

# The Bonneville Dam

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THE \$31,000,000 Bonneville Dam, a power and navigation project, Federal Public Works Project Number 28, now under construction by the Corps of Engineers, is situated in the gorge of the Columbia River, 42 miles east of, and above Portland, Oregon.

At the site of the dam the Columbia River is divided into two channels by Bradford Island, the main channel some 1,100 feet wide lying to the north between the island and the Washington shore. The south channel, known as Bradford Slough, is 500 feet wide and separates the island from the Oregon shore. All of the low water flow and about 75 per cent of the normal high water flow passes through the north channel. The river stages will vary from +7 to +40 feet during the course of the year. A railroad and a highway pass the damsite on each bank of the river.

In constructing the dam, advantage is taken of the natural diversion channel formed by Bradford Island with the result that the spillway section is located in the north channel while the powerhouse is located in Bradford Slough at a point some 800 feet farther downstream. An earth fill levee is being constructed on Bradford Island which will connect the powerhouse and the spillway dam, thus completing the closure of the river. Immediately south of the powerhouse on the Oregon shore the navigation lock is under construction. This lock will be connected to the river by a short approach canal with a bottom width of 150 feet.

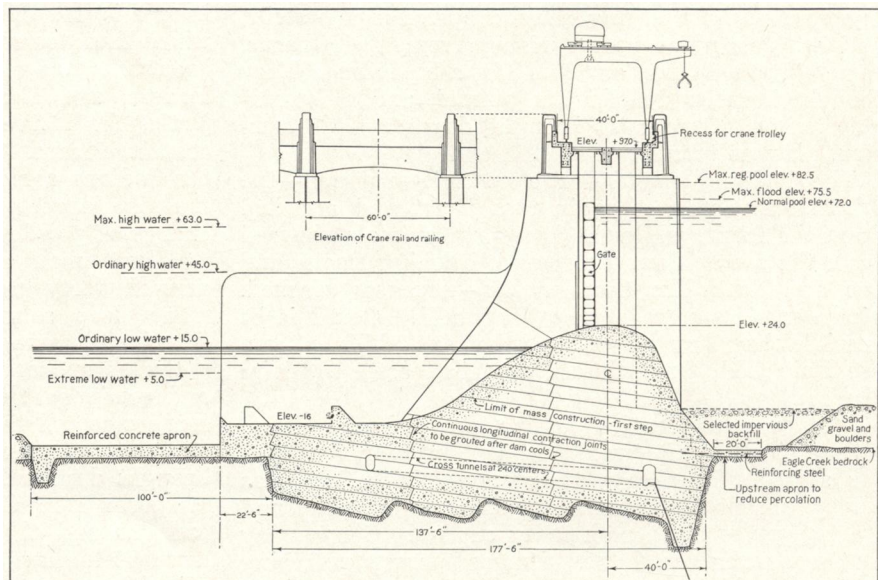
## The Spillway Dam

The spillway dam is to be an overflow gravity-type structure consisting of a mass concrete sill roughly 1,100 feet long, 185 feet wide, and 75 feet high topped by large piers forming eighteen openings which will be closed by vertical-lift gates, each 50 feet wide and 50 feet high. The elevation of the gate sills is fixed at +24 and by means of the gates the normal pool surface will be held at elevation +72. The foundation of the gravity section of the dam will vary from -40 to -76. Above the gates, at elevation +97, provision is made for the passage of two gantry cranes which are to lift the gates. At each end of the dam a concrete cut-off wall will extend into the river bank and a reinforced concrete apron 5 feet thick will extend 100 feet downstream from the base of the spillway section. The abutment structures will house electrical operating machinery and conduits, and gates for the fishways. At either end of the dam a concrete wing wall will extend upstream for the purpose of guiding the

stream flow into the gate openings. These wing walls will carry the fishways.

