	254115.6	254400.9	254686.3	254971.9	255257.7	255543.6	255829.8	256116.1	256402.6	256689.3
3486	256976.1	257263.2	257550.4	257837.8	258125.4	258413.1	258701.1	258989.2	259277.5	259566.0
3487	259854.6	260143.5	260432.5	260721.7	261011.1	261300.7	261590.4	261880.3	262170.4	262460.7
3488	262751.2	263041.8	263332.7	263623.7	263914.9	264206.2	264497.8	264789.5	265081.4	265373.5
3489	265665.8	265958.2	266250.8	266543.7	266836.7	267129.8	267423.2	267716.7	268010.4	268304.3
3490	268598.4	268892.6	269187.1	269481.8	269776.6	270071.7	270367.0	270662.4	270958.1	271254.0
3491	271550.1	271846.4	272142.8	272439.5	272736.4	273033.5	273330.8	273628.3	273926.0	274223.8
3492	274521.9	274820.2	275118.8	275417.4	275716.3	276015.4	276314.8	276614.2	276914.0	277213.9
3493	277514.0	277814.3	278114.8	278415.5	278716.4	279017.6	279318.9	279620.4	279922.1	280224.0
3494	280526.2	280828.5	281131.0	281433.8	281736.7	282039.8	282343.2	282646.7	282950.4	283254.4
3495	283558.5	283862.8	284167.4	284472.1	284777.1	285082.2	285387.5	285693.1	285998.8	286304.7
3496	286610.8	286917.2	287223.7	287530.4	287837.3	288144.5	288451.8	288759.3	289067.0	289374.9
3497	289683.1	289991.4	290299.9	290608.6	290917.5	291226.6	291535.9	291845.4	292155.2	292465.0
3498	292775.2	293085.4	293395.9	293706.7	294017.5	294328.6	294639.9	294951.4	295263.1	295575.0
3499	295887.1	296199.4	296511.9	296824.6	297137.4	297450.5	297763.8	298077.3	298390.9	298704.8
3500	299018.9	299332.9	299647.4	299962.1	300277.0	300592.0	300907.3	301222.7	301538.3	301854.2
3501	302170.2	302486.3	302802.8	303119.3	303436.1	303753.1	304070.2	304387.5	304705.1	305022.8
3502	305340.7	305658.8	305977.1	306295.6	306614.2	306933.1	307252.2	307571.4	307890.8	308210.5
3503	308530.3	308850.3	309170.5	309490.8	309811.4	310132.2	310453.1	310774.3	311095.6	311417.1
3504	311738.8	312060.8	312382.8	312705.1	313027.6	313350.3	313673.1	313996.2	314319.4	314642.8
3505	314966.5	315290.3	315614.3	315938.5	316262.8	316587.4	316912.2	317237.1	317562.2	317887.6
3506	318213.1	318538.8	318864.7	319190.8	319517.1	319843.5	320170.2	320497.1	320824.1	321151.3
3507	321478.8	321806.3	322134.2	322462.2	322790.3	323118.7	323447.3	323776.0	324105.0	324434.1
3508	324763.4	325092.9	325422.6	325752.5	326082.6	326412.9	326743.3	327074.0	327404.8	327735.9
3509	328067.1	328398.5	328730.1	329061.9	329393.9	329726.1	330058.5	330391.0	330723.8	331056.7
3510	331389.8	331722.8	332056.3	332390.0	332723.9	333058.0	333392.2	333726.7	334061.4	334396.2
3511	334731.3	335066.5	335402.0	335737.6	336073.4	336409.5	336745.7	337082.1	337418.8	337755.6
3512	338092.6	338429.8	338767.2	339104.8	339442.5	339780.5	340118.7	340457.1	340795.6	341134.4
3513	341473.4	341812.5	342151.9	342491.4	342831.2	343171.1	343511.2	343851.6	344192.1	344532.8
3514	344873.7	345214.8	345556.1	345897.6	346239.3	346581.2	346923.3	347265.6	347608.1	347950.7
3515	348293.6	348636.6	348979.9	349323.4	349667.0	350010.9	350355.0	350699.2	351043.6	351388.3
3516	351733.2	352078.2	352423.5	352768.9	353114.6	353460.4	353806.5	354152.7	354499.2	354845.8
3517	355192.6	355539.7	355886.9	356234.4	356582.0	356929.8	357277.8	357626.1	357974.5	358323.2
3518	358672.0	359021.0	359370.2	359719.6	360069.2	360419.1	360769.1	361119.3	361469.8	361820.4
3519	362171.2	362522.2	362873.4	363224.8	363576.4	363928.2	364280.2	364632.4	364984.8	365337.4
3520	365690.2	366043.2	366396.4	366749.8	367103.3	367457.1	367811.0	368165.1	368519.4	368873.8
3521	369228.4	369583.3	369938.3	370293.5	370648.8	371004.4	371360.2	371716.1	372072.2	372428.5
3522	372785.0	373141.6	373498.5	373855.5	374212.8	374570.2	374927.7	375285.5	375643.4	376001.6
3523	376359.9	376718.4	377077.1	377435.9	377795.0	378154.2	378513.6	378873.2	379233.0	379593.0
3524	379953.2	380313.5	380674.0	381034.7	381395.6	381756.7	382117.9	382479.4	382841.0	383202.8

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3525	383564.8	383926.7	384289.1	384651.6	385014.4	385377.3	385740.4	386103.6	386467.1	386830.6
3526	387194.4	387558.4	387922.6	388286.9	388651.4	389016.0	389380.9	389745.9	390111.1	390476.5
3527	390842.0	391207.8	391573.6	391939.7	392306.0	392672.4	393039.0	393405.8	393772.8	394139.9
3528	394507.2	394874.7	395242.4	395610.2	395978.2	396346.4	396714.8	397083.4	397452.1	397821.0
3529	398190.1	398559.3	398928.8	399298.4	399668.2	400038.1	400408.2	400778.6	401149.1	401519.7
3530	401890.6	402261.6	402632.8	403004.2	403375.7	403747.4	404119.4	404491.4	404863.6	405236.1
3531	405608.7	405981.5	406354.4	406727.6	407100.9	407474.4	407848.1	408221.9	408595.9	408970.1
3532	409344.5	409719.0	410093.8	410468.6	410843.8	411219.0	411594.4	411970.0	412345.8	412721.8
3533	413097.9	413474.2	413850.7	414227.4	414604.2	414981.2	415358.4	415735.8	416113.4	416491.1
3534	416869.0	417247.1	417625.3	418003.8	418382.4	418761.2	419140.1	419519.2	419898.6	420278.1
3535	420657.7	421037.2	421417.2	421797.4	422177.8	422558.3	422939.0	423319.8	423700.9	424082.1
3536	424463.5	424845.1	425226.8	425608.8	425990.8	426373.1	426755.6	427138.2	427521.0	427904.0
3537	428287.2	428670.5	429054.0	429437.7	429821.5	430205.6	430589.8	430974.2	431358.8	431743.5
3538	432128.4	432513.5	432898.8	433284.2	433669.8	434055.6	434441.6	434827.8	435214.1	435600.6
3539	435987.2	436374.1	436761.2	437148.4	437535.7	437923.3	438311.0	438698.9	439087.0	439475.3
3540	439863.7	440252.4	440641.1	441030.1	441419.2	441808.5	442197.9	442587.5	442977.4	443367.3
3541	443757.4	444147.7	444538.2	444928.8	445319.6	445710.6	446101.8	446493.1	446884.6	447276.2
3542	447668.0	448060.0	448452.2	448844.5	449237.0	449629.7	450022.5	450415.5	450808.7	451202.0
3543	451595.5	451989.2	452383.1	452777.1	453171.3	453565.6	453960.2	454354.9	454749.7	455144.8
3544	455540.0	455935.4	456330.9	456726.6	457122.5	457518.5	457914.8	458311.1	458707.7	459104.4
3545	459501.3	459898.0	460295.2	460692.6	461090.2	461488.0	461885.9	462283.9	462682.1	463080.5
3546	463479.0	463877.7	464276.6	464675.6	465074.7	465474.0	465873.5	466273.2	466673.0	467072.9
3547	467473.0	467873.3	468273.8	468674.4	469075.1	469476.0	469877.1	470278.3	470679.7	471081.2
3548	471483.0	471884.8	472286.9	472689.0	473091.4	473493.9	473896.6	474299.4	474702.4	475105.5
3549	475508.8	475912.2	476315.8	476719.6	477123.6	477527.6	477931.9	478336.3	478740.9	479145.6
3550	479550.5	479955.6	480360.8	480766.1	481171.6	481577.3	481983.2	482389.2	482795.3	483201.6
3551	483608.1	484014.8	484421.5	484828.5	485235.6	485642.9	486050.3	486457.9	486865.6	487273.6
3552	487681.6	488089.8	488498.2	488906.8	489315.5	489724.4	490133.4	490542.5	490951.9	491361.4
3553	491771.0	492180.8	492590.8	493000.9	493411.2	493821.7	494232.3	494643.1	495054.0	495465.1
3554	495876.3	496287.7	496699.3	497111.0	497522.9	497934.9	498347.1	498759.5	499172.0	499584.7
3555	499997.5	500410.4	500823.4	501236.7	501650.1	502063.7	502477.4	502891.4	503305.4	503719.6
3556	504134.0	504548.6	504963.3	505378.2	505793.2	506208.4	506623.8	507039.3	507455.0	507870.9
3557	508286.9	508703.1	509119.4	509535.9	509952.6	510369.4	510786.4	511203.6	511620.9	512038.4
3558	512456.1	512873.9	513291.8	513710.0	514128.3	514546.8	514965.4	515384.2	515803.1	516222.2
3559	516641.5	517061.0	517480.6	517900.4	518320.3	518740.4	519160.6	519581.1	520001.6	520422.4

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3560	520843.3	521264.4	521685.6	522107.0	522528.6	522950.3	523372.2	523794.2	524216.5	524638.9
3561	525061.4	525484.1	525907.0	526330.0	526753.2	527176.6	527600.1	528023.8	528447.6	528871.6
3562	529295.8	529720.1	530144.6	530569.3	530994.1	531419.1	531844.2	532269.6	532695.1	533120.7
3563	533546.5	533972.4	534398.6	534824.9	535251.3	535677.9	536104.8	536531.7	536958.8	537386.1
3564	537813.5	538241.1	538668.8	539096.8	539524.8	539953.1	540381.5	540810.1	541238.8	541667.7
3565	542096.8	542526.3	542955.8	543385.3	543815.0	544244.9	544674.9	545105.1	545535.4	545965.9
3566	546396.5	546827.3	547258.2	547689.3	548120.6	548552.0	548983.6	549415.2	549847.1	550279.1
3567	550711.3	551143.6	551576.1	552008.7	552441.5	552874.4	553307.5	553740.8	554174.1	554607.7
3568	555041.4	555475.2	555909.2	556343.4	556777.8	557212.2	557646.9	558081.6	558516.6	558951.6
3569	559386.9	559822.2	560257.8	560693.5	561129.4	561565.4	562001.5	562437.8	562874.3	563310.9
3570	563747.7	564184.6	564621.7	565058.9	565496.3	565933.9	566371.6	566809.4	567247.4	567685.6
3571	568123.9	568562.3	569000.9	569439.7	569878.6	570317.7	570756.9	571196.3	571635.9	572075.6
3572	572515.4	572955.4	573395.6	573835.8	574276.3	574716.9	575157.7	575598.6	576039.7	576480.9
3573	576922.2	577363.8	577805.5	578247.3	578689.3	579131.4	579573.8	580016.2	580458.8	580901.6
3574	581344.5	581787.6	582230.8	582674.1	583117.7	583561.4	584005.2	584449.2	584893.3	585337.6
3575	585782.1	586226.7	586671.4	587116.4	587561.4	588006.7	588452.1	588897.6	589343.4	589789.2
3576	590235.2	590681.4	591127.8	591574.3	592021.0	592467.8	592914.8	593361.9	593809.2	594256.7
3577	594704.3	595152.1	595600.0	596048.1	596496.4	596944.8	597393.4	597842.1	598290.9	598740.0
3578	599189.2	599638.6	600088.1	600537.8	600987.6	601437.6	601887.8	602338.1	602788.6	603239.2
3579	603690.0	604140.9	604592.0	605043.3	605494.7	605946.3	606398.1	606849.9	607302.0	607754.2
3580	608206.6	608659.1	609111.8	609564.7	610017.8	610470.9	610924.3	611377.9	611831.6	612285.4
3581	612739.5	613193.8	613648.1	614102.7	614557.4	615012.2	615467.3	615922.6	616377.9	616833.5
3582	617289.2	617745.1	618201.2	618657.4	619113.9	619570.4	620027.2	620484.1	620941.1	621398.4
3583	621855.8	622313.4	622771.1	623229.1	623687.1	624145.4	624603.8	625062.4	625521.1	625980.1
3584	626439.1	626898.4	627357.8	627817.4	628277.2	628737.1	629197.2	629657.5	630117.9	630578.6
3585	631039.3	631500.2	631961.4	632422.8	632884.4	633346.2	633808.2	634270.5	634732.9	635195.6
3586	635658.5	636121.6	636584.9	637048.4	637512.1	637976.1	638440.2	638904.6	639369.2	639833.9
3587	640299.0	640764.2	641229.6	641695.2	642161.1	642627.2	643093.4	643559.9	644026.7	644493.6
3588	644960.7	645428.1	645895.6	646363.4	646831.4	647299.6	647767.9	648236.6	648705.4	649174.4
3589	649643.7	650113.2	650582.9	651052.8	651522.9	651993.2	652463.8	652934.5	653405.4	653876.6
3590	654348.0	654819.6	655291.5	655763.7	656236.1	656708.9	657181.9	657655.1	658128.6	658602.4
3591	659076.5	659550.9	660025.5	660500.4	660975.6	661451.0	661926.8	662402.7	662879.0	663355.5
3592	663832.3	664309.4	664786.8	665264.4	665742.2	666220.4	666698.9	667177.6	667656.6	668135.8
3593	668615.3	669095.1	669575.2	670055.6	670536.2	671017.1	671498.2	671979.7	672461.4	672943.4
3594	673425.6	673908.2	674390.9	674874.0	675357.4	675840.9	676324.9	676808.9	677293.4	677778.2
3595	678263.1	678748.4	679234.0	679719.9	680206.2	680692.8	681179.6	681666.9	682154.4	682642.2
3596	683130.5	683619.1	684107.8	684596.9	685086.5	685576.3	686066.4	686556.9	687047.7	687538.8
3597	688030.2	688522.0	689014.1	689506.4	689999.2	690492.2	690985.6	691479.2	691973.4	692467.7
3598	692962.4	693457.4	693952.8	694448.3	694944.3	695440.6	695937.2	696434.2	696931.4	697428.9
3599	697926.9	698425.2	698923.8	699422.6	699921.8	700421.4	700921.2	701421.4	701921.9	702422.8

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3600	702923.9	703425.4	703927.4	704429.8	704932.6	705435.8	705939.6	706443.8	706948.3	707453.4
3601	707958.8	708464.8	708971.1	709477.8	709984.9	710492.6	711000.6	711509.1	712018.1	712527.4
3602	713037.2	713547.4	714058.2	714569.2	715080.8	715592.8	716105.1	716617.9	717131.2	717644.9
3603	718159.1	718673.7	719188.8	719704.2	720220.1	720736.4	721253.1	721770.3	722287.9	722806.0
3604	723324.5	723843.4	724362.8	724882.6	725402.8	725923.5	726444.6	726966.2	727488.2	728010.5
3605	728533.4	729056.8	729580.6	730104.9	730629.9	731155.4	731681.4	732208.0	732735.1	733262.8
3606	733790.9	734319.6	734848.9	735378.8	735908.9	736439.8	736971.2	737503.2	738035.7	738568.8
3607	739102.2	739636.4	740171.1	740706.2	741241.8	741778.2	742314.9	742852.2	743390.1	743928.5
3608	744467.4	745006.9	745546.9	746087.5	746628.6	747170.2	747712.4	748255.1	748798.3	749342.1
3609	749886.4	750431.2	750976.8	751522.6	752069.1	752616.1	753163.6	753711.7	754260.3	754809.5
3610	755359.2	755909.8	756461.5	757014.5	757568.6	758124.0	758680.6	759238.4	759797.2	760357.5
3611	760918.8	761481.4	762045.2	762610.2	763176.2	763743.6	764312.2	764881.9	765452.9	766025.1
3612	766598.4	767172.9	767748.8	768325.6	768903.8	769483.1	770063.7	770645.4	771228.4	771812.5
3613	772397.8	772984.4	773572.2	774161.1	774751.2	775342.6	775935.1	776528.8	777123.8	777719.8
3614	778317.2	778915.8	779515.4	780116.4	780718.5	781321.8	781926.4	782532.1	783139.1	783747.1
3615	784356.4	784967.1	785579.2	786192.8	786807.6	787424.0	788041.8	788661.1	789281.8	789903.8
3616	790527.4	791152.4	791778.8	792406.8	793036.0	793666.8	794298.9	794932.5	795567.5	796204.0
3617	796841.9	797481.2	798122.1	798764.2	799407.8	800052.9	800699.5	801347.4	801996.9	802647.7
3618	803299.9	803953.6	804608.8	805265.2	805923.2	806582.8	807243.6	807905.9	808569.7	809234.9
3619	809901.5	810569.6	811239.1	811909.9	812582.3	813256.2	813931.2	814608.0	815286.1	815965.6
3620	816646.6	817329.2	818014.2	818701.2	819390.3	820081.6	820775.1	821470.5	822168.2	822867.9
3621	823569.8	824273.8	824980.1	825688.4	826398.8	827111.2	827826.0	828542.8	829261.8	829982.8
3622	830706.0	831431.2	832158.8	832888.4	833620.1	834353.9	835089.8	835828.0	836568.2	837310.6
3623	838055.1	838801.6	839550.4	840301.2	841054.2	841809.4	842566.6	843326.0	844087.6	844851.2
3624	845616.9	846384.9	847154.9	847927.1	848701.2	849477.8	850256.2	851036.9	851819.8	852604.8
3625	853391.8	854181.2	854973.8	855769.2	856567.4	857368.6	858172.6	858979.6	859789.5	860602.2
3626	861417.8	862236.4	863057.8	863882.2	864709.5	865539.6	866372.8	867208.6	868047.4	868889.2
3627	869733.8	870581.4	871431.8	872285.1	873141.4	874000.5	874862.5	875727.4	876595.2	877465.9
3628	878339.6	879216.1	880095.5	880977.8	881863.1	882751.1	883642.2	884536.1	885432.9	886332.6
3629	887235.1	888140.6	889049.1	889960.3	890874.5	891791.6	892711.6	893634.5	894560.2	895488.9
3630	896420.5	897355.6	898295.1	899238.6	900186.5	901138.6	902094.9	903055.4	904020.2	904989.2
3631	905962.5	906940.0	907921.8	908907.7	909897.8	910892.3	911891.1	912893.8	913900.9	914912.4
3632	915928.0	916947.8	917971.8	919000.2	920032.8	921069.5	922110.5	923155.8	924205.2	925258.9
3633	926316.9	927379.1	928445.4	929516.2	930591.1	931670.2	932753.4	933841.1	934932.9	936028.9
3634	937129.2	938233.8	939342.5	940455.5	941572.8	942694.2	943819.8	944949.8	946083.9	947222.4

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3635	948364.9	949511.9	950663.2	951818.9	952978.9	954143.2	955312.0	956485.1	957662.5	958844.3
3636	960030.5	961220.9	962415.8	963615.1	964818.8	966026.8	967239.1	968455.7	969676.8	970902.2
3637	972131.9	973366.1	974604.5	975847.4	977094.6	978346.2	979602.1	980862.3	982126.9	983395.9
3638	984669.2	985947.1	987229.1	988515.6	989806.4	991101.5	992400.9	993704.9	995013.1	996325.8
3639	997642.8	998964.0	1000289.7	1001619.7	1002954.2	1004292.9	1005635.9	1006983.4	1008335.2	1009691.4
3640	1011052.0	1012415.5	1013780.6	1015147.2	1016515.6	1017885.4	1019256.8	1020629.8	1022004.3	1023380.4
3641	1024758.2	1026137.5	1027518.4	1028900.8	1030284.8	1031670.4	1033057.6	1034446.4	1035836.8	1037228.6
3642	1038622.2	1040017.2	1041413.8	1042812.1	1044211.8	1045613.2	1047016.2	1048420.8	1049826.9	1051234.5
3643	1052643.9	1054054.6	1055467.1	1056881.1	1058296.6	1059713.9	1061132.5	1062552.9	1063974.8	1065398.2
3644	1066823.2	1068249.9	1069678.1	1071107.9	1072539.2	1073972.1	1075406.6	1076842.8	1078280.4	1079719.6
3645	1081160.5	1082602.8	1084046.4	1085491.2	1086937.4	1088384.9	1089833.6	1091283.8	1092735.1	1094187.9
3646	1095641.9	1097097.2	1098553.9	1100011.8	1101471.0	1102931.5	1104393.4	1105856.5	1107321.0	1108786.8
3647	1110253.9	1111722.2	1113191.9	1114662.9	1116135.2	1117608.8	1119083.8	1120559.9	1122037.5	1123516.2
3648	1124996.4	1126477.9	1127960.6	1129444.6	1130930.0	1132416.6	1133904.6	1135393.9	1136884.5	1138376.4
3649	1139869.5	1141364.0	1142859.9	1144357.0	1145855.4	1147355.1	1148856.1	1150358.4	1151862.1	1153367.0
3650	1154873.2	1156380.8	1157889.8	1159400.0	1160911.6	1162424.6	1163939.0	1165454.8	1166971.8	1168490.1
3651	1170009.9	1171531.0	1173053.5	1174577.4	1176102.5	1177629.0	1179156.9	1180686.1	1182216.8	1183748.6
3652	1185282.0	1186816.6	1188352.6	1189890.0	1191428.6	1192968.8	1194510.1	1196052.9	1197597.0	1199142.5
3653	1200689.4	1202237.5	1203787.1	1205338.0	1206890.2	1208443.9	1209998.8	1211555.1	1213112.8	1214671.8
3654	1216232.1	1217793.9	1219356.9	1220921.4	1222487.1	1224054.2	1225622.8	1227192.6	1228763.8	1230336.4
3655	1231910.2	1233485.5	1235062.2	1236640.2	1238219.8	1239800.6	1241383.0	1242966.6	1244551.8	1246138.2
3656	1247726.1	1249315.4	1250906.1	1252498.1	1254091.6	1255686.5	1257282.9	1258880.5	1260479.6	1262080.1
3657	1263682.0	1265285.2	1266890.0	1268496.1	1270103.6	1271712.5	1273322.8	1274934.5	1276547.6	1278162.1
3658	1279778.0	1281395.2	1283014.0	1284634.1	1286255.6	1287878.5	1289502.9	1291128.5	1292755.6	1294384.1
3659	1296014.1	1297645.4	1299278.1	1300912.2	1302547.8	1304184.6	1305823.0	1307462.8	1309103.8	1310746.4
3660	1312390.2									

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EXHIBIT VI

SEASONAL RUNOFF FORECAST PROCEDURE

YELLOWTAIL DAM AND BIGHORN RESERVOIR

EXHIBIT VI
SEASONAL RUNOFF FORECAST PROCEDURE
YELLOWTAIL DAM AND BIGHORN RESERVOIR

Table of Contents

Tables

Plates

1. General

Since the drainage area above Yellowtail Dam is almost entirely bounded by mountains, about one-half of its annual inflow normally occurs during the May-July period because of mountain snowmelt. In years when the snow accumulation is high, it is necessary that reservoir storage space be made available in advance of the anticipated runoff. To determine the amount of space needed to store and control this runoff a seasonal volume forecast has been developed.

2. Development of forecast procedure

Multiple correlation studies were made which related independent variables (October and November antecedent runoff, antecedent yearly precipitation, 1st of the month or peak yearly snow-water content, and January through June precipitation) to the dependent variable (May through July runoff volume). Reliable reservoir data starts in 1965, but an adequate SNOTEL record did not become available until 1979, leading to the use of a 42-year record (1979-2020) for forecast development. The dependent variable, May through July runoff volume, and the independent variable, antecedent runoff, were obtained using inflow values from reservoir operations records maintained by the U.S. Army Corps of Engineers Omaha District and U.S. Bureau of Reclamation. Snow water equivalent (SWE) data was taken from SNOTEL automated measurements by the Natural Resources Conservation Service. Precipitation amounts were taken from climatological data compiled by the National Oceanic and Atmospheric Administration. Plate EVI-1 is a map of the Yellowtail Dam drainage basin showing the location of the snow and precipitation stations used in developing the forecast.

a. May through July runoff

For the analysis, the dependent variable (May through July runoff volume) was the natural inflow at Yellowtail Dam. Natural inflow was calculated by adding the cumulative Bull Lake, Boysen, and Buffalo Bill May-July change in storage to the actual Yellowtail inflow volume. The effects of evaporation were implicit in calculating inflow. Plate EVI-2 shows historic monthly inflow to Bighorn Lake for the period 1979 to 2020.

Average May-Jul inflow = 1.35 Million Acre Feet (MAF)
Maximum May-Jul inflow = 2.90 MAF (2011)
Minimum May-Jul inflow = 0.28 MAF (2001)
Note: The Average May-Jul inflow is based on 1979-2020 period to align with runoff forecast analysis.

b. Antecedent runoff

Antecedent runoff was calculated from the natural historical inflow to Bighorn Lake for the months of October and November. The effects of evaporation were ignored in calculating the inflow.

Average Oct-Nov inflow = 0.29 MAF
Maximum Oct-Nov inflow = 0.43 MAF (2016)
Minimum Oct-Nov inflow = 0.19 MAF (2001)
Note: The Average Oct-Nov inflow is based on 1979-2020 period to align with runoff forecast analysis.

c. Snow-water content

Analysis of the Yellowtail basin indicated accurate up-to-date snowpack water content could be provided by 27 different SNOTEL sites. Plate VI-1 shows a map of these stations. Plate 5-4 of the Yellowtail Water Control Manual lists these stations and their average first of the month and mid-month snow water content. Real-time and historical SNOTEL data for all 27 stations can be found at https://www.nrcs.usda.gov/wps/portal/wcc/home/. Note that during the analysis, the Burroughs Creek data was not included. This station is within the basin, but a recent wildfire burnt the gaging area. To assure anomalies in the snow accumulation pattern do not distort the estimates, this gage will not be used in the computation until growth around the gaging area returns.

d. Spring and summer precipitation

Monthly precipitation data is available from the National Weather Service at 5 reliable reporting stations. Table 1 shows a listing of these stations and their elevations. Other reliable stations have current readings, but only stations with data back to 1979 were used.

Table 1. Spring and Summer Precipitation Stations

Precipitation Station	Elevation (feet)
Powell Field Airport	5092
Lander/Hunt Field	5587
Cody, WY 12 SE	5240
Riverton	5443
Worland, WY	4226

3. Application of forecast equation

An average of the SWE at the SNOTEL sites (Plate VI-1) on the first of the month is used from February 1st through April 1st. For the forecast on May 1st, June 1st, and July 1st, the peak snowpack is used. Antecedent inflow (ANTQ) for October and November and the total antecedent precipitation (ANTPREC) from the previous year will remain constant for each year's forecast period. For the March 1st forecast the average precipitation that fell in January plus February (P_{J+F}) is used; for the April 1st forecast the

average precipitation from January plus February plus March (P_{J+F+M}) is used, and so on. Coefficients (C_{swe}, C_{antQ}, $C_{antprec}$, and $C_{intercept}$) are specific to the month of the forecast and should be updated as necessary to maximize the accuracy of inflow forecasting. A multiple linear regression analysis is applied to the historical dataset determining these coefficients. The forecasted total inflow volume to the reservoir in MAF (1,000,000 ac-ft) from May-July (Q) is the result.

May-July inflow volume forecast equations:

March 1st:
$Q=C_{swe}(SWE_{MAR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_p(P_{J+F}) + C_{intercept}$

April 1st:
$Q=C_{swe}(SWE_{APR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_p(P_{J+F+M}) + C_{intercept}$

May 1st:
$Q=C_{swe}(SWE_{peak}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_p(P_{J+F+M+A}) + C_{intercept}$

June 1st:
$Q=C_{swe}(SWE_{peak}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_p(P_{J+F+M+A+M}) + C_{intercept}$

July 1st:
$Q=C_{swe}(SWE_{peak}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_p(P_{J+F+M+A+M+J}) + C_{intercept}$

NOTE: Coefficients (C) are specific to the month of the forecast and are updated as necessary.

The coefficients developed based on 1979-2020 data are shown in Table 2. These coefficients should be updated as necessary to maximize the accuracy of inflow forecasting. Updating the coefficients is completed by collecting the model data (inflow, SWE and precipitation) since the coefficients were last updated and including them in the multiple linear regression analysis. During some years the majority of the snow has melted before the July 1 forecast. In these cases alternative methods such as regression or hydrologic forecasting can be used to better predict inflows.

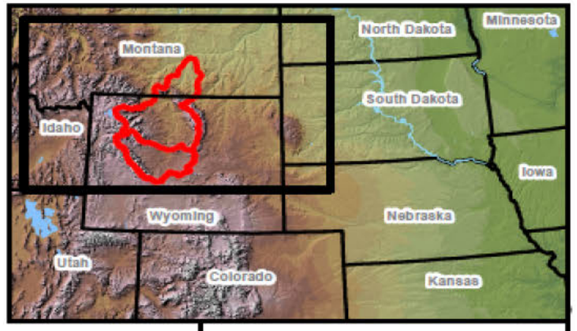
Table 2. Linear Regression Coefficients

	March	April	May	June	July
Intercept	-0.9547	-1.3862	-1.3028	-1.9008	-2.0234
SWE - (SWE_{xxx})	0.1370	0.1421	0.1313	0.1255	0.1105
ANT Flow - (ANTQ)	1.0777	0.8684	0.3844	0.9292	0.9691
ANTPREC - (ANTPREC)	0.0291	0.0346	0.0290	0.021895	0.0222
Year-to-Date Precip - (P_{xx})	0.3442	0.1834	0.1548	0.2239	0.2357

**Note: These coefficients are as of WY 2020. These coefficients should be updated as necessary to maximize the accuracy of inflow forecasting.

4. Pertinent data

Plates E-VI-3 and E-VI-4 present a more detailed summary of the independent variables. Plates E-VI-5 and E-VI-6 show the observed inflows and forecasted inflows. Plates E-VI-7 and E-VI-8 show the residual and squares of residuals of the forecasts.



Montana

Idaho

Wyoming

Yellowstone River

Bighorn River

Wind River

Billings

Yellowtail Dam

Boysen Dam

Buffalo Bill Dam

Bull Lake Creek Dam

Cody 12 SE

Soda Mountain

Pryor Mountain

Derby Mountain

Pryor

Fishtail

Hillsboro

Soda Butte

Timbercrest

Rattlesnake Mtn

Crandall

Powell

Field Station

Sylvan Road

Evening Star

Sylvan Lake

Grebe

Blackwater

Eagle

Cabin Creek

Two Ocean Plateau

Timber Creek

Kirwin

Togwotee Pass

Castle Creek

Owl Creek

Little Warm

Elkhorn

Raspberry

Cold Springs

St. Lawrence Alt

Hobbs Park

Lander Airport

Townsend Creek

Wind River Raws

Deer Park

South Pass

Little Bighorn

Wolf Mountain

Bighorn Mountain

Bald Mtn

Bone Springs Div

Dome Lake

Shell Creek

Burgess

Mill Creek

Hyatt High

Powder River Pass

Echeta

Leigh Creek

School House Park

Bear Trap Meadow

Grass Creek Divide

Middle Powder

Grave Springs

Pistol Draw

Poker

Split Rock Creek

Riverton Regional Airport

Sharpnose

Fales Rock

N

Reclamation Dams

- Buffalo Bill & Bull Lake Creek

Section 7 Reclamation Dams

- Boysen & Yellowtail
- Cities
- Snotel Station
- Real-Time Precip Station
- Stream
- Bighorn River Basin

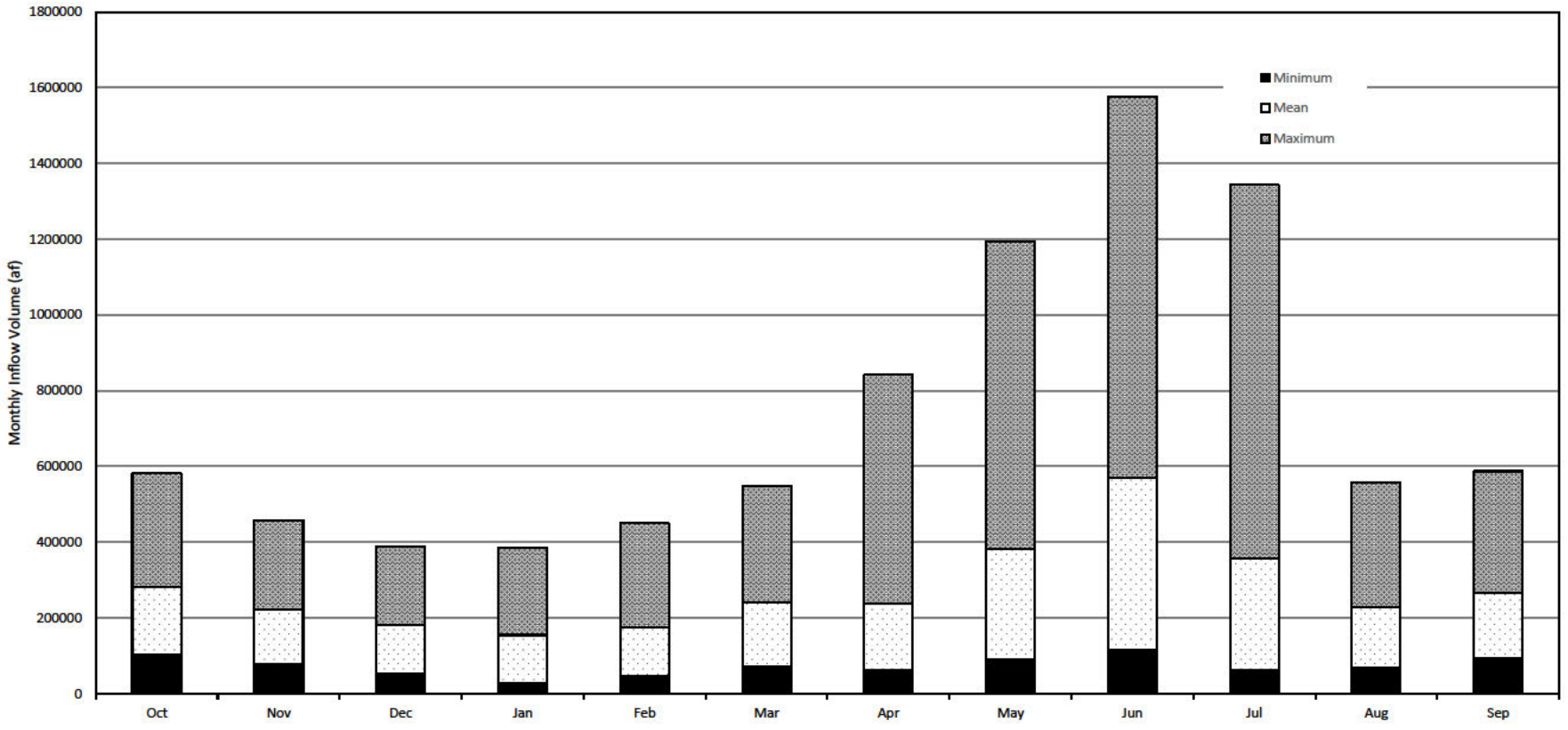
0 12.5 25 50 Miles

Water Control Manual
Canyon Ferry Reservoir and Dam, Montana

SNOTEL and Precipitation Gaging Stations

U.S. Army Engineers District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate E-VI-1



Period Analyzed: 1966-2020
Total Average Annual Inflow Volume = 2,423,372 ac-ft

Source of Data: USBR HydroMet-Hydrological Database

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Monthly Min, Max and Mean Inflow Volume

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate E-VI-2

	Previous yrs	Average Snow Water Equivalent, Inches						
	OCT-NOV							
Years	Inflow, maf	Jan	Feb	Mar	Apr	May	Jun	Annual Max
1979	0.28	7.64	9.86	11.24	13.01	13.36	3.74	13.36
1980	0.32	4.30	7.55	8.89	12.40	10.48	4.23	12.40
1981	0.32	4.83	5.91	7.64	9.91	7.37	5.26	9.91
1982	0.52	8.01	12.00	13.64	17.46	18.60	11.90	18.60
1983	0.45	8.04	10.37	12.17	15.51	17.84	14.19	17.84
1984	0.43	7.95	9.28	10.61	13.73	17.56	9.45	17.56
1985	0.23	6.64	7.71	9.69	12.37	10.40	3.44	12.37
1986	0.36	8.45	10.82	17.99	20.07	21.67	11.91	21.67
1987	0.31	6.99	8.93	10.66	13.17	8.13	1.41	13.17
1988	0.20	4.68	7.01	9.18	11.97	10.69	3.40	11.97
1989	0.33	5.30	8.14	10.21	14.46	12.73	6.33	14.46
1990	0.25	6.67	9.95	11.37	13.56	13.81	8.28	13.81
1991	0.31	6.76	8.47	10.02	13.84	17.65	9.73	17.65
1992	0.25	6.83	7.65	8.66	10.71	8.50	1.14	10.71
1993	0.34	5.82	7.50	8.87	11.08	13.72	3.87	13.72
1994	0.25	4.60	7.28	10.23	12.40	10.50	0.56	12.40
1995	0.31	7.44	9.93	11.86	15.01	18.56	16.60	18.56
1996	0.29	9.30	12.86	15.33	18.66	19.77	13.62	19.77
1997	0.37	11.47	15.12	17.20	19.82	21.48	8.12	21.48
1998	0.39	5.97	9.54	11.08	14.14	14.64	4.31	14.64
1999	0.34	7.34	10.77	14.32	15.99	20.11	12.24	20.11
2000	0.27	4.23	7.33	9.96	12.36	10.54	2.81	12.36
2001	0.18	4.61	5.20	6.99	8.77	8.00	0.19	8.77
2002	0.19	5.18	7.27	8.59	11.73	11.82	4.45	11.82
2003	0.20	5.02	7.55	10.27	15.03	13.11	4.17	15.03
2004	0.20	6.58	8.18	10.50	10.58	10.37	3.38	10.58
2005	0.27	6.05	7.69	8.95	11.29	11.41	4.76	11.41
2006	0.22	6.50	8.94	10.76	12.78	10.73	2.48	12.78
2007	0.23	5.24	7.09	9.45	11.11	9.91	2.23	11.11
2008	0.27	6.37	9.18	11.45	15.14	15.58	11.33	15.58
2009	0.32	6.64	9.72	11.15	14.74	16.33	4.89	16.33
2010	0.24	5.19	6.71	7.83	10.47	11.29	9.34	11.29
2011	0.36	7.65	10.20	12.16	15.67	20.21	20.52	20.52
2012	0.25	6.70	9.20	12.60	12.40	9.70	4.40	12.60
2013	0.32	5.90	7.20	8.80	10.90	12.50	2.70	12.50
2014	0.32	6.94	9.59	13.86	18.10	17.70	7.68	18.10
2015	0.25	6.23	8.02	10.33	9.94	8.30	3.62	10.33
2016	0.34	4.60	6.10	8.34	12.65	12.65	4.35	12.65
2017	0.51	7.14	10.30	14.70	17.80	21.50	11.00	21.50
2018	0.33	8.38	10.34	13.57	16.24	15.74	4.74	16.24
2019	0.37	5.44	7.44	10.87	12.28	12.43	10.34	12.43
2020	0.32	6.26	8.60	11.41	13.78	12.53	4.62	13.78
Ave	0.31	6.47	8.77	11.03	13.64	13.81	6.61	14.62
Max	0.52	11.47	15.12	17.99	20.07	21.67	20.52	21.67
Min	0.18	4.23	5.20	6.99	8.77	7.37	0.19	8.77

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, Montana

Regression Analysis

Independent Variables

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate E-VI-3

		Cumulative Rainfall, Inches					
	Annual Precip		Jan-	Jan-	Jan-	Jan-	Jan-
Years	Inches	Jan	Feb	Mar	Apr	May	Jun
1979	7.71	0.52	0.61	0.93	1.85	4.13	4.86
1980	8.51	0.38	0.67	1.44	2.19	5.29	6.01
1981	7.68	0.25	0.55	1.57	2.13	5.26	5.55
1982	9.58	0.15	0.22	0.54	0.76	1.76	3.91
1983	9.14	0.03	0.25	0.90	2.01	3.59	5.22
1984	7.53	0.53	0.91	1.32	2.64	3.18	4.54
1985	7.08	0.28	0.38	0.62	0.93	1.82	3.30
1986	8.44	0.17	0.87	1.19	2.19	3.33	4.27
1987	9.52	0.35	1.08	1.87	2.19	4.57	5.79
1988	5.96	0.04	0.31	0.73	1.50	3.57	3.95
1989	9.77	0.09	0.52	0.93	1.64	4.57	5.85
1990	8.26	0.03	0.08	0.86	2.52	3.66	4.27
1991	10.73	0.19	0.39	0.71	2.56	4.86	6.52
1992	10.48	0.13	0.20	1.11	1.70	3.65	6.16
1993	11.85	0.53	0.71	1.37	2.25	4.24	7.51
1994	7.71	0.34	0.67	1.23	1.89	2.16	2.50
1995	12.58	0.75	1.08	1.80	3.21	5.92	8.05
1996	8.96	0.54	0.86	1.78	2.32	4.65	5.46
1997	11.43	0.43	0.67	1.14	2.05	3.65	6.27
1998	11.83	0.38	0.65	2.54	3.34	4.12	6.57
1999	8.70	0.07	0.21	0.52	3.79	5.11	6.07
2000	7.71	0.32	0.53	0.99	2.13	3.93	4.77
2001	5.71	0.10	0.49	0.89	1.56	2.03	3.40
2002	6.14	0.23	0.33	0.70	1.63	2.43	2.92
2003	7.41	0.17	0.76	1.81	2.59	3.74	5.07
2004	8.73	0.08	0.87	0.90	2.55	3.09	4.08
2005	10.77	0.38	0.48	1.02	2.59	6.25	7.13
2006	5.06	0.14	0.49	0.82	1.62	2.18	2.26
2007	8.57	0.37	0.57	1.55	2.16	3.47	4.70
2008	9.59	0.17	0.46	0.77	1.11	5.42	5.99
2009	10.67	0.33	0.34	1.34	3.04	3.85	6.40
2010	8.97	0.27	0.64	1.39	2.57	5.48	6.96
2011	11.42	0.24	0.83	1.09	2.12	7.08	7.96
2012	4.49	0.17	0.58	0.84	1.27	2.63	2.88
2013	10.39	0.33	0.78	1.03	2.41	4.38	4.52
2014	9.18	0.52	1.10	1.65	2.67	3.72	5.34
2015	9.35	0.06	0.92	1.18	2.34	6.06	6.85
2016	13.22	0.28	0.34	2.06	4.60	7.10	7.57
2017	11.85	0.60	1.18	3.18	5.73	6.93	7.66
2018	9.84	0.28	0.79	1.37	2.44	5.54	7.17
2019	12.95	0.22	0.62	1.17	2.48	6.80	7.39
2020	9.32	0.14	0.79	1.04	2.02	2.37	3.47
Ave	9.16	0.28	0.61	1.23	2.32	4.23	5.41
Max	13.22	0.75	1.18	3.18	5.73	7.10	8.05
Min	4.49	0.03	0.08	0.52	0.76	1.76	2.26

