COPY NO. 33

UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REGION 6

YELLOWTAIL UNIT

MONTANA-WYOMING

LOWER BIGHORN DIVISION

MISSOURI RIVER BASIN PROJECT

BILLINGS, MONTANA

JUNE 1962

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

REGIONAL OFFICE, REGION 6
P. O. BOX 2553
BILLINGS, MONTANA 59101

June 1965

IN REPLY
REFER TO: 750

To: All Holders of Report

From: Regional Director, Billings, Montana

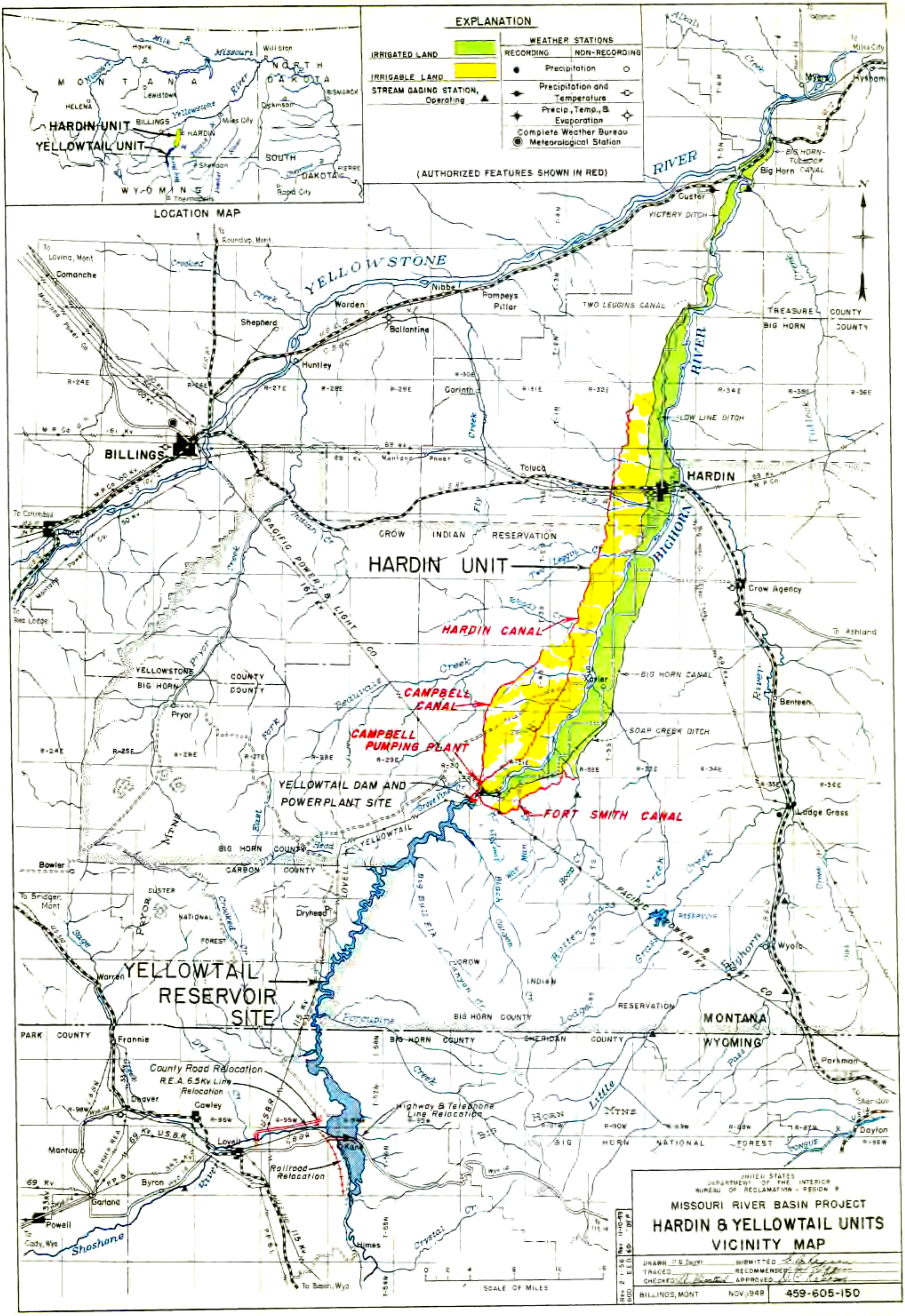
Subject: Report on Yellowtail Unit (June 1962) Lower Bighorn Division - Missouri River Basin Project

The Definite Plan Report on Yellowtail Unit, dated January 1950, was approved by the Commissioner, Bureau of Reclamation, by letter dated November 10, 1950. The Congress did not approve construction, however, until 1961. To record information on changes in the Unit plan and to update the estimates and other data, the attached report was prepared in June 1962 at the beginning of construction on the Unit.

New summary sheets (dated January 1965) have been inserted to reflect changes since the beginning of construction. They show the change in powerplant capacity, the latest cost estimates, and the results of economic and financial analyses based on these estimates.

The report updated with the summary sheets is intended as an information report for administrative use only within the Bureau of Reclamation.

A. E. Admiral


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION - REGION 6
MISSOURI RIVER BASIN PROJECT
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NOV 1949
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GFO 835730

January 1965

SUMMARY SHEETS

YELLOWTAIL UNIT

Lower Bighorn Division, Montana-Wyoming
Missouri River Basin Project

LOCATION

On the Bighorn River 45 miles southwest of Hardin in Big Horn County, Montana.

AUTHORIZATION

Flood Control Act of 1944 (58 Stat. 887).

PLAN

Yellowtail Unit consists of a dam and reservoir, a powerplant and switchyard, and an afterbay and dam. Yellowtail Dam, which is being constructed at the mouth of the Bighorn Canyon, will impound flows of the Bighorn River for multipurpose use, including power production, irrigation, flood control, sediment retention, fishery and waterfowl resource improvement, and recreation. Yellowtail Reservoir will be about 72 miles long at maximum water surface elevation, 66 miles long at the top of joint-use storage, and will extend into the Bighorn Basin of Wyoming. The reservoir will be confined in canyon for most of its length. A powerplant is being constructed at the toe of the dam, and a switchyard will be located on the right or east rim of the canyon above the dam. An afterbay dam is being constructed $2\frac{1}{4}$ miles downstream for regulation of the widely varying releases from the powerplant to minimize downstream fluctuations in the Bighorn River.

Provision is being made for gravity diversion from Yellowtail Reservoir to Hardin Unit, which contains 42,600 acres of irrigable land proposed for full water supply and 950 acres of presently irrigated land proposed for supplemental supply. This land lies on benches beginning directly downstream from the dam and extending to a point near Hardin. Stored water from Yellowtail Reservoir can also be used to irrigate additional land in widely separated areas along the Yellowstone River, of which the Bighorn River is a tributary.

Necessary relocations, all at the upper or south end of the reservoir area, have been completed or substantially completed. They include portions of a railroad, a State highway and bridge across the Bighorn River, a county road and bridge

across the Shoshone River, a telephone line, and an REA transmission line.

COSTS

The following costs are based on bid and January 1964 prices:

Feature or Item	Cost
Yellowtail Dam and Reservoir	$63,721,000
Yellowtail Afterbay Dam	3,300,000
Yellowtail Powerplant, Switchyard, and tieline	21,000,000
Minimum basic health and safety facilities	500,000
Wildlife management area	364,000
Net cost of permanent operating facilities, housing, and visitors' center	2,115,000
Total construction cost	$91,000,000
Total unit cost	$91,000,000

Operation, maintenance, and replacement costs for the dam and reservoir are based on average prices for 1962, 1963, and 1964, and those for power facilities are based on criteria of the Federal Power Commission, a 3-percent sinking fund, and current Bureau directives. The total annual OM&R cost is estimated to be $446,762.

BENEFITS, COSTS, AND RATIO

Bureau method (100-year analysis - 3-percent interest).

Function	Annual benefits 1/	Annual costs	Benefit-cost ratio
Multipurpose	$7,306,800	$2,861,000	2.55

1/ All benefits are direct benefits.

COST ALLOCATION

Function	Federal Investment Total ($1,000)	Transfers ($1,000)	Adjusted allocation ($1,000)	OM&R ($)
Irrigation	19,876	-19,876 1/	0	(5,753) 1/
Power	62,442	-11,677 2/	50,765	411,921 3/
Flood control	6,409	-	6,409	1,618
Fish and wildlife	1,129	-	1,129	3,223
Recreation	900	-	900	30,000
Access road	192	-	192	-
P. L. 87-874	52	-	52	-
Total construction	91,000	-31,553	59,447	-
Interest during construction-power	4,751	- 888	3,863	
Total	95,751	-32,441	63,310	446,762

1/ Suballocated to Hardin and Lower Yellowstone Pumping Units.
2/ 18.7 percent interest-free power investment.
3/ Also includes OM&R from dam and reservoir: Joint, $9,744; separable, $2,177; total, $11,921.

Derivation of Commercial Power Investment

Construction Cost

Separable cost:		
Powerplant	$16,000,000	
Switchyard	5,000,000	
Afterbay dam	3,300,000	
Other (dam and reservoir)	5,378,000	
		$29,678,000
Joint cost		32,764,000
		62,442,000
Less 18.7 percent for interest-free power investment		11,677,000
Construction cost allocated to commercial power		50,765,000

Interest During Construction

Separable cost	$ 2,258,000
Joint cost	2,493,000
Total interest during construction--power allocation	4,751,000
Less 18.7 percent for interest-free power investment	888,000
Interest during construction allocated to commercial power	3,863,000
Total commercial power investment	$54,628,000

IRRIGATION

No irrigation is included in Yellowtail Unit, and no irrigation benefits or costs are included in the economic justification. The stream regulation provided by Yellowtail Dam and Reservoir will make downstream irrigation possible, however. The Hardin Unit will have a physical association with Yellowtail Unit, inasmuch as diversion to Hardin Unit will be by gravity through a tunnel from the reservoir. Detailed study of this irrigation development has been essentially completed, and the proposed development appears to be feasible from engineering and economic standpoints. Land in Hardin Unit is suitable for sustained irrigation agriculture. Studies of potential irrigation development along the Yellowstone River (Yellowstone Pumping Units) indicate that sufficient land can be irrigated to warrant the assignment of Yellowtail costs.

REPAYMENT

Yellowtail Unit is an integral part of the Missouri River Basin Project, and the total investment in the unit will be repaid from power revenues, with 3-percent interest on that portion of the investment assigned to commercial power. The MRBP is divided into the Eastern and Western Divisions for power marketing with different rates applicable for each of the two areas. One-half of the power produced at Yellowtail Powerplant will be marketed in the Eastern Division and one-half in the Western Division. Repayment ability is demonstrated annually in the Power System Average Rate and Repayment Study for the MRBP.

UNIT WORKS

Yellowtail Dam:

Type	Concrete arch
Height above streambed	500 ft.
Structural height	525 ft.
Crest length	1,450 ft.
Spillway: total tunnel length	1,975 ft.
crest elevation	3,593 ft.
maximum discharge capacity	92,000 c.f.s.

Yellowtail Reservoir:

Storage allocation	Elevation (ft.)	Acre-feet
Flood control	3,640 - 3,657	259,000
Joint use	3,614 - 3,640	250,000
Active conservation	3,547 - 3,614	364,000
Inactive	3,296.5 - 3,547	483,000
Dead storage	3,166 - 3,296.5	19,000
Approximate streambed	3,166	0
Total storage capacity		1,375,000 1/

1/ Includes 315,000 acre-feet of space for sediment deposition.

Reservoir area:

Land ownership status	Acres
Crow tribal land	5,678 1/
Indian allotments	727
Private land	12,463
State land	2,625
Public domain	11,413
Total	32,906

1/ Acquired under the Act of July 15, 1958 (72 Stat. 361).

UNIT WORKS (continued)

Afterbay dam:
Type . Earthfill embankment with concrete spillway, sluiceway, and diversion works
Height of dam above foundation . . . . . 72 ft.
Height from streambed to maximum controlled water surface . . . . . 53 ft.
Overall crest length of dam and dike . . . . . 1,360 ft.
Spillway . 162 ft. wide, controlled by five radial gates, each 30 ft. by 13.5 ft.
Sluiceway. .34 ft. wide, controlled by three slide gates, each 10 ft. by 8 ft.
Discharge capacity of spillway . . . . . 20,000 c.f.s.
Storage capacity of afterbay at maximum controlled water surface elevation of 3,192 ft. . . . . 3,150 acre-ft.

Note: Replacement headworks for Big Horn Canal (Indian) are in right abutment adjacent to sluiceway section.

Yellowtail Powerplant:
Installed capacity (4 units of 62,500 kw.) . . . . 250,000 kw.
Effective operating head . . . . . 355-466 ft.

Estimated energy output, 1st year . . . . 898,000,000 kw.-hr.
Estimated energy output, ultimate . . . . 710,500,000 kw.-hr.
Average annual generation, 50 years . . . 775,000,000 kw.-hr.

HYDROLOGY

Drainage area above Yellowtail Dam . . . . . 19,650 sq. miles
Annual runoff, average (1924-58) . . . . . 2,639,900 acre-ft.
Annual runoff, maximum (1924) . . . . . 4,079,400 acre-ft.
Annual runoff, minimum (1934) . . . . . 1,371,000 acre-ft.
Peak discharge of record (June 1935) . . . . . 37,400 c.f.s.
Minimum discharge of record (December 1937) . . . . 228 c.f.s.
Inflow design flood, 10-day volume . . . . . 1,070,000 acre-ft.
Inflow design flood, peak discharge . . . . . 126,000 c.f.s.

REMARKS

Because the recreational aspects of Yellowtail Unit are considered of National significance, the National Park Service recommends establishment of the Bighorn Canyon National Recreation Area.

REMARKS (continued)

The Bureau of Sport Fisheries and Wildlife expects Yellowtail Unit to have a beneficial effect on fishery resources but believes that wildlife, except waterfowl, will sustain some losses. Considerable use of the reservoir by waterfowl is expected, and possibilities for waterfowl management in the Wyoming portion appear good.

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INTRODUCTION

Yellowtail Unit is planned as a multipurpose development to provide for irrigation, flood control, power generation, sediment retention, fishery and waterfowl resource improvement, recreation enhancement, and municipal-industrial water supply. It will consist of a dam and reservoir, a powerplant, an afterbay and dam, a switchyard, and related or appurtenant structures and facilities.

Purpose of Revised Report

Funds totaling $2,500,000 for start of construction on Yellowtail Unit were made available in the Public Works Appropriation Act of 1961. The first construction contract was awarded in December 1960, and the prime contract for construction of the dam and powerplant was awarded in April 1961. Start of construction was supported by the Definite Plan Report on Yellowtail Unit, dated January 1950, and approved November 10, 1950.

The desirability of revising the definite plan report to reflect several changes in the plan and a general updating of estimates and other data was recognized, and revision of the report was scheduled for the early part of the construction period. The report revised herein presents plans for the unit immediately before beginning of construction of the dam and powerplant (May 1961). The parts of the report on recreation and fish and wildlife represent studies completed early in 1962. The cost estimate is dated April 1962.

Authority

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. Authority to make this report and the supporting investigations is provided in Federal reclamation laws: the Act of June 17, 1902 (32 Stat. 388), and acts amendatory thereof or supplementary thereto.

Relation to Basin Plan

Yellowtail Unit is essential to the over-all plan for the development of land and water resources of the Missouri River basin. Located in south-central Montana with the reservoir extending into Wyoming, the unit will provide for conservation, control, and use of surplus water of the Bighorn River leaving Wyoming. A dependable and adequate supply of water will be available from storage in Yellowtail Reservoir for downstream irrigation and for municipal and industrial

uses. The dam will provide a high-level diversion to irrigable land in the proposed Hardin Unit of the Missouri River Basin Project. The powerplant will produce power for pumping to irrigable land in downstream units of the Missouri River Basin Project and for integration with other power developments in the Missouri River basin. Regulation of streamflows of the Bighorn River will alleviate flood damage to downstream properties, installations, and facilities. The river has been a major contributor of sediment to the Yellowstone River, and downstream irrigators and other water users will benefit substantially from retention of sediment in the reservoir. An excellent fishery is expected in the reservoir and in the river downstream from the reservoir, and considerable use of the reservoir by waterfowl is anticipated. The scenic attraction and recreation potentialities of the reservoir will draw many visitors, sportsmen, and vacationists from all parts of the country.

Relationship of Yellowtail and Hardin Units

Water for irrigation on Hardin Unit will be released directly from storage in Yellowtail Reservoir. This unit contains 42,600 acres of irrigable land, which will receive a full water supply, and 950 acres of irrigated land, which will receive a supplemental water supply. The land lies on benches on each side of the Bighorn River directly below the mouth of the Bighorn Canyon. About 27,500 acres of irrigable land on Hardin Bench, on the west side of the river, and 2,400 acres of irrigable land plus the 950 acres of irrigated land in the Fort Smith area, on the east side of the river, can be served by gravity diversion. About 12,700 acres of irrigable land on higher benches on the west side of the river can be served by hydroturbine-driven pumping units utilizing releases for gravity service to the land on Hardin Bench.

Acknowledgment

Federal, State, and local governmental agencies, and local groups and individuals provided valuable assistance and information during investigations of Yellowtail Unit.

The Bureau of Indian Affairs was very helpful in relations with the Crow Indians whose land is involved in Yellowtail and Hardin Units. This agency also prepared findings of fact as to description and ownership of tribal and allotted land, and the agency headquarters at Crow Agency furnished hydrological data, ownership records, and other useful local information.

The Bureau of Sport Fisheries and Wildlife provided information relative to the fish and wildlife aspects of the Yellowtail development, and the National Park Service furnished information on

the recreation potential. The Corps of Engineers, Department of the Army, estimated flood control benefits, determined flood control storage requirements, and furnished other essential information.

Water supply studies were based on Water Supply Papers of the Geological Survey, and field forces of that agency made available advance runoff records and specialized data on ice and sediment. The agency also furnished geology maps of the adjacent area and of the reservoir site.

Special acknowledgment is made to contributions of the Coast and Geodetic Survey, various agencies of the Department of Agriculture, the Federal Power Commission, the Census and Weather Bureaus of the Department of Commerce, the Montana State Engineer and the State Water Conservation Board, officials of Big Horn County in Montana, the Yellowstone Basin Association, the Two Leggins Water Users Association, the Crow Tribal Council, and the Hardin Chamber of Commerce.

GENERAL DESCRIPTION

The Bighorn Basin in Wyoming is separated from the Lower Bighorn Basin in Montana by the Pryor and Bighorn Mountains, which form a distinct physiographic division approximately along the State line. The Bighorn River, flowing northeastward from Wyoming into Montana to join the Yellowstone River, has cut a deep canyon between the Pryor Mountains and the northwest tip of the Bighorn Mountains for passage from the one basin to the other. The Lower Bighorn Basin merges into and becomes identified with the larger and broader Yellowstone Basin.

Physical Geography

Location

Yellowtail Dam will be 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, in the Lower Bighorn Basin, Montana. Yellowtail Reservoir will extend the full length of the canyon and onto the valley floor in the Bighorn Basin, Wyoming.

The Crow Indian Reservation encompasses the damsite, a large portion of the reservoir site within the Bighorn Canyon, and about two-thirds of the proposed Hardin Unit. The reservation begins a short distance south of Hardin on the west side of the Bighorn River and extends to the Big Horn-Carbon County line in Montana. It begins a short distance north of Hardin on the east side of the river and extends to the Montana-Wyoming State line.

Climate

The climate of the Lower Bighorn Basin is semiarid. It is marked by wide seasonal fluctuations in temperature with recurrent droughts and generally low annual precipitation. Fall months are usually open and dry with very little snowfall before October. Winter months are cold with moderate snowfall. The growing season averages about 112 days (May 26 to September 15) near the damsite and about 135 days (May 13 to September 24) in the stream valleys north of the damsite.

Table 1 shows the climatological pattern as recorded at Weather Bureau stations near the damsite.

Table 1 - Climatological Data, Yellowtail Area

Item	Campbell Farm Camp 4	Hardin	Crow Agency
Elevation (ft.)	3,650	2,885	3,030
Years of record	1940-60	1942-60	1931-60
Mean annual temperature (°F)	47.4	47.0	46.1
Mean maximum temperature (°F)	60.3	61.3	62.4
Mean minimum temperature (°F)	34.5	30.6	29.9
Highest temperature (°F)	107.0	109.0	110.0
Lowest temperature (°F)	- 35.0	- 42.0	- 50.0
Average annual precipitation (in.)	15.5	12.0	14.5
Average annual snowfall (in.)	52.9	36.3	39.5

Regional Geology

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.

Settlement and Development

Early History

The early history of the area is closely identified with that of the Crow Indian Reservation, which was created by treaty in 1851. The reservation then contained about 38 million acres of land. An area lying west of the 107th meridian, south of the Yellowstone River, and north of the Montana-Wyoming State line, containing about one-fourth of the original area, was set aside by act of Congress in 1868 for use and occupation of the Crow Indian Tribe. Encroachment of white settlers on the Indian land, beginning about 1870, brought about successive reductions in the reservation area in 1880, 1890, and 1904. Today, the diminished reservation contains about 2,282,760 acres in an area extending roughly 74 miles from east to west and 54 miles from north to south.

The first permanent white settlers were mostly stockmen who grazed large herds of cattle over the unfenced range. The coming of the Northern Pacific Railway in 1882 hastened settlement, and the competition for land brought the "free range" era to an end about 1890, with beginning of the present pattern of farming and ranching.

Allotment of Indian tribal land to individual members of the Crow Tribe was begun about 1900 to encourage agricultural use of the land by the Indians and to promote self-sufficiency among them. Many Indians leased or sold their allotments to non-Indians, and a considerable acreage on the reservation is now under lease to or owned by non-Indians.

Population

Big Horn County is sparsely populated, containing only 10,007 people with an average density of about two persons per square mile according to the latest (1960) census. Indians make up slightly more than a third of the total population. Most non-Indians live in Hardin or in the irrigated valleys nearby.

The following tabulation shows population trends for the county:

Location	1920	1930	1940	1950	1960
Hardin	1,312	1,169	1,886	2,306	2,789
Lodge Grass		373	839	536	687
Crow Agency			300	300	
St. Xavier			80	80	
Wyola			75	75	
Big Horn County	7,015	8,543	10,419	9,824	10,007
White	4,859	6,246	8,416	6,991	
Nonwhite	2,156	2,297	2,003	2,883	

Note: Population not available where no figure is given.

Local Industry

Agriculture is the principal industry in Big Horn County, and much of the nonfarm industry and related employment is supported by the marketing and processing of agricultural commodities and related activities. There are no important heavy industries or manufacturing plants, other than a beet sugar refinery, in the county. Significant agricultural values for the county in 1954, as recorded in the agricultural census for that year, were: value of all crops sold, $4,818,700; and value of all livestock and livestock products sold, $6,356,600.

Transportation

A branch line of the Chicago, Burlington, and Quincy Railroad from Omaha, Nebraska, passes through Big Horn County by way of Lodge Grass, Crow Agency, and Hardin to Billings where it connects to the main line of the Northern Pacific Railway from St. Paul, Minnesota, to Seattle, Washington. An improved highway (U. S. 87 or Interstate 90) from Sheridan, Wyoming, to Billings roughly parallels the railroad through the county. Other roads are generally adequate for access to most parts of the county. One road, designated State Highway 313 for part of its length, extends from Hardin toward Yellowtail Dam site. This road is bituminous surfaced for 28-1/2 miles and gravel surfaced for 14-1/2 miles. The gravel-surfaced portion of this road needs further improvement over part of its length for heavy-haul use. To reach the damsite area from this road, about 5 miles of access road will be built. Service roads will also be built to major features within the damsite area.

The nearest regular airline service is at Billings, where three airlines provide scheduled flights into and out of the city. Limited airport facilities near Hardin can accommodate most noncommercial planes.

Marketing, Trade, and Service

A full complement of marketing, trade, and service facilities is available in the county, mainly at Hardin, the principal trade and service center as well as the seat of county government. The smaller centers of Crow Agency, Lodge Grass, and St. Xavier provide minimum essential services and facilities.

The hub of commercial and industrial activities for south-central Montana and northern Wyoming is at Billings, 50 miles west of Hardin. This city of more than 50,000 population is the largest center in the area. It is a major marketing point for livestock; a wholesale, retail, and industrial center; and a center where many services that are not available in the smaller towns can be obtained.

Utilities

A 115-kilovolt transmission line of the Bureau of Reclamation begins at Lovell, Wyoming, and terminates near Yellowtail Dam site. This line is presently connected by a short transmission line to a substation of Pacific Power and Light Company situated north of the Government community area. This substation connects to the company's 161-kilovolt transmission line from Billings to Casper, Wyoming.

The Big Horn County Electric Cooperative, Inc. (REA) has 3-phase, 12.47-kilovolt and single-phase, 7.2-kilovolt service available near the damsite. The cooperative purchases power for delivery over its system from the Montana Power Company at Hardin.

Telephone service will be extended to the damsite area by the Mountain States Telephone and Telegraph Company.

Natural Resources

The Lower Bighorn Basin has a favorable complement of land, water, mineral, and timber resources. Land is used for grazing and for crop production under both irrigation and dry-farm methods. Water resource development is generally limited to irrigation, domestic, and stock water uses. There is some production of oil and natural gas from local wells. Commercial lumbering is negligible.

Forests in the mountains and foothills consist mainly of coniferous trees, principally Western yellow pine, with scattered junipers and aspens. Streams and gullies of the lower areas are generally lined with cottonwoods, willows, boxelders, buffalo berry brush, chokecherry, and miscellaneous small shrubs. Native vegetation on open land includes western wheatgrass, blue grama, niggerwool, needlegrass, meadow barley, and sagebrush, with some greasewood and salt grass.

Land Use

Practically all bottom land along the Bighorn River is included under existing irrigation projects, both Indian and private, leaving only the higher but equally productive benchland for future irrigation development. The upland benches, containing thousands of acres of arable land, are mostly dry-farmed for small grains, mainly wheat. The rougher areas, and some arable land partially covered with timber and brush, are used for grazing. The foothills and mountains are grazed wherever practicable. An area of 35,000 acres between Black Canyon and Little Bull Elk Creek is reserved by the Crow Indians as a buffalo grazing range.

Big Horn County comprises a total area of about 3,221,000 acres. About 83 percent of this acreage is included in farms. However, only about 9 percent of the acreage in farms is cropland. The remainder of the acreage in farms is mostly pasture land used for grazing livestock.

Irrigation

Irrigation started with development of the Reno Unit in 1885 by the Indian Service (now Bureau of Indian Affairs) for the benefit of the Crow Indians. This unit was followed by the Soap Creek Unit in 1894 and other units in later years for a total of eleven units in the Crow Irrigation Project. About 45,800 acres in this project are under constructed works and about 32,000 acres are being irrigated. Some additional land on the reservation is under private non-Indian development.

Flood Control

No important flood control projects have been undertaken along the Bighorn River in Montana, but flood protection is needed for the bottom-land areas. Floods in the river are caused by flash storms, rapid snowmelt, and ice jams. The annual spring runoff sometimes reaches flood proportions.

