

WATER CONTROL MANUAL
FOR
CERRILLOS DAM AND RESERVOIR
PORTUGUES AND BUCANA RIVERS
PUERTO RICO

JACKSONVILLE DISTRICT
U.S. ARMY CORPS OF ENGINEERS
JULY 1997

NOTICE TO USERS OF THIS MANUAL

This document supersedes all other documents concerning water control at the Cerrillos Dam and Reservoir.

EMERGENCY REGULATION ASSISTANCE

In the event that unusual conditions arise during non-duty hours, emergency regulation assistance can be achieved by contacting, in order listed, one of the following persons.

Keith Jones
Jim Vearil
Beeper *
Ron Hilton
Dr. Ed Middleton

Note: Jim Vearil or Keith Jones will have the beeper. After dialing the beeper number wait for the tone. After the tone, dial the phone number that you want the call to be returned to.

Last Updated: 01 July 1997

WATER CONTROL MANUAL FOR CERRILLOS RESERVOIR

U.S. Army Corps of Engineers
Jacksonville District

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Exhibit B	- Drought Contingency Plan
Exhibit C	- Coordination
Exhibit D	- Code of Federal Regulations
Exhibit E	- Standing Instructions to Damtender

CERRILLOS DAM AND RESERVOIR
PERTINENT DATA

<u>Location:</u>	Municipality of Ponce in south-central Puerto Rico
<u>Purpose:</u>	Flood control, water supply, recreation, fish & wildlife, water quality enhancement
<u>Stream:</u>	Cerrillos River
<u>Distance from Ponce:</u>	Approximately 4 miles (NE)
<u>Drainage Area:</u>	17.5 square miles
<u>Dam:</u>	
Type	Rockfill w/impervious core
Height	323 feet
Length	1,555 feet
Upstream side slope	1V - 2.2H and 1V - 3.5H
Downstream side slope	1V - 1.8H
Crest Elevation	634.7
Crest Width	32.8 feet
<u>Outlet Works:</u>	
Type	Multiple-use inclined intake structure
Regulating outlet slide gates w/ Emergency gates	Two - 3' X 4'9"
Low-flow withdrawal slide gates w/ Emergency gates	Two - 1' X 1'8"
Selective withdrawal levels	Multiple level intake at 4
Opening at each level	One 5' X 5' to 3' X 3' to 3' round
Centerline elevation of the withdrawal ports feet, NGVD	407.5, 435.0, 474.5, 524.5
Regulating outlet tunnel lined	18-foot-diameter, concrete
Length (including cut & cover)	1,425 feet
Cut and cover length	69 feet
Upstream invert elevation	345 feet
Downstream invert elevation	308 feet

CERRILLOS DAM AND RESERVOIR
PERTINENT DATA

Stilling Basin:

Elevation	308.80 to 290.00 feet
Length	188 feet
Width	varies 18 feet to 28 feet
Endsill elevation	291.34 feet
Baffle Block elevation	291.75 feet
Rows of baffle blocks	1

Emergency Spillway:

Location	Right abutment
Type	Unpaved, ungated overflow
Crest length	394 feet
Crest elevation	611.3 feet
Design discharge	75,280 cfs

Storage and Principal Elevations:

Flood control storage	15,975 acre-feet
Water supply storage	25,200 acre-feet
Minimum and sediment storage	5,635 acre-feet
Total storage	46,810 acre-feet

Elev., max. pool	629.4 feet
Elev., max. flood control pool	611.3 feet
Elev., min. flood control pool/ max. conservation pool	573.0 feet
Elev. min. conservation pool	451.0 feet

Reservoir:

Area, maximum pool	525 acres
Area, minimum flood control pool	350 acres
Area, minimum conservation pool	100 acres
Length	1 mile

Note: All elevations in this report are referenced to the 1929 mean sea level datum known as the National Geodetic Vertical Datum (NGVD).

I-INTRODUCTION

1-01. Authorization. This report is prepared in response to CESAD-EN-HW letter dated 5 September 1989 concerning preparation of water control manuals. It is prepared pursuant to ER 1110-2-240 according to guidance in EM 1110-2-3600 and ER 1110-2-8156.

1-02. Purpose and Scope. This volume is written to assist project personnel in the day-to-day operation of the Cerrillos Reservoir. Additionally, it serves as a reference source with information pertinent to the project. Procedures for operation and maintenance are covered under different regulations and published under a separate cover.

