EVALUATION OF FACTORS AND MODELS PERTINENT TO ESTIMATING NATURAL LOSSES IN WYOMING STREAMS

(Conveyance Losses Due to Reservoir Releases in Natural Streams in Wyoming)

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CHAPTER I

INTRODUCTION

Wyoming is truly the "headwaters of the West" with 96 percent of its land area in four major drainage basins--the Missouri River, the Colorado River, the Great Salt Lake, and the Columbia River. The water produced from these lands due to rainfall and snowmelt flows from Wyoming to the major river systems of the Western United States. These waters help meet the needs of industries in Wyoming, such as the energy and mineral development industry and the recreation and tourism industry. The water is also used by municipalities and by others for agricultural, livestock, and domestic purposes (Brosz and Jacobs, 1980). Proper allocation of the available water resources between all of these users is necessary for their prosperity and, consequently, the prosperity of the State of Wyoming.

In order to meet future needs, it has become necessary for existing and prospective appropriators to acquire additional water rights. However, in many situations, all of the available water has already been appropriated. To meet this increase in demand, various users have purchased existing water rights with hopes of transferring the water to a new point downstream. Conveyance losses must be assigned to this transference of water to insure that all of the available water is properly allocated and that no existing lawful appropriators are injured.

Background

The allocation of the water in the State of Wyoming is the responsibility of the State. The Wyoming constitution declares that the water of all natural streams, springs, lakes or other collections of still water within the boundaries of the State are the property of the State. The constitution also states that the Board of Control, which consists of the State Engineer and the Superintendents of the four water divisions in the State, has the supervision of the waters of the State and their appropriation, distribution and diversion. The constitutional powers granted to the State Engineer and the Board of Control places a great deal of responsibility on them, with their actions and decisions affecting the economic welfare of the State.

The recent growth in the areas of energy development and, to a lesser extent, agriculture and municipalities has increased pressure on the available water resources in the State. In order to satisfy these increased needs, it has become necessary to develop unappropriated water or to transfer water already appropriated for other uses. Energy development companies and municipalities have found it necessary to purchase agricultural water rights and then petition for a change in use, a change in place of use, and a change in the point of diversion of these water rights. Wyoming water law allows these changes to occur provided the Board of Control feels that certain conditions stated in the state statutes are met. The Wyoming state statutes, Section 41-3-104(a) (Wyoming State Engineer's Office, 1982) declare:

> ". . . The change in use, or change in place of use, may be allowed, provided that the quantity of water transferred by the granting of the petition shall not exceed the amount of water historically diverted under the existing use, nor exceed the historic rate of diversion under the existing use, nor increase the historic amount consumptively used under the existing use, nor decrease the historic amount of return flow, nor in any manner injure other existing lawful appropriators. The Board of Control

shall consider all facts it believes to be pertinent to the transfer which may include the following:

(i) The economic loss to the community and the state if the use from which the right is transferred is discontinued;

(ii) The extent to which such economic loss will be offset by the new use;

(iii) Whether other sources of water are available for the new use."

Wyoming is not the only state concerned with the responsible management of its water resources. Growth in other western states has also placed increased demands on their water resources. New and existing water users in these states have also found it necessary to purchase existing water rights and then apply for changes in use, place of use, and point of diversion. Changes of this sort are allowed in several other western states.

Of them all, Colorado has perhaps been the most active in the area of water transportation in natural streams. A large portion of their work has dealt with reservoir water. Colorado water law allows the owner of a reservoir to use a natural stream to convey stored water to the place of use, provided that allowance is made for losses that occur while the water is in the natural stream. The Colorado State Engineer has the responsibility of determining these losses (Radosevich and Hamburg, 1971).

Transfers in the place of use of a water appropriation in Nebraska were not permitted until new legislation was passed and became effective on August 26, 1983. Before this time, Nebraska state law did allow the use of natural streams for the transportation of stored water to the point of use. The law required that due allowances be made for losses in transit to insure that no injury occurred to other appropriators and that these losses be determined by the Nebraska Department of Water Resources (Bishop, 1983).

States such as Texas, Arizona, Idaho, and New Mexico have had little experience with water rights transfer cases and associated conveyance losses, even though transfers are allowed. For instance, Texas has no legal provisions which require an estimate of conveyance losses to a waterway when a change in point of diversion is desired. However, the Texas Water Commission is charged with ensuring that water is put to a beneficial use and that existing senior or vested water rights are not impaired (Nemir, 1983). There are cases in Arizona where a natural stream is used to convey reservoir water; however, no losses have been assigned (Steiner, 1983).

Purpose and Objectives

Wyoming state law allows a change in use, a change in place of use and a change in the point of diversion of existing water rights. These changes must be petitioned for, and it is the responsibility of the State Engineer and the Board of Control to review and then approve or disapprove these petitions which propose to use natural streams for the transportation of water. Prior to the approval of a petition of this sort, the Board of Control is required by law to insure that no other lawful appropriators would be injured if the petition were accepted. If this condition cannot be met, the transference of the water cannot be accepted.

In order to protect other appropriators when water is transferred to a point downstream, conveyance losses need to be assigned to the transported water. However, there is a scarce amount of technical data available to aid the Board of Control in determining values of conveyance losses that would be equitable to all parties concerned. Many decisions in the past have been based on the best estimates of the people managing the stream in question. This is not unrealistic, but better quantification of conveyance losses through analysis of the water budget would be desirable.

To improve the quantification of instream losses of water being transferred within natural stream systems, information is required on the actual physical processes causing water losses. The initial objectives of this research paper were to specify the various factors/parameters affecting instream losses and to describe methods for their evaluation. Specific objectives included:

1. Identify all factors or parameters which may contribute to the loss/gain of water in a stream system.
2. An estimate of the magnitude each factor or parameter has on the amount of water loss within the stream system.
3. An examination and critical analysis of existing instream loss model/models as to their applicability to Wyoming water transfer problems.
4. A listing of physical models that may be used to quantify various instream water losses and the ability and utility of measurement techniques to help in this quantification.
5. An evaluation of the available information that can be used to estimate instream losses, and an evaluation of the technical information and methods or models that could be developed to allow reasonable estimates of all instream losses.

The review of individual factors affecting instream flows required an interdisciplinary approach. Thus, a working team was put together from the various disciplines needed to evaluate instream losses. Members of the team compiled pertinent information concerning the factors that affect losses and the available techniques for their quantification. After examining this information, it became apparent that there exists a multitude of factors that are important in the determination of conveyance losses, making it difficult to identify them all. Estimating the influence each factor has on the amount of water loss would not be any less arduous.

There exist techniques for measuring all of the factors and their effect on losses, but the accuracy with which this could be achieved is questionable. For this reason, it was decided that it would be difficult to use a system model as an evaluation tool because the parameters required in the model cannot be measured accurately enough in the field to evaluate small increases in flow and the associated losses. Any error in the measurement of the factors necessary for the development of a model could conceal the changes to the system as caused by a small increase. Nonetheless, a portion of these factors have been discussed throughout the paper.

Due to the problems involved in the development of a system model, another approach was taken using a water budget methodology with the sources of loss reduced to five major components. However, there is also error involved in the measurement of these components. To minimize the influence of these errors, it was necessary to determine losses associated with sufficiently large increases in flow. The additional objectives that were established for this approach are as follows.

1. Identify the components of the water budget that are important for the determination of stream losses.
2. Examine existing methods for determining incremental losses in streams.
3. Develop a methodology for determining losses associated with an incremental increase of flow in natural streams.
4. Determine losses associated with an incremental increase of flow in some streams in Wyoming using this methodology.
5. Discuss the magnitude of influence each major component of loss has on the amount of the water loss with an incremental increase of flow.
6. Compare measured losses to the results of past studies and to past water transfer cases.

During the course of this study, several western states were contacted for the purpose of acquiring information concerning their approaches to conveyance losses. An extensive search for relevant literature was also conducted. Information gained as a result of these contacts and searches is discussed in both Chapter I and Chapter II. Copies of the correspondence received from other state agencies and engineering firms are included in Appendix B.

Following the accumulation of pertinent information, data was collected on a few streams in Wyoming for the purpose of determining conveyance losses. A discussion of the methodology used for data collection and analysis is located in Chapter III. The data was then analyzed, and a discussion of the results of this analysis is located in Chapter IV. Conclusions and recommendations for future work are contained in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

A summary of the literature pertaining to this study is contained in this chapter. Topics to be discussed include: (1) Factors Affecting Conveyance Losses; (2) Review of Past Studies; and (3) Past Water Transfer Cases in Wyoming.

