by our department must have final approval of the Director or Assistant Director — regardless of source of origin.

10. All personnel is instructed to answer all questions pertaining to our department and its work that are asked by individuals, groups or publicity media. We ask only that they be sure of their answer, and we suggest that if the question applies to a division other than their own that they direct the question to the proper division, if time will permit.

We require that all materials intended for publication and initiated and written by our personnel be cleared through the main office.

11. We encourage our personnel to join and take an active part in all wild life organizations.

13. We conduct a two-day public hearing each year at which time all suggestions on seasons, bag limits and regulations are heard, tape recorded, and then carefully studied. These hearings are conducted in a centrally located city, before the Commission in public meeting and on Friday and Saturday to permit as large attendance as possible. All department divisions participate.

14. We prepare talks for personnel and Commission members, when there is need to do so. However, we have found that numerous of our personnel have become quite adept "after-dinner" speakers, usually requiring only a few notes and often speaking without notes.

15. We welcome the opportunity to appear before women's organizations — many of whom have in turn become our department's strongest supporters.

There just is no place where this subject can be ended, and there are still many things I would like to tell you.

There are, as you know, other speakers and related topics. If the chairman wishes, I will answer such questions as I can.

In closing just let me say that no program is any better than its public acceptance, and public acceptance comes with selling and performance results.

Our wildlife resources all over America depend upon you and your state departments. If we are to perpetuate these God-given resources, we must continuously keep our study before the public by every possible means.

PLANNING AND DESIGN OF SMALL LAKES FOR FISH AND WILDLIFE MANAGEMENT

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GENERAL:

For the purposes of this discussion, we will define small lakes for fish and wildlife management as lakes with earthfill dams less than 50 feet high. Also the watershed area to lake-surface area ratio would be relatively small when compared with water supply, irrigation and power lakes.

The economic justification for any lake is hard to calculate, but in a lake designed for fish and wildlife, it is even more nebulous.

Generally the need for a fish and wildlife lake in a particular area is based on the judgment of the administrators of the State's fish and wildlife department. Rarely in wildlife programs is a lake project introduced by the engineering section. Thus, when a lake project is presented to the designer, it has already been decided that a need exists. It then becomes the engineer's problem either to find a lake in the area or to build a lake on a site already selected. To place himself in a position to judge the economic feasibility of the project, it is im-

portant for the designer to become familiar with the purpose of the project, its justification, and the funds available.

At this stage, it is important that engineers make a very brief study to determine how extensive an investigation will be necessary, and a rough estimate of the lake's cost. It is quite possible that a costly investigation would be necessary just to prove that the project is not feasible. On the other hand, the cost of the investigation could be a major portion of the cost of the dam, and be economically unjustified.

It is the engineers' job to make the administration aware of the probable investigation and construction costs as early in the life of the project as possible.

In Missouri, we have made the task of guessing at the justification somewhat easier by establishing several arbitrary rules:

1. The construction cost should be less than $1,000.00 per surface acre, excluding land costs. This cost criterion was based only on experience and need, but it seems to be a good rule.
2. The lake surface to watershed area ratio should be between 10 : 1 and 20 : 1. This precludes sedimentation problems and reduces the size of the spillways. The ratio was selected from a fisheries management standpoint—the low ratio lakes tend to be clearer and more fertile.

INVESTIGATION:

Possibly the best way to discuss investigation is to go through the procedures we use in Missouri, or rather, the procedures we would like to use. The steps in an investigation should be in sequence that places the most likely items that would cause trouble first.

The first step in investigating a site, as mentioned before, is to determine the extent of the investigation program.

The program can usually be prepared from map studies and a brief field inspection. It is very helpful to gather all the maps, aerial photos, and other data available before attempting to plan the program.

Some of the necessary data would be U.S.G.S. topo maps, U.S.D.A. aerial photos, original G.L.O. land plats, U.S.D.A. soil maps, and recent land ownership plats.