The recorded Columbia River flow varies from a minimum of 40,000 second feet to a maximum of 1,170,000 second feet and the necessity for providing passage for such a variable flow was one of the chief problems to be solved in the design of the dam. This was accomplished by designing a relatively low sill and controlling the overflow by means of the eighteen exceptionally large gates set in the deep slots between the piers. When the gates are raised to their full open position a clear opening is left beneath them sufficient to pass a flood in excess of 1,600,000 second feet, or one-third greater than the maximum recorded flood of 1894.

The foundation material is a relatively soft deposit of volcanic fragments and volcanic ash which has been solidified by pressure. It occurs in both agglomerate and conglomerate forms. It is not highly resistant to shear or scour. In order to provide a safe foundation on material of this type the



Section through Spillway Dam

dam was designed for a foundation load of not to exceed 110 pounds per square inch and in order to give additional safety against sliding the sill is to be locked to the rock by means of a series of steps or notches.

A third problem encountered was the destruction of the energy of the large flows of water which will pass through the gates. This will be accomplished by designing the overflow section to insure the formation of a hydraulic jump which will occur on the deck of the dam and by installation of baffle piers. The 100-foot apron mentioned above is a further protection against this severe destructive action.

On account of the depth of water, current velocity, and limited working period, the actual con-

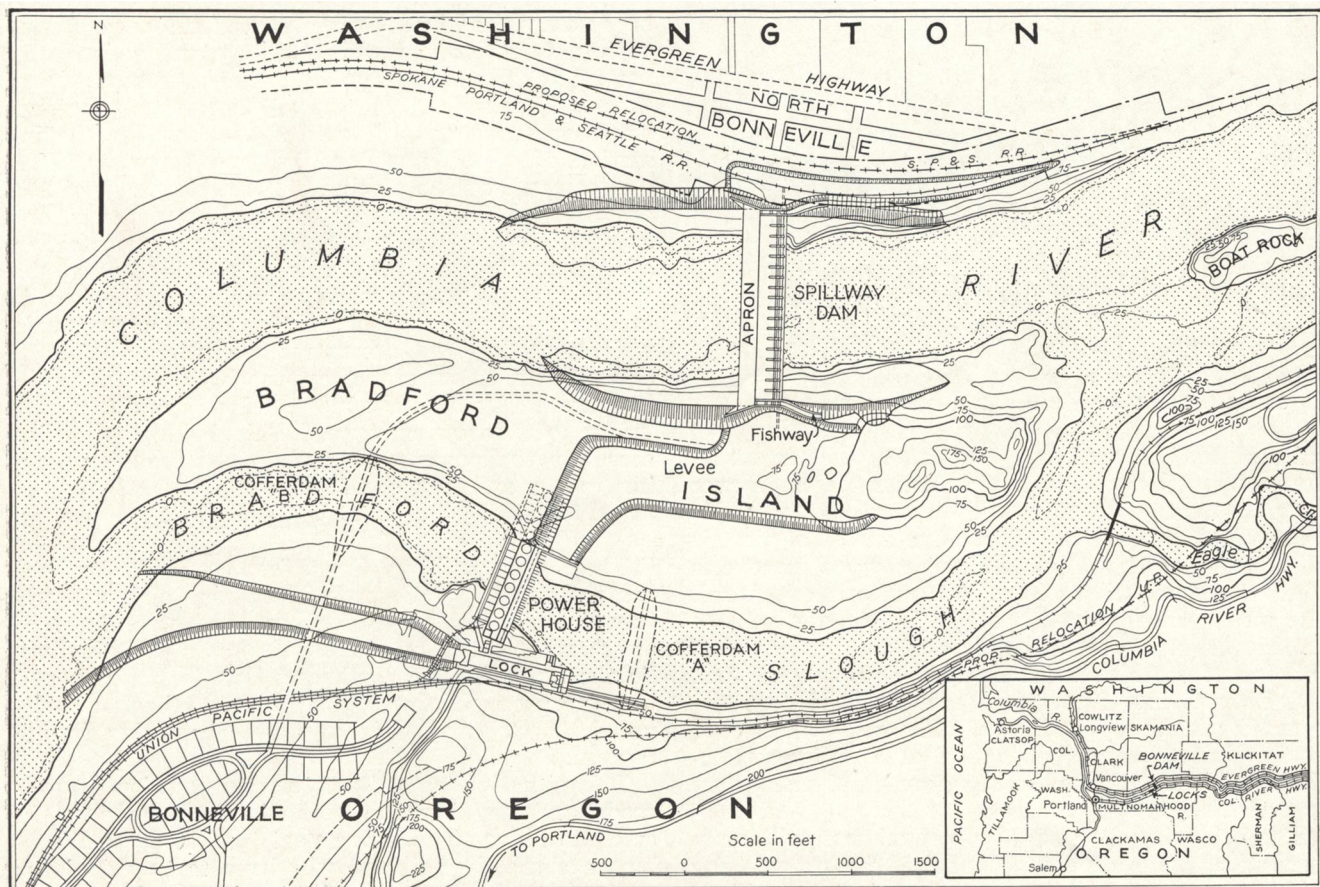
struction of the dam presents a very difficult problem in river diversion. The plan adopted and which is now in progress provides for construction of a horseshoe-shaped timber crib cofferdam to enclose the south half of the spillway section site. The area will then be unwatered and the south half of the structure partially completed therein, that is to say, the mass section will be completed to elevation —5 while the piers will be built to full height, thus leaving a series of deep slots in the structure. The cofferdam will then be removed and after the passage of the 1936 summer flood another cofferdam will be constructed extending from the north shore and enclosing the northern portion of the partially completed half. The river will then be diverted through the deep slots left in the south half of the dam. Within the north cofferdam the remaining half of the dam will be brought to full completion and prior to the summer flood of 1937 the cofferdam will be removed. After the 1937 flood the south half of the dam in the slots between the piers will be completed in units of one or two openings by placing concrete within small cofferdams. It will be noted that this plan provides for diversion of the flow of the river during the low water season through approximately one-half its normal channel and in order to prevent excessive velocities the north and south banks of the river have been excavated to increase the area available for this diversion. A portion of the flood flow will also pass through the draft tubes in the powerhouse in Bradford Slough. A continuous diaphragm of steel sheet piling has been driven as close to the sheeted face of the cribs as possible and extends around the outer two-thirds