Factors Affecting Conveyance Losses

When discussing conveyance losses in a stream, it is first necessary to define the term "losses." There are losses associated with the total flow in the stream that will exist year round. There are also losses associated with an incremental increase in the natural flow that will only exist when the increase exists. This increase may be the result of a reservoir release or of a change in the point of diversion of an existing water right. In a case involving an incremental increase in flow due to a water transfer or reservoir release, the problem arises as to which "losses" the water user should be responsible. There are those who feel that a percentage of the total losses should be assigned to the increase, and others who feel that the incremental losses caused by the increase should be used. The amount of the increase in relation to the natural flow will partly determine which loss is the greatest. The incremental loss approach was taken in this paper due to the difficulties involved in determining total losses.

Nonetheless, incremental losses and total losses are affected by similar factors existing in the environment. In a report by Wright

Water Engineers (1970), a number of factors affecting conveyance losses were given. A portion of this list is as follows:

Length of reach

Natural flow in river

Size of increase in flow

Precipitation

Elevation and slope of water table

Stream channel characteristics

Silt layer characteristics

In addition to this list, there are a multitude of other factors that also influence conveyance losses. Some additional factors are as follows:

Evaporation

Evapotranspiration

Hydraulic characteristics of the aquifer

Irrigation return flows

Surface flows

Diversions

Valley cross sections

The large number of factors affecting conveyance losses complicates the determination of the losses. In 1938, M.C. Hinderlider, Colorado State Engineer, presented a paper entitled "Determination of Losses Properly Chargeable to Flows of Water Released from Storage Reservoirs and Transmountain Diversions" where he discussed the difficulties involved in determining conveyance losses. Hinderlider's paper is quoted by Wright Water Engineers (1970) as stating:

> "These factors alone, through hundreds of different combinations and changes daily imposed by the elements of nature, may produce a million different results having a direct bearing on this complicated problem. . . . All of these factors are seriously affected from time to time by periodic changes in the hydrologic cycle, and in the normalcy of the rate and amount of precipitation, which have profound effects upon the underground water table of a drainage basin, and the rate and amount of return flow tributary to any natural water course."

Hinderlider's comments summarize the difficulties involved in determining conveyance losses. In order to simplify the quantification of losses, the water budget method is most often used. The water budget is a basic accounting of all components of flow into and out of a particular system, with the influence of a majority of the factors, as listed on the previous page, included in the components.

The loss components that Colorado's administrators and engineers have used in determining the incremental conveyance losses that are chargeable to reservoir releases are: evapotranspiration, inadvertent diversions, channel storage, and bank storage. In addition to these components, this paper examines losses due to a decrease in groundwater inflow. These five components, to a large degree, include the effects of the factors listed above and account for a majority of the incremental losses in a perennial stream. A discussion of these components and the available methods for their quantification follows.

Evapotranspiration

Evapotranspiration is the process by which water is evaporated from wet surfaces or transpired by plants (Veihmeyer, 1964). Evapotranspiration can be broken into two categories: water surface evaporation and vegetative evapotranspiration.

Evaporation takes place both from free water surfaces and from soil surfaces. The determination of evaporation is generally based on the following methods: water budget, energy budget, mass transfer, and evaporation pans. Most applications of these methods have pertained to still water bodies. Little is known about the effects of moving water on evaporation.

Of these four methods, the evaporation pan is generally the cheapest and most accepted means of measuring evaporation. The application of the other methods is difficult due to the lack of sufficient data.

Many evaporation maps have been developed based upon pan data and may be useful in determining evaporation losses. Lewis (1978) developed average evaporation maps for Wyoming using the available meteorological and evaporation pan data from 26 weather stations in Wyoming and the surrounding states. It is felt that these maps could be used to estimate average incremental evaporation losses.

The incremental losses occur since an increase in stream flow will increase the surface area of the water, resulting in an increase of the total evaporation loss. However, the amount that the surface area increases may be negligible depending on the study area's characteristics and the amount of the increase in flow. It is even possible for the "total" evaporation loss to be minimal. For instance, the total evaporation loss in a stream reach 50 feet wide by 10 miles long would be only 0.7 c.f.s. based upon an average evaporation for the month of July of 8.00 inches. If the stream is flowing 200 c.f.s., this would be a total loss of 0.04% per river mile. Any incremental loss would possibly be much less than the 0.7

c.f.s., depending upon the amount of the increase and the channel geometry.

Evapotranspiration (ET) is the process by which water moves from the soil to the atmosphere. It consists of transpiration, the movement of water through the plant to the atmosphere, and evaporation, the movement of water vapor from soil and vegetative surfaces (Veihmeyer, 1964). ET losses can be attributed to irrigated crops and other herbaceous vegetation, and woody phreatophytes. Many approaches have been used to determine these losses.

There have been a number of models developed for estimating ET from crop areas given climatic and crop parameters (Jensen, 1980). They range from methods such as Penman (1948), where the equations are derived from a combination of the energy balance and mass transport or aerodynamic terms, to the Blaney-Criddle (1950) method that assumes ET is proportional to the product of the day length percentage and mean air temperature.

After evaluating several methods for estimating ET, Jensen (1974) concluded that no single existing method using meteorological data is universally adequate under all climatic regions, especially for tropical areas and for high elevations (which exist at most Wyoming locations), without some local or regional calibration. Of all of the existing methods, the calibrated Blaney-Criddle method is as accurate as any for determining ET from crops (Burman, et al, 1975). It should be noted that the climatic parameters needed for the Blaney-Criddle method are available.

In addition to crops, phreatophytes (plants with roots tapping the groundwater) are known to account for a significant portion of the losses in a stream system. However, most of the commonly used methods for measuring water use of plants have severe drawbacks when considering phreatophytes. Lysimeters, which are usually considered the most straightforward and reliable method of measuring water use, are not readily adapted to measurements of phreatophyte water use.

The Penman (Hughes, 1972) and Blaney-Criddle (Rantz, 1968) methods have been utilized for estimating ET of phreatophytes. Van Klaveran, et al (1975) employed the Blaney-Criddle approach to estimate phreatophyte ET in the North Platte Basin of Wyoming. Although no estimate of accuracy was mentioned, annual ET values for cottonwood and willow-dominated riparian communities were calculated to have a range from 2.20 to 3.08 feet (0.67 to 0.94 meters) for low to high density vegetation, respectively.

Another approach that has been taken for estimating ET is known as the transpiration-well method (Jaworski, 1968; Bowie and Kam, 1968). It involves the monitoring of daily fluctuations in the water table and the specific yield of the soil. Aerial photographs and infrared imagery have also been used to provide a general estimate of ET (Culler, 1971; Jones, 1973).

Transpiration, by itself, is most accurately quantified through porometry and gas exchange techniques. These involve the placement of one to several leaves in a chamber with water loss determined electronically and being dependent on stomatal behavior and environmental conditions. Porometry and gas exchange techniques are accurate and relatively inexpensive; however, to quantify transpiration for an entire community of wood phreatophytes, one must extrapolate from the measurements of individual leaves. A large amount of error is possible in the extrapolation process. No investigations using these techniques have been found for phreatophytes native to Wyoming.

Any of the approaches discussed above could be used, separately or in combination with others, to determine total losses due to ET. However, the main concern is with the increase in the total ET that is associated with an increase in the river stage and groundwater levels. It is generally accepted that ET increases as the depth to the groundwater table decreases; but since this process is extremely complex and few empirical relations exist that relate water use for a particular plant species to depth of water, quantification of incremental ET losses is difficult (Anderson, 1976). Even still, Anderson developed estimated relationships between the depth to the groundwater and the annual water use by different types of vegetation in the southwest (Figure 1).

With small increases in streamflow of short durations, the incremental ET losses will, in all likelihood, be negligible. In studies of losses due to reservoir releases in the Arkansas River in Colorado, Livingston (1973, 1978) and Luckey and Livingston (1975) assumed the incremental transpiration losses were of the same magnitude as the incremental water surface evaporation losses and could, therefore, be neglected. It should be noted that long durations of streamflow increases may encourage additional vegetative types to grow in the area, as well as increase the density of the existing species. In this case, incremental ET losses may increase through the years.