Note: Precipitations are the average of the following stations:
Lander Hunt Field Airport
Cody 12 SE
Powell Field Station
Riverton
Worland

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, Montana
Regression Analysis
Independent Variables
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate E-VI-4

	*Reported in maf		Deviation	
	Natural	Arithmetic	from	Deviation
Years	Inflow	Mean	Mean	Squared
1979	0.96	1.35	-0.39	0.15
1980	1.32	1.35	-0.03	0.00
1981	1.25	1.35	-0.10	0.01
1982	1.66	1.35	0.31	0.09
1983	1.78	1.35	0.43	0.18
1984	1.60	1.35	0.25	0.06
1985	0.57	1.35	-0.78	0.61
1986	1.88	1.35	0.53	0.28
1987	0.88	1.35	-0.47	0.22
1988	0.53	1.35	-0.82	0.68
1989	1.00	1.35	-0.35	0.12
1990	0.87	1.35	-0.48	0.23
1991	1.94	1.35	0.59	0.35
1992	0.96	1.35	-0.39	0.15
1993	1.54	1.35	0.19	0.04
1994	0.34	1.35	-1.01	1.02
1995	2.30	1.35	0.95	0.90
1996	1.82	1.35	0.47	0.22
1997	2.34	1.35	0.99	0.98
1998	1.43	1.35	0.08	0.01
1999	2.25	1.35	0.90	0.81
2000	0.75	1.35	-0.60	0.36
2001	0.28	1.35	-1.07	1.15
2002	0.53	1.35	-0.82	0.68
2003	0.78	1.35	-0.57	0.33
2004	0.54	1.35	-0.81	0.66
2005	1.19	1.35	-0.16	0.03
2006	0.53	1.35	-0.82	0.68
2007	0.57	1.35	-0.78	0.61
2008	1.72	1.35	0.37	0.14
2009	1.87	1.35	0.52	0.27
2010	1.72	1.35	0.37	0.14
2011	2.90	1.35	1.55	2.40
2012	0.57	1.35	-0.78	0.61
2013	0.73	1.35	-0.62	0.39
2014	1.85	1.35	0.50	0.25
2015	1.58	1.35	0.23	0.05
2016	1.18	1.35	-0.17	0.03
2017	2.73	1.35	1.38	1.90
2018	2.50	1.35	1.15	1.32
2019	1.91	1.35	0.56	0.31
2020	1.15	1.35	-0.20	0.04
Ave	1.35		SST	19.43
Max	2.9	SST = Sum of the squares due to total variability.		
Min	0.28			

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, Montana
Regression Analysis
Observed Inflows
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

		Forecast Natural May-Jul Inflow						
	Natural	maf						
Years	Inflow	Jan	Feb	Mar	Apr	May	Jun	Jul
1979	0.96	1.75	1.77	1.49	1.33	1.22	1.26	1.17
1980	1.32	0.73	1.11	0.99	1.12	0.98	1.24	1.18
1981	1.25	0.95	0.82	0.85	0.86	0.69	0.99	0.86
1982	1.66	1.60	1.76	1.48	1.68	1.58	1.23	1.37
1983	1.78	1.91	1.68	1.53	1.67	1.79	1.74	1.79
1984	1.60	1.83	1.76	1.49	1.45	1.82	1.57	1.56
1985	0.57	1.43	1.25	1.11	1.06	0.82	0.56	0.63
1986	1.88	1.72	1.59	2.31	2.17	2.19	1.97	1.80
1987	0.88	1.51	1.49	1.48	1.41	1.14	1.27	1.31
1988	0.53	0.84	0.77	0.93	0.97	0.86	0.82	0.66
1989	1.00	0.87	0.96	1.05	1.24	1.11	1.28	1.31
1990	0.87	1.46	1.45	1.26	1.31	1.31	1.16	1.04
1991	1.94	1.37	1.21	1.10	1.24	1.76	1.85	1.92
1992	0.96	1.43	1.00	0.89	0.93	0.77	0.73	1.09
1993	1.54	1.18	1.24	1.08	1.02	1.25	1.23	1.74
1994	0.34	0.95	1.11	1.30	1.24	1.06	0.64	0.45
1995	2.30	1.53	1.86	1.58	1.60	1.97	2.19	2.38
1996	1.82	2.14	2.33	2.13	2.29	2.13	2.17	2.02
1997	2.34	2.47	2.54	2.17	2.17	2.19	2.05	2.27
1998	1.43	1.36	1.66	1.48	1.77	1.60	1.42	1.72
1999	2.25	1.75	1.73	1.82	1.71	2.41	2.37	2.25
2000	0.75	0.79	1.10	1.15	1.10	1.01	0.98	0.93
2001	0.28	0.80	0.49	0.66	0.50	0.41	0.05	0.16
2002	0.53	0.77	0.82	0.70	0.77	0.74	0.42	0.28
2003	0.78	0.81	0.91	1.14	1.49	1.34	1.16	1.19
2004	0.54	1.20	0.95	1.22	0.72	0.78	0.48	0.47
2005	1.19	1.25	1.24	1.02	0.97	0.97	1.40	1.40
2006	0.53	1.38	1.28	1.30	1.19	1.04	0.68	0.43
2007	0.57	0.89	1.02	0.97	0.89	0.74	0.63	0.69
2008	1.72	1.30	1.33	1.33	1.45	1.27	1.72	1.58
2009	1.87	1.34	1.49	1.24	1.50	1.69	1.45	1.74
2010	1.72	1.10	1.00	0.97	0.98	1.00	1.25	1.39
2011	2.90	1.49	1.43	1.48	1.53	2.02	2.64	2.51
2012	0.57	1.54	1.46	1.67	1.22	0.98	0.81	0.60
2013	0.73	0.98	0.95	0.90	0.71	0.93	0.97	0.75
2014	1.85	1.69	1.90	2.08	2.22	1.95	1.82	1.88
2015	1.58	1.29	1.07	1.36	0.81	0.74	1.18	1.18
2016	1.18	0.83	0.78	0.83	1.32	1.43	1.70	1.59
2017	2.73	1.84	2.12	2.31	2.55	2.95	3.03	2.86
2018	2.50	2.08	1.89	1.98	1.95	1.71	2.03	2.13
2019	1.91	1.11	1.06	1.33	1.16	1.11	1.66	1.58
2020	1.15	1.53	1.39	1.65	1.53	1.33	0.98	0.96

Water Control Manual

Yellowtail Dam and Bighorn Reservoir, Montana

Regression Analysis

Forecast Variables

U. S. Army Engineer District, Omaha

Corps of Engineers, Omaha, Nebraska

October 2022

Plate E-VI-6

		Residuals (Natural Inflow-Forecasted)						
	Natural	maf						
Years	Inflow	Jan	Feb	Mar	Apr	May	Jun	Jul
1979	0.96	-0.79	-0.81	-0.53	-0.37	-0.26	-0.30	-0.21
1980	1.32	0.59	0.21	0.33	0.20	0.34	0.08	0.14
1981	1.25	0.30	0.43	0.40	0.39	0.56	0.26	0.39
1982	1.66	0.06	-0.10	0.18	-0.02	0.08	0.43	0.29
1983	1.78	-0.13	0.10	0.25	0.11	-0.01	0.04	-0.01
1984	1.60	-0.23	-0.16	0.11	0.15	-0.22	0.03	0.04
1985	0.57	-0.86	-0.68	-0.54	-0.49	-0.25	0.01	-0.06
1986	1.88	0.16	0.29	-0.43	-0.29	-0.31	-0.09	0.08
1987	0.88	-0.63	-0.61	-0.60	-0.53	-0.26	-0.39	-0.43
1988	0.53	-0.31	-0.24	-0.40	-0.44	-0.33	-0.29	-0.13
1989	1.00	0.13	0.04	-0.05	-0.24	-0.11	-0.28	-0.31
1990	0.87	-0.59	-0.58	-0.39	-0.44	-0.44	-0.29	-0.17
1991	1.94	0.57	0.73	0.84	0.70	0.18	0.09	0.02
1992	0.96	-0.47	-0.04	0.07	0.03	0.19	0.23	-0.13
1993	1.54	0.36	0.30	0.46	0.52	0.29	0.31	-0.20
1994	0.34	-0.61	-0.77	-0.96	-0.90	-0.72	-0.30	-0.11
1995	2.30	0.77	0.44	0.72	0.70	0.33	0.11	-0.08
1996	1.82	-0.32	-0.51	-0.31	-0.47	-0.31	-0.35	-0.20
1997	2.34	-0.13	-0.20	0.17	0.17	0.15	0.29	0.07
1998	1.43	0.07	-0.23	-0.05	-0.34	-0.17	0.01	-0.29
1999	2.25	0.50	0.52	0.43	0.54	-0.16	-0.12	0.00
2000	0.75	-0.04	-0.35	-0.40	-0.35	-0.26	-0.23	-0.18
2001	0.28	-0.52	-0.21	-0.38	-0.22	-0.13	0.23	0.12
2002	0.53	-0.24	-0.29	-0.17	-0.24	-0.21	0.11	0.25
2003	0.78	-0.03	-0.13	-0.36	-0.71	-0.56	-0.38	-0.41
2004	0.54	-0.66	-0.41	-0.68	-0.18	-0.24	0.06	0.07
2005	1.19	-0.06	-0.05	0.17	0.22	0.22	-0.21	-0.21
2006	0.53	-0.85	-0.75	-0.77	-0.66	-0.51	-0.15	0.10
2007	0.57	-0.32	-0.45	-0.40	-0.32	-0.17	-0.06	-0.12
2008	1.72	0.42	0.39	0.39	0.27	0.45	0.00	0.14
2009	1.87	0.53	0.38	0.63	0.37	0.18	0.42	0.13
2010	1.72	0.62	0.72	0.75	0.74	0.72	0.47	0.33
2011	2.90	1.41	1.47	1.42	1.37	0.88	0.26	0.39
2012	0.57	-0.97	-0.89	-1.10	-0.65	-0.41	-0.24	-0.03
2013	0.73	-0.25	-0.22	-0.17	0.02	-0.20	-0.24	-0.02
2014	1.85	0.16	-0.05	-0.23	-0.37	-0.10	0.03	-0.03
2015	1.58	0.29	0.51	0.22	0.77	0.84	0.40	0.40
2016	1.18	0.35	0.40	0.35	-0.14	-0.25	-0.52	-0.41
2017	2.73	0.89	0.61	0.42	0.18	-0.22	-0.30	-0.13
2018	2.50	0.42	0.61	0.52	0.55	0.79	0.47	0.37
2019	1.91	0.80	0.85	0.58	0.75	0.80	0.25	0.33
2020	1.15	-0.38	-0.24	-0.50	-0.38	-0.18	0.17	0.19

Water Control Manual

Yellowtail Dam and Bighorn Reservoir, Montana

Regression Analysis

Forecast Residuals

U. S. Army Engineer District, Omaha

Corps of Engineers, Omaha, Nebraska

October 2022

Plate E-VI-7

	Square of Residuals						
Years	Jan	Feb	Mar	Apr	May	Jun	Jul
1979	0.62	0.66	0.28	0.14	0.07	0.09	0.04
1980	0.35	0.04	0.11	0.04	0.12	0.01	0.02
1981	0.09	0.18	0.16	0.15	0.31	0.07	0.15
1982	0.00	0.01	0.03	0.00	0.01	0.18	0.08
1983	0.02	0.01	0.06	0.01	0.00	0.00	0.00
1984	0.05	0.03	0.01	0.02	0.05	0.00	0.00
1985	0.74	0.46	0.29	0.24	0.06	0.00	0.00
1986	0.03	0.08	0.18	0.08	0.10	0.01	0.01
1987	0.40	0.37	0.36	0.28	0.07	0.15	0.18
1988	0.10	0.06	0.16	0.19	0.11	0.08	0.02
1989	0.02	0.00	0.00	0.06	0.01	0.08	0.10
1990	0.35	0.34	0.15	0.19	0.19	0.08	0.03
1991	0.32	0.53	0.71	0.49	0.03	0.01	0.00
1992	0.22	0.00	0.00	0.00	0.04	0.05	0.02
1993	0.13	0.09	0.21	0.27	0.08	0.10	0.04
1994	0.37	0.59	0.92	0.81	0.52	0.09	0.01
1995	0.59	0.19	0.52	0.49	0.11	0.01	0.01
1996	0.10	0.26	0.10	0.22	0.10	0.12	0.04
1997	0.02	0.04	0.03	0.03	0.02	0.08	0.00
1998	0.00	0.05	0.00	0.12	0.03	0.00	0.08
1999	0.25	0.27	0.18	0.29	0.03	0.01	0.00
2000	0.00	0.12	0.16	0.12	0.07	0.05	0.03
2001	0.27	0.04	0.14	0.05	0.02	0.05	0.01
2002	0.06	0.08	0.03	0.06	0.04	0.01	0.06
2003	0.00	0.02	0.13	0.50	0.31	0.14	0.17
2004	0.44	0.17	0.46	0.03	0.06	0.00	0.00
2005	0.00	0.00	0.03	0.05	0.05	0.04	0.04
2006	0.72	0.56	0.59	0.44	0.26	0.02	0.01
2007	0.10	0.20	0.16	0.10	0.03	0.00	0.01
2008	0.18	0.15	0.15	0.07	0.20	0.00	0.02
2009	0.28	0.14	0.40	0.14	0.03	0.18	0.02
2010	0.38	0.52	0.56	0.55	0.52	0.22	0.11
2011	1.99	2.16	2.02	1.88	0.77	0.07	0.15
2012	0.94	0.79	1.21	0.42	0.17	0.06	0.00
2013	0.06	0.05	0.03	0.00	0.04	0.06	0.00
2014	0.03	0.00	0.05	0.14	0.01	0.00	0.00
2015	0.08	0.26	0.05	0.59	0.71	0.16	0.16
2016	0.12	0.16	0.12	0.02	0.06	0.27	0.17
2017	0.79	0.37	0.18	0.03	0.05	0.09	0.02
2018	0.18	0.37	0.27	0.30	0.62	0.22	0.14
2019	0.64	0.72	0.34	0.56	0.64	0.06	0.11
2020	0.14	0.06	0.25	0.14	0.03	0.03	0.04
SSE	12.19	11.25	11.81	10.33	6.74	2.99	2.12
MSE	0.29	0.27	0.28	0.25	0.16	0.07	0.05
Std Err	0.056855	0.057412	0.057961	0.050467	0.032591	0.010802	0.00896
R^2	0.372957	0.421357	0.39215	0.468371	0.653119	0.846238	0.890889

Water Control Manual

Yellowtail Dam and Bighorn Reservoir, Montana

Regression Analysis

Squares of Residuals

U. S. Army Engineer District, Omaha

Corps of Engineers, Omaha, Nebraska

October 2022

Plate E-VI-8

EXHIBIT VII

DETERMINATION OF SEASONAL
FLOOD CONTROL STORAGE REQUIREMENTS

YELLOWTAIL DAM AND BIGHORN RESERVOIR

EXHIBIT VII
DETERMINATION OF SEASONAL FLOOD CONTROL STORAGE REQUIREMENTS YELLOWTAIL DAM AND BIGHORN RESERVOIR

Table of Contents

Tables

Plates

DETERMINATION OF SEASONAL FLOOD CONTROL STORAGE REQUIREMENTS YELLOWTAIL DAM AND BIGHORN RESERVOIR

1. General. Bighorn Reservoir joint use storage space (a total of 232,735 acre-feet (af) between elevations 3614.0 and 3640.0 feet) will be vacated for flood control purposes, provided it can be reasonably assured of refill prior to the end of the snowmelt period while conservation release requirements are satisfied.

2. Forecast Accuracy. Long-term runoff forecasting is not an exact science. The May-July inflow volume forecast equations were developed based on historical data and are not wholly predictive into the future. Therefore, determining the amount of vacated space needed to minimize flooding in any given year also contains uncertainty. The May-July inflow volume forecast, outlined in Exhibit VI, is initially made on March 1 and then updated monthly with the most up-to-date information. The uncertainty, sometimes referred to as error allowance, in making this inflow volume forecast will, in some years, result in the observed May-July inflow being much greater or much less than the forecast May-July inflow volume.

3. Reasonable Assurance of Refill. The evacuation of joint use storage for flood control purposes is designed such that there is a reasonable assurance that refill of the joint use zone will occur. To balance the impact of the May-July inflow volume forecast uncertainty to non-flood control purposes, an assured inflow (85-90 percent exceedance) volume forecast is made. The U.S. Bureau of Reclamation (Reclamation) determines and provides a Bighorn Reservoir release volume estimate for the May-July period. The assured inflow volume forecast combined with the estimated release are used to determine the required joint use zone evacuation.

4. Assured Inflow. The established criteria for reasonable assurance of filling the joint use storage is satisfied by using an assured forecast that will be exceeded during 85-90 percent of the years. The May-July assured inflow forecast is determined by applying a volume deviation factor (assured inflow factor) to May-July inflow volume calculated in Exhibit VI. The volume deviation factors, which are different for each month, are sometimes referred to as the assured inflow factors. They were determined by analyzing the variation between historical May-July forecasted and observed inflow volumes. The monthly assured inflow factors are outlined in Table 1 and were mutually agreeable to the U.S. Army Corps of Engineers (Corps) and Reclamation. Plates E-VII-1 through E-VII-5 outline how the assured inflow factors were determined for March 1 through July 1, respectively.

Table 1 - Assured Inflow Factors
(Volume Deviation Factors)

March 1	534,000 af
April 1	475,000 af
May 1	325,000 af
June 1	310,000 af
July 1	224,000 af

As the runoff season advances the assured inflow factor becomes progressively smaller. This is because more observed data has become available and the forecasts become more accurate. These factors represent the volume to be subtracted from the most probable May-July inflow volume, as determined in Exhibit VI, to obtain the assured forecast volume.

5. Estimated Outflow. Shortly after the first of each month, from March 1 through July 1, Reclamation will furnish the Corps an estimate for May-July conservation release requirements based on power generation and irrigation requirements. The release estimate is provided in Reclamation's monthly water supply outlook and Yellowtail projected operations plan. The release estimate should be used as the conservation release whenever available and relevant. If the current month's data is not yet available, the previous month's conservation release estimate should be used. In the absence of recent Reclamation estimates, Table 2 shows estimated monthly conservation releases during the runoff period.

Table 2 - Monthly Conservation Releases (Volume and Rate)

May	61,500 af	1,000 cfs/day
June	59,500 af	1,000 cfs/day
July	61,500 af	1,000 cfs/day

6. Determining Storage Requirements. An example is provided to demonstrate how the flood control storage requirement is determined. Refer to Exhibit VI for additional information about determining the May-July inflow volume forecast. Table 3 lists the monthly distribution percentages, based on 1979-2020 observed inflows, which are useful when determining the joint use storage evacuation.

Table 3 – Monthly Percentages of May-July Inflow Volume

Period	Percentage of Inflow		
	May	June	July
May – July	27	45	28
June – July		61	39
July			100

Water stored in Boysen, Buffalo Bill, and Bull Lake between May-July has a large impact on inflows into Yellowtail. The forecaster should account for this by estimating an expected beginning of May storage and end of July storage at all three projects. The change in storage over this period would be the expected storage holdout from these three projects. This holdout is subtracted from the most probable forecast volume to account for the water retained in these three reservoirs over this period.

After the most probable May-July inflow volume has been determined, Table 4 is used to determine the necessary evacuation of the joint use zone. A detailed explanation of the joint use storage requirement calculations and a step-by-step look at Table 4 is detailed in an example below. Table 4 is available in the Corps and Reclamation's electronic file systems. For some, the logic and methods used in these tables is better understood in the electronic version.

The following example is provided to demonstrate the theoretical regulation of the joint use storage zone. The example scenario is based on the spring 2017 runoff season. Table 4 shows the example calculations in tabular form. Plate 7-2 in the Water Control Manual helps graphically show how and when the joint use zone is used for flood control.

Conditions on March 1 (note storages have been updated to match latest capacity survey): Pool elevation: 3630.8 feet; 130,500 af of joint use space vacant.

March 1 forecast: The most probable May-July inflow forecast from methods in Exhibit VI was 2,206,000 af. After adjustment for the assured factor (534,000 af) and the expected May-July upstream storage holdout (433,000 af) the May-July assured inflow forecast was 1,239,000 af. May-July release in Reclamation's March Operation Plan was 1,349,000 af. Subtracting the 1,349,000 af release from the 1,239,000 af assured inflow forecast showed a 0 af joint use drawdown by May 1. In most situations a forecasted volume of 2,206,000 af would be enough to require a joint use drawdown, but due Reclamation's proactive release plans, no modification to Reclamation's operations were necessary.

April 1 forecast: Pool elevation was 3610.8 feet (251,000 af drawdown). The most probable May-July inflow forecast was 2,402,000 af. After adjustment for the assured factor (475,000 af) and the expected May-July upstream storage (433,000 af) the May-July assured inflow forecast was 1,494,000 af. May-July release in Reclamation's April Operation Plan was 1,376,000 af. Subtracting the 1,376,000 af release from the 1,494,000 af assured inflow forecast showed a joint use evacuation requirement of 120,000 af by May 1. The maximum joint-use evacuation requirement is 232,735 af. Any drawdown larger than 232,735 af is Reclamation's decision and responsibility.

The May 1 expected pool elevation of 3602.29 feet (299,000 af drawdown) in Reclamation's April Operation Plan exceeded the Corps' flood control requirement and no modification to Reclamation's operations were necessary.

May 1 forecast: Pool elevation was 3607.9 feet, 6.1 feet below the base of joint use zone. This pool level on May 1 met and exceeded the Corps' flood control requirement set in April. The most probable May-July inflow forecast was 3,025,000 af. The upstream storage holdout was increased to 600,000 af due to Boysen and Buffalo Bill drafting storage during March and April. After adjustment for the assured factor (325,000 af) and the expected May-July upstream storage, the May 1 May-July assured inflow forecast was 2,100,000 af. May-July release in Reclamation's May Operation Plan was 2,181,000 af. Subtracting the planned release from the expected inflow (2,100,000 af – 2,181,000 af) produced no additional drawdown required for the month of May. The May 1 forecast also provides a joint-use pool target for June 1. This is determined first by multiplying the assured May-July inflow forecast by the average June-July share of May-July runoff (73%) from Table 3 (2,100,000 af * 73% = 1,580,000 af). Lastly, subtracting the June-July release (1,319,000 af) from the 2,100,000 af assured June-July inflow forecast would show a joint use evacuation requirement of 781,000 af on June 1. The maximum joint-use evacuation requirement is 232,735 af. Any drawdown larger than 232,735 af is Reclamation's decision and responsibility. The June 1 expected pool elevation of 3611.9 feet (245,000 af drawdown) in Reclamation's May Operation Plan exceeded the Corps' flood control requirement and no modification to Reclamation's operations were necessary. It should be noted that if downstream flood targets at St Xavier, Bighorn River at Bighorn, Miles City or Sidney were threatened during the month of May releases from Yellowtail could be decreased and the joint-use zone and possibly the exclusive flood control zone could be filled to mitigate downstream flooding.

June 1 forecast: Pool elevation was 3605.8 feet. This pool level on June 1 met and exceeded the Corps' flood control requirement. The June 1 most probable natural May-July inflow was 2,990,000 af. After adjustment for the assured factor (310,000 af) and the expected May-July upstream storage (600,000 af) the June 1 May-July assured inflow forecast was 2,080,000 af. 815,000 af of inflow was received in May, leaving a forecast of 1,265,000 af to come in June and July. June-July release in Reclamation's June Operation Plan was 803,000 af. Subtracting the planned release from the remaining inflow (1,265,000 af – 803,000 af) created a joint use requirement of 462,000 af. Since this requirement is larger than the joint use storage zone, the entire joint use storage zone was to be evacuated as of June 1. The June 1 forecast also provides Reclamation with a joint-use pool target for July 1. This is determined first by multiplying the assured June-July inflow forecast by the average July share of June-July runoff (39%) from Table 3 (1,265,000 af * 0.39 = 490,000 af). Lastly subtracting the 213,000 af expected release by

Reclamation from the 490,000 af assured July inflow forecast would show a joint use evacuation requirement of 277,000 af on July 1. This indicated the entire joint-use storage zone should remain vacant through July 1 and filled with the remaining runoff in July. However, the downstream flooding experienced in June required the joint-use storage be filled to mitigate flooding along the Bighorn River.

July 1 forecast: Pool elevation was 3638.6 feet, 1.4 feet from the top of the joint use storage zone. Due to high flows threatening the reach downstream of Yellowtail Dam the Corps and Reclamation made the decision to store floodwater in the exclusive flood control zone in late June and early July. Since the plan to store above the joint use zone was already made in June, a July 1 joint-use evacuation target was not needed. If real-time operations had not already planned to utilize the exclusive flood control zone the joint use storage requirement would have been calculated to assure adequate volume was evacuated without entering the exclusive flood control zone.

7. Other Considerations.

   a. Some factors involved in assured storage refill are as follows. By using an assured inflow forecast there exists an 85-90 percent chance that inflow will be greater than the forecast, thereby resulting in an 85-90 percent chance that releases will have to be increased above conservation requirements in order to maintain evacuated flood control storage space in the joint use zone. However, releases necessary for conservation purposes are generally much less than those which can be tolerated without contributing to flood damages. For example conservation requirements may be satisfied with a release of 1,500 cfs while releases up to 8,000 cfs may be made without impacting downstream fisheries and releases up to 11,000 cfs can be made with minimal impacts to property owners. Plate 7-3 in the Water Control Manual should also be consulted during flood control operations.

   b. Forecasts made prior to May 1 will determine joint use space requirements on May 1. Any evacuation of space needed to achieve this will be made by Reclamation in a gradual and orderly manner.

   c. On or after May 1, if pool levels encroach into the evacuated space required for flood control as determined from the techniques shown in Table 4, the Corps will determine evacuation flood control releases. During May, the Corps shall schedule flood control releases, which may be sometimes described as excess conservation spill necessary to target the June 1 requirement, to occur uniformly throughout the month. After June 1, the Corps shall schedule flood control evacuation releases

necessary to meet the July 1 requirement as rapidly as downstream conditions permit. The above scenario from prior to May 1 through July 1 assumes the flood targets outlined in this manual are not exceeded during that period. If the flood targets are exceeded while at any pool elevation below 3657.0 feet, releases from the project will be reduced to a level that minimizes downstream flooding without creating undue risk of higher discharges later in the runoff season. See regulation Plate 7-3 in the Water Control Manual for assistance in determining flood control operations.

Table 4 - Yellowtail Joint-Use Requirements

6/30/2022 DO NOT DELETE DATA IN BLUE OR YELLOW CELLS

	Date of Forecast				
Yellowtail May-July Forecast:	1-Mar	1-Apr	1-May	1-Jun	1-Jul
Most Probable Natural	2.206	2.402	3.025	2.99	
Less Water Holdouts	0.433	0.433	0.6	0.6	1.09
Most Probable Actual	1.773	1.969	2.425	2.39	
Assured Factor	0.534	0.475	0.325	0.31	0.224
Assured Actual	1.239	1.494	2.1	2.08	
Measured Inflow After 1 May				0.815	
Remaining May-July Assured	1.239	1.494	2.1	1.265	
Assured Inflow May-July	1.239	1.494	2.1		
Conservation Requirements May-July	1.34	1.38	2.20		
1 May Requirement	**0.00**	**0.12**	**0.00**		
1 May Elevation Requirement	**3640**	**3629.6**	**3640**		
Assured Inflow June-July			1.58	1.27	
Conservation Requirements June-July			1.32	0.80	
1 June Requirement			**0.23**	**0.23**	
1 June Elevation Requirement			**3614**	**3614**	
Assured Inflow July				0.49	
Conservation Requirements July				0.21	
1 July Requirement				**0.23**	
1 July Elevation Requirement				**3614**	

Notes:
July forecast not produced in 2017, as the joint use storage was already full.
In the event the runoff pattern occurs significantly different than anticipated, additional (middle of the month) forecast of remaining runoff should be made to determine new space requirements to protect both the flood control and conservation (assurance of joint use fill) useage of the joint use zone.
Table 4 is generated from a Microsoft Excel spreadsheet and is used to calculate the drawdown requirement. This spreadsheet is maintained by the Omaha District and is available on request.

Color Codes
- User Entered
- Static Data from WCM
- Calculated Value

Years	Col 1 - Observed YETL May-Jul Inflow Natural (maf)	Col 2- Forecast YETL May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1979	0.96	1.49	0.95	**0.01**	Exceeded
1980	1.32	0.99	0.45	**0.87**	Exceeded
1981	1.25	0.85	0.32	**0.93**	Exceeded
1982	1.66	1.48	0.95	**0.71**	Exceeded
1983	1.78	1.53	0.99	**0.78**	Exceeded
1984	1.60	1.49	0.96	**0.65**	Exceeded
1985	0.57	1.11	0.58	**0.00**	**Not Exceeded**
1986	1.88	2.31	1.78	**0.10**	Exceeded
1987	0.88	1.48	0.95	**-0.07**	**Not Exceeded**
1988	0.53	0.93	0.40	**0.14**	Exceeded
1989	1.00	1.05	0.51	**0.48**	Exceeded
1990	0.87	1.26	0.73	**0.14**	Exceeded
1991	1.94	1.10	0.56	**1.37**	Exceeded
1992	0.96	0.89	0.35	**0.60**	Exceeded
1993	1.54	1.08	0.55	**0.99**	Exceeded
1994	0.34	1.30	0.77	**-0.43**	**Not Exceeded**
1995	2.30	1.58	1.05	**1.26**	Exceeded
1996	1.82	2.13	1.60	**0.22**	Exceeded
1997	2.34	2.17	1.64	**0.70**	Exceeded
1998	1.43	1.48	0.94	**0.49**	Exceeded
1999	2.25	1.82	1.29	**0.96**	Exceeded
2000	0.75	1.15	0.61	**0.13**	Exceeded
2001	0.28	0.66	0.13	**0.16**	Exceeded
2002	0.53	0.70	0.17	**0.37**	Exceeded
2003	0.78	1.14	0.60	**0.18**	Exceeded
2004	0.54	1.22	0.69	**-0.15**	**Not Exceeded**
2005	1.19	1.02	0.48	**0.70**	Exceeded
2006	0.53	1.30	0.76	**-0.23**	**Not Exceeded**
2007	0.57	0.97	0.44	**0.13**	Exceeded
2008	1.72	1.33	0.80	**0.92**	Exceeded
2009	1.87	1.24	0.71	**1.16**	Exceeded
2010	1.72	0.97	0.43	**1.29**	Exceeded
2011	2.90	1.48	0.94	**1.96**	Exceeded
2012	0.57	1.67	1.13	**-0.56**	**Not Exceeded**
2013	0.73	0.90	0.37	**0.36**	Exceeded
2014	1.85	2.08	1.55	**0.31**	Exceeded
2015	1.58	1.36	0.83	**0.76**	Exceeded
2016	1.18	0.83	0.30	**0.89**	Exceeded
2017	2.73	2.31	1.78	**0.95**	Exceeded
2018	2.50	1.98	1.44	**1.06**	Exceeded
2019	1.91	1.33	0.80	**1.11**	Exceeded
2020	1.15	1.65	1.12	**0.04**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.534 maf**
Years in Record:	42
Years Forecast Exceeded:	36
Exeedance Probability:	**86%**

Water Control Manual
Yellowtail Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Mar 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate E-VII-1

Years	Col 1 - Observed YETL May-Jul Inflow Natural (maf)	Col 2- Forecast YETL May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1979	0.96	1.33	0.86	**0.10**	Exceeded
1980	1.32	1.12	0.65	**0.67**	Exceeded
1981	1.25	0.86	0.39	**0.86**	Exceeded
1982	1.66	1.68	1.20	**0.46**	Exceeded
1983	1.78	1.67	1.20	**0.58**	Exceeded
1984	1.60	1.45	0.98	**0.63**	Exceeded
1985	0.57	1.06	0.58	**-0.01**	**Not Exceeded**
1986	1.88	2.17	1.69	**0.19**	Exceeded
1987	0.88	1.41	0.94	**-0.06**	**Not Exceeded**
1988	0.53	0.97	0.50	**0.03**	Exceeded
1989	1.00	1.24	0.77	**0.23**	Exceeded
1990	0.87	1.31	0.84	**0.03**	Exceeded
1991	1.94	1.24	0.77	**1.17**	Exceeded
1992	0.96	0.93	0.45	**0.50**	Exceeded
1993	1.54	1.02	0.54	**1.00**	Exceeded
1994	0.34	1.24	0.76	**-0.42**	**Not Exceeded**
1995	2.30	1.60	1.12	**1.18**	Exceeded
1996	1.82	2.29	1.81	**0.01**	Exceeded
1997	2.34	2.17	1.70	**0.64**	Exceeded
1998	1.43	1.77	1.30	**0.13**	Exceeded
1999	2.25	1.71	1.24	**1.01**	Exceeded
2000	0.75	1.10	0.62	**0.13**	Exceeded
2001	0.28	0.50	0.03	**0.25**	Exceeded
2002	0.53	0.77	0.29	**0.24**	Exceeded
2003	0.78	1.49	1.01	**-0.23**	**Not Exceeded**
2004	0.54	0.72	0.24	**0.30**	Exceeded
2005	1.19	0.97	0.49	**0.69**	Exceeded
2006	0.53	1.19	0.71	**-0.18**	**Not Exceeded**
2007	0.57	0.89	0.41	**0.16**	Exceeded
2008	1.72	1.45	0.98	**0.74**	Exceeded
2009	1.87	1.50	1.03	**0.84**	Exceeded
2010	1.72	0.98	0.51	**1.21**	Exceeded
2011	2.90	1.53	1.05	**1.85**	Exceeded
2012	0.57	1.22	0.74	**-0.17**	**Not Exceeded**
2013	0.73	0.71	0.24	**0.49**	Exceeded
2014	1.85	2.22	1.74	**0.11**	Exceeded
2015	1.58	0.81	0.34	**1.24**	Exceeded
2016	1.18	1.32	0.84	**0.34**	Exceeded
2017	2.73	2.55	2.08	**0.65**	Exceeded
2018	2.50	1.95	1.48	**1.02**	Exceeded
2019	1.91	1.16	0.68	**1.23**	Exceeded
2020	1.15	1.53	1.05	**0.10**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.475 maf**
Years in Record:	42
Years Forecast Exceeded:	36
Exeedance Probability:	**86%**

Water Control Manual
Yellowtail Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Apr 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Years	Col 1 - Observed YETL May-Jul Inflow Natural (maf)	Col 2- Forecast YETL May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1979	0.96	1.22	0.90	**0.06**	Exceeded
1980	1.32	0.98	0.66	**0.66**	Exceeded
1981	1.25	0.69	0.36	**0.88**	Exceeded
1982	1.66	1.58	1.25	**0.41**	Exceeded
1983	1.78	1.79	1.46	**0.31**	Exceeded
1984	1.60	1.82	1.50	**0.11**	Exceeded
1985	0.57	0.82	0.50	**0.08**	Exceeded
1986	1.88	2.19	1.87	**0.01**	Exceeded
1987	0.88	1.14	0.81	**0.07**	Exceeded
1988	0.53	0.86	0.54	**-0.01**	**Not Exceeded**
1989	1.00	1.11	0.79	**0.21**	Exceeded
1990	0.87	1.31	0.98	**-0.12**	**Not Exceeded**
1991	1.94	1.76	1.44	**0.50**	Exceeded
1992	0.96	0.77	0.45	**0.51**	Exceeded
1993	1.54	1.25	0.92	**0.62**	Exceeded
1994	0.34	1.06	0.74	**-0.40**	**Not Exceeded**
1995	2.30	1.97	1.64	**0.66**	Exceeded
1996	1.82	2.13	1.81	**0.01**	Exceeded
1997	2.34	2.19	1.87	**0.47**	Exceeded
1998	1.43	1.60	1.27	**0.16**	Exceeded
1999	2.25	2.41	2.08	**0.17**	Exceeded
2000	0.75	1.01	0.68	**0.06**	Exceeded
2001	0.28	0.41	0.08	**0.20**	Exceeded
2002	0.53	0.74	0.41	**0.12**	Exceeded
2003	0.78	1.34	1.01	**-0.23**	**Not Exceeded**
2004	0.54	0.78	0.45	**0.09**	Exceeded
2005	1.19	0.97	0.64	**0.55**	Exceeded
2006	0.53	1.04	0.72	**-0.19**	**Not Exceeded**
2007	0.57	0.74	0.42	**0.15**	Exceeded
2008	1.72	1.27	0.95	**0.77**	Exceeded
2009	1.87	1.69	1.36	**0.51**	Exceeded
2010	1.72	1.00	0.68	**1.04**	Exceeded
2011	2.90	2.02	1.69	**1.21**	Exceeded
2012	0.57	0.98	0.66	**-0.09**	**Not Exceeded**
2013	0.73	0.93	0.61	**0.12**	Exceeded
2014	1.85	1.95	1.63	**0.23**	Exceeded
2015	1.58	0.74	0.42	**1.16**	Exceeded
2016	1.18	1.43	1.11	**0.08**	Exceeded
2017	2.73	2.95	2.63	**0.10**	Exceeded
2018	2.50	1.71	1.39	**1.11**	Exceeded
2019	1.91	1.11	0.78	**1.13**	Exceeded
2020	1.15	1.33	1.01	**0.15**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.325 maf**
Years in Record:	42
Years Forecast Exceeded:	36
Exeedance Probability:	**86%**

Water Control Manual
Yellowtail Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (May 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Years	Col 1 - Observed YETL May-Jul Inflow Natural (maf)	Col 2- Forecast YETL May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1979	0.96	1.26	0.95	**0.01**	Exceeded
1980	1.32	1.24	0.93	**0.39**	Exceeded
1981	1.25	0.99	0.68	**0.57**	Exceeded
1982	1.66	1.23	0.92	**0.74**	Exceeded
1983	1.78	1.74	1.43	**0.35**	Exceeded
1984	1.60	1.57	1.26	**0.35**	Exceeded
1985	0.57	0.56	0.25	**0.33**	Exceeded
1986	1.88	1.97	1.66	**0.21**	Exceeded
1987	0.88	1.27	0.96	**-0.08**	**Not Exceeded**
1988	0.53	0.82	0.51	**0.02**	Exceeded
1989	1.00	1.28	0.97	**0.02**	Exceeded
1990	0.87	1.16	0.85	**0.01**	Exceeded
1991	1.94	1.85	1.54	**0.40**	Exceeded
1992	0.96	0.73	0.42	**0.54**	Exceeded
1993	1.54	1.23	0.92	**0.62**	Exceeded
1994	0.34	0.64	0.33	**0.01**	Exceeded
1995	2.30	2.19	1.88	**0.42**	Exceeded
1996	1.82	2.17	1.86	**-0.05**	**Not Exceeded**
1997	2.34	2.05	1.74	**0.60**	Exceeded
1998	1.43	1.42	1.11	**0.32**	Exceeded
1999	2.25	2.37	2.06	**0.19**	Exceeded
2000	0.75	0.98	0.67	**0.08**	Exceeded
2001	0.28	0.05	-0.26	**0.54**	Exceeded
2002	0.53	0.42	0.11	**0.42**	Exceeded
2003	0.78	1.16	0.85	**-0.07**	**Not Exceeded**
2004	0.54	0.48	0.17	**0.37**	Exceeded
2005	1.19	1.40	1.09	**0.09**	Exceeded
2006	0.53	0.68	0.37	**0.16**	Exceeded
2007	0.57	0.63	0.32	**0.25**	Exceeded
2008	1.72	1.72	1.41	**0.31**	Exceeded
2009	1.87	1.45	1.14	**0.73**	Exceeded
2010	1.72	1.25	0.94	**0.78**	Exceeded
2011	2.90	2.64	2.33	**0.56**	Exceeded
2012	0.57	0.81	0.50	**0.07**	Exceeded
2013	0.73	0.97	0.66	**0.07**	Exceeded
2014	1.85	1.82	1.51	**0.34**	Exceeded
2015	1.58	1.18	0.87	**0.72**	Exceeded
2016	1.18	1.70	1.39	**-0.21**	**Not Exceeded**
2017	2.73	3.03	2.72	**0.01**	Exceeded
2018	2.50	2.03	1.72	**0.78**	Exceeded
2019	1.91	1.66	1.35	**0.56**	Exceeded
2020	1.15	0.98	0.67	**0.48**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.31 maf**
Years in Record:	42
Years Forecast Exceeded:	38
Exeedance Probability:	**90%**