Other Water Use

Use of the water resources of the Lower Bighorn Basin other than for irrigation is negligible. The municipal water supply for the city of Hardin is taken from the river, but water for domestic and municipal uses elsewhere in the basin is obtained mostly from wells. Very little use is made of either surface water or ground water for industrial purposes. The Holly Sugar Company uses a relatively small amount of water from the Bighorn River in its refinery near Hardin. Numerous stock water ponds have been constructed throughout the area.

A number of free-flowing wells or springs are found along the northern base of the Pryor Mountains. Along the Bighorn River, the principal source of ground water is the alluvial fill, which is replenished mainly from the streams or from irrigation seepage. Because this water is generally hard and in some places suitable only for stock water, no appreciable future use of ground water is anticipated.

Minerals

Known mineral resources in the basin include coal, petroleum, natural gas, bentonite, kaolin, gypsum, and small amounts of metallic minerals. Several deposits of lignite coal are present, but the veins are relatively thin and have not been developed to any extent. No markets are available for the nonmetallic minerals, and the metallic minerals occur either as traces or are insufficiently prospected to disclose commercial quantities. Uranium-bearing deposits have been found in the Pryor Mountains, but little development of these deposits has taken place.

Natural gas from a shallow local field has been available to residents of Hardin for many years. The field is small, however, and the supply of gas appears to be about exhausted. The Soap Creek oil field, situated about 10 miles east and south of Yellowtail Dam site, contains only a few wells, and the low-grade product is used mainly for oiling roads and highways.

Community Needs

Future economic growth and development in the Lower Bighorn Basin is dependent primarily on conservation and use of undeveloped land and water resources. A large acreage of arable land is available for irrigation development, and an abundant supply of water is obtainable from the Bighorn River. With the storage regulation that will be provided by Yellowtail Dam and Reservoir, the land can be made more productive by irrigation and practically free from threat of drought. Hydroelectric power produced at the dam will meet growing needs of southern Montana and northern Wyoming for irrigation pumping and domestic, industrial, and municipal uses. The storage regulation will also provide needed flood control and sediment retention, improve fish and wildlife resources, and create new recreational opportunities.

Irrigation produces a high degree of stability in farming, eliminating the effects of recurrent droughts and permitting diversification in farm enterprises and cropping programs. Irrigated farms are smaller than dryland farms and provide support for more families within a given area. The greater density of population makes possible more and better community facilities and services. In addition, irrigated land has a stabilizing influence on nearby grazing land through the assured production of winter feed for livestock, thus preventing forced liquidation or reduction of breeding herds in unfavorable seasons.

Investigations and Reports

Previous Investigations

The Reclamation Service (now Bureau of Reclamation), with cooperation of the Indian Service, first made investigations for a water diversion near Yellowtail Dam site in 1903–05. These investigations, later known as the Savage-Stockton Survey, were concerned with a gravity diversion from the Bighorn River, by means of a dam about 150 feet high, to a canal system along the west side of the river. An alternative canal route across the divide to Fly Creek was also considered but found to be impracticable because of high canal costs for the relatively small acreage of suitable land.

In 1917, the first detailed investigations for a major structure at the canyon mouth for irrigation and power generation were reported by the Big Horn Canyon Irrigation and Power Company. This company was incorporated in 1912 and started the investigations in 1913. In the report prepared for the company by A.W.F. Koch, dated October 24, 1917, it was proposed to build a rubble-concrete, gravity-arch dam, about 480 feet high, which would impound 830,000 acre-feet of water; a powerplant with a primary output of 100,000 horsepower; 500 miles of transmission line; 36 miles of railroad from the dam to Hardin, with a continuation 32 miles northward for valley development; and 62 miles of highline canals for irrigation of about 60,000 acres of benchland.

The investigations included topographic surveys of the damsite and reservoir area, and partial subsurface explorations at the damsite.

A report titled "Report on the Big Horn Canyon Irrigation and Power Project, Hardin, Montana," prepared by G. W. Goethals, consulting engineer of New York City, and dated May 16, 1917, relied upon the data included in the October 1917 report. Mr. Goethals reviewed and checked previous data and concluded his report with findings and recommendations dealing principally with the economic rather than the engineering practicability of the proposal.

A report titled "Report on Water Power of Big Horn Canyon, Wyoming and Montana," by B. E. Jones, hydraulic engineer, Geological Survey, and D. V. Guy, engineer, Federal Power Commission, dated April 16, 1923, was transmitted to the chief hydraulic engineer of the Geological Survey. This report substantiated the report of the Big Horn Canyon Irrigation and Power Company and suggested alternative schemes of development.

The results of reconnaissance surveys and studies made of the Bighorn Basin by the Corps of Engineers, Department of the Army, were embodied in a survey report titled "Yellowstone River, Wyoming, Montana, and North Dakota," dated March 31, 1932. This report was published in final form as House Document 256, 73d Congress, 2d session.

The Montana Agricultural Experiment Station, in cooperation with the Bureau of Plant Industry, Department of Agriculture, and the Corps of Engineers, made a reconnaissance land resource survey of the Hardin Bench area in 1938. This survey was followed by a similar survey by the Bureau of Reclamation in 1939, limited mainly to areas below the Savage-Stockton canal route. In 1938, a detailed soil survey was made of the irrigated land below the Soap Creek Ditch by the Montana Agricultural Experiment Station and the Bureau of Plant Industry.

A report titled "Survey Report on the Big Horn Basin, Montana-Wyoming" (Project Investigations Report No. 81), dated June 1942, outlined plans for potential development in the Bighorn Basin, based on investigations made by the Bureau of Reclamation from 1939 to 1942. This report proposed a 375-foot-high dam at the Yellowtail site and a 150-foot-high dam at the Kane site above the head of the canyon. The two reservoirs to be formed by these dams were to have a combined storage capacity of 1,220,000 acre-feet, and the Kane and Yellowtail powerplants were to have a total installed capacity of 105,000 kilowatts. The proposals of this report were included in the report titled "Conservation, Control, and Use of Water Resources of the Missouri River Basin," published as Senate Document 191, 78th Congress, 2d session, dated April 1944.

The Corps of Engineers prepared a report late in 1946 titled "Review Report on Flood Control and Other Purposes, Yellowstone River and Tributaries, Wyoming, Montana, and North Dakota." In this report, the Corps concluded from further studies and surveys that the basin-wide plan to use storage space in reservoirs for flood control was practicable to minimize the destructiveness of future floods.

From funds for the Missouri River Basin Project that were made available in the Interior Department Appropriation Act of 1946, the sum of $50,000 was allocated for a start on preconstruction work on Yellowtail Unit, and work was begun in 1946. The results of the investigations, explorations, and studies, which were made in this and subsequent years, through 1949, together with information and data obtained from surveys furnished from related investigations by other agencies, were the basis for the "Definite Plan Report on Yellowtail Unit, Montana," prepared by the Yellowstone District, Billings, Montana, and dated January 1950.

Scope of Investigations

Investigations on the two dams, Kane and Yellowtail, proposed in Senate Document 191, were based on a survey datum at Kane taken from outside sources, which was later found to be 15 feet in error. After correction, the potential storage capacities and firm power capabilities were sufficiently affected that a single high dam at the Yellowtail site was found to be more economical. From three known possible locations near the mouth of the Bighorn Canyon, the present site was selected on the basis of physical characteristics and economic considerations. This choice was then confirmed by preliminary geologic surveys and foundation drilling indicating comparable or more favorable conditions. Work thereafter included foundation and materials explorations adequate for final designs and specifications, and detailed surveys and studies.

Complete subsurface examinations were made of the dam, reservoir, powerplant, and afterbay sites. Sources of materials for construction were located and explored, and samples were tested and analyzed. Detailed topographic surveys were made of the damsite and adjacent area. Surveys were made for access road and construction camps. Detailed hydrologic, power production, and marketing studies were made.

A board of consulting engineers, composed of Edward B. Burwell, Jr., Dr. Raymond E. Davis, John J. Hammond, Dr. John W. Vanderwilt, and Julian Hinds (chairman), made an inspection of the damsite and vicinity in September 1960 and conferred with Bureau of Reclamation engineers from Billings, Montana, and Denver, Colorado. The board was particularly concerned with the geology of the damsite and the vicinity both upstream and downstream, and conclusions and recommendations of the board were presented in a letter report. An earlier examination to determine the adequacy of the damsite was made by a consulting board composed of Bureau engineers and J. L. Savage, consulting engineer, and findings of the board were of material assistance in studying foundation conditions.

Hardin Unit Investigations

The 1950 report on Yellowtail Unit presented a plan for irrigation development on Hardin Unit. The irrigable acreage to be supplied with water under the plan was determined by reconnaissance land classification. Detailed investigations, including a detailed land classification, were completed in 1959, and a separate report, titled "Report on Hardin Unit, Lower Bighorn Division," was issued in January 1960. Under the plan presented in this report, a change in method of serving the irrigable land was proposed. This plan and the irrigable area to be developed are described in a following chapter of this report on Yellowtail Unit.

Plans to expand Hardin Unit to include service to Fly Creek area, Beauvais Creek Valley, Sorrel Horse Bench, Dunmore Unit, and Little Bighorn Valley were eliminated because of the high cost for the relatively small acreage of additional land that could be served. After it was decided that none of the outlying areas was feasible of development, rather detailed studies were made to determine the relative merits of pumping to unit land from Yellowtail afterbay and diverting by gravity to unit land from Yellowtail Reservoir. The gravity plan proved to be more advantageous. Several possibilities for diverting by gravity were then considered before deciding upon the present plan. These possibilities included diversion through the right abutment of the dam to shorten the tunnel length; cut-and-cover conduit on the left side of the river in lieu of the proposed tunnel; alternate location of the diversion tunnel with terminus in Grapevine Valley; and several variations of each of these schemes.

Lower Yellowstone Investigations

The Bureau of Reclamation made a reconnaissance survey of potential irrigation developments in the Yellowstone River Basin in 1939 to 1941. Twenty-five potential pumping units were found in this survey. In 1948, funds were appropriated for detailed studies of a few of the pumping units. These detailed studies were discontinued in 1953. Studies were resumed in 1958 with a view toward reanalyzing the entire development plan for the basin. A basin-type report on potential development in the basin is scheduled for completion in 1962. Inasmuch as such development is considered in the Yellowtail allocations, a brief discussion of the Yellowstone Pumping units is included in a following chapter of this report on Yellowtail Unit.

Related Investigations

The National Park Service, Region II, made an initial field investigation to ascertain the recreation aspects of the Yellowtail development in July 1946. It made a more comprehensive investigation in September 1947; investigations of specific areas in April 1948, August 1960, and March 1961; and an over-all field study in May 1961.

In a "Preliminary Report of Recreational Use and Development, Yellowtail Reservoir Site, Big Horn River, Wyoming-Montana," dated February 1947, the National Park Service pointed out the recreation potential of Yellowtail Reservoir and the Bighorn Canyon area and tentatively outlined plans for recreation development in two areas - one at the north end and the other at the south end of the proposed reservoir. In a supplement to this report, the National Park Service revised or modified findings, conclusions, and recommendations of the earlier report as a result of further investigation and study and because of certain changes in plans of the Bureau of Reclamation.

In a "Recreation Planning Report on Yellowtail Reservoir, Missouri River Basin, Lower Big Horn Division, Yellowtail Unit, Montana-Wyoming," dated March 1962, the National Park Service evaluates the recreation opportunities that may be derived under present plans for development of Yellowtail Unit. The National Park Service suggests public recreation uses and outlines an over-all plan for recreation development. It concludes that Yellowtail Unit offers a recreation potential of National significance and recommends that a single Federal agency administer the recreation interests. A summary of this report is presented in a later chapter.

The Smithsonian Institution made two field surveys of the Bighorn Canyon area and described their findings in a preliminary appraisal report of May 1947 and in a supplemental report of October 1952. These reports were prepared for the National Park Service and are titled, respectively, "Preliminary Appraisal of the Archeological and Paleontological Resources of Yellowtail Reservoir, Montana and Wyoming," and "Appraisal of the Archeological and Paleontological Resources of the Yellowtail Reservoir Site, Montana and Wyoming, Supplement."

The Bureau of Sport Fisheries and Wildlife issued "A Report on Fish and Wildlife Resources in Relation to the Water Development Plan for the Hardin Unit (Yellowtail Reservoir), Big Horn River, Montana and Wyoming," in June 1948. The Bureau made a further appraisal of the effects of Yellowtail Unit under current plans on fish and wildlife resources and presented its findings, conclusions, and recommendations in the report titled "Fish and Wildlife Resources and the Yellowtail Unit, Lower Bighorn Division, Missouri River Basin Project, Montana and Wyoming," dated February 1962. This report is abstracted in a later chapter.

PLAN OF DEVELOPMENT

Yellowtail Unit is planned for maximum practicable conservation, control, and use of surplus water of the Bighorn River leaving Wyoming. Unit features will include a dam and reservoir, an afterbay dam, and a powerplant and a switchyard. Locations of these features are shown on the vicinity map, drawing No. 459-D-227, on the following page.

Unit Plan

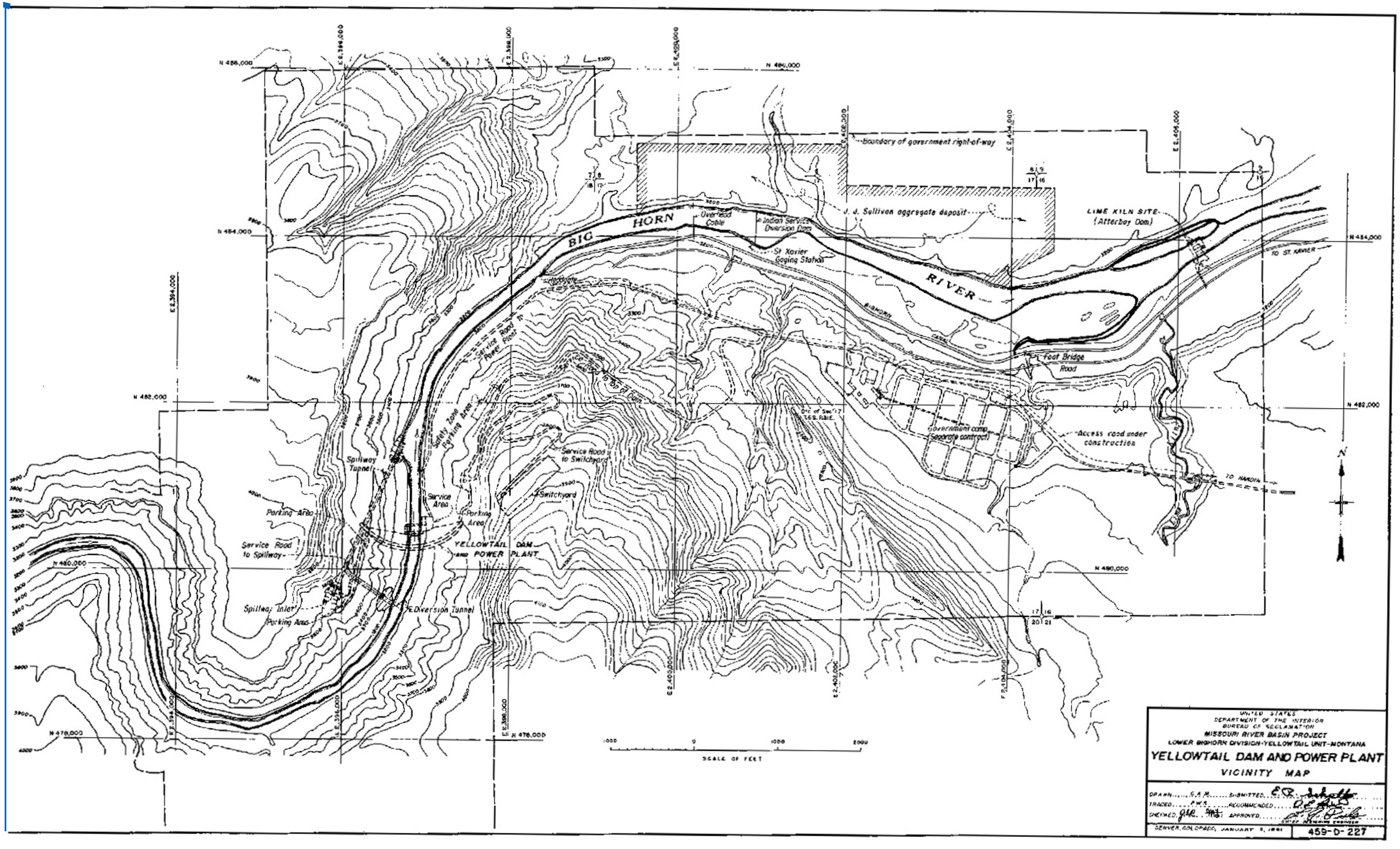
The Bighorn Canyon, which extends southward and opens into a broad valley in Wyoming, offers a physically suitable storage site for providing almost complete regulation of the erratic flows of the Bighorn River. Yellowtail Dam, a concrete arch structure, will be constructed at the mouth of the canyon in Montana. Water impounded in Yellowtail Reservoir will be passed through a powerplant to be located at the toe of the dam, and will be reregulated in an afterbay to reduce severe fluctuations in the river. For complete regulation of streamflows, an estimated gross storage capacity of 1,375,000 acre-feet will be required, with allocations to various purposes as follows:

Purpose	Volume (acre-feet)
Flood control	259,000
Joint use, flood control and conservation	250,000
Conservation	363,000
Recommended minimum operating storage	503,000
Total	1,375,000

Part of the water stored in Yellowtail Reservoir can be used for irrigation on the proposed Hardin Unit, and provision will be made for gravity diversion from the reservoir to the irrigable land in this unit. Water released for power production will be used for irrigation farther downstream along the Bighorn and Yellowstone Rivers. The reservoir will provide control of floods in the Bighorn River, alleviate the effect of floods in the Yellowstone River, and trap sediment now carried downstream. It will serve other functions also, including fish and wildlife conservation and recreation.

Plan of Operation

An inviolate flood control capacity of 259,000 acre-feet will always be available to control flash floods or unusually high runoff, and water so retained will be released as soon as possible


BIG HORN RIVER
boundary of government right-of-way
J. J. Sullivan aggregate deposit
LIME KILN SITE
(Atterbay Dam)
Overhead Cable
Indian Service Diversion Dam
St Xavier Gaging Station
TO ST. XAVIER
Hoodgate
Service Road Power Plant
Foot Bridge
Road
BIGHORN CANAL
Safety Zone Parking Area
Spillway Tunnel
Service Road to Switchyard
Switchyard
Service Area
Parking Area
Parking Area
Service Road to Spillway
YELLOWTAIL DAM AND POWER PLANT
Spillway Inlet Parking Area
E.Diversion Tunnel
Government camp (Separate contract)
Access road under construction
TO HARDIN
N
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-MONTANA
YELLOWTAIL DAM AND POWER PLANT
VICINITY MAP
DRAWN G.A.M. SUBMITTED
TRACED A.W.S. RECOMMENDED
CHECKED APPROVED
CHIEF ENGINEER
DENVER, COLORADO, JANUARY 8, 1961
459-D-227

within safe operating limits to avoid damage downstream. The 250,000 acre-feet of joint-use storage will be drawn down in advance of snowmelt or at flood warning when it becomes evident that the evacuated storage space can be refilled.

Maximum use for power generation will be made of all reservoir releases, except spillway discharges and diversions to Hardin Unit. Specified minimum flows will be maintained for protection of fish habitat. Studies show that releases for power generation will be in excess of mandatory requirements for other purposes.

Yellowtail Powerplant will include four generating units with a total installed capacity of 200,000 kilowatts. Average annual firm energy output, based on ultimate upstream water depletions and active storage loss to sediment, is estimated at 528,500,000 kilowatt-hours. This is equivalent to a firm continuous output of 60,300 kilowatts. (Average initial output will be higher.)

The variable powerplant discharges will be smoothed out in the afterbay. An existing diversion dam serving the Big Horn Canal of the Crow Irrigation Project will be removed, and new headworks for that canal will be constructed in the afterbay dam.

Major features of Yellowtail Unit are described in this chapter, and pertinent information on construction and estimates of costs are given. The plan for Hardin Unit, which will receive its water supply for irrigation directly from Yellowtail Reservoir, is outlined in a later chapter.

Unit Works

Yellowtail Dam

The multipurpose Yellowtail Dam will be constructed near the mouth of the Bighorn Canyon, in section 18, T. 6 S., R. 31 E., M.P.M., Big Horn County, Montana. It will be an arch-type concrete structure about 500 feet high above streambed, 520 feet high above foundation (structural height), and 1,450 feet long at the crest. (See drawings Nos. 459-D-229 and 459-D-230 following this page.) The site is physically suitable for such a structure: the right abutment consists of solid rock for the full height of the dam, and the left abutment consists of solid rock for all but the upper 50 feet of the height. The crest of the dam will be at elevation 3,660 feet; and the top of the parapet wall will be at elevation 3,664 feet, allowing a freeboard of 4 feet above maximum water surface elevation 3,660 feet.

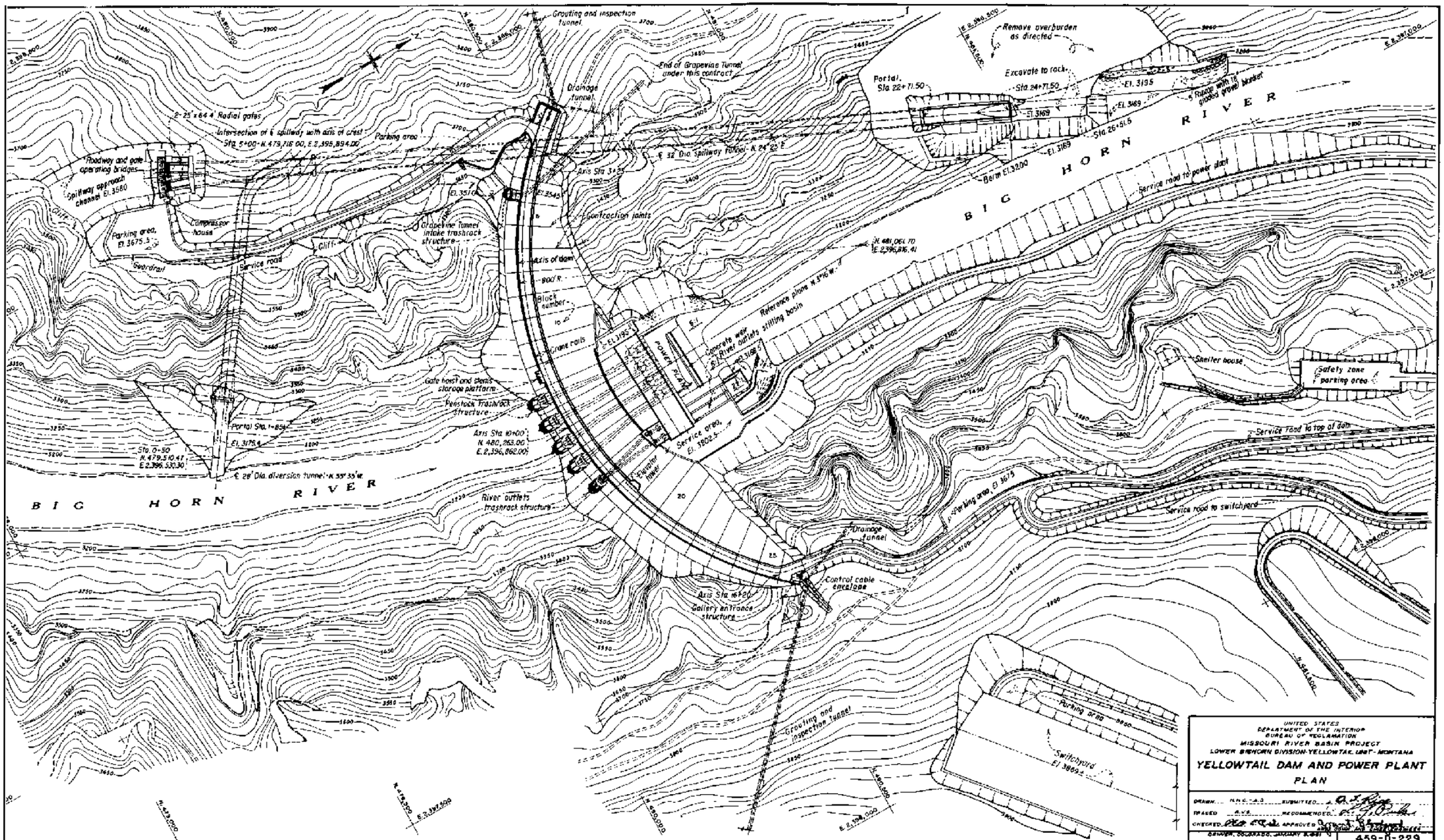
Yellowtail Reservoir

The following tabulation summarizes the reservoir data for Yellowtail Reservoir:

Space allocation	Elevation (feet)	Capacity (acre-feet) Increment	Capacity (acre-feet) Accumulated	Surface acres
Surcharge	3657 - 3660	52,800	-	-
Flood control	3640 - 3657	259,000	1,375,000	17,286
Joint use (flood control and conservation)	3614 - 3640	250,000	1,116,000	12,685
Active conservation	3547 - 3614	363,000	866,000	7,386
Inactive 1/	3296.5 - 3547	484,000	503,000	4,229
Dead storage 1/	3165 - 3296.5	19,000	19,000	
Approximate streambed	3162	0	0	

1/ Inactive space and dead storage space include 315,000 acre-feet for sediment deposition.