A tentative dam site and water level can be plotted with fair accuracy on most U.S.G.S. maps.

The next step is to determine the land available and its probable cost. The landowners are then asked for trespass rights to allow our survey crew and drill rig to work on the site.

At this point we arrange for a geologist from the Missouri Geological Survey to accompany our engineer on a field inspection of the site. The geologist prepares an opinion on the nature of the geology of the area and its suitability for lake construction. The soil maps are studied to determine the suitability of the soil for economical lake construction.

If the site seems reasonably suited, then a field survey of the dam site and waterline of the lake is made.

We run a transit traverse line around the lake near the contour chosen in map studies as the waterline. Then stadia shots are used to establish the waterline contour and contour lines four feet above and below the waterline. This method is fast and easy and, if the waterline is changed, the contours can be extrapolated with fair accuracy.

If possible, we try to schedule the drill rig for the soil explorations to be on the site at the same time as the survey crew. Then, if any random borings are necessary, the survey crew can tie them into the traverse.

SOIL INVESTIGATIONS:

The investigation of the dam foundation and borrow material is possibly the hardest phase of the determination of what is adequate and economical.

A lot depends on the supervisor of the drilling operation, for if the drilling is to be done economically, he must decide in the field

what is adequate. We have a rule of thumb that borings should be taken every 100 feet along the dam centerline and to a depth equal to the height of the dam.

Penetration tests and samples are taken in every other boring at all changes in soil strata.

Field identification tests are made on all strata represented by the samples taken. From the boring logs and field identification test, the soil strata are tentatively classified in the United Soil Classification Chart.

From these preliminary soil studies, it can usually be decided if any problem soils are present and if further testing is necessary to prove the feasibility of the dam.

HYDROLOGY AND OTHER:

A detailed field inspection is made to determine the obstructions in the lake site, such as powerlines, gas lines, buildings, roads, etc. Also a field check is made of the water-course below the dam, and the buildings, roads, and land use are noted, along with possible sites for future developments. From this information on downstream conditions, the dam is classified as to the degree of hazard to property and life. The damage that can be expected from the failure of the dam will decide what factors of safety should be used in its design.

A hydrograph for the stream at the dam site is then developed. We use methods that have been developed by the S.C.S. The infiltration rates and time of concentration can be established from soil maps, topo maps and aerial photos. The design storm is selected on the basis of the hazard condition created by the dam. For a low hazard condition, a design storm is chosen that will adequately protect the investment in the dam.

For small lake and earthfill dams in Missouri, it is uneconomical to route the entire design flood through one spillway. We route a 25, 50 or 100-year storm through the principal spillway and construct an emergency grass spillway to take the remainder of the project storm.

A cost estimate is made of the proposed construction from the preliminary designs made in the investigation.

The estimate and a critique on the concept, geology, soils, and hydrology is presented in a feasibility report to the department administration for approval.

When the project is approved and secure arrangements have been made for purchase of the land, work is started on the final design.

The final design retraces the steps taken in the investigation. Laboratory tests are made of the soil samples, if necessary, and the maximum density of borrow material is found.

The dam foundation condition is reconsidered and the design of the embankment slopes is refined. The hydrology is reviewed and checked and the final design made on the spillways.

This discussion has been brief and has only touched on some of the points to be considered in the design of a small lake. However, I see by the program that some of the more important features will be discussed in detail in other papers.

SMALL WATERSHED HYDROLOGY[1]

Introduction

Very little work had been done to develop small watershed hydrology prior to 1936 when the Flood Control Act was passed. This act authorized the Department of Agriculture to develop conservation and flood prevention plans on river basins of the United States. The Washita River in Oklahoma and the Trinity and Middle Colorado Rivers in

[1] Paper prepared by Dean Snider, Hydraulic Engineer, Engineering and Watershed Planning Unit, Soil Conservation Service, Fort Worth, Texas, for presentation at a meeting of the Engineering Section, Game and Inland Fish Commission, Hot Springs, Arkansas, September 30, 1963.