1-03. Related Manuals and Reports. Upon completion of the Portugues Dam a separate water control manual for the Portugues Reservoir will be written. The specific reports that relate to the Cerrillos Dam and Reservoir portion of the Portugues and Bucana Rivers Project are as follows:

a. Authorizations. The projects for flood control and other purposes on the Portugues and Bucana Rivers, Puerto Rico, were authorized by Section 201 of the Flood Control Act of 1970, Public Law 91-611. The part of the act applicable to this report relates to flood protection and other purposes for the Cerrillos Dam and Reservoir, Puerto Rico, authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Number 91-422.

b. Corps of Engineers Studies. Design Memoranda prepared by the Corps of Engineers are listed in Table 1-1 beginning on page T1-1.

1-04. Project Owner. The local sponsor of the Portugues and Bucana Rivers (P&B) project is the Department of Natural and Environmental Resources (DNER) of the Commonwealth of Puerto Rico.

1-05. Operating Agency. Under the local cooperation agreement between the Corps of Engineers and the Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico that became effective on 22 July 1974, the DNER is required to operate and maintain all completed works in accordance with regulations prescribed by the Secretary of the Army.

1-06. Regulating Agencies. Projects constructed by the U.S. Army Corps of Engineers for local flood protection are subject to regulations prescribed to cover operation and maintenance. These regulations are contained in section 208.10 and 208.11, Title 33 of the Code of Federal Regulations. A copy of these regulations is found in Exhibit D of this manual. These regulations are supplemented by approved water control plans and manuals.

Table 1-1

Design Memoranda

NUMBER	TITLE	SUBMISSION DATE
1	Basic Hydrology	May 72
2	Plan Formulation and Site Selection (General Design Memorandum - Phase I)	Jul 73
3	Lower Ponce Channel Improvements (General Design Memorandum - Phase II)	Jan 74
	Lake Cerrillos Site Geology	Sep 83
5	Cerrillos Dam (General Design Memorandum - Phase II)	Sep 80
6	Upper Ponce Channel Improvements (General Design Memorandum - Phase II)	Oct 76
7	Lake Cerrillos Dam Construction Facilities	Sep 80
8	Lake Cerrillos - Diversion & Tunnels DM	Mar 82
9	Lake Cerrillos Concrete Material DM	Feb 81
10	Lake Cerrillos Master Recreation Plan	Jan 89
11	Lake Cerrillos Outlet Works	Feb 83
12	- Unassigned -	-
13	Lake Portugues Site Geology	Nov 81
14	Lake Cerrillos Instrumentation	Oct 83
15	Lake Cerrillos Recreation	Oct 89
16	Portugues Dam (General Design Memorandum - Phase II)	Jun 83
16A	Portugues Dam Comparative Analysis	Sep 82
17	Lake Cerrillos Dam and Spillway	Jun 83
18	Lake Cerrillos Reservoir Clearing	Dec 88
19	Cerrillos Dam Hydroelectric Powerplant	Jun 83

Table 1-1 (Continued)

Design Memoranda

NUMBER	TITLE	SUBMISSION DATE
20	Lake Portugues Concrete Materials	Jul 86
21	Lake Portugues Structural Properties and Special Studies	Feb 88
22	Lake Portugues Foundation Investigations	May 88
23	Lake Portugues Instrumentation	Dec 97
24	Lake Portugues Dam and Spillway	Dec 89
25	Lake Portugues Reservoir Clearing	May 98
26	Lake Cerrillos Initial Filling	Jan 89
27	Lake Portugues Recreation	Apr 95
28	Lake Portugues Initial Filling	Dec 99
29	Portugues Concrete and Bridges	May 81
30	Ponce Channel Recreation Master Plan	Apr 84
31	Inundation Mapping for use in Emergency Action Planning - Cerrillos Dam	May 83
32	Interim - Emergency Action Plan for Cerrillos Dam(During Construction)	May 84
33	Ponce Channel Recreation FDM	Jul 87

II - DESCRIPTION OF PROJECT

2-01. Location. The Bucana River is formed by the confluence of the Cerrillos and Bayagan Rivers, which originate on the southern slopes of Cordillera Central and flows from this central ridge of the island to the Caribbean Sea. Ponce, the second largest city in Puerto Rico, is located in the lower coastal area along the Bucana River. The Cerrillos Dam is located on the Cerrillos River approximately four miles northeast of Ponce (see Plate 2-1).

2-02. Purpose. The total project plan of improvement consists of two multipurpose reservoirs, with downstream channel improvements on both the Portugues and Bucana Rivers and a diversion channel from the Portugues River to the Bucana River. This total project plan will provide essentially standard project flood protection, a dependable surface water supply for Ponce and surrounding area, fish and wildlife enhancement, and recreation facilities for full public use of the reservoirs. In addition, the project reservoirs will be operated to assist in helping improve downstream sanitary conditions by periodic release of impounded water to provide flow in the Portugues and Bucana downstream riverbeds. Such flows will curtail mosquito breeding in stagnant pools during the dry season.