The minimum water surface for power operation will be at elevation 3,547 feet.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT - MONTANA

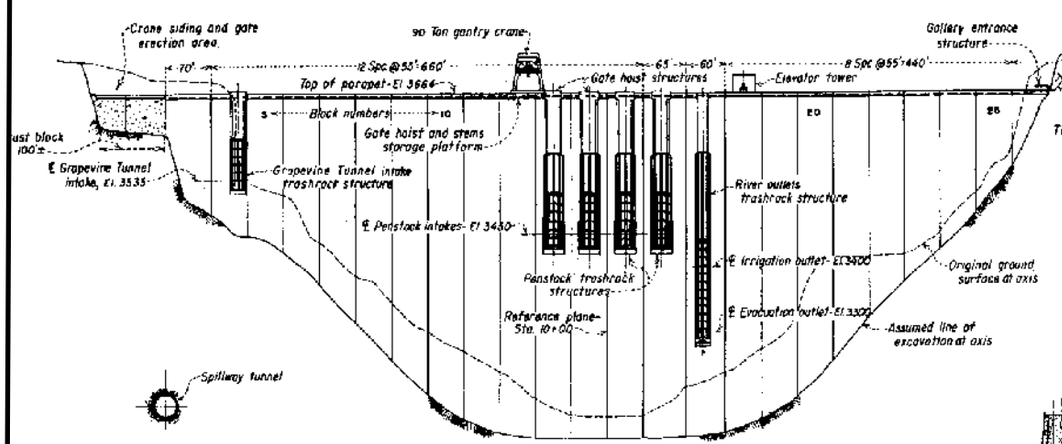
YELLOWTAIL DAM AND POWER PLANT

PLAN

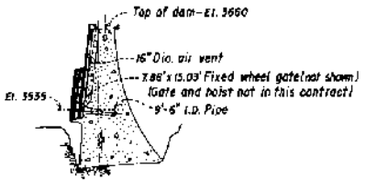
DRAWN N.R.C. A.D. SUBMITTED
TRACED A.V.S. RECOMMENDED
CHECKED APPROVED

DENVER, COLORADO, JANUARY 8, 1951

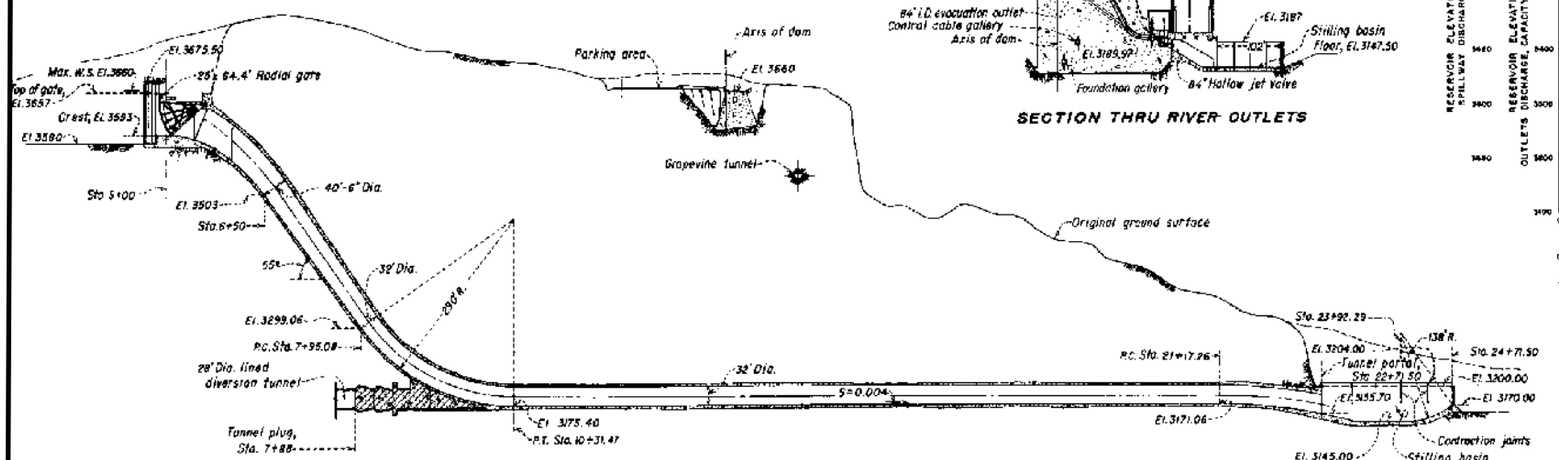
459-D-229



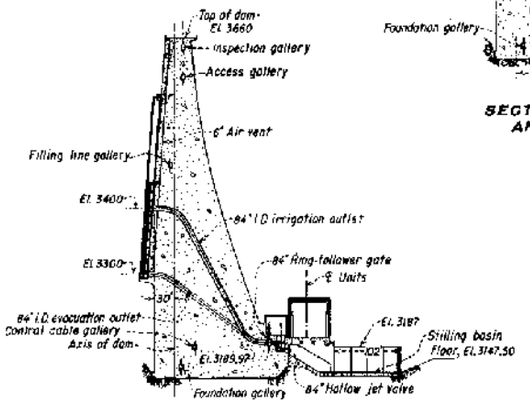
UPSTREAM ELEVATION
DEVELOPED ALONG AXIS



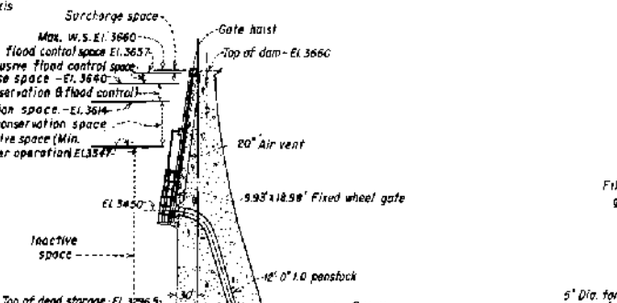
SECTION THRU GRAPEVINE TUNNEL INTAKE



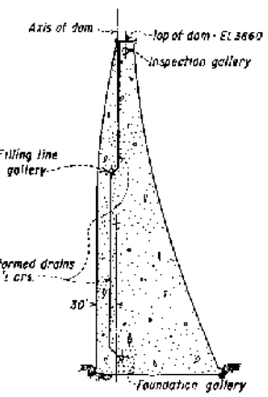
SECTION THRU SPILLWAY



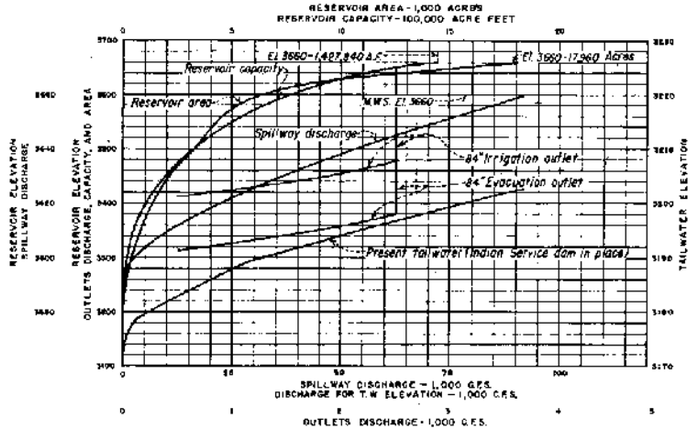
SECTION THRU RIVER OUTLETS



SECTION THRU PENSTOCK AND POWER PLANT



SECTION THRU DAM



TAILWATER, AREA, CAPACITY, AND DISCHARGE CURVES

NOTE

Actual required foundation may vary widely from assumed excavation lines shown.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-MONTANA

YELLOWTAIL DAM AND POWER PLANT
ELEVATION AND SECTIONS

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DIST. DOWN AND CHIEF ENGINEER
DENVER, COLORADO, JAN. 31, 1961

459-D-230

At the top of the joint-use storage, elevation 3,640 feet, Yellowtail Reservoir will be about 66 miles long. At the top of the flood control pool, elevation 3,657 feet, the water will be backed up an additional 5 miles to a point about 5-1/2 miles south of the town of Kane, Wyoming, necessitating its relocation. At maximum water surface elevation of 3,660 feet (crest of dam), the water will be backed up an additional three-fourths of a mile to a point about 6-1/4 miles south of Kane. The area to be flooded with the water surface at elevation 3,657 feet will be 17,286 acres, or about 27 square miles. The maximum area that would be flooded (water surface at elevation 3,660 feet) would be about 17,960 acres, or about 28 square miles.

It will be necessary to clear about 4,600 acres within the reservoir area between elevation 3,542 feet (5 feet below active conservation storage or minimum operating water surface) and elevation 3,657 feet (top of spillway gates). Of this acreage, 300 acres will be in the canyon section.

Spillway

The spillway will consist of an intake structure, a concrete-lined tunnel transition section, and a concrete-lined tunnel 32 feet in diameter. The reinforced concrete intake structure will be located about 850 feet upstream of the dam axis on the left abutment. It will be divided into two bays, each to be controlled by a radial gate 25 feet long and 64.4 feet high, and will have a maximum discharge capacity of 92,000 cubic feet per second. The spillway crest will be at elevation 3,593 feet. It will be necessary to excavate a channel from the reservoir to the intake structure. Total length of the spillway tunnel, including the transition section, will be about 1,975 feet. The tunnel will extend to the stilling basin, which will discharge into the afterbay downstream from the powerplant.

The lower or downstream portion of the spillway tunnel (about 1,240 feet) will be used for river diversion during construction of the dam. A concrete-lined diversion tunnel, about 28 feet in diameter and 860 feet in length, will connect to the spillway tunnel. The diversion tunnel will bend to the southeast to meet the river and will be plugged and sealed when reservoir storage begins.

Outlet Works

Outlets through the dam will include four penstocks to the powerplant, an outlet for downstream irrigation releases, an outlet for emergency evacuation of the reservoir and for facilitating releases during filling of the reservoir, and an outlet for gravity diversion to Hardin Unit.

The four penstocks will be located near the center of the dam with intakes centered at elevation 3,450 feet. Each penstock will have an inside diameter of 12 feet and a capacity of 1,730 cubic feet per second. Flow through the penstocks will be controlled by fixed-wheel gates on the upstream face of the dam and by turbine wicket gates. Provision will be made for maintaining the fixed-wheel gates back of steel stop logs on the face of the dam. Trash-rack structures will be provided in front of the stop-log frames. Releases for power production will supply most of the downstream irrigation requirements.

The outlet for downstream irrigation, to be used for meeting irrigation requirements when the powerplant is not in operation and for supplementing releases from the powerplant, will be located to the right side of the power penstocks with intake centered at elevation 3,400 feet. It will have an inside diameter of 84 inches. Maximum flow from this outlet will be controlled to 2,500 cubic feet per second with reservoir surface above elevation 3,480 feet. Discharge will be controlled by a ring-follower gate at the toe of the dam and a hollow jet valve at the end of the outlet.

The evacuation outlet will be located below and to the right of the irrigation outlet with intake centered at elevation 3,300 feet. It will have an inside diameter of 84 inches. Maximum flow from this outlet will be controlled to 2,500 cubic feet per second with reservoir surface above elevation 3,380 feet. Discharge will be controlled by a ring-follower gate at the toe of the dam and a hollow jet valve at the end of the outlet.

The outlet for Hardin Unit will be located near the left abutment with intake centered at elevation 3,535 feet. This outlet will have an inside diameter of 9 feet 6 inches and a capacity of 862 cubic feet per second with the reservoir water surface at top of inactive storage, elevation 3,547 feet. This capacity will allow for peaking during the month of maximum irrigation demand on Hardin Unit. Flow will be controlled by a fixed-wheel gate on the upstream face of the dam. The outlet will discharge into the Grapevine Tunnel, and the outlet works plus 275 feet of tunnel will be constructed concurrently with the dam. The pipe through the dam will be plugged at the upper end with a removable dished bulkhead. The fixed-wheel gate will be installed when irrigation on Hardin Unit is developed.

Yellowtail Powerplant

The powerplant will be located at the toe of the dam, completely filling the present streambed portion of the canyon. The substructure will be of reinforced concrete, and the superstructure will have a structural steel frame with reinforced brick masonry walls

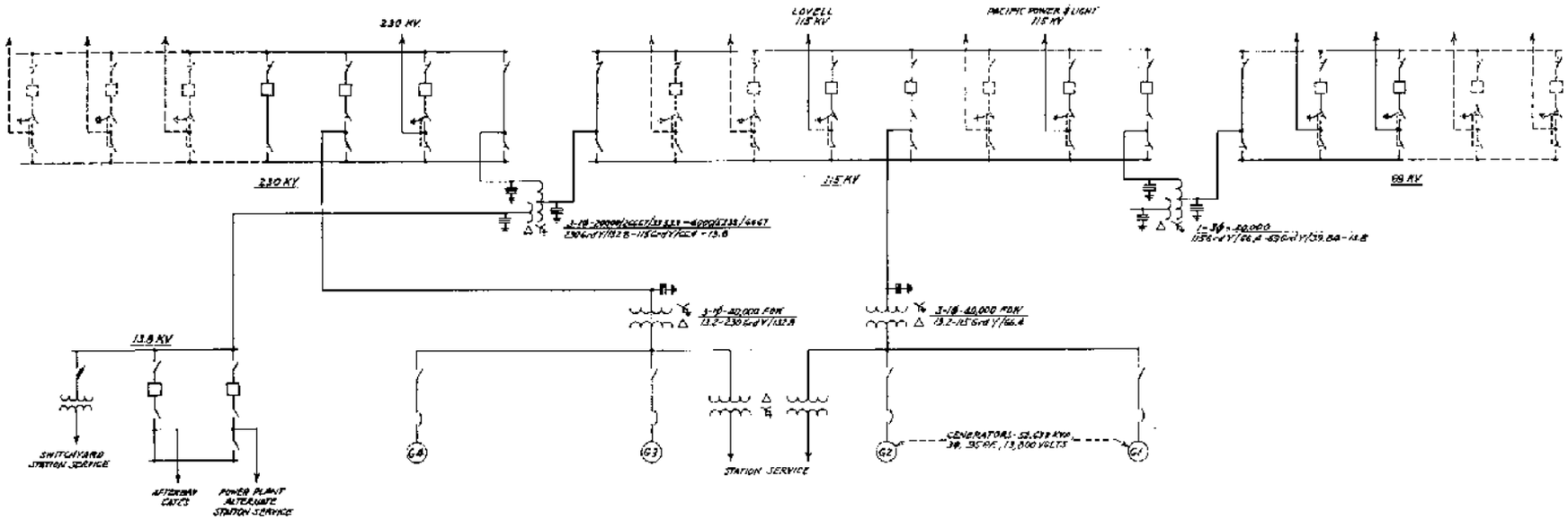
and steel roof deck. The powerplant will house four hydroelectric generating units with appurtenant equipment and facilities, an office, and shops and equipment for maintenance and repairs. The generating units will be vertical type, direct connected. Each unit will have an installed capacity of 50,000 kilowatts and will be driven by a 70,000-horsepower hydraulic turbine supplied by a penstock through the dam. The units will operate over a range in hydraulic head from 480 to 370 feet, with an average head of 444 feet, and will develop rated output at a design head of 420 feet. The normal head range will be 93 feet, from elevation 3,547 feet to elevation 3,640 feet.

Two transformer banks will be located on the deck of the powerplant with two generators connected directly to each bank. The rating of each transformer bank will be 120,000 kilovolt-amperes. One will transform generator voltage to 115 kilovolts and the other to 230 kilovolts. Two lines, one at 115 kilovolts and one at 230 kilovolts, will transmit the power from the transformers to the switchyard.

Yellowtail Switchyard

The switchyard will be located on the right or east rim of the canyon above the dam and powerplant. Ultimate installation of 69-, 115-, and 230-kilovolt sections with main and auxiliary buses in each section is planned. An autotransformer bank with a capacity of 100,000 kilovolt-amperes will interconnect the 115-kilovolt and 230-kilovolt portions of the switchyard, and the 69-kilovolt section will be supplied from the 115-kilovolt section through a 115/69-kilovolt autotransformer of adequate capacity. With this arrangement, two generators will be connected directly to the 115-kilovolt bus and two directly to the 230-kilovolt bus. The autotransformer between the high voltage buses will also contain a tertiary winding that will be utilized in supplying the station service requirements of the switchyard and possibly as a source of power supply for the permanent Yellowtail community. Consideration is also being given to using the tertiary of the autotransformer interconnecting the high voltage buses as an alternate source for station service at the powerplant. Drawing No. 459-D-14, on the following page, presents a switching diagram showing details of the switchyard arrangement.

Power and energy from the powerplant will be delivered through the switchyard at 115 kilovolts to the Western Division, Missouri River Basin power system, by interconnection with the 115-kilovolt transmission line to Lovell, Wyoming, and at 230 kilovolts to the Eastern Division by interconnection with the 230-kilovolt transmission line to Dawson County, Montana. In addition, Big Horn County Electric Cooperative will be served directly from the switchyard at 69 kilovolts, and the Pacific Power and Light Company will interconnect its system at 115 kilovolts. Additional deliveries and interconnections from the switchyard are contemplated. However,



PRELIMINARY

8	11-67	REVISED & REDRAWN

YELLOWTAIL POWER PLANT & SWYD
SWITCHING DIAGRAM

studies underway must be completed to establish firmly the needs of the ultimate system.

Construction of the 230-kilovolt, single-circuit, steel-tower transmission line from Yellowtail switchyard to Dawson County substation near Glendive, a distance of 220 miles, is planned in two stages. Completion of the second stage to the switchyard is scheduled to coincide with the availability of power from Yellowtail Powerplant.

Afterbay Dam and Storage

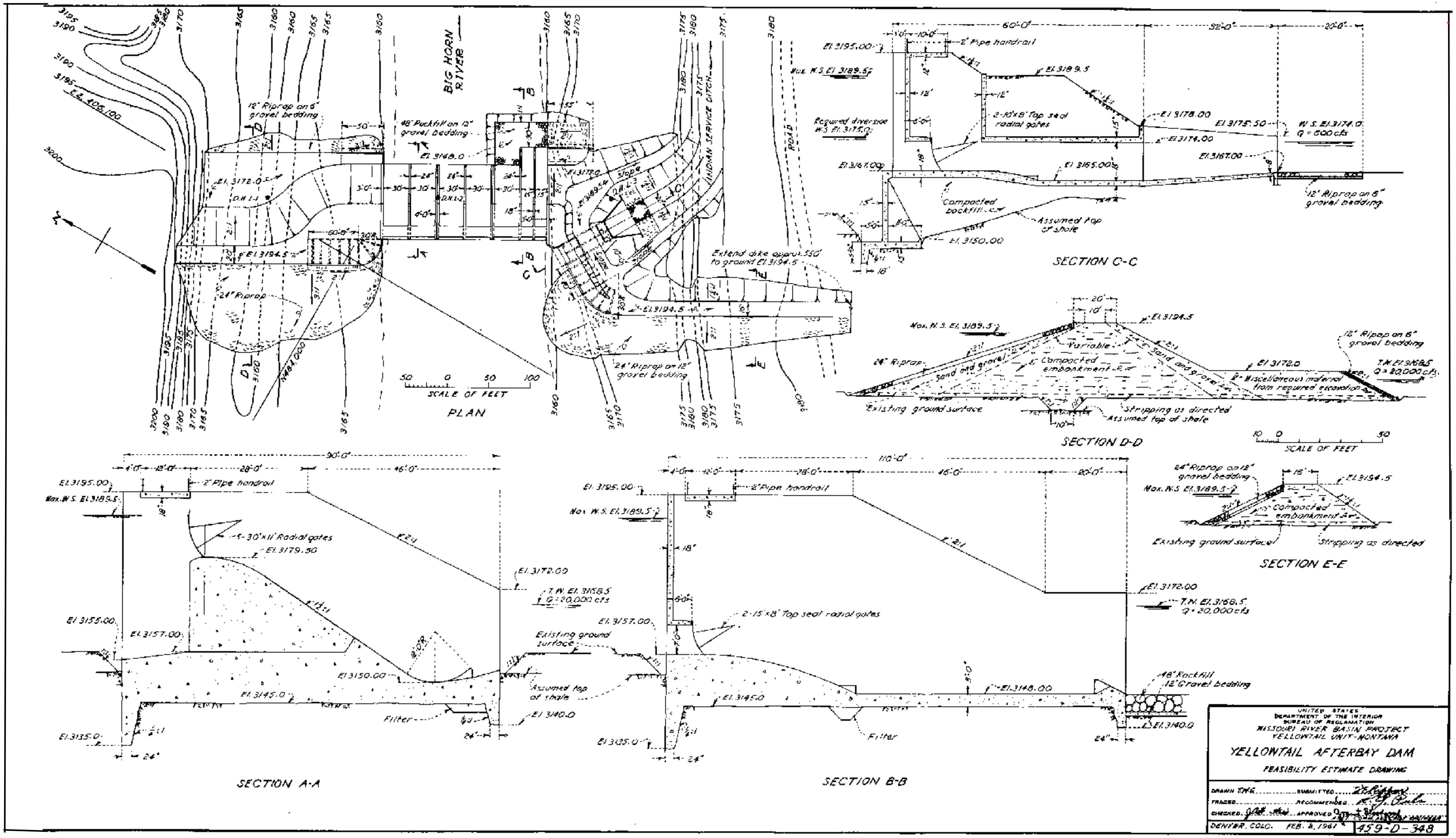
The widely varying releases from the powerplant will be regulated by an afterbay to minimize downstream fluctuations in the Bighorn River. The afterbay dam will be located about 2-1/4 miles below Yellowtail Dam and will consist of an earthfill embankment with concrete spillway and sluiceway structure and diversion works. (See drawing No. 459-D-348 following this page.) The top of the embankment section will be at elevation 3,194.5 feet, providing a freeboard of 5 feet. The embankment section will be 37-1/2 feet high above streambed, and the spillway crest will be 22-1/2 feet high. The over-all crest length of the dam will be 1,350 feet, including the spillway and sluiceway structure of 201-1/2 feet and a long, low earthfill dike on the right abutment. Regulation will be provided by five radial gates, each 30 feet by 11 feet, resting on the spillway crest, and by two top-seal radial gates, each 15 feet by 8 feet, set in the sluiceway channel at the right end of the spillway section. All gates will be electrically operated. In the right abutment, adjacent to the sluiceway section, a new headworks for the Big Horn Canal will be constructed. Two top-seal radial gates, each 10 feet by 8 feet, will control diversion to this canal. The present headworks and diversion dam will be removed.

Storage capacity of the afterbay will be 2,700 acre-feet at maximum water-surface elevation of 3,189.5 feet.

Discharge capacity of the spillway will be 20,000 cubic feet per second, which is the downstream capacity of a bankful river channel. A discharge of this amount is also the maximum release that will be made from Yellowtail Reservoir with an inflow flood with a frequency of one in 100 years.

Geology

The Bighorn Canyon in the vicinity of Yellowtail Dam site is about 2,500 feet wide and 800 feet deep. The site is excellent for construction of a dam. The canyon has steep rock slopes and vertical cliffs, and the axis of the dam can be placed approximately at right angles to the canyon. Formations exposed in the canyon, from top to bottom, are the Tensleep sandstone, Amsden formation, and Madison limestone. The Madison limestone is about 735 feet thick at the damsite, and its upper limit is


BIG HORN RIVER
INDIAN SERVICE DITCH
ROAD
12" Riprap on 6" gravel bedding
48" Rockfill on 12" gravel bedding
El. 3148.0
El. 3172.0
El. 3194.5
24" Riprap
24" Riprap on 12" gravel bedding
Extend dike approx. 550' to ground El. 3194.5
SCALE OF FEET
PLAN
El. 3195.00
2" Pipe handrail
Max. W.S. El. 3189.5
El. 3189.5
2-10'x8' Top seal radial gates
Required diversion W.S. El. 3175.0
El. 3178.00
El. 3175.50
El. 3174.00
W.S. El. 3174.0 Q = 600 cfs
El. 3167.00
El. 3165.00
Compacted backfill
Assumed top of shale
El. 3150.00
12" Riprap on 6" gravel bedding
SECTION C-C
El. 3194.5
Variable
Compacted embankment
Sand and gravel
24" Riprap
El. 3172.0
Miscellaneous material from required excavation
T.W. El. 3168.5 Q = 20,000 cfs
Existing ground surface
Stripping as directed
Assumed top of shale
SECTION D-D
SCALE OF FEET
24" Riprap on 12" gravel bedding
El. 3194.5
Max. W.S. El. 3189.5
Compacted embankment
Existing ground surface
Stripping as directed
SECTION E-E
5-30'x11' Radial gates
El. 3179.50
El. 3172.00
T.W. El. 3168.5 Q = 20,000 cfs
El. 3155.00
El. 3157.00
El. 3150.00
El. 3145.0
Filter
El. 3140.0
El. 3135.0
Assumed top of shale
SECTION A-A
Existing ground surface
El. 3157.00
2-15'x8' Top seal radial gates
El. 3148.00
48" Rockfill
12" Gravel bedding
El. 3140.0
El. 3135.0
Filter
SECTION B-B
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
YELLOWTAIL UNIT-MONTANA
YELLOWTAIL AFTERBAY DAM
FEASIBILITY ESTIMATE DRAWING
DRAWN T.H.G. SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED
DENVER, COLO. FEB. 2, 1961
459-D-348
GPO 844698

about 550 feet above the streambed. The dam will abut against this formation for its entire height. The formation may be described in three members according to the character of the rock and the topographic forms displayed in the canyon. The lower member extends about 160 feet above the streambed. The middle member is about 200 feet thick, and the upper member is about 150 feet thick. The foundation and abutments, extending to the base of the upper member of the Madison formation, consist of sound limestone which will require relatively shallow stripping to expose unweathered rock free of open joints. The foundation is competent to support the dam. The upper member of the Madison formation shows evidence of intense weathering by solution. Numerous cavities are present in this member, and they could present a serious leakage problem. Extensive grouting may be necessary to seal the reservoir in the contact area of the upper member, which will be exposed to reservoir water for distances of about 5,000 feet along the left wall and 1,800 feet along the right wall from the dam. Two tunnels, from which grouting of cavernous zones can be accomplished, are planned, one 1,100 feet long into the right wall and the other 3,100 feet long into the left wall. It is believed that this treatment will be sufficient to seal the reservoir.

Construction Materials

Sources of materials for construction were explored in the vicinity of the damsite, and laboratory tests of representative samples were made. Concrete aggregate in sufficient quantity was located on the left bank of the river below the mouth of the canyon. The tests showed that the aggregate is satisfactory for concrete mix provided that proper gradings are obtained, low-alkali cement is used, and about 3 percent of air is entrained in the mix. Sand in some sizes is deficient, but this deficiency can be corrected by crushing either local limestone or the oversize material from the aggregate deposits.

Embankment material for cofferdams, for diversion and care of the river during construction, and for the afterbay dam is available in sufficient quantity. The cofferdams can be constructed from talus material excavated from side slopes, with the addition of a relatively thin impervious core. Material for the core can be taken from the overburden at the aggregate deposits. This overburden, a homogeneous material, is also available in sufficient quantity for use as embankment material for the impervious section of the afterbay dam. Oversize produced in processing the concrete aggregate, loose rock from talus slopes, or quarried rock can be used for riprap.

Water for concrete mix and for washing aggregates is available from the Bighorn River. Tests showed that the river water is of satisfactory quality; but the water normally contains an excess of sediment, and primary settlement would probably be necessary.