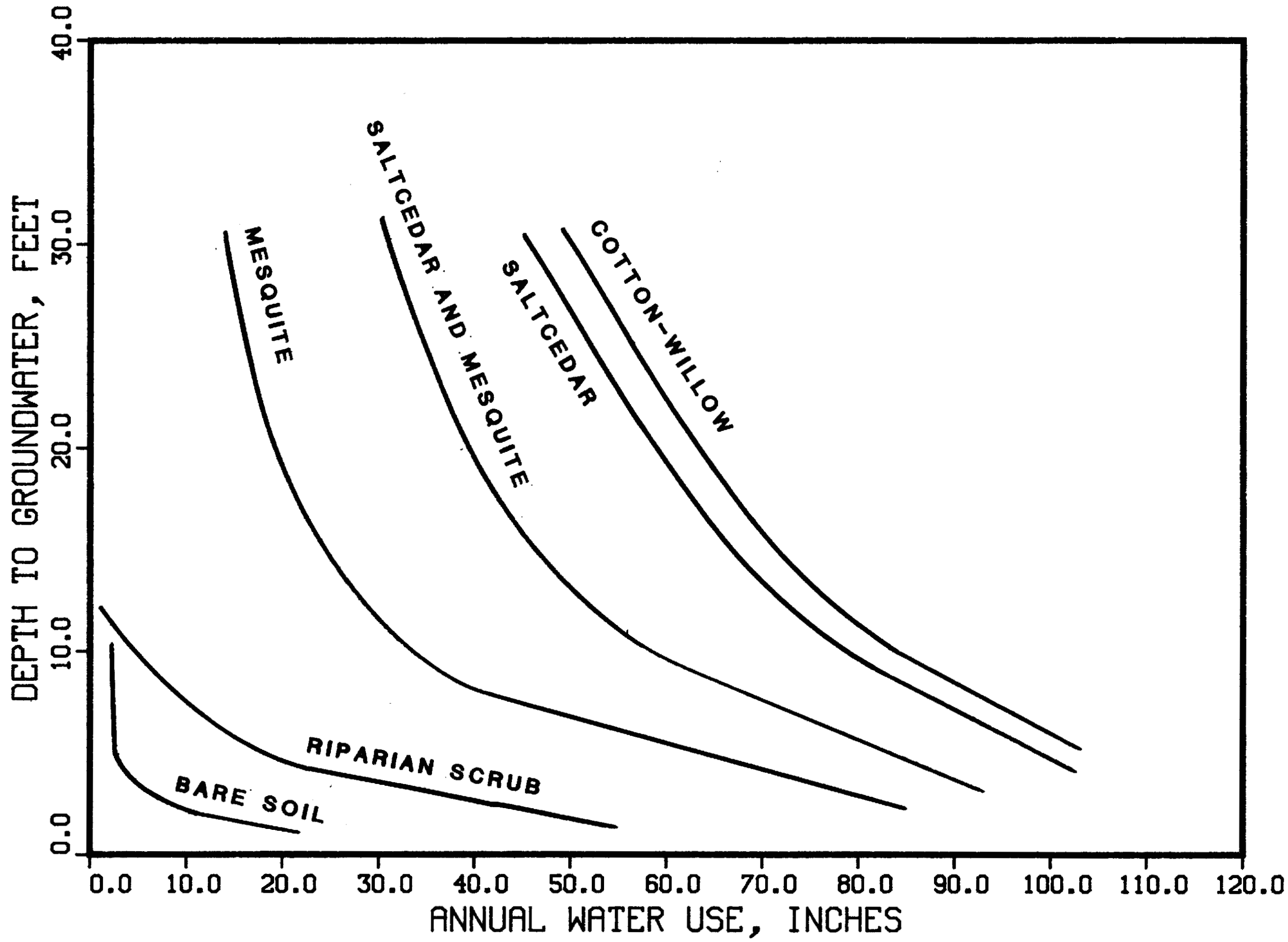

Figure 1. Estimated Relation between Depth to Groundwater and Annual Water Use by Different Types of Vegetation

Inadvertent Diversions

During a rise in the stage of a river, the head of water on diversion structures along the river will increase, forcing more water into the ditches. This additional water which is diverted is termed inadvertent diversions. This water may or may not be lost to the river. Some of the water may re-enter the river in the form of increased surface or subsurface return flows. However, the time it takes for this water to return to the river depends on the characteristics of the river basin and the alluvium. Losses due to inadvertent diversions can easily be estimated based upon measurements in the field (Livingston, 1973) or calculations using discharge equations for submerged orifices (Wright Water Engineers, 1982).

Inadvertent diversions are the result of head gates not being adjusted during the increase of flow in the river. Once the gates can be adjusted to the legal diversion rates, there ceases to be any water lost due to inadvertent diversion. This is not the case on a portion of the Arkansas River in Colorado. Ditches upstream from Salida, Colorado, are especially subject to inadvertent diversions. As a result of the unsophisticated nature of the diversion structures on this reach of the Arkansas River, many of the ditches are unable to divert their legal water right when the river is low. When the stage of the river rises due to a reservoir release, additional water is diverted into the ditches. However, the total amount of the diversions, including the increase, is usually less than the ditches' legal rights, so no attempt is made to adjust the headgates (Livingston, 1973). In this situation, inadvertent diversion losses can possibly continue throughout the duration of the release.

Channel Storage

As the discharge in a section of stream increases, the channel itself acts as a reservoir that must first be filled with water. This phenomenon is called channel storage (Luckey and Livingston, 1975). Wright Water Engineers (1982) used two different techniques for calculating channel storage losses due to reservoir releases in the Colorado River in western Colorado. The first technique consisted of multiplying the anticipated stage increase by the average water surface area in the study reach to determine the volume of water stored in the channel. The second technique utilized the Muskingum method for routing the reservoir releases through the system.

As the discharge in the section decreases, the channel quickly releases the water that was temporarily stored, resulting in little or no measurable losses. Even though no water is usually lost to the stream system, the shape of an upstream hydrograph will be modified by the storage characteristics of the channel. The extent to which the hydrograph is modified is dependent upon the storage characteristics of the channel and the length of the channel.

Bank Storage

During a rise in the stage of a river, groundwater levels may be temporarily raised near the channel by inflow from the river. This inflow of water, and its detention, is known as bank storage (Wright Water Engineers, 1970). The magnitude of bank storage is dependent on the magnitude of the increase in stage, the degree to which the alluvium and the river are hydraulically connected, and the hydraulic characteristics of the alluvium.

Bank storage losses can be estimated using the water budget method given the proper conditions. Losses to the stream banks can also be estimated with the application of theoretical groundwater flow equations. Livingston (1973) developed relationships useful in calculating bank storage for different magnitudes of releases and antecedent streamflow conditions by using well data in conjunction with equations given by Ferris, et al. (1962). This approach requires knowledge of the groundwater levels and the hydraulic characteristics (storage coefficient and transmissivity) of the surrounding alluvium.

The initial rate at which water enters bank storage is high, but rapidly decreases with time (Livingston, 1973). Given sufficient time, the flow of water into the banks may totally cease depending upon the conditions that exist in the alluvium prior to the increase in stage. Once the stage of the river decreases, the water in bank storage re-enters the stream, however, not necessarily at the same rate that it left.

Given sufficient time, most of the water stored in the banks could drain from the alluvium under the proper conditions, resulting in minimal bank storage losses. However, this water's contribution to the stream may become very small with time, making it difficult for this water to be accounted for by the hydrographer.

The amount of water that does not return to the stream is influenced by the antecedent moisture conditions of the alluvial material, the geologic conditions surrounding the basin, evapotranspiration activities, etc. In the case of evapotranspiration losses, water is removed from the alluvium by the vegetation during and following the release. As the duration of the reservoir release increases, so does the volume of water lost through evapotranspiration.

Reduction in Groundwater Inflow

Under effluent conditions, subsurface water is contributing to a stream's total flow. For this to occur, the groundwater surface must slope towards the stream. During a rise in the stage of the stream, the increase in head forces water into bank storage and temporarily prevents any groundwater from entering the stream. If the increase in stage is maintained, the groundwater table will gradually rise and reach a gradient similar to that which existed prior to the increase. The resulting gradient may be slightly less than the pre-release gradient, but the area through which the water flows will increase. Once the water table has stabilized, it is possible for the losses due to a reduction in the groundwater inflow to be negligible. As with bank storage, losses due to a reduction in groundwater inflow can be estimated with the water budget method or the more theoretical method, as discussed by Livingston (1973).