Water Control Manual
Yellowtail Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Jun 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Years	Col 1 - Observed YETL May-Jul Inflow Natural (maf)	Col 2- Forecast YETL May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1979	0.96	1.17	0.94	**0.01**	Exceeded
1980	1.32	1.18	0.95	**0.37**	Exceeded
1981	1.25	0.86	0.63	**0.61**	Exceeded
1982	1.66	1.37	1.14	**0.52**	Exceeded
1983	1.78	1.79	1.57	**0.21**	Exceeded
1984	1.60	1.56	1.33	**0.27**	Exceeded
1985	0.57	0.63	0.41	**0.16**	Exceeded
1986	1.88	1.80	1.58	**0.30**	Exceeded
1987	0.88	1.31	1.09	**-0.20**	**Not Exceeded**
1988	0.53	0.66	0.44	**0.10**	Exceeded
1989	1.00	1.31	1.08	**-0.09**	**Not Exceeded**
1990	0.87	1.04	0.81	**0.05**	Exceeded
1991	1.94	1.92	1.70	**0.24**	Exceeded
1992	0.96	1.09	0.87	**0.09**	Exceeded
1993	1.54	1.74	1.51	**0.03**	Exceeded
1994	0.34	0.45	0.23	**0.11**	Exceeded
1995	2.30	2.38	2.15	**0.15**	Exceeded
1996	1.82	2.02	1.79	**0.02**	Exceeded
1997	2.34	2.27	2.05	**0.29**	Exceeded
1998	1.43	1.72	1.49	**-0.06**	**Not Exceeded**
1999	2.25	2.25	2.03	**0.22**	Exceeded
2000	0.75	0.93	0.71	**0.04**	Exceeded
2001	0.28	0.16	-0.07	**0.35**	Exceeded
2002	0.53	0.28	0.05	**0.48**	Exceeded
2003	0.78	1.19	0.96	**-0.18**	**Not Exceeded**
2004	0.54	0.47	0.25	**0.29**	Exceeded
2005	1.19	1.40	1.18	**0.01**	Exceeded
2006	0.53	0.43	0.20	**0.33**	Exceeded
2007	0.57	0.69	0.46	**0.11**	Exceeded
2008	1.72	1.58	1.35	**0.37**	Exceeded
2009	1.87	1.74	1.52	**0.35**	Exceeded
2010	1.72	1.39	1.16	**0.55**	Exceeded
2011	2.90	2.51	2.29	**0.61**	Exceeded
2012	0.57	0.60	0.38	**0.19**	Exceeded
2013	0.73	0.75	0.53	**0.20**	Exceeded
2014	1.85	1.88	1.65	**0.20**	Exceeded
2015	1.58	1.18	0.95	**0.63**	Exceeded
2016	1.18	1.59	1.37	**-0.19**	**Not Exceeded**
2017	2.73	2.86	2.64	**0.09**	Exceeded
2018	2.50	2.13	1.91	**0.59**	Exceeded
2019	1.91	1.58	1.36	**0.55**	Exceeded
2020	1.15	0.96	0.73	**0.42**	Exceeded

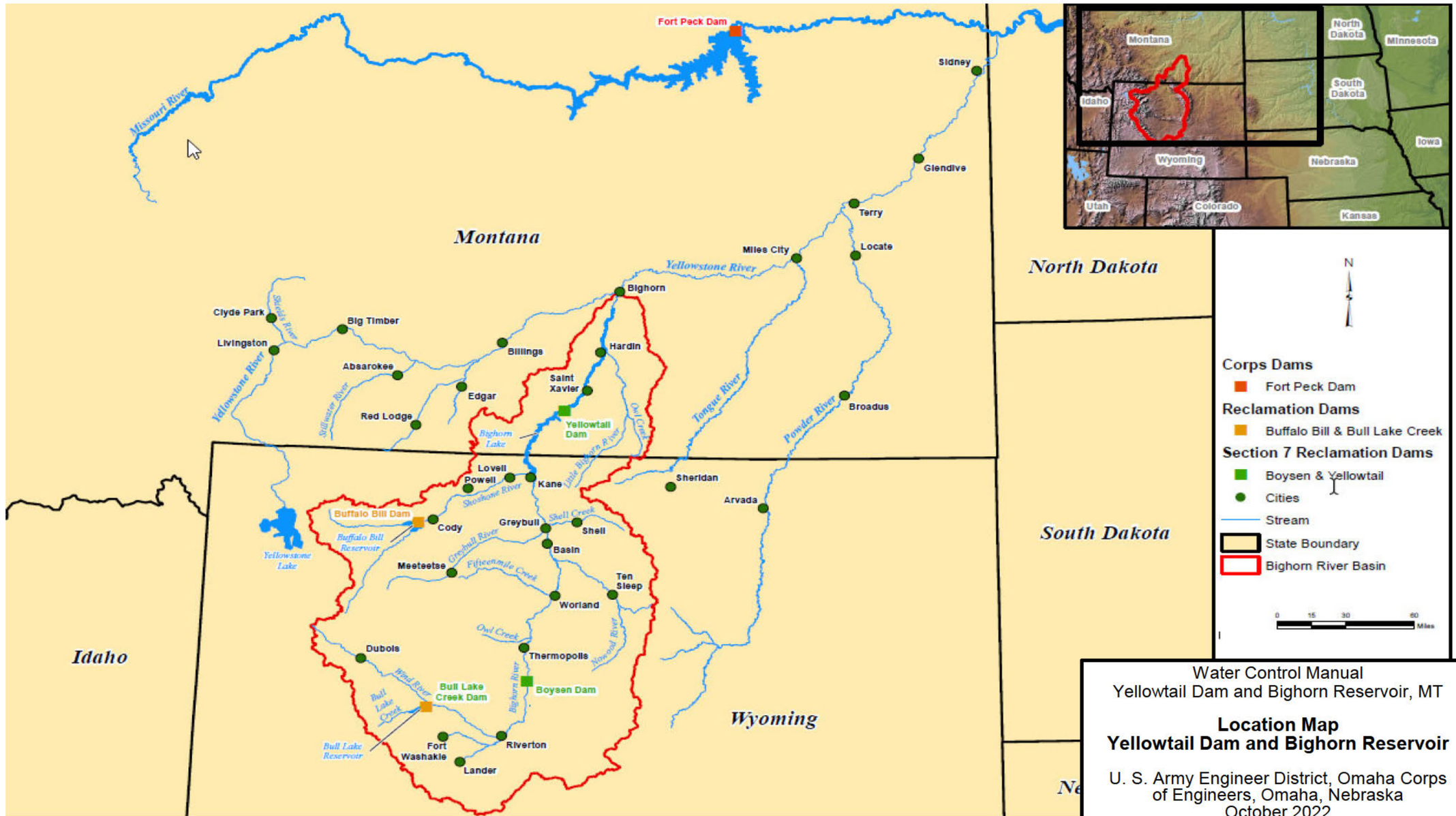
Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.224 maf**
Years in Record:	42
Years Forecast Exceeded:	37
Exeedance Probability:	**88%**

Water Control Manual
Yellowtail Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Jul 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

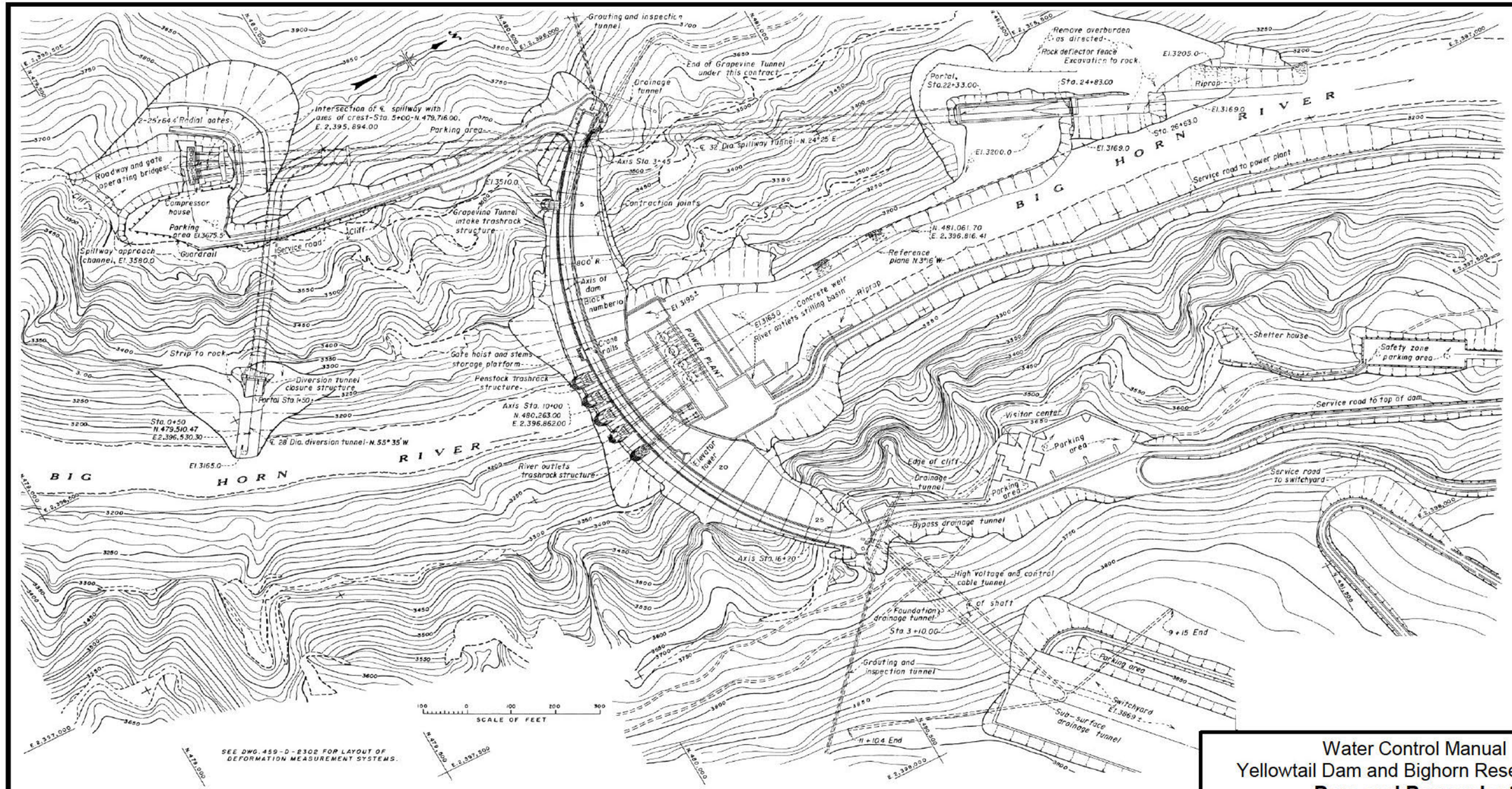


Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Location Map
Yellowtail Dam and Bighorn Reservoir

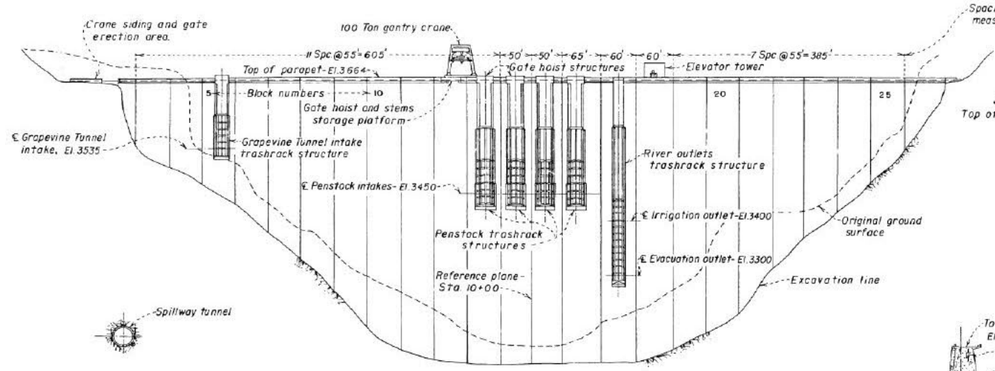
U. S. Army Engineer District, Omaha Corps of Engineers, Omaha, Nebraska
October 2022

Plate 2-1

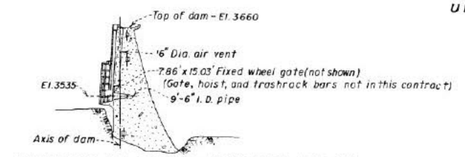


Scanned from Drawing 459-D- 229 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

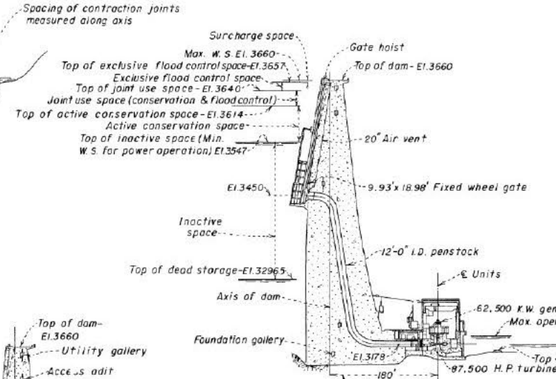
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT
Dam and Powerplant
General Plan
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



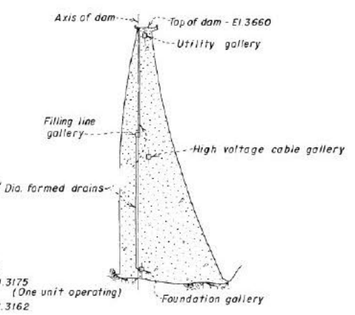
UPSTREAM ELEVATION
DEVELOPED ALONG AXIS



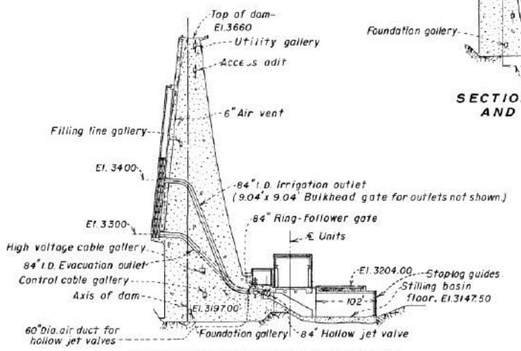
SECTION THRU GRAPEVINE TUNNEL INTAKE



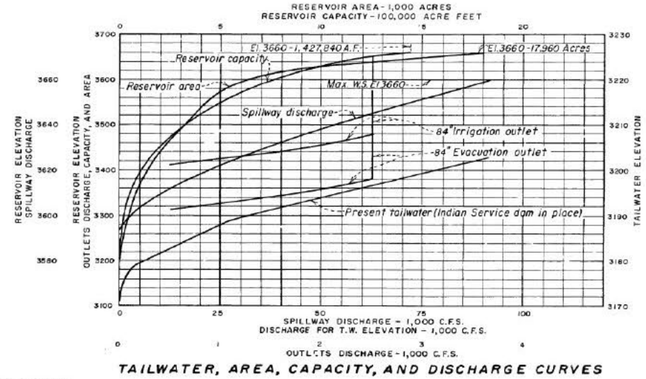
SECTION THRU PENSTOCK AND POWER PLANT



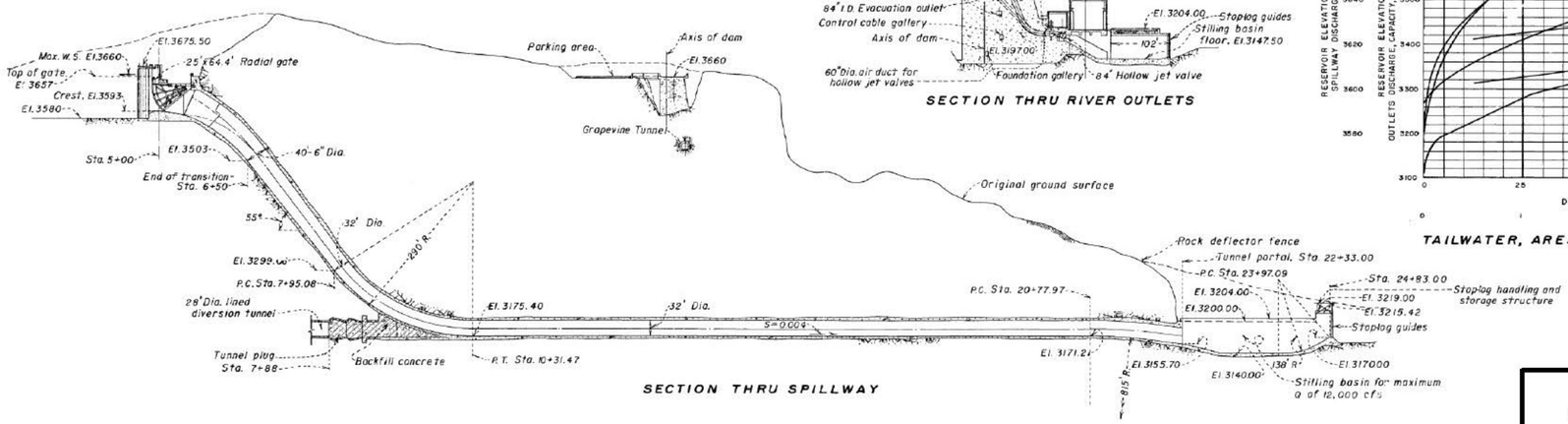
SECTION THRU DAM



SECTION THRU RIVER OUTLETS



TAILWATER, AREA, CAPACITY, AND DISCHARGE CURVES



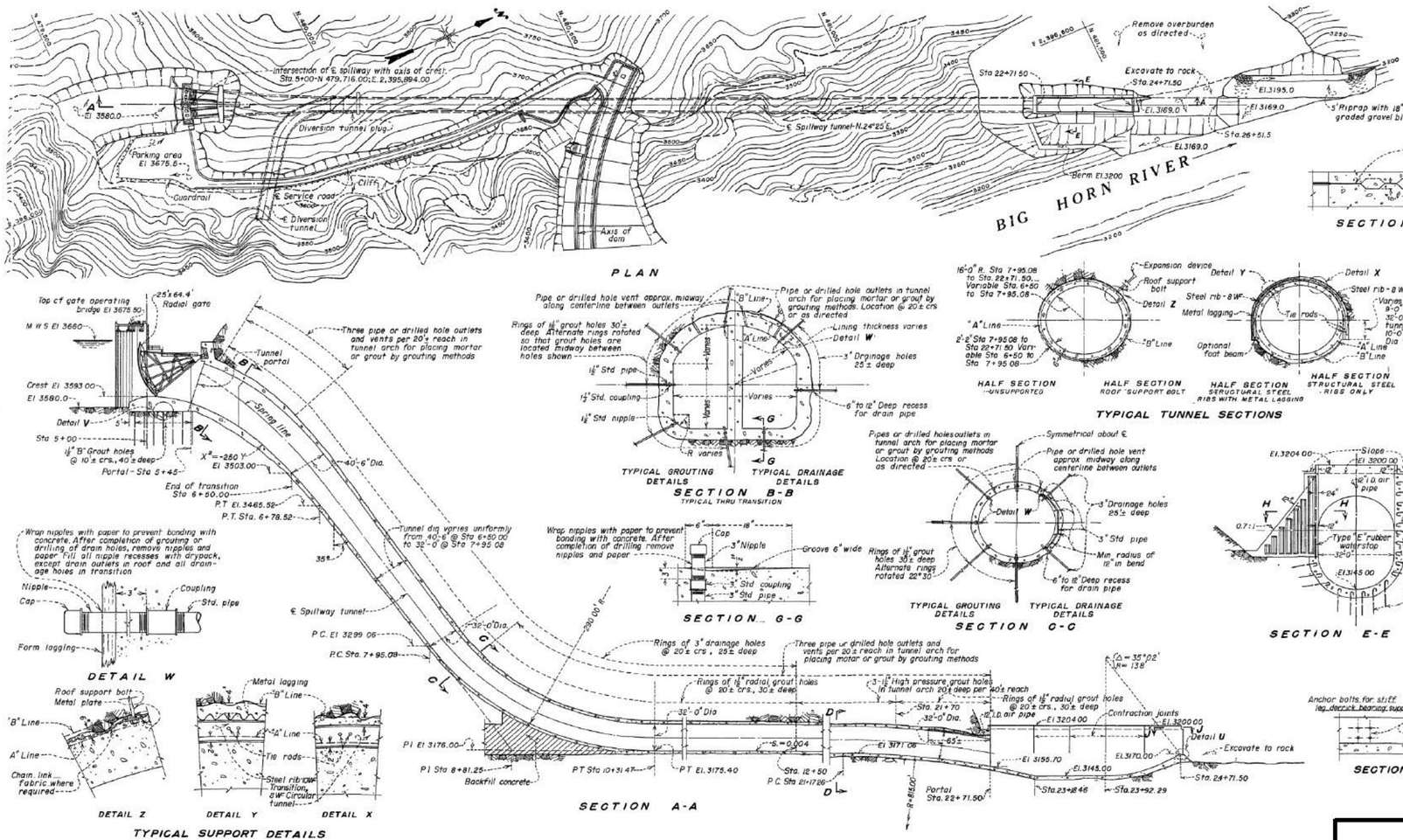
SECTION THRU SPILLWAY

Scanned from Drawing 459-D- 230 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Dam and Powerplant Elevation and Sections

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



CONCRETE FINISHES

Tunnel below spring line and interior surface of stilling basin ..... F4 or U3
Tunnel below spring line from Sta. 7+90 to Sta. 10+35 ..... F4 with special finish or U3
All other surfaces ..... F2 or U3
Contraction joint surfaces F1

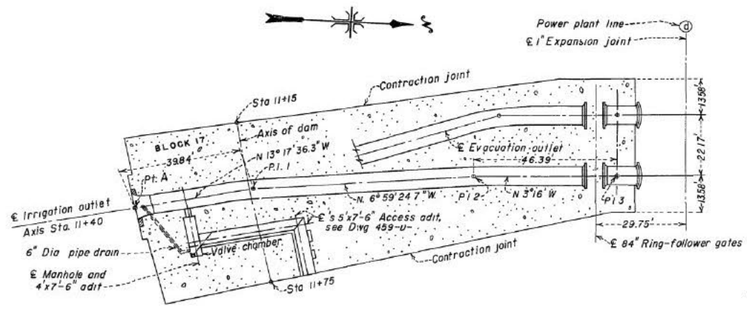
NOTES

Chamfer all exposed corners ¾" unless otherwise specified
Radial grout holes in tunnel to be drilled after tunnel lining is completed, including placing of mortar or grout by grouting methods
Drainage holes to be drilled after all grouting is completed
Reinforcement required but not shown.
"B" Grout holes to be drilled and grouted after completion of excavation for intake structure and prior to placement of concrete in intake structure

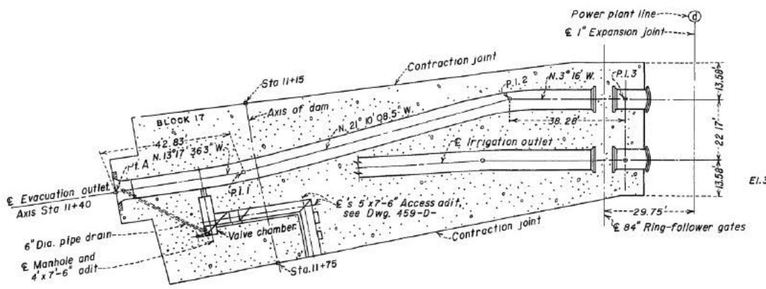
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Spillway Plan and Sections
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

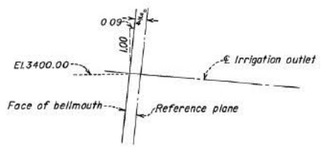
Scanned from Drawing 459-D- 241 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000



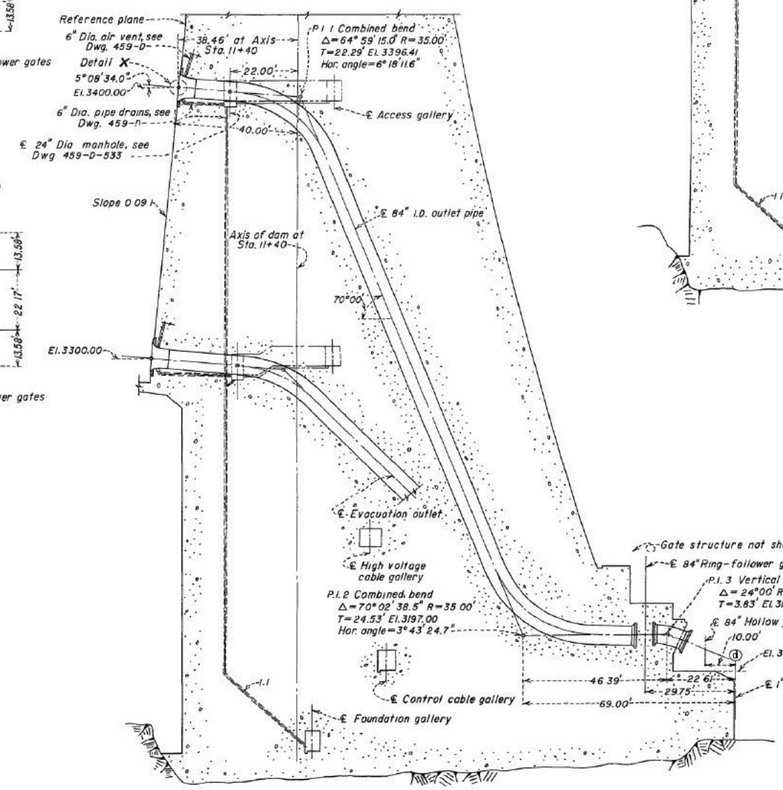
PLAN – IRRIGATION OUTLET



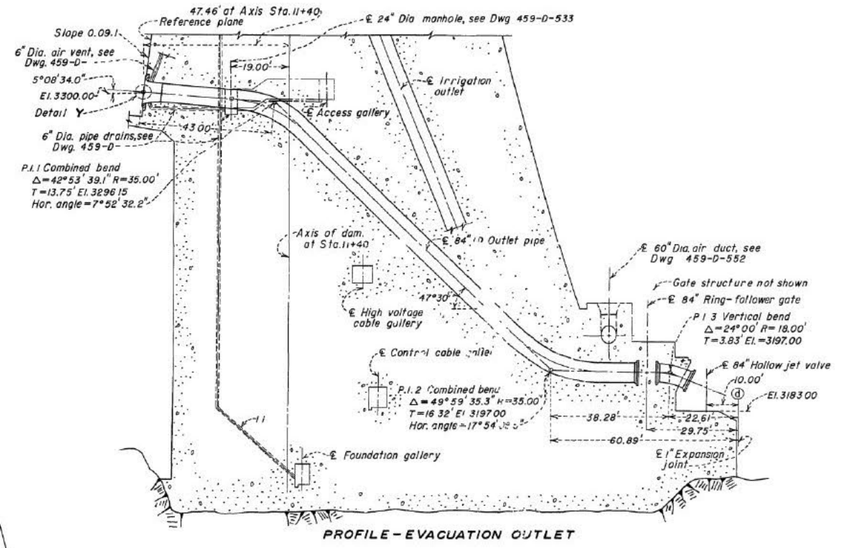
PLAN – EVACUATION OUTLET



DETAIL X
DETAIL Y SIMILAR



PROFILE – IRRIGATION OUTLET



PROFILE – EVACUATION OUTLET

NOTES

Reinforcement required but not shown.
The reference plane is 15.00' upstream from the axis, at Sta 11+40.00 and El 3660.00, with slope of 0.09 1 horizontal to vertical

TABLE OF COORDINATES

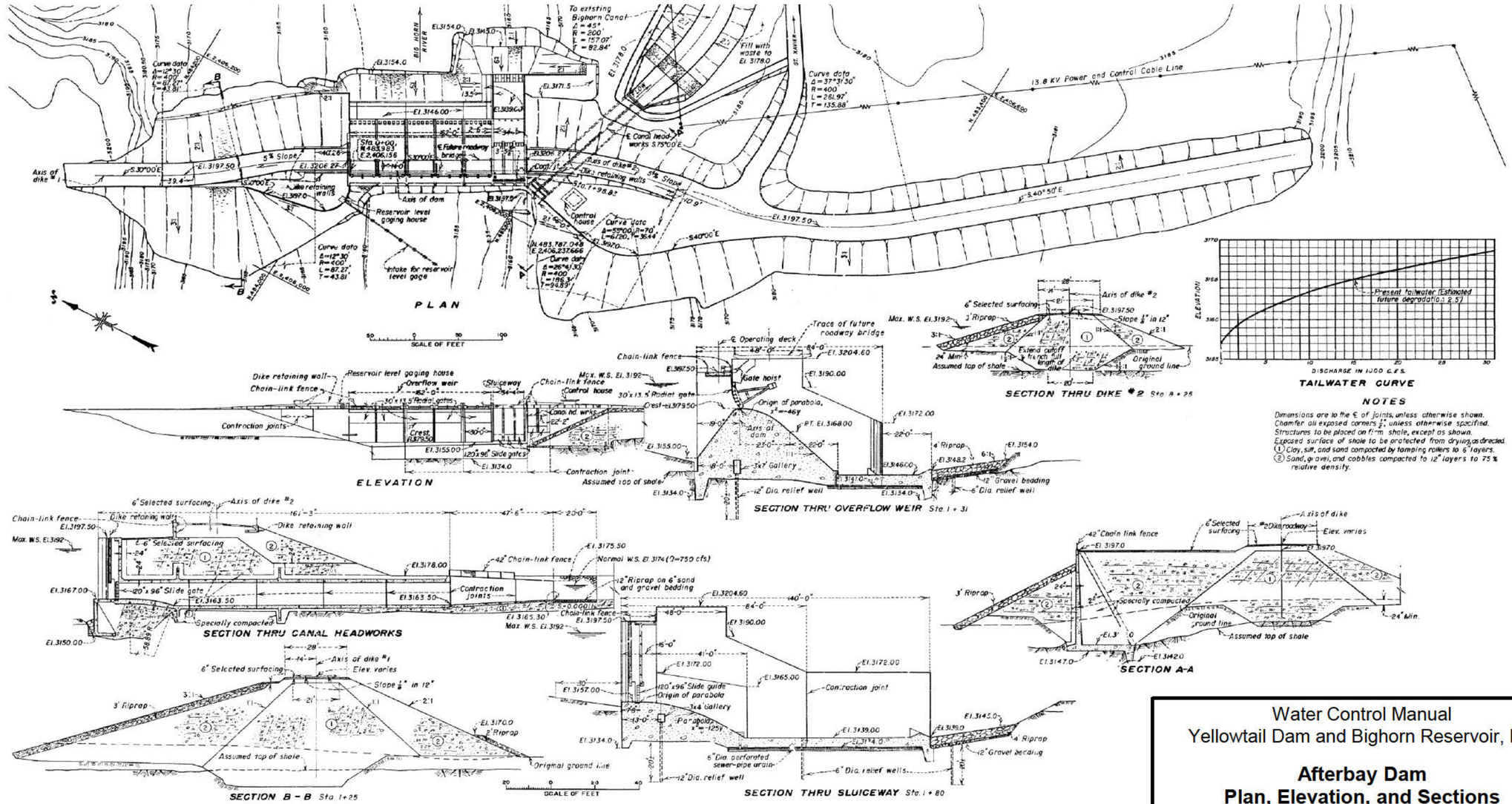
	Pt. A	P.I. 1	Pt. 2	P.I. 3
Irrigation outlet El. 3400.00	N 480,245.704 E 2,397,009.208'	N 480,284.475 E 2,397,000.047	N 480,356.517 E 2,396,991.214	N 480,402.828 E 2,396,988.571
Evacuation outlet El. 3300.00	N. 480,236.945 E 2,397,011.277	N 480,278.624 E 2,397.001.430	N. 480,363.344 E 2,396,968.622	N.480,401.565 E 2,396,966.440

Scanned from Drawing 459-D- 543 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

River Outlets
Plans and Profiles

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



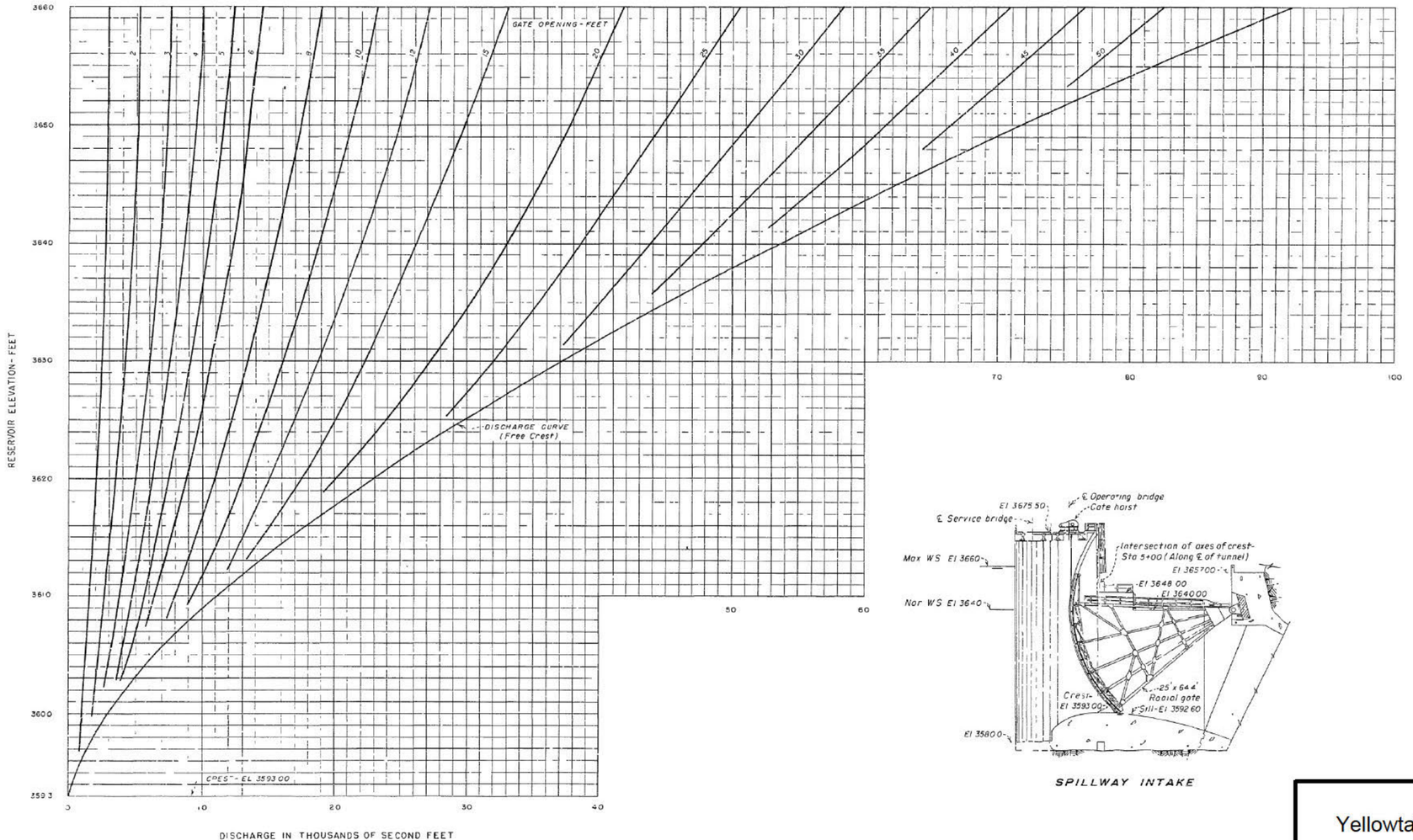
NOTES

Dimensions are to the ℄ of joints, unless otherwise shown.
Chamfer all exposed corners $\frac{3}{4}$", unless otherwise specified.
Structures to be placed on firm shale, except as shown.
Exposed surface of shale to be protected from drying as directed.
(1) Clay, silt, and sand compacted by tamping rollers to 6" layers.
(2) Sand, gravel, and cobbles compacted to 12" layers to 75 % relative density.

Scanned from Drawing 459-D- 1048 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Afterbay Dam
Plan, Elevation, and Sections
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



SPILLWAY INTAKE

NOTES

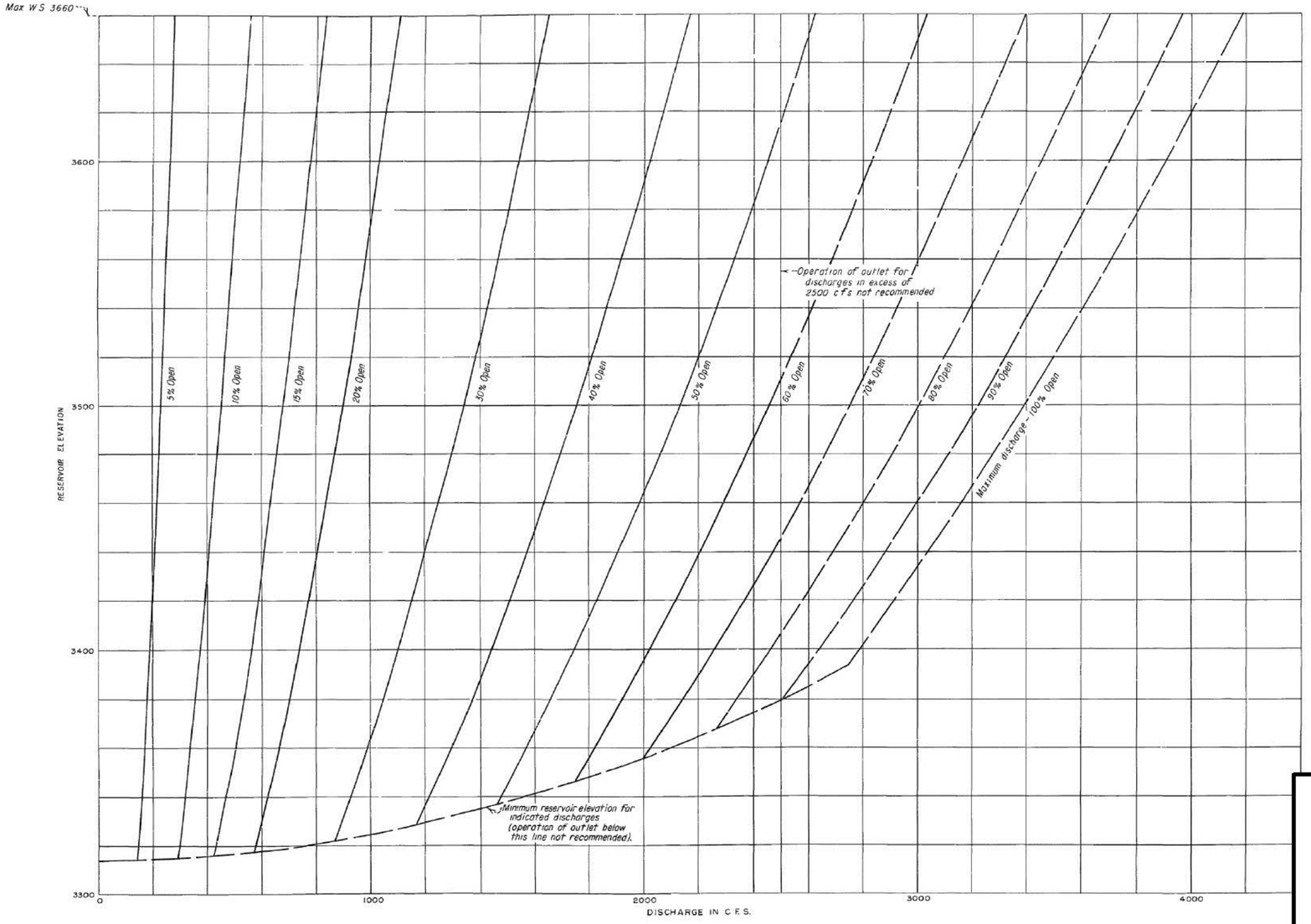
Discharge curves are for two 25'x64.4' radial gates
Gate opening is measured vertically above spillway crest (El 3593.00)
The two spillway gates should be operated simultaneously at equal openings
The curves were obtained from a 1:49.95 scale hydraulic model

Scanned from Drawing 459-D- 1380 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

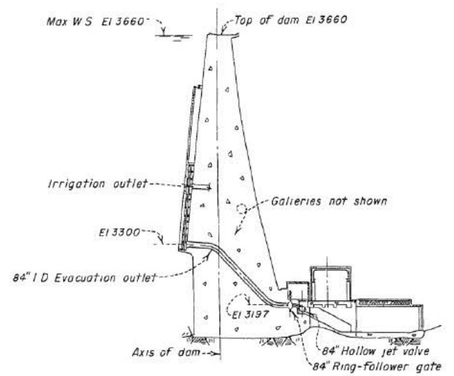
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Spillway Discharge Curves for Two Radial Gates

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



Scanned from Drawing 459-D- 881 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

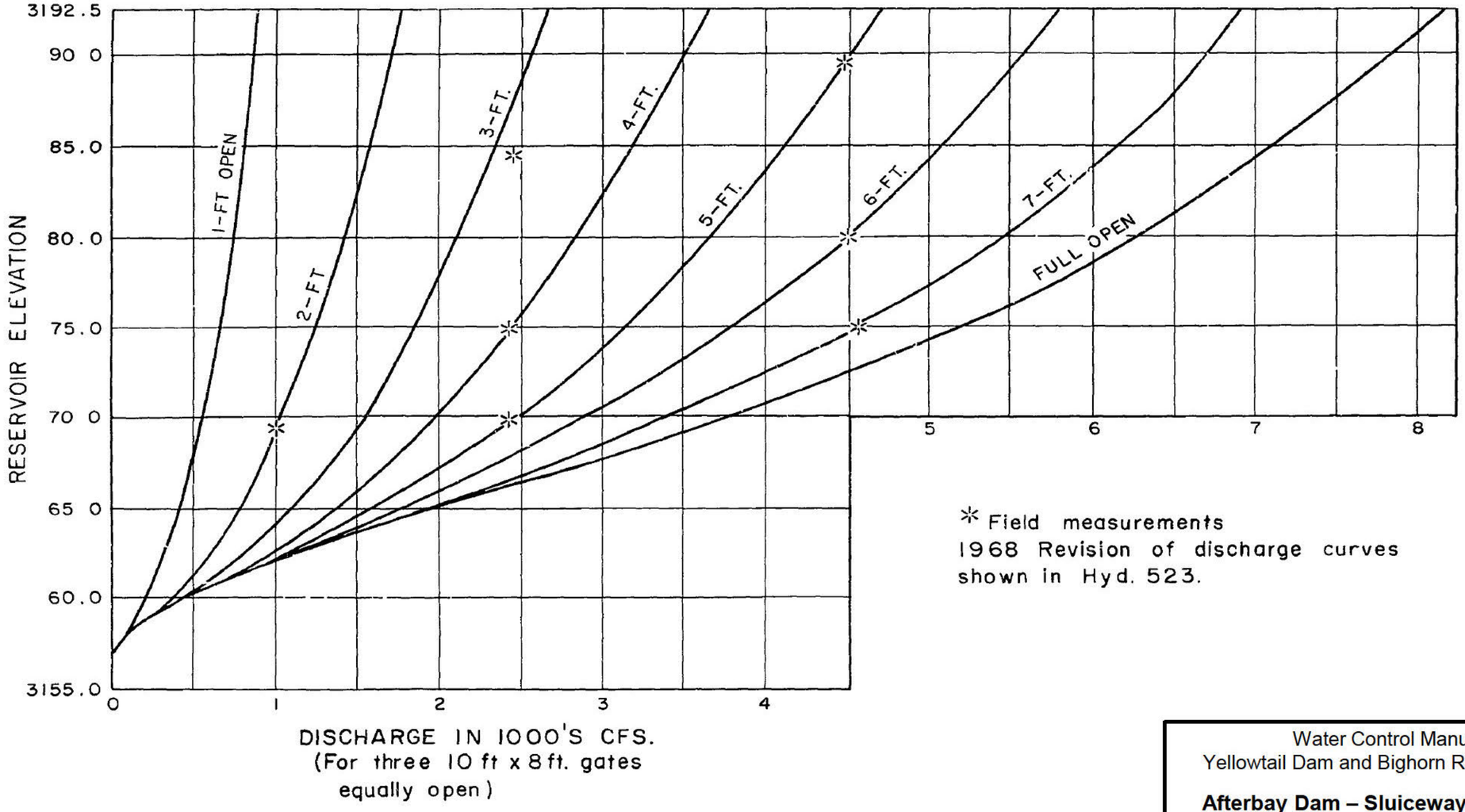


SECTION THRU EVACUATION OUTLET

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

River Outlets- Evacuation Outlet Discharge Curves

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



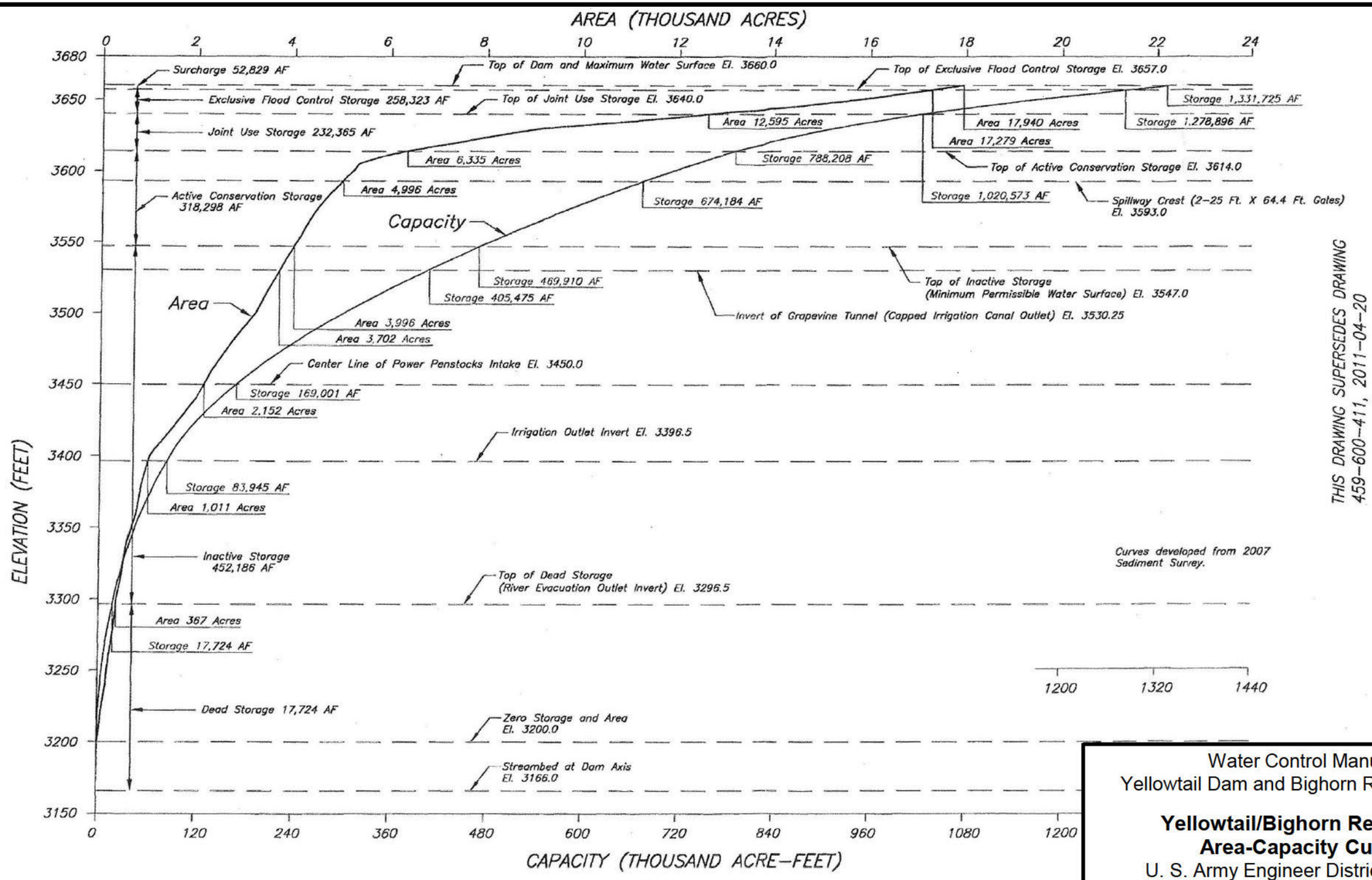
* Field measurements
1968 Revision of discharge curves shown in Hyd. 523.