Design and Construction Factors

Accessibility

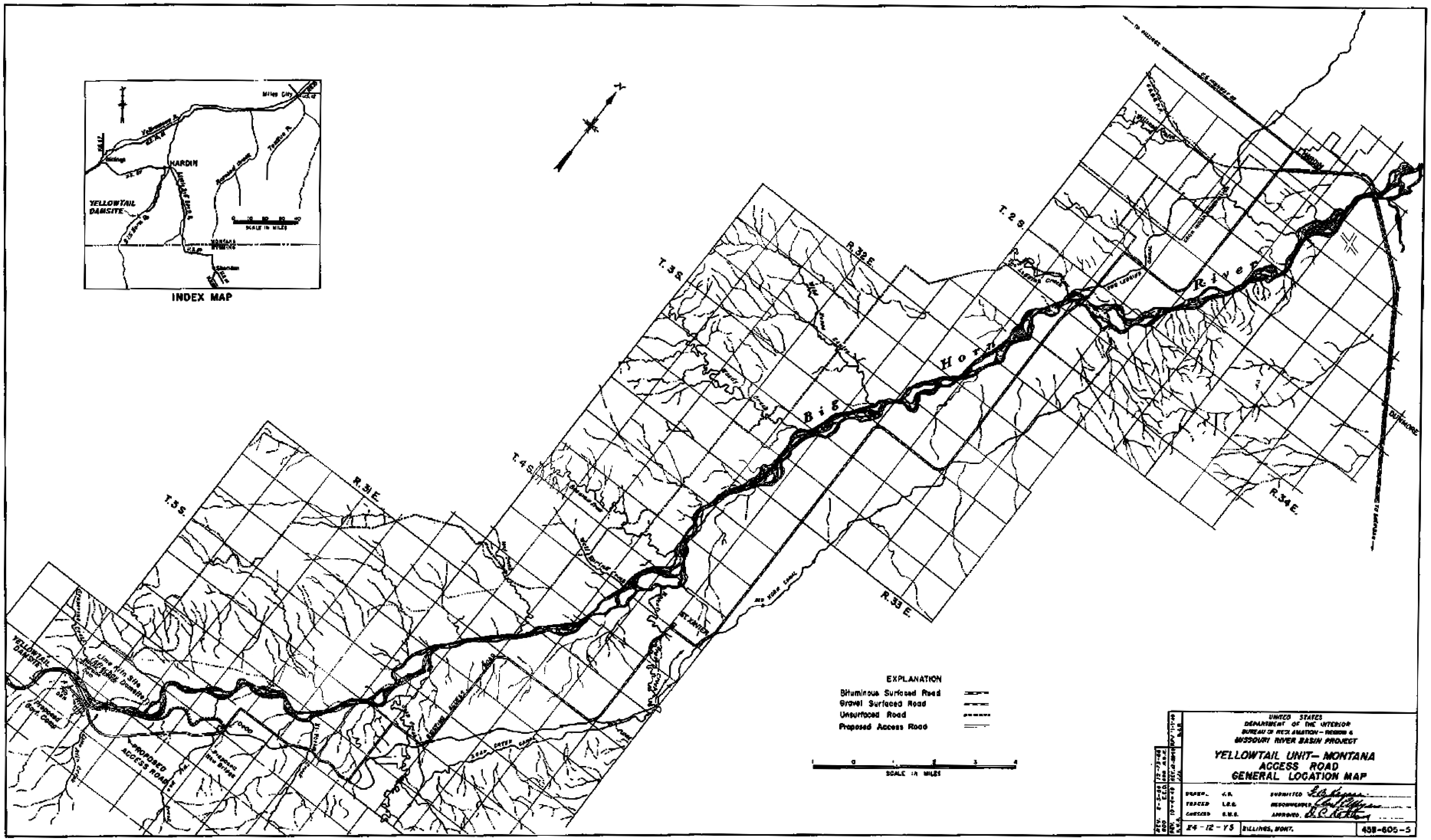
Construction materials and supplies must be trucked from Hardin, the selected unloading point on the Chicago, Burlington, and Quincy Railroad, about 45 miles by road to the damsite. The present route is over 28-1/2 miles of improved bituminous-surfaced road (State Secondary 313), 14-1/2 miles of gravel-surfaced road, and 2 miles of unimproved road. It crosses the Bighorn River about 8-1/2 miles south of Hardin. The bridge at this crossing is a new steel and concrete structure, designed for a H-15, S-12 loading. The gravel-surfaced road will require some grading, improvement in alignment, and bituminous surfacing for a distance of about 10-4/5 miles to make it suitable for heavy-haul use. The remaining portion of this road is the patrol road for the Big Horn Canal and headworks and is not suitable for access to the damsite.

To complete access to the Government community, it will be necessary to construct about 5 miles of new road. From the end of this road, permanent service roads will be constructed to the powerplant, the switchyard, and the top of the dam. The service road to the dam will cross the crest of the dam and extend up the west side of the canyon to the spillway inlet.

Drawing No. 459-605-5, on the following page, shows the location of the access road to Yellowtail Unit.

Construction Camps

A community for Government employees will be located on the east bank of the Bighorn River about 1-3/4 miles below the damsite. Official name of the community will be Fort Smith, derived from the name of an early infantry post which was built nearby to protect travelers on the Bozeman Trail. The community will consist of 19 permanent 3-bedroom houses, with lot spaces for 4 additional houses; 33 relocatable 3-bedroom houses; 3 relocatable dormitories; 42 trailer houses, with spaces for 8 additional trailer houses; 7 2-bedroom Transa houses; 14 5-stall temporary garages; 3 wash houses; an administrative building; a laboratory building; a warehouse and a storage yard; a garage and firestation; a comfort station; and a 12-car garage. Space has been tentatively reserved at the northeast edge of the community for a service station and shopping center, to be constructed by private enterprise should the need develop. Plans call for the local school district to build and operate an elementary school with Federal aid. Operation and maintenance personnel at the dam and powerplant will occupy the permanent houses after the construction period.


INDEX MAP
HARDIN
YELLOWTAIL DAMSITE
SCALE IN MILES
Big Horn River
T. 2 S.
T. 3 S.
T. 4 S.
T. 5 S.
R. 31 E.
R. 32 E.
R. 33 E.
R. 34 E.
DUNMORE
YELLOWTAIL DAMSITE
PROPOSED ACCESS ROAD
EXPLANATION
Bituminous Surfaced Road
Gravel Surfaced Road
Unsurfaced Road
Proposed Access Road
SCALE IN MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION — REGION 6
MISSOURI RIVER BASIN PROJECT
YELLOWTAIL UNIT— MONTANA
ACCESS ROAD
GENERAL LOCATION MAP
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
24-12-Y5
BILLINGS, MONT.
458-605-5

The water supply for the Government community will be obtained from springs on the east side of the river. A collection system and stabilization ponds will be provided for sewage disposal. Electric power for the community will be supplied by the Big Horn County Electric Cooperative under a rate contract with the Government. The cooperative will increase the capacity of its present line, construct the distribution system in the area, furnish and install meters, install power drops, and bill the consumers.

A contractor's camp consisting of permanent-type residences for key personnel will be constructed adjacent to the Government community. A small trailer court and quarters for other personnel will also be provided. The contractor's work area can be located northwest of the Government community, on the east side of the river. This area, consisting of about 5 acres, was the site of the preconstruction investigations camp.

Power for Construction

Power for construction will be obtained from the Bureau of Reclamation 115-kilovolt Yellowtail-Lovell transmission line. A temporary substation will be constructed to step down the voltage to that which will be usable by the contractor.

Diversion During Construction

Flood hydrographs were developed to determine the magnitude and volume of floods with frequencies of 5, 10, 20, and 100 years. The results are as follows:

Flood frequency (years)	Peak discharge (c.f.s.)	15-day volume (acre-feet)
5	30,100	725,000
10	33,600	822,000
20	37,100	902,000
100	44,400	1,082,000

During construction of the dam, protection should be provided in the river diversion to accommodate a flood with probable peak discharge of 37,000 cubic feet per second. Cofferdams above and below the damsite will be required to complete the diversion and allow unwatering of the foundation excavation and construction of the dam and powerplant.

Rights-of-way

From the Montana-Wyoming State line northward for about two-thirds of the distance to the Yellowtail Dam site, the Bighorn River marks the western boundary of the Crow Indian Reservation. The boundary

then cuts west to include the Pryor Creek drainage. The damsite and about 5,000 acres or 28 percent of the total reservoir area of 17,300 acres at elevation 3,657 feet (top of flood control pool) lie within the reservation boundary. All of this portion of the reservoir area will be in the Bighorn Canyon. The Crow Tribe will control access to some 85 miles of the 195 miles of shore line. Tribal land in the reservoir and damsite area to elevation 3,675 feet was acquired under the Act of July 15, 1958 (72 Stat. 361). The Crow Tribe was awarded $2,500,000 as just compensation for the land. The act permitted the Crow Tribe to bring suit in the U. S. District Court for additional compensation. A suit asking $10,000,000 in addition has been instituted.

Land to be inundated by Yellowtail Reservoir has little or no agricultural value. The Bighorn Canyon is narrow, rugged, and generally inaccessible. The canyon walls are of solid rock with numerous talus slopes of loose rock, and the streambed is strewn with rocks and boulders and has very limited areas supporting vegetation. This is also true of Black Canyon and smaller tributary ravines and gullies in this mountainous section. Above the head of the canyon, the reservoir area broadens and the valley is rimmed by rough broken uplands. The uplands are used for grazing livestock, although the land has relatively low carrying capacity. The alluvial land in the valley bottom and on the intermediate terraces contains soils of widely varying texture and depth.

At water surface elevation of 3,657 feet, the reservoir will extend to a point about 5-1/2 miles south of Kane and about 6 miles above the mouth of the Shoshone River. The reservoir at this level will inundate an area of valley land about 1-1/2 miles wide, extending 11 miles upstream from the head of the canyon. The area down to elevation 3,640 feet (top of joint-use storage) will be subject to periodic flooding, but lower land will be under water most of the time. Although a very small acreage of irrigated land in Shoshone Valley will be subject to inundation in spring and summer, practically no land of agricultural value will be permanently damaged by the reservoir.

The taking area for Yellowtail Unit totals 29,445 acres, of which 42 percent is in Montana and 58 percent is in Wyoming. This area includes land for which title has been or will be acquired or easements will be negotiated. Bureau policy requires that fee title generally will be acquired to all land 300 feet horizontally or 10 feet vertically from the edge of the joint-use pool. Flood easements or fee title can be acquired in the flood zone. Acquisitions are generally by 40-acre tracts.

Ownership of land in the taking area is as follows:

	Acres
Crow tribal land	5,678 1/
Indian allotments	727
Private land	10,682
State land	2,259
County land	12
Public domain	10,087 2/
Total	29,445

1/ Acquired under the Act of July 15, 1958 (72 Stat. 361).
2/ Withdrawn or subject to withdrawal by the Bureau of Reclamation.

Relocation of Properties

The cost of relocating the town of Kane was estimated on the basis of procurement of lieu land and removal or replacement of buildings and utilities, and other related costs. The town includes a combined post office and store, a railroad station, a small stockyard, and a few dwellings and service buildings. It is unlikely that these structures can be economically moved and re-erected, and their procurement will probably be necessary.

It will be necessary to relocate portions of several utilities at the upper end of the reservoir area. Relocation construction will include 5 miles of Chicago, Burlington, and Quincy railroad, 5 miles of REA transmission line, and 3-1/2 miles of telephone line.

Wyoming State Highway 14, a bituminous-surfaced secondary road, crosses the Bighorn River about 1-1/2 miles east of Kane. At elevation 3,657 feet, the reservoir would inundate 1-1/2 miles of this highway. Since the early planning studies were made, the Wyoming Highway Department found it necessary to relocate and rebuild the bridge across the river. It was determined to be most economical to the Government to participate in the construction cost by paying the additional cost of building the bridge about 17 feet above the elevation planned by the highway department. The Bureau of Reclamation entered into an agreement with the highway department, and, in 1956, the bridge was completed with deck and short approaches constructed to elevation 3,656 feet. The roadway beyond the east end of the bridge will be above the 100-year-frequency flood; however, some 6,100 feet of causeway to the west of the bridge will be raised to elevation 3,651 feet. A preliminary analysis of flood frequencies and

maximum reservoir water surfaces indicated that, for a 100-year-frequency flood, the backwater elevation in the vicinity of the highway would be 3,649.5 feet. This elevation would be 1-1/2 feet below the grade of the raised causeway and 6-1/2 feet below the deck of the bridge. The elevation of 3,651 feet was chosen as the top of causeway in order that floods in excess of this elevation would pass across an extensive length of the causeway and thereby not endanger girders of the bridge.

A 4-wire telphone line and an REA transmission line parallel Wyoming State Highway 14. These lines will either be relocated or raised with grade of the causeway.

The county farm-to-market road that crosses the Shoshone River on a timber-truss bridge about 1-1/2 miles above the river's confluence with the Bighorn River will be inundated by the reservoir and must therefore be relocated. This road provides access for farmers and ranchers to the area lying west of the Bighorn River and south of the Wyoming-Montana State line. It will be necessary to build a new bridge and road system upstream from the present location. The Bureau of Reclamation plans to enter into an agreement with Big Horn County, Wyoming. This agreement will provide that the Bureau will pay the county $294,000, the equivalent cost of constructing the bridge across the Shoshone River at the most feasible location, building about 2 miles of new road, and improving 5 miles of existing gravel road. The agreement will provide further that the county may utilize the payment for replacement of facilities of at least equal kind and utility as part of its highway program in cooperation with the Wyoming Highway Department, provided that the county will assume all responsibility for ingress and egress to land and properties now served by the county road and bridge that will be inundated.

Minerals and Archaeological Deposits

Very little information is available on the extent and possible commercial value of minerals within the Yellowtail Reservoir area, and no development of importance has taken place. However, the Bureau of Mines reports that the reservoir will not adversely affect any known significant mineral resources. Some gold-placer claims will be inundated, but past operation of these claims has been unprofitable. Uranium was discovered in the Pryor Mountains a few miles west of the reservoir area in 1955, and mineral claims were staked on Government land near the reservoir area. The reservoir at maximum capacity will not affect uranium deposits as presently known, although the taking area includes uranium-bearing deposits. Bentonite beds are known to be present in the upper end of the reservoir, north of Kane.

A report of the Smithsonian Institution prepared for the National Park Service, dated May 1947, contains the following recommendations:

"The abundant and varied remains discovered at Yellowtail during a brief reconnaissance suggest that many archaeological sites exist both within and around the reservoir area. The reservoir also possesses good possibilities from the historical standpoint. Consequently, it is recommended that an intensive survey be made of the valley above the canyon, in the rock shelters along the canyon borders, at creek mouths in the canyon bottom, and around the damsite. For some of this work boats probably will be essential. Many of the sites disclosed by such a survey might not be endangered by flooding, but might be damaged by tourists in the event the recreational potentialities of Yellowtail are developed. Any proposed recreational areas should be thoroughly investigated as a precaution against looting. None of the known sites are of such nature as to be legitimate tourist attractions. The time required for an intensive survey of the reservoir is exceedingly difficult to estimate because of the many unknown and variable factors involved, but it is believed that at least 100 man-days should be allowed for the project. Until the recommended survey is carried out, no definite statement can be made regarding which sites should be excavated and how much time such excavation would require."

Construction Period

The normal construction season in this climate averages about 8 months, taken from the time the frost leaves the ground in the spring, usually early in April, to freezing weather late in November. This will apply for most activities, but minor work can be carried on throughout the year. The time necessary for construction of the dam, spillway, powerhouse, switchyard, and afterbay dam will be about 6 years. The control schedule, form PF-2, following this page, shows the proposed construction program.

Special Problem

Diversion is made from the river to the existing Big Horn Canal by means of a fixed-crest diversion dam located about 1 mile above the afterbay damsite. Headgate for this canal is located about one-half mile above the diversion dam. Height of the dam (about 8 feet above streambed) is sufficient to reduce the power head, and storage capacity above the dam is too small to be advantageous in smoothing out power-peaking discharges.

The diversion dam must be removed to permit full operation of the afterbay. Its removal will, of course, necessitate revision of the canal headworks. Plan for the new headworks is discussed under the heading "Afterbay Dam and Storage."

LEGEND: Types of Activity

Preconstruction | Construction

LINE NO.	CLASS AND ACCOUNT	PROGRAM ITEM	QUANTITY	UNIT	ESTIMATED TOTAL	TOTAL TO JUNE 30,'62	FISCAL YEARS 1963 1/	1964	1965	1966	1967	1968	1969	BALANCE TO COMPLETE	ESTIMATED COMPLETION DATE	LINE NO.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1		Power Development	200,000	Kw						100,000 Kw	100,000 Kw					1
2	107	CONSTRUCTION PROGRAM														2
3	01.01	Yellowtail Dam and Reservoir	1,375,000	AF	70,840,000	14,478,317	9,402,000	17,519,000	13,835,000	7,187,000	6,418,683			Start Storage		3
4																4
5	02.01	Yellowtail Afterbay Dam	36 x 1320	Ft.	2,500,000	90,970	70,000	488,000	1,355,000	496,030						5
6																6
7	11.01 13.01	Yellowtail Powerplant, Switchyard, and Tie Line	200,000 240,000	Kw Kva	25,076,000	1,837,455	2,990,000	6,484,000	8,650,000	4,424,000	730,545			Initial Power—First Unit		7
8																8
9	15.01	Permanent Operating Facilities			1,145,000	843,233	148,000		69,000	40,000	44,767					9
10																10
11	15.01	O&M Housing			461,000	372,433	6,000			69,000	13,567					11
12																12
13	15.02 & 15.03	Wildlife Management Area and Upstream Fishery Rehabilitation			294,000					294,000						13
14																14
15		Temporary Camp			980,000	896,340	83,660									15
16																16
17		Service Fac., Depreciation and Salvage			-1,104,000	329,250	-220,000	-291,000	-308,000	-308,000	-306,250					17
18																18
19		TOTAL CONSTRUCTION COST			100,192,000	18,847,998	12,439,660	24,200,000	23,601,000	14,202,030	6,901,312					19
20																20
21		TOTAL PROJECT COST			100,192,000	18,847,998	12,439,660	24,200,000	23,601,000	14,202,030	6,901,312					21
22																22
23		Consolidated Expenditures and Credits			-1,809,000	-2,150,869	35,340		-1,000	-8,030	515,559					23
24																24
25		TOTAL EXPENDITURES			98,383,000	16,497,129	12,475,000	24,200,000	23,600,000	14,194,000	7,416,871					25
26		Undelivered Orders				325,000	-325,000									26
27		TOTAL OBLIGATIONS			98,383,000	16,822,129	12,150,000	24,200,000	23,600,000	14,194,000	7,416,871					27
28																28
29																29
30																30
31																31
32																32
33																33

Notes: 1/ Construction started F.Y. 1961.

Form 89-1 JUNE 1960

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

CONTROL SCHEDULE

MISSOURI RIVER BASIN PROJECT
YELLOWTAIL UNIT

Fort Smith, Montana (OFFICE) April, 1962 (DATE) 6 (REGION)

☐ GENERAL INVESTIGATIONS ☒ CONSTRUCTION ☐ OPERATION & MAINTENANCE ☐ OTHER

It will be necessary to operate the afterbay from two different base levels, one during the irrigation season and one at other times. During the irrigation season, the minimum water surface elevation in the afterbay should be about 3,175 feet. During the non-irrigation season, the afterbay will be operated at the lowest possible water surface elevation to take advantage of lowered tailwater at the powerplant.

Cost Estimates

Construction Cost

The total cost for Yellowtail Unit, based on bid prices for certain features or items and January 1962 prices for other features or items, is estimated to be $100,192,000, as shown on the form PF-1 at the end of this chapter. A summary of costs follows:

Feature or items	Cost
Yellowtail Dam and Reservoir	$ 70,840,000
Yellowtail Afterbay Dam	2,500,000
Yellowtail Powerplant	21,416,000
Yellowtail Tie Line and Switchyard	3,660,000
Permanent operating facilities	1,606,000
Wildlife management area	229,000
Rehabilitation of upstream fishery	65,000
Temporary camp	980,000
Other service facilities	813,000
Depreciation during construction, and salvage	-1,917,000
Total construction cost	$100,192,000 1/

1/ This cost estimate does not include costs of "minimum basic health and safety facilities," although costs of these facilities are being included on official estimates and schedules for budgetary use until authority and appropriations for the Bighorn Canyon National Recreation Area, recommended by the National Park Service, have been obtained.

Because of the cavernous nature of the upper member of the Madison limestone, considerable leakage might occur and extensive grouting and other remedial treatment might be necessary. Two tunnels, one in each wall, are planned for construction, and a grout curtain will be provided below these tunnels to seal off cavernous zones. It is believed that this treatment will be sufficient to seal the reservoir. However, additional contingencies are provided in the cost estimate to cover the cost of an extensive sealing program if necessary.

Operation, Maintenance, and Replacement

Annual costs of operation, maintenance, and replacement for Yellowtail Unit are estimated to be $358,610, distributed as follows:

	Cost
Operation and maintenance of powerplant and switchyard	$265,000
Operation and maintenance of dam and reservoir	17,210
Replacement reserve - powerplant and switchyard	76,400
Total OM&R	$358,610

A full complement of personnel is assumed in the estimate for operation and maintenance of the dam, powerplant, and switchyard. Included are 22 employees for operation and maintenance of the powerplant and switchyard. Allowances have been made for overtime and holiday pay, night differential, station supplies, supervision and overhead, administrative and general expense, reservoir control, and wage increases and miscellaneous contingencies. The estimate is based on current information and costs. It does not include joint and transmission costs assigned to power.

PR-1
(6-57)
Bureau of Reclamation

OFFICIAL
ESTIMATE

Project: Missouri River Basin
Yellowtail Unit

Date of Estimate: April 1962

Cost Classification	DESCRIPTION	Quantity	Unit Cost	Total Estimate	Labor and materials by contractor	Materials and Equipment by Govt.	Labor by Government Forces	Service Facilities	Investigations, Engineering and Other Costs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
01.01	YELLOWTAIL DAM AND RESERVOIR	1,375,000	AP	70,845,000	56,011,770	1,231,700	4,600	1,041,000	11,950,929
.30	Land and Land Rights			3,900,900	3,780,000			20,000	100,000
.31	Relocation of Existing Property			2,980,000	2,254,272			49,500	676,228
.32	Clearing Reservoir			1,060,000	900,000			20,000	140,000
.33	Structures and Improvements			7,000		2,200	3,600	500	700
.34	Reservoir			11,530,000	9,465,500	500	1,000	851,000	1,512,000
.35	Dam			50,730,000	39,110,000	1,185,000		1,290,000	9,185,000
.36	Waterways			360,000	260,000	44,000		5,000	71,000
.50	Roads, Railroads and Bridges			313,000	242,000			5,000	66,000
02.01	YELLOWTAIL AFTERBAY DAM	36,320	Pt.	2,500,000	1,780,000	150,000		50,000	520,000
.31	Relocation of Existing Property				35,600				
.35	Dam				1,654,400	138,000			
.36	Waterways				90,000	30,000			
11.01	YELLOWTAIL POWERPLANT	200,000	KW	21,416,000	7,276,000	5,619,000		415,000	4,104,000
.33	Structures and Improvements			4,302,000	3,347,000	120,000		100,000	735,000
.36	Waterways			4,324,000	2,217,000	1,104,000		80,000	923,000
.41	Waterwheels, Turbines and Generators			10,640,000	1,210,000	7,190,000		200,000	2,040,000
.48	Accessory Electrical Equipment			1,416,000	310,000	880,000		20,000	260,000
.49	Misc. Powerplant Equipment			555,000	54,000	385,000		10,000	106,000
.50	Roads, Railroads, and Bridges			185,000	140,000			5,000	40,000
13	YELLOWTAIL TIE LINE AND SWITCHYARD			3,660,000	1,038,000	1,773,000		61,000	788,000
.01	Yellowtail Switchyard	245,000	KVA	3,620,000	1,006,000	1,773,000		60,000	781,000
.33	Structures and Improvements			265,000	208,000			3,000	54,000
.50	Roads, Railroads and Bridges			144,000	120,000			2,000	22,000
.51	Station Equipment			2,939,000	527,000	1,712,000		50,000	650,000
.52	Towers and Fixtures			141,000	111,000			2,000	28,000
.54	Overhead Conductors and Devices			40,000	30,000			1,000	9,000
.78	Communication Equipment			91,000	10,000	61,000		2,000	18,000
.02	115-Kv Tie to Lovell-Yellowtail Line			40,000	32,000			1,000	7,000
.33	Poles and Fixtures				16,290				
.54	Overhead Conductors and Devices				15,710				
15.01	PERMANENT OPERATING FACILITIES			1,506,000	1,330,425	5,700	6,375	22,500	141,000
.30	Land and Land Rights			8,936	4,936				4,000
.33	Structures and Improvements								
	.01 Permanent Operating Facilities Except O&M Housing			320,799	228,099	2,700		5,000	85,000
	.02 O&M Housing			461,000	397,793	3,000	6,375	4,867	49,000
.50	Roads, Railroads and Bridges			710,265	607,134			10,133	93,000
.73	Transportation Equipment			85,000	75,000			2,000	8,000
.78	Communication Equipment			20,000	17,500			500	2,000
15.02	WILDLIFE MANAGEMENT AREA			229,000	229,000				
.30	Land and Land Rights			229,000	229,000				
15.03	REHABILITATION OF FISHERY UPSTREAM FROM DAM			65,000	65,000				
G.L.									
315.01	TEMPORARY CAMP			980,000	538,760	231,240	40,000	10,000	160,000
.33	Structures and Improvements			980,000	538,760	231,240	40,000	10,000	160,000
.02	OTHER SERVICE FACILITIES			813,000	184,598	542,402	7,000	6,000	73,000
.33	Structures and Improvements			271,000	184,598	36,402	7,000	4,000	39,000
.49	Miscellaneous Equipment			227,000		212,000		2,000	13,000
.72	Office Furniture and Equipment			49,000		45,000			4,000
.73	Transportation Equipment			136,000		130,000			6,000
.74	Stores Equipment			19,000		18,000			1,000
.75	Shop Equipment			6,500		6,000			500
.76	Laboratory Equipment			25,500		23,000			2,500
.77	Tools and Work Equipment			80,000		75,000			5,000
.78	Communication Equipment			19,000		17,000			2,000
	DEPRECIATION AND SALVAGE			-1,917,000	-826,658	-771,642	-47,000	-19,000	-250,700
	TOTAL CONSTRUCTION COST			100,192,000	67,628,896	12,769,400	10,975	2,186,500	17,576,229
	TOTAL PROJECT COST			100,192,000	67,628,896	12,769,400	10,975	2,186,500	17,576,229
	Investigations, Engineering and Other Costs:								
	Investigations								3,078,929
	Construction Engineering and Supervision								5,760,000
	Designs and Specifications								5,933,000
	Other Costs								1,055,000
	Less Depreciation During Construction								-250,700

The principal headwater tributaries of the Bighorn River rise in the Wind River Mountains in west-central Wyoming. These tributaries join to form the Wind River which flows northeastward through the Wind River Basin, thence through a low range of mountains by way of the Wind River Canyon to the Bighorn Basin. At the mouth of this canyon, the Wind River becomes the Bighorn River in name and flows northward through the Bighorn Basin along the foot of the Bighorn Mountains. Principal tributaries in this reach of the river are the Greybull and Shoshone Rivers which rise in the Absaroka Mountains to the west. The Bighorn River leaves the basin by way of the deep Bighorn Canyon and enters the Lower Bighorn Basin, then continues northeastward to join the Yellowstone River near Custer, Montana. Main-stream regulation is presently provided only by Boysen Dam and Reservoir on the Wind River at the head of the Wind River Canyon. Construction of the dam was completed in 1951.

Water Resources

Runoff Characteristics

A major part of the runoff of the Bighorn (Wind) River is derived from melting snows in the high mountains during early summer months. About one-half of the annual runoff occurs during May, June, and July, with about one-fourth in June alone. Beginning in late summer, the flow diminishes greatly. Most tributary streams have their sources in the mountains along the west and southwest and together contribute the greater part of the snowmelt runoff. The entire drainage area is subject to showers and cloudbursts throughout the spring, summer, and fall. Showers are generally localized, and the resulting floods are largely confined to the smaller tributary streams.

