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"Current Drainage Construction on the Columbia Basin Project is Based on Past Experience"

by

G. G. Stamm and H. R. Gray

The paper describes current drainage planning studies, designs, and construction and their evolution in terms of 20 years of experience on the Columbia Basin Project. Hopefully this experience will provide guidance to others concerned with the planning of new irrigation and drainage projects.

The paper will compare what was originally thought needed to what experience has dictated must be investigated and provided. For example, early assumptions regarding cropping patterns have been modified by experience. The paper will cover early concepts of land classification standards, water requirement studies, farm unit layout, and other applicable items as related to present policies of integrated land classification standards and drainage investigations prior to scheduling land areas for development.

The occurrence of difficult drainage problems will be tied to insufficient early drainage studies. The solution to some of these difficult problems will also be covered.
INTRODUCTION

Successful long-term irrigation of any area depends on adequate drainage. Experience has borne this out on the Columbia Basin Project. Over the last 20 years, the authors have witnessed an evolution in investigation, design, and construction methods brought about by the need to provide adequate drainage for Project lands. Hopefully, our experiences as related in this paper will provide guidance to others concerned with planning new projects.

GENERAL

The Columbia Basin Project consists of land located on a semi-arid plateau in northwestern United States. (Figure 1.) The plateau is about 100 miles long and 60 miles wide. Elevations of Project lands range from about 400 feet to 1,800 feet above sea level. Underlying the entire area is a great sequence of basalt lava flows, with individual flows ranging in thickness from a few feet to several hundred feet. The basalt was deformed by folding that produced several large basins separated by east-west trending structural ridges. Partially filling these basins are lacustrine and glacial-fluvial deposits of clay, silt, sand, gravel, and boulders. Erosion of these deposits by glaciation resulted in numerous coulees and depressions below the basin floor. (Figure 2.)

The Project area is divided into two principal parts on the basis of physical characteristics and irrigation system layout. The Desert Plain consists of most of the presently developed land in which surface soils
vary from wind-worked sands to fine sandy loams and silt loams. Sub-
surface materials range from coarse, clean gravel and cobbles to
moderately fine-textured lacustrine deposits overlying basalt. The
Eastern Uplands include most of the undeveloped land. Soils in this
area are developed on medium-textured loessial materials deposited by
the action of the prevailing southwest winds to a general depth of 20
to 50 feet over basalt.

The Project area was settled in the late 19th and early 20th centuries.
Agriculture in the area at this time consisted largely of livestock pro-
duction or grain crops dependent on natural precipitation. By 1910, many
of the original settlers had concluded that irrigation was necessary for
successful agriculture. A private company attempted to pump water from
the Columbia River to nearby lands; however, the venture failed because
of inadequate financing. About this time most of the early settlers
failed and departed. From 1914 to 1939, several studies and proposals
were made in attempts to bring all or a part of the Project into being.
The Project, as we know it today, was authorized in 1943. Construction
of carriage and distribution works began in 1945. First water was de-
livered to two small blocks in the south end of the Project in 1948, and
1950, by pumping from the Columbia and Snake Rivers. Large-scale gravity
delivery was commenced in 1952. Climatic conditions permit landowners
to grow a wide variety of crops. In 1966 alfalfa, wheat, potatoes, sugar
beets, dry and edible beans, irrigated pasture, pea seed, and silage, in
that order, were raised on 82 percent of the lands in production. Present
facilities serve nearly 500,000 acres. Ultimate development of the Project
will provide full water service to about 1-million acres.
In its early years the Bureau of Reclamation's role in irrigation was generally limited to planning, financing, and constructing facilities required to deliver water to the land. Drainage works were expected to be provided by the individual landowners as needs arose. Later the Bureau of Reclamation included construction of backbone project drainage works within the federally planned and financed system leaving what was called "farm drainage" to be provided by the water users, individually or collectively. Because of inability to precisely differentiate between farm and project drainage and responsibility for surface and subsurface drainage problems, application of the policy was difficult and so the policy was further revised to recognize that required subsurface drainage should generally be considered a project responsibility, although farm surface drainage is still generally considered to be a non-Federal responsibility.
In the early days, the Bureau of Reclamation's role in irrigation was generally limited to planning, financing, and constructing the facilities required to deliver water to the land. Drainage works were usually provided by the individual landowner affected as the need arose or, in later years, by the Bureau of Reclamation under supplemental or amendatory repayment arrangements between the United States and the Irrigation District representing the landowners. In planning the Columbia Basin Project a survey of Bureau-constructed projects then in operation disclosed that drainage works costing an average of $4 per acre had been constructed using the latter approach. To allow for cost increases, both historical and anticipated, $8 per acre of the construction repayment obligation provided for in the repayment contracts between the three Columbia Basin Irrigation Districts and the United States was identified and reserved for construction of drainage works as required. It should be stressed that this was not an estimate of the ultimate requirement for drainage expenditures, but was merely the definition of the anticipated limit of United States participation. In addition, the repayment contracts provided that drainage required in excess of the $8 per acre allowance would be financed by the water users through annual assessments adequate to pay the costs.