2-03. Physical Components. The approved project consists of a multiple purpose dam and reservoir on the Cerrillos River. A rockfill dam with outlet works consisting of an inclined intake structure, a regulatory outlet tunnel, and a stilling basin located in the left abutment, and a spillway excavated in the ridge adjacent to the right abutment. These features are shown on Plate 2-2. A more complete description of the Cerrillos Dam is found in Exhibit A.

a. Main Embankment. The main embankment is a 323 feet high zoned rockfill embankment consisting of a central clay core flanked by a two stage filter which is supported by zoned rock shells. The embankment's axis is approximately 1,555 feet long and arched upstream. The crest elevation is 634.7 feet NGVD, and is 32.8 feet wide along its entire length. The upstream and downstream sideslopes are 1V on 2.2H and 1V on 1.8H, respectively. A 105-foot high cofferdam, constructed within the upstream slope of the main dam to protect downstream areas during construction of the main dam, serves as an integral part of the main dam. Riprap is placed on the upstream slope for protection against wave action. A triple line grout curtain 200 feet deep is provided beneath the embankment along the centerline axis. Typical cross sections of the embankment are shown on Plate 2-3.

b. Outlet Works. The outlet works consist of an inclined multipurpose intake structure, an 18-foot diameter regulatory outlet tunnel and a stilling basin located in the left abutment.

The intake structure features two regulatory outlet gates which will provide for flood control releases up to the downstream bank full capacity of 2,500 cfs from the minimum flood control pool elevation of 573 feet, NGVD, to the maximum pool elevation of 629.4 feet, NGVD. A low flow withdrawal system is provided to permit small releases from different levels within the reservoir pool. A section view of the intake structure is shown on Plate 2-4.

c. Spillway. An ungated spillway is cut through the ridge adjacent to the right abutment of the dam as shown on Plate 2-2. The spillway crest is at elevation 611.3 feet, NGVD.

d. Reservoir. Lake Cerrillos is a multipurpose reservoir with a maximum storage of 46,810 acre-feet at the maximum flood control pool elevation of 611.3 feet, NGVD. Included in this maximum storage are 15,975 acre-feet of flood control storage, 25,200 acre-feet of water supply storage, and a minimum sediment storage of 5,635 acre-feet. The conservation pool ranges from the minimum conservation pool elevation, 451.0 feet, NGVD, to the minimum flood control pool elevation, 573.0 feet, NGVD. The flood control pool ranges from the minimum flood control pool elevation to the maximum pool elevation, 629.4 feet, NGVD. Table 2-1 shows the storage and area of the reservoir at key pool elevations. The lake has a length of approximately one mile and about 12 miles of shoreline. A plan view of the reservoir is shown on Plate 2-5.

Table 2-1

Storage and Area of the Reservoir at Key Pool Elevations

	<u>Elevation</u> <u>(Ft., NGVD)</u>	<u>Storage</u> <u>(Acre-feet)</u>	<u>Area</u> <u>(Acres)</u>
Minimum Conservation Pool	451.0	5,635	100
Minimum Flood Control Pool	573.0	30,835	350
Spillway Crest	611.3	46,810	470
Maximum Pool	629.4	55,500	525

Source: Design Memorandum No. 26, Feature Design Memorandum - Lake Cerrillos Initial Filling Plan - January 1989, Table 2-1, Page 2-2, Revised June 1997 by ENHW

2-04. Related Control Facilities. The total project includes 10 miles of channel improvements, 16 drop structures, 2 debris basins, and 2 multi-purpose reservoirs. The Lower Portugues Channel extends for a distance of 1.1 miles to the confluence with the Bucana Channel, approximately 1.5 miles from the mouth. The Lower Bucana Channel extends for a distance of 2.6 miles. Both channels are provided with stone protection against high velocity flows. The Upper Bucana Channel improvements extend 2.95 miles as a rectangular concrete channel. The remaining 2.45 miles of

channels consists of earth revetted channels with stone protection against high velocity flows on the side slopes. Five 125-foot wide drop structures were constructed in this segment because the low velocities would increase gradually and become erosive as the flows moved downstream. The Upper Portugues Channel Improvements extend for 1.7 miles. The channel consists of 1.0 mile of rectangular concrete channel with the remainder consisting of earth revetted channel. The Cerrillos Dam and Portugues Dam will impound water to form multi-purpose reservoirs.