Scanned from Drawing 459-D- 2370 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Afterbay Dam – Sluiceway Discharge Capacity

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

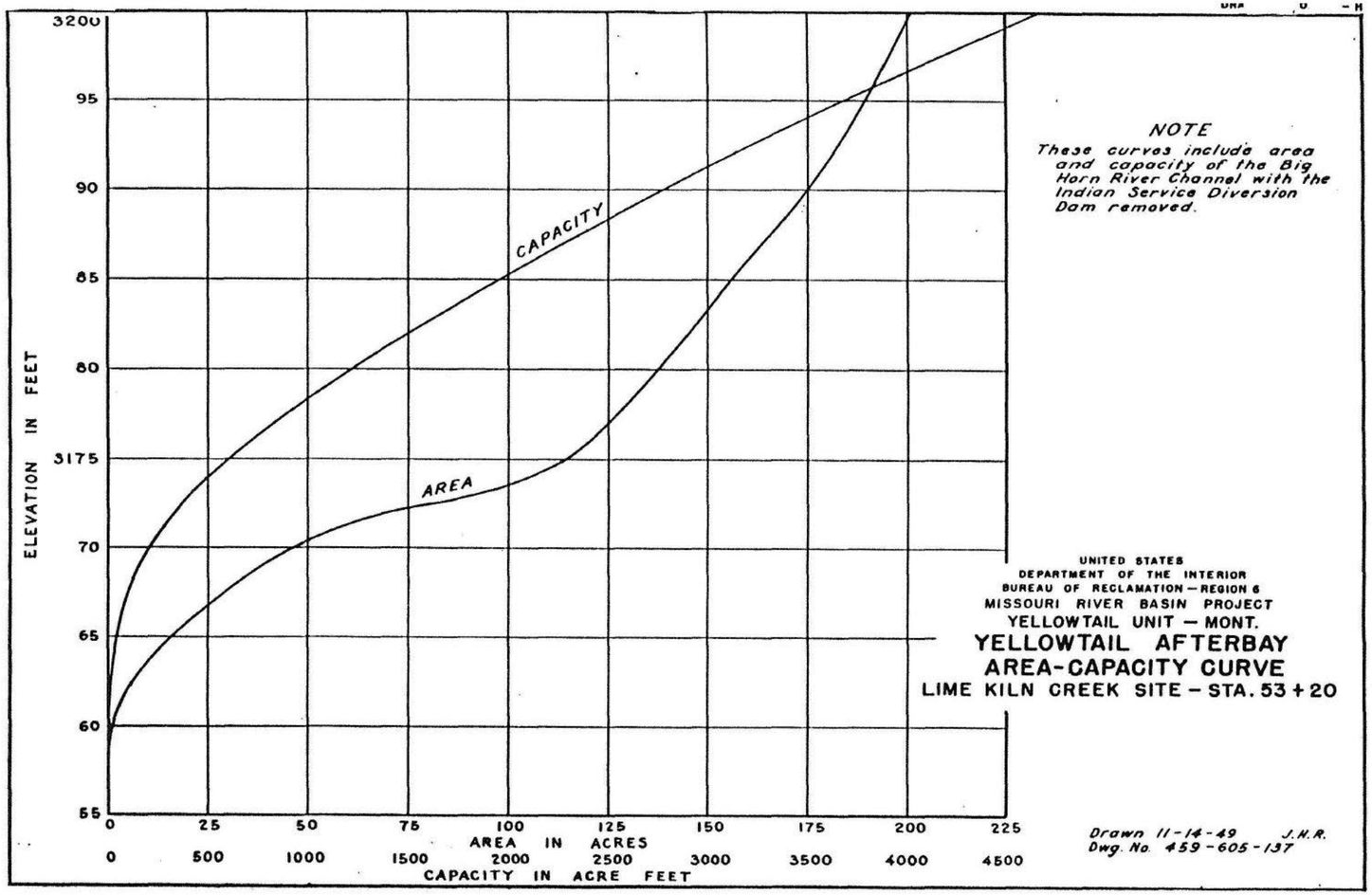


Scanned from Drawing 459-600-4600 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Yellowtail/Bighorn Reservoir
Area-Capacity Curve

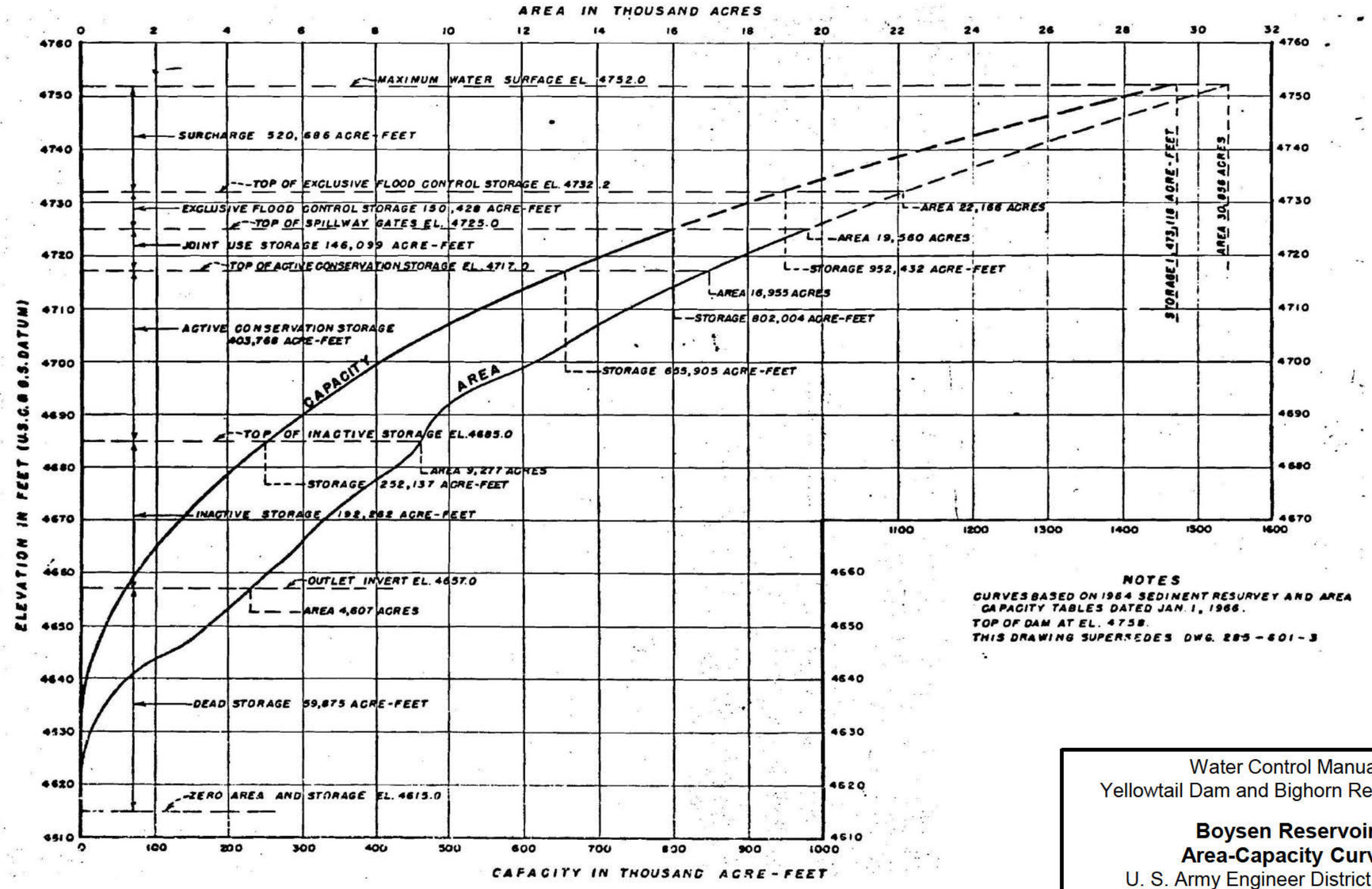
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



Scanned from Drawing 459-605-137 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Yellowtail Dam Afterbay
Area-Capacity Curve
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



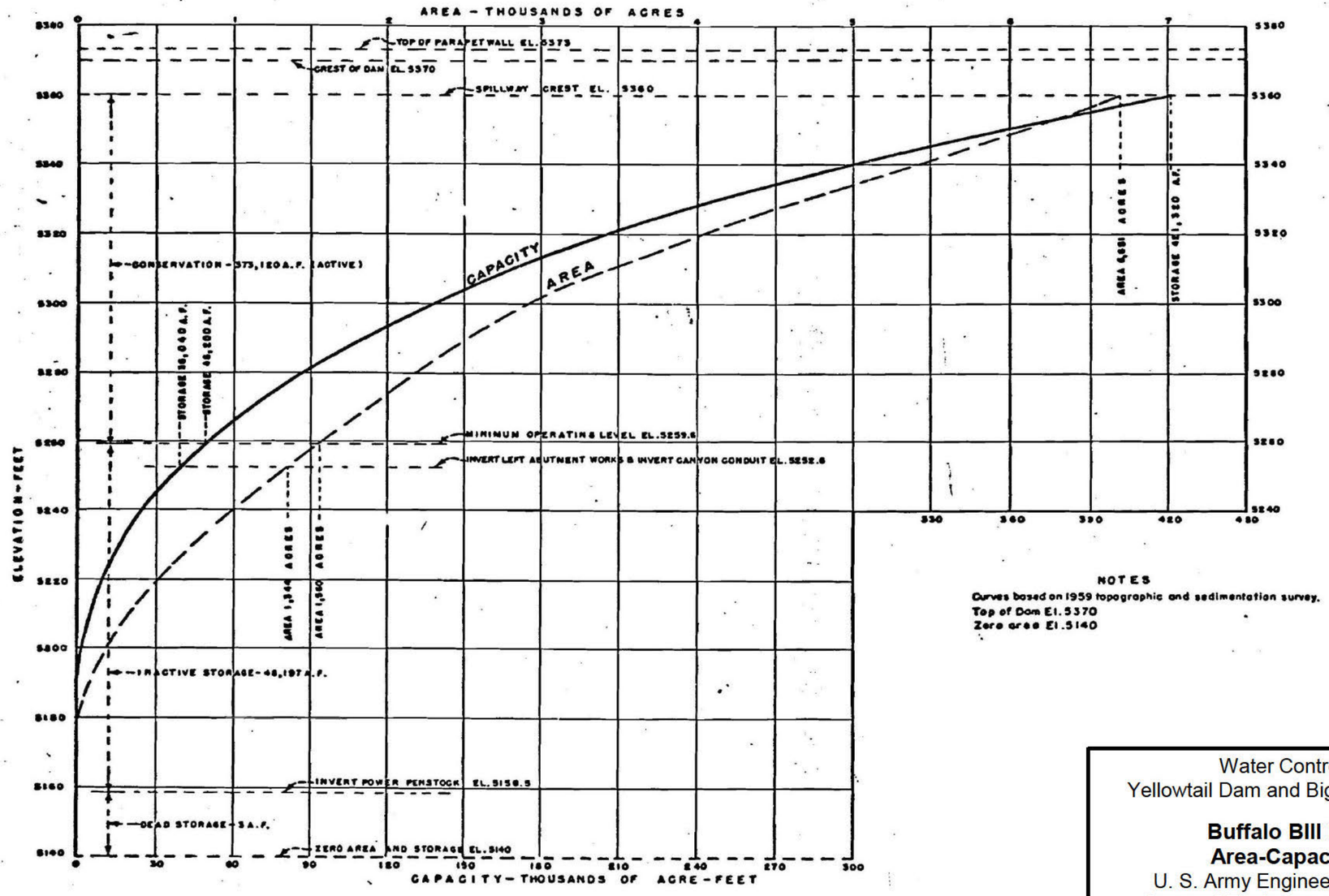
NOTES

CURVES BASED ON 1964 SEDIMENT RESURVEY AND AREA CAPACITY TABLES DATED JAN. 1, 1966.
TOP OF DAM AT EL. 4758.
THIS DRAWING SUPERSEDES DWG. 285-601-3

Scanned from Drawing 459-600-4600 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Boysen Reservoir
Area-Capacity Curve
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



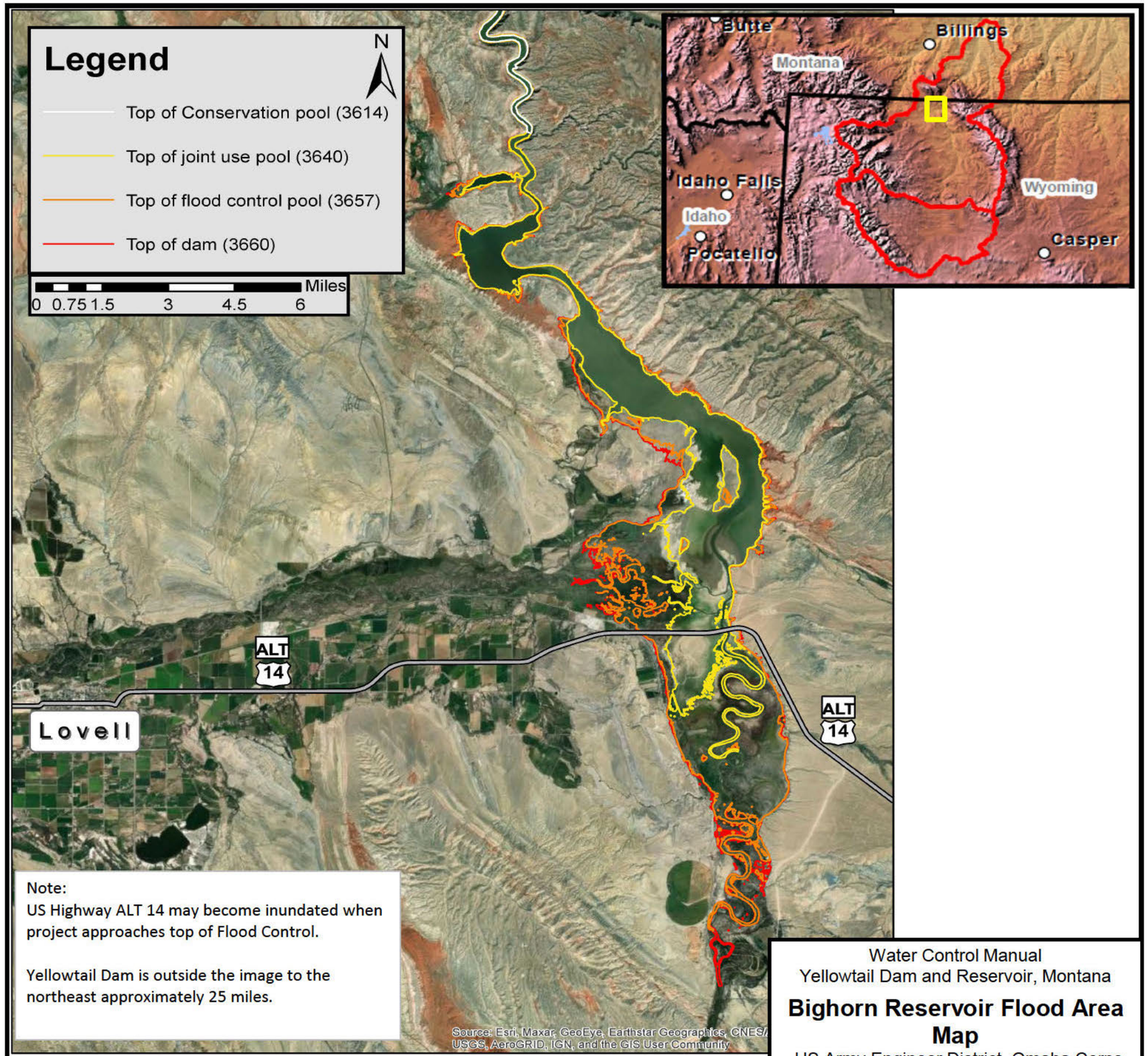
NOTES

Curves based on 1959 topographic and sedimentation survey.
Top of Dam El. 5370
Zero area El. 5140

Scanned from Drawing 459-600-4600 Bureau of Reclamation Yellowtail Reservoir Standing Operating Procedures August 2000

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

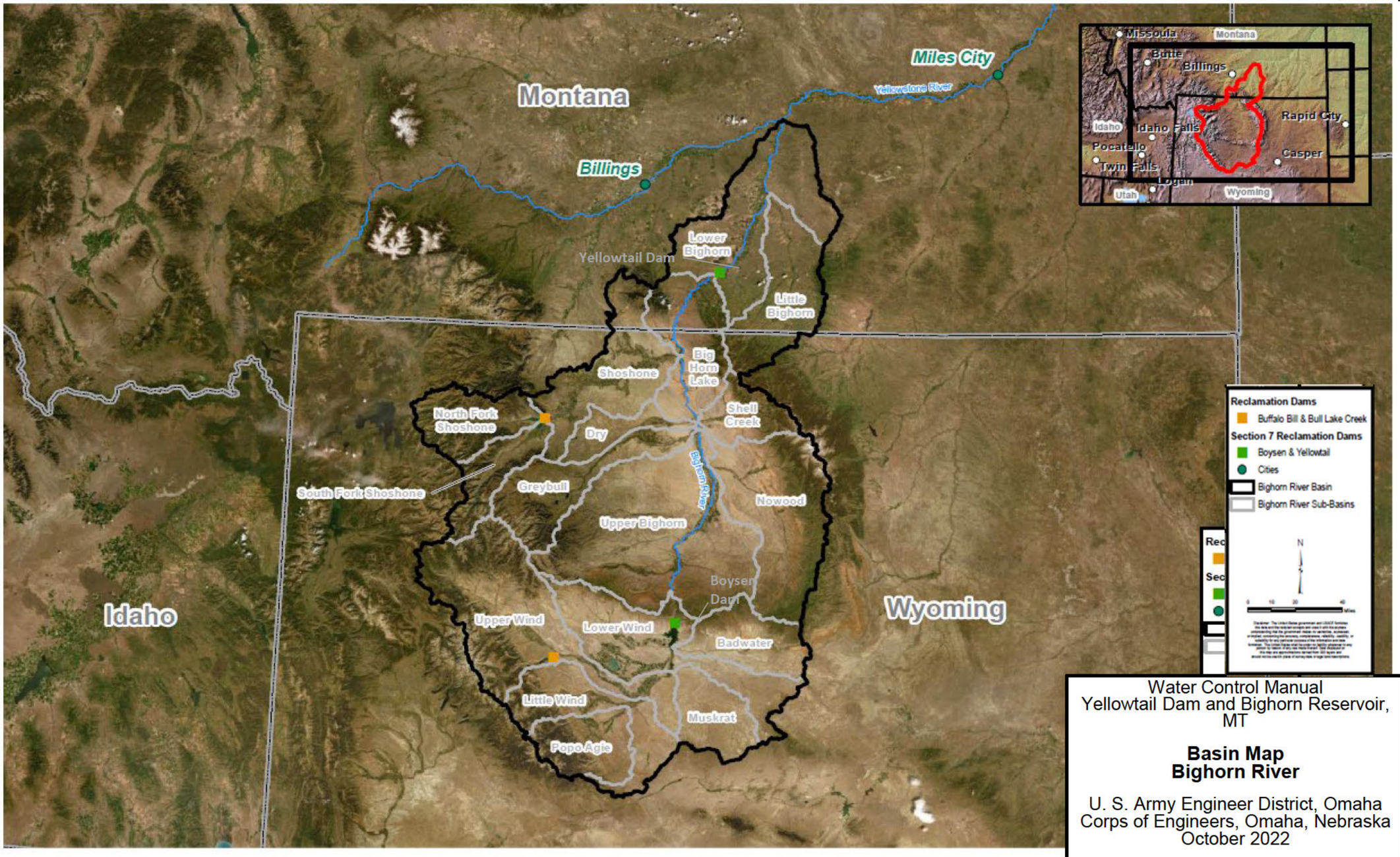
Buffalo Bill Reservoir
Area-Capacity Curve
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



Water Control Manual
Yellowtail Dam and Reservoir, Montana

Bighorn Reservoir Flood Area Map

US Army Engineer District, Omaha Corps of Engineers, Omaha, Nebraska
October 2022

