Maintenance of equipment can be the difference between profit and loss for a contractor, and it therefore follows that the quality of maintenance could make a "purchase-and-hire" job cost more than a contract job. Considering overhead, taxes, material, equipment and profit, you should have an advantage of up to 20%.

One other advantage about owning equipment is that it safeguards against abnormally high bids. Sometimes and under certain conditions, the low bid is much too high. Re-advertising doesn't always produce lower bids. Personally, I think it would be a good practice to have the engineering department fix a maximum price, or in other words, bids on jobs which they are able to perform. I know this practice is being used by big corporations within their own organization. For example: The Singer Manufacturing Company, who at one time manufactured 90% of the sewing machines used in the world, has a subsidiary at Truman — in the state, wholly owned by them, called the Poinsett Lumber and Manufacturing Company, and it is the largest woodworking plant in the state. It represents an investment of many millions of dollars, but the plant must bid against anyone on all the parts it produces, and unless it is low, the job goes to the outsider.

All of this adds up to this: State agencies should own and operate enough equipment to perform needed maintenance, phase construction, and let us say — smaller construction jobs for the following reasons:—

1. Work can be performed for less money (a very important one), or put it another way, you can do more work for the same money. We are all limited by the funds available.
2. You will develop an organization that will perform the particular type of work you need "efficiently and without continuous inspection."
3. You will have at your disposal "men and equipment that can be used as you wish in emergency."
4. You will have protection from vagaries of bidding.
5. You may, if you desire, or it is expedient to do it, waive certain provisions of the specifications if it has developed that this may be safely done at an increased savings to the state.

TO DO THIS, YOU MUST AT LEAST, IN MANY RESPECTS, MOVE ACROSS THE TABLE AND THINK LIKE A CONTRACTOR!

THE USE OF AVAILABLE MATERIAL AND ITS INFLUENCE ON EMBANKMENT DESIGN[1]

There are only two good reasons that I know for building any dam. You either want to prevent water from doing something that is undesirable or you want to make water do something that is desirable. Either of these objectives may be accomplished independently, but more often than not in the accomplishment of one we also accomplish the other to some degree, as a special dividend or as a sort of by-product. Most dams are built for both reasons. It is much easier to justify the expense of building a dam if it is to serve two purposes rather than one. It is the same old idea of buy one and get the second one free.

There are all kinds of dams, depending on what kind of yardstick or criteria you use for purposes of classification. There are storage dams, detention dams, and diversion dams depending on, shall we say, the functional use of the storage basin. If we take water use as a criterion we may have power dams, irrigation dams, water supply dams (municipal, industrial, etc.), flood prevention dams, fish and wildlife dams and recreational dams. There is evidently room for much overlapping in these classifications. As has been demonstrated by the Soil Conservation Service's small watershed program, multi-purpose

[1] Presented at the conference of the Southeastern Association of Fish and Game Commissioners at Hot Springs, Arkansas, September 30 - October 2, 1963, by Hal C. Normand, Civil Engineer (Soil Mechanics), Engineering and Watershed Planning Unit, SCS, Fort Worth, Texas.

dams may serve several purposes equally well so long as the purposes are compatible.

We find many different types of the aforementioned classes of dams. The spillway hydraulics may call for a weir type or overflow dam or a non-overflow dam. The materials of construction employed lead us into concrete, masonry, steel, timber, log, rockfill, earth dams, etc., or combinations of some of these materials. Dams typed according to materials are subject to subclassification with respect to design or features of construction such as gravity, arch, haunch, internal or external membrane, zoned, etc. For the time being we are interested in one particular type of dam, the rolled or compacted earth dam. Let us then forget all other classifications, based on utilization or purpose, and concentrate on a compacted earth dam across a stream and valley to impound water to within a few feet of its crest, and equipped with a spillway for the safe disposal of all floodwater in excess of the storage capabilities of the reservoir.

Let us assume that feasibility of the project has been established. The hydrologic analysis has established the height of dam and spillway capacity. A preliminary survey and geologic investigation have revealed that there is sufficient earth material on the site for construction purposes. We are, therefore, in a position to make an estimate of total cubic yards of material required, the amount of required excavation, and the additional amount that will need to be obtained from borrow sources. These estimates will be based on a tentative design and, therefore, are subject to alteration as a final design is developed. Unlike designing a building, where it can be assumed that whatever materials are required can be obtained, the design of an earth dam must begin with an assay of the stockpile of available material, and the design developed accordingly. In other words, the choice of design of an earth dam is dictated by the materials available, rather than the design dictating the choice of materials. It is, therefore, evident that a detailed geologic and soils investigation must precede the final design.

A dam consists of two different but very closely related and interdependent parts, the embankment and the foundation. The site investigation must, therefore, consist of two phases, foundation investigation and embankment materials investigation, and the methods employed should be appropriate to the purpose and objectives of each. Primarily, the purpose of a site investigation is to determine (1) the kinds of material present, (2) the location and relative position of each kind, and (3), the amount of each kind available. Each of these items may have a vital influence on the final design.

The kinds of material are best described by use of an appropriate system of soil classification. In our case the Unified Soil Classification System gives us not only a method of dividing all soils into groups according to texture and/or behavior but also into groups of similar engineering characteristics. This knowledge in itself is a big step toward a choice of design. Under certain circumstances the delineation and classification of the materials into their correct groups may be all that is necessary for a safe and adequate design. In other cases the materials may occur in such a complex and heterogeneous state as to make even the most detailed investigation something less than might be desired.