Streamflow Records

Streamflow measurements of the Bighorn River have been made at Kane, Wyoming, about 1 mile above the mouth of the Shoshone River, since August 1928, and of the Shoshone River at Byron, Wyoming, about 20 miles above its mouth, since January 1929. Measurements of the Bighorn River have also been made near St. Xavier, Montana, about 1-1/4 miles downstream from Yellowtail Dam site, since October 1934, and at Hardin, Montana, from June 1904 to May 1925 and from August 1928 to June 1933. A gaging station was installed near the mouth of the Bighorn River in May 1945, and records from this station are continuous to date.

Four perennial streams - Porcupine, Bull Elk, Black Canyon, and Dry Head Creeks - flow directly into the Yellowtail Reservoir site between the gaging stations at Kane and near St. Xavier. Contribution of runoff from these streams is small.

Inflow to Yellowtail Reservoir

Yellowtail Reservoir will be the lowermost storage on the Bighorn River and will in effect operate with residual flows from all upstream developments. Water supply studies for the upper and middle subbasins, which were made principally in connection with Boysen Reservoir, were utilized in estimating the depleted inflow to Yellowtail Reservoir. The average annual depletion amounts to 535,000 acre-feet above the level of depletion in 1944, the year in which the Missouri River Basin Project was authorized. This depletion allows for full supply of all potentially irrigable land that appears feasible of development and supplemental supply of presently irrigated land that can be feasibly furnished additional water.

Records of streamflow near St. Xavier, extended back to 1924, provide the basis for estimating inflow to Yellowtail Reservoir. Table 2 shows the estimated inflow to the reservoir with the depletions for the anticipated upstream development.

Since 1924, the historic runoff at the gage near St. Xavier has ranged from an estimated 1,371,000 acre-feet in 1934 to about 4,079,400 acre-feet in 1924, and the lowest recorded discharge was 228 cubic feet per second in 1937. Operation studies showed the critical period to be from 1934 to 1941. Average annual runoff during this period was 2,108,800 acre-feet, and for the period 1924 through 1958 was 2,639,900 acre-feet.

Downstream Tributaries

Eight streams are tributary to the Bighorn River below the Yellowtail Dam site: namely, Grapevine, War Man, Soap, Rotten Grass, Lime Kiln, Beauvais, and Tullock Creeks, and the Little Bighorn River. Records of streamflow in the Little Bighorn River are available for a gage about 14 miles above the mouth of the river for the periods September 1911 to September 1924, August 1928 to December 1932, and April 1938 to date. Streamflows during the intervening periods were established by correlation with the recorded flows of the Tongue River near Decker, Montana. Average annual flow of the Little Bighorn River during the period 1929 through 1958 was 178,600 acre-feet.

Streamflow of Soap Creek was recorded at a gage about 6 miles above the mouth of the creek from March 1939 through September 1953. Average annual flow of the creek during this period was 20,400 acre-feet.

Periodic records of streamflow in Rotten Grass Creek, obtained prior to 1922, are of little value. No records are available for the remaining tributaries.

Comparison of concurrent records for the gage on the Bighorn River near St. Xavier and the gage near the mouth of the river shows

Table 2 - Depleted Inflow to Yellowtail Reservoir After Full Irrigation Development 1/
(Unit - 1,000 acre-feet)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1924	263.1	231.9	127.7	135.1	143.2	173.0	638.0	586.2	805.7	203.7	105.3	117.5	3530.4
25	179.5	154.8	113.4	104.5	99.0	125.4	100.3	199.1	581.1	438.6	113.0	132.3	2341.0
26	162.3	160.5	128.4	100.5	89.9	167.7	180.8	344.2	285.7	181.7	107.2	113.9	2022.8
27	112.0	122.5	108.6	101.8	88.4	117.6	98.7	144.8	851.9	393.2	121.0	120.5	2381.0
28	195.8	175.6	119.7	106.2	88.8	132.8	98.8	835.7	511.3	468.2	100.8	100.9	2934.6
29	109.4	132.6	103.0	96.8	94.5	320.2	204.6	270.1	463.8	175.3	130.8	145.8	2246.9
30	133.3	136.4	134.9	106.6	109.5	130.7	134.3	137.6	185.8	150.5	272.8	146.7	1779.1
31	198.6	188.4	128.6	114.1	106.3	121.0	98.8	210.2	335.6	132.7	152.3	106.6	1893.2
32	114.4	123.1	116.5	116.0	114.5	151.9	136.3	221.9	293.3	232.7	128.5	126.4	1875.5
33	124.1	134.7	111.4	100.8	85.6	117.1	119.8	178.7	559.2	166.6	185.9	135.9	2019.8
34	116.2	144.3	122.5	122.3	98.6	112.1	96.3	90.6	118.0	128.5	119.8	108.8	1378.0
35	109.8	119.2	102.2	107.1	95.5	110.2	106.7	98.2	294.1	174.5	116.7	103.5	1537.7
36	107.3	126.6	113.2	105.9	94.4	129.4	108.8	103.2	259.2	112.9	110.8	104.0	1475.7
37	129.4	143.8	118.7	128.5	105.4	140.4	101.7	117.2	206.3	356.8	125.5	108.7	1782.4
38	123.3	125.1	110.2	111.7	99.6	134.3	88.9	150.7	355.4	270.3	90.3	113.0	1772.8
39	121.9	136.8	118.1	106.7	86.7	164.4	101.2	157.0	234.1	117.6	102.1	100.1	1546.7
40	111.0	124.6	120.5	95.7	100.9	124.1	103.5	123.7	210.0	157.2	100.4	106.1	1477.7
41	167.8	128.8	116.1	126.6	124.8	140.1	101.6	168.9	220.6	99.1	152.7	170.6	1717.7
42	172.0	171.7	149.7	115.7	122.6	219.9	214.4	255.1	384.7	152.9	97.0	122.7	2178.4
43	147.0	154.6	119.2	120.0	137.1	188.6	143.9	99.5	511.5	551.9	120.6	115.8	2409.7
44	161.5	166.0	120.5	100.6	108.4	100.2	106.8	287.2	824.0	516.7	64.8	153.0	2709.7
45	165.0	152.3	101.9	127.5	121.1	127.4	61.3	37.4	455.4	579.3	178.5	270.8	2377.9
46	205.5	169.8	143.7	137.3	126.5	146.0	116.3	16.0	308.7	250.0	49.7	212.4	1881.9
47	217.0	163.0	150.0	111.0	128.0	130.0	86.0	305.0	716.0	757.0	197.0	180.0	3140.0
48	181.8	164.6	137.8	116.8	173.5	283.7	193.2	173.8	555.0	198.7	109.7	124.9	2413.5
49	137.5	142.1	117.4	126.4	112.1	275.0	159.8	174.1	319.2	149.6	81.1	118.6	1912.9
50	179.5	167.2	137.1	144.2	141.8	252.5	206.8	168.1	258.7	325.4	165.1	195.5	2341.9
51	235.9	188.2	169.6	131.8	147.4	272.8	272.2	247.3	297.7	434.9	275.5	156.6	2929.9
52	173.0	151.0	121.8	135.9	119.5	134.3	128.7	198.4	173.5	92.2	130.5	123.5	1682.3
53	170.9	144.0	140.7	151.9	148.5	152.3	101.7	27.3	164.9	37.3	103.6	110.8	1453.9
54	155.5	174.7	161.2	119.6	95.5	99.7	77.8	150.6	126.7	193.5	108.9	119.6	1583.3
55	162.4	162.4	165.2	139.4	105.5	167.6	162.8	136.8	207.8	81.7	87.4	100.7	1679.7
56	132.3	133.7	161.5	173.9	172.1	196.3	100.2	113.6	234.1	101.8	107.7	155.0	1782.2
57	195.9	208.3	172.7	128.3	127.0	148.2	82.4	164.6	577.1	575.5	146.7	157.3	2684.0
58	243.2	238.1	197.5	214.9	205.4	190.0	84.9	128.1	151.5	95.4	95.5	134.2	1978.7
Total	5615.1	5461.4	4581.2	4282.1	4117.6	5696.9	4918.3	6820.9	13137.6	9053.9	4455.2	4712.7	72852.9
Mean	160.4	156.0	130.9	122.3	117.6	162.8	140.5	194.9	375.4	258.7	127.3	134.7	2081.5

1/ Average of 535,000 acre-feet annually above level of development in 1944.

Remarks: Period 1924 through 1943 from detailed depletion study of 1944.
Period 1944 through 1958 by correcting historic flow by estimated future depletions in excess of that existing in 1944.

an average gain in flow of 207,000 acre-feet annually. The general increase in flow indicates that most of the water used for irrigation and other purposes is replenished by inflows from the downstream tributaries.

Quality of Water for Irrigation

Water samples obtained by the Geological Survey from the Bighorn River near Yellowtail Dam site over a 2-year period ending September 30, 1939, were analyzed by the Montan Agricultural Experiment Station. The analyses showed that the water, after mixing in Yellowtail Reservoir, would have a low sodium hazard but a high salinity hazard and should not be used on soils with restricted drainage. This restriction was recognized in the classification of land on Hardin Unit, and all land that cannot be adequately leached was eliminated. Water from the Bighorn River has been used for irrigation in Montana for 50 years without apparent adverse effects.

The period in which the water samples were gathered was one of the driest of record, and it is anticipated that the quality of water over a long period will average somewhat better than indicated. This would be due to the mixing of the better quality water during years of high flow with water of low-flow years.

No additional analyses have been made of water at the Yellowtail Dam site since 1939; however, many analyses have been made of water from the river both upstream and downstream from the site. Results of these analyses confirm the fact that the water is satisfactory for irrigation use.

Water Rights

The water of the Bighorn River in Montana has not been adjudicated. However, it has been held that, under the Treaty of May 7, 1868 (15 Stat. 649-651) with the Crow Indian Tribe, the water within the Crow Reservation is reserved for the benefit of the tribe and the right to use some portion of the water needed for cultivation of land in the reservation is held by owners of the Indian allotments and their assignees.

A nondecreed right can be obtained on nonreservation land in Montana in two ways: (1) by posting a notice on the stream and filing a copy of the notice in the office of the county clerk, and proceeding to use the water; and (2) by diverting and using water from a stream without posting or filing notice. In adjudications, both methods have been recognized by the courts. In either case, the amounts of water finally decreed and the dates of priority are determined by the evidence and proofs.

The water supply for land having water rights on the Bighorn River in Montana has generally been adequate. Shortages that have occurred have been due to the physical limitations at the points of diversion during low flows. The most serious shortage was experienced in 1934 when a prolonged period of low streamflow made it necessary for some water users to buy water from Buffalo Bill Reservoir on the Shoshone River. Water right filings on the Bighorn River in Montana total 1,866 cubic feet per second for supplying 52,874 acres of irrigable land under ditch (43,008 acres actually irrigated).

Water right conflicts between future irrigators on the Hardin Unit and present irrigators along the Bighorn River in Montana are not anticipated. The Hardin Unit will receive its water supply directly from Yellowtail Reservoir. Operation of the reservoir for power production, combined with reregulation by Yellowtail afterbay, will improve the water supply considerably for present irrigators by providing a relatively stable base flow during the irrigation season. Regulation of streamflow in the Bighorn River will also improve the water supply for water users along the Yellowstone River below the mouth of the Bighorn River.

Interstate Water Use Agreement

The plan of development for the Missouri River Basin Project provides for an increase in the irrigated acreage in Wyoming, Montana, and North Dakota. In order that each state could proceed without conflict in use of water, the Yellowstone River Compact was formulated to divide the water of the Yellowstone River and its tributaries among the three states. This compact was negotiated by the Yellowstone River Compact Commission, which was composed of representatives of the states and a representative of the United States. The compact was ratified by the State legislatures and was consented to by the Congress in an act approved by the President on October 30, 1951 (65 Stat. 663).

The compact, as it pertains to the Bighorn River and its tributaries, provides that existing water rights in Wyoming and Montana be honored; sufficient water, of that which is unused and unappropriated, be allocated to each state to furnish supplemental supplies to land with existing rights; and the remaining unused and unappropriated water be allocated for storage or direct diversion in the ratio of 80 percent to Wyoming and 20 percent to Montana. These percentages are based on divertible flow, which is considered to be total diversions plus or minus the change in storage for a year beginning October 1 and ending September 30. The inflow of the Little Bighorn River is excluded from the water subject to allocation.

An optimistic appraisal of potential development indicates that Wyoming will not use all of the water allocated to it under the compact. Yellowtail Reservoir, because of its large capacity and its location on the Montana-Wyoming State line, offers opportunity for providing a simple physical solution to any interstate water problem and easing the administration of the compact.

Irrigation Requirements

Existing Irrigation

The following tabulation shows the acreages of land now under irrigation and being supplied by diversion from the Bighorn River below Yellowtail Dam site:

Ditch	Canal capacity (c.f.s.)	Irrigated acreage	Additional acreage irrigable under existing works	Total irrigable acreage
Big Horn Canal	720	20,372	4,333	24,705
Two Leggins Canal	400	15,498	2,896	18,394
Big Horn Lowline Canal	150	4,362	1,846	6,208
Victory Ditch	45	1,431	224	1,655
Big Horn-Tullock Canal	25	1,345	567	1,912
Total		43,008	9,866	52,874

Source of data: Montana State Engineer's Water Resources Surveys of Big Horn, Treasure, and Yellowstone Counties.

The channel of the Bighorn River tends to change from year to year. This tendency, together with the heavy sediment load carried by the river, makes gravity diversion difficult without diversion dams or extensive control structures. Trouble has been experienced in the past in maintaining works for most of the present systems to provide adequate diversions at low streamflow. From observations made at diversion sites, it appears that a base flow of 1,000 cubic feet per second is needed in addition to diversion requirements.

The average diversion requirement for irrigable land under existing works along the Bighorn River, computed for the period 1924-58, is 3.72 acre-feet per acre. The maximum diversion requirement for the 35-year period was 4.48 acre-feet per acre in 1934, and the minimum requirement was 2.68 acre-feet per acre in 1927.

No set amount of water can be appropriated under Montana law; however, when a stream is adjudicated by the courts, the amount normally allowed is 1 miners inch per acre, which is 1 cubic foot per second for 40 acres. The Bighorn River in Montana has not been adjudicated; but if the rate normally set in adjudications were to be used by present irrigators in making diversions, the annual diversion would be about 7.5 acre-feet per acre.

The full diversion requirement will have to be released from Yellowtail Reservoir for land under the Big Horn Canal, the headgate for which is above points of available return flows and other inflows. Some return flow is available to the Two Leggins Canal, and releases from the reservoir for diversion to this canal can be reduced by the amount of return flow available. Other existing canals and ditches along the Bighorn River divert below the mouth of the Little Bighorn River, and in most years they can obtain a full irrigation supply from tributary inflow and return flows.

To provide a full supply of water for irrigation of the 52,874 acres of irrigable land under existing works, the net demand at Yellowtail Reservoir by months of the irrigation season, based on diversion of 1 cubic foot per second for 40 acres, is as follows:

Month	Net irrigation demand (average c.f.s.)			Base flow (c.f.s.)	Required reservoir release (average c.f.s.)	Average Yellowtail release to Bighorn R. (c.f.s.) 1/
	Above Yellowtail afterbay	Afterbay to Little Bighorn River	Below Little Bighorn River			
May	618	307	0	1,000	1,925	3,150
June	618	186	0	1,000	1,804	3,330
July	618	159	0	1,000	1,777	3,270
Aug.	618	179	0	1,000	1,797	2,230
Sept.	618	228	0	1,000	1,846	2,100
Oct.	618	291	0	1,000	1,909	2,140

1/ Average powerplant releases for period 1924-58 with depleted inflow.

The foregoing tabulation shows that the powerplant releases will be adequate to meet the downstream irrigation demand along the Bighorn River in addition to providing a base flow of 1,000 cubic feet per second. However, with a regulated supply available, it is anticipated that annual diversions will be nearer 3.7 acre-feet per acre than 7.5 acre-feet per acre.

Future Irrigation

Future downstream irrigation developments that will benefit from the stream regulation provided by Yellowtail Dam and Reservoir include the Hardin Unit along the Bighorn River and the Yellowstone Pumping Units along the Yellowstone River. These potential developments are discussed in a later chapter of this report.

The gross diversion requirement for Hardin Unit, measured at the outlet of the diversion tunnel from Yellowtail Reservoir, is 3.07 acre-feet per acre, or 125,800 acre-feet for the irrigation season May through October. This requirement comprises all water needed to satisfy productive consumptive use of irrigation water and to provide for wastes and losses in the supply and distribution systems, and was computed for the period 1924 through 1958. The following tabulation shows the mean gross diversion requirement by months of the irrigation season:

Month	Gross diversion requirement	
	Acre-feet per acre	Total acre-feet 1/
May	.28	11,500
June	.47	19,400
July	1.02	41,700
August	.83	34,100
September	.40	16,300
October	.07	2,800
Total	3.07	125,800

1/ Based on productive acreage (40,920) in Hardin Unit.

The productive acreage excludes nonproductive areas such as farm roads and feed lots and is estimated at 94 percent of the irrigable area.

From preliminary studies of existing and potential irrigation developments along the Yellowstone River, it is concluded that sufficient carrier flow can be maintained in the river to meet the requirements for presently irrigated land and to furnish a water supply for irrigable land in the Yellowstone Pumping Units. Effects of Yellowtail Reservoir on the Yellowstone River at Miles City, Montana, from May through September in an average-flow year and a low-flow year, with ultimate upstream depletion, are shown in the following tabulations:

Average-flow Year - 1938
Unit: 1,000 acre-feet

	May	June	July	Aug.	Sept.
Yellowstone River at Miles City, Mont. 1/	847.0	2352.4	1519.2	422.7	321.7
Effect of Yellowtail Reservoir operation	-14.0	-225.9	-135.5	+49.8	+12.5
Yellowstone River at Miles City, Mont., regulated by Yellowtail Reservoir	833.0	2126.5	1383.7	472.5	334.2

1/ Flow corrected for estimated ultimate depletion of Bighorn River above Montana-Wyoming State line.

Low-flow Year - 1940
Unit: 1,000 acre-feet

	May	June	July	Aug.	Sept.
Yellowstone River at Miles City, Mont. 1/	797.2	1461.6	540.9	178.1	182.1
Effect of Yellowtail Reservoir operation	+ 5.8	- 80.2	-15.7	+51.5	+32.1
Yellowstone River at Miles City, Mont., regulated by Yellowtail Reservoir	803.0	1381.4	525.2	229.6	214.2

1/ Flow corrected for estimated ultimate depletion of Bighorn River above Montana-Wyoming State line.

Studies are underway for a report on potential irrigation development along the Yellowstone River. If more regulation is required than will be made available in Yellowtail Reservoir, it can be obtained by providing storage on the Yellowstone River.

Other Downstream Water Requirements

The following downstream requirements are insignificant when compared with those for irrigation. For this reason, they were given no special consideration in reservoir operation studies. There are no specific requirements for downstream fishery; however, investigations of the Bureau of Sport Fisheries and Wildlife show that substantial improvements in fishery conditions will be obtained from regulation of streamflows by Yellowtail Dam and Reservoir and from the smoothing of powerplant releases by the afterbay.

Municipal, Industrial, and Sanitary

The city of Hardin, which had a population of 2,789 according to the 1960 census, takes its municipal water supply from the Bighorn River. Water consumption during 1960 is estimated at 117,110,000 gallons (359.4 acre-feet).

The only industry of consequence in the Lower Bighorn Basin is the refinery of the Holly Sugar Company near Hardin. This plant requires an average of 3,000,000 gallons of water a day (4.64 cubic feet per second) for a period of 100 days beginning about September 20.

Normal powerplant releases will supply sufficient water for dilution of sewage after primary treatment for both Fort Smith and the city of Hardin, and of sugar refinery waste.

Construction

The river water is suitable for washing aggregates and mixing concrete. More water is available than will be needed, and the water can be clarified sufficiently for construction uses by passing it through a desilting basin. Springs in the vicinity of the damsite provide only enough water for domestic uses.

Channel Losses

Channel losses in the Bighorn River between the damsite and the mouth of the river cannot be determined accurately because of deficient data on temperature, precipitation, streamflow, return flow, and diversions to irrigated land between St. Xavier and the mouth of the river.

Simultaneous records of streamflow for a 13-year period 1946-58 near St. Xavier and at the mouth of the river show that the inflow from tributaries supplied sufficient water to offset the stream depletion during the 5-month irrigation season and that the inflow during the remaining 7 months exceeded the channel losses by an average of 360 cubic feet per second.

Closure Release Requirements

The flow of the Bighorn River cannot be completely interrupted with closure of the river diversion at Yellowtail Dam, because water is required at all times for fish maintenance, stock and domestic supply, and irrigation during the summer months. It is not considered feasible to maintain a large continuous flow during closure to provide for irrigation; therefore, closure should be made during the nonirrigation season when requirements are at a minimum.

Closure should be made during the latter part of October or the first part of November. The storage space below the centerline of the lowest permanent outlet (elevation 3,300 feet) is 20,400 acre-feet. This space can be filled in about 4-1/2 days under average-flow conditions in November, 4 days under upper-quartile flow conditions, and 5 days under lower-quartile flow conditions.

A bypass around the diversion tunnel bulkhead gate capable of discharging about 100 cubic feet per second would provide sufficient flow for downstream water users during the nonirrigation season; however, heavy equipment should be available near the points of diversion for the city of Hardin and the refinery of the Holly Sugar Company to ensure diversion at low flow during closure. Additional flow during closure can be obtained from the afterbay if it becomes operable before closure of the dam. Capacity of the pool (2,700 acre-feet) is sufficient to provide an average flow of about 270 cubic feet per second for 5 days. Use of the afterbay would eliminate the possibility of complete interruption of flow while reservoir storage is building up sufficient head to discharge through a bypass around the diversion tunnel bulkhead gate.

If conditions warrant, additional water can be released from Boysen Reservoir so that filling of the dead storage pool can be accomplished in a shorter time.

Evaporation

An evaporation station was established at Yellowtail Dam site in 1948, and records of evaporation were maintained for the months of June through September from 1948 through 1950. Because of the short period of record at the site, the annual evaporation rate was estimated from the Weather Bureau Technical Paper No. 37. The net annual loss through evaporation for Yellowtail Reservoir was estimated to be 2.21 feet. Average monthly distribution of the annual evaporation varies from 1.6 percent in December, January, and February to 18.6 percent in July and August. The estimated monthly rates of evaporation for June through September agree closely with rates for those months over the short period of record at the damsite.

Power Operation

Operation studies for Yellowtail Reservoir are based mainly on power generation. Many factors were considered in determining a satisfactory method of power operation. Irrigation requirements, both existing and future, must be met; fish resources must be maintained; flood and ice-jam control must be effective; and the regimen of the stream must not be unduly disturbed. Release of sufficient water from the reservoir for these purposes, at rates that permit normal utilization of the water, must be assured.

The potential energy output at Yellowtail will gradually be reduced as more upstream irrigation is developed, resulting in diminished flow at the site, and as the amount of active storage space is reduced by deposition of sediment. Detailed monthly studies were made, therefore, to determine the energy output under two conditions: (1) with streamflow under the level of irrigation development existing in 1944 (undepleted condition), and (2) with streamflow adjusted for future upstream development (depleted condition). Tables 3 and 4 present summaries, by years, of the operation studies assuming undepleted and depleted conditions, respectively.

In the study for the undepleted condition, regulation by Boysen Reservoir and no sediment deposition in Yellowtail Reservoir were assumed. The latter reservoir was operated between elevations 3,547 and 3,640 feet, with total storage capacity of 1,116,000 acre-feet and active storage capacity of about 613,000 acre-feet between these elevations. Firm energy was generated all year, and nonfirm energy was generated during the spring and summer months when forecasts of runoff showed that additional releases could safely be made in view of impending spills. In other months, nonfirm energy was produced only when the reservoir was full and inflow was in excess of that needed to produce firm energy. The only demands on the reservoir, other than for power generation, were for downstream fishery and existing irrigation. In this study, the generation potential was shown to be 650,000,000 kilowatt-hours of firm energy and an average of 281,800,000 kilowatt-hours of nonfirm energy annually. It is not known when the Hardin Unit will be developed; supplying water to this unit would reduce the annual generation potential to 618,200,000 kilowatt-hours of firm energy and 278,800,000 kilowatt-hours of nonfirm energy.

The study for the depleted condition was based on an average depletion of 535,000 acre-feet above that for 1944, with regulation by Boysen Reservoir and sediment deposition of 315,000 acre-feet in Yellowtail Reservoir. Total storage capacity in the latter reservoir was reduced to 801,000 acre-feet, of which 546,000 acre-feet was between the recommended operating elevations of 3,547 and 3,640 feet. Hardin Unit was furnished water by gravity from the reservoir. Under the depleted condition of this study, 528,500,000 kilowatt-hours of firm energy and an average of 182,000,000 kilowatt-hours of nonfirm energy were shown to be produced annually.