With the close of World War II Federal officials and the Congress were anxious to see rapid development of the Columbia Basin Project in order to provide returning servicemen an opportunity to settle the land. Under special provisions of the Act of Congress authorizing development of the Project, approximately 150,000 acres of land, both acquired and public
domain, were divided into 1,000 farm units and made available to a like number of the approximately 60,000 who applied.

The development schedule required early completion of the major canal systems in order that lands might be irrigated in each of the three Irrigation Districts concurrently. Further, the schedule provided that water be available for more than 80,000 acres of land in the spring of 1952, only 6 years after construction began.

Irrigable lands scheduled for service from Project facilities were determined from land classification performed during the period 1937 to 1941, utilizing the accepted techniques and procedures of the era. Classification was based on data obtained from holes 5 feet or less in depth. The investigations did not indicate the discontinuities of aquifers or of stratification below 5 feet needed to evaluate drainage requirements. Many of the early drainage problems encountered in the Project reflect land classification on such a superficial basis.

This was a most unusual period in agricultural history in the United States. Following the close of World War II many of the large manufacturers concentrated on the development of new lines of farming equipment which were much more sophisticated and efficient than anything produced prior to that time. At the same time there was a great deal of interest in extending financial assistance for farming operations to young people who had recently been in military service. Thus both private and Federal financing was readily available to those planning to develop new lands on irrigation projects. The influence of these two factors resulted in a rate of development far surpassing any experienced on previous irrigation projects in the United States. Several of the irrigation blocks
were almost completely developed and placed in productive status the first year water was available. In 1967, 96 percent of the farm units on the Project received irrigation water.

Cropping patterns were somewhat different from those forecast from historical studies—view of the repayment burden assumed by the settlers, most found it necessary to begin development with a row-crop program. This unusual emphasis on high water-use crops in the early years of Project development also influenced the contribution to the ground water table. With the intensive rate of development, ground water tables rose many feet each year and it soon became evident that extensive drainage, historically experienced 10 to 20 years after beginning of development, would be required much earlier.

Typical examples of the rapid rate of ground water rise as the result of this intensive irrigation development are portrayed in the hydrographs shown in Figure 3. It may be noticed that the hydrographs follow a sinusoidal curve and that the high portion of the curve corresponds quite closely with the irrigation season. Also, it is apparent that as water tables rose, the rate of drain out became less.

In 1956, small and isolated drainage problems began developing in many areas of the Project. In line with the earlier planning and the limitation in the repayment contracts, these were corrected, where possible in conjunction with the construction of major drainage outlets and multipurpose channels serving both drainage and operating wasteway functions. By 1959, it was evident that this was not an adequate program. Many drainage problems were uncorrected, the $8 per acre drainage limitation in the repayment contracts was exhausted, and financing of
additional drainage construction by the landowners would be an unreasonably burden. Irrigation District and Bureau officials began discussions in 1952 which led to amendatory repayment contracts approved in 1962 providing for drainage costs to be borne by the United States as part of the total cost of Project construction. The landowners' repayment obligation was also increased under these contracts.

**Types of Early Drainage Problems**

Although all tests performed to date indicate that the basalt bedrock underlying the Columbia Basin Project is extremely dense and evidently a drainage barrier, there was one area underlying some of the land first irrigated in 1952 which had been badly broken as the result of folding or faulting. The only information available on this area were the logs of early day drillers of private domestic wells. These drillers had great imagination but their vocabularies tended to lack precision. Unfortunately, however, this was not recognized as significant at the time plans went forward for development of the block. The result has been that gradually over a period of 10 to 15 years we have seen the development of sufficient artesian pressures in this area to require that we not only build a considerable system of spaced buried pipe drains but also that we supplement these drains with deep wells and pumping plants to counteract the effect of an increasing artesian pressure. Present results indicate that we are successfully draining this area, but at a rather high cost. Fortunately, the lands are almost entirely Class 1 and will, therefore, support a rather large investment in drainage works.
Generally, the original land classification classed as irrigable the bottoms of small valleys, if the overburden was at least 5 feet deep. Under intensive irrigation, water tables rose rapidly and the land became too wet to cultivate where the soils were incapable of transmitting the water moving in from the irrigation of higher lands. Investigations disclosed that in many instances drain spacing to correct this situation would be so close as to render the drainage of these lands economically infeasible. Therefore had no choice but to reclassify these lands as Class 6 or nonirrigable.