Over a period of years such agencies as the U. S. Corps of Engineers and the Bureau of Reclamation have accumulated a vast amount of data on the engineering properties of the soil groups. These data are derived from laboratory tests for shear strength, compressibility, permeability, and compaction characteristics or moisture-density relationships. Statistical averages of these property evaluations have been compiled and are readily available in published form.[2]

From these statistical data and from the experience of agencies and private engineers tables and charts showing the relative suitability of different materials for certain specific purposes have been set up. These tables of averages and charts of suitability are valuable guides in the preliminary and trial design stage, but they should be used only

[2] "Design of Small Dams," Bureau of Reclamation, 1960.

when their origin, significance and applicability are well understood and appreciated. The unpredictable variability of all soils and the variation in the values of the different engineering properties within a soil classification group render the use of average values for final design purposes extremely hazardous. The cost of obtaining samples and performing essential tests usually is tivial compared to the total cost of a project, or the cost of repairing a failure and satisfying damage claims.

The engineer's choice with respect to use of the foundation materials is very limited. He may either make use of what is available or, within the limits of certain economic restrictions, he may remove undesirable material and replace it with selected borrow material. The expense of a deep cutoff, particularly below the water table, and grouting to reduce seepage losses is quite often the determining factor in the choice of location for small dams. The importance of thorough foundation investigation and the use of reliable foundation design data for dams of all sizes cannot be overstressed.

Compared to foundation materials the opportunities to improve the engineering capabilities of embankment materials are much greater. It has long been recognized that engineering properties of most soils are susceptible to change under the application of either or all of three things, water, energy and heat. The ancient Egyptians demonstrated this very simply by adding Nile River water to delta soil, molding the resulting mud into bricks and placing them in the sun to dry. But don't let this deflate your technical ego. We make better bricks and build higher dams today than our predecessors did some two thousand years ago, and that's progress. In earth dam construction moisture control and compaction are our chief means of improving the soil capabilities.

Based on the use or placement of materials, earth embankments may be either homogeneous or zoned. It should be understood that the term homogeneous, as used here, will not stand up too well under a barrage of academic criticism but it answers our purpose of describing a condition where the embankment materials are sufficiently similar that any approved material may be placed any place in the embankment without impairing the safety of the dam. When it is specified that certain material must be placed in some designated place in the embankment, the embankment is said to be zoned. In the five-state area of the Fort Worth Engineering and Watershed Planning Unit a third method of placement is employed that we call "selective placement." There are many cases where the nature and position of the borrow materials make homogeneous placement impossible or, at best, impractical. At the same time a rigidly zoned embankment is not essential to the adequacy and safety of the dam. Selective placement provides for placing certain selected materials at designated but loosely defined locations rather than in rigidly defined zones. This method provides considerable flexibility in construction, eliminates the expense of stockpiling and double handling material, and saves considerable time in staking and checking. Considering the goal of adequacy at the lowest practicable cost, rather than the best possible dam irrespective of cost, this method of placement has very definite advantages.

As has been stated previously, the final design of an earth dam is dictated by the materials available for construction. First consideration, therefore, should be given to the materials invoice; the kinds of material that are available, where each different material is located and the quantity of each that will be available. Each kind of material to be used may then be evaluated. For preliminary or tentative design purposes the unified group classification will provide sufficiently reliable data on the general characteristics of the materials such as workability, moisture-density relationship or compaction, shearing strength, compressibility, swell characteristics and permeability, as well as the relative desirability for certain functional uses.[2, 3] For

[3] "Engineering Soil Classification for Residential Developments," Federal Housing Administration, FHA No. 373, Washington, D. C.

purposes of stability analysis of a trial design, statistical average values of maximum dry density and optimum moisture, permeability, compressibility and shear strength may be used.[2] Approximate engineering property values also may be obtained from standard penetration or blow count correlation studies.[4]

Final design of all embankments should be based on the most reliable data available. For very small dams and dams built to minimum slope and top width specification established by organization or agency policy, the use of approximate design data may be permissible provided the minimum factor of safety obtained by stability analysis is sufficiently high to erase all doubt as to the safety of the structure. Final design of higher and more important dams, and dams where the available materials are known or suspected to be weak or unpredictable, and dams where zoning is required for stability should be based only on authentic and reliable test data. In cases where destruction of property or loss of life could result from structure failure the minimum acceptable factor of safety employed in design should be increased in proportion to the hazard involved.

No completed dam is any better than its construction. Regardless of all that goes into a design in the way of money, time, technical knowledge and ability, and past experience, the dam may well be a total failure unless it is constructed as well or better than designed. Therefore, the responsibility for success or failure rests with the contruction engineer, to the extent that the structure was installed to meet requirements used in design, or whoever may be responsible for construction. The translation of design specifications into a physical structure demands particular attention to the following three phases of construction:

1. Each different material used in the embankment should be the same or equivalent to the material considered in the design.
2. Materials should be placed in the embankment at the locations specified.
3. Materials when placed should be:
   a. Compacted in accordance with specified methods and/or procedures, or
   b. Compacted to comply with the allowable limits of dry density or unit dry weight and moisture content as specified.

If reasonable control can be maintained over these three phases of construction, I think we might rest assured that the dam will be as good or better than the design.

[4] "Principals of Soil Mechanics and Applications to Planning and Investigations," Soil Mechanics Laboratory, SCS, Lincoln, Nebraska.