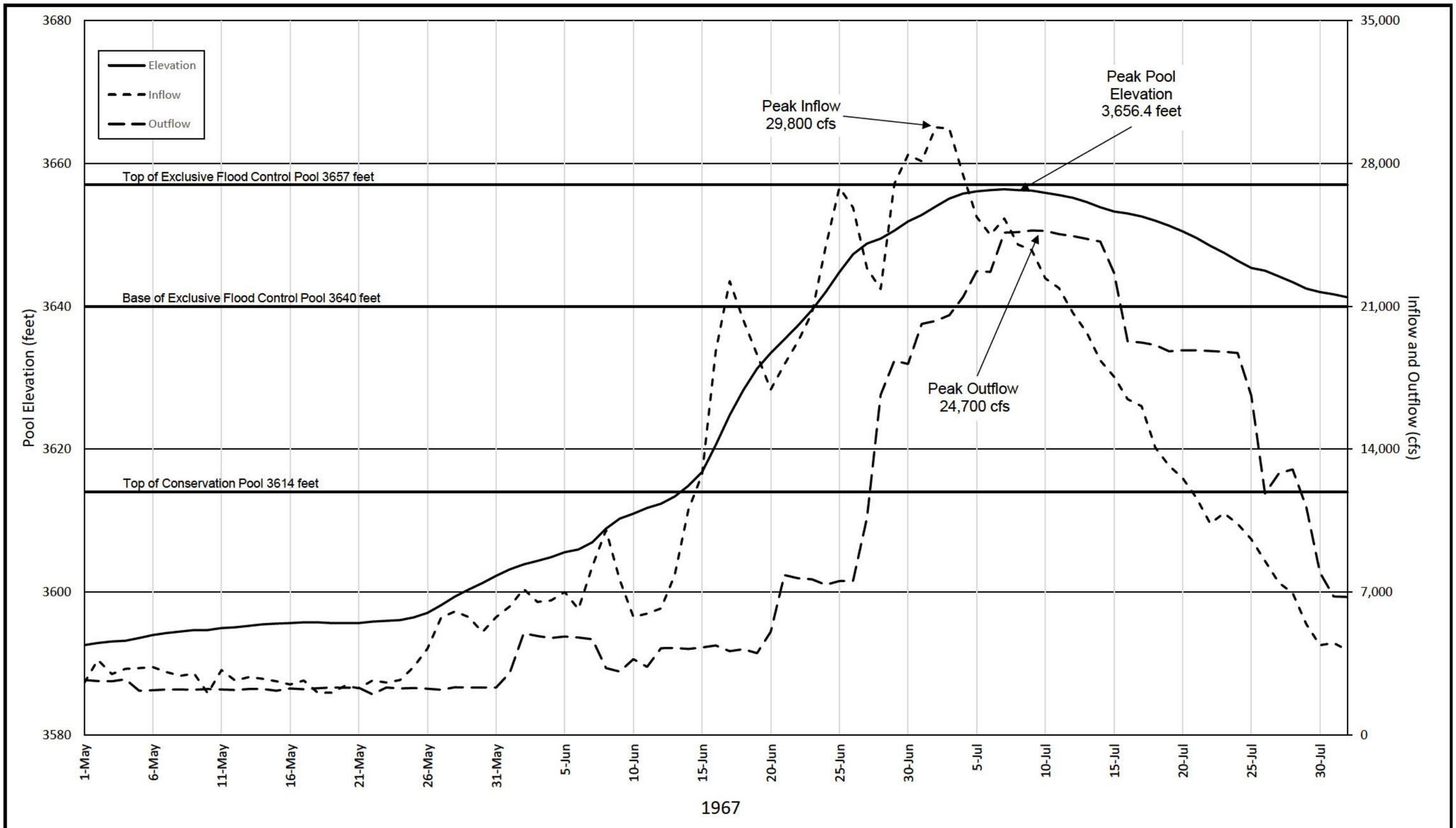


Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Basin Map
Bighorn River

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-2



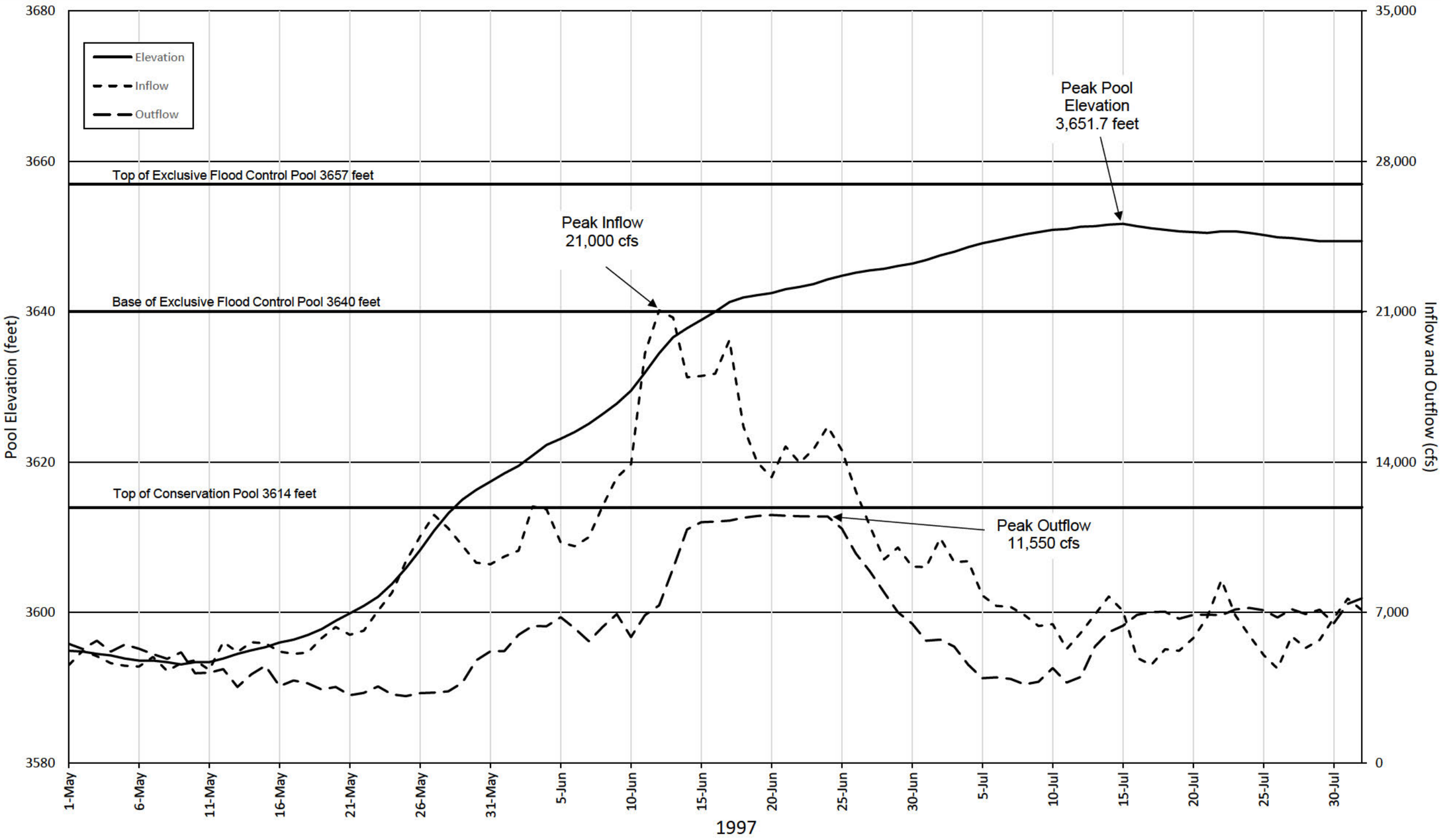
Source: USBR Hydromet Data

Water Control Manual
Yellowtail Dam and Reservoir, Montana

1967 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-3



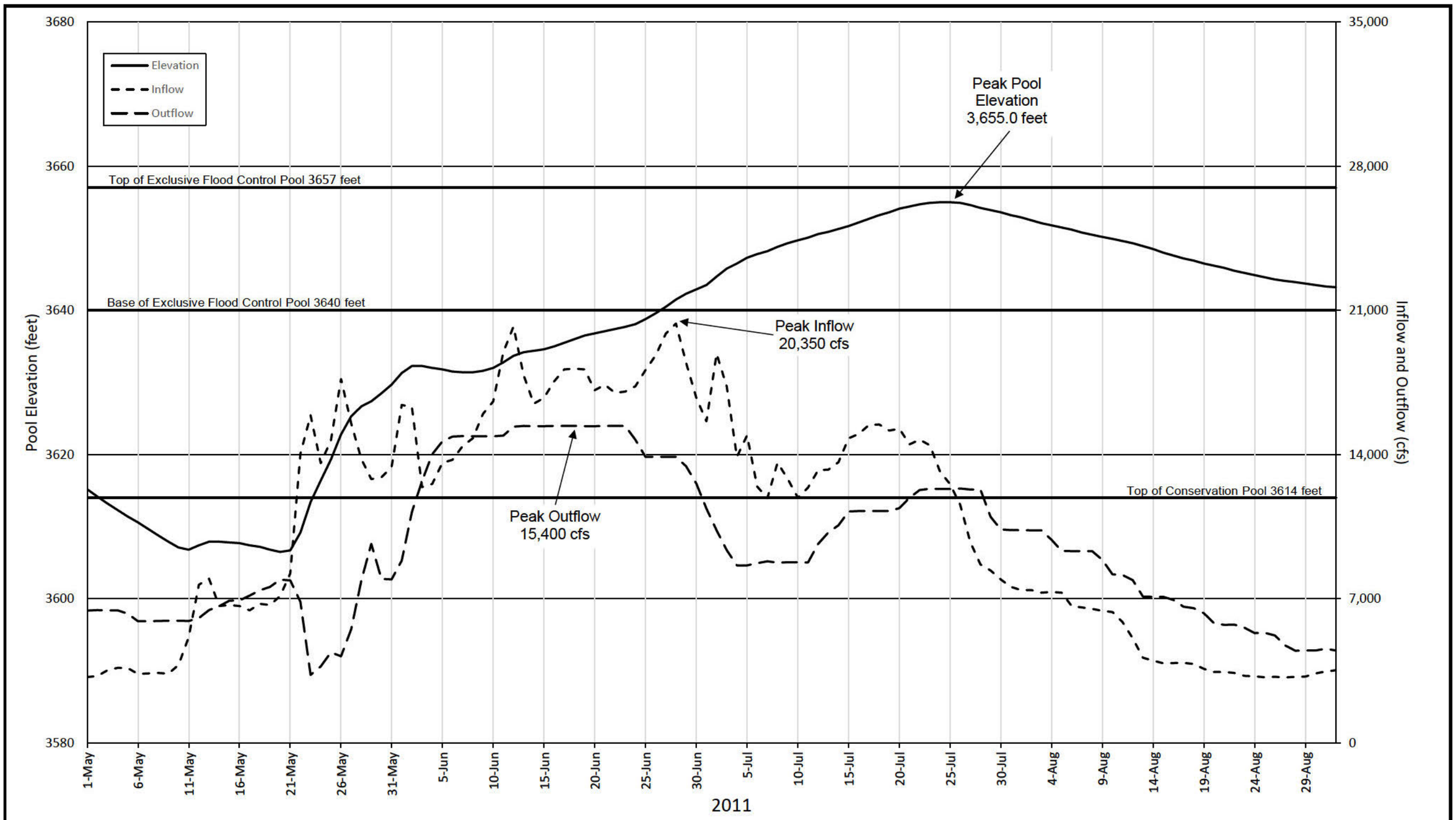
Source: USBR Hydromet Data

Water Control Manual
Yellowtail Dam and Reservoir, Montana

1997 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-4



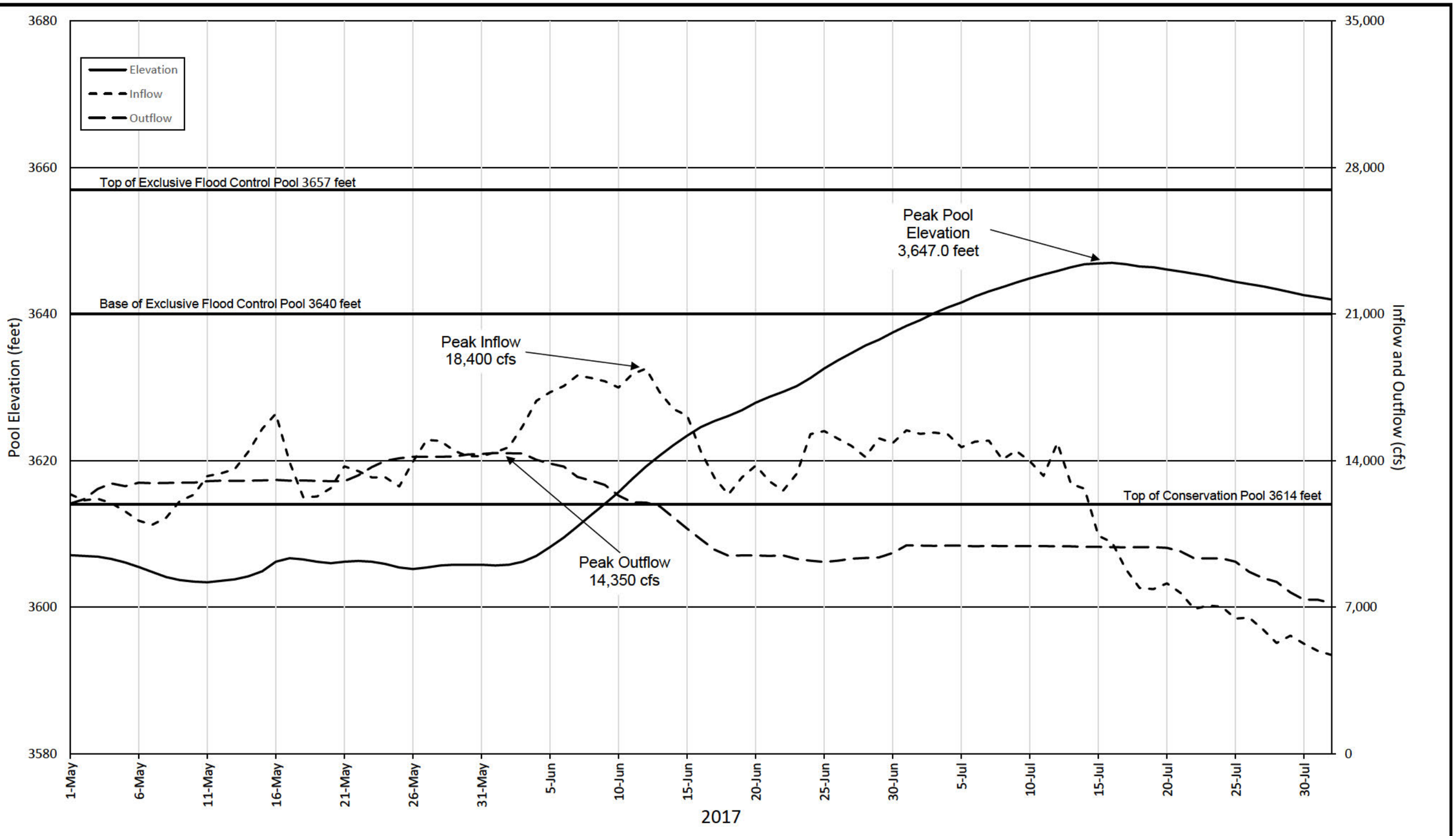
Source: USBR Hydromet Data

Water Control Manual
Yellowtail Dam and Reservoir, Montana

2011 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-5



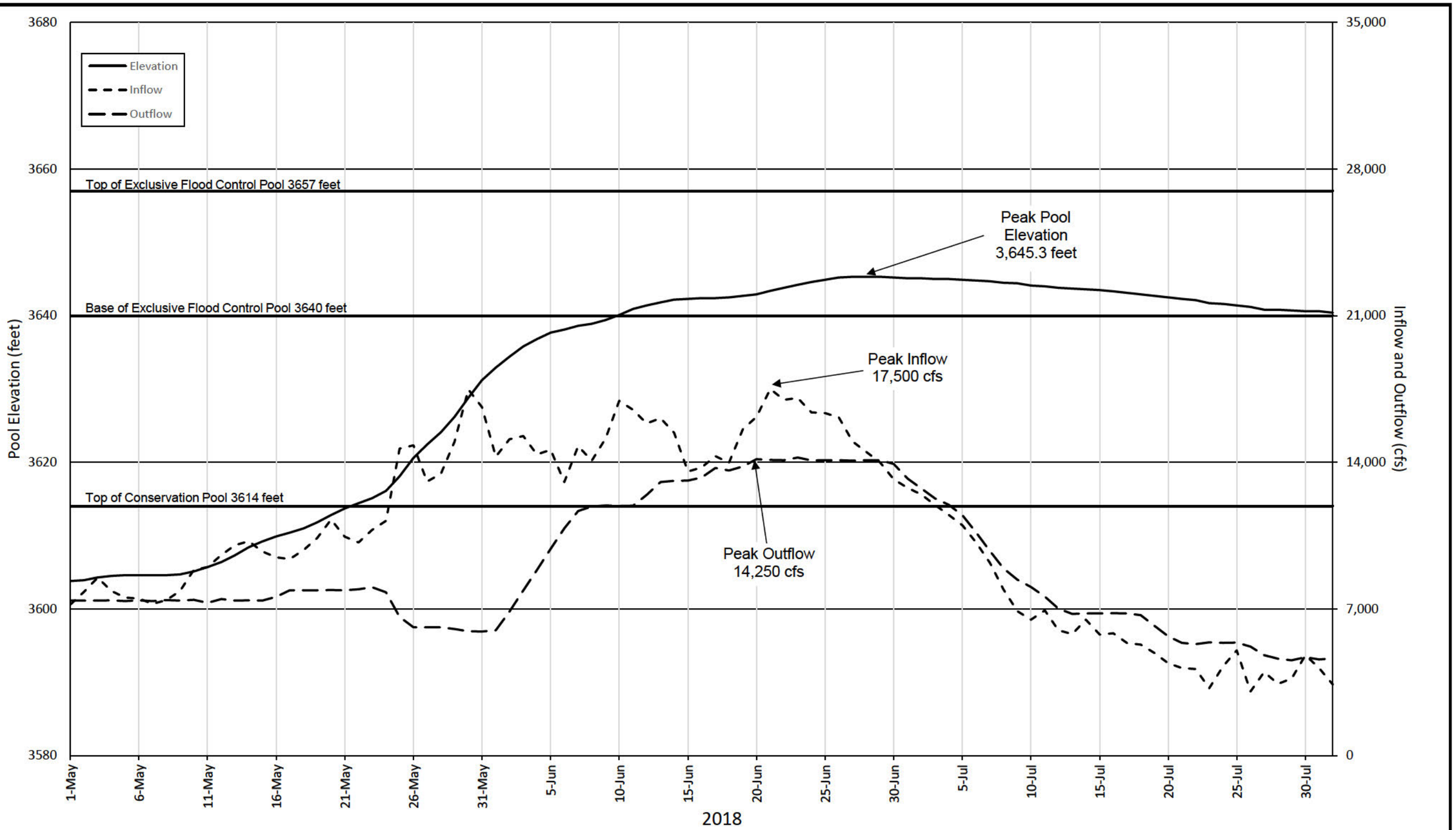
Source: USBR Hydromet Data

Water Control Manual
Yellowtail Dam and Reservoir, Montana

2017 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-6



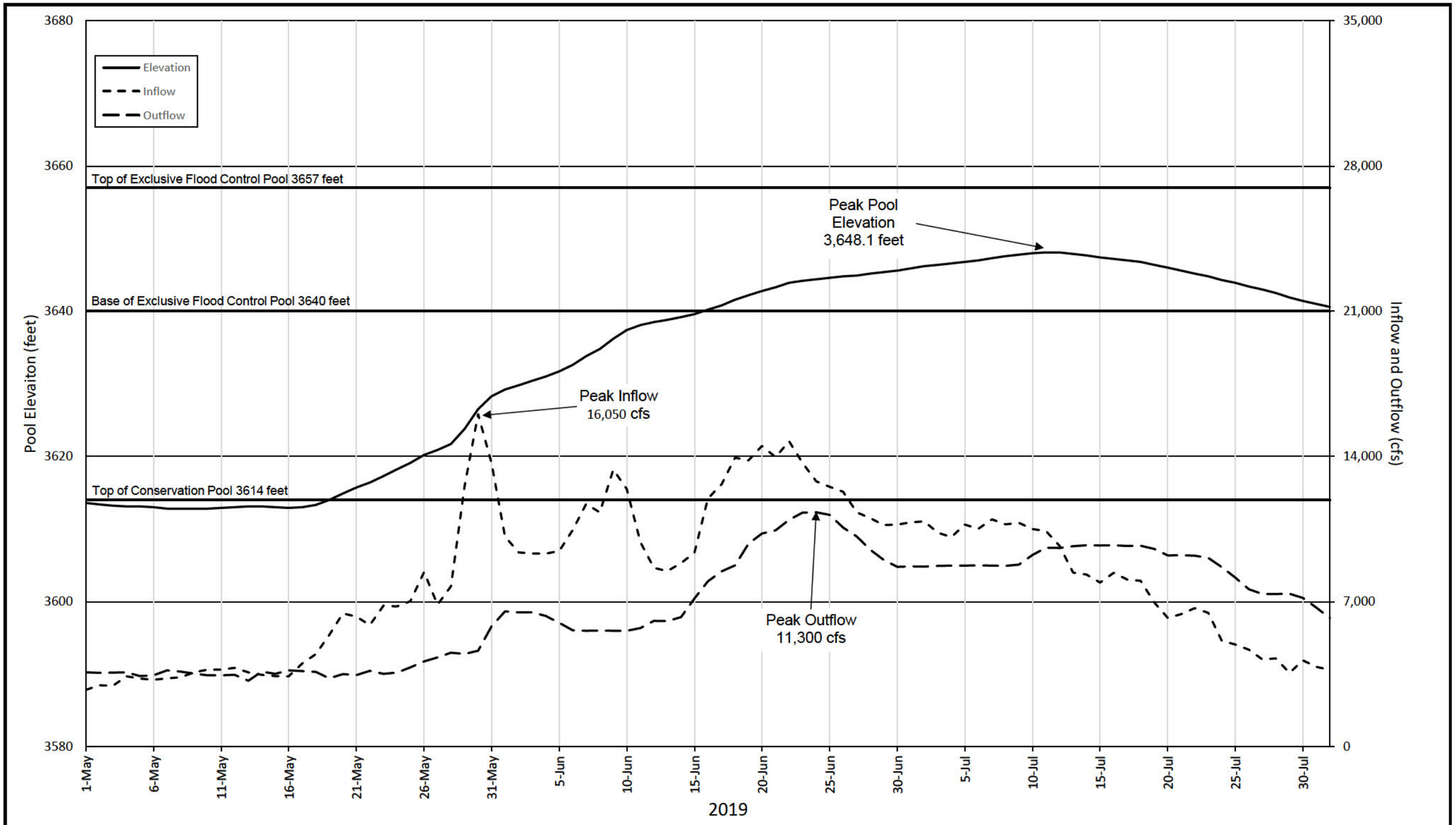
Source: USBR Hydromet Data

Water Control Manual
Yellowtail Dam and Reservoir, Montana

2018 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-7



Source: USBR Hydromet Data

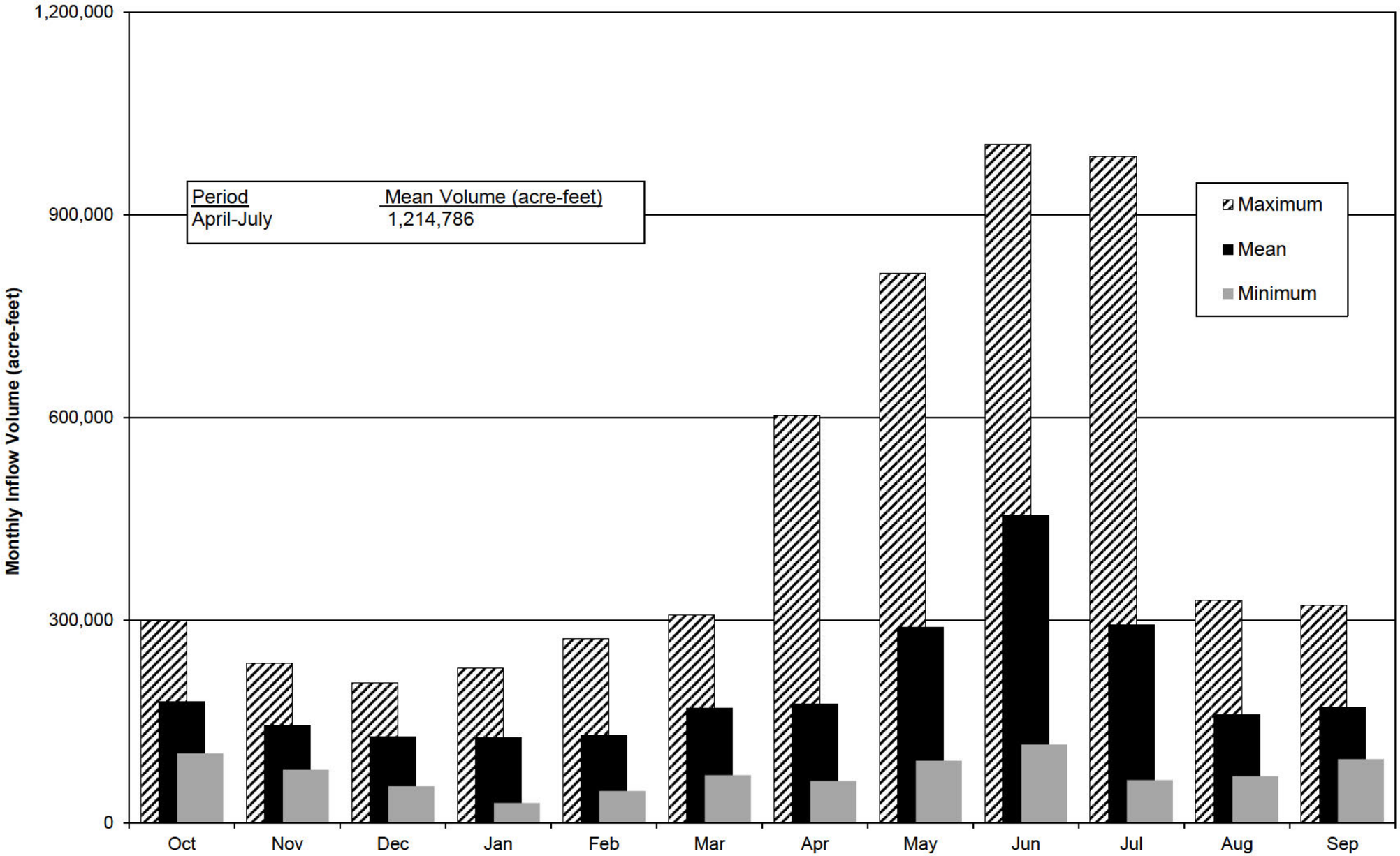
Water Control Manual
Yellowtail Dam and Reservoir, Montana

2019 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-8

Historical Monthly Inflow Volume at Bighorn Reservoir



Period Analyzed: 1966-2020
Total Average Annual Inflow Volume = 2,423,372 ac-ft

Source of Data: USBR HydroMet-Hydrological Database

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Monthly Inflow Volume at Bighorn Reservoir

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-9

Yellowtail Reservoir

Historical Monthly Inflow Volumes (ac-ft)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1966	259,974	190,493	199,977	154,474	133,467	123,867	97,759	129,916	134,947	103,999	95,954	116,027
1967	137,481	120,433	114,313	124,481	135,153	202,385	144,205	210,324	930,204	986,387	175,987	177,348
1968	193,093	209,726	200,514	189,348	213,652	231,961	196,072	202,427	531,882	191,343	227,111	218,396
1969	216,119	230,793	201,832	165,006	194,207	232,514	213,549	212,068	326,676	269,910	126,928	149,374
1970	195,434	189,734	152,827	139,721	185,856	198,322	158,289	280,349	476,666	296,141	108,414	154,960
1971	178,394	169,235	154,258	175,057	194,770	223,493	226,053	374,443	662,700	498,407	162,643	196,368
1972	286,871	235,861	179,751	207,962	273,023	287,254	263,128	285,151	587,537	276,210	237,458	200,005
1973	232,373	208,597	184,373	187,062	159,068	205,861	198,461	343,582	349,291	205,865	141,457	322,195
1974	249,872	201,570	163,759	150,412	174,184	207,940	229,780	282,060	645,936	425,573	199,062	164,525
1975	189,646	158,728	157,404	144,821	126,014	170,325	200,133	387,526	551,427	723,996	225,158	186,545
1976	214,151	161,852	198,534	201,856	215,341	241,528	272,293	322,726	520,179	241,081	191,130	186,257
1977	208,947	169,513	203,379	189,441	132,764	111,372	138,385	200,003	148,320	63,146	80,881	94,481
1978	113,880	89,187	77,485	64,387	74,952	170,661	241,432	488,004	473,461	625,607	244,927	223,260
1979	242,321	198,706	179,798	167,507	133,890	252,109	227,186	266,718	285,614	130,630	160,382	126,074
1980	145,715	134,029	128,375	117,868	130,047	159,854	140,219	214,152	350,321	295,039	196,167	215,173
1981	165,346	155,192	146,334	135,144	118,482	129,204	92,154	269,242	505,918	171,555	126,719	127,944
1982	168,918	149,881	150,244	124,036	144,931	188,293	127,789	140,511	393,914	411,705	232,403	225,498
1983	299,035	218,802	207,274	229,440	212,771	197,399	150,878	258,959	563,657	509,268	209,946	201,606
1984	244,284	205,425	123,011	155,291	143,220	198,750	189,066	363,481	483,482	320,556	230,656	230,298
1985	219,377	211,882	175,505	157,932	132,335	200,531	154,246	174,176	139,214	94,364	92,279	134,384
1986	137,616	88,703	106,134	118,576	136,140	194,664	218,715	315,660	699,616	425,129	205,809	204,530
1987	184,186	171,469	135,439	131,635	155,279	183,656	177,996	237,864	238,734	129,116	141,746	172,902
1988	164,322	141,249	126,919	113,258	119,400	136,502	119,841	316,798	141,922	75,129	69,747	94,168
1989	105,273	89,814	59,377	61,079	53,750	99,460	100,868	153,795	215,813	152,243	126,491	149,575
1990	189,723	144,563	109,017	115,655	117,907	138,884	144,528	198,408	310,248	213,500	134,355	121,976
1991	138,800	115,599	81,593	83,771	98,056	99,572	128,719	354,583	833,686	302,231	148,122	255,159
1992	164,175	144,208	141,731	151,201	141,065	113,770	105,706	199,474	267,898	228,216	123,952	143,831
1993	144,021	107,799	77,633	72,610	74,028	127,056	102,428	312,402	388,498	321,513	180,905	183,303

Source of Data: USBR HydroMet-Hydrological Database

Water Control Manual
Yellowtail Dam and Bighorn Reservoir

Table of Historical Monthly Inflow Volumes at Bighorn Reservoir

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-10a

Yellowtail Reservoir

Historical Monthly Inflow Volumes (ac-ft)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1994	215,805	119,557	131,895	124,027	98,934	156,037	169,813	213,354	119,899	84,302	91,185	132,306
1995	147,103	98,239	72,721	72,735	91,990	98,666	86,872	251,964	674,104	674,560	228,676	220,328
1996	180,401	126,410	118,530	117,075	159,831	234,479	344,463	351,921	523,538	352,436	159,197	172,118
1997	157,510	127,573	112,048	131,504	165,664	295,948	328,625	403,610	821,725	403,423	329,324	239,490
1998	235,963	135,413	133,028	133,417	139,213	216,831	243,985	256,213	279,357	470,791	284,911	258,788
1999	223,409	166,262	133,361	138,127	131,672	241,955	195,610	560,880	810,296	387,576	233,641	224,400
2000	184,774	153,629	143,552	135,051	134,459	132,586	108,369	227,364	197,048	109,550	107,091	142,551
2001	154,936	119,200	108,371	103,079	85,068	130,254	102,733	130,955	153,657	82,515	68,866	108,352
2002	102,385	81,852	60,765	63,187	47,968	82,218	79,224	91,959	162,653	74,736	72,404	110,471
2003	116,320	78,170	58,126	57,477	47,222	95,562	73,321	143,356	244,104	87,467	78,442	128,750
2004	118,773	78,882	56,420	29,517	65,389	70,700	62,007	108,867	115,878	105,397	100,245	129,496
2005	117,922	83,697	53,897	69,649	65,481	77,625	104,276	319,224	453,374	188,167	145,407	169,266
2006	160,938	104,336	102,148	107,196	93,829	126,869	105,978	183,971	163,588	74,662	81,932	127,187
2007	125,649	98,734	82,492	67,362	77,839	100,240	100,596	206,669	219,176	87,460	91,257	106,722
2008	138,105	95,822	66,328	66,275	68,017	86,129	80,868	291,621	595,103	330,727	129,608	184,624
2009	151,366	118,907	98,008	112,025	112,993	138,615	142,596	268,251	771,605	474,082	188,918	152,344
2010	180,715	141,442	111,822	134,766	120,794	137,708	121,407	341,224	761,330	280,765	122,345	119,561
2011	122,182	122,633	122,714	121,862	111,876	167,356	245,829	529,353	1,004,222	792,902	279,243	196,835
2012	213,599	142,344	132,407	136,214	137,482	177,239	149,707	204,741	238,545	100,162	102,747	118,781
2013	132,473	111,566	95,183	90,109	86,785	109,446	99,371	180,808	215,132	132,575	97,312	157,028
2014	185,661	130,342	96,084	97,343	102,190	209,493	316,194	534,290	522,702	351,694	199,940	219,974
2015	178,926	136,021	138,758	133,630	166,422	161,534	130,504	311,757	876,918	223,590	150,146	134,164
2016	133,477	121,080	116,138	118,116	123,511	111,466	122,000	358,275	422,823	128,698	135,893	180,908
2017	202,620	139,889	109,224	120,538	212,901	306,734	603,393	812,986	920,417	616,326	216,433	219,041
2018	277,811	229,846	177,380	177,336	158,924	308,210	391,173	657,088	896,156	373,453	171,230	163,010
2019	175,383	154,431	132,924	128,328	116,099	173,049	185,456	354,644	676,935	461,153	206,877	208,624
2020	202,336	172,669	134,188	139,025	129,720	217,556	264,848	259,131	322,464	195,226	133,153	152,203
2021	144,794	110,538	98,000	96,429	89,791	117,106	149,103	166,814	192,777	98,208	140,693	141,839

Source of Data: USBR HydroMet-Hydrological Database

Water Control Manual

Yellowtail Dam and Bighorn Reservoir

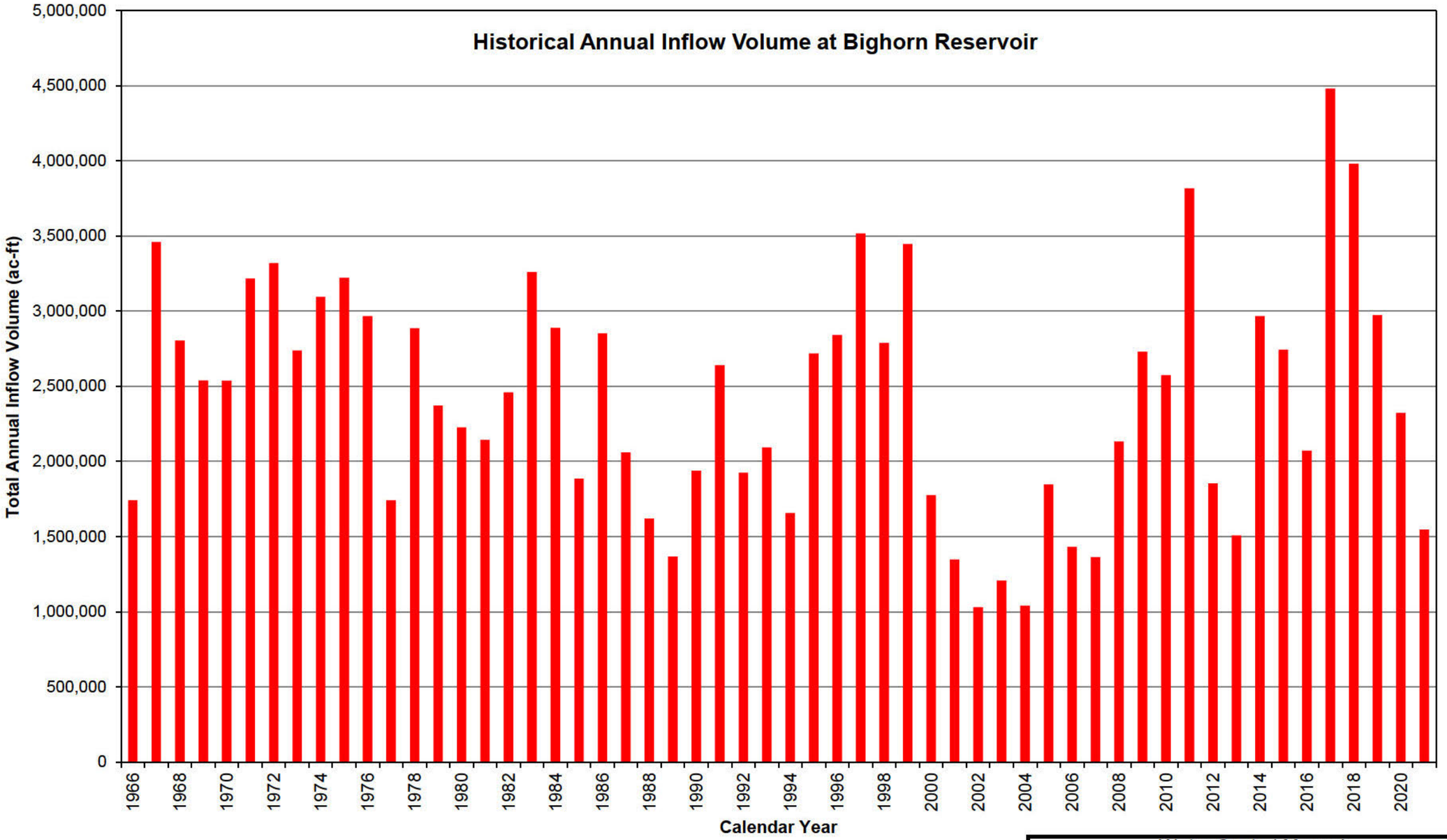
Table of Historical Monthly Inflow Volumes at Bighorn Reservoir

U.S. Army Engineer District

Corps of Engineers, Omaha, Nebraska

October 2022

Plate 4-10b



Annual Inflow Volume is an accumulation of monthly inflows over a water year.

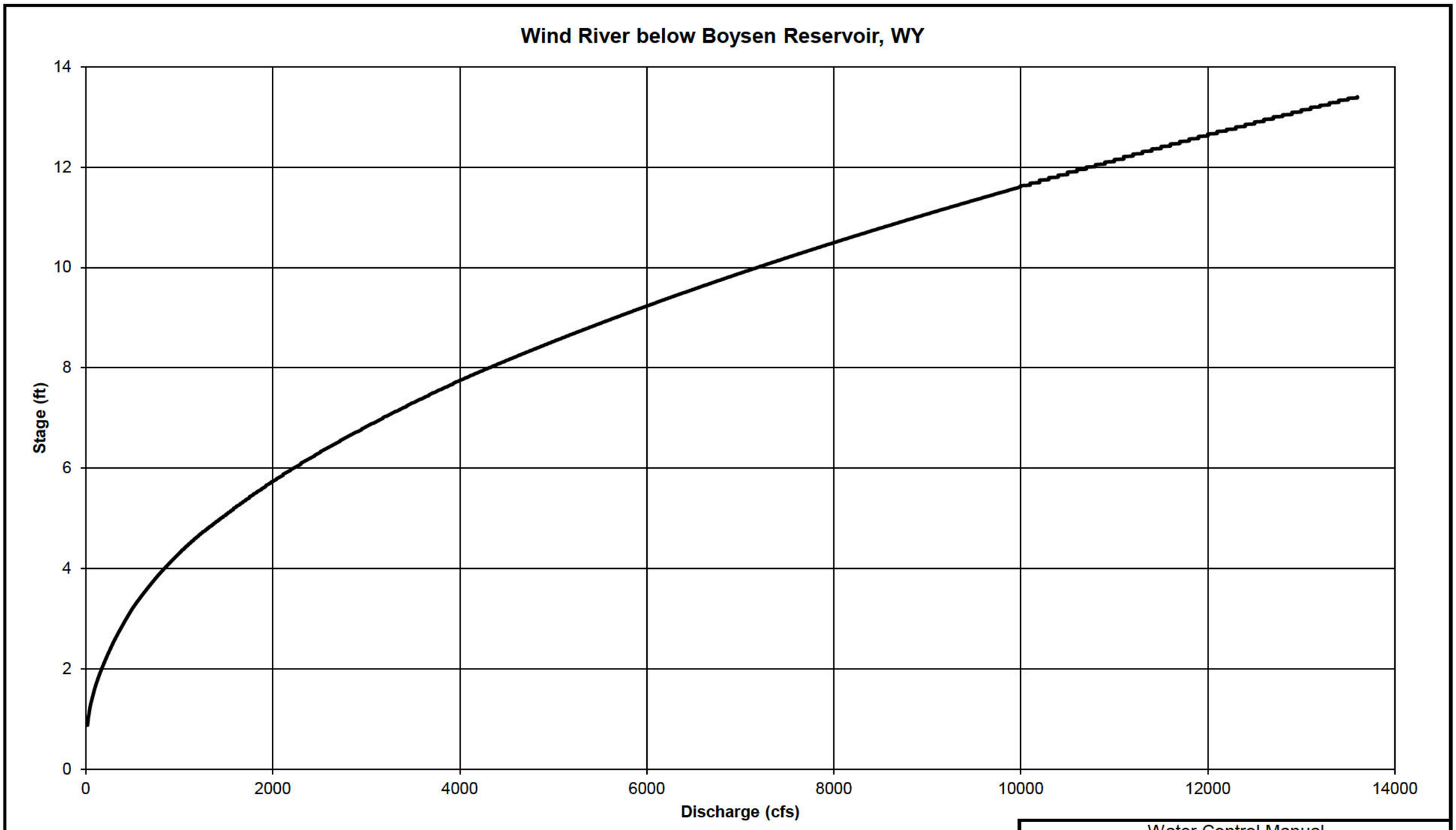
Source of Data: USBR HydroMet-Hydrological Database

Water Control Manual
Yellowtail Dam and Reservoir, MT

Historical Annual Inflow Volume
Bighorn Reservoir

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-11



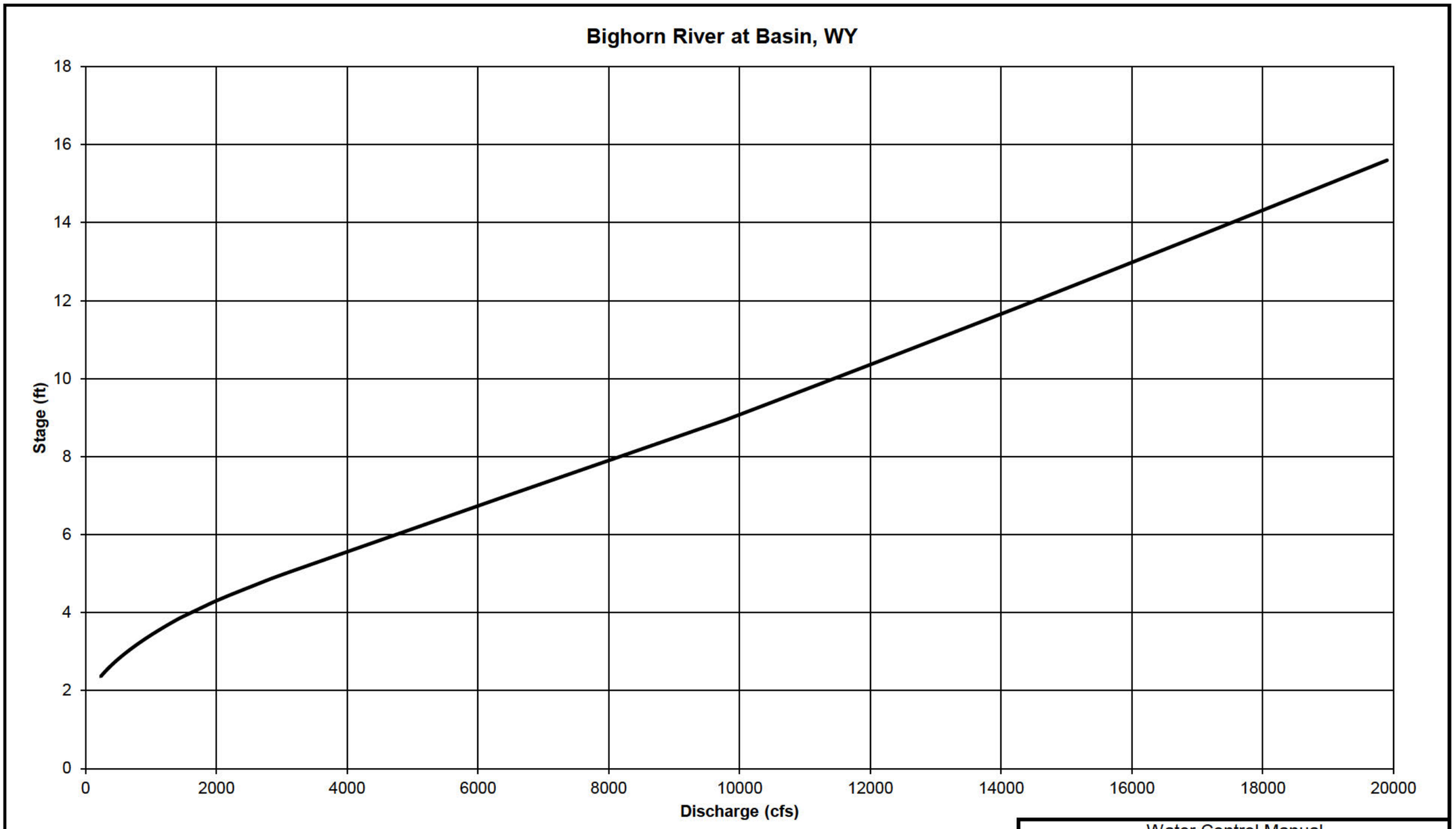
Gage Datum: 4,608.58 feet ab NGVD29

Rating curve data obtained from the USGS
Rating ID: 10.0, 14 October 2014

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Wind River below
Boysen Reservoir, WY

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



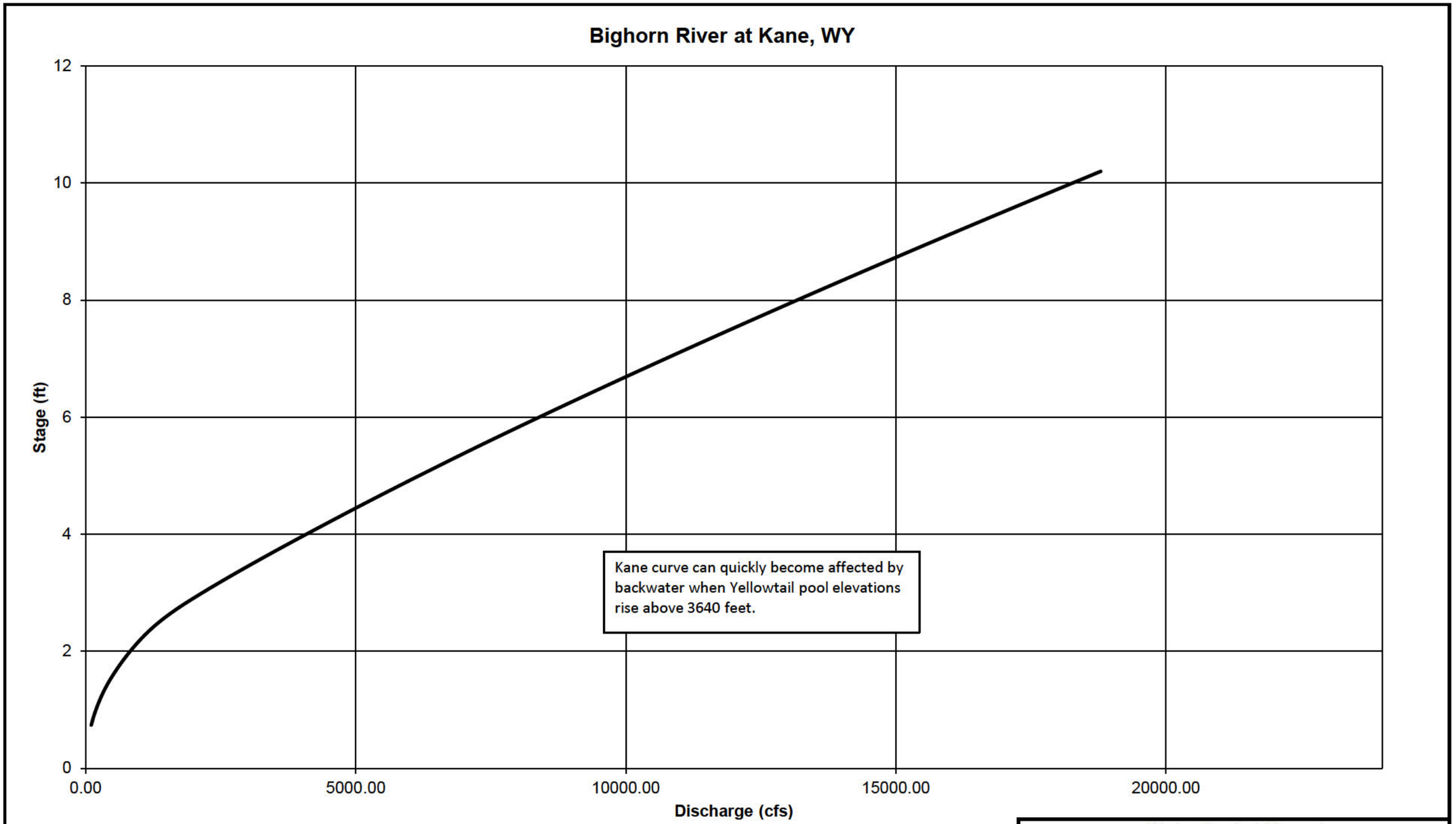
Gage Datum: 3,821.29 feet ab NGVD29

Rating curve data obtained from the USGS.
Rating ID: 9.0, Shift Date: 24 August 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Bighorn River at Basin, WY

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



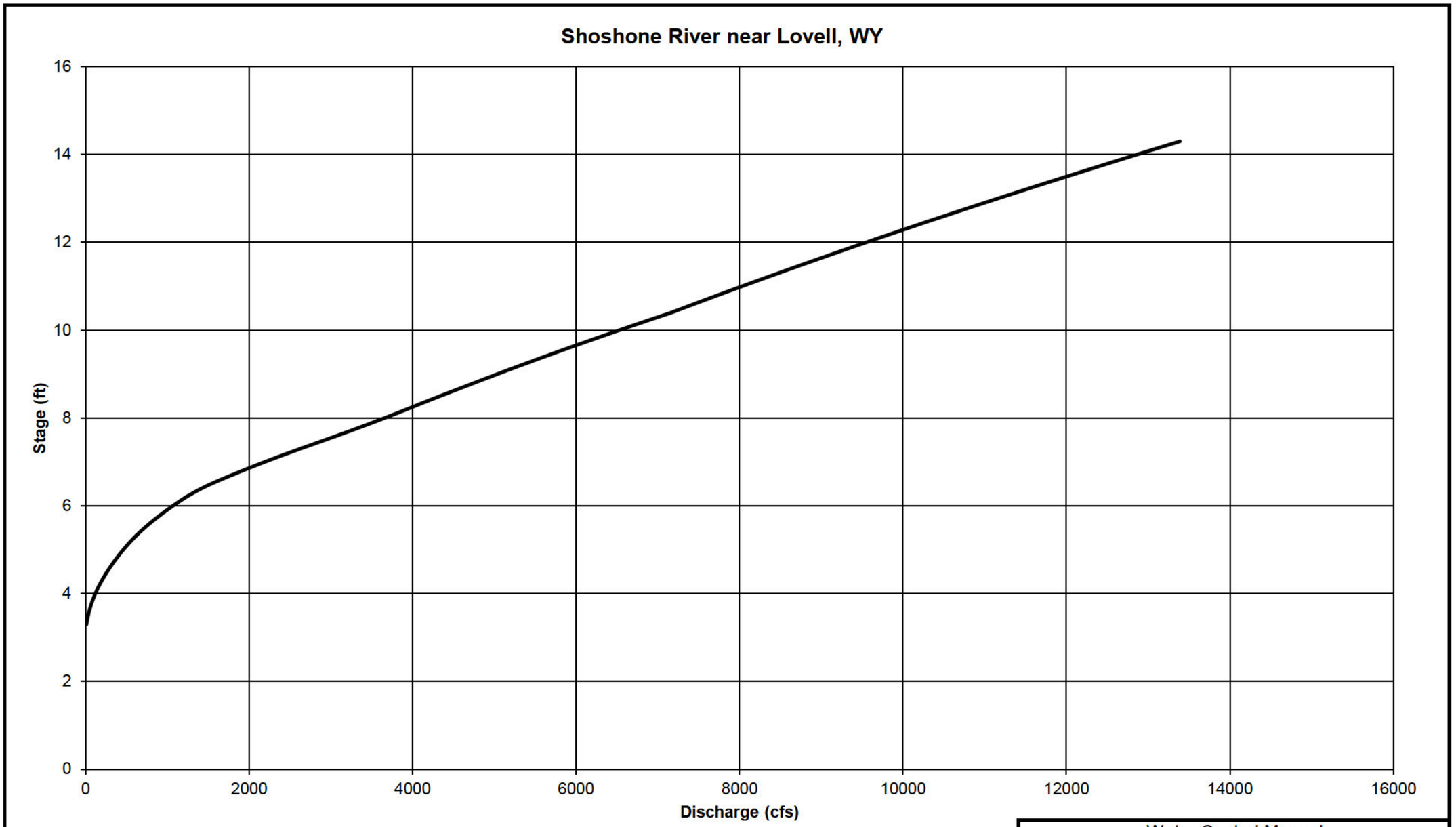
Gage Datum: 3,660.00 feet ab NGVD29

Rating curve data obtained from the USGS
Rating ID: 15.0, Shift Date: 24 August 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Bighorn River at Kane, WY

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



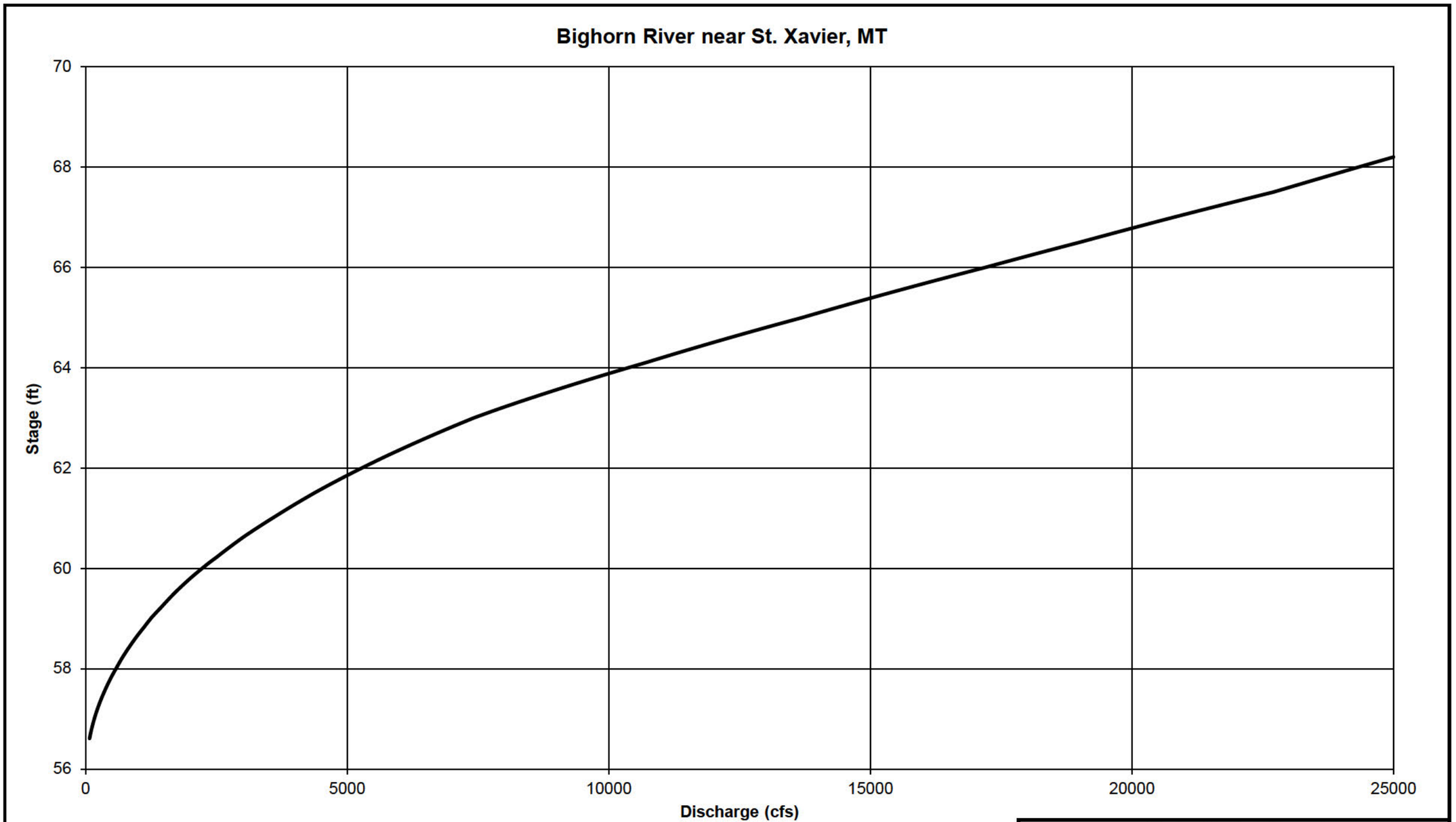
Gage Datum: 3,850 feet ab NGVD29

Rating curve data obtained from the USGS
Rating ID: 16.0, Shift Date: 24 August 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Shoshone River near Lovell, WY

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



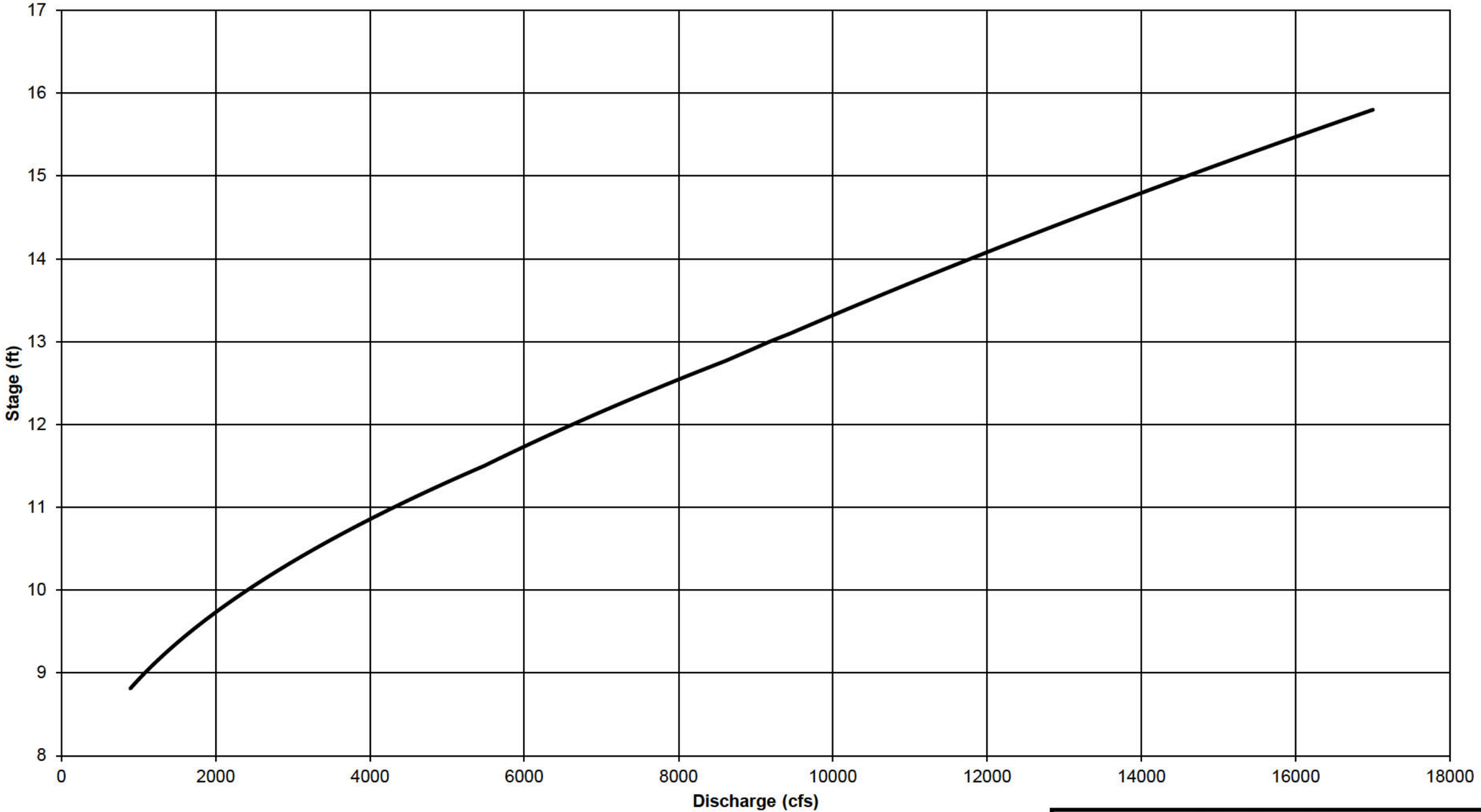
Gage Datum: 3,100.00 feet ab NGVD29

Rating curve data obtained from the USGS ADAPS computer system.
Rating ID: 7.0, Shift Date: 13 September 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Bighorn River nr St. Xavier, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