The water that is considered to be lost is merely detained in the surrounding alluvium. Once the stage decreases, the detained water will enter the stream in the form of increased gains to the system. This increase in the groundwater inflow is the result of the increased gradient between the groundwater table and the river's stage that exists after the recession of the reservoir release. However, the detained water's contribution to the stream may become very small with time, making it difficult to be accounted for by the hydrographer.

Review of Past Studies

The determination of conveyance losses is a complex problem requiring an understanding of all the factors forming the hydrologic cycle. Changes in any one of these factors can influence the amount of the losses. A large amount of work has been performed in an attempt to define the extent to which some of these factors influence the hydrologic cycle and concurrently influence streamflow.

One area of research has pertained to stream-aquifer interaction and its effects upon groundwater levels and streamflow. Pinder and Sauer (1971) and Zitta and Wiggert (1971) developed computer models to predict the effects of bank storage on a hypothetical flood wave. A stream-aquifer model was developed for the purpose of routing reservoir releases in the North Canadian River in central Oklahoma. Hydrographs calculated from this model were in good agreement with the measured hydrographs (Moench, et al., 1974). The modeling method used by Cunningham (1977) on the Truckee River in Nevada predicted streamflows and groundwater depths in the adjacent alluvium during natural fluctuations in the river. His results agreed well with the observed values. There exist several other computer models, but only a few deal specifically with conveyance losses.

The State of Colorado has been responsible for a large amount of work done in the area of conveyance losses as a result of an increase in the number of water development projects in the state. Conveyance losses have been determined based upon the experiences of the administrators, any available studies, models, or seepage measurements (Danielson, 1983). However, in the case where small amounts of water have been introduced into the South Platte River, the State of

Colorado recognized that the small flows did add water to the stream system, but did not appreciably change the river regime. Therefore, no loss charges were assigned to these small quantities (Trelease, 1983).

A large portion of Colorado's studies have been on the Arkansas River. Concern over conveyance losses started with the completion of the Twin Lakes transmountain diversion project in the 1930's. The purpose of the project was to convey water from the western slope of Colorado, through tunnels, into several reservoirs on the eastern slope. Later, the water was to be released into the Arkansas River. Shortly after the completion of the Twin Lakes project, several studies were made by Colorado State Engineer M. C. Hinderlider to determine transportation losses of reservoir releases down the Arkansas River. As a result of these studies, a policy was adapted charging releases a loss of 0.07 percent per mile of river from Twin Lakes Reservoir to the Colorado Canal headgate, a distance of approximately 175 miles. This charge had not been changed from that time until 1970 (Wright Water Engineers, 1970). With the advent of the Fryingpan-Arkansas project, which would also use the Arkansas River to transport water, it became desirous to further study conveyance losses.

In 1970, Wright Water Engineers (1970) continued the study of conveyance losses in the Arkansas River from Twin Lakes Reservoir to the Colorado Canal. In their study, thirty reservoir releases made from 1966 to 1970 were studied. The problem of whether to assign total losses or incremental losses to the releases was addressed in this study. The paper stated that it was the writer's opinion that incremental losses be examined rather than a percentage of the total losses. However, the final determination of this might very well be the subject of a high level administrative decision and/or litigation.

In an attempt to determine the incremental losses due to the releases, Wright Water Engineers divided the losses into three components: evaporation, inadvertent diversions, and bank storage. Evaporation losses were determined by using pan evaporation data and applying this to the incremental increase in surface area during the releases. The study ignored the increase in transpiration losses related to the increase in water levels, simply stating that no data exists to quantify this loss. All losses due to inadvertent diversions were assigned to the releases, whereas only a portion of water flowing into bank storage was considered to be a loss since some of this water will come out of the banks during the recession side of the releases in time to be diverted by the Colorado Canal. The sum of these three components gave the total incremental losses chargeable to the releases. No average losses or range of losses were given, but the report did state that the results were somewhat lower than the 0.07 percent per mile determined by Hinderlider.

After the completion of the Wright Water Engineers' study, Livingston (1973) performed a more extensive study of losses on the same 175 mile reach of the Arkansas River. Of this reach, approximtely 90 miles of the river traverses through alluvial deposits, with the remaining 85 miles consisting mainly of hardrock canyons. Livingston also divided the chargeable incremental losses into losses due to evaporation, inadvertent diversions, bank storage and channel storage. Evaporation and inadvertent losses were determined from evaporation data and diversion records. Increased transpiration losses were assumed to be of the same magnitude as the evaporation losses and were neglected.

One area where Livingston's study differed from Wright Water Engineers' was in the study of bank storage. He took two approaches to this problem. The first approach was to study the streamflow records of the gaging stations along the river. Streamflow gains and losses before and during reservoir releases were compared in order to estimate the amount of flow into bank storage. He concluded that large errors are possible with this method due to the sensitivity of the stage-discharge relationships at the gaging stations, and any errors are accumulated through the reach. For this reason, another method was used.

The second approach involved the installation of a series of wells in the alluvium along the Arkansas River. Head changes in the observation wells during reservoir releases were monitored. The well data was then used in conjunction with equations given by Ferris, Knowles, Brown, and Stallman (1962) to develop relationships useful in calculating bank storage for different magnitudes of releases and antecedent streamflow conditions. Of the water that went into bank storage, Livingston determined that 30 percent was found to return to the river soon enough to be divertible by the Colorado Canal. The other 70 percent was considered to be a loss.

The losses due to the three loss components were combined and resulted in an average chargeable conveyance loss of 16 percent (0.09 percent per mile) or 8 percent due to inadvertent diversions, 7 percent due to bank storage, and 1 percent due to evaporation. The average loss was determined based upon a typical release of 450 c.f.s. for a period of 12 days, with an antecedent flow in the river of approximately 450 c.f.s. Channel storage did not result in any loss, but its effects upon downstream hydrographs were included in the analysis. A series of tables and charts were developed to enable one to calculate anticipated losses under a variety of hydrologic conditions. Livingston reported an expected range of incremental losses of 6 percent (0.03 percent per mile) to 28 percent (0.16 percent per mile) due to antecedent river conditions, the amount and duration of the reservoir release, and the time of the year.

In 1975, Luckey and Livingston (1975) developed a computer model for routing reservoir releases from Twin Lakes Reservoir to the Colorado Canal. They found that during periods when conditions on the river were relatively stable (i.e., constant gains before and during the release), the model accurately predicted downstream hydrographs at the Colorado Canal. With the aid of these flow hydrographs, administrators could determine the amounts divertible by the canal. The incremental conveyance losses calculated by the model were similar to those reported by Livingston in 1973.

Three years later, Livingston (1978) modified the previous model to route releases from Pueblo Reservoir to John Martin Reservoir. In this reach, the Arkansas River traverses a distance of 142 miles, 85 miles of which was considered to be surrounded by alluvial material. For a 10-day release of 100 cubic feet per second, Livingston reported incremental losses that ranged from an average of 0.35 percent per mile during very low antecedent streamflow conditions (e.g., 10 c.f.s.), to an average of 0.05 percent per mile during very high antecedent streamflow conditions (e.g., 4000 c.f.s.). Releases of less than 10 days were found to double the transit loss, while longer releases could decrease the loss by as much as 25 percent.

Eighty percent of the total incremental losses reported by Livingston were attributed to bank storage, 10 percent to channel storage, and 10 percent to evaporation. Inadvertent diversions were not a source of loss due to the type of diversion structures in the reach. Livingston argues that the evaporation loss is the only true loss to the system; therefore, conveyance losses to a downstream on-channel reservoir, which has the capability of collecting virtually all water in bank and channel storage in the recession of a release from an upstream reservoir, should be only those losses from evaporation, transpiration, and groundwater withdrawal.

The most recent study performed in Colorado was completed in 1982 by Wright Water Engineers (1982). They analyzed conveyance losses of reservoir releases from Ruedi Reservoir to Battlement Mesa and the Colony Shale Oil Project on the western slope. The proposed reservoir releases were to be transported approximately 80 miles in the Fryingpan, Roaring Fork, and Colorado Rivers to the point of diversion. Incremental losses were based on the hydraulic calculations of bank storage, channel storage, inadvertent diversions and evapotranspiration. The calculations were based upon equations which related these four loss components to the change in river stage that could be expected during a reservoir release. Such a procedure was necessary because field measurements of river stages and rating curves for the Fryingpan, Roaring Fork, and Colorado Rivers were not sufficiently accurate to estimate losses associated with releases of the size expected. Wright Water Engineers stated that "flow measurements on rivers such as Fryingpan and Roaring Fork Rivers are generally accurate to within ±5 percent, an unacceptably large range of error, considering that theoretical estimates of transit loss components are frequently less than this margin of error."