2-05 Real Estate Interests and Acquisition. The Corps of Engineers requested from Department of Natural and Environmental Resources (DNER), Project Sponsor, approximately 1060 acres of land required in fee for project purposes. DNER acquired and certified the necessary lands for project life.

2-06. Public Facilities. There will be five recreational sites developed along the reservoir. These sites will have a variety of recreational opportunities for the people of Ponce and surrounding communities. Other recreation sites have been developed along the channels downstream of the Dam. Table 2-2 shows the recreation sites and the opportunities available at the reservoir.

Table 2-2

Recreational Opportunities

<u>Recreation Site</u>	<u>Activities</u>
Campo De Recreo de Cerrillos	Sightseeing Picnicking Outdoor Games Nature Walks Drive for Pleasure
Bella Mirada	Sightseeing Nature Walks Drive for Pleasure
El Mirador	Sightseeing Nature Walks Drive for Pleasure
El Atracadero	Boating Fishing Hiking Picnicking Outdoor
Puerto Rustico	Boating Camping Hiking

Source: Design Memorandum No. 15, Lake Cerrillos Recreation - October 1989

III - HISTORY OF PROJECT

3-01. Authorization. The projects for flood control and other purposes on the Portugues and Bucana Rivers, Puerto Rico, were authorized by Section 201 of the Flood Control Act of 1970, Public Law 91-611 dated 31 December 1970. The part of the act applicable to this report relates to flood protection and other purposes for the Cerrillos Dam and Reservoir, Puerto Rico, authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Numbered 91-422.

3-02. Planning and Design. This section briefly summarizes the studies leading to the development of the authorized project. Preauthorization studies were initiated with a public meeting in March 1965, the District Engineer's report was completed in February 1970, and the project was authorized in December 1970. The principle alternatives evaluated were a combination of storage and channelization, channelization alone and nonstructural alternatives. Storage alone would not provide adequate flood protection to Ponce.

Thirteen damsites were investigated during the preauthorization studies; four on the Cerrillos River, three on the Portugues River, two on the Chiquito River, one on the Bayagan River, and three which would impound both Portugues and Chiquito Rivers. Preliminary costs for comparison of damsites were based on constructing rockfilled dams, with spillways to be excavated in saddles adjacent to the dams or in one of the dam abutments. Concrete dams with ungated overflow spillways were also considered but would cost about twice as much as rock-filled dams. Because of the extremely fast flood runoff and need for quick and dependable operation, dams with gated spillways were not considered. Single dams on Portugues and Cerrillos Rivers were found to be the best alternative of the lake plans investigated. Control of Chiquito and Bayagan Rivers would reduce downstream improvements and would afford additional water supply and other multipurpose benefits, but the savings and additional benefits were not sufficient to justify the cost for storage on these rivers.

Three general plans were investigated in the preauthorization studies for modifying the channels through Ponce to remove the runoff downstream of the dams: channelizing both rivers to the sea; diverting Portugues River to Bucana River; and diverting both rivers to the east of the Bucana River. The Portugues River diversion plan was found to be the best of these alternatives. Two diversion routes were considered in detail, one in the northern section of the city and another in the southern section. The lower diversion proved to be the better route in the final plan formulation.

Several nonstructural alternatives were considered in

preauthorization studies, including a flood-warning system, flood plain evacuation, flood plain regulation, and floodproofing. A flood-warning system would be inadequate because of flood characteristics of the basin. There would be insufficient time to safely evacuate the population and protect valuable property.

A study was made of the feasibility of permanent evacuation of flood prone urban development within the area flooded in 1954. It was assumed that a flood-free area with the same geographic advantages would be available to relocate all residences and commercial establishments, though such an area could not be readily identified. An evaluation was also made of a plan to floodproof the structures in the 1954 flood plain. Both of these plans were rejected on the basis of excessive costs.

To determine the most economical combination of reservoir storage and downstream channelization, cost curves were developed for reservoirs with varying amounts of flood storage and for the channel project for varying design capacities. The reservoir costs for flood control were the separable costs of adding this storage to reservoirs serving dual purpose of water supply and recreation. Routings were then made for project scales of 50-year, 100-year, and Standard Project Flood protection. By varying the amount of reservoir storage for each project scale, the optimum storage was determined. In all cases the most cost efficient plan required that the reservoirs store enough of the inflow to prevent any increase in downstream peaks from the uncontrolled portion of the basin.

The preauthorization studies found that flood control benefits would be maximized for a project that would provide protection against a flood with a recurrence interval of 190 years. However, a project to provide as nearly as practicable complete protection against the Standard Project Flood was selected due to the residual hazard to life and property for a project of smaller scope. The authorized plan of improvement is shown on Plate 3-1.

A public meeting was conducted on 8 August 1972 at Ponce, Puerto Rico, in cooperation with the Department of Public Works to involve the public in the preconstruction planning studies. A detailed presentation was made on the description of the authorized project; the current status of planning; probable project effects on the environment and the need to consider post-authorization modifications or alternatives. At the recommendation of the Secretary of Public Works all persons owning water rights in the Portugues and Bucana River basins or having information on such rights were urged to attend the meeting and submit copies of pertinent documents of information to the Department of Public Works.

Subsequent plan formulation studies involved a review of the basic planning and decisions made during the general investigations stage in light of the current conditions and with the benefits of more detailed economic, environmental, and

engineering data. During the short time period between completion of general investigation studies and initiation of preconstruction planning (about 18 months), no major changes in local conditions, desires, or needs occurred that altered the basic formulation of the authorized project plan. The Cerrillos damsite had to be moved upstream for geotechnical reasons, and water supply storage was increased at both dams. These matters, however, were found to have little impact on the overall location and scope of the authorized project works.

A series of design memorandums were prepared for the project. A list of these reports is found in Table 1-1. During the preparation of these reports no major changes were made to the general plan for the Cerrillos Dam. However, there were several changes made in the type and location of the outlet works, spillway location, the dam axis location, and some hydraulics design. Also an inclined-type intake structure was proposed in lieu of the freestanding intake structure presented in the General Design Memorandum for the dam. This structure is safer than the freestanding structure from the standpoint of seismicity, and was more economical to construct.

3-03. Construction. The Local Cooperation Agreement (LCA) for the Cerrillos Dam was signed on 15 March 1982. Construction contract DACW17-84-C-0058 for the Cerrillos Dam Embankment, Spillway, and Outlet Works was awarded to Dillingham Construction Company on 28 September 1984 for \$68,421,540. The contractor was given notice to proceed on 15 October 1984. Work on the dam was virtually complete in April 1991 when the Cerrillos Dam was dedicated. Subsequent modifications and claims have resulted in the dam costing approximately \$140,383,000.

3-04. Related Projects. There are no other related projects in the basin. However, the Cerrillos Dam is just one project feature of the multi-purpose Portugues and Bucana Rivers Project. Channelization of these rivers along with the Cerrillos and Portugues Dams will provide ample and direct protection to Ponce from floods. The total project includes 10 miles of channel improvements, 16 drop structures, 2 debris basins, and 2 multi-purpose reservoirs.

The Portugues Dam is a concrete, three-centered, double-curvature arch dam, curved in both the vertical and horizontal planes. The dam is designed as a multi-purpose dam to be constructed in two phases. The Commonwealth has requested that the dam be constructed as soon as possible for flood control and recreation, but to defer the water supply feature to a later date. The proposed dam is located on the Portugues River, 8.3 miles above its mouth and is designed with a crest height of 270.6 feet and length of 1,505 feet. Its reservoir will provide 8,626 acre-feet for flood control and 14,000 acre-feet for water supply and water quality. The expected water supply yield is 12.4 mgd. The Portugues Dam is currently scheduled for completion in June 1999.

3-05. Modifications to Regulations. At this time no modification to project regulations has been requested.

3-06. Principal Regulation Problem. No problems associated with regulation of the reservoir have been reported or are foreseen. However several unforeseen conditions have developed during the initial filling of the reservoir.

a. Seepage collected and measured in the toe-drain system has been greater than projected in the design process. An analysis done during the design of the dam predicted a seepage rate of approximately 1 cfs. Upon initial filling of the reservoir seepage measured in the toe drain system has exceeded 5 cfs. A "Cerrillos Dam Seepage Investigation Task Force" was formed to determine the cause of the increased seepage and any associated problems that may be caused. The Task Force determined that the increased seepage does not affect the integrity of the dam, nor affect its function of meeting its project purposes. Although the exact source of the seepage is not known, it is believed to be coming through rock fractures in the left abutment.

b. Also during initial filling many leaks developed in the intake structure. Several large leaks directly affected the operating equipment of the intake structure. The Jacksonville District used in-house drill crews to drill and grout these leaks in the intake structure. As part of the seepage investigation, it was determined that poor concrete compaction and vibration was the major cause of the leaks.

In October 1985, a tropical wave (later named Isabel) inundated Puerto Rico - hitting the Ponce area particularly hard. Due to the excessive rainfall, a landslide occurred in the left abutment, striking the partially completed intake structure. Damage to the concrete, rebar, and waterstops at this elevation is felt to have contributed to the excessive leakage in the intake structure during initial filling.