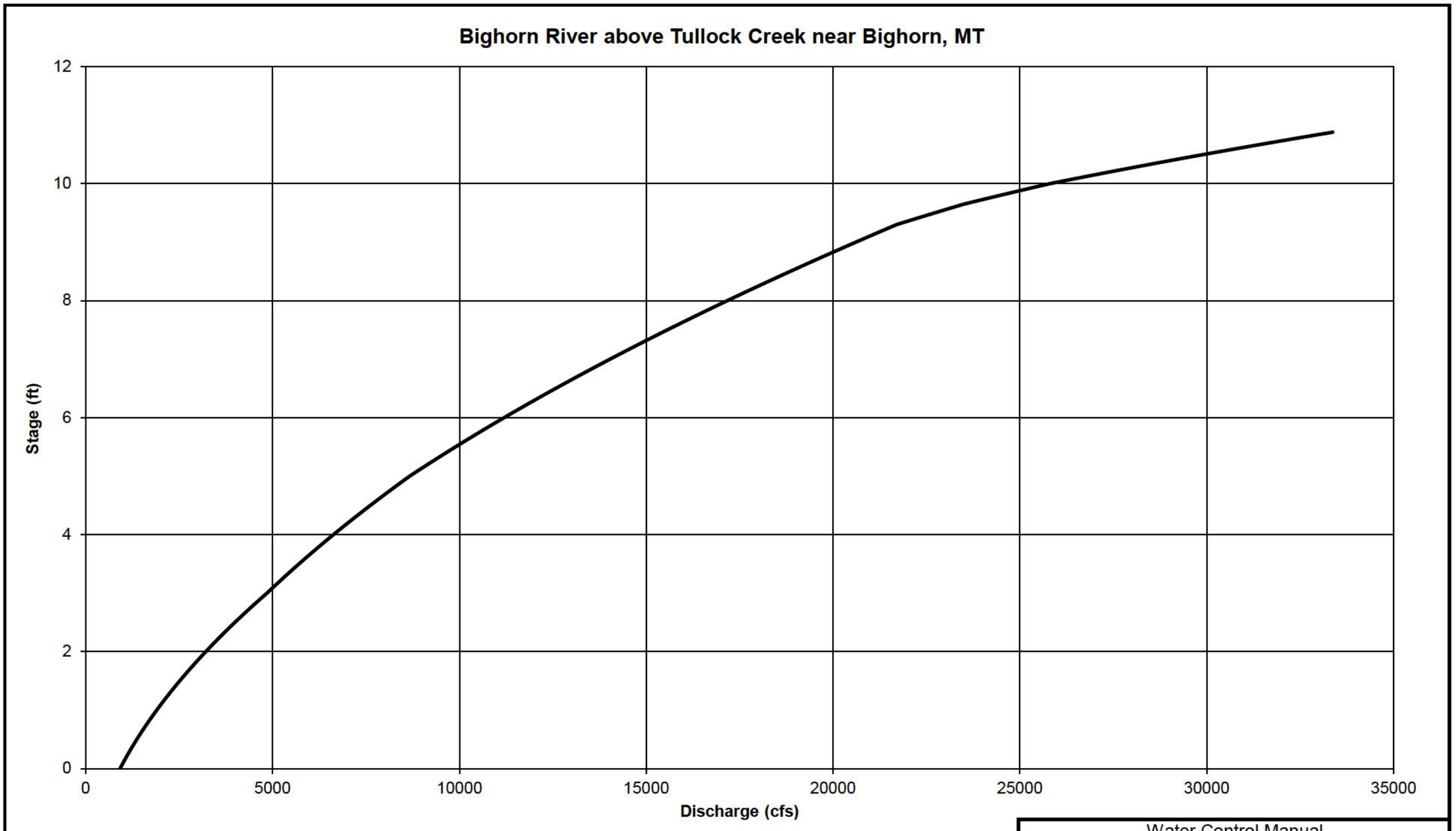
Gage Datum: 2,930 feet ab NGVD29

Rating curve data obtained from the USGS
Rating ID: 3.0, Shift Date: 22 July 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Bighorn River at Two Leggins Bridge, near Hardin, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



Gage Datum: 2,700.00 feet ab NGVD29

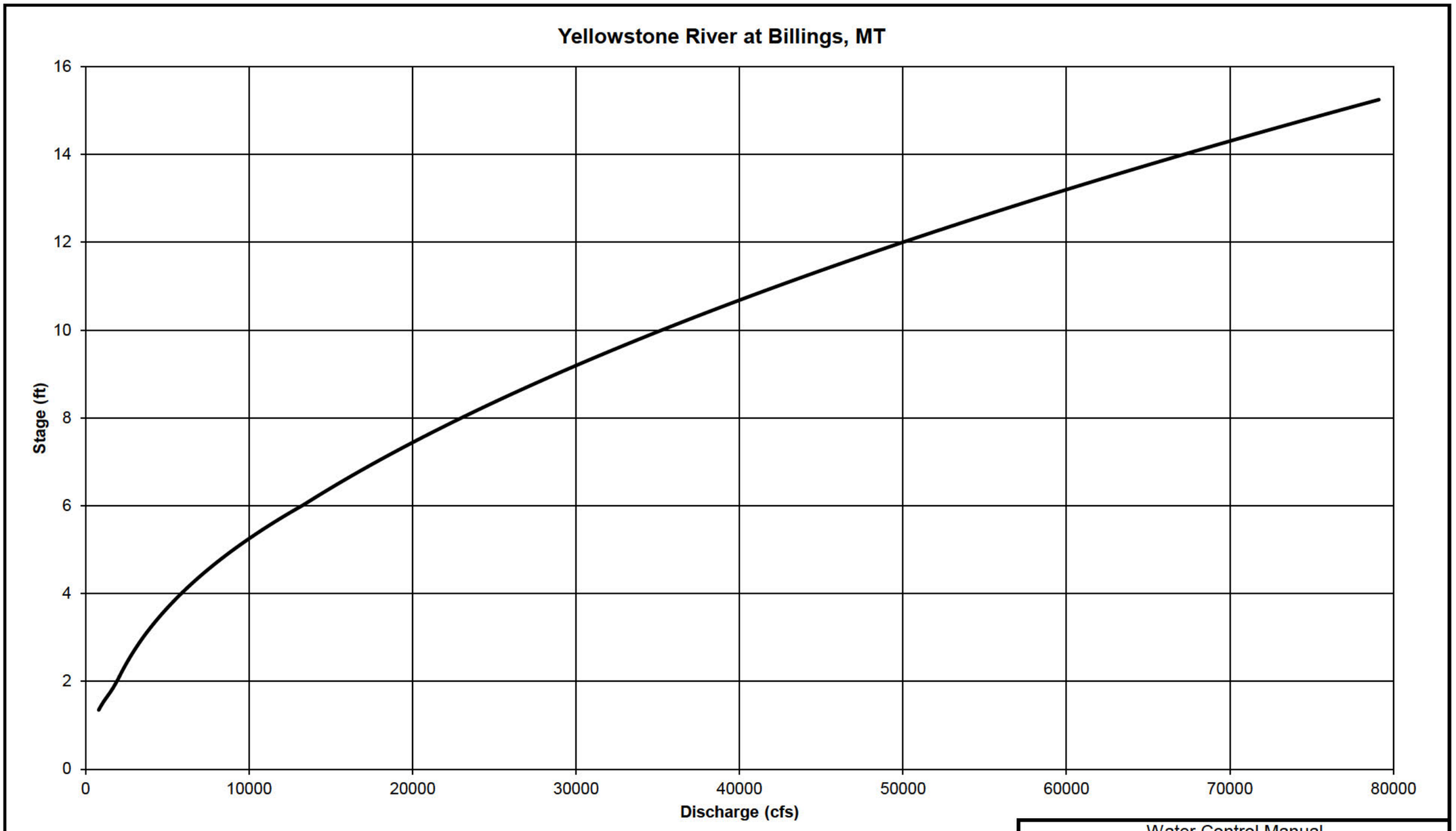
Rating curve data obtained from the USGS
Rating ID: 5.0, Shift Date: 23 July 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Bighorn River nr Bighorn, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-18



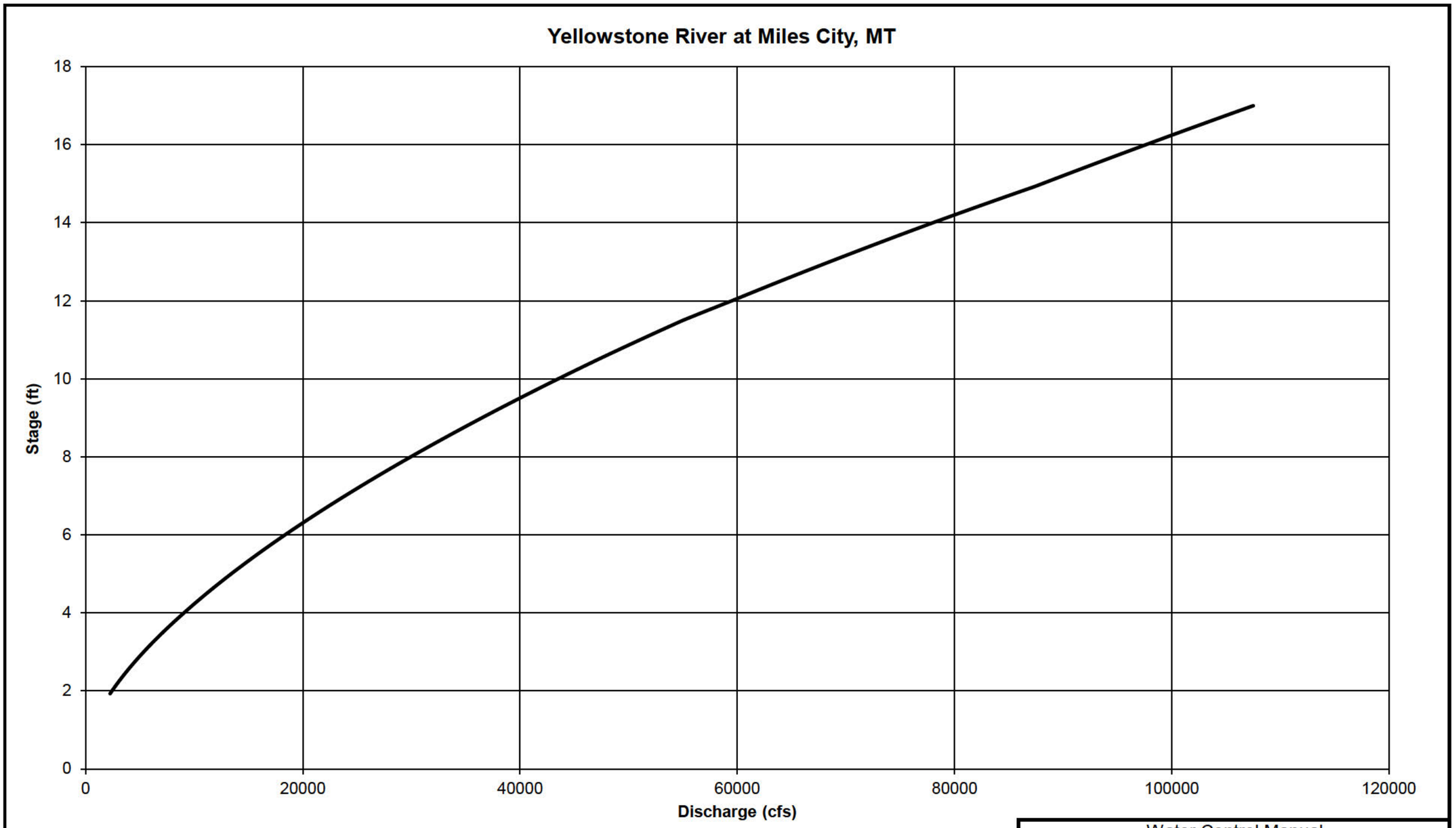
Gage Datum: 3,081.36 feet ab NGVD29

Rating curve data obtained from the USGS
Rating ID: 20.1, Shift Date: 12 July 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Yellowstone River at Billings, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



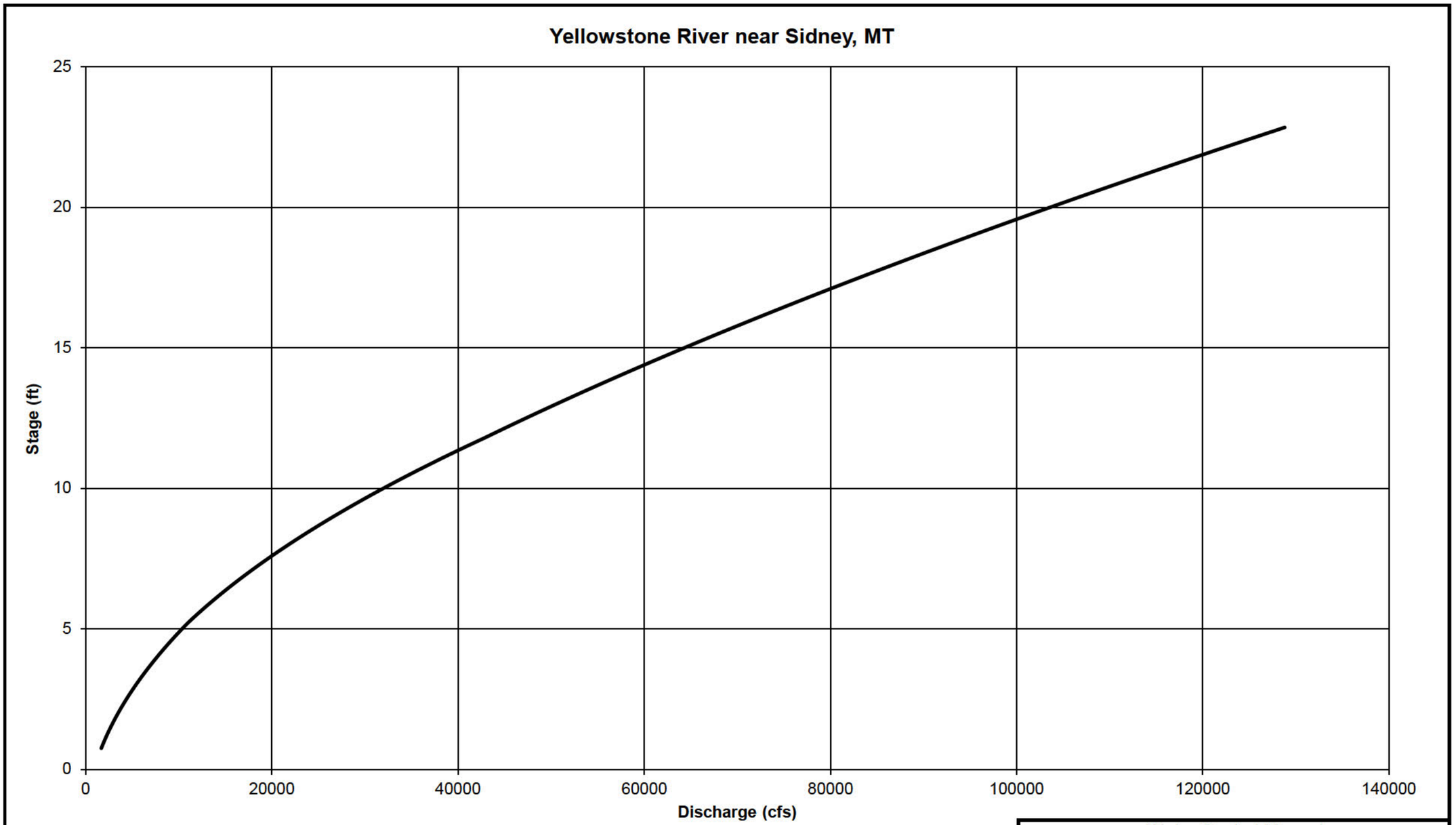
Gage Datum: 2,333.30 feet ab NGVD29

Rating curve data obtained from the USGS ADAPS computer system.
Rating ID: 12.2, Shift Date: 19 June 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Yellowstone River at Miles City, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



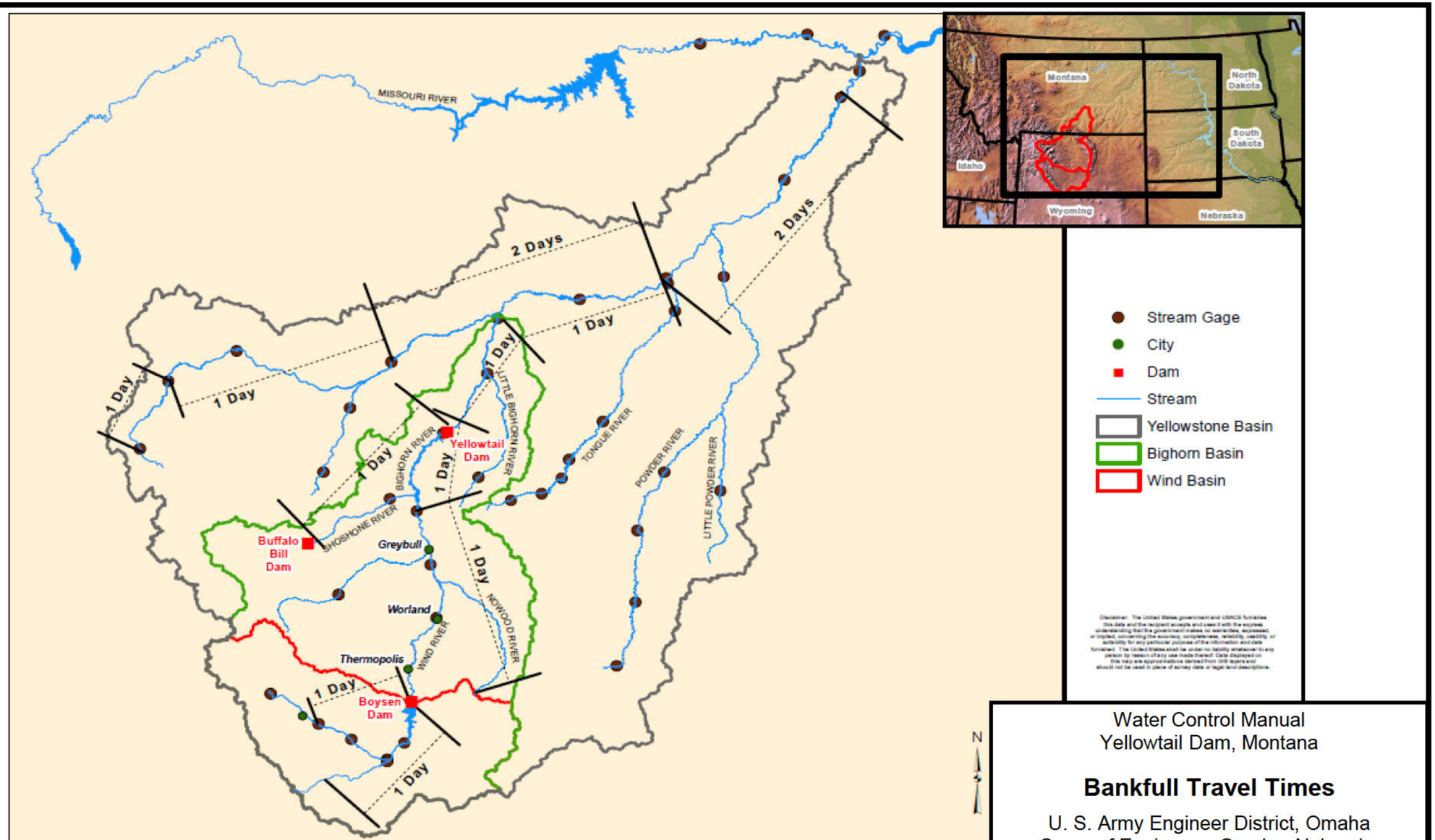
Gage Datum: 1,881.30 feet ab NGVD29

Rating curve data obtained from the USGS
Rating ID: 29.0, 10 August 2021

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Rating Curve
for Yellowstone River near Sidney, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

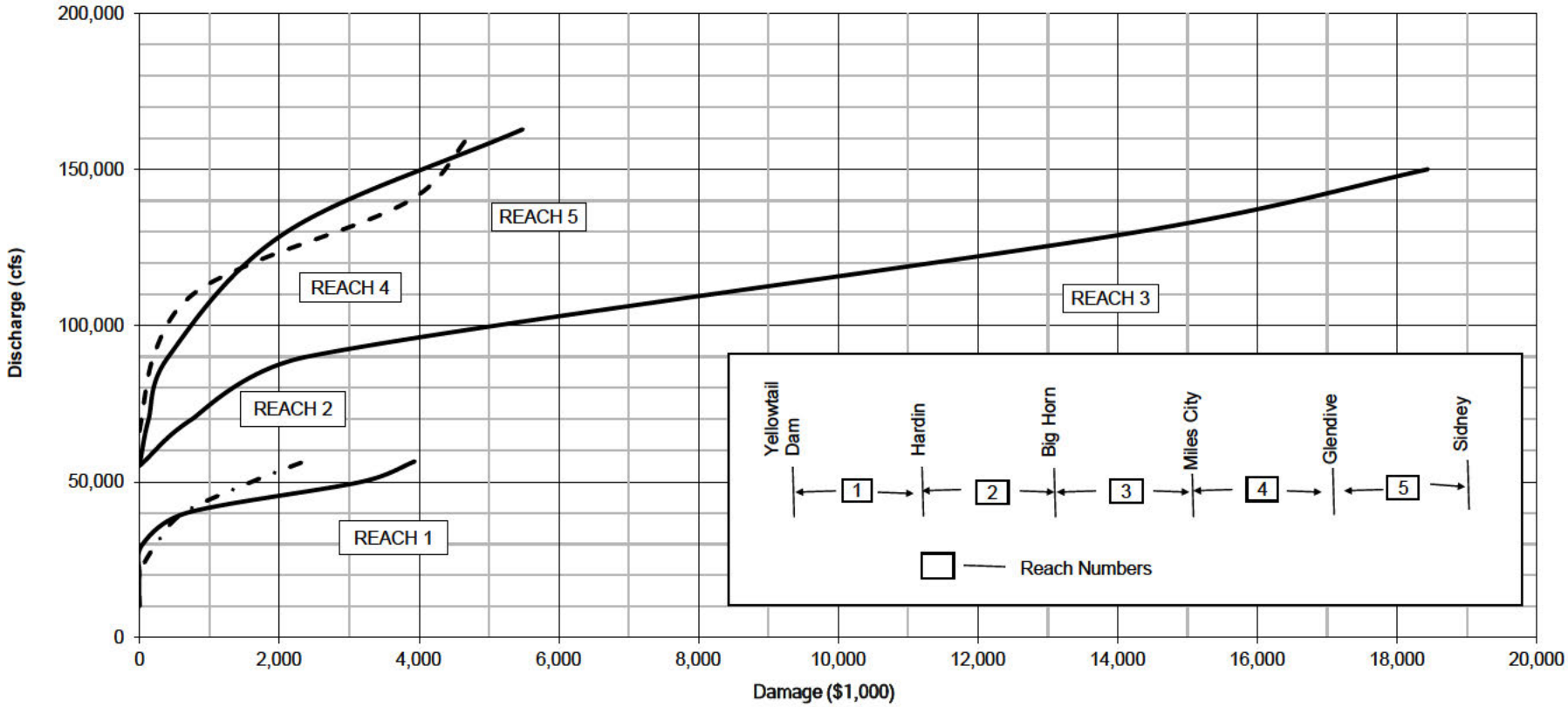


Water Control Manual
Yellowtail Dam, Montana

Bankfull Travel Times

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-22



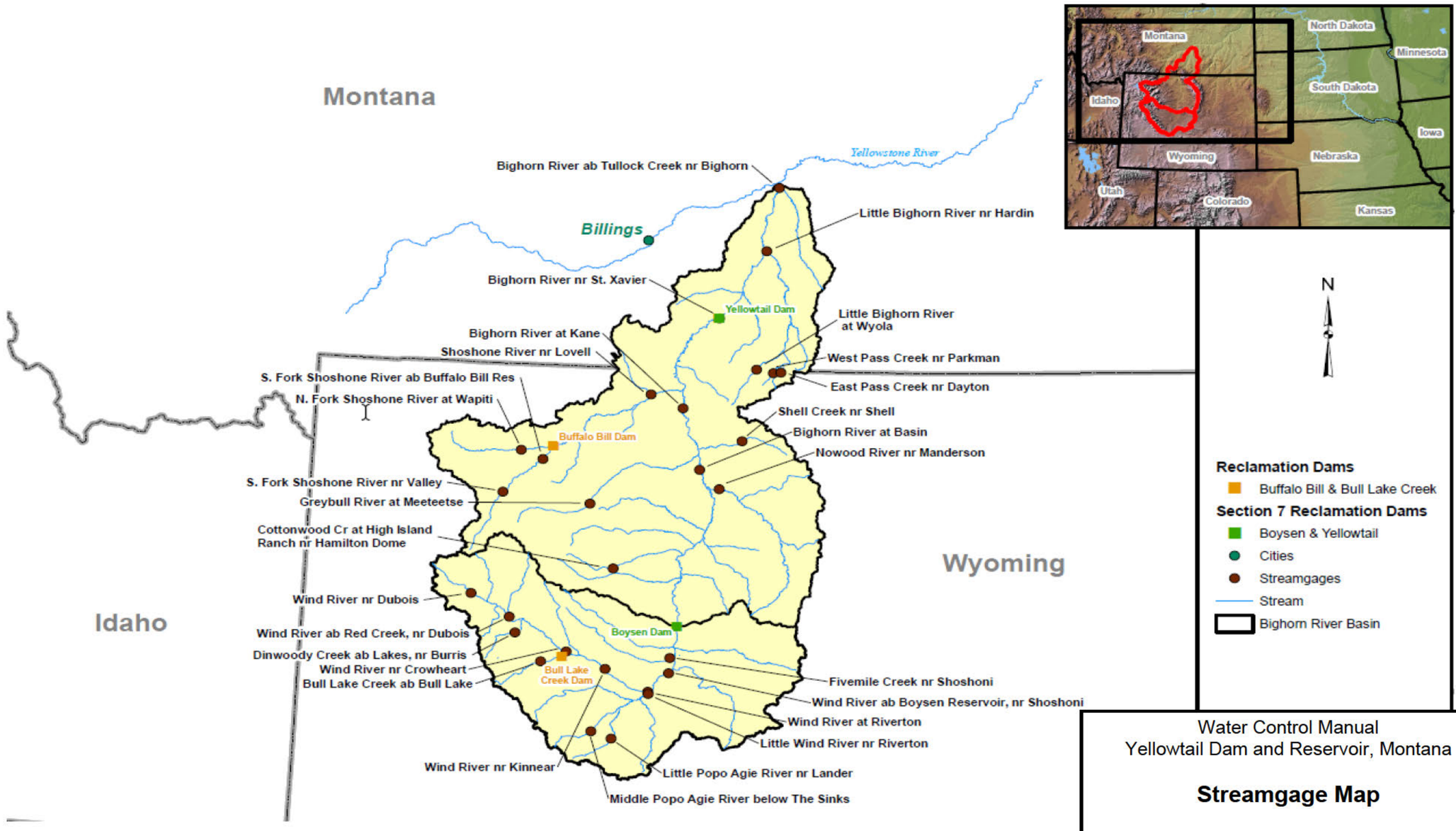
September 2020 Price Levels
Data provided by Environmental, Economics and Cultural Resource Section,
Project Management Branch, Corps of Engineers, Omaha District

Water Control Manual
Yellowtail Dam/Bighorn Reservoir, MT

Bighorn/Yellowstone River Discharge Damage Curves (2020 Price Levels)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 4-23



Water Control Manual
Yellowtail Dam and Reservoir, Montana

Streamgage Map

U. S. Army Engineer District, Omaha
October 2022

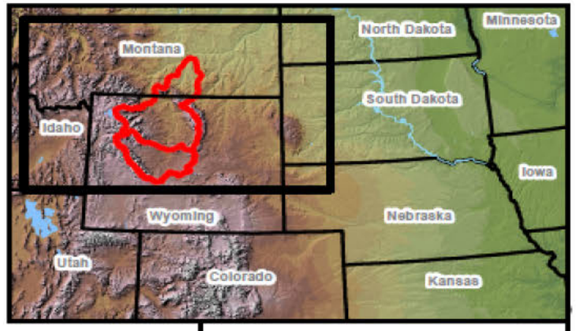
Plate 5-1

Gage	USGS Number	Corps Station ID in CWMS	NWS NESSID	USBR Hydromet ID	Drainage Area (sq. mi.)	Flood Stage (ft)	Annual Mean (cfs)	Period of Record.
Bighorn River ab Tullock Cr near Bighorn MT	06294500	BHMT	CE790122	BHMT	22419	Unknown	3756	1945-current
Bighorn River at Basin, WY	06274300	BHDY	DD5B4350	-	13223	10.5	1652	1984-current
Bighorn River at Bridge, at St. Xavier, MT	06287800	STMT	DF05E0C6		19900	Unknown	2827	2012-current
Bighorn River at Kane, WY	06279500	KAWY	DD3DA25E	KAWY	15762	Unknown	2174	1929-current
Bighorn River at Two Leggins Bridge, near Hardin, MT	06288400	HBMT	DF0566D2	-	-	Unknown	2947	2012-current
Bighorn River near St. Xavier, MT	06287000	SXMT	344727D2	BHSX	19672	Unknown	3424	1935-current
Bull Lake Creek above Bull Lake, WY	06224000	BLAY	173524B6	BLAY	187	Unknown	289	1942-1953; 1967-current
Bull Lake Creek near Lenore, WY	06225000	BLCK	DD7AD526	BLR	213	Unknown	273	1918-1923; 1926-2017
Dinwoody Creek above lakes near Burris, WY	06221400	DCBY	DE08518C	DCBY	88.2	Unknown	144	1958-1979; 1989-current
Fivemile Creek near Shoshoni, WY	06253000	FMWY	17B037B8	FMSY	285	Unknown	165	1941-1942; 1948-1983; 1989-
Greybull River at Meeteetse, WY	06276500	MEWY	DDF8D76A	GRMY	681	7.5	440	1921-current
Little Bighorn River at State Line near Wyola, MT	06289000	WYMT	1734353A	LBSM	182	Unknown	151	1939-current
Little Popo Agie River near Lander, WY	06233000	LPWY	DDD38550	LPLY	125	Unknown	112	1946-current
Little Wind River near Riverton, WY	06235500	RILW	178BE408	LWRV	1904	8.0	568	1941-current
North Fork Shoshone River at Wapiti, WY	06279940	NFS	F231F5C8	NFS	699	8.0	880	1990-current
Powder River at Arvada, WY	06317000	-		-	6050	Unknown	64	1990-current
Powder River at Moorhead, MT	06324500	-		-	8020	Unknown	138	1989-current
Powder River nr Locate, MT	06326500	LOMT	CE78DB62	-	13060	Unknown	142	1995-current
Shoshone River below Buffalo Bill Reservoir, WY	06282000	SRBB	347683A0	SRBB	1538	Unknown	1095	1921-2016
Shoshone River near Lovell, WY	06285100	SRLY	F0033016	SRLY	2350	11.0	909	1967-current
South Fork Shoshone River ab Buffalo Bill Res, WY	06281000	SFS	F2320242	SFS	585	9.5	446	1903-1908; 1921-1926; 1974-
South Fork Shoshone River near Valley, WY	06280300	VSWY	17AFD546	SFVY	297	8.00	419	1957-1958; 1960-
Stillwater River nr Absarokee, MT	06205000	ABMT		-	976	7.5	605	1990-current
Tongue River at State Line nr Decker, MT	06306300	-		-	1451	Unknown	232	1994-current
Tongue River at Tongue R. Dam nr Decker, MT	06307500	-		-	1783	Unknown	293	1994-current
Tongue River at Birney Day School Br nr Birney, MT	06307616	-		-	2633	7.0	280	1994-current
Tongue River bl Brandenberg bridge nr Ashland, MT	06307830	-		-	3879	Unknown	275	2000-current
Tongue River at Miles City	06308500	MIMT	CE5DB8AA	-	5404	10.0	195	1991-current
Wind River ab Boysen Reservoir, nr Shoshoni, WY	06236100	WRSY	1662058E	-	-	Unknown	1116	1990-2013
Wind River above Red Creek, near Dubois, WY	06220800	WRDY	DDF8F186	WRDY	1073	9.5	890	1991-2007; 2009-
Wind River at Riverton, WY	06228000	WRRY	17972714	WRRY	2309	9.0	774	1912-1917; 1919-1928; 1930-
Wind River below Boysen Reservoir	06259000	BYWY	34766052	WRBD	7701	Unknown	1471	1951-2016
Wind River near Crowheart, WY	06225500	WRCH	DD7AC650	WRCH	1891	10.0	1192	1946-2017
Wind River near Dubois,WY	06218500	WDWY	DD5A7430	-	232	5.0	173	1946-1992; 2001-
Wind River near Kinnear, WY	06227600	WRKY	DD35D068	WRKY	2194	9.0	815	1974-1979; 1991-
Yellowstone River at Corwin Springs, MT	06191500	-	CE3091C0	-	2616	Unknown	1820	1990-current
Yellowstone River nr Livingston, MT	06192500	-	DDE53060	-	3551	10.0	2260	1995-current
Yellowstone River at Billings, MT	06195750	BIL	CE51B936	-	3081	13.5	4100	1989-current
Yellowstone River at Forsyth, MT	06295000	THMT	DE0655E4	-	40152	14.0	7040	1994-current
Yellowstone River at Miles City, MT	06309000	MLS	CE5DB678	-	48288	14.0	7420	1995-current
Yellowstone River at Glendive, MT	06327500	GVMT	DD580754	-	66731	53.5	7300	2002-current
Yellowstone River nr Sidney, MT	06329500	SIMT	CE78A320	-	69099	19.0	7180	1989-current

Water Control Manual
Yellowtail Dam and Reservoir, Wyoming

Table of Relevant Hydrologic Stations

US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



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Reclamation Dams
- Buffalo Bill & Bull Lake Creek

Section 7 Reclamation Dams
- Boysen & Yellowtail
- Cities
- Snotel Station
- Real-Time Precip Station
- Stream
- Bighorn River Basin

Water Control Manual
Yellowtail Dam, Montana

SNOTEL and Precipitation Gaging Stations

U.S. Army Engineers District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Snotel Site Name	NRCS SITE ID	Elevation (feet)	Basin Name	Average Snow Water Equivalent in Inches (1981-2010)																									
				1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	Peak	Date
Burroughs Creek*	379	8750	Upper Wind	0.2	0.5	1.2	2.5	3.8	5.3	6.7	8.2	9.5	10.6	11.8	12.8	14.0	14.3	13.2	9.7	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	14.3	11-Apr
Castle Creek	1130	8400	Upper Wind	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cold Springs	405	9630	Upper Wind	0.1	0.3	0.9	1.6	2.4	3.0	3.6	4.3	4.8	5.3	6.0	6.6	7.2	5.7	4.1	2.6	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	7.2	1-Apr
Deer Park	923	9700	Popo Agie	0.1	0.9	2.3	3.6	4.5	5.8	7.4	8.8	10.2	11.7	12.9	14.2	16.0	17.1	17.7	15.1	6.9	3.0	0.0	0.0	0.0	0.0	0.0	0.1	18.1	25-Apr
Grave Springs	501	8550	near Badwater	0.1	0.5	1.1	1.7	2.3	2.9	3.8	4.6	5.3	6.2	7.0	7.8	9.1	9.6	9.1	5.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	10-Apr
Hobbs Park	525	10100	Popo Agie	0.3	1.1	2.3	3.6	4.8	5.9	6.9	8.0	8.8	9.8	10.9	12.4	14.3	15.5	16.4	14.6	8.3	3.7	0.5	0.0	0.0	0.0	0.0	0.1	16.5	27-Apr
Little Warm	585	9370	Upper Wind	0.2	0.5	1.2	2.2	3.2	4.1	5.0	6.0	6.9	7.7	8.6	9.6	10.7	10.9	9.4	6.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	11-Apr
Owl Creek	676	8975	Owl Creek	0.2	0.5	0.9	1.4	1.8	2.1	2.5	2.9	3.2	3.6	4.0	4.6	5.4	4.5	2.9	1.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.4	3-Apr
South Pass	775	9040	Popo Agie	0.1	0.5	1.6	2.9	4.4	6.0	7.5	8.9	10.2	11.6	12.9	14.5	16.0	16.3	15.5	10.8	4.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	16.5	9-Apr
St. Lawrence Alt	786	8620	Popo Agie	0.1	0.3	0.9	1.4	2.1	2.6	3.1	3.6	4.0	4.6	5.2	5.9	6.7	5.9	4.3	2.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	3-Apr
Togwotee Pass	822	9580	Upper Wind	0.3	1.3	2.7	4.9	7.2	9.2	11.5	13.8	15.8	17.7	19.4	21.2	23.3	24.7	25.6	24.3	18.1	10.8	2.2	0.0	0.0	0.0	0.0	0.0	25.6	2-May
Townsend Creek	826	8700	Popo Agie	0.1	0.5	1.2	1.9	2.7	3.4	4.2	4.8	5.4	6.2	6.9	7.8	9.2	9.1	7.5	4.3	1.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1	9.5	8-Apr
Bald Mtn.	309	9380	Mid Bighorn	0.5	1.6	3.0	4.2	5.7	7.1	8.9	10.6	12.1	13.4	14.9	16.3	18.5	19.8	20.9	20.0	13.3	5.9	0.3	0.0	0.0	0.0	0.0	0.1	21.1	7-May
Bear Trap Meadow	325	8200	Nowood River	0.1	0.3	0.6	1.0	1.5	2.0	2.6	3.0	3.5	3.9	4.5	5.1	5.3	4.0	1.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.3	1-Apr
Blackwater	350	9780	NF Shoshone	0.4	1.4	3.0	4.9	7.2	9.0	11.1	13.0	14.9	16.7	18.8	20.7	23.2	24.9	26.5	25.6	19.0	12.0	2.6	0.2	0.0	0.0	0.0	0.1	26.5	1-May
Bone Springs Div	358	9350	Shell Creek	0.5	1.4	2.8	4.0	5.2	6.2	7.5	8.8	10.0	11.1	12.5	13.7	15.7	16.7	17.1	15.0	6.8	1.9	0.0	0.0	0.0	0.0	0.0	0.1	17.1	1-May
Dome Lake	451	8880	Nr Shell Creek	0.2	0.8	1.9	2.9	3.9	4.6	5.6	6.4	7.2	8.0	8.8	9.9	11.8	12.2	11.1	8.0	2.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1	12.3	10-Apr
Evening Star	472	8880	Nr NF Shoshone	0.2	1.0	2.5	4.5	7.2	9.5	12.1	14.6	16.9	19.1	21.2	23.0	25.3	26.7	27.0	24.9	17.4	9.8	1.2	0.1	0.0	0.0	0.0	0.0	27.0	1-May
Kirwin	560	9200	Wood River	0.2	0.8	1.7	2.6	3.5	4.2	5.0	5.8	6.4	7.0	7.8	8.6	9.9	10.6	11.1	9.0	3.4	0.5	0.0	0.0	0.0	0.0	0.0	0.1	11.1	28-Apr
Middle Powder	625	9550	Nowood River	0.2	0.7	1.3	2.1	3.2	4.1	5.2	5.9	6.6	7.5	8.5	9.6	11.5	12.4	11.9	8.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	12.5	18-Apr
Powder River Pass	703	7760	Ten Sleep Cr	0.2	0.5	1.4	2.2	3.2	3.9	4.9	5.8	6.6	7.4	8.4	9.3	10.4	10.5	8.9	6.4	1.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	10.7	10-Apr
Shell Creek	751	9480	Shell Creek	0.7	1.7	2.9	3.9	5.1	6.0	7.2	8.4	9.5	10.5	11.7	12.8	14.5	15.6	16.5	15.3	8.2	2.9	0.0	0.0	0.0	0.0	0.0	0.2	16.9	5-May
Sylvan Lake	806	9580	Nr NF Shoshone	0.3	0.7	1.8	3.5	5.8	7.5	9.7	11.5	13.4	15.0	16.8	18.3	20.2	20.9	19.6	15.9	7.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	20.9	13-Apr
Sylvan Road	807	8420	NF Shoshone	0.0	0.1	0.5	1.5	3.1	4.3	5.6	7.0	8.1	9.2	10.2	11.0	11.9	10.7	6.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	1-Apr
Timber Creek	819	7120	Greybull River	0.1	0.3	0.9	1.3	1.7	1.9	2.3	2.5	2.8	3.1	3.5	4.2	5.1	4.7	3.6	1.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	1-Apr
Two Ocean Plateau	837	7950	Nr SF Shoshone	0.3	1.4	3.3	5.7	8.5	11.0	13.7	16.3	18.6	20.6	23.1	25.2	28.2	30.1	31.4	30.3	23.4	15.6	4.0	0.1	0.0	0.0	0.0	0.1	31.4	3-May
Marquette**	616	8760	SF Shoshone	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
AVERAGE OF ALL STATIONS				0.2	0.8	1.8	2.9	4.2	5.3	6.5	7.7	8.8	9.9	11.0	12.2	13.7	14.1	13.6	11.2	6.0	2.8	0.4	0.0	0.0	0.0	0.0	0.1	13.8	1-Jan

Source - Natural Resources Conservation Service (NRCS) National Water and Climate Center

* Burroughs Creek site was affected by wildfires and the snow may not accumulate and melt as it had during the 1981-2010 period.