Results of the study indicated that the average conveyance losses for a maximum release of 24 c.f.s. would be expected to vary from 0.12 percent per mile for a release of 14 days to 0.02 percent per mile for a 4 month release, with the average antecedent flows ranging from approximately 100 c.f.s. in the Fryingpan River to 1800 c.f.s. in the Colorado River. During a dry year, such a 1977, with low antecedent flows, losses ranging from 0.03 to 0.18 percent were calculated.

Conveyance loss studies for streams in Wyoming are not nearly as numerous as those performed on Colorado streams. One of the first Wyoming studies computed total river carriage losses in the North Platte River from Alcova to the Wyoming-Nebraska state line, a distance in excess of 200 miles. This study was prompted by the legal action regarding North Platte River water that was taken by Nebraska against Colorado and Wyoming in the 1930's. In the 1945 Decree handed down by the U.S. Supreme Court, river carriage losses were assigned to the transportation of water in the North Platte River. These losses were computed based upon the surface area of the river and the average monthly evaporation at Pathfinder Reservoir as measured from 1921 to 1939 (Wyoming State Engineer's Office, 1982). The result of the decree was the assignment of a set loss that varied from month to month, with no regard to the actual flow in the river. These loss values are still used in the management of the North Platte River.

Another Wyoming study was performed by Wright Water Engineers for the Casper Board of Public Utilities (1980). Casper PBU was considering the purchase of the Daly Dam and Reservoir for the purpose of developing exchange water. Wright Water Engineers studied the losses in Middle Casper Creek for a distance of 2.2 miles. Middle Casper Creek downstream of the Daly Dam is an intermittent stream for several miles. At a point approximately 2.2 miles downstream, Middle Casper Creek was found to be flowing due to inflows from surface and groundwater. It was assumed that a majority of the losses would occur from the dam to the location of the live streamflow. Prior to the field tests, there was no flow in Middle Casper Creek, but the channel bed was wet with cattails and rushes growing along the channel.

To determine losses in the study reach, a flow of 7 to 9 c.f.s. was pumped from the reservoir for a period of 4 days. A loss of 16.5 percent per mile was measured the first 2 days of the test, and a loss of 11.5 percent per mile for the last 2 days. These losses are high compared to those measured in Colorado.

This difference in losses could be attributed to the dry conditions that existed on Middle Casper Creek at the time, and the water table in the area was probably some distance below the creek bed. With this situation, a large amount of water would be required to saturate the surrounding alluvium before losses could be minimized. The conditions on this creek are similar to those of ephemeral streams or canals, which generally have greater water losses than natural streams in irrigated valleys.

Losses of water released from Shell Reservoir and Adelaide Lake into Shell Creek have also been a point of interest to the water administrators in Wyoming. It has been recognized for some time that a large amount of water in Shell Creek is lost in the lower portion of Shell Canyon where the creek passes through the Madison Formation. From 1977 to 1979, the Soil Conservation Service monitored a short stretch of Shell Creek (approximately 5 miles) which included the Madison Formation contact area. Total losses ranged from 18 cubic feet per sec. (c.f.s.) when the streamflow was 45 c.f.s., to 26 c.f.s. when the streamflow was 118 c.f.s. (Gilbert, 1984). Considering the length of the reach studied, the losses measured are rather high; however, it must be kept in mind that this was a very site specific study.

The State of Arizona has also attempted to quantify water losses in streams. Anderson (1976) studied the possible increase in water losses that may occur as a result of an increase in the availability of water at the upstream end of selected streams in Central Arizona. The calculated losses were attributed largely to transpiration by vegetation in the riparian zone and to evaporation from soil and open water surfaces along the stream channels. Anderson calculated present day losses and future losses due to a predicted increase in the streamflow, and the results showed little difference between the two situations. In cases where a difference was found, Anderson expressed a lack of confidence in these values since the relationship between water depth and the amount of water consumed by vegetation is poorly defined.

Other work that has been performed in Arizona has dealt mainly with losses in ephemeral streams. Lane (1983) developed a procedure for estimating the volume of runoff and peak discharges in ephemeral streams. The method incorporates transmission losses in the calculations and can be used with or without observed flow data.

Past Water Transfer Cases in Wyoming

Even though conveyance losses have not been researched to a great extent in Wyoming, the Board of Control has been faced with the problem of reviewing several petitions that have proposed to convey transferred water in a natural stream to a new point of diversion. The lack of conveyance loss data has made the review process difficult and has forced the Board of Control to rely on their experience and the experience of the administrative personnel associated with the river in question. In reviewing the water transfer cases discussed below, the Board of Control has taken the view that a proportionate sharing of the total river losses is a necessary condition for approval of the petitions (Wyoming State Board of Control, October 1981).

One of the first transfer cases presented to the Board of Control was from Basin Electric Power Cooperative in 1975 (Wyoming State Board of Control, April 1976). Basin Electric proposed a change in use and point of use of three agricultural appropriations diverting from the Laramie River through the Boughton Ditch, with the total water rights of these appropriations equaling 98.73 c.f.s. The petition requested that the water be transported a distance of 110 miles down the Laramie River to Grayrocks Reservoir to be used for steam power generation purposes at the Laramie River Steam Electric Generating Plant near Wheatland, Wyoming. The Board of Control determined that 41.86 c.f.s. with an annual maximum volume of 3117 acre-feet was the maximum amount of the agricultural rights that was transferable, depending on the amount of water available in the river.

At the time of this petition, no conveyance loss studies had been performed on the stretch of the Laramie River in question; and since determination of such conveyance losses is dependent upon many variables, some of which may not be susceptible to accurate measurement, conveyance losses were established at a rate sufficient to protect other water users. Conveyance loss percentages were assigned as follows:

a). 30% - when the maximum daily gross diversion entitlement is 35 c.f.s. or greater;

b). 40% - when the maximum daily gross diversion entitlement is 22.5 c.f.s. or greater and less than 35 c.f.s.;

c). 50% - when the maximum daily gross diversion entitlement is less than 22.5 c.f.s. and greater than 5 c.f.s.;

d). 100% - when the maximum daily gross diversion entitlement is 5 c.f.s. or less.

The above conveyance losses are subject to revision by the Board of Control based upon the submission of conveyance loss studies acceptable to the Board. These figures convert to a loss rate that ranges from 0.3 prcent to 0.9 percent per mile of the river.

The second such petition was presented to the Board of Control by the Green River Development Company in 1978 (Wyoming State Board of Control, February 1981). The Green River Development Company petitioned for a change in use and point of diversion of existing agricultural water rights that diverted water from the Green River and Cottonwood Creek through the Green River Supply Canal and the

Cottonwood Canal, respectively. Of the original water rights which totaled 28.62 c.f.s, the Board of Control determined that 14.31 c.f.s. with an annual volume of 2000 acre-feet was the maximum amount of the agricultural water rights that was transferable, depending upon the availability of water in the Green River and Cottonwood Creek. It was proposed that the 14.31 c.f.s. be transported some 130 miles down the Green River where the water would then be diverted by the Jim Bridger Power Plant Pumping Facility to be used at the power plant.

There was no conveyance loss study presented by the Green River Development Company for their proposed transfer. They argued that the Green River is usually abundant with flow and, therefore, such losses as seepage, bank storage and evaporation should not be assessed against a flow as small as 14.31 c.f.s. The Board of Control was not persuaded by this argument, stating that such water must be treated as introduced water, which is entitled to none of the gains in the river, but can only be assessed losses. Relying on their experience, the Board of Control found that a conveyance loss of 25 percent (0.2 percent per mile) was reasonable under the situation presented in the petition.

In 1981, the Board of Control reviewed two petitions for changes in use and points of diversions of existing agricultural water rights in the North Platte River basin. In the first petition, the Town of Mills, Wyoming, and the Wardwell Water and Sewer District proposed to transport 6.48 c.f.s., for municipal purposes, a distance in excess of 200 miles in the North Platte River system (Wyoming State Board of Control, March 1982). Later that same year, the Board of Control reviewed a petition presented by the Pacific Power and Light Company which proposed to transport 1915 acre-feet per year a distance of 223 miles in the North Platte River for steam power generation at the Dave Johnston Power Plant (Wyoming State Board of Control, October 1981). In both cases, the transferred water would pass through Seminoe, Kortes, Pathfinder, and Alcova Reservoirs which inundate 57 miles of the river. The amount of water proposed to be transferred with the two petitions was very small in comparison to the normal flow in the North Platte River.