of the cofferdam. This sheet piling is backed with clay to a height of 10 feet as a further precaution against leakage.

#### The Cofferdam

The cofferdam enclosing the south half of the dam site has just been completed. It consists of twenty-one timber cribs seated in a trench excavated in the river bottom. Each crib is faced with 3-inch tongue and groove sheeting and a continuous row of sheet piling has been driven immediately outside the sheeting to serve as a further seal against the inflow of water. The main cribs were 61 feet wide, 61 feet long, and are carried up to elevation +27 making the average height about 50 feet. The arrangement of the timber courses divided the cribs into a series of 12-foot by 12-foot pockets, some of which were floored and sheeted to serve as weight pockets for trimming and sinking the cribs. The cribs were partially constructed on ways on shore, then launched, towed into position, and completed by the use of floating equipment.

One unique feature of the crib construction was due to the fact that it was found to be impossible to excavate the crib footing to a reasonably level bottom because of large embedded boulders and pinacles of bed rock which could not be removed except at excessive cost and loss of time. As a result the contour of the river bottom was developed by means of soundings on 4-foot centers made with special equipment and the crib bottom "tailored" to fit the irregularities so developed. The results obtained by this method of constructing crib bottoms were surprisingly satisfactory and all cribs were



General Map of Bonneville Power Navigation Project

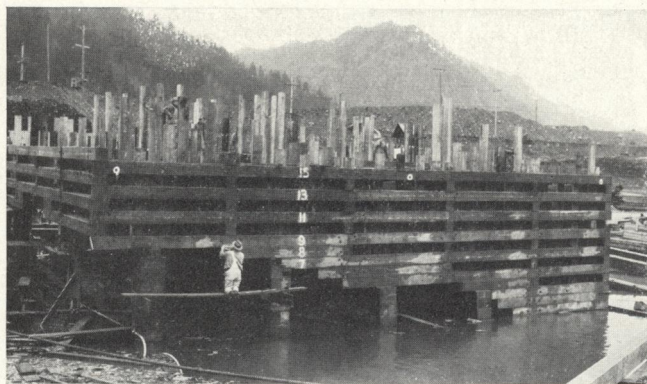
successfully seated without undue trouble. After the cribs had been placed in position by loading the weight pockets, the remainder of the pockets were filled with rock and gravel except the outside row which were filled with impervious material. The cribs were then decked with 6-inch by 12-inch timber to prevent scouring of the filled material as they will be overtopped by the spring freshet.

#### Power Installation

Power installation, as authorized, provides for ten 43,000 kw. generating units of which only two are to be installed now. Reference to the general map will show that the powerhouse is to act as a dam connecting Bradford Island with the Oregon shore. The exact location was determined by the fact that an andesite intrusion was located extending from the Oregon shore well into the island, offering the most suitable foundation in the vicinity, and also by the fact that at this point practically no tail race excavation would be required for the first six power units, which, spaced at 82-foot centers, will be sufficient to close the 500-foot channel.

The present plan calls for a completed powerhouse superstructure to house the house service unit and two 43,000 kw. units and a skeleton substructure for four more units in order to complete the closure of Bradford Slough. To complete the project and install the remaining four units required to develop the ultimate power capacity it will be necessary to excavate a portion of the south side of Bradford Island.

For the purpose of facilitating this excavation and permitting the construction of the last four



Cofferdam Crib Showing Bottom Shaped to Fit River Bottom

units without interrupting the power production, an unusually heavily reinforced concrete cantilever wing wall, 140 feet high, will be constructed. This wall, which extends as a continuation of a pier, is so placed that it will not be necessary to remove it when the installation of the four units is completed. The wall, which is an inverted "T" in section, has a thickness of 12 feet at the base of the vertical stem and is 3 feet thick at top. It is founded on rock and extends into impervious material 145 feet upstream from the powerhouse. The sole purpose of this wall is to act as a portion of a cofferdam behind which excavation for the four final units may be made.

The operating head at the powerhouse will vary through a range of 20 to 70 feet. To provide for this large variation it is planned to install turbines

of the Kaplan type with blades automatically adjustable to changes in load and head.

#### The Navigation Lock

The navigation lock is excavated through a continuation of the andesite intrusion which forms the powerhouse foundation. The lock will have a usable length of 500 feet and a width of 76 feet with a minimum depth over the sills of 27 feet. This lock is considerably larger than the barge lock originally



Lock Chamber and Deep Excavation at East End of Lock

planned and is intended to enable ocean-going vessels to reach the pool above the dam and permit them to proceed 45 miles farther inland.

The lock is remarkable for the extremely high lift of 65 feet necessary at low river stages. Normally the lift will be about 58 feet. The lower miter gates will be 102 feet high and will exert a thrust of 15,000,000 pounds. Filling of the lock will be accomplished by means of a central culvert supplying water to forty-six ports opening into the bottom of the lock chamber. The estimated filling time is 15 minutes. In case of emergency, provision has been made at each end of the lock for the insertion of metal stop logs in grooves provided in the lock walls. The placing of these stop logs will be accomplished by means of two stiff-leg derricks, one at each end of the lock. As a further protection against accident a chain fender is provided above the upper gate. The approach of vessels to the lock is facilitated by a 500-foot reinforced concrete guide wall at the up and downstream entrances. At the downstream entrance the approach to the lock will be spanned by a combination railroad and highway bridge of the swing type. This bridge will give access to the powerhouse and to the roadway leading to the spillway dam.