Table 3 - Annual Summary - Yellowtail Hydropower Operation Study
(Inflow - undepleted condition, regulated by Boysen Reservoir; no sediment deposition)

Year	Reservoir operation (1,000 acre-feet)							Electric energy output (million kw-hr.)		
	Inflow	Release to Hardin Unit	Release to Bighorn River	Evapo-ration	Spill	Annual storage Max.	Annual storage Min.	Firm	Nonfirm	Total
1924	4026.2		3049.7	20.5	406.8	1116.0	505.0	650.0	420.2	1070.2
25	2837.3		2719.0	21.7	79.5	1116.0	795.1	650.0	376.3	1026.3
26	2515.7		2511.2	22.9		1116.0	890.0	650.0	303.4	953.4
27	2876.4		2815.3	20.9	33.6	1116.0	706.5	650.0	388.8	1038.8
28	3429.1		3003.7	22.4	428.2	1116.0	663.5	650.0	483.5	1133.5
29	2740.1		2667.7	22.0		1116.0	791.1	650.0	343.2	993.2
30	2820.0		2636.7	22.9	128.3	1116.0	930.1	650.0	363.5	1013.5
31	1975.4		2106.8	21.9		1116.0	942.9	650.0	157.6	807.6
32	2787.0		2516.5	20.8	96.4	1116.0	694.3	650.0	276.6	926.6
33	2476.9		2485.8	22.0		1116.0	812.5	650.0	288.3	938.3
34	1465.5		1722.8	18.5		1069.9	809.3	650.0		650.0
35	2266.8		2025.8	17.2		1116.0	505.9	650.0	49.8	699.8
36	2091.8		2034.8	21.5		1116.0	830.1	650.0	114.7	764.7
37	2539.5		2380.1	21.7	165.9	1116.0	897.5	650.0	256.4	906.4
38	2347.8		2185.0	20.9	70.5	1116.0	796.5	650.0	171.1	821.1
39	1900.7		1899.8	22.3		1116.0	941.1	650.0	78.6	728.6
40	1665.5		1720.7	22.4		1116.0	1012.7	650.0	13.4	663.4
41	2216.1		2089.3	23.5		1116.0	1042.2	650.0	159.6	809.6
42	2977.5		2860.4	28.9	137.1	1116.0	981.0	650.0	454.2	1104.2
43	3538.1		2934.3	21.8	539.1	1116.0	795.5	650.0	470.7	1120.7
44	3209.8		2804.7	22.2	446.0	1116.0	794.0	650.0	417.5	1067.5
45	2867.3		2562.9	22.6	218.7	1116.0	938.6	650.0	330.6	980.6
46	2375.3		2374.0	24.3		1116.0	1005.6	650.0	274.8	924.8
47	3635.7		3082.4	22.9	507.4	1116.0	896.9	650.0	535.6	1185.6
48	2907.5		2840.4	22.9	62.2	1116.0	882.6	650.0	441.2	1091.2
49	2405.8		2418.7	22.9		1116.0	919.8	650.0	276.1	926.1
50	2845.7		2767.9	24.0		1116.0	1000.7	650.0	421.2	1071.2
51	3421.5		3284.0	22.6	114.9	1116.0	925.6	650.0	616.6	1266.6
52	2176.3		2152.7	23.6		1116.0	913.0	650.0	177.7	827.7
53	1947.9		1940.2	24.2		1116.0	1034.0	650.0	101.3	751.3
54	1977.3		1942.6	22.5		1116.0	903.8	650.0	96.4	746.4
55	2073.7		2086.8	23.9		1116.0	1021.8	650.0	158.5	808.5
Mean	2604.3		2457.0	22.4	107.3			650.0	281.8	931.8

Table 4 - Annual Summary - Yellowtail Hydropower Operation Study
(Inflow - depleted condition, regulated by Boysen
Reservoir; 315,000 acre-feet of sediment deposition)

Year	Reservoir operation (1,000 acre-feet)							Electric energy output (million kw.-hr.)		
	Inflow	Release to Hardin Unit	Release to Bighorn River	Evapo-ration	Spill	Annual storage Max.	Annual storage Min.	Firm	Nonfirm	Total
1924	3530.4	120.9	2603.5	24.7	648.9	801.0	709.5	528.5	474.4	1002.9
25	2341.0	142.1	2143.2	22.9	1.7	801.0	529.9	528.5	287.4	815.9
26	2022.8	102.3	1892.7	25.3	0	801.0	704.7	528.5	200.7	729.2
27	2381.0	90.6	2251.1	22.3	0	801.0	241.3	528.5	303.7	832.2
28	2934.6	134.4	2839.0	22.2	11.9	801.0	250.0	528.5	534.1	1062.6
29	2246.9	131.6	1995.5	24.2	0	801.0	646.6	528.5	230.1	758.6
30	1779.1	142.7	1590.0	27.2	0	801.0	785.5	528.5	89.3	617.8
31	1893.2	131.0	1809.4	23.9	0	801.0	729.9	528.5	168.8	697.3
32	1875.5	130.8	1690.8	24.9	0	801.0	678.9	528.5	120.8	649.3
33	2019.8	138.0	1817.2	24.5	0	801.0	500.9	528.5	162.5	691.0
34	1378.0	152.3	1427.1	20.5	0	801.0	577.1	528.5	18.9	547.4
35	1537.7	120.4	1450.7	15.3	0	619.4	456.6	528.5	0	528.5
36	1475.7	143.2	1488.9	11.9	0	534.1	360.1	528.5	0	528.5
37	1782.4	151.7	1574.4	10.5	0	499.7	275.1	528.5	0	528.5
38	1772.8	99.4	1535.6	13.4	0	634.5	293.9	528.5	0	528.5
39	1546.7	115.8	1448.4	15.5	0	664.5	494.8	528.5	0	528.5
40	1477.7	136.7	1515.9	11.0	0	490.0	311.4	528.5	0	528.5
41	1717.7	111.8	1622.5	8.2	0	377.9	255.0	528.5	0	528.5
42	2178.4	115.8	1619.6	21.4	0	801.0	329.0	528.5	53.5	582.0
43	2409.7	116.9	2124.9	23.9	113.9	801.0	527.6	528.5	287.3	815.8
44	2709.7	104.7	2509.4	21.4	87.1	801.0	310.3	528.5	407.2	935.7
45	2377.9	121.8	2009.5	25.5	145.5	801.0	749.2	528.5	243.1	771.6
46	1881.9	102.3	1781.9	24.8	0	801.0	693.5	528.5	161.7	690.2
47	3140.0	125.6	2644.8	24.1	318.4	801.0	397.2	528.5	470.3	998.8
48	2413.5	122.4	2343.1	24.0	0	801.0	552.3	528.5	372.4	900.9
49	1912.9	152.4	1788.9	23.5	0	801.0	673.1	528.5	161.2	689.7
50	2341.9	101.0	2086.2	26.8	0	801.0	741.3	528.5	281.0	809.5
51	2929.9	126.2	2770.4	27.0	6.3	801.0	711.9	528.5	546.0	1074.5
52	1682.3	139.1	1645.7	24.4	0	801.0	674.1	528.5	109.1	637.6
53	1453.9	134.7	1486.1	18.3	0	801.0	488.9	528.5	38.3	566.8
54	1583.3	139.4	1443.9	14.1	0	628.9	474.9	528.5	0	528.5
55	1679.7	133.1	1417.2	20.3	0	801.0	516.4	528.5	1.9	530.4
56	1782.2	135.3	1508.8	22.8	0	801.0	602.1	528.5	48.0	576.5
57	2684.0	102.4	2318.8	24.5	136.6	801.0	502.1	528.5	361.1	889.6
58	1978.7	142.6	1978.4	23.2	0	801.0	635.5	528.5	236.9	765.4
Mean	2081.5	126.0	1890.7	21.1	42.0			528.5	182.0	710.5

The annual generation by years was estimated from the foregoing studies for the Yellowtail Unit. The rate at which the upstream depletions will occur was taken from the Missouri River Basin Average Rate and Repayment Study of 1960. Hardin Unit will deplete the flow available for power generation by an average of 126,000 acre-feet annually. It was assumed that this unit would start receiving water in 1971 and the rate of development would be the same as shown in the report on the unit. Table 5 shows the estimated annual energy output of Yellowtail Powerplant.

Afterbay Operation

The power operation studies show that the monthly outflows from Yellowtail Powerplant are more than adequate to meet all downstream requirements, but they do not show the effect of a load peaking operation on daily river stages. Discharge from the powerplant can vary from about 7,000 cubic feet per second to no discharge in less than 12 hours. This type of operation will obviously interfere with downstream water use and materially affect the fishery. Discussions with operators of irrigation works along the river have indicated that fluctuations in daily river stage at diversion headgates should not exceed 2 feet. Wider fluctuations would necessitate either automatic headgates or full-time employment of a gate tender at each canal. The effect of fluctuating river stage on ice formation and breakup is discussed in a later chapter of this report. On the basis of this information, the following limitations in daily stage changes were established:

(1) The period between ice breakup and the beginning of irrigation, normally from March 15 to May 1, will impose no limitation in most years.

(2) Between May 1 and September 30, fluctuations in river stage must be limited to 2 feet in any one day with existing diversions and headgate facilities.

(3) There is normally no limitation between October 1 and November 20. This period comes between the end of irrigation operation and the beginning of ice formation.

(4) During the normal ice-cover period, November 20 to March 15, the river stage should not change more than 3 feet on the open water curve. This roughly represents a fluctuation of 3-1/2 feet with ice covering.

(5) For a period of a few days in most years, usually in early March, powerplant releases will need to be curtailed to a near constant flow while the normal ice-cover breakup occurs and the river becomes clear of floe ice.

Table 5 - Estimated Energy Output, Yellowtail Powerplant

Payout year	Calendar year	Annual depletion - 1,000 acre-feet	Potential energy generation (million kilowatt-hours)		
			Firm	Nonfirm	Total
1	1967	150.5	637.4	260.2	897.6
2	68	154.0	637.0	259.5	896.5
3	69	158.4	636.5	258.6	895.1
4	1970	164.9	635.5	257.3	892.8
5	71	225.7	617.9	249.0	866.9
6	72	280.9	598.5	241.6	840.1
7	73	317.6	579.5	236.5	816.0
8	74	326.6	578.0	235.4	813.4
9	75	335.6	577.6	234.8	812.4
10	76	347.1	575.0	232.0	807.0
11	77	358.7	573.2	230.1	803.3
12	78	370.2	571.5	228.3	799.8
13	79	381.8	570.0	226.6	796.6
14	1980	393.3	568.1	224.8	792.9
15	81	408.0	565.8	222.3	788.1
16	82	422.7	563.9	220.0	783.9
17	83	437.3	562.0	217.6	779.6
18	84	452.0	559.5	215.2	774.7
19	85	466.7	557.2	213.0	770.2
20	86	473.2	556.2	211.9	768.1
21	87	479.6	555.2	211.0	766.2
22	88	486.1	554.1	210.0	764.1
23	89	492.5	553.2	209.0	762.2
24	1990	499.0	552.3	207.9	760.2
25	91	502.1	552.0	207.3	759.3
26	92	505.2	551.5	206.8	758.3
27	93	508.4	551.0	206.4	757.4
28	94	511.5	550.5	205.9	756.4
29	95	514.6	550.0	205.3	755.3
30	96	518.9	549.5	204.8	754.3
31	97	523.3	549.0	204.0	753.0
32	98	527.6	548.3	203.2	751.5
33	99	532.0	547.6	202.5	750.1
34	2000	536.3	547.0	201.9	748.9
35	01	541.6	546.2	201.1	747.3
36	02	546.9	545.3	200.3	745.6
37	03	552.3	544.5	199.2	743.7
38	04	557.6	543.8	198.5	742.3
39	05	562.9	543.0	197.7	740.7
40	06	566.3	542.5	197.0	739.5
41	07	569.7	541.9	196.4	738.3
42	08	573.1	541.2	196.0	737.2
43	09	576.5	540.9	195.5	736.4
44	2010	579.9	540.3	195.0	735.3
45	11	589.5	539.0	193.4	732.4
46	12	599.1	537.6	191.9	729.5
47	13	608.8	536.2	190.4	726.6
48	14	618.4	534.8	188.9	723.7
49	15	628.0	533.3	187.3	720.6
50	16	636.4	532.0	186.0	718.0
	2017	644.7	530.8	184.7	715.5
	18	653.1	529.7	183.2	712.9
	Ultimate	661.4	528.5	182.0	710.5

It will be necessary to reregulate powerplant outflows in order to meet the foregoing limitations if Yellowtail Powerplant is operated as a peaking plant. Yellowtail afterbay will serve this purpose.

Incorporation of the diversion works of the Big Horn Canal in the afterbay dam will necessitate an inactive pool of about 600 acre-feet (elevation 3,175 feet) to provide sufficient head to divert into the canal. After the irrigation season, the inactive pool can be utilized to reregulate the powerplant outflows. Maximum fluctuation in powerplant outflows will probably occur in December when the extra storage capacity will be available in the afterbay for reregulation.

The maximum afterbay capacity requirement will occur in August and was determined to be 2,700 acre-feet. This capacity includes a reservation of 600 acre-feet to enable diversion to the Big Horn Canal and an allowance of 2,100 acre-feet for control of powerplant outflows.

It is anticipated that, under normal operating conditions, the average afterbay water surface elevation over a year will be about 3,177 feet.

ALTERNATIVE PLANS

Introductory

The plan adopted for development of Yellowtail Unit evolved from studies and investigations made over a period of years, beginning about 1939. The original plan was reported in the "Survey Report on the Big Horn Basin, Montana-Wyoming" (Project Investigations Report No. 81), dated June 1942, and was included in the program for conservation, control, and use of water resources of the Missouri River Basin presented in Senate Document No. 191 (78th Cong., 2d sess.), dated April 1944. The plan provided for construction of two dams on the Bighorn River, one at the Yellowtail site near the mouth of the Bighorn Canyon and one at the Kane site about 26 miles upstream in Wyoming. A revision in the plan was made when detailed studies completed in the late 1940's showed that a single high dam at the Yellowtail site would be more desirable than the two dams previously considered. This plan for a single high dam proposed to serve irrigable land in the Hardin Unit by pumping from the Bighorn River below the dam. These studies were documented in the "Definite Plan Report on Yellowtail Unit," dated January 1950 and approved November 10, 1950, by the Commissioner of the Bureau of Reclamation. Because of litigation over right-of-way with the Crow Indian Tribe, construction of Yellowtail Dam was postponed indefinitely.

Detailed studies completed on the Hardin Unit in 1959 showed that about one-third of the land originally proposed for irrigation development did not meet irrigability standards. This land was therefore eliminated, but an equivalent acreage of irrigable land was found at a higher elevation. Direct diversion from Yellowtail Reservoir was determined to be the most feasible method for serving the Hardin Unit with inclusion of this higher land.

The plan for Yellowtail Unit presented in the 1950 report differs from that presented in this report mainly in the method used to supply water to Hardin Unit.

Selection of Plan

A combined operation of two reservoirs to be formed by dams at the Yellowtail and Kane sites were planned to provide irrigation, power production, sediment retention, and flood control. The reservoir at the Kane site was to have a storage capacity of 750,000 acre-feet, and the reservoir at the Yellowtail site was to have a storage capacity of 470,000 acre-feet. Installed powerplant capacities were to be 30,000 kilowatts at Kane, with an annual firm power production of 139,300,000 kilowatt-hours, and 75,000 kilowatts at Yellowtail, with an annual firm production of 332,000,000 kilowatt-hours, or totals of 105,000 kilowatts and 471,300,000 kilowatt-hours.

Later surveys disclosed an error of 15 feet in the datum elevation obtained from outside sources. Topographic surveys then showed that the storage capacities at the Kane and Yellowtail sites would actually be 610,300 and 473,500 acre-feet, respectively. The storage capacities of the two reservoirs would therefore total 1,083,800 acre-feet compared with 1,220,000 acre-feet previously reported. No space allocations were established for individual reservoir functions, but it is known that flood control was to be incidental and would therefore have been of minor benefit. After allowing for irrigation requirements and the power generation proposed, it is obvious that no provision was made specifically for flood control storage space. The Corps of Engineers, Department of the Army, later recommended that 250,000 acre-feet of storage capacity (subsequently increased to 259,000 acre-feet) be reserved solely for flood control, with an additional 250,000 acre-feet allocated for joint use with conservation. This recommendation would be impossible to follow without increasing the original storage capacities. With the recommendation in mind, studies were made to explore three Kane-Yellowtail possibilities based on corrected potential storage capacities:

(1) As proposed in the survey report of June 1942 and in Senate Document 191 but with flood control requirements added.

(2) With a combined storage capacity equal to that of the single high dam at Yellowtail site.

(3) With storage capacities sufficient to provide for a combined annual firm power output equal to the single high dam at Yellowtail site.

The three studies are discussed in the following paragraphs.

Flood Control Benefits Added

The relatively small capacities under the two-reservoir plan would preclude allocation of the flood control requirement of 500,000 acre-feet entirely to one reservoir. The 250,000 acre-feet of joint-use space was therefore allocated to Yellowtail in this study, as its capacity would be limited to 473,500 acre-feet by the tailwater of Kane dam, and all irrigation and other demands on conservation storage are below the Yellowtail site.

A study of sediment deposition in Kane reservoir showed that the necessary allowance for encroachment would reduce the active storage to a point at which the reservoir would be ineffective for multipurpose use if the inviolate flood control space were set aside in the original capacity of 610,300 acre-feet. The flood control space was therefore added, raising the total reservoir capacity to 860,300 acre-feet. The combined storage capacity at both sites would then be 1,333,800 acre-feet compared with a storage capacity of 1,375,000 acre-feet with a single high dam at Yellowtail site.

Reservoir operation studies were made for conditions that would prevail after 50 years of operation with full upstream depletion and 200,000 acre-feet of sediment deposition in Kane reservoir, and with conditions of operation and demands the same as for the plan presented in the 1950 report. These studies showed that the annual net firm power production for Kane and Yellowtail, after deduction of pumping energy to supply the Hardin Unit under the plan presented in the 1950 report, would be 124,000,000 and 401,000,000 kilowatt-hours, respectively, or a total of 525,000,000 kilowatt-hours, compared with an annual net firm power production of 558,800,000 kilowatt-hours for the single high dam at Yellowtail site.

The difference of 33,800,000 kilowatt-hours annually in firm power production would amount to a loss of $185,900 in gross revenue, or $9,295,000 in 50 years, as estimated for the 1950 report. Preliminary field estimates indicated that construction costs, based on price levels of September 1949, would total some $104,640,000 for the Kane-Yellowtail combination compared with $99,640,000 for a single high dam at Yellowtail site, a difference of about $5,000,000. A major item of increased cost for the combination would be the railroad relocation around the Kane reservoir site. Total increased costs and losses were thus estimated at $14,295,000 during a 50-year repayment period when compared with the 1950 plan of development. This figure excluded the increased operation and maintenance costs which could be expected from location of facilities at separated points.

Equivalent Storage Capacity

With storage capacity at Yellowtail site limited to 473,500 acre-feet by the tailwater of Kane dam, a capacity of 901,500 acre-feet would be needed at Kane to provide a total of 1,375,000 acre-feet. Operation studies were made for conditions pertaining after 50 years, with full upstream depletion and 200,000 acre-feet of sediment deposition in Kane reservoir, and with conditions of operation and demands the same as for the plan presented in the 1950 report. These studies showed the combined net annual firm power production, after deduction of pumping energy to supply the Hardin Unit under the plan presented in the 1950 report, to be about 529,000,000 kilowatt-hours, or a loss of 29,000,000 kilowatt-hours. The loss in gross revenue, as estimated for the 1950 report, would amount to $159,500 annually, or $7,975,000 in 50 years. Cost estimates were not prepared for this plan, as it was apparent that construction costs would be even greater than for the first plan discussed.

Equivalent Power Output

A study was made to determine the Kane and Yellowtail storage capacities needed to provide an equivalent net firm power output of 558,800,000 kilowatt-hours annually, after providing for pumping energy for the Hardin Unit as contemplated in the 1950 report. With Yellowtail

reservoir limited in storage capacity to 473,500 acre-feet as before, it was found that a storage capacity of 1,290,000 acre-feet would be needed in Kane reservoir, bringing the combined storage capacity to 1,763,500 acre-feet compared with a storage capacity of 1,375,000 acre-feet with a single high dam. The maximum water surface elevation for the Kane reservoir would be about 3,719 feet, backing water almost to the city of Greybull. A long and very costly dam would be required, and right-of-way costs involved in relocation of the Chicago, Burlington, and Quincy railroad for the full length of the reservoir and acquisition of several thousand acres of highly developed irrigated land would be prohibitive. Detailed study was not made of this combination of reservoirs at Kane and Yellowtail sites because of the apparent high costs.

Conclusions

The three studies discussed in the foregoing paragraphs showed conclusively that no combination using both the Kane and Yellowtail sites could be expected to produce as much power with as little storage as a single high dam at Yellowtail site, with other requirements and operating conditions the same. Construction costs for the combination would be higher, and with installations divided and separated the annual operation and maintenance costs would be higher. The plan for a single high dam at the Yellowtail site was therefore adopted and presented in the 1950 report on Yellowtail Unit.

Selection of Site for High Dam

Three different sites near the mouth of the Bighorn Canyon were examined for a high dam. These were designated damsites Nos. 1, 2, and 3, proceeding upstream. Damsite No. 1 was considered to be the most suitable site in profile and competency of rock foundation within the reach of river between the mouth of the canyon and damsite No. 3. It appeared that an axis located a short distance downstream might result in slightly less volume of dam, but this location is too close to the mouth of the canyon and is unfavorable for percolation control in the right abutment.

Damsite No. 2 offered no advantages over damsite No. 1. A dam of greater volume would be required. No economic benefits of features of a dam at this site could be ascertained.

Damsite No. 3 is about 2 miles upstream by river channel from damsite No. 1. The rock is similar at the two sites, but the cross-sectional area at damsite No. 3 is smaller. The disadvantages of this damsite are the additional costs for constructing access roads and hauling materials and equipment, the loss of 60,000 acre-feet of storage capacity, and the loss of 20 feet of power head. The unfavorable aspects of the site appear to offset the benefits that would be obtained from a dam of less volume.

I - Hardin Unit

Hardin Unit is a part of the Missouri River Basin Project, which was authorized by section 9 of the Flood Control Act of December 22, 1944 (58 Stat. 887). It was included originally as an integral part of Yellowtail Unit, but the storage and irrigation functions were later divided to provide a more convenient programing arrangement. Yellowtail Dam in its relationship to Hardin Unit, will serve primarily as a high diversion structure and for storage.

Location and Description

Hardin Unit comprises irrigable land on a series of benches along the Bighorn River in Big Horn County, Montana. A large part of the irrigable land lies in an almost continuous strip, 2 to 3 miles wide and about 40 miles long, extending along the west side of the river below the mouth of the Bighorn Canyon. This bench, locally known as Hardin Bench, lies adjacent to or near the river for the first 27 miles of its length and above the existing Two Leggins Canal for the remaining distance. Additional irrigable land on the west side of the river is situated on higher benches, together called the Upper Benches and separately named Campbell Bench, Beacon Bench, and Woody Bench. A relatively small acreage of irrigable land is situated in the Fort Smith area on the east side of the river near the mouth of the canyon. Additional land under existing ditches in the Soap Creek Unit of the Crow Irrigation Project is included for supplemental supply from Hardin Unit works. The northern boundary of the Crow Indian Reservation crosses the unit about 3 miles south of Hardin, placing about two-thirds of the irrigable land within the reservation.

Plan of Development

In the original plan of development for Hardin Unit presented in the 1950 Definite Plan Report on Yellowtail Unit, it was proposed to provide a full water supply to 44,000 acres of irrigable land and a supplemental supply to 1,800 acres of irrigated land. The plan called for pumping the total water supply for irrigation from the Yellowtail afterbay after passing the water through Yellowtail Powerplant. This method of serving all land then proposed for development in Hardin Unit was selected, rather than direct diversion from Yellowtail Reservoir, because studies showed that there would be a net financial gain from first utilizing the water for power production.

Of the total irrigable acreage to be served under this plan, 40,000 acres were included on Hardin Bench, to be supplied by a canal

about 69 miles long, and 4,000 acres were included in the Fort Smith area, to be supplied by a canal about 10 miles long. Of the latter acreage, 2,130 acres were to be supplied directly from the canal and 1,870 acres lying on a higher bench were to be supplied by pumping from the canal. This canal was also to carry water for supplemental supply of the 1,800 acres of irrigated land in the Soap Creek Unit. The irrigable acreages were based on reconnaissance land classification.

Detailed investigations on Hardin Unit were completed in 1959 for the report that was issued in January 1960. Of all land originally proposed for service, about 14,300 acres of irrigable land (including 12,700 acres on Hardin Bench) and 850 acres of irrigated land were eliminated in detailed land classification. At the same time, an acreage equal to that eliminated on Hardin Bench was found to be irrigable on higher benches (Campbell, Beacon, and Woody Benches) on the west side of the river and was substituted. However, studies showed that, with the elimination of the land on Hardin Bench and substitution of an equal acreage on the higher benches, there would not be a net financial gain from passing the total water supply for irrigation through the powerplant and then pumping to the land. A change in method of serving all irrigable land in the Hardin Unit was therefore made.

The present plan for Hardin Unit proposes to provide a full supply of water to 42,600 acres of irrigable land and a supplemental supply to 950 acres of irrigated land. The irrigable land is distributed by areas as follows: Hardin Bench, 27,500 acres; Upper Benches (Campbell, Beacon, and Woody), 12,700 acres; and Fort Smith area, 2,400 acres. The most economical method of serving this land proved to be direct diversion from Yellowtail Reservoir with use of hydraulic turbines to pump water to the Upper Benches. This method will also enable delivery of water at a higher elevation on the east side of the river, eliminating the need for a pumping plant to supply part of the irrigable acreage on that side.

The plan calls for maximum diversion of 862 cubic feet of water per second from Yellowtail Reservoir through outlet works to be incorporated into and constructed as part of Yellowtail Dam. The outlet works will discharge into a pressure tunnel beginning near the face of the dam and extending through the west wall to the canyon mouth. This tunnel, 275 feet of which will be constructed concurrently with the dam, will connect to a penstock leading to the Campbell Pumping Plant. Hydraulic turbines in this plant will be powered by releases to the Hardin Canal. They will drive pumps that will lift water to the Campbell Canal. Diversion will be made from the penstock to the Fort Smith Canal, which will be carried in siphon across the Bighorn River.

The Hardin Canal will have an initial capacity of 533 cubic feet per second for supplying the irrigable land on Hardin Bench. It will begin at the tailrace from the pumping plant and extend about 50 miles in a northerly direction to a point about 8 miles north of Hardin,

where a terminal waste will carry surplus water back to the Bighorn River. A bypass is incorporated in designs of the pumping plant to permit delivery of water directly to the Hardin Canal without passing the water through the hydraulic turbines.

The Campbell Canal will have an initial capacity of 239 cubic feet per second for supply of the irrigable land on the Upper Benches. It will begin at the outlet of the discharge line from the Campbell Pumping Plant and extend about 12-1/2 miles to terminate in the lateral system on Woody Bench.

The Fort Smith Canal will have a capacity of 70 cubic feet per second for supply of irrigable land in the Fort Smith area and delivery of supplemental water to the irrigated land in the Soap Creek Unit. It will extend about 13-1/2 miles in a northeasterly direction to its terminous at a drop structure into the existing Soap Creek Ditch.

The vicinity map (No. 459-605-150) at the beginning of this report shows the location of Hardin Unit with relation to Yellowtail Dam and Reservoir and the general location of the pumping plant and of each of the canals.

Unit Land

Soils

Soils on Hardin Unit have developed from fine-textured alluvium overlying a thick layer of sand and gravel. The depth of the soil mantle over this incoherent sand and gravel layer ranges from 2 to 80 feet. Depth of the terrace soils is usually between 2 and 8 feet; deeper soil profiles are found on the slopes along the west edge of each terrace level. The soils have retained most of their original fertility, and the organic matter content has developed to a relatively high level. They have good productive capacity, and all crops adapted to the area will produce well with proper management.

Topography

The unit area is divided into numerous segments by deeply entrenched natural drainageways. Land on the alluvial terraces has slope gradients generally of about 1 percent, and land on the intervening slopes has gentle to steep slope gradients. The terrace topography is characterized by surface irregularities, and moderate to heavy leveling will be necessary to obtain adequate field sizes and uniform irrigation patterns. On the slopes, crop production will be influenced primarily by complexity and gradients of the slopes. Water consumption will be high, and irrigation efficiency will be low. These factors were evaluated and reflected in the land classification.

Drainage

The numerous natural drainageways crossing unit land will furnish adequate outlets for surface runoff and irrigation wastewater. Some artificial control or channel improvement will be necessary. Surface drainage on the slopes along the west side of each terrace is good, but the undulating, relatively flat terrace land has poor natural surface drainage and will require extensive drainage systems to remove surface wastes.