Another condition which led to the rapid development of drainage problems was the decision made at the time construction of the carriage and distribution system began to provide only minimum amounts of lining in order to avoid over-designed and costly channels. It was intended that a continuing program of observation would be undertaken to identify those reaches of channels which would actually require lining and thereafter embark upon a program of "deferred and supplemental construction" to gradually bring the channels to a satisfactory level of performance. The deferred and supplemental lining program has continued and as time goes on the techniques available for identifying leaky reaches of these channels are improving.

Ponding tests of selected suspect reaches of channels are made at the close of each irrigation season to determine rate of leakage. Temporary earth dikes are placed across the channel, the reach between is filled with water, and frequent observations of the water level are made. From such observations, the rate of loss, expressed as loss in cubic feet per square foot of wetted perimeter per day, is calculated. No specific
maximum rate of loss is used to determine if lining will be provided. Many other factors, such as stability and safety of channel, capability to provide amount of water required, affects of loss on drainage problems, and whether water lost is recovered in other parts of the supply system are evaluated prior to reaching a decision whether to provide lining. We believe that at this time the performance of the system is generally satisfactory although we expect that several more years of such evaluation will be required before all necessary lining of the works in service has been completed.

Another example of the early appearance of wet areas occurred at breaks in slopes and also at breaks in continuity of more permeable layers. Most of the wetlands of this type were found to be economically feasible to drain and drainage work has been performed.

In retrospect, we recognize the need for a sufficient number of deep transverse and longitudinal profiles in connection with the land classification as well as with estimating the drainage requirements. Unfortunately the original land classification work did not provide any data for profiles which might have made possible classing as nonirrigable such areas as those with a thin overburden. At the present time we are spending a great deal of time and effort in obtaining more precise data relating to such unusual situations.

In a number of instances the need for drainage was at least in part related to poor farm management or poor farm system layout. In such cases we attempted to work closely with the landowner and an agricultural technician in whom he had confidence. Generally, the drainage problem could be
reduced by improvements in the farm irrigation systems and practices, including replacing earth ditches with concrete lined, reducing length of surface runs, better control of waste water from fields, and closer attention to timing of irrigations. In general, cooperation of these individual landowners was good; such improvements resulted in the drainage facilities contracted by the Project being more effective.

Current Drainage Problems

Although they removed certain limitations and thereby permitted an accelerated drainage program, consisting almost exclusively of buried pipe systems, the current amendatory repayment contracts, as mentioned earlier, provide that drainage will be financed by the United States. Also they provide that drainage will be limited to that which is determined by the United States to be economically and financially feasible. In order to provide guidelines for evaluating the economic and financial feasibility of proposed drainage construction, a "Task Force" of Bureau technical and administrative officials established the following criteria:

1. Consider each drainage proposal on the basis of the usual techniques for evaluating feasibility of new irrigation projects; that is, the land benefitted must have a benefit-cost ratio in excess of 1:1 (current values per acre for determining benefits are Class 1 - $58.23, Class 2 - $49.48, Class 3 - $32.98, and Class 4 - $19.40). In developed blocks the investment in carriage and distribution systems may be considered as "sunk cost."

2. In cases where drainage is found to be infeasible, land resources of the United States should be made available to the landowner to partially offset his loss.
3. Make a detailed drainage investigation and cost estimate of each new block or area and develop only those with a favorable benefit-cost ratio after making full allowance for all incremental costs, including drainage.

In following these criteria and guidelines each proposal for drainage construction in developed areas is subjected to a careful economic analysis. Total benefits associated with the various land classes are determined and compared with the estimated cost of construction of the system. If a favorable benefit-cost ratio is developed, construction is scheduled at the earliest date possible. Most of these systems are designed to serve fairly large land areas, from several hundred up to 2,000 acres with complete buried pipe spaced drains and are provided at such time as ground water tables have risen near the ground surface. At the present time we are designing works for relief of those lands where the water table is 8 feet or less below the ground surface.