The Board of Control did not approve either of these petitions due to the unacceptable nature of the conveyance loss studies presented by the petitioners. The quality of the loss studies supplied with these petitions was of great concern since the North Platte River is a highly regulated river subject to numerous legal and operational constraints which result in complex management problems. The margin of error in the measuring and control devices on the outlet structures of the four reservoirs through which the transferred water would pass is of such a magnitude as to absorb the small amounts of water to be transferred. Accurately tracking these small amounts of water would be difficult, and any error in the delivery of these introduced waters could result in injury to other downstream appropriators. The Board of Control felt that these administration problems, along with losses due to bank storage, deep percolation, and inadvertent diversions were not adequately addressed by the petitioners.

A methodology for determining a portion of these losses that concern the Board of Control is presented in the following chapter. The methodology may not be directly applicable to future water transfer cases, but its use could provide valuable insight into the problem.

CHAPTER III

METHODOLOGY

A description of the methods used to collect and analyze the data pertaining to this study are contained in this chapter. Topics to be discussed include: (1) Site Selection; (2) Data Collection; (3) Discussion of Study Areas; (4) Method of Data Analysis; and (5) Statistical Analysis.

Site Selection

At the beginning of this project, the Board of Control presented several stream reaches that they considered to be potential study areas. A list of these stream reaches is shown in Table I. Several of these suggested areas were examined to determine their suitability for conveyance loss studies.

A number of factors were considered in the final site selection process. Streams that could be accurately monitored from a surface water standpoint, whether it be streamflows or diversions, were chosen. To achieve this, a system of gaging stations would need to be established at the points of surface water inflow and outflow along the stream. It was necessary that access to these locations be acquired. Due to the amount of instrumentation available, the number of gaging locations was limited, thus limiting the length of the reaches that could be studied. The availability of reservoir water to be used for releases was perhaps the largest factor in the final selection of study sites. Without this water, the methodology discussed in this paper would not be applicable.

TABLE I

POTENTIAL STUDY REACHES

Water Division 1

North Platte River - Whalen Dam to Wyoming-Nebraska State Line

North Platte River - Guernsey Dam to Whalen Dam

North Platte River - Above Seminoe Reservoir

North Platte River - Grey Reef to Glendo Inflow

Laramie River - Cramer Ditch to Greyrocks Reservoir

Horse Creek - Wye Cross Ranch to Downer Bird Farm

Water Division 2

Piney Creek - Lake DeSmet to Clear Creek Confluence

Clear Creek - Healey Reservoir to below Town of Clearmont

Water Division 3

Greybull River - Lower Sunshine Reservoir to Farmer's and Bench Canals

Shell Creek - Adelaide and Shell Reservoirs to National Forest Boundary

Wind River - Dubois to Riverton

Water Division 4

Green River - Horse Creek to Fontenelle Reservoir

Green River - Fontenelle Reservoir to City of Green River

From the list presented by the Board of Control, two study sites were selected that satisfied the requirements discussed above. The sites chosen were Piney Creek in Water Division 2 and the Laramie

River in Water Division 1. A study of the New Fork River in Water Division 4 was also included in this paper. The locations of these study areas in the State of Wyoming are shown on Figure 2. A discussion of the three study areas is given in this chapter.

Data Collection

At each study site, a network of stream gages was established at all locations of surface flow into and out of the systems. Some flows were not monitored since they remained fairly constant during the study periods and were generally small. Continuous stage recorders of the type manufactured by Leupold and Stevens, Incorporated, were installed at all flow measurement locations. However, existing gaging stations operated by the State of Wyoming were used whenever possible. At each recorder location, actual flow measurements were taken at different water depths using Price AA or Pygmy current meters as manufactured by Scientific Instruments Company. This data was then used to develop stage-discharge rating curves which were used to convert the continuous stage records into continuous flow records.

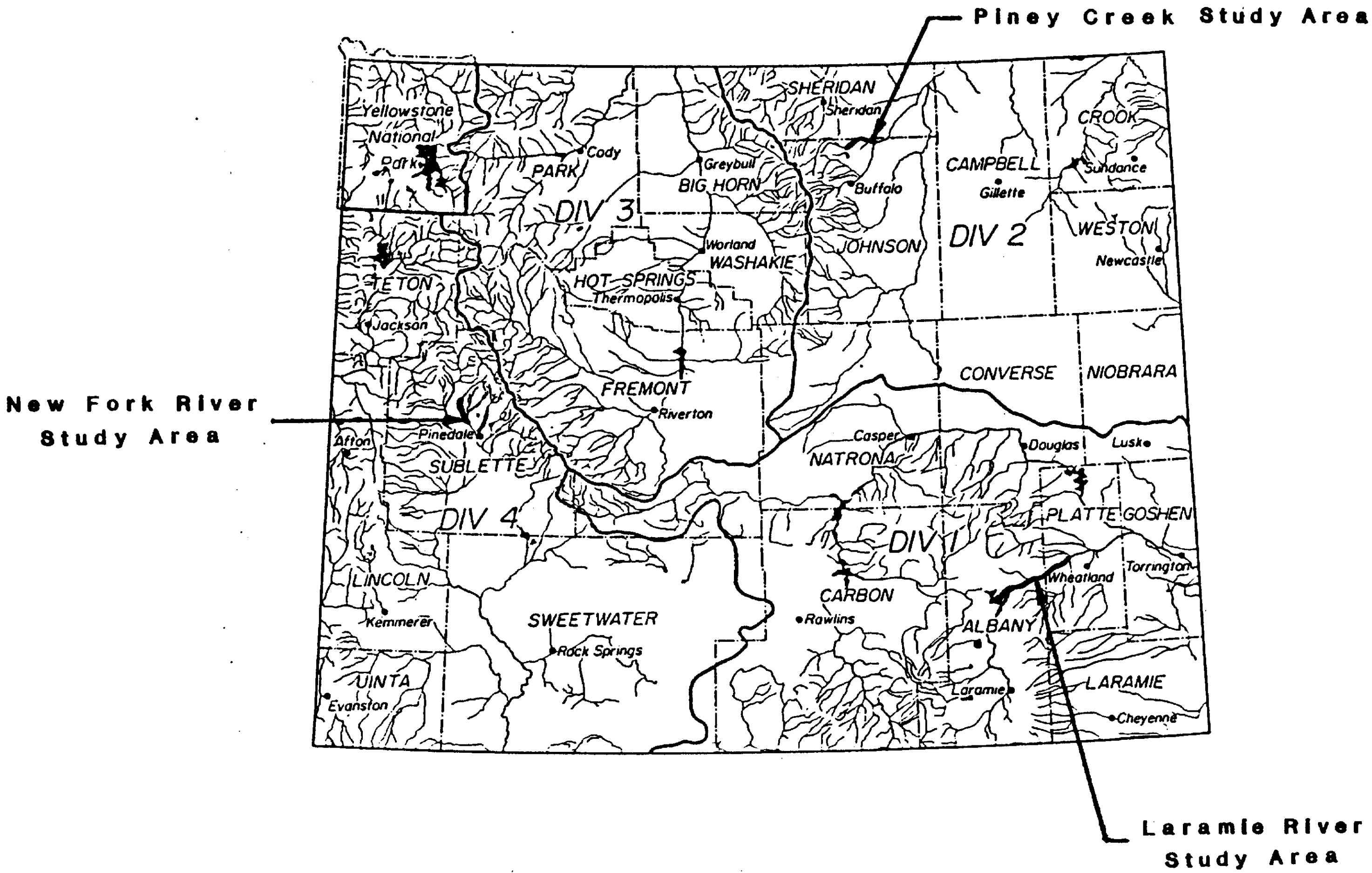

Figure 2. Location of Study Areas in Wyoming

Discussion of Study Areas

Piney Creek Study Area

Setting. The portion of Piney Creek that was studied extended from a point where Lake DeSmet discharge water enters Piney Creek to the confluence of Piney Creek and Clear Creek near Ucross, Wyoming (See Figure 3). In this reach, the creek traverses a total of approximately 22 miles through a narrow valley comprised of alluvial deposits (Lowry and Cummings, 1962). Alfalfa and native grasses are grown in this area, with flood irrigation and some sprinkler irrigation commonly practiced.