Subsurface drainage is excellent because of the thick layer of underlying sand and gravel. The presence of the numerous natural drainageways will greatly reduce the amount of constructed drainage works needed to remove excess subsurface water accumulating in the gravel.

Land Classification Summary

The irrigable acreage in Hardin Unit is distributed by land classes and areas as follows:

Area	Irrigable acreage (rounded)			
	Class 1	Class 2	Class 3	Total
Hardin Bench	2,260	11,270	13,970	27,500
Upper Benches	290	5,660	6,750	12,700
Fort Smith	640	1,110	650	2,400
Total full service	3,190	18,040	21,370	42,600
Soap Creek (supplemental)	50	400	500	950
Total land benefited	3,240	18,440	21,870	43,550

Present Agriculture

Dryland production of wheat is the most important agricultural activity in the Hardin Unit area. An irrigated area adjoins the unit on the east; and a large grazing area, which is Indian owned and leased in large blocks to non-Indian livestock operators, adjoins on the west.

About two-thirds of the unit area is cropland and the remainder is used for grazing. Wheat is the principal crop grown on the dryland, and about one-half of the cropland is fallowed each year. The unit area is divided among 22 operating units, of which 4 include about two-thirds of the land. On these large operating units, livestock raising is combined with dryland grain production.

Large-scale dryland wheat farming on the Crow Indian Reservation started about 1918 with establishment of the Montana Farming Corporation, now known as the Campbell Farming Corporation. Considerable land in Hardin Unit is dry farmed by the corporation.

About 58 percent of the irrigable land in Hardin Unit is Indian owned, with multiple ownership of numerous tracts. Ownership records for 1956 show that the irrigable land was divided among 410 ownerships, of which 325 were Indian. A considerable acreage of the Indian-owned land is in heirship status.

Agriculture With Irrigation

Land use with irrigation is expected to follow the pattern prevailing on presently irrigated land along the Yellowstone, Bighorn, and Little Bighorn Valleys. The principal crops that will be grown on unit land will be alfalfa hay, sugar beets, beans, barley, oats, wheat, corn, and pasture. Crop and livestock production will be combined to make optimum use of the resources within the unit area. Increased amounts of feed, grain, and forage will provide support for additional livestock in areas adjacent to the unit and will permit some livestock fattening.

The proposed farm unit layout includes 276 farm units. These units will be of family size and each unit will require the labor of a full-time operator, some additional family labor, and some hired labor during peak periods of crop cultivation, harvesting, and livestock feeding. Farm types will vary from a strictly cash crop farm with livestock maintained solely for home use to a farm with a beef cow herd and no cash crops.

II - Yellowstone Pumping Units

The Yellowstone Pumping Units comprise a series of separate irrigable areas along the Yellowstone River. Only one area, the Savage Unit containing 2,215 acres, has been developed for irrigation. This unit is served by pumping from the main canal that supplies the Lower Yellowstone Project. Investigations of other units have been completed, and results of the investigations will be presented in a report on the Yellowstone Division. Nine potential units containing about 24,200 acres of irrigable land and ranging in size from about 1,000 acres to 6,500 acres could be irrigated by pumping from the Yellowstone River or from existing canals.

Twenty-five pumping units along the Yellowstone River, containing about 95,000 acres, were originally authorized for development as part of the Missouri River Basin Project under the Flood Control

Act of 1944 (58 Stat. 887). To meet irrigation requirements with the anticipated development, it was concluded that storage would be required on the Yellowstone River. Many of the authorized pumping units have been found to be infeasible of development, and it appears now that the stream regulation to be provided by Yellowtail Dam and Reservoir will maintain sufficient flow in the Yellowstone River to meet the irrigation requirements of both present and future developments, eliminating need for irrigation storage on that stream.

Description

Arable land in the Yellowstone Valley consists of river bottom land, river terraces, and bordering slopes and upland. The river bottom land has generally been irrigated for many years, although a few irrigable tracts remain to be developed and are included in the plans for potential development. The bordering slopes and upland are mostly nonirrigable, either because of adverse soils and topography or because the land is extremely difficult and expensive to supply with water. The river terraces appear to offer the best opportunity for development.

The terraces border the Yellowstone River throughout its entire length in Montana. Along the upper reach of the river, the terraces are covered with a soil mantle that is too thin for irrigation development. Along the lower reach, the soils on the terraces are deeper and the land is generally attractive for irrigation development. Unfortunately, many terraces are too high above the river to permit economical development.

Land in the Yellowstone Pumping Units is now grazed or dry farmed. With irrigation, farming would follow the pattern established on presently irrigated land along the Yellowstone River. The principal crops would be alfalfa hay and sugar beets. Other crops would include irrigated pasture, alfalfa seed, corn, beans, and small grains. Dry cropland and dry rangeland would probably be associated with the irrigated land. Raising beef cattle would be the predominant livestock enterprise. Breeding herds would be run on the irrigated pasture and available dry range. Yearling cattle would probably be put in feed lots and fattened to slaughter grades. A small expansion in numbers of hogs, farm flocks of sheep, dairy cattle, and poultry would result from the development.

FLOOD CONTROL

Regulation of the erratic and widely fluctuating flows of the Bighorn River to alleviate flood damage is one of the primary functions of the Yellowtail Unit. The spring runoff from snowmelt in the mountains sometimes reaches flood proportions, and the drainage basin is subject to flash storms. Damaging floods are also caused by ice jams. Because of the intervening distance of more than 250 miles and the prolific drainage area between Boysen Dam and Hardin, little or no alleviation of the flood menace in the Lower Bighorn Basin can be accomplished through Boysen operation.

Floods

Historical Floods

Of 19 damaging floods recorded from 1908 to 1945, 3 were attributed to ice jams, 2 to rainfall, and the remaining 14 to a combination of snowmelt and rainfall. The flood causing the most damage occurred in July 1923 and was attributed directly to rainfall; damage was estimated at $1,850,000. This flood was followed by one in September 1923, also attributed to rainfall, with an estimated damage of $50,000.

Design Floods

A hydrograph of the reservoir design flood was plotted from data furnished by the Corps of Engineers, Department of the Army, and was used in computing flood control benefits. It showed a peak discharge of 55,900 cubic feet per second with a volume of 2,044,000 acre-feet.

The inflow design flood has a peak discharge of 126,000 cubic feet per second and a 10-day volume of 1,070,000 acre-feet. Preplanned releases while operating in the flood control pool, utilizing 3 feet of surcharge between elevations 3,657 and 3,660 feet, show that the inflow design flood can be reduced to a peak outflow of about 92,000 cubic feet per second with a spillway capacity of that amount.

Ice Jams

Control of streamflow during the spring period of ice breakup and prevention of ice jams will be important flood control functions of Yellowtail Reservoir. Ice normally forms in the Bighorn River in the latter part of November, and reaches a thickness of 3 feet or more before the breakup in March or April. Of particular concern in power operations is the effect of reservoir regulation on river ice. This

effect must be carefully considered to assure that ice-jam flooding will be reduced rather than aggravated. It is known that wide fluctuations in river stage tend to break the cover. Normal river stage changes during the winter months are gradual and daily fluctuations are small. It is therefore difficult to predict the effect of fluctuating powerplant releases on downstream ice cover.

The maximum permissible fluctuation during the ice season is tentatively estimated to be about 3 feet on the basis of conclusions reached from experimental study, with the reservation that experience must be gained in actual operation before definite limits can be established. During periods when prolonged warmth would tend to cause a normal breakup, any noticeable fluctuation would hasten the process and probably be undesirable. Inasmuch as normal ice breakup in the Bighorn and Yellowstone Rivers occurs in their upper reaches first, the ice-jam flood potentialities are peculiarly inherent even without the influence of unnatural river discharges.

Flood Control Storage

Flood control storage requirements were furnished by the Corps of Engineers, and an agreement was reached for allocation of flood control storage and the method of operation during floods. Storage requirements were placed at 259,000 acre-feet to be reserved solely for flood control, and 250,000 acre-feet to be used jointly with conservation on a restricted basis. Operation studies showed that, by use of these storage capacities at Yellowtail Reservoir, a flood of 2,044,000 acre-feet could be controlled to a peak outflow of 20,000 cubic feet per second.

Plan of Operation

According to the agreement with the Corps of Engineers, the top 259,000 acre-feet of storage capacity is to be used only for temporary impoundment of flood waters. Advance estimates will be made of the expected spring runoff on the basis of snow surveys and winter climatic conditions, with due regard to the effect of upstream reservoir regulation. When this forecast indicates a high flood in prospect, the joint-use storage capacity will be evacuated, up to the full amount if necessary, as rapidly as possible but consistent with downstream channel conditions. Because of the danger of causing ice jams, it will probably be desirable to withhold any major evacuation until after April 1 except in years of exceptionally heavy, early snowfall. The evacuated joint-use storage capacity will be refilled during the flood season. If the flood proves greater than forecast and flood control storage begins, releases up to 20,000 cubic feet per second will be made until the water surface recedes to the top of the joint-use

storage capacity, unless with continued high inflow the water surface reaches a level which calls for an increase in spillway discharge as established by the Emergency Release Diagram.

Benefits

On the basis of flood control operation as outlined herein, the Corps of Engineers has estimated that benefits will average $323,000 annually. These benefits include alleviation of damage to crops, livestock, farm buildings, irrigation structures, roads, bridges, and railroads. Damage has also resulted in the past from soil and bank erosion and sediment deposition.

SEDIMENTATION

Both the Wind River Basin and the Bighorn Basin in Wyoming are prolific sources of sediment. The valley bottoms are underlain by essentially flat-lying, poorly consolidated sedimentary rocks. On the margins of the basins, the strata have become inclined and the underlying older sediments have been more sharply folded and faulted to form the foothills. Dissection of the bedrock has been quite effective because of the differences in durability of the weaker formations which are dominantly shales and friable sandstones. Erosion is more apparent in the southeastern portion of the drainage basin and in other localized areas where barren wastelands or badlands appear.

All tributaries of the Bighorn (Wind) River, both perennial and intermittent, have high gradients ranging from about 20 feet per mile in the central portions of the basins to about 50 feet per mile in the foothills. The main streams have flood plains, many of which exceed a mile in width.

Rainfall governs to a large extent the character and type of ground cover. In the basin interiors, rainfall is not only deficient in quantity but irregular in distribution. Vegetation is therefore of desert type. The barren shale slopes support a sparse vegetative cover, mainly salt sage; the better soils on terraces and alluvial fans along water courses support a grass cover, with some cottonwood and willow trees. The mountainous areas, with their greater precipitation, support more verdant growths of grasses and trees.

The easily erodable formations, the steep stream gradients, the sparse vegetation, and the irregular distribution of rainfall in the form of flash storms or cloudbursts are conducive to high sediment production in the Bighorn drainage.

Sediment Studies

The original sediment study for Yellowtail Reservoir was made in 1949 before closure of Boysen Dam (October 1951). The estimated average annual storage depletion was 4,570 acre-feet, of which 746 acre-feet was estimated to be derived from the Shoshone River drainage below Buffalo Bill Dam. This study was based on available sediment records with allowance made for the estimated trap efficiency of Boysen Reservoir. The sediment storage allocation in Yellowtail Reservoir is 315,000 acre-feet below elevation 3,640 feet. At an annual storage-depletion rate of 4,570 acre-feet per year, this space would be used in about 69 years.

A recent flow-duration, sediment-rating curve analysis based on sediment records for the period 1952-58, which was after closure of Boysen Dam, with a 10 percent correction for bedload, indicates that

the average annual sediment load for the Bighorn River at Kane is 4,576,000 tons per year.

The Shoshone River is a major sediment contributor to the Bighorn River between Kane and Yellowtail Dam site. The sediment load of the Shoshone River was determined on a unit-yield basis. The sediment yield of the Bighorn River between Manderson and Kane was considered applicable to the Shoshone River below Buffalo Bill Dam. This assumption was based on a comparison of geologic, vegetative, soils, and other factors. The period of concurrent records at Manderson and Kane was 1947-51, or before closure of Boysen Dam. The annual sediment inflow from the 4,000 square mile drainage area between Manderson and Kane was 2,940,000 tons, an annual unit-yield rate of 737 tons per square mile. The total unit-yield rate was developed by adding 10 percent for bed load, resulting in a total annual yield of 811 tons per square mile. This rate multiplied by the 1,485 square mile drainage area of the Shoshone River below Buffalo Bill Dam gives a total sediment load of 1,210,000 tons per year.

The total sediment inflow to Yellowtail Reservoir would be 5,786,000 tons per year as determined from the foregoing estimates for the Bighorn and Shoshone Rivers.

All of the suspended-sediment-size analysis data available at the Kane station through water year 1958 have been averaged to obtain the percentages of sand, silt, and clay in transport. The averages for the station are: sand, 27 percent; silt, 41 percent; and clay, 32 percent. The initial unit weight was determined to be 61.3 pounds per cubic foot. A compaction correction to this unit weight value was made at intervals, the results of which are as follows:

Years	Unit weight (lb. per cu.ft.)	Sediment volume (acre-feet)
Initial	61.3	4,330
10	66.3	40,100
20	68.3	77,800
30	69.4	115,000
50	71.0	187,000
70	72.0	258,000
100	72.6	366,000

The sediment volumes in the foregoing tabulation indicate that the space allocated for sediment in Yellowtail Reservoir would be used in about 86 years.

FISH AND WILDLIFE

The information that follows was taken from the report titled "Fish and Wildlife Resources and the Yellowtail Unit, Lower Bighorn Division, Missouri River Basin Project, Montana and Wyoming," prepared in the office of Missouri River Basin Studies, Bureau of Sport Fisheries and Wildlife, Department of the Interior, and dated February 1962. This report presents an appraisal of the effects of Yellowtail Dam and Reservoir on fish and wildlife resources in the Bighorn Canyon area of Montana and Wyoming, including the effects on the fishery of the lower Bighorn River to be caused by water regulation in Yellowtail Reservoir. Certain monetary values relating to fishery resources are presented as an aid in demonstrating effects of the project on these resources. Losses will be sustained by wildlife, but the impact of the project on wildlife has not been demonstrated monetarily. All effects discussed and evaluations assigned in this report are based on conditions over the life of the project from initial through ultimate development. The appraisal assumes that public access may be limited to a few entry points because of the nature of the terrain in the canyon area and because of control by the Crow Indian Tribe of about two-thirds of the area around the reservoir site.

Fish and Wildlife Resources

Yellowtail Unit will influence directly about 147 miles of the Bighorn River and may have a less direct effect on the character of fish populations in portions of the Bighorn and Shoshone Rivers upstream from the zone of inundation.

The reach of Bighorn River to be inundated by the reservoir offers little fishing because of three factors: inaccessibility of the canyon area, the preponderance of less desirable fish species, and the restrictions on general public use because of the existence of the Crow Indian Reservation. Headwater portions of the Bighorn and Shoshone Rivers support good trout fishing.

The fishery in the Bighorn River between the damsite and the mouth is of moderate quality. Fishing is generally rather light, however, because the resident human population is low and the area is largely under the control of the Crow Indians.

The area of impact on wildlife resources will be confined mainly to the Bighorn Canyon and the upper portion of the reservoir site in Wyoming. Mule deer, elk, and black bears are present in the canyon area, and deer are present in the upper portion of the reservoir site in Wyoming. Hunting big game by the general public is prohibited on the Crow Indian Reservation.

Blue grouse, ruffed grouse, and cottontails are found throughout the area to be inundated, and pheasants are present in the Wyoming portion. The important fur animals are beaver, muskrat, and mink, their best habitat being the upper portion of the reservoir site. The only waterflowl area of significance is near the mouth of the Shoshone River.

In summary, the entire Bighorn Canyon area is important to wildlife but much of the project site is inaccessible or under restrictions by the Crow Indian Tribe.

Effect of Unit on Fish and Wildlife

Fishery Resources

Yellowtail Unit will have a beneficial impact on fishery resources. Fishing will be improved in the Bighorn River below Yellowtail Dam, mainly because of the reduction of silt load, the colder water temperatures, and the elimination of flood crests and periods of low flow. Improvement in the river fishery will be most marked in the 15-mile reach below Yellowtail afterbay. It is believed that valuable trout fishing will be established and maintained in this reach of the river. There will be progressively smaller benefits downstream from the afterbay, and warm-water species such as sauger, channel catfish, carp, and suckers will predominate in the lower reaches. It is expected that Yellowtail Reservoir will provide fishing for such species as walleye and lake trout, which will help to satisfy a considerable amount of fishing demand from the surrounding area. However, benefits to the fisheries are dependent on adequate public access and satisfactory downstream flows.

Of special concern is the need for adequate access facilities at a minimum of two locations on the reservoir, one near the lower end and the other near the upper end. It is a certainty that without appropriate development of access facilities at two well-separated points on the reservoir, fishing will be minimal.

Of similar importance is the need to assure the maintenance of substantial and uninterrupted downstream releases. A striking improvement in the fishery of segments of the lower Bighorn River is anticipated, and it will be vitally important that the planned flow regimen be maintained. A minimum instantaneous flow of not less than 1,000 cubic feet per second is needed for downstream fishery.

Wildlife Resources

Construction of Yellowtail Unit will result in wildlife losses. Although only nominal upland game, fur animals, and waterfowl resources will be affected, losses will be sustained by all these groups except waterfowl. Waterfowl resources will be increased moderately.

Big game inhabiting the area has appreciable value to the Crow Indians. Loss of big-game habitat will lessen hunting of such animals.

Considerable use of the reservoir by waterfowl is expected, and possibilities for waterfowl management in the Wyoming portion of the reservoir appear good.

Measures Needed to Compensate for Project-Associated Losses

Despite the over-all net benefits to fishery resources that will accrue from the project, one undesirable ramification may be indicated. This concerns the possible spread of certain species from the reservoir into the Bighorn and Shoshone Rivers above the project area. It is likely that a marked increase in the numbers of carp and goldeyes will occur in the reservoir. Also, the possibilities of intrusion of heavy populations of such species into upstream reaches of trout habitat is indicated by experience in other areas. Concern relative to this aspect is warranted in view of the substantial deleterious effects which would be encountered should the spread of these species occur.

A fish eradication program between the damsite and points about 25 miles above Kane, Wyoming, on the Bighorn River, and about 10 miles above Kane on the Shoshone River would minimize the possible spread of carp and goldeyes into upstream waters. A program of eradication by use of fish toxicants should be undertaken at the time of gate closure at the dam. The cost of fish toxicants would total about $65,000. This cost should be borne by the Federal government as a nonreimbursable expenditure, but application should be undertaken at the expense of the Montana and Wyoming fish and game agencies.

It is proposed that 17,700 acres of the reservoir and peripheral land be made available to the Wyoming Game and Fish Commission for management and development of fish and wildlife resources. Of this total, 1,700 acres are recommended for acquisition specifically for wildlife. To compensate for wildlife losses and to improve the attractiveness of the area for waterfowl and other wildlife, together with preventing depredations by waterfowl on irrigated land, it is urged that the 1,700 acres of additional land be acquired in fee simple near the junction of the Shoshone and Bighorn Rivers. Cost of acquiring this land is estimated to be $229,000.

Net damages to wildlife expected annually would justify acquisition of 1,100 acres of the total at Federal nonreimbursable expense. Acquisition of the remaining 600 acres would constitute enhancement of wildlife resources and is justified in the interest of the National migratory waterfowl program.

Enhancement of Fish and Wildlife Resources

No measures are suggested for the sole purpose of directly enhancing fish and wildlife in the post-development period. It is evident, however, that the recommendation to reclaim the reservoir area and upstream portions of the Bighorn and Shoshone Rivers to protect existing trout habitat will enhance the fishery in Yellowtail Reservoir. Even if only partial reclamation is accomplished through the use of toxicants, it is apparent that development and maintenance of a fully manageable fishery will be far more effective than would be the case otherwise. Although it is recommended that the toxicants be introduced as a damage-prevention measure to preclude or lessen upstream movements of large numbers of coarse fish, improved fishing in the reservoir would result. The addition of only one fisherman-day, per acre, per year, would add annual benefits totaling about $10,000. For the purposes of analysis, it is judged that annual benefits of this magnitude will prevail for a 5-year period. This is a very modest estimate of the benefits and is included merely to demonstrate that the single expenditure of $65,000 of nonreimbursable funds for fish toxicants is eminently justified.

Establishment of a wildlife area in Wyoming under State management, including the extra 1,700 acres recommended for acquisition, would result in enhancing the value of the project to waterfowl. Losses of other wildlife values will be substantial, however, and in the broader and more valid need to mitigate such undesirable effects, the acquisition of the 1,700 acres is justified largely on the basis of meeting the need to compensate for wildlife losses. That portion of the total acquisition costs in excess of needs for compensation for losses, and involving only 600 acres, is justified as a desirable enhancement. Enhancement benefits that would accrue annually from purchase of the 600-acre portion would amount to about $4,500. Extensive management improvements would be undertaken at the expense of the Wyoming Game and Fish Department after the 1,700 acres are acquired.

Summary

Any attempt to fix monetary values on fish and wildlife resources so as to make possible an accurate comparison of the resources with and without the project is complicated by the fact that the existing resources are available only to a limited number of people. Wildlife resources, in particular, are important to the Crow Indians and are used by them. Wildlife losses will certainly occur, but these are not public losses in the usual sense. Furthermore, with the exception of waterfowl, wildlife species essentially will be eliminated from the canyon area.

Restrictions on public use are less rigid relative to fishing, and it is possible to equate more readily the anticipated extent and

quality of fishing with the present situation. Based on estimated existing expenditures of fishermen in the area of direct influence, as compared with anticipated future expenditures, it is concluded that the project will show an increase in fishery values of $66,000 annually. This value is contingent on (1) sustained instantaneous flow releases as stated herein, and (2) adequate access being provided at a minimum of two locations.

Recommendations

It is recommended that:

(1) A site near the lower end of the reservoir and another near the upper end, readily accessible and designed specifically for free public use as fishing and boat-launching areas, be established on Yellowtail Reservoir as part of the project, and provision be made that boat-launching facilities offer safe access to the water from full pool (elevation 3,657 feet) down to reservoir elevation 3,590 feet.

(2) A fish-eradication program be undertaken within the impoundment area, extending upstream from the dam along the Bighorn River to a point about 25 miles above Kane, Wyoming, and extending upstream along the Shoshone River to a point about 10 miles above Kane, the materials for such fish eradication to be provided at project expense to the extent of $65,000 and the program to be executed at the time of closure of the dam.

(3) The planned schedule of flow releases through the afterbay dam be adhered to, and a minimum instantaneous firm flow of not less than 1,000 cubic feet per second be provided.

(4) As the need develops, a zoning plan be formulated which will assure the perpetuation of multirecreational uses of the reservoir, including adequate protection of fishermen against all forms of high-speed boating.

(5) A total of about 17,700 acres of land and water be made available to the Wyoming Game and Fish Commission under the terms of a General Plan as provided for in the Fish and Wildlife Coordination Act (48 Stat. 401 as amended; 16 U.S.C. 661 et seq.), 1,700 acres of which would be purchased at nonreimbursable project cost specifically for wildlife management.

Note: The Bureau of Reclamation concurs with the recommendations of the Bureau of Sport Fisheries and Wildlife. Recommendations 1 and 4

will apparently be implemented in the program of the National Park Service described in the following chapter of this report. The cost estimate of the Bureau of Reclamation for Yellowtail Unit includes an amount of $65,000 for upstream fishery rehabilitation and an additional amount of $229,000 for acquiring 1,700 acres of land near the junction of the Shoshone and Bighorn Rivers for a wildlife management area in accordance with recommendations 2 and 5, respectively. Downstream releases from Yellowtail afterbay are planned to exceed 1,000 cubic feet per second, which is the minimum instantaneous flow recommended by the Bureau of Sport Fisheries and Wildlife (recommendation 3).

RECREATION

A summary follows of the "Recreation Planning Report on Yellowtail Reservoir, Missouri River Basin, Lower Big Horn Division, Yellowtail Unit - Montana-Wyoming," prepared by the National Park Service, Region Two, Department of the Interior, issued in March 1962. This report presents an evaluation of recreation opportunities that may be derived from construction of Yellowtail Dam. It also offers a general plan for recreation development considered to be justifiable at this time and recommends public recreation uses.

Factors Influencing Recreation Development

Yellowtail Reservoir and environs will provide outstanding recreation opportunities, both of local or regional interest and of National interest.

The reservoir should be an attractive body of water. Inflowing sediment will be carried along the bottom or deposited well upstream of any proposed recreation area.

Climate of the Bighorn Canyon area is typical of the Northern Great Plains with hot summers, severe winters, cool springs, and mild, pleasant falls. Summer nights are pleasantly cool, and over 60 percent of the annual daylight hours have sunshine. Precipitation is infrequent and scattered. Prevailing winds are from the northwest; however, the adverse effect of these winds on water recreation within the canyon will be generally nullified by the high walls and tortuous channel.

Access for recreation purposes will be a problem. The dam and the upper reaches of the reservoir in Wyoming will be accessible, but the deep, long tributary canyons preclude access along the east side of the Bighorn Canyon and much of the west side will be difficult of access.

Preliminary findings of the Bureau of Sport Fisheries and Wildlife indicate that the project will have a beneficial effect upon sport fishing provided public access is available and adequate downstream releases are maintained. Wildlife values, with the exception of waterfowl values, will be reduced because of the flooding of habitat. An area recommended for wildlife management at the upper end of the reservoir and near the mouth of the Shoshone River appears to be compatible with recreation use and would provide additional recreation opportunities.

No known historic values will be lost because of the reservoir. Precautions should be taken, however, to avoid damage to Old Fort C. F. Smith by relic hunters during the construction period.

Twenty known archeological sites will be inundated by the reservoir, some of which may be of outstanding significance. The Smithsonian Institution's preliminary surveys show other sites outside the impoundment area. These sites include buffalo kills, rock shelters, campsites, and aboriginal trails.

It is believed that the project will have no adverse effect upon any existing parks or recreation areas either within the roughly 100-mile-radius regional zone of recreation influence or beyond, but will serve to complement them. It is also believed that proposed recreation development will help to alleviate current and future public recreation pressures within the zone of influence.

The reservoir and its recreation development will serve as a new recreation outlet for residents within the zone of influence, primarily for day and week-end use activities such as pleasure boating and driving, swimming, fishing, and camping.

It is believed that the area will receive even greater use by persons from beyond this region as a vacation area. Suitable activities may include sightseeing boat trips, pleasure boating, diversified camping, hiking, horseback riding and pack trips into the tributary canyons and the nearby mountains, and visits to interpretive features having historic, scenic, or scientific interests. If found to be feasible, winter sports would provide new and additional recreation outlets for both local and nonlocal visitors.

It is estimated that local or regional recreation use in the canyon area will amount to about 154,000 visitor-days by 1970, at which time initial recreation developments are expected to be in operation. In addition, 406,000 visitor-days are estimated for visitors from beyond the local zone.

Special Considerations

The recreation potential and significance of the Bighorn Canyon area are based on the following special considerations as well as the preceding analysis:

1. The scenery and other natural and historical values of the Bighorn Canyon itself and its environs have long been recognized and considered worthy of preservation - the mountains, foothills, geologic formations, prehistoric sites, wildlife and historic sites.