Figure 4 presents general investigation data relating to a large relatively flat body of land in the south portion of the Project. This area is cited as an example because unlike most of the remainder of the developed portion of the Project, the need for drainage did not occur until after the 14th year of irrigation. This particular block is underlain by a very deep lacustrine deposit which, although not a drainage barrier, actually transmits water at a relatively slow rate. The low moisture content of the deep lacustrine deposit permitted a gradual filling of the available storage space to a point where the need for drainage is now critical. Prior to irrigation the water table in this area was at a
depth of about 500 feet below the ground surface. We expect that within the next 5 years more than 80 percent of the irrigable land in this block will require buried pipe drains. Under such circumstances it is desirable to defer construction of such an extensive system of drains until the need arises, particularly if the developing agency is required to pay interest on the investment. Moreover, we have been able to profit from our experience in planning and construction and can do a more efficient and satisfactory job at this time.

Land found to be infeasible to drain presents a serious problem to the landowner. Classifying substantial acreages of developed land as non-irrigable is a major obstacle to obtaining finances for expansion or improvements. In some cases it is possible to manage such land in a way that there is a nominal return to the landowner. In other cases the soil and physical conditions preclude any revenues. We are perfecting plans to make United States-owned land available for purchase by the affected landowner on an acre for acre basis. Although, in most cases, the land available will not be contiguous to present holdings, it will be possible to recover some of the loss through sale of the land to adjoining landowners, or, if the acreage is large, to develop it.

In line with the requirement to develop only those lands meeting the test of economic feasibility, an integrated land classification and drainage investigation is now completed for each block of land proposed for development. Full consideration of drainage factors is reflected in the classification assigned. Soil scientists and drainage engineers work closely together in obtaining and interpreting data fundamental to such investigations. One 5-foot deep hole is drilled and logged for
each 40 acres of land as a minimum. A minimum of one 10-foot deep auger hole is drilled and logged for each 160 acres. Deeper holes are drilled as required to identify stratification with depth and characteristics of the drainage barrier where one exists. Hydraulic conductivity is measured by pump-in tests. Every effort is made to avoid classifying as irrigable land which is impossible or economically infeasible to drain.

Another item of interest might be our observation that the sequence of development of a large irrigation project can have a major influence on the rate of drainage construction, and the amount of money necessary to carry out such a program. For example, during the period 1956 through 1959, our development program called for irrigation service to very large land areas which were relatively shallow to drainage barrier. The inevitable result is that starting at the present time A substantial investment will be required to provide drainage facilities for these relatively shallow lands. It would be desirable to give considerable thought to the projection of total annual fund requirements by blocks, including the cost of drainage works, prior to deciding on a schedule for development.

Present Construction Practices

With the experience gained from construction of some 500 miles of buried pipe drains during the past 8 years we have made many minor changes and some innovations in the drain construction specifications. A few of these will be discussed briefly in the following paragraphs.
Manholes are constructed at abrupt changes in both vertical and horizontal alignments and at the intersection of drain lines. They are also built at intervals of 2,000 feet or less on tangent. Wherever possible they are located on field boundaries. They are constructed to provide access for the purpose of measuring discharge, sampling the water for quality, or, where necessary, for rodding or repairing the lines.

It is inevitable that in some cases, these manholes must be built in the landowner's cultivated fields. We have worked out arrangements with the Irrigation Districts to allow landowners to remove the top 3 feet of the concrete manholes and replace the tops below the ground surface if they have a history of 2 years of trouble-free operation, and we see no reason for any immediate concern in future operation. There has been a considerable change in philosophy toward manholes during the past several years.

It was not so long ago that a quarter-mile spacing for manholes was considered extreme. New rodding and cleaning equipment, however, permits spacing at greater intervals and is believed to be of considerable advantage both to the agency owning and constructing the drainage system, and to the farm operators who must work around the manholes if extended above the ground surface. The manholes have heavy concrete lids, the center portion of which weighs about 85 pounds, and does not seem to offer an attractive nuisance to children who might otherwise seek access to these structures. We have had very little damage to these structures after they have been placed in service. Operation and maintenance personnel inspect the drain systems at least once each year and examine each manhole to determine whether the system appears to be functioning satisfactorily. Observations made from such inspections are recorded on a simple form which is returned to the Drainage Engineers for review in the event that any weakness or malfunction has been observed.
Soils of the Project are generally lacking in cohesion. We therefore, require shielded excavation to protect the filter material in all situations where there is likelihood that, during the preparation of bedding for the pipe, the mud in the bottom of the excavated trench and the filter material might become mixed together. We have had excellent results with the shielded excavation performed on this Project.