The natural streamflow in Piney Creek is due to runoff from rainfall, snowmelt, and irrigation return flows within its drainage basin. A portion of the natural flow is diverted and stored in Lake DeSmet, which is an off-channel reservoir. Lake DeSmet also stores water that is diverted from Clear Creek and is then pumped approximately 6 miles to the reservoir. Water is then discharged from Lake DeSmet into Piney Creek where it is diverted by downstream users on Piney Creek and Clear Creek.

Instrumentation and Data Collection. In order to determine the quantity of surface water flowing into and out of Piney Creek during the study period, a network of eleven Stevens continuous stage recorders was installed throughout the study reach. The locations of these recorders are listed in Table II and shown on Figure 3. An additional State operated gage (06323500), located at the lower end of the study reach, was also used. A majority of the surface flow in the area was accounted for with this network of gages. Any flows that

TABLE II
PINEY CREEK GAGING STATIONS

Recorder Location	Control Section	Recorder
Piney Creek below Lake DeSmet	Natural	Type F
Senff Ditch	2 ft. Parshall	Type F
Upper Flying E Ditch	1 ft. Parshall	Type F
Lower Flying E Ditch	2 ft. Parshall	Type F
Maverick Ditch	18 in. Parshall	Type F
Sturdevant Ditch	3 ft. Parshall	Type F
WJD Ditch	3 ft. Parshall	Type F
Athorpe-Rogers Ditch	2 ft. Parshall	Type F
Dunlap Ditch	3 ft. Parshall	Type F
Boxelder Creek	Natural	Type F
Pratt & Ferris #1 Ditch	6 ft. Parshall	Type F
Piney Creek at Ucross, WY, 06323500*	Natural	Type A-35

*Operated by the State Engineer

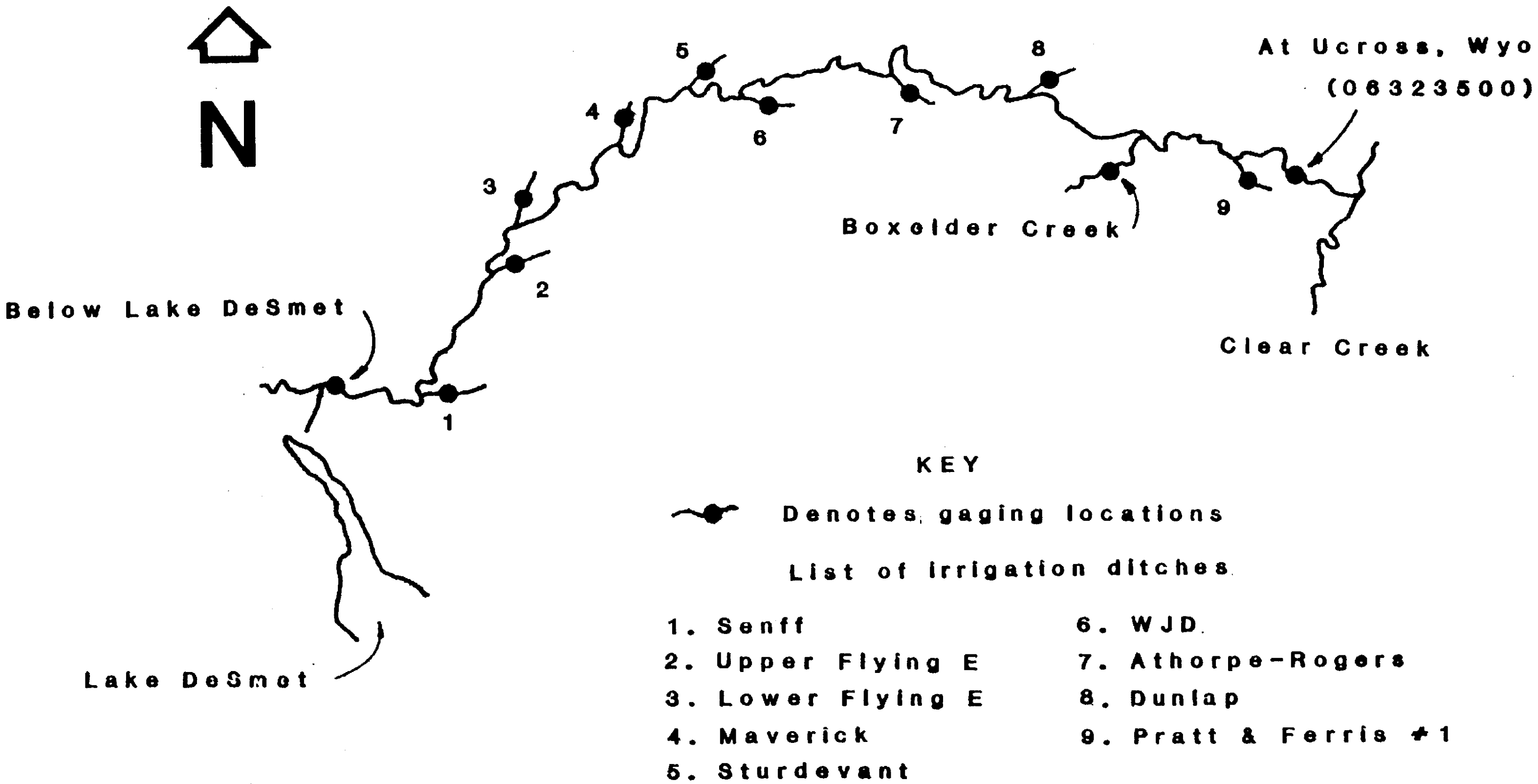

Figure 3. Piney Creek Study Area

were not continuously monitored were visually checked on a regular basis and were found to be small and relatively constant during the study.

A total of nine of these monitoring locations were on irrigation diversion ditches which already contained Parshall flumes for flow measurement. Since these flumes did not have stilling wells in which to place the recorders' floats, the instrumentation was placed at the upstream end of the flumes. This location did not appear to disturb the flow as it entered the flume. However, the head at the recorder's stilling well was generally a little higher and would fluctuate at a rate different from the head at the staff gage in the flume. This was not much of a problem, except during large changes in the flow. However, this situation was dealt with by regularly checking the recorders and making adjustments in the record if necessary.

Once the gaging locations were established, stage-discharge rating curves were developed for the particular stream sections. At those locations with Parshall flumes, it was possible to use the flumes' theoretical rating curves. However, since many of the flumes were found to have settled unevenly through the years and were no longer level, flow measurements were taken at the flumes in order to check their theoretical rating curves. If the flow measurements were not within 10 percent of the theoretical flow, new stage-discharge relationships were developed based on the field measurements. Otherwise, the theoretical rating curves for the various size flumes were considered adequate. A limit of 10 percent was chosen since it exceeds the expected accuracy of a single flow measurement. A single determination of discharge may be expected to be within ±7 percent of the actual value at the 95 percent confidence limits (Herschy, 1978).

With the recorders installed, the system was then monitored for a period of time to insure that the surface flows in and out of the system were relatively stable; i.e., gains into the creek from groundwater, irrigation return flows, and ungaged surface flows were constant. Once a stable condition was maintained, additional water was released from Lake DeSmet to provide an incremental increase in flow. This increased flow was then maintained for a period of several days, after which time the flow was reduced to approximately the same rate that existed prior to the reservoir release. Two releases were made during the summer of 1984 and are discussed separately in Chapter IV. The methodology used to analyze the data collected is discussed later in this chapter.

Laramie River Study Area

Setting. The Laramie River was studied from Wheatland Reservoirs No. 2 and No. 3 to the confluence of the Laramie River and Sybille Creek for a distance of approximately 51 miles (See Figure 4). In the first 10 miles of the study reach, the river traverses through a wide valley containing alluvial deposits. There is limited irrigation in this region. The Laramie River then cuts through the Laramie Mountains in a narrow precipitous canyon consisting of Precambrian rock for a distance of approximately 27 miles. The river then exits the canyon west of Wheatland, Wyoming, and traverses approximately 14 miles in a narrow valley containing flood-plain deposits (Lowry, et al., 1973). Hay is grown in this area, with flood irrigation commonly practiced.