Impoundment of Yellowtail Reservoir will destroy much of the vegetative growth in the canyon, as well as cover about 80 percent of the canyon walls for the first mile or so above the dam. However, throughout most of the canyon section, and notably in the

deeper and more spectacular portions, the pool levels will fluctuate against the talus slopes and well below the sheer canyon walls. Such losses as there are will be alleviated by retaining the over-all scenic and natural values in the area and making them more available to the public via the reservoir surface and recreation development.

2. Yellowtail Dam and Reservoir will be notable attractions in themselves. The dam will be among the highest in the United States. The reservoir will provide a water surface of a size and setting presently not available or proposed in this section of Montana and Wyoming. According to proposed operation of the reservoir during years of normal inflows, the recreation boater will have some 70 river miles and over 12,000 surface acres for his use during most of the summer.

3. The geographical location of the Bighorn Canyon area in a major vacation land adds to its significance, contributing greater variety to the recreation attractions of the region. Primary access will be provided by U. S. Highway 87 (Interstate 90) on the north and Wyoming State Highway 14 on the south, both used heavily by vacation travelers.

4. The reservoir will lie in two states. By the very nature of its setting and types of suitable public use, neither part independently could provide fully for public enjoyment.

5. Land acquired by the Bureau of Reclamation for the project provides only for operation and protection of primary project purposes. Considerable additional land will be needed for access, development sites, and as a reasonable safeguard for the setting. Much of the surrounding land is in public ownership - some state, but mostly public domain plus Indian tribal land. Inasmuch as Crow Indian tribal land borders about two-thirds of the reservoir shoreline, a full realization of the project's recreation potential will hinge upon a cooperative arrangement with Crow Tribe.

An over-all evaluation of this project and its setting indicates a recreation potential of National significance and the desirability of a single Federal agency administering recreation interests.

Proposed public recreation areas recognize this conclusion; they include three major sites, designated as Yellowtail Dam, Horseshoe Bend, and Barry's Landing, and seven minor sites, designated as Kane Bridge, Devils Canyon Overlook, Black Canyon, Big Bull Elk, Devils Canyon, Dryhead Creek, and Crooked Creek. Developments should provide for a variety of activities - use of the reservoir itself and enjoyment of the setting and surroundings. They must recognize problems peculiar

to a canyon reservoir, its isolation and access problems, and a combination of local and vacation use. As a result, they might ultimately range from simple, primitive back-country facilities to more highly developed resort-type areas. The latter developments would be provided as far as possible by or through private enterprise concessions.

Any recreation development or access on Crow Indian tribal land, which encompasses about two-thirds of the total reservoir area, will be dependent upon cooperative solutions to be worked out between the tribe and the administering agency.

The costs in the following tabulation, with benefits to be derived, are estimated for land acquisition, recreation development, administration, and operation and maintenance. They are based on Yellowtail Reservoir and the Bighorn Canyon area being administered as a National recreation area. Expenditures are assumed to be from Federal sources.

	Amount
Acquisition of recommended recreation land	$ 856,700
Total basic recreation development costs	7,822,000*
Total administration facilities development costs	768,000
Annual operation and maintenance cost	152,500
Annual monetary benefits - general recreation	952,000

* Includes costs for suggested facilities on tribal land.

Recommendations

The following recommendations are made with the National Park Service taking responsibility for initial action:

1. That the boundary of the area indicated in the General Development Plan be considered as study boundary of an area proposed to be designated as the Bighorn Canyon National Recreation Area to be administered by the National Park Service under agreement with the Bureau of Reclamation. Such an agreement would define administrative authority over land and water within the Bureau takeline. Subsequently, legislative recognition would be desirable to provide adequate authority for land acquisition and for its management, development, and protection as a National recreation area.

2. That, to provide for access, public use, and enjoyment commensurate with its potential, about 98,000 acres of land in addition to that proposed for acquisition by the Bureau of Reclamation be studied for incorporation in or administration as part of the National recreation area. This land would include 1,000 acres of private or allotted land around the site of Old Fort C. F. Smith, Big Horn County, Montana; 14,920 acres of private land, 32,040 acres of public domain, and 2,040 acres of State land in Carbon County, Montana; and 6,700 acres of private land, 39,480 acres of public domain, and 1,760 acres of State land in Big Horn County, Wyoming. These land requirement studies do not involve any Crow Indian tribal land.

3. That the further refinement of this tentative study boundary be worked out through close cooperation between the National Park Service and other interested agencies: the two states, the Bureau of Reclamation, the Bureau of Land Management, the Bureau of Indian Affairs, and the Bureau of Sport Fisheries and Wildlife.

4. That recreation use of the proposed Bighorn Canyon National Recreation Area be provided for as outlined on the General Development Plan. The development would include day, weekend, and vacation use. No group camping areas, seasonal cabins or club sites are recommended at this time.

5. That concession developments in major recreation areas include overnight accommodations because of the isolation of the canyon area and to contribute to the enjoyment of the recreation areas visitors.

6. That cooperative studies be initiated as promptly as possible between the Crow Indian Tribe, the Bureau of Indian Affairs, and the National Park Service, and, when concerned, the Bureau of Reclamation to determine the best solution for recreation development and public use within the Crow Indian Reservation in order to round out and complement the proposed National recreation area. These studies should give due recognition to providing economic return to the Crow Indian Tribe.

7. That archeological survey and salvage, as recommended by the Smithsonian Institution, be completed in the reservoir area prior to inundation.

8. That cooperative studies be initiated with the Wyoming Highway Department and Big Horn County, Wyoming, with regard to the alignment and construction of the new county road between State Highway 14 and the Wyoming-Montana State line for access to the proposed National recreation area.

9. That the location of connecting recreation roads and trails between Custer or Bighorn National Forest and the proposed National recreation area be coordinated with the Forest Service in the best interests of the public.

The following recommendations are made with the Bureau of Reclamation taking responsibility for initial action in collaboration with the National Park Service:

1. That, even though reservoir operations appear to be reasonably good for recreation interests at Yellowtail Reservoir, the Bureau of Reclamation give consideration to recreation needs in their ultimate water control plans of the Bighorn (Wind) River.

2. That the Bureau of Reclamation and the National Park Service cooperate in any further planning of the Government community at Fort Smith in view of possibilities that this site may be logical for the administration headquarters of the proposed National recreation area.

Note: The Bureau of Reclamation agrees fully with the foregoing recommendations of the National Park Service and will cooperate in implementing any of the recommendations with which it is directly concerned. For this report, approval by the Congress of the Bighorn Canyon National Recreation Area has been assumed. The National Park Service would therefore acquire the additional land needed for recreational development of the area and would provide for "minimum basic health and safety facilities."

Yellowtail Dam site is a very desirable location for development of hydroelectric power. The advantages of a high head and a short penstock installation will be available. The reservoir will provide adequate storage capacity without excessive drawdown.

Preliminary operation studies were made for various reservoir capacities between 500,000 and 1,400,000 acre-feet. Energy output for each capacity was determined, and costs, revenues, and benefits were estimated. Using these data, a curve was prepared showing the relationship of average annual benefits and revenues for each dollar of construction cost. The economic height of dam was determined to be that which would be necessary to provide a gross storage capacity of 1,366,000 acre-feet at elevation 3,656.5 feet. An increase in height of 0.5 foot was recommended to provide additional operating margin, which would increase the gross storage capacity to 1,375,000 acre-feet. Further studies showed that any additional increase in flood storage capacity solely to decrease the spillway size would not be economical.

In planning Yellowtail Powerplant, it was recognized that an installation of about 130,000 kilowatts would probably be sufficient to assure the sale of the firm energy available. However, it was evident that, because of the high head and short penstocks, Yellowtail Dam will afford opportunity for economically adding firm peaking capacity, which when integrated with the energy from other existing and prospective power installation in the area will increase the area firm power supply. The plan adopted for the Yellowtail Unit contemplates installation of four 50,000-kilowatt hydroelectric generating units for a total installed generator capacity of 200,000 kilowatts.

Design of the powerplant was based on operating the reservoir at sufficiently high levels to assure full peaking capacity from the powerplant at practically all times. The generating units were rated to produce the full 200,000 kilowatts only down to an operating head of 420 feet. Operation studies showed that the head was less than 420 feet only three times in a study period of 24 years, and the minimum head reached was 370 feet for a period of less than 1 month.

Present Power Development

Hydroelectric generating plants in the general service area of the proposed Yellowtail Powerplant include the Pilot Butte, Shoshone, Heart Mountain, and Boysen Powerplants of the Bureau of Reclamation in the Bighorn and Wind River Basins of northwestern Wyoming and the Canyon Ferry Powerplant of the Bureau near Helena, Montana. The capacity of these plants totals 77,000 kilowatts. Other Bureau plants are located south of Casper, Wyoming. Also within the

general area is the hydroelectric powerplant of the Corps of Engineers, Department of the Army, at Fort Peck, Montana. This plant has an installed capacity of 165,000 kilowatts. Its power is marketed by the Bureau of Reclamation, as is the power from other plants of the Corps on the Missouri River. Hydroelectric powerplants of the Montana Power Company, with total generating capacity of 193,000 kilowatts, are located on the Missouri River in the vicinity of Great Falls, Montana. The company also has a small plant at Mystic Lake near Columbus, Montana.

Steam-electric powerplants within transmission distances of the proposed Yellowtail Powerplant include a plant of Montana Power Company at Billings, with installed capacity of 66,000 kilowatts; a plant of Montana-Dakota Utilities Company at Sidney, Montana, with installed capacity of 66,000 kilowatts; and a plant of Pacific Power and Light Company at Glenrock, Wyoming, with installed capacity of 200,000 kilowatts.

Yellowtail Unit area is presently served by a 115-kilovolt transmission line about 46 miles long from Lovell, Wyoming. This line connects near the damsite with the 161-kilovolt transmission line of Pacific Power and Light Company from Billings to Casper. The line from Lovell, constructed by the Bureau of Reclamation, was placed in service in December 1956. It connects with the Western Division of the Missouri River Basin power system at Lovell. The Montana Power Company, Big Horn Electric Cooperative, and Yellowstone Valley Electric Cooperative have distribution lines in the area also.

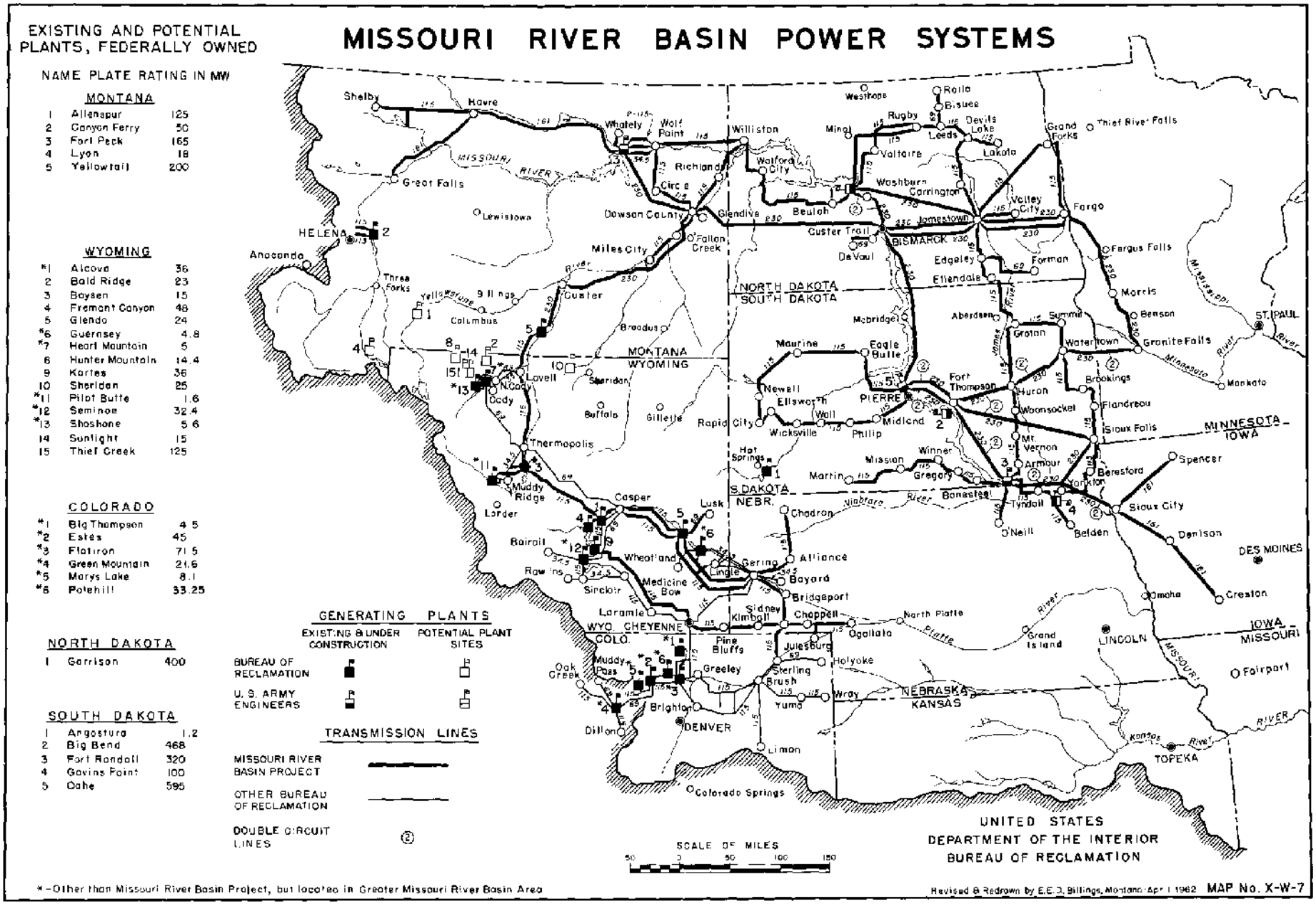
Power Market

A ready market will be available for all power and energy to be produced at Yellowtail Powerplant. The marketing area covers a large part of central, southern, and eastern Montana and Northeastern Wyoming, and extends into northwestern South Dakota and southwestern North Dakota. Within this area, power and energy marketed by the Bureau of Reclamation is being made available to preference customers primarily by wheeling over lines of the Montana-Dakota Utilities Company, Pacific Power and Light Company, and Black Hills Power and Light Company.

The power to be produced at Yellowtail Powerplant will be fully integrated with the power produced at other Missouri River Basin power developments, both in the Eastern and the Western Divisions of the basin power system. (See map on following page.) This will not only insure an immediate market for all power and energy, but will provide the means for mutual support.

Several rural electric cooperatives located within relatively short distances of the Yellowtail site are not now receiving power from

MISSOURI RIVER BASIN POWER SYSTEMS



the Bureau of Reclamation. A recent survey indicates that the combined loads of these cooperatives in Montana will approximate 65,000 kilowatts in 1967, with an anticipated growth rate of 7 percent a year thereafter. There are additional customers in this category in Wyoming. These preference customers have expressed interest in obtaining power when it can be made available to them. Potential irrigation developments in the area will require an estimated 17,000 kilowatts for pumping. Thus it appears that at least 50 percent of Yellowtail's firm output will probably be absorbed immediately within the local area.

Table 6 compares the potential power requirements of preference customers in the Missouri River Basin power system and the power system capability for the years 1967, 1970, and 1975. The deficits between total demand and system capability in 1967, the first year that Yellowtail Powerplant is expected to be in full operation, are estimated to be 152,000 kilowatts and 208,000,000 kilowatt-hours.

Table 6 - Estimated Hydrosystem Power Supply and Customer Requirements - Missouri River Basin Project

Item	1967	1970	1975
Hydro system supply (firm and nonfirm):			
Firm peaking capability - Thousands of kilowatts 1/	2,067	2,260	2,241
Average year hydro energy - Millions of kilowatt-hours	9,028	11,102	10,792
Firm power:			
December - thousands of kilowatts	1,576	1,584	1,551
Annual - millions of kilowatt-hours	8,273	8,478	8,306
Customer requirements: 2/			
December - thousands of kilowatts	1,728	2,145	3,104
Annual - millions of kilowatt-hours	8,481	10,520	15,190
Deficits:			
December - thousands of kilowatts	- 152	- 561	- 1,553
Annual - millions of kilowatt-hours	- 208	- 2,042	- 6,884

1/ Peaking capability of hydro system in December with adverse-year water conditions.

2/ From table I of July 1961 Integration Study (Eastern Division), plus Western Division from "Rocky Mountain Power Pool Load Forecast and Power Resources 1958-1967" projected for annual growth.

Power Development

The first of four 50,000-kilowatt generating units in Yellowtail Powerplant is scheduled for commercial operation in February 1966. The other three units are scheduled for operation at intervals of 3 months, the last being scheduled in November 1966.

Hydropower operation studies show that the powerplant will generate 898 million kilowatt-hours in the first year of full operation (1967) and 710.5 million kilowatt-hours when ultimate upstream depletion is attained (see table 5, page 46). Average annual generation over a period of 50 years is estimated to be 775 million kilowatt-hours.

Average annual sales of power produced at the powerplant are expected to be:

Power classification	Average annual sales 1/
Firm commercial	501,856,000 kw.-hr.
Nonfirm commercial	194,290,000 kw.-hr.
Irrigation pumping	9,088,000 kw.-hr.
Peaking capacity	62,812 kw.

1/ System losses of 9 percent are assumed.

The economic analysis presented herein is an evaluation of the economic benefits and costs of the Yellowtail Unit under the present plan of development with distribution of costs according to their reimbursability status. Yellowtail Dam will be a key control structure for regulation of streamflows of the Bighorn River and, to a lesser extent, of the Yellowstone River. Hardin Unit will be associated with Yellowtail Unit for both storage and diversion of water for irrigation. The Yellowstone Pumping Units will be associated with Yellowtail Unit for irrigation storage. These potential irrigation units are referred to in this chapter as the "participating irrigation units."

Because the recreational aspects of Yellowtail Unit are considered of National significance, the National Park Service will assume complete responsibility for obtaining funds for constructing and maintaining the recreation program for the unit. Inasmuch as the funds to be obtained by the National Park Service for recreational development will not be Missouri River Basin Project funds, recreation costs and benefits will not be included in either the economic justification or the financial analysis of Yellowtail Unit or the Missouri River Basin economic and financial analyses, although it is recognized that the development would not be possible without construction of Yellowtail Unit.

Benefits

Monetary evaluation of benefits from Yellowtail Unit includes estimates for irrigation, power, flood control, and fish and wildlife.

Irrigation Benefits

Both direct and indirect irrigation benefits are considered. Direct benefits are the measure of the net increase in personal income. Indirect and public benefits are the measures of the net increases in profits to agricultural processing and less tangible effects such as better community facilities.

Direct irrigation benefits from the participating irrigation units are estimated at $1,217,562 annually, and total irrigation benefits are estimated at $3,621,773 annually. Irrigation benefits are based on a 250-265 price level (1910-14 = 100) for prices received and prices paid.

Power Benefits

Power benefits are the estimated value of electric power from a non-Federal steam plant which would likely be developed in the immediate area in the absence of Yellowtail Powerplant. Criteria for determining value of power at the alternative plant are based on information furnished by the Federal Power Commission.

The following power values comprise the total of $5,860,000 used as the annual power benefit:

200,000 kilowatts at $20 per kw.	= $4,000,000
775,000,000 kilowatt-hours at $0.0024 per kw.-hr.	1,860,000
Total	$5,860,000

The figure of $20 per kilowatt is composed of capital investment costs, insurance, taxes, depreciation, repair, fuel costs.

Flood Control Benefits

Flood control benefits, as estimated by the Corps of Engineers, Department of the Army, will total $323,000 annually. These benefits will accrue through control of floods, including a flood with a peak discharge of 55,900 cubic feet per second and a volume of 2,044,000 acre-feet. This flood would be controlled to a maximum discharge of 20,000 cubic feet per second or 565,000 acre-feet. The final agreement and design for Yellowtail Unit provide for 509,000 acre-feet of flood control space, which will include 259,000 acre-feet of flood control space and 250,000 acre-feet of joint flood control and conservation space.

Fish and Wildlife Benefits

The Bureau of Sport Fisheries and Wildlife expects Yellowtail Unit to have a beneficial effect on fishery resources but believes that wildlife, except waterfowl, will sustain losses. Considerable use of the reservoir by waterfowl is expected, and possibilities for waterfowl management in the Wyoming portion appear good.

The total annual increase in fishery values is estimated at $67,269. This figure includes increases of $66,000 annually in the fishery both above and below the dam and $1,269 annually from improvement of the reservoir fishery resulting from introduction of toxicants to prevent upstream movement of coarse fish. The latter amount is based on annual benefits totaling about $10,000 for a 5-year period.

Only one of the participating irrigation units is credited with producing measurable benefits. Hardin Unit would produce wildlife benefits valued at $3,000 annually.

Supplemental Benefits

Population.- Development of Yellowtail Unit will not cause any permanent, large increase in population itself. However, development on the participating irrigation units would result in some population increase, possibly totaling as much as, or more than, the 1960 population of one of the smaller Montana counties.

Other.- Recreation and increased hunting and fishing will have supplemental effects. These effects are described in the individual reports of the National Park Service and the Bureau of Sport Fisheries and Wildlife.

Summary of Benefits

Annual benefits from the various purposes that will be served by Yellowtail Unit are summarized in table 7.

Table 7 - Summary of Annual Direct and Total Benefits Associated With Development of Yellowtail Unit

Purpose	Direct	Total
Irrigation	$1,217,562 1/	$3,621,733 1/
Power	5,860,000	5,860,000
Flood control	323,000	323,000
Fish and wildlife	71,769	71,769
Total	$7,472,331	$9,876,542

1/ Irrigation benefits will result from the application of stored water on Hardin and the Yellowstone Pumping Units through construction of diversion and distribution works for those units.

Costs

Construction costs for Yellowtail Unit, estimated to total $100,192,000, are based on bid prices for part of the costs and on January 1962 prices for the remainder of the costs. Interest during construction is estimated at $6,354,000.

Operation, maintenance, and replacement costs for the dam and reservoir are based on average prices for the years 1958, 1959, and 1960, and those for power facilities are based on criteria of the Federal Power Commission, a 3-percent sinking fund, and current directives of the Bureau of Reclamation. The total OM&R cost for the dam, reservoir, powerplant, and switchyard is estimated to be $358,610.

Allocation of Costs

All costs joint to irrigation, power, flood control, and fish and wildlife were allocated to these functions by the separable cost-remaining benefits method. Table 8 shows the allocation without adjustment for transfer of allocated costs to participating irrigation units or adjustment of power costs to commercial power investment.

Table 8 - Summary of Allocation of Costs, Yellowtail Unit

Function	Total construction cost	Interest during construction	Annual OM&R
Irrigation	$ 21,644,000	$1,372,000	$ 5,590
Power	68,498,000	4,344,000	351,330
Flood control	8,722,000	544,000	1,470
Fish and wildlife	1,136,000	72,000	220
Provision for adequate access	192,000	12,000	--
Total	$100,192,000	$6,354,000	$358,610

For the economic and financial analyses, the basic allocation is adjusted to provide for transfers of costs to the participating irrigation units and the Missouri River Basin Project interest-free power investment. Table 9 shows the adjusted allocation of the Federal investment and the operation, maintenance, and replacement costs.

Table 9 - Adjusted Allocation of Federal Investment and Operation, Maintenance, and Replacement, Yellowtail Unit

Function	Total construction cost	Transfers	Adjusted cost	Operation, maintenance, replacement
Irrigation	$21,644,000	$-21,644,000 1/		$(- 5,590)1/
Power	68,498,000	-12,809,000 2/	$55,689,000	351,330 3/
Flood control	8,722,000	--	8,722,000	1,470
Fish and wildlife	1,136,000	--	1,136,000	220
Provision for adequate access	192,000	--	192,000	--
Total cost	$100,192,000	$-34,453,000	$65,739,000	$353,020
Interest during construction-power	4,344,000	- 812,000 2/	3,532,000	
Adjusted total	$104,536,000	$-35,265,000	$69,271,000	

1/ Transferred to Hardin and Yellowstone Pumping Units.

2/ 18.7 percent interest-free power investment.

3/ Includes the following costs:

Powerplant, switchyard, and afterbay dam		$341,400
Yellowtail Dam and Reservoir:		
	Separable	1,130
	Joint	8,800
	Total	$351,330

Benefit-Cost Analysis

Economic feasibility of the Yellowtail Unit is measured on the basis of the costs remaining in Yellowtail Unit after deducting transfers of irrigation storage costs and costs of interest-free power investment. A benefit-cost ratio for Yellowtail Unit and the participating irrigation units without adjusting interest-free power investment in Yellowtail Unit would duplicate interest-free power investment costs with such assignment to the participating irrigation pumping units. The adjustment of dam and reservoir costs for storage and interest-free power investment has been standard practice in the Missouri River Basin Project. Table 10 shows the adjusted economic costs and benefits for the benefit-cost analysis of Yellowtail Unit.

Table 10 - Benefit-Cost Analysis, Yellowtail Unit

Function	Annual benefits	Annual costs	Benefit-cost ratio
(100-year period of analysis @ 2.5 percent interest)			
Irrigation	-- 1/	-- 1/	--
Power	$ 5,860,000 2/	$ 3,034,655 2/	1.93
Flood control	323,000	254,798	1.27
Fish and wildlife	71,769	33,210	2.16
Provision for adequate access	--	5,570	--
Total	$ 6,254,769	$ 3,328,233	1.88
(50-year period of analysis @ 2.742 percent interest)			
Irrigation	-- 1/	-- 1/	--
Power	5,860,000 2/	$ 3,607,323 2/	1.62
Flood control	323,000	344,496	.94
Fish and wildlife	71,769	44,892	1.60
Provision for adequate access	--	7,544	--
Total	$ 6,254,769	$ 4,004,255	1.56

1/ Benefits and costs transferred to irrigation units.
2/ Includes $1,066,000 taxes foregone.

Financial Analysis

All irrigation costs associated with Yellowtail Unit, amounting to $21,644,000, will be assigned to the participating irrigation units; and $12,809,000 will be transferred to Missouri River Basin Project basin-wide account as interest-free power investment. The adjusted power allocation of construction and interest during construction comprises the commercial power investment. The adjusted allocation of the Federal investment and operation, maintenance, and replacement cost is shown in table 9.

The allocation of costs of Yellowtail Dam and Reservoir according to their reimbursability status is as follows:

Reimbursable without interest	
Irrigation	$(21,644,000) 1/
Interest-free power	(12,809,000) 2/
Reimbursable with interest	
Commercial power:	
Construction cost	$ 55,689,000
Interest during construction	3,532,000
Subtotal	$ 59,221,000
Nonreimbursable	
Flood control	$ 8,722,000
Fish and wildlife	1,136,000
Provision for adequate access	192,000
Subtotal	$ 10,050,000
Total - remaining in unit	$ 69,271,000

1/ Transferred to participating irrigation units.

2/ Transferred to Missouri River Basin Project interest-free power investment.