Pipe used on the Project meet general specifications established by the Bureau of Reclamation. Spacer lugs are required in all cases where there is likelihood the joints may be too closely abutted during the laying operation. If concrete pipe is used, the cement must be Type 2 modified, or Type 5 sulfate resistant. The cohesionless soils emphasize the need for careful inspection of the ends of the pipe, to assure that joints have not been spalled, and of the placement of backfill after the pipe has been laid in order to prevent damage to the pipe which could allow migration of such soils.

Project specifications also require separated excavation wherever the subsoils are of such a nature that they would not be desirable if deposited on the ground surface. We require that deleterious materials be removed from the construction site as a part of the cleanup following completion of the work. We are most anxious that the landowner retain full use of the buried pipe rights-of-way after construction has been completed. Under the terms of our construction specifications the top 2 feet, or less if directed, of the surface soils are separated and set aside to be replaced on top of the embankment in the trench after the pipe has been laid.
Project specifications for filter envelope material placed to a minimum thickness of 4 inches around all buried pipe drains call for a reasonable minimum of fine material and are so designed that the filter material will prevent movement of the base soils but will not require undue or extremely expensive processing.

We attempt to work out a construction schedule which will minimize interference with agricultural production. Landowners are expected to donate easements for rights-of-way to permit construction, operation, and maintenance of drains. We pay for crops or improvements destroyed within the rights-of-way during the construction operations. Construction schedules spell out the controlling dates for commencement of the work. We have had excellent cooperation from the landowners in this regard.

Consolidation of backfill in pipe trenches is required only at certain structures. Our specifications permit the contractor to puddle the relatively cohesionless soils. We have found that consolidation by this method is generally more satisfactory than by conventional methods of compaction.

**Studies Relating to Completion of the Project**

In line with present Bureau policy, a feasibility study for completion of the Project was completed in 1965 and is now under review. This study includes estimates of drainage requirements. Since there was a limitation on time and personnel available for the conduct of the drainage estimate, it was necessary that certain shortcuts be developed. The estimate was therefore prepared on the following bases:
1. Within the presently developed area costs were projected to all acreage anticipated to require drain construction based upon an average drain spacing of 550 feet on centers. Interceptor and outlet drains were estimated from paper locations at a per mile cost already established for typical works. In establishing the boundaries of the acreage expected to require drainage, use was made of all available drainage investigation, ground water observation well, geological, and other data. Review by technical representatives of higher offices supported our belief that the information at hand made possible the preparation of a relatively accurate estimate of the ultimate drainage requirement. During the period since the estimate was completed, we have found general agreement between our paper projections and our experience in the field.

2. In the Eastern Uplands area we used a typical section approach—after careful review of the surface and subsurface geological conditions, we broke the total land area up into subareas with soil conditions considered to be typical. Within each of these subareas we made a detailed drainage investigation of from one to four cadastral sections (a nominal one square mile each). On the basis of the actual geometric layout of the drainage required within each of the cadastral sections we projected this requirement to establish per acre drainage costs of all of the irrigable acreage within each subarea.

The drainage estimates in the feasibility study identify those areas where additional drainage investigations will be necessary to support development. Also identified are certain areas which will require
unusually close drain spacing as well as areas where subsurface conditions are expected to prove so unfavorable that drains should be built prior to the anticipated rise in the water table. The study also proposed changes in design of major open outlets to serve areas where unstable soils prevail—future design will minimize depth of excavation and gradient, and will require flatter sideslopes.

**Conclusion**

It is anticipated that continued development of the Columbia Basin Project will result in further innovations and improvements in drainage investigation and construction. We are interested in development of new materials or techniques as well as new equipment which will render the work more effective and, if possible, reduce the total time required between initiation of drainage investigations and placing completed drainage works in service.

We believe that considerable progress has been made in identifying and eliminating from development lands which could not, within limits of economic feasibility, be maintained in permanent productive status. At the present time the greatest likelihood of overlooking undesirable areas would occur where the drainage barrier is relatively close to the surface and where the bedrock or barrier contact is much more irregular than the ground surface. We are using Seismic timers and other specialized equipment in an effort to identify unusual situations of this type. We are extremely reluctant to recommend development of any lands where the drainage barrier is shallower than 10 feet. Despite the argument of
many specialists that this limitation is too restrictive. **Our concern**

is with the high cost for drainage facilities to accommodate a shallower
barrier and the difficulty of justifying economic development of such
lands at the present time.

We will continue to investigate new blocks in advance of plans for
irrigation service, and expect that in the future there will be a mini-
mum of **these** cases where lands are developed and drainage is later found
to be infeasible.

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