** NRCS has not calculated 30 year values for Marquette.

Water Control Manual
Yellowtail Dam, Montana

Table of Snow Water Equivalent for SNOTEL Stations

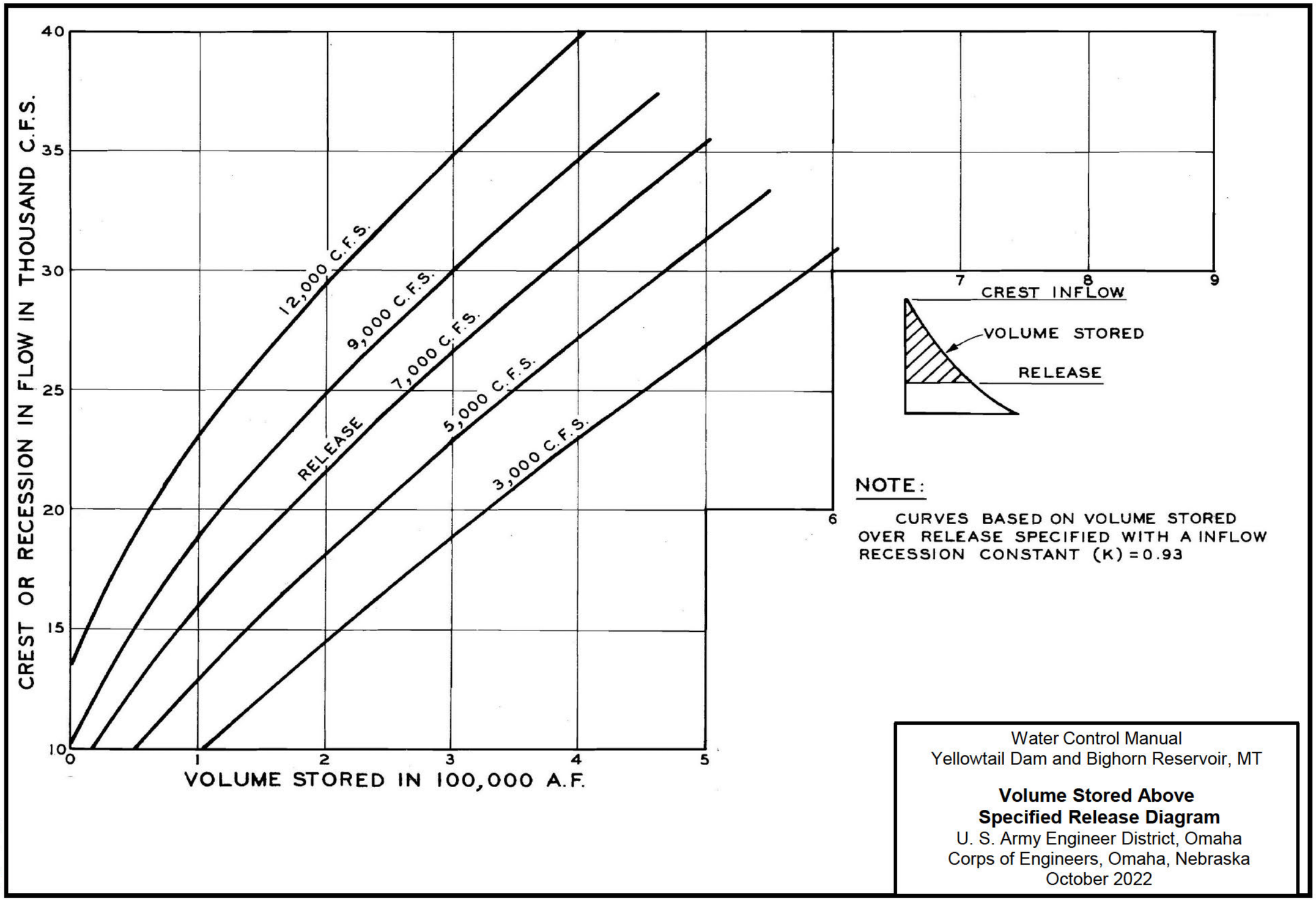
US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Station Name	Elevation ft	Period of Record	Average Precipitation (Inches)												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Crandall	6612	1993-2019	0.09	0.29	0.36	0.81	1.42	1.45	1.14	0.99	0.97	0.98	0.58	0.20	9.30
Eagle	7500	1999-2019	0.18	0.16	0.64	0.82	1.76158	1.59	0.83	1.11	1.26	1.23	0.34	0.33	10.25
Elkhorn	8325	1989-2019	0.08	0.14	0.26	0.85	1.59	1.33	0.92	0.76	1.12	1.66	0.28	0.07	9.08
False Rock	6380	1997-2019	0.02	0.13	0.38	0.97	1.57	0.99	0.75	0.66	0.84	0.58	0.10	0.18	7.16
Grass Creek Divide	7100	1991-2019	0.06	0.10	0.52	0.98	2.31	2.17	1.49	1.06	1.39	0.77	0.16	0.09	11.10
Lander	5587	1892-2019	0.41	0.58	1.16	1.87	2.20	1.27	0.78	0.61	1.05	1.29	0.86	0.58	12.66
Leigh Creek	8202	1999-2019	0.25	0.30	0.68	1.14	2.14	1.43	1.00	0.99	1.53	1.11	0.37	0.27	11.20
Pistol Draw	4520	2016-2019	0.03	0.10	1.06	2.16	1.24	0.31	0.16	0.25	1.63	1.00	0.63	0.15	8.71
Raspberry	10040	1985-2019	0.14	0.14	0.47	0.93	1.62	1.40	1.16	2.16	1.48	0.94	0.32	0.24	11.00
Rattlesnake Mtn	6800	1988-2019	0.11	0.23	0.64	1.76	2.71	2.03	1.37	1.18	1.31	1.08	0.33	0.11	12.86
Riverton	5443	1907-2019	0.24	0.27	0.55	1.30	1.72	1.28	0.89	0.57	0.90	0.89	0.50	0.32	9.43
Sharpnose	5555	2015-2019	0.04	0.14	1.41	1.96	3.24	0.68	0.10	0.49	0.70	0.63	0.26	0.08	9.72
Split Rock	6000	1988-2019	0.06	0.14	0.50	1.31	2.69	1.60	1.30	0.80	1.40	1.12	0.40	0.09	11.41
Wind River Raws	9235	1991-2019	0.11	0.19	0.48	1.28	2.27	1.45	0.97	1.00	1.19	0.77	0.19	0.13	10.00
Lander Airport	5587	1990	0.48	0.64	1.20	2.05	2.57	1.37	0.68	0.51	1.03	1.28	0.82	0.57	13.06
Poker	6440	1992	0.03	0.10	0.37	1.28	2.645	1.59	1.46	0.83	1.28	0.83	0.13	0.03	10.58
Hyatt High	5720	1992	0.07	0.61	0.64	1.17	1.98	1.49	1.09	0.60	1.34	1.06	0.51	0.22	10.78
Mill Creek	8930	1989	0.07	0.16	0.28	0.59	1.79	1.88	1.37	1.20	1.53	0.76	0.19	0.07	9.90
Grebe,	7900	2011	0.03	0.95	1.86	2.18	2.23	2.02	1.20	1.52	2.13	1.97	1.24	0.66	17.99
Riverton Regional Airport*	5443	1990	0.23	0.40	0.62	1.31	1.91	0.82	0.50	0.47	0.79	0.83	0.34	0.27	8.25
Burgess,	7743	1992	0.03	0.04	0.17	0.51	1.88	1.77	1.55	1.11	1.37	0.78	0.09	0.02	9.31
Echeta,	4320	1990	0.04	0.17	0.25	0.89	2.04	1.59	1.23	0.90	0.90	0.79	0.15	0.06	9.02
Bighorn Mountain	7280	1991	0.01	0.07	0.45	1.29	2.77	2.37	1.48	1.44	1.89	1.00	0.17	0.03	12.97
Cabin Creek	8680	2005	0.03	0.52	0.82	1.38	1.70	1.54	1.17	1.29	1.48	1.63	0.61	0.34	12.51
Hillsboro	3986	2003	0.01	0.15	0.47	0.75	1.74	1.23	0.60	0.57	1.18	0.74	0.27	0.32	8.03
School House Park	8080	1989	0.02	0.07	0.33	0.92	2.36	1.97	1.73	1.13	1.25	0.76	0.29	0.15	10.97
Pryor	8150	2004	0.01	0.27	0.57	1.16	2.75	1.67	1.11	1.24	1.63	0.96	0.33	0.13	11.84
Pryor Mountain	6186	1991	0.06	0.38	0.97	2.03	3.2131	2.94	1.14	1.14	1.45	1.60	0.45	0.16	15.53
Timbercrest	6400	2001	0.01	0.09	0.30	1.32	3.75	2.24	1.81	1.43	1.57	1.35	0.66	0.06	14.58
Soda Butte	7800	2009	0.04	0.85	1.36	2.28	2.19	2.17	1.68	2.00	2.47	3.05	1.33	0.55	19.97
Soda Springs	4020	2003	0.01	0.22	0.62	1.43	3.08	1.77	1.13	0.96	1.40	1.19	0.38	0.18	12.37
Fishtail	4550	1992	0.02	0.26	0.63	1.46	3.55	1.88	1.12	0.81	1.39	1.33	0.41	0.15	12.99
Derby Mountain	7000	2001	0.02	0.50	0.94	1.64	4.15	2.98	1.59	1.34	1.65	1.77	0.62	0.27	17.47
Wolf Mountain	5217	1985	0.21	0.29	0.70	1.52	3.59	2.59	1.64	1.15	1.79	1.65	0.50	0.13	15.76
Little Bighorn	3400	1997	0.05	0.46	0.87	1.58	2.63	1.72	0.68	0.86	1.43	1.23	0.48	0.38	12.38
Powell Field Station	4390	1981	0.16	0.16	0.26	0.52	1.39	1.20	0.78	0.47	0.76	0.59	0.20	0.13	6.47
Cody 12 SE	5380	1948	0.32	0.34	0.54	1.20	2.03	1.84	0.94	0.84	0.99	0.65	0.41	0.30	9.73

Water Control Manual
Yellowtail Dam, Montana

Table of Average Monthly Precip Totals at Precipitation Stations

US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



NOTE:

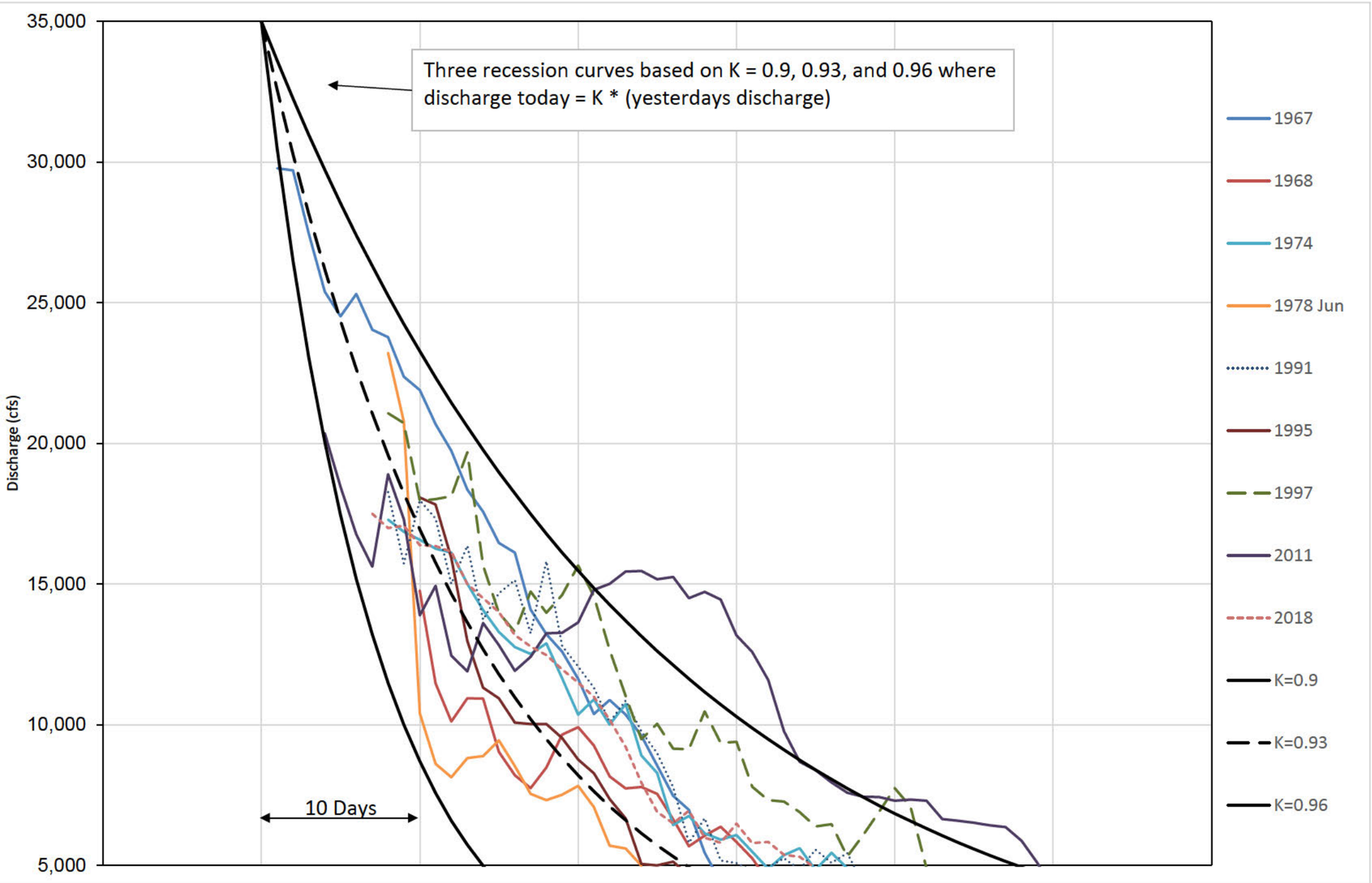
CURVES BASED ON VOLUME STORED OVER RELEASE SPECIFIED WITH A INFLOW RECESSION CONSTANT (K) = 0.93

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Volume Stored Above Specified Release Diagram

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

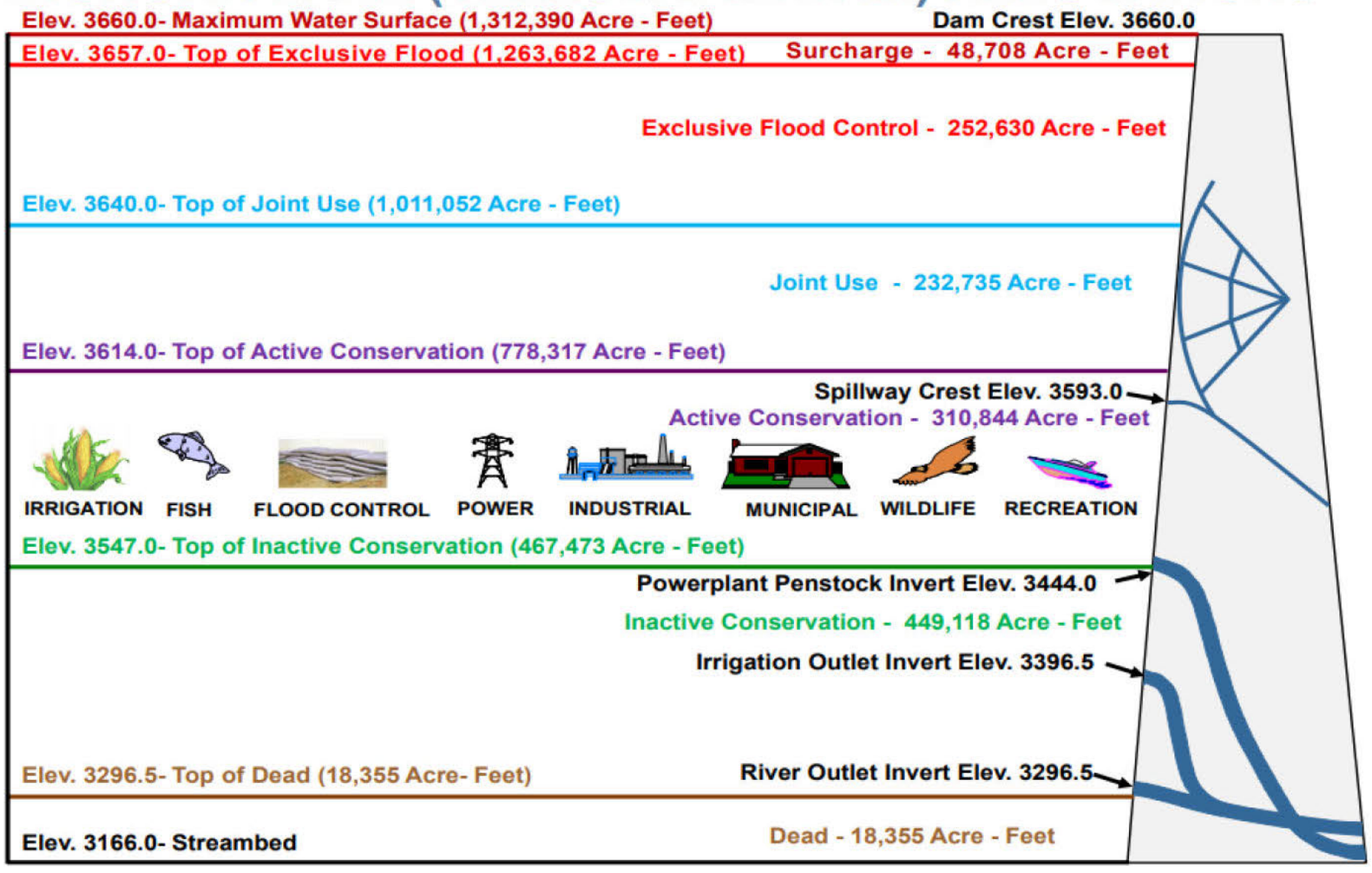
Plate 6-1



Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT
Yellowtail Inflow Hydrograph Recessions
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 6-2

BIGHORN LAKE (YELLOWTAIL DAM) ALLOCATIONS



Revised 8/27/2020

Source of Data: US Bureau of Reclamation

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

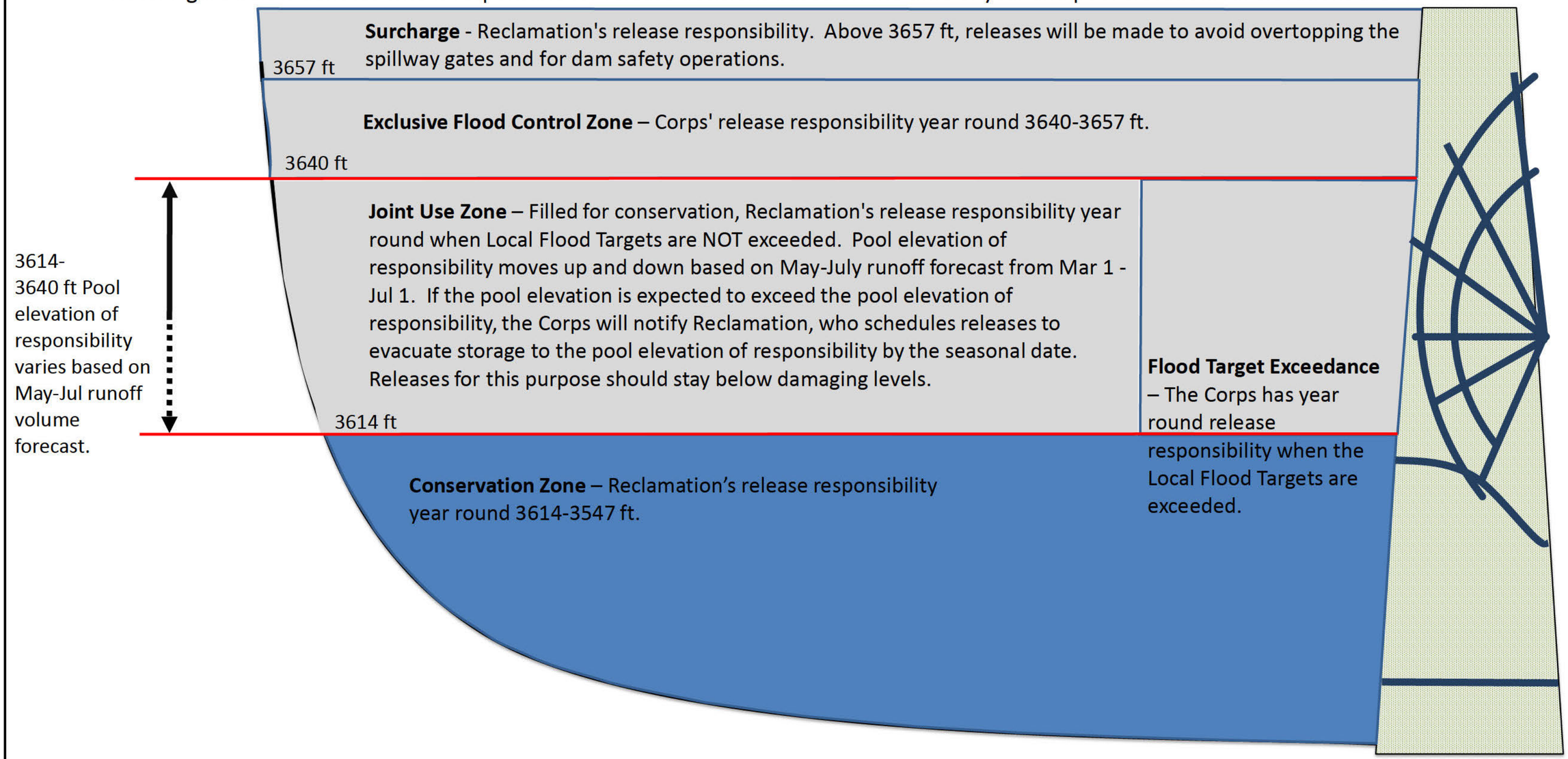
Reservoir Storage Allocations

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 7-1

Release Responsibility Diagram

Note: Figure below denotes who is responsible for release decisions based on the time of year and pool elevation. All elevations are NGVD29.



Note: Drawing not to scale

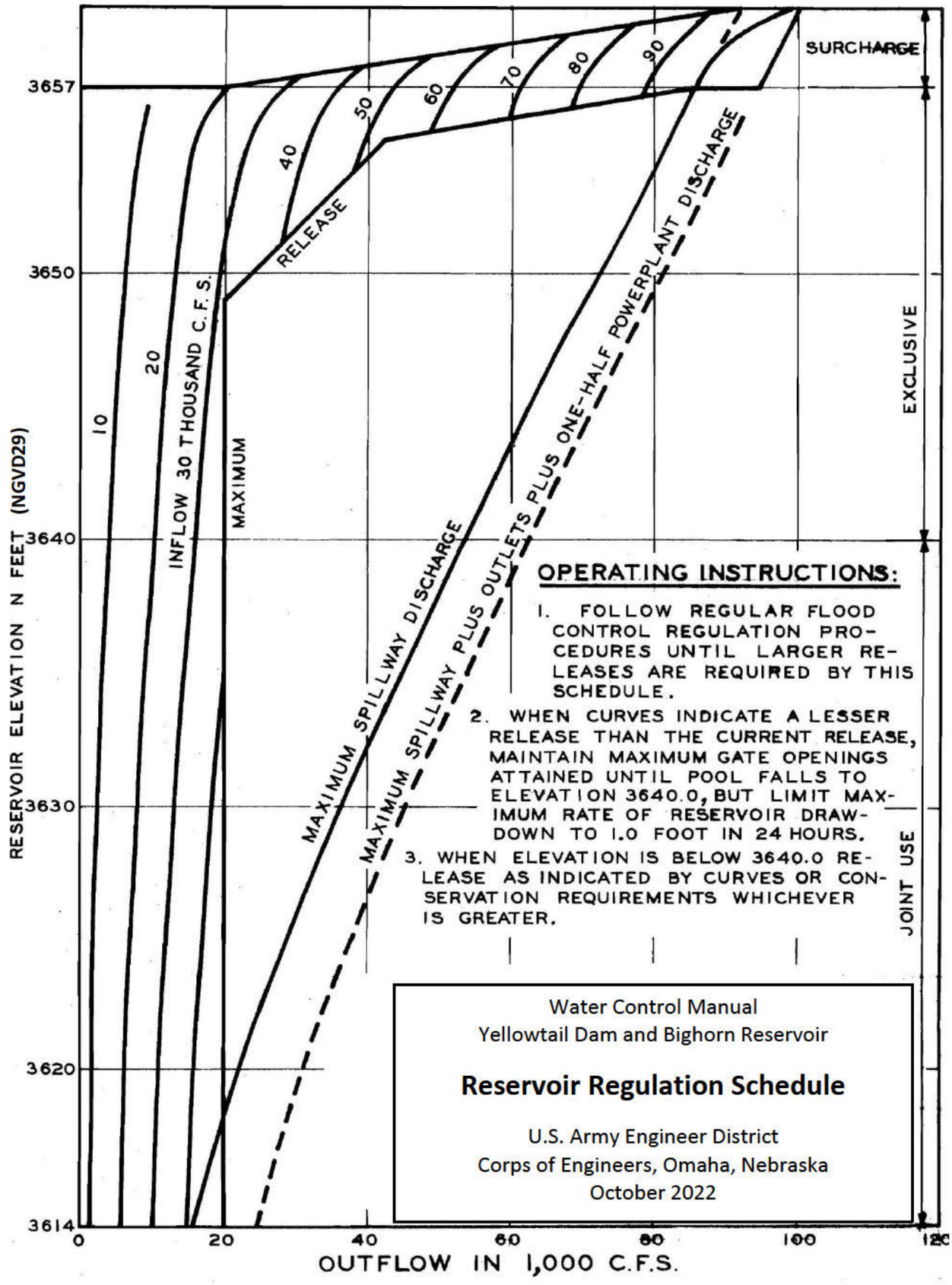
Water Control Manual
Yellowtail Dam, Montana

Release Responsibility Diagram

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 7-2

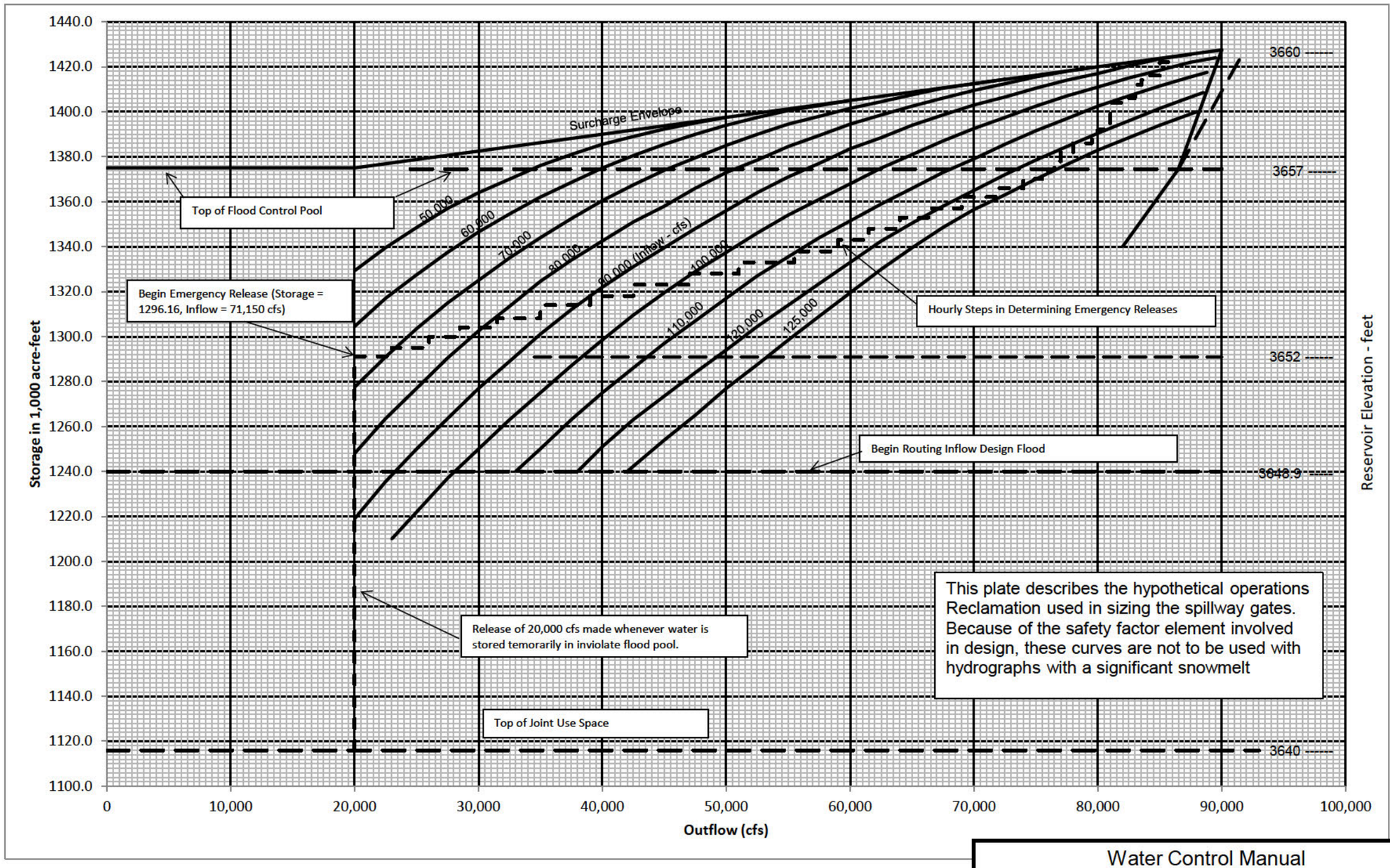
Scanned from Plate 34, Report on Reservoir Regulations for Flood Control, Yellowtail Dam and Bighorn Lake, MT, U.S. Army Engineer Distirct, Omaha, NE, January 1974.



Water Control Manual
Yellowtail Dam and Bighorn Reservoir

Reservoir Regulation Schedule

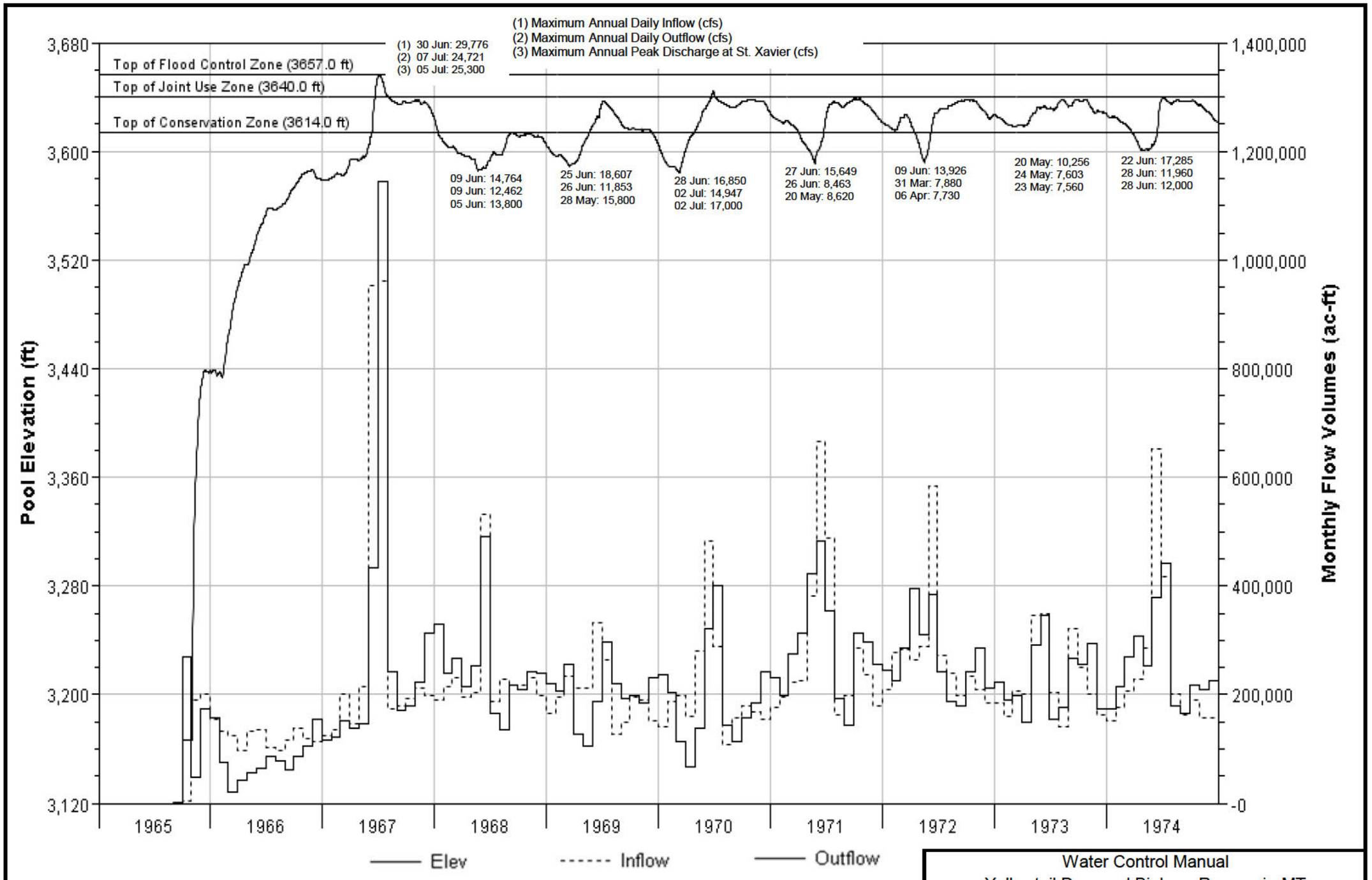
U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022



Developed from Plate 35 Report on Reservoir Regulations for Flood Control, Yellowtail Dam and Bighorn Lake, MT, U.S. Army Engineer Distirct, Omaha, NE, January 1974.

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Emergency Release Diagram II
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source of Data: USBR HydroMet-Hydrological Database

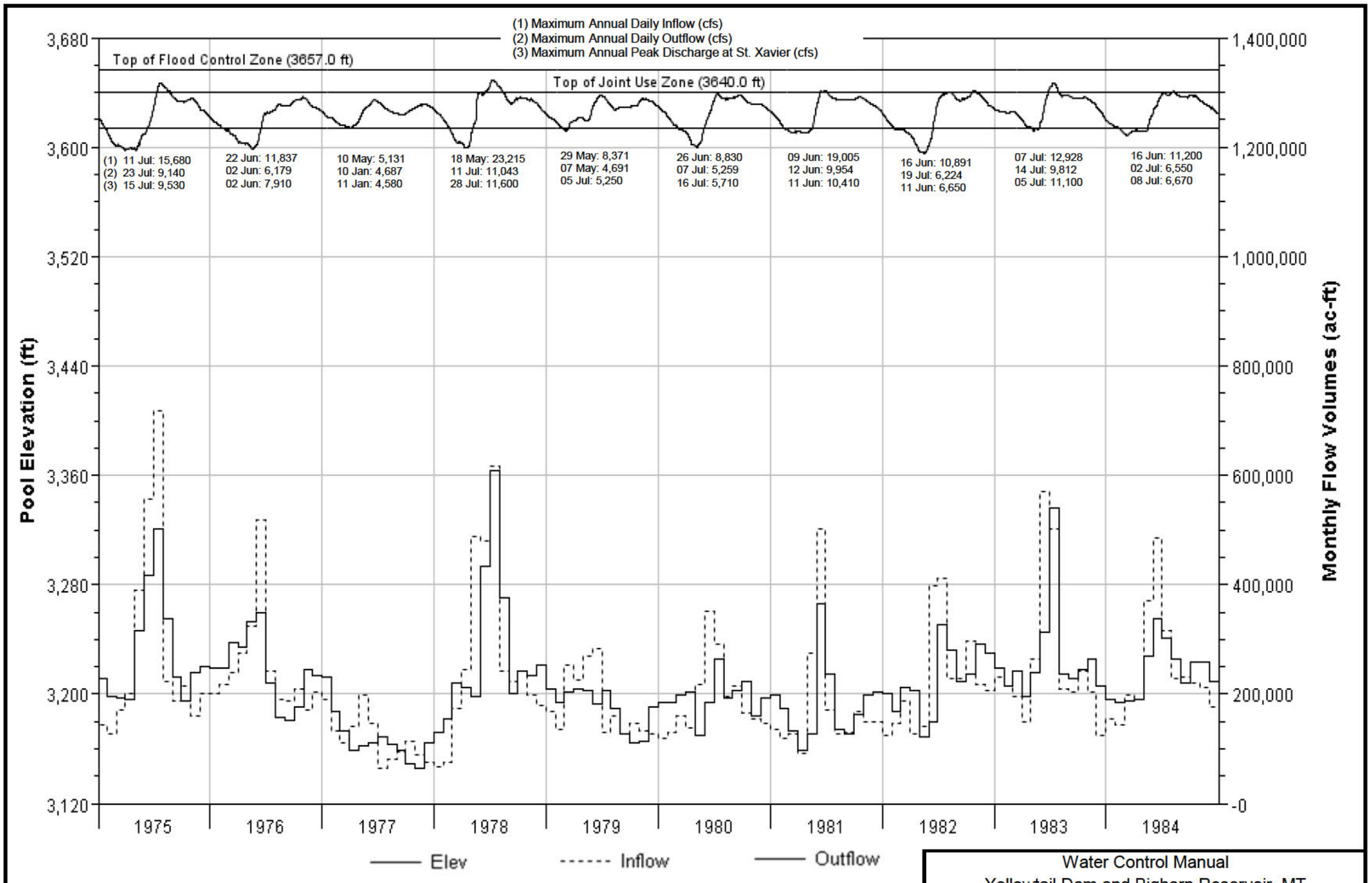
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation, Inflows, and Releases

1965-1974

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-1



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source of Data: USBR HydroMet-Hydrological Database

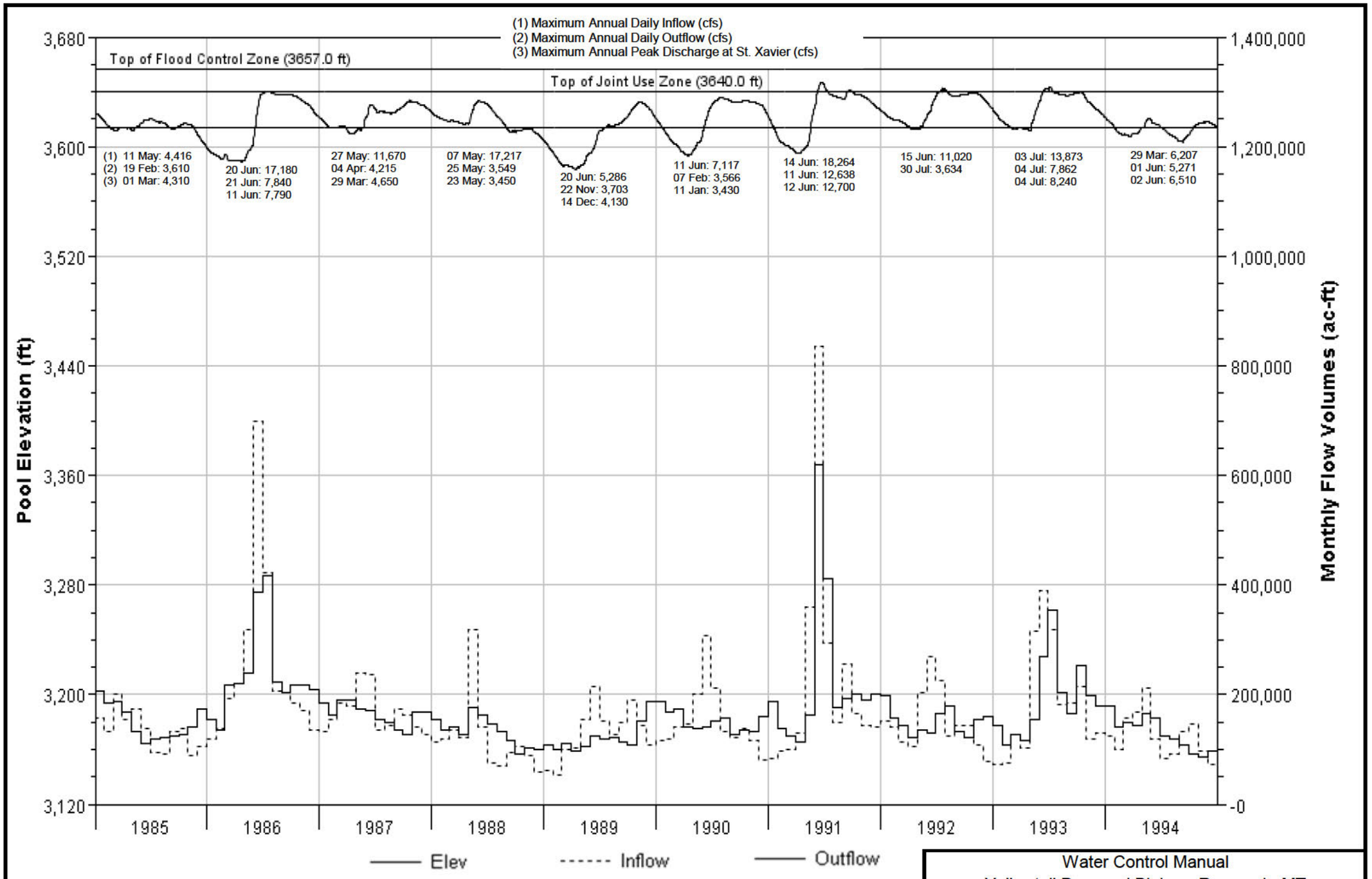
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation, Inflows, and Releases

1975-1984

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-2



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source of Data: USBR HydroMet-Hydrological Database