#### Railroad and Highway Relocation

The Columbia River Gorge is the only water level route through the Cascade Mountains and is therefore the natural route for east and west lines of communication. On the north bank of the river lie the Spokane, Portland, and Seattle Railway and the Evergreen Highway. On the south bank are situated the Columbia Highway and the Union Pacific System.

This situation necessitates some relocation of railroads and highways on both sides of the river in order to bring them above pool level. On the Washington shore the railroad will have to be raised for a distance of about 4.8 miles while on the Oregon

shore the line change for the railroad will cover about 4 miles. While these distances are relatively short and on the Washington shore offer no serious difficulty, the problem on the Oregon shore is much more difficult.

On the Oregon shore there exists, a short distance above Bonneville, a large landslide which has given serious trouble to the railroad for many years. This slide covers an area  $1\frac{1}{2}$  miles in length and  $\frac{1}{2}$  mile in width. In order to stabilize this slide over which the railroad must pass it is proposed to weight the toe at the river bank with a heavy riprap wall and to drive drainage tunnels above pool level into the slide for the purpose of removing the water which is believed to lubricate the underlying plane of impervious Eagle Creek formation.

Highway changes on both banks consist of local changes in alignment and grade and do not require any continuous relocation.

#### Fishways

One of the most difficult problems which must be solved in connection with the Bonneville Project is the matter of providing over the dam adequate passage of the annual salmon run.

A number of different solutions to this problem have been considered and the plan which is apparently most likely to be adopted provides for the use of three conventional fish ladders, one at each end of the spillway dam and the third at the north end of the powerhouse. In addition to these fishways two fish lifts or locks will be installed, one at the north end of the spillway dam and another at the south end of the powerhouse. A bypass will probably be constructed on the Oregon shore for the purpose of providing downstream passage for the fingerlings on their journey to the Pacific Ocean.

The fish ladders will be concrete troughs 40 feet in width through which a good flow of water will guide the fish upstream. The ladders will present a series of pools 40 feet in width and 16 feet long with a 1-foot waterfall at the upper end so that an easy climb will be obtained with adequate pools for resting always available.

The fish lift operates on the general principle of a navigation lock. The lifts are constructed in pairs and operate alternately, one lift always being open for the entrance of the fish. The fish having entered

the lift, the gates are closed and the water level raised to the reservoir level. As the water rises in the lock a grillage is also raised to force the fish to the upper level and out of the lift into the reservoir. The complete operating cycle for the lift requires about 15 minutes and requires a constant flow of about 1,500 second feet. The capacity of each lift is 100,000 fish per day.

The project was authorized on September 30, 1933. Immediately after the authorization exploratory drilling was commenced and on November 6 actual construction work was started.

At the present time the relocation of the railroad on the Washington shore is practically complete and a contract for some grading, a tunnel, and a concrete viaduct for the railroad on the Oregon shore is well under way.

A contract was awarded in February, 1934, for excavation for the powerhouse and lock which required the placing of two earth-fill cofferdams in Bradford Slough. These cofferdams were completed on May 1, 1934, and the task of pumping out the pool covering 25 acres was started on May 12, 1934. This excavation contract was completed in September. Work was immediately started on the powerhouse substructure and locks which were to be completed to elevation +34 by April 1, 1935, at which time the cofferdams were to be removed. The masonry for the locks and powerhouse substructure is scheduled to be completed in October of this year.

A contract has been let for construction of the main dam. Such excellent progress has been made on this work that the closure of the south cofferdam has already been completed. The channel enlargement excavation on both sides of the river is well under way and will be completed on schedule.

In addition to these major features twenty sets of quarters for the permanent operating personnel have been completed and are now occupied by the engineering force. An administration building and auditorium are now in process of construction. A contract has just been awarded for the construction of a 135-foot swing span railroad and highway bridge across the locks to give access to the powerhouse and spillway dam.

The project is under immediate charge of Major C. F. Williams, District Engineer, Portland, Oregon. Lt. Col. T. M. Robins is Division Engineer.



View of the Bonneville Project Looking Southeast from Washington Shore