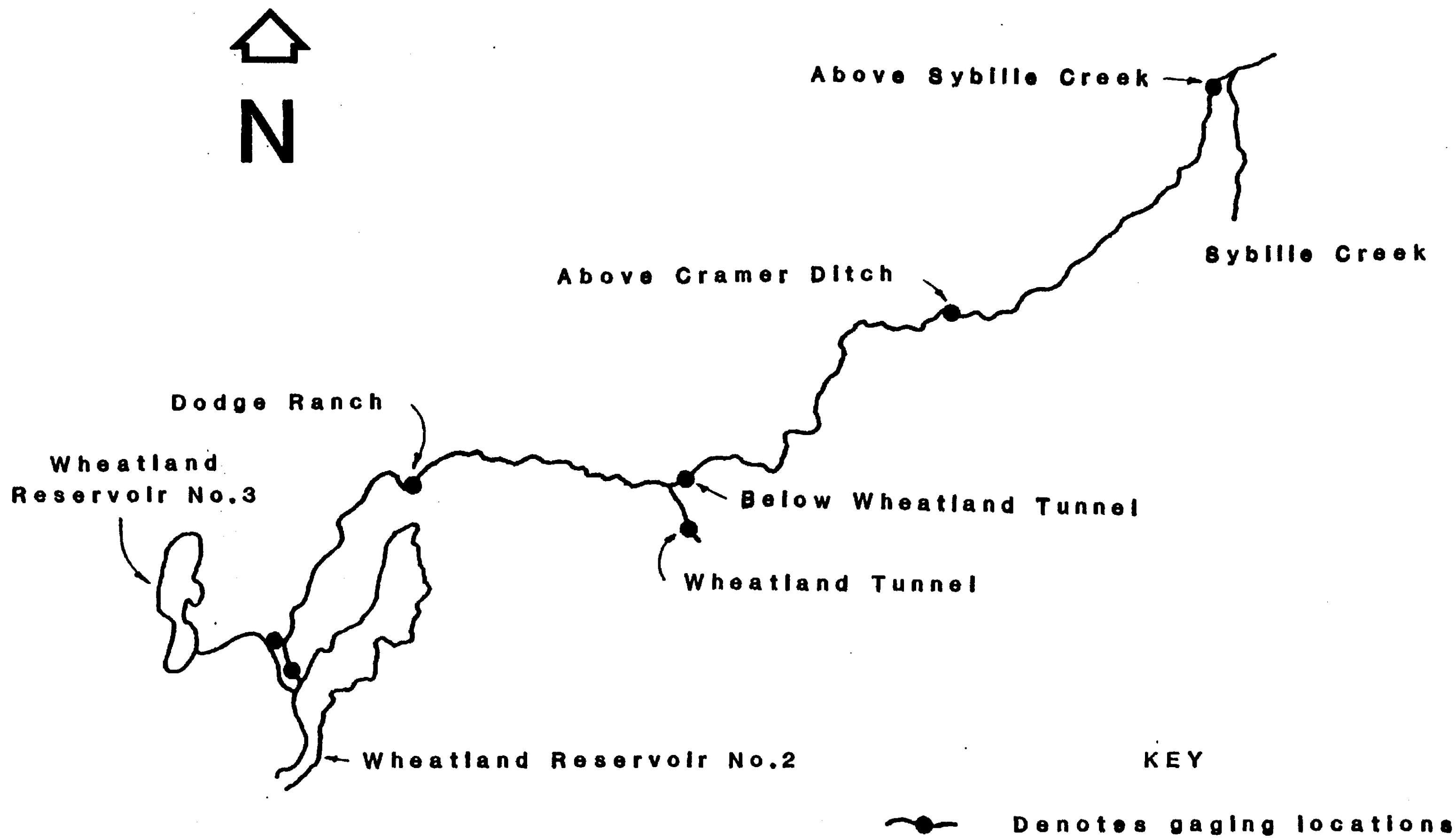

Figure 4. Laramie River Study Area

The natural streamflow in the Laramie River is due to runoff from rainfall, snowmelt, and irrigation return flows within its drainage basin. Near the head of the study reach, the Laramie River enters Wheatland Reservoir No. 2. Some of this water is then diverted for storage into Wheatland Reservoir No. 3. Both of these reservoirs are owned and operated by the Wheatland Irrigation District. Water that is released from the reservoirs is transported in the Laramie River for approximately 21 miles, where it is then diverted through the Wheatland Tunnel into Bluegrass Creek for use by the Wheatland Irrigation District. At this point, a majority of the water is diverted from the Laramie River, via the Wheatland Tunnel, with the remaining water continuing to flow down the Laramie River to other downstream appropriators.

Instrumentation and Data Collection. On the reach of the Laramie River that was studied, there existed several streamflow gaging stations operated by the State Engineer. Therefore, it was necessary to install only one additional Stevens continuous stage recorder at the lower end of the study reach. The locations of these recorders are listed in Table III and noted on Figure 4. This network of gages accounted for a majority of the surface flow in the area. Several small springs and draws within the canyon contribute water to the Laramie River, but were not gaged due to the inaccessibility of these areas. Any flows that were not gaged were assumed to be relatively constant during the study.

TABLE III

LARAMIE RIVER GAGING STATIONS

Recorder Location	Control Section	Recorder
Wheatland Reservoir No. 2 Outflow*	Concrete Artificial Control	Type A-71
Wheatland Reservoir No. 3 Outflow*	Natural	Type A-35
Wheatland Tunnel*	Natural	Type A-35
Laramie River below Wheatland Tunnel*	8 ft. Parshall	Type A-35
Laramie River above Cramer Ditch*	Natural	Type A-35
Laramie River above Sybille Creek	Natural	Type F

*Operated by the State Engineer

With the recorders installed and operating, the system was then monitored for a period of time to insure that a stable system existed. The Wheatland Tunnel was then shut off to provide an incremental increase in flow in the lower portion of the Laramie River. Additional water was later discharged from Wheatland Reservoir No. 2 which provided an increase in flow throughout the whole study area. This increase was then monitored for the remainder of the study period. Due to the changing geological conditions surrounding the river, the study area was divided into two reaches, an upper and a lower, which are discussed separately in Chapter IV. The methodology used to analyze the data collected is discussed later in this chapter.

New Fork River Study Area

Setting. The portion of the New Fork River that was studied extended from New Fork Lake to a point approximately 8 miles downstream (See Figure 5). In this reach, the river traverses for a distance of approximately 1 mile through material consisting of glacial deposits. The New Fork River then enters a narrow valley consisting of alluvial deposits (Welder, 1968). Native hay is grown in this area, with flood irrigation commonly practiced.

The natural streamflow in the New Fork River is due to runoff from rainfall, snowmelt and irrigation return flows within its drainage basin. Above the head of the study reach, the river enters the New Fork Lakes where some of the water is stored and used later by the New Fork River Irrigation District.

Instrumentation and Data Collection. Instrumentation was installed in a 21 mile stretch of the New Fork River basin in the summer of 1984 mainly for the purpose of quantifying the irrigation return flows that occur in the area. A network of 32 continuous stage recorders and 22 wells were installed throughout the basin for data collection. Two existing wells were also monitored. Of this network, only the data collected from 7 of the stage recorders were used in the determination of conveyance losses. The study reach was limited to 8 miles since the river system becomes much more complex. Beyond the 8 miles, a large number of irrigation ditches divert a majority of the water in the river, reducing the amount of the desired incremental increase and severely affecting the rate of return flows that recharge the river. The locations of the recorders used are listed in Table IV and noted on Figure 5. With this series of gages, it was possible to

TABLE IV

NEW FORK RIVER GAGING STATIONS

Recorder Location	Control Section	Recorder
New Fork River below New Fork Lakes	Natural	Type F
Marsh Creek	Natural	Type F
Jenkins Ditch	Natural	Type F
Rahm Ditch	Natural	Type F
Wright Ditch	Natural	Type F
Lane Ditch	Natural	Type F
New Fork River below Barlow's	Natural	Type F

account for a majority of the surface flow in the area. Any flows that were not continuously monitored were generally small and were assumed to be constant during the study period.

With the recorders installed, the study reach was then monitored for a period of time to insure that a stable system existed. Additional water was then released from the New Fork Lakes to supply irrigation water to the downstream users. The data collected prior to the release and during the release was analyzed in an attempt to determine the conveyance loss in that stretch of the New Fork River. The methodology used is discussed in the next section.