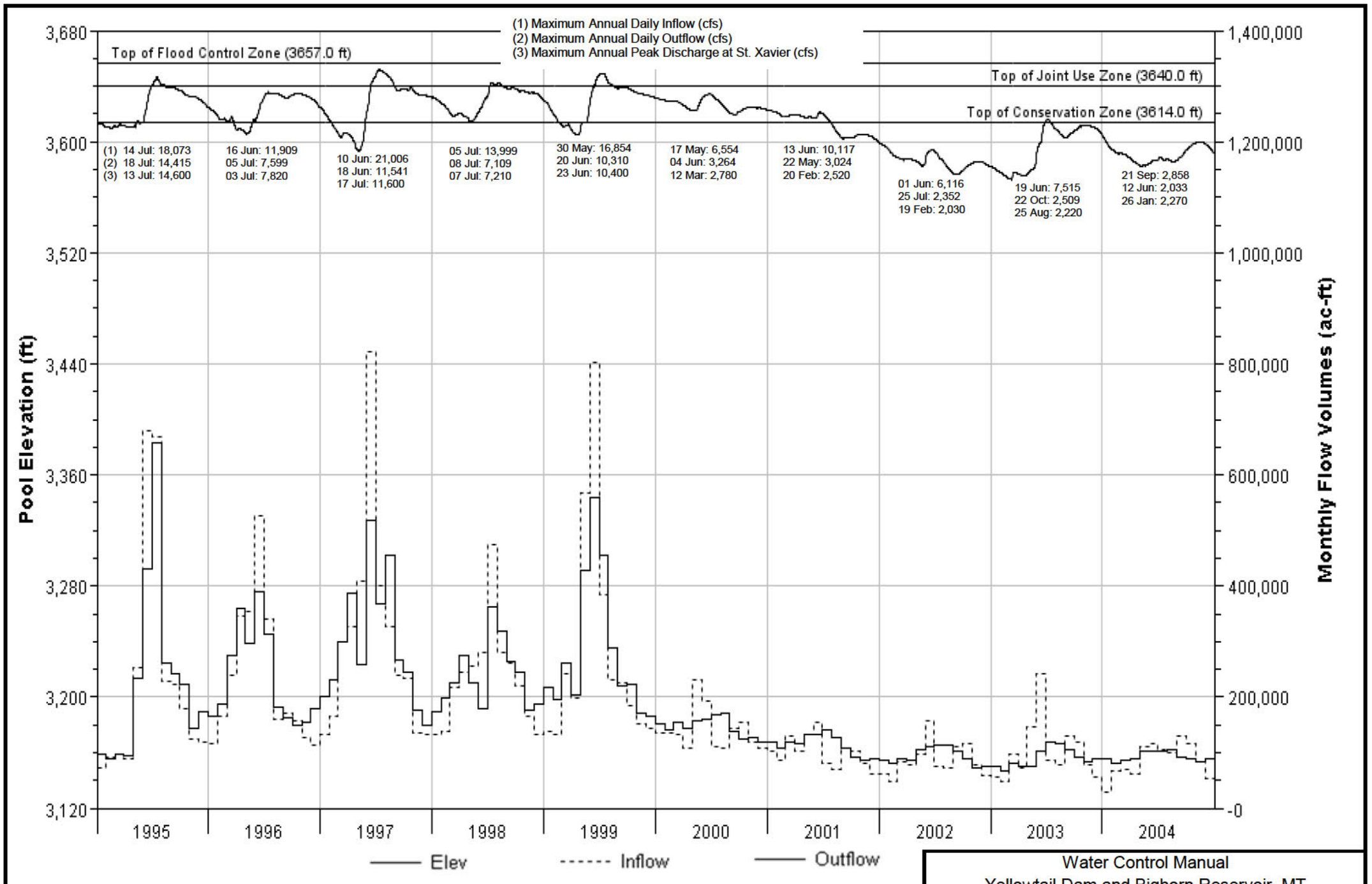
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation, Inflows, and Releases

1985-1994

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-3



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source of Data: USBR HydroMet-Hydrological Database

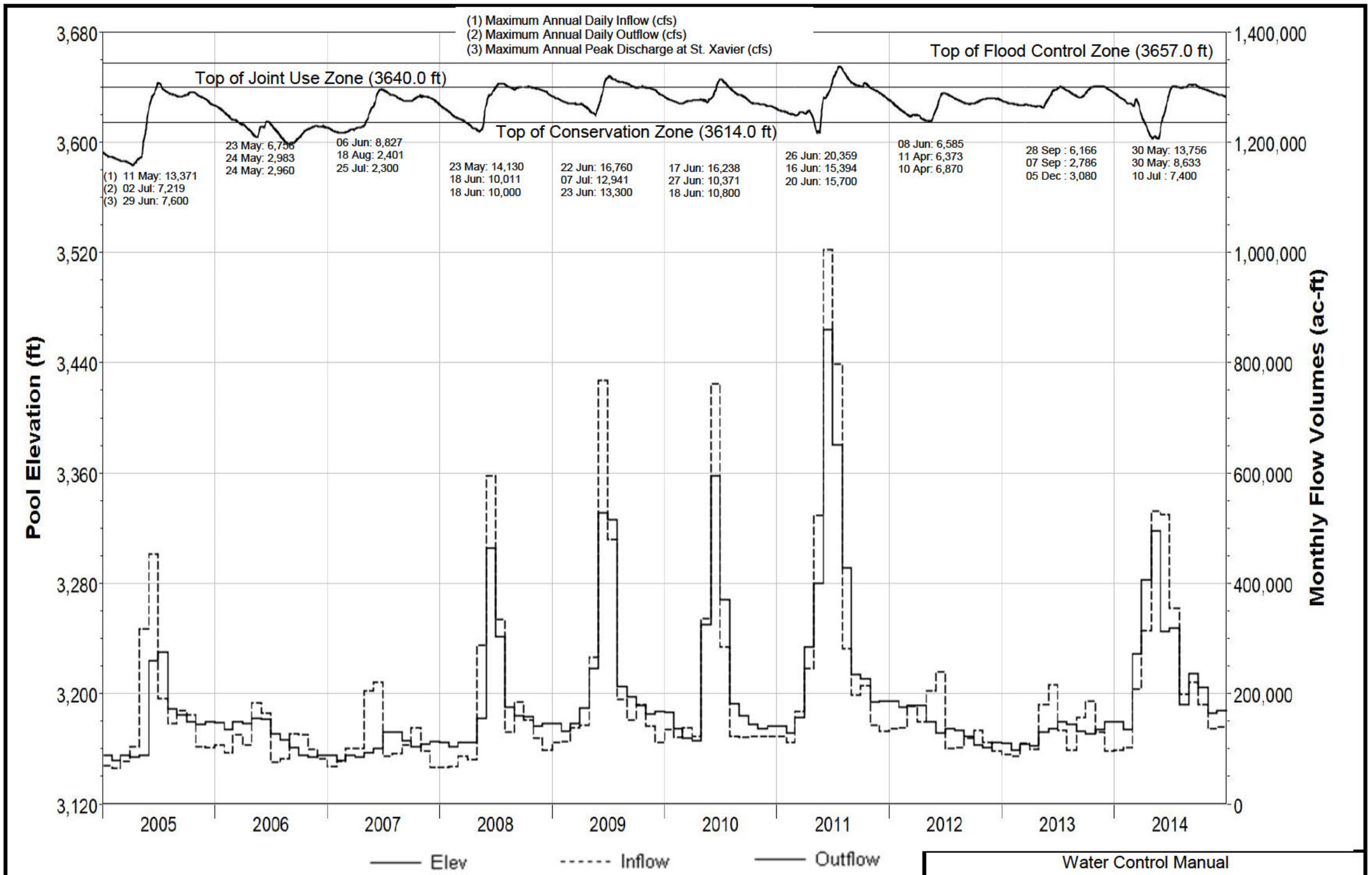
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation, Inflows, and Releases

1995-2004

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-4



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source of Data: USBR HydroMet-Hydrological Database

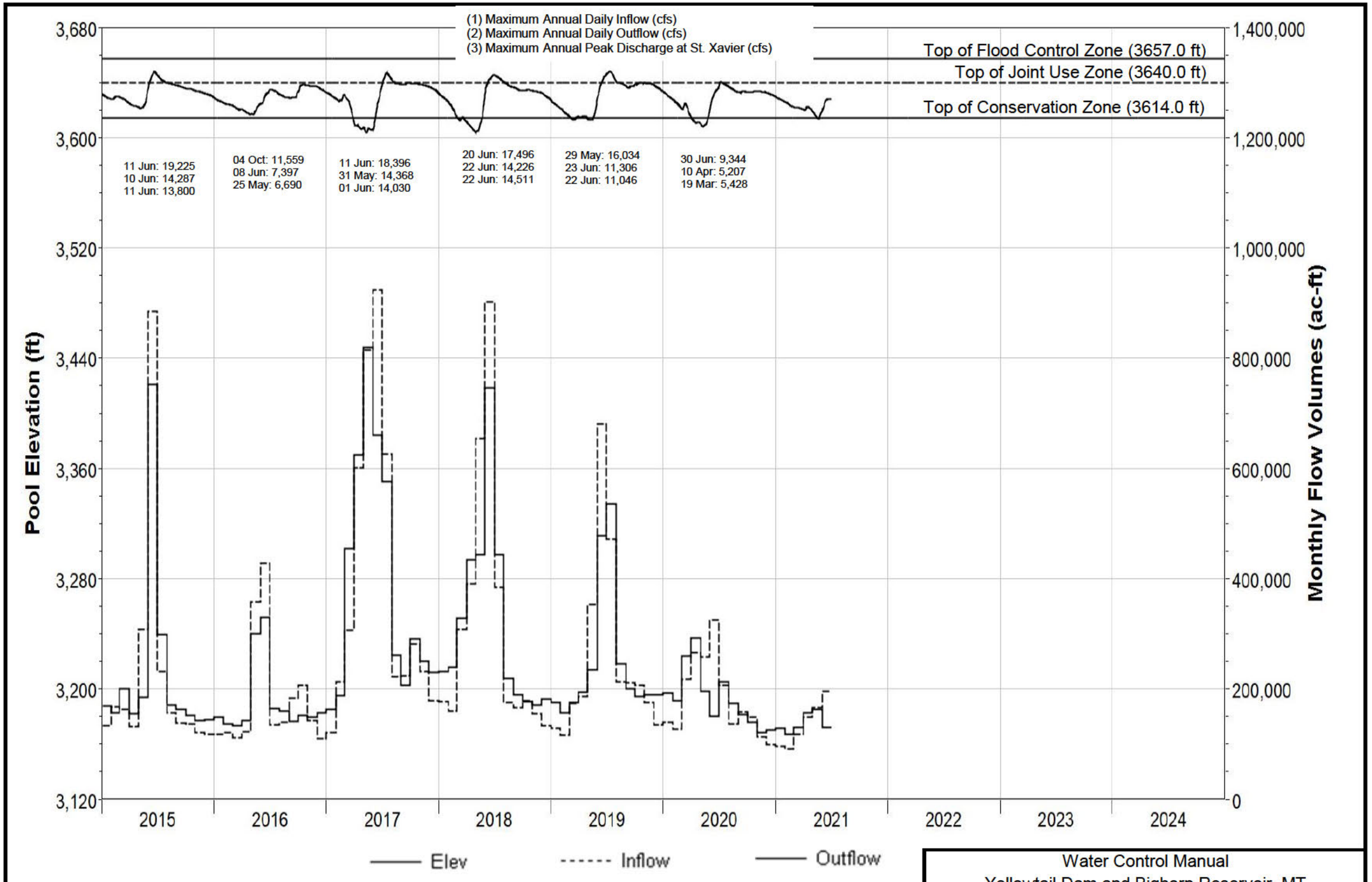
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation, Inflows, and Releases

2005-2014

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-5



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source of Data: USBR HydroMet-Hydrological Database

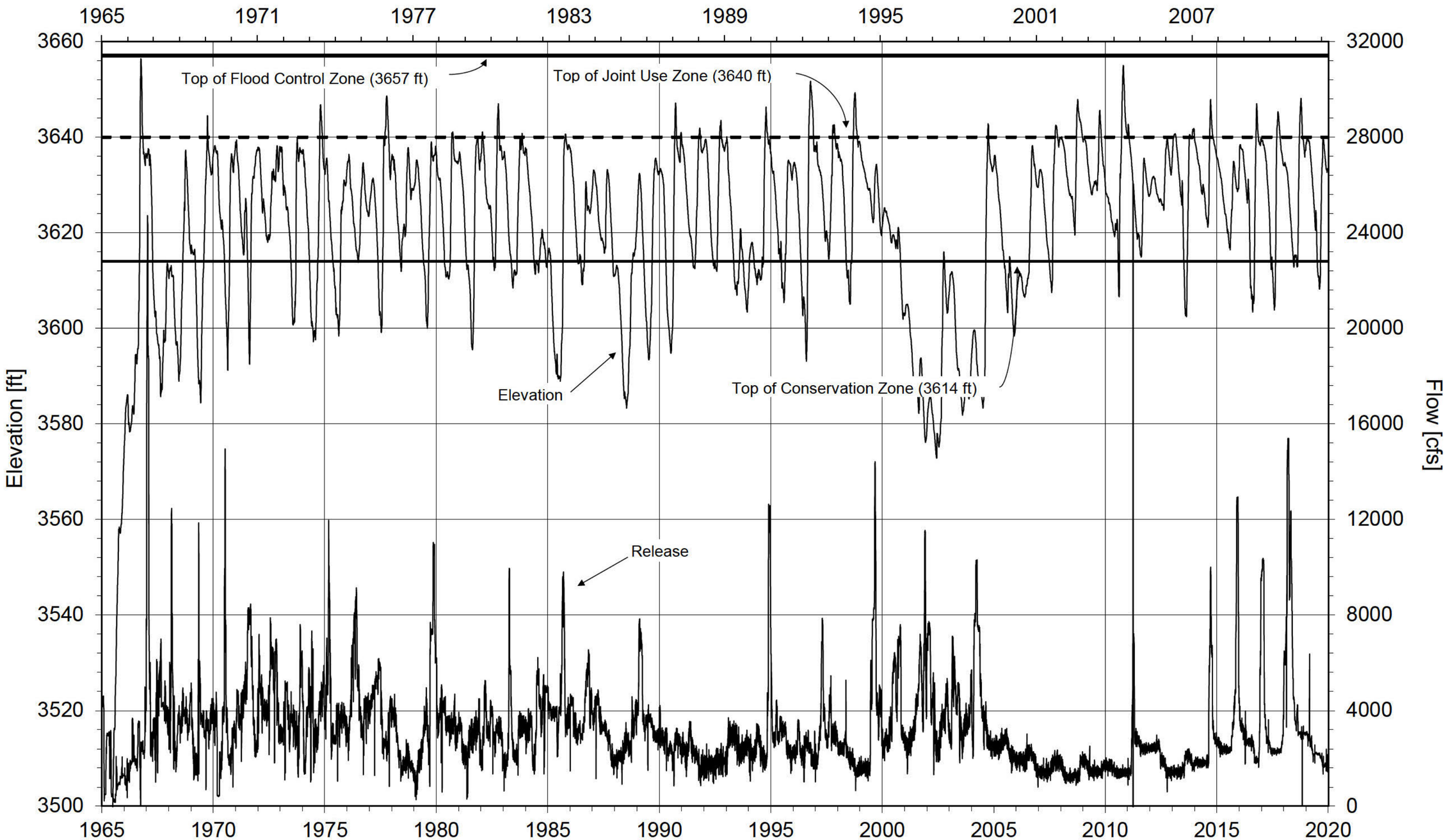
Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation, Inflows, and Releases

2015-2024

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-6



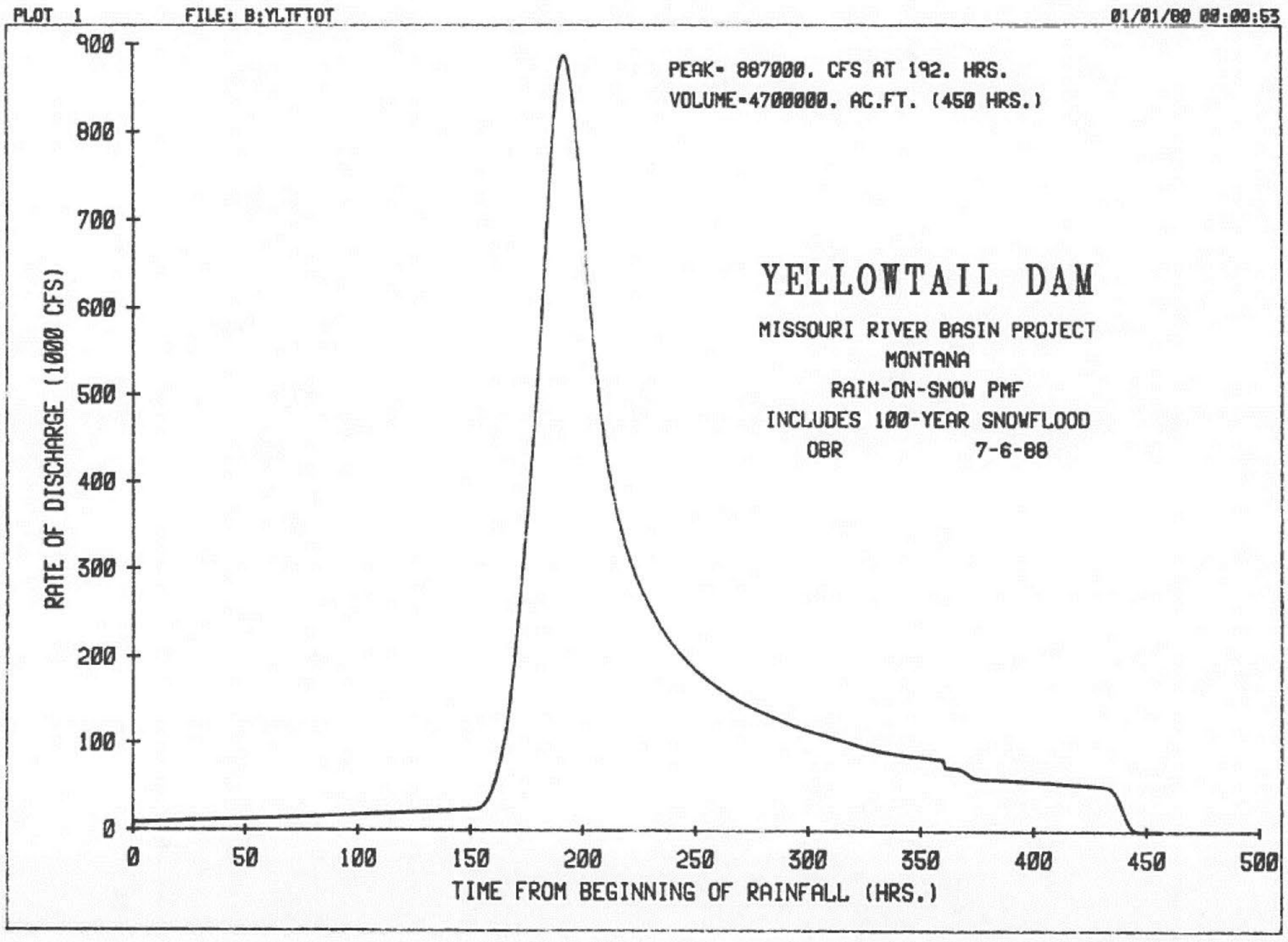
Source of data: CWMS 0168 data

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Historical Pool Elevation and Releases
Period of Record

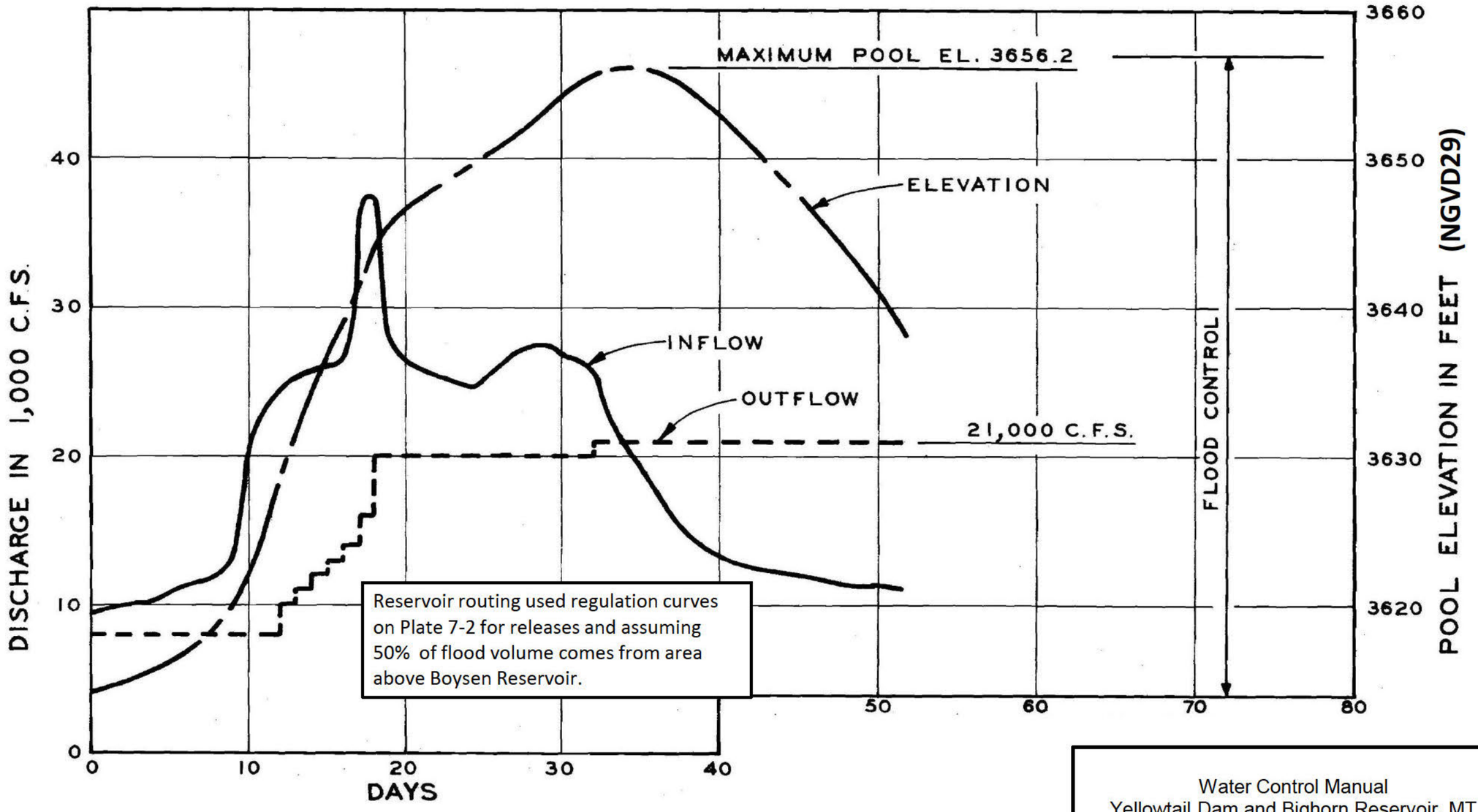
U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

Plate 8-7



Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Probable Maximum Flood Routing
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



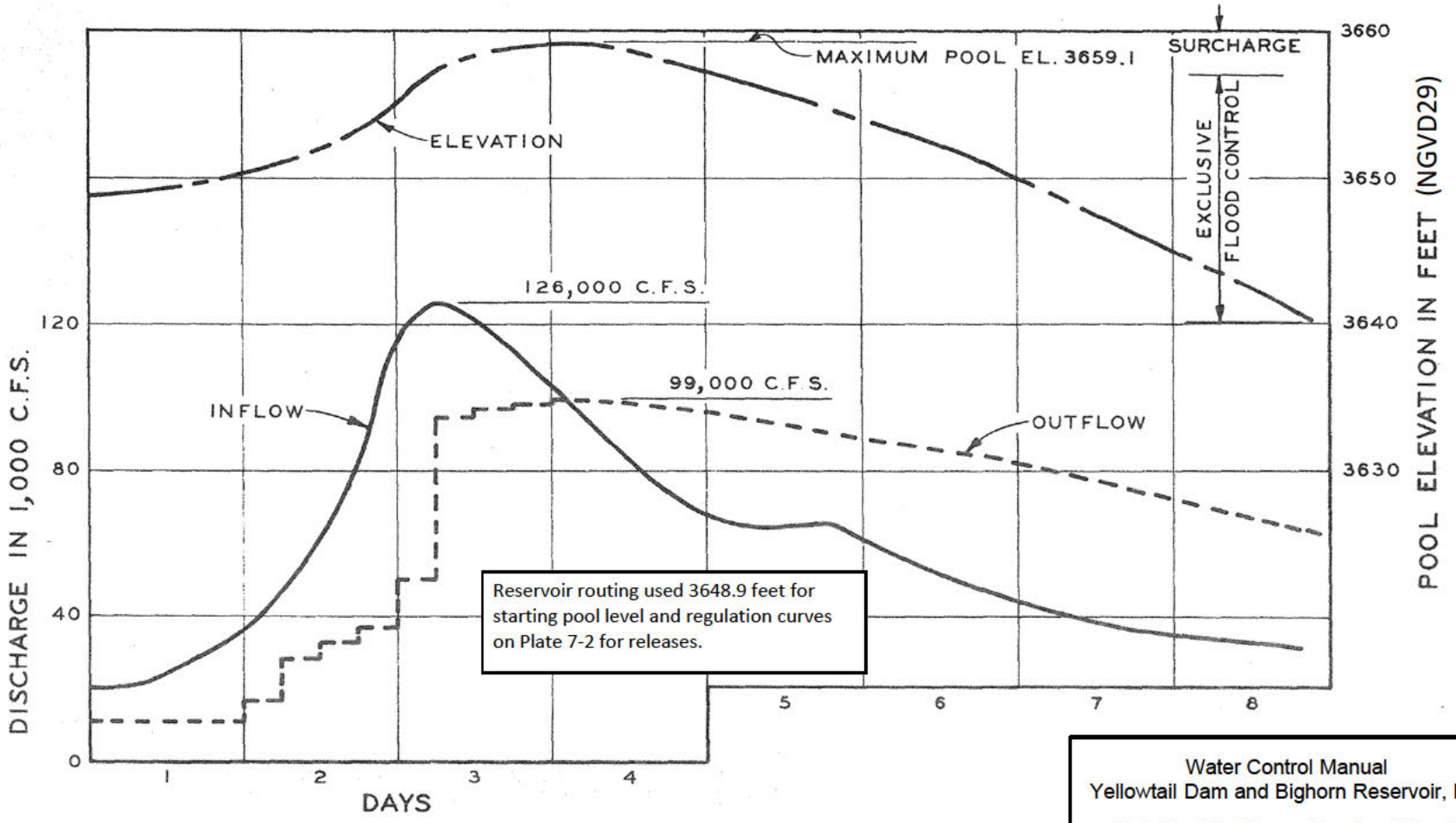
Reservoir routing used regulation curves on Plate 7-2 for releases and assuming 50% of flood volume comes from area above Boysen Reservoir.

Scanned from Plate 36, Report on Reservoir Regulations for Flood Control, Yellowtail Dam and Bighorn Lake, MT, U.S. Army Engineer Distirct, Omaha, NE, January 1974.

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Reservoir Design Flood

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



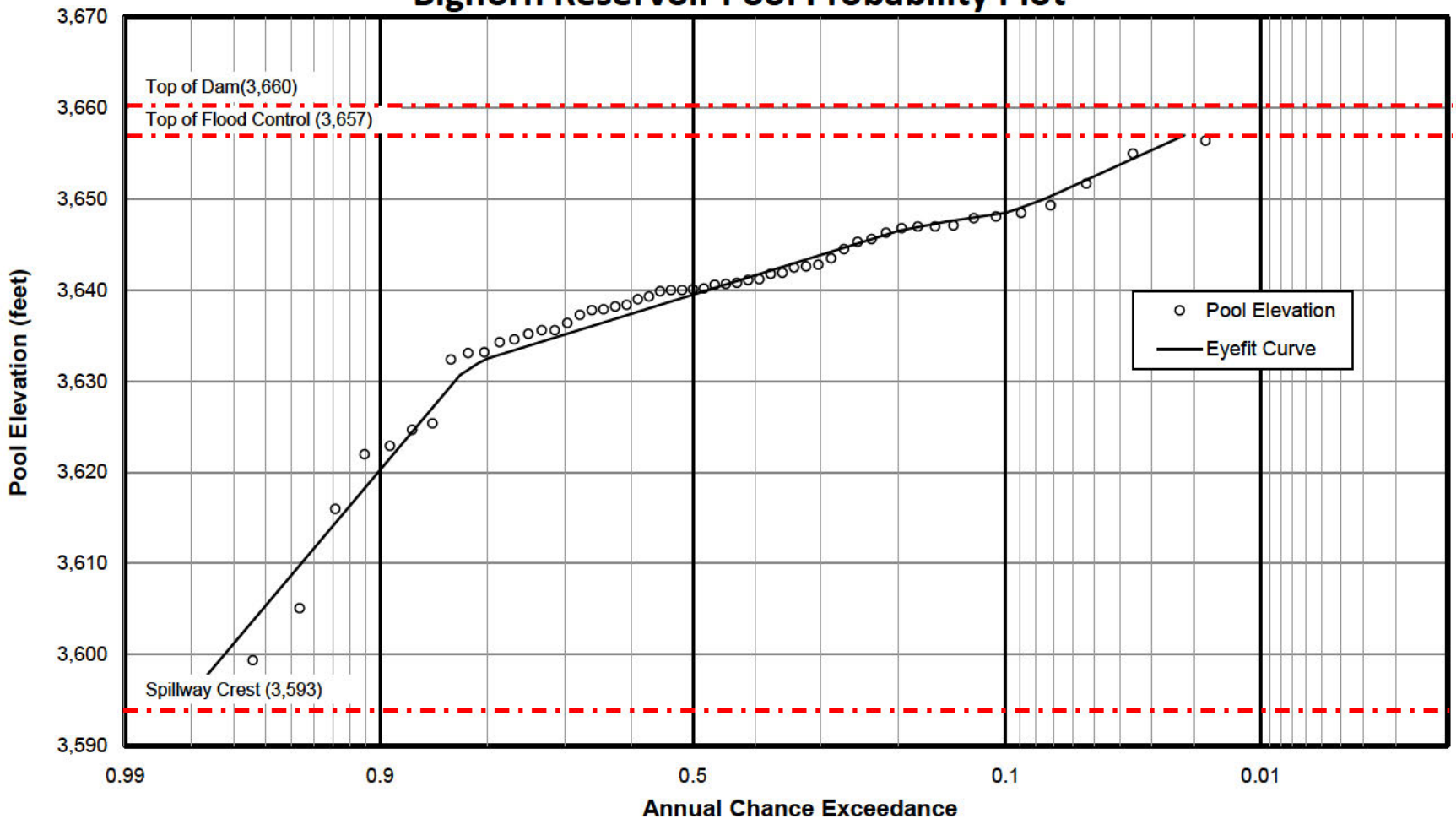
Reservoir routing used 3648.9 feet for starting pool level and regulation curves on Plate 7-2 for releases.

Scanned from Plate 37, Report on Reservoir Regulations for Flood Control, Yellowtail Dam and Bighorn Lake, MT, U.S. Army Engineer Distirct, Omaha, NE, January 1974.

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Original Spillway Design Flood

U. S. Army Engineer District, Omaha Corps of Engineers, Omaha, Nebraska
October 2022



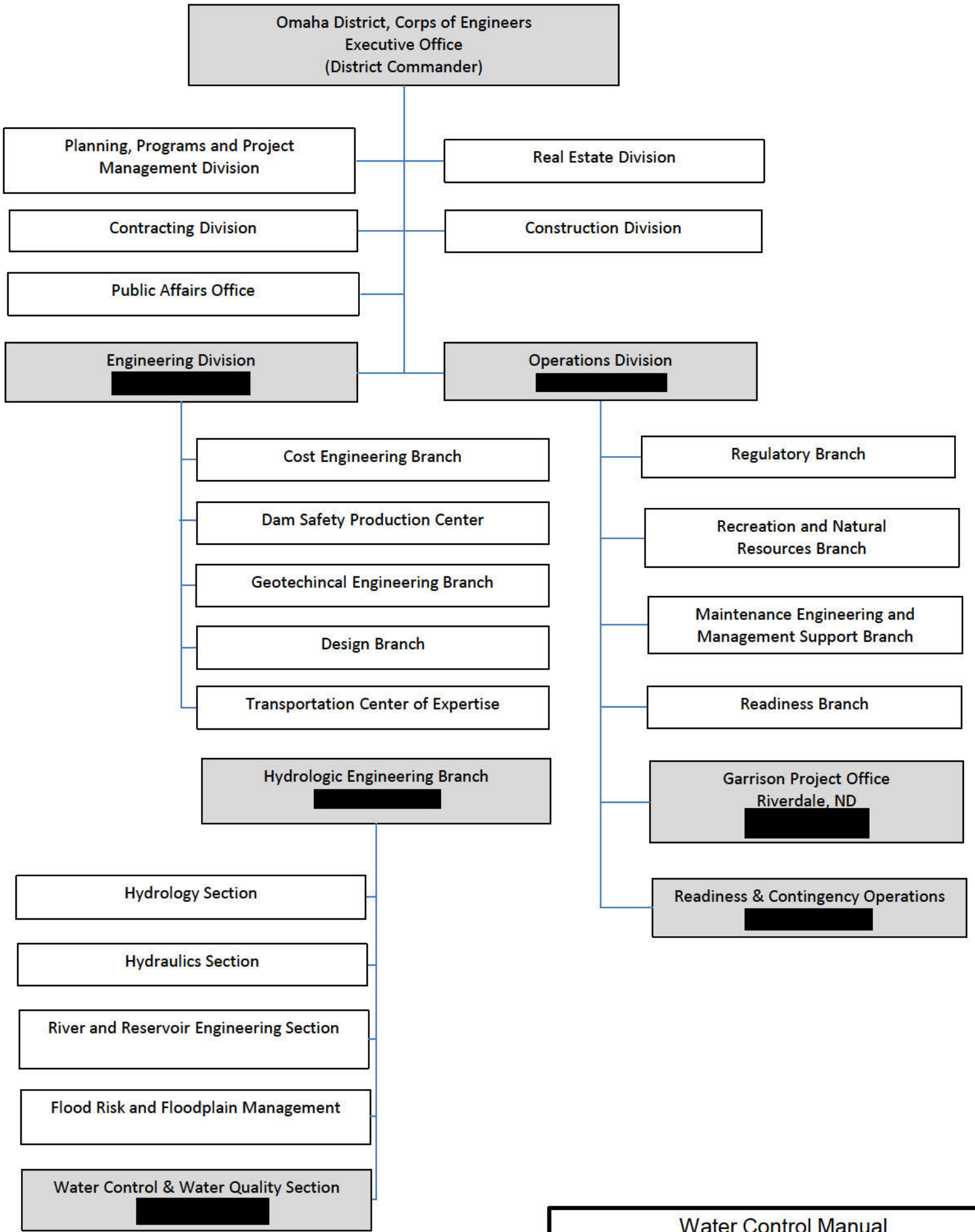
NOTE: The above plot was created based only on historical pool levels from 1967-2020; no modeling or routing was used to compute data points. The curve was plotted using the eyefit method.

Water Control Manual
Yellowtail Dam and Bighorn Reservoir, MT

Pool Probability Plot

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
October 2022

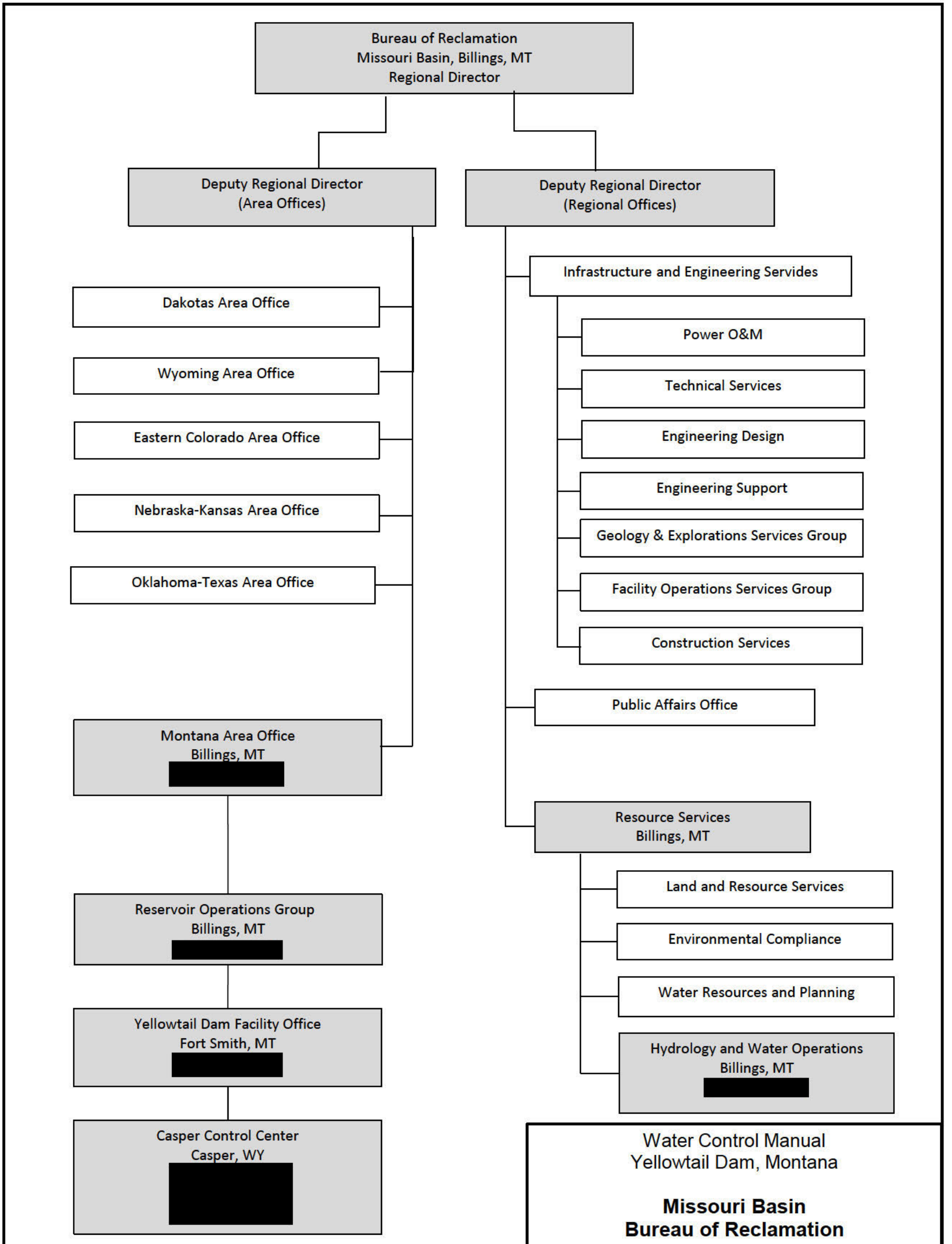
Plate 8-11



Water Control Manual
Yellowtail Dam, Montana

Omaha District
Corps of Engineers
Organization Chart

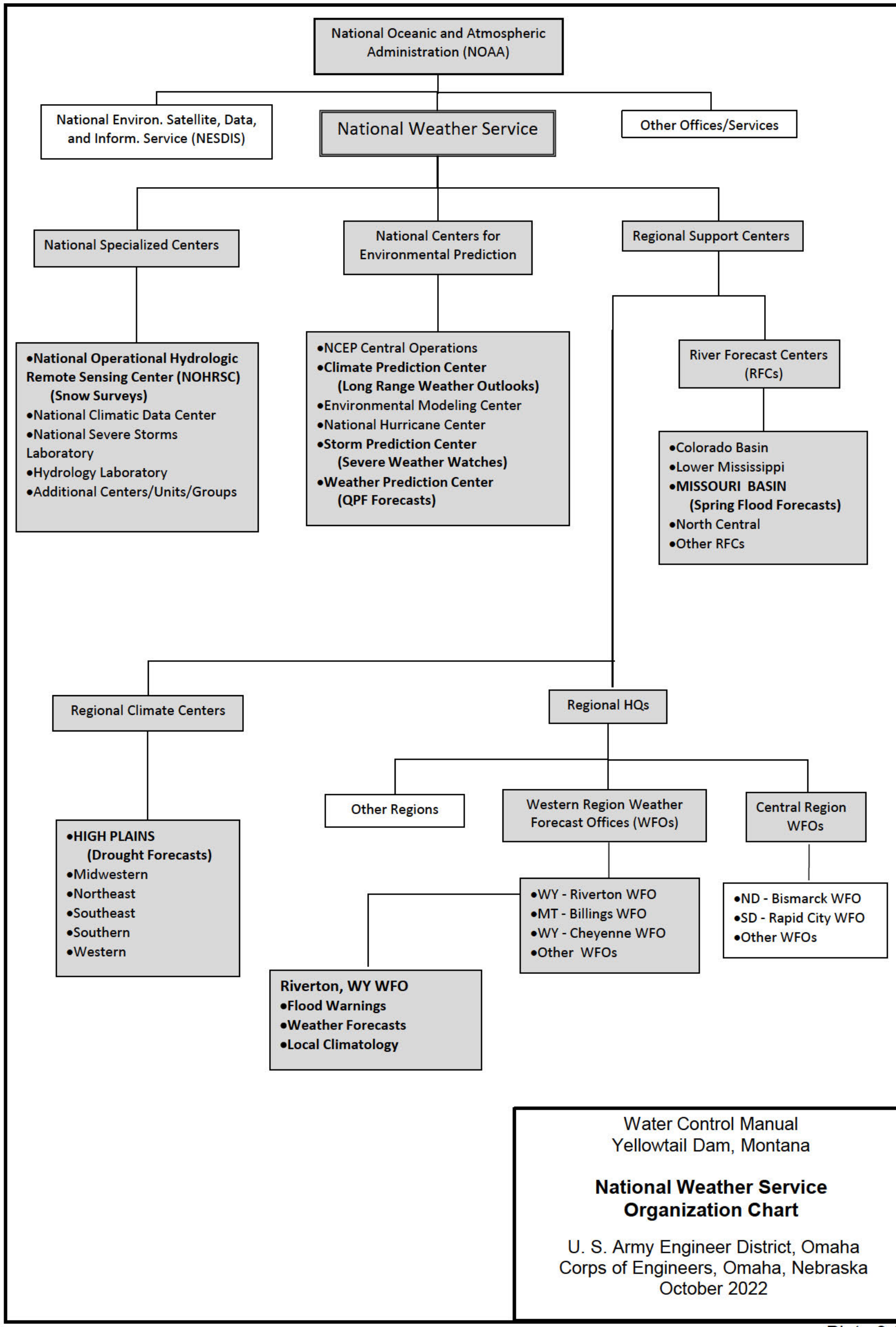
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



Water Control Manual
Yellowtail Dam, Montana

Missouri Basin
Bureau of Reclamation
Organization Chart

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022



Water Control Manual
Yellowtail Dam, Montana

National Weather Service Organization Chart

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
October 2022