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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

COMMUNITY AND ECONOMIC
DEVELOPMENT DIVISION

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Lieutenant General J. W. Morris
Chief of Engineers
Corps of Engineers
Department of the Army

Dear General Morris:

We have reviewed the Corps of Engineers' procedures and practices for establishing flood control operating criteria at Federal multipurpose water resource projects. Our work was done primarily at Corps headquarters in Washington, D.C.; the North Pacific, Ohio River and Missouri River divisions in Portland, Oregon; Cincinnati, Ohio, and Omaha, Nebraska We also visited Corps district offices of the Missouri River, Southwestern, Lower Mississippi Valley and South Pacific divisions located in Kansas City, Missouri; Tulsa, Oklahoma, Little Rock, Arkansas, Vicksburg, Mississippi, Fort Worth, Texas, and Sacramento, California In addition, we visited the Bureau of Reclamation's Upper Missouri, Lower Missouri, and Mid-Pacific Regions in Billings, Montana, Denver, Colorado; and Sacramento, California. We also visited the Tennessee Valley Authority.

We believe that opportunities exist for obtaining increased benefits from Federal multipurpose water resource projects by using known improvements in the methodology for establishing flood control operating criteria At the present time, there is a wide variance in the sophistication of methods used at various Federal projects in establishing such criteria

INTRODUCTION

According to section 7 of the Flood Control Act of 1944 (58 Stat. 890, 33 U.S.C. 709) the Secretary of the Army is responsible for prescribing regulations for the use of storage space allocated for flood control or navigation purposes at all reservoirs constructed wholly or partially with Federal funds where part of these funds were originally provided for the purposes of flood control or navigation Projects operated by the Bureau of Reclamation and the Tennessee Valley Authority (TVA), which are subject to the above provisions of the 1944 Act, use flood control operating regulations developed by the Corps.

089039

Reservoir regulation plans prepared by the Corps for their reservoirs set the operating criteria, guidelines, rule curves and specifications that govern the storage and release functions of a reservoir and the other provisions necessary for collecting and analyzing basic data and preparing detailed operating instructions. Engineering Regulation No. 1110-2-240, entitled "Reservoir Regulation," states the following policies for Corps projects:

> "Thorough analysis and testing studies will be made as necessary to establish the optimum regulation plans possible within prevailing constraints."
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> "Necessary actions will be taken to keep approved reservoir regulation plans up-to-date***"

Some of the purposes for which Federal multipurpose projects are operated are flood protection, irrigation water, municipal and industrial water, hydroelectric power, and recreational opportunities. Some of these purposes are listed in the legislation authorizing the project while others are incidental to normal operations. The way a project is operated may benefit some purposes while negatively affecting others

Various methods are available for establishing project operating levels to maximize project benefits For example, one of the variables used to set reservoir operating levels is the antecedent precipitation index (API). The standard API is derived by historical testing and is used to predict the run-off that can be expected from a given precipitation amount As time passes from the last storm, and the basin becomes dryer, the amount of run-off from a given amount of precipitation can be expected to decrease. To account for this, a decaying factor, such as three percent per day, can be added to the standard API to provide more realistic run-off projections.

Using a decaying API, instead of the standard API, can produce added project benefits Generally, the higher a reservoir pool is maintained, the more hydroelectric power can be produced. Higher reservoir pools may also increase other project benefits such as recreation and irrigation Using a decaying API allows the dam operators to decrease the reservoir's flood control space and increase the pool size as time passes from the last storm. For example, the State of California changed its operating criteria at the Oroville Dam based on a 3 percent decaying API and estimated that the change will result in additional average annual power generation of 6.4 million kilowatt hours.

FLOOD CONTROL OPERATING METHODS VARY

We found different flood control methods and guidelines in use at the Federal multipurpose projects we visited. They ranged from a simple straight line rule curve which required that the reservoir be kept at one level year round, to a sophisticated computer operation which considered the basin's runoff potential by measuring such data as evaporation, river flows, moisture content, and weather forecasts. This data was used to determine the amount of reservoir space required for possible flood inflows. Between these extremes, we found that projects were being operated using methods based on various combinations of variables such as weather forecasts, temperature predictions, river flows, transpiration, basin ground moisture, and percolation into ground water.

We discussed with officials at the Office of the Chief of Engineers these varying operating methods and the possibility of increasing project benefits by more fully utilizing advanced methods for determining flood control requirements They said that the Corps recognizes the need for updating the operating methods at some projects to increase overall benefits, but that these methods cannot be standardized for all projects. They said that studies to update reservoir regulation plans usually are given low funding priority.

These Corps officials told us that the Hydrologic Engineering Center in Davis, California, performs studies of reservoir operating methods for all Corps districts and divisions. They said that the Center has the capability to provide whatever technical assistance the various Corps districts and divisions need for implementing modern flood control operating methods and, thus, increase project benefits.

The diversity of factors considered in establishing reservoir operating plans was evident at the Corps field offices we visited For example, some Corps districts (Sacramento, Tulsa, Kansas City, and Fort Worth) used an antecedent precipitation index or decaying API as one of the variables considered for flood control operations while others (Little Rock and Vicksburg) do not use the API at all. In four Corps districts (Tulsa, Little Rock, Vicksburg, Sacramento) and one division (Missouri) the flood control methods were not fully computerized. In addition, one district (Sacramento) and one division (Missouri) did not use rain or ground moisture measurements, and four districts (Little Rock, Kansas City, Vicksburg, and Fort Worth) and one division (Missouri) did not use transpiration or percolation into ground water in establishing their flood control operational methods.

Corps' North Pacific Division

The most advanced operating methods we observed were in use at the Corps' North Pacific Division. The Division uses computerized simulation techniques to test the possible results of various operating decisions. Regulation of each reservoir is guided by predetermined operating criteria based on computerized hydrologic studies and reservoir systems analysis. Simulation is used to provide more timely, specialized information.

The Division has not calculated the benefits of using their modeling techniques in specific situations. They told us, however, that simulation of stream flow and reservoir regulation results in improvement of reservoir regulation techniques and that direct benefits have been achieved through the lowering of regulation flood stages, and the resulting ability to generate additional power.

Corps' Sacramento District

The Corps' Sacramento District is responsible for establishing operating regulations for projects in the Bureau's Central Valley Project (CVP) which are operated for flood control. The flood control operating regulations for the Shasta Dam--largest in the CVP--were established by the Corps in 1956 Reservoir operating levels were based on total actual inflow to Shasta for the prior 29 day period.

This method did not take into account the fact that the basin upstream from the reservoir becomes drier as time passes since the last storm, and consequently consumes more of the rainfall before it reaches the reservoir. As a result, the Bureau's operations officials said that the water release criteria established by the Corps was too conservative, and that they intentionally operated Shasta in a manner which encroached on the flood control space established in 1956.

The Bureau officials said that they encroached on the flood control space established by the Corps by an amount which was based on actual and forecasted inflows, current level of encroachment, and a 5-day weather forecast They stated that this method provided greater flexibility and, as a result, fewer nonpower generating releases were made The Bureau officials estimated that this method allowed generation of more than one billion kilowatt hours of electricity during the 10-year period 1965 through 1975, which otherwise would have been lost through nongenerating releases The Bureau was not able to quantify the increased risk of flood damage, however.

We contacted Corps and Bureau officials to determine if any agreements could be reached to modify existing regulations. The Corps agreed that the method it established in 1956 could be improved After analysis and discussion, the Corps and Bureau compromised and changed the regulations to their mutual satisfaction. The new method gives greater weight to recent rainfall and discounts the effect of historical rainfall as time passes. This change should improve project benefits over those obtainable under the 1956 criteria while complying with the flood control protection determined to be necessary by the Corps.

Corps officials in Washington told us that they recognize that dam operators at non-Corps projects often deviate from Corps approved reservoir regulation plans where such plans have not been kept up-to-date

Corps' Nashville District

The projects of the Cumberland basin in Kentucky and Tennessee which have both flood control and power purposes are operated by the Corps TVA, however, has full authority over the operating methods used in the power pool (the reservoir elevation from the minimum pool level to the flood pool level) without constraint. Once the water reaches the flood control pool level, however, the Corps establishes water releases to be made based on downstream constraints The TVA officials we spoke to expressed concern over the level of flood control space required in the Cumberland basin during the summer. They stated that the Corps requirement which provided the same amount of flood control space in the summer and winter is too conservative. They said that additional power could be generated in the summer if the power pool operating level could be raised.

We asked the Chief, Reservoir Control Center of the Corps' Ohio River Division whether unacceptable flood risks would occur if higher pools were allowed during the summer. He stated that a change increasing the summertime pool level would not cause unacceptable flood risks. He also stated that this alternative was discussed once in the past, but TVA declined to pursue the matter when the Corps stated that they would require TVA to pay for the cost of clearing some trees and scrubs along the reservoir banks.

A TVA official told us in August 1976, that TVA had found that additional power could be produced by increasing summer reservoir levels. He said that TVA would be willing to jointly study with the Corps the benefits and costs of increasing the summertime reservoir levels. He said, however, that TVA would prefer that the Corps propose the study.

CONCLUSIONS

The hydrologic conditions present in each river system determine, to a large extent, the variables that can be considered for flood control operating decisions. It is impractical, therefore, to expect the standardization of flood control operations. But many of the advanced techniques being used for flood control operations in some Corps districts can be applied advantageously to other districts. Improvement costs applicable to such techniques should be compared to the potential advantages, however, since these costs can range from a one time investment in a basin study to substantial, recurring expenses in computer equipment

While we realize that operating methods for reservoirs are based on many factors and that flood protection must be maintained, we believe that the most cost-effective methods should be used to accomplish project purposes. Making accurate flood assessments to determine reservoir levels, and adjusting operations accordingly, can increase project benefits without infringing on flood control protection. We believe that additional benefits to power operations, irrigation, municipal and industrial use, recreation and other project purposes are possible through greater utilization of sophisticated flood operating techniques.

RECOMMENDATIONS

Because of the potential benefits available at Federal multipurpose reservoir projects, and to discourage operators from unilaterally changing Corps established flood control operating criteria which the project operators consider obsolete, we recommend that the Corps·

--Identify the flood control operating method used by each Federal multipurpose project which has flood control as one of its purposes.

--Ascertain the potential for improving the operating methods presently in use at such projects.

--Determine the cost/benefit ratio of making various degrees of improvements where the potential for improvement exists.

--Prepare an action program designed to obtain as quickly as possible those improvements which are identified as having a favorable cost/benefit ratio.

We are sending copies of this report to the Commissioner of Reclamation; the Chairman, Tennessee Valley Authority; and the Chief, U.S. Army Audit Agency.

We appreciate the cooperation received during our review and would like to be informed of any action taken on our recommendations. We would be glad to discuss this report with you or your staff.

Sincerely yours,

Lloyd L. Gregory

Lloyd L. Gregory
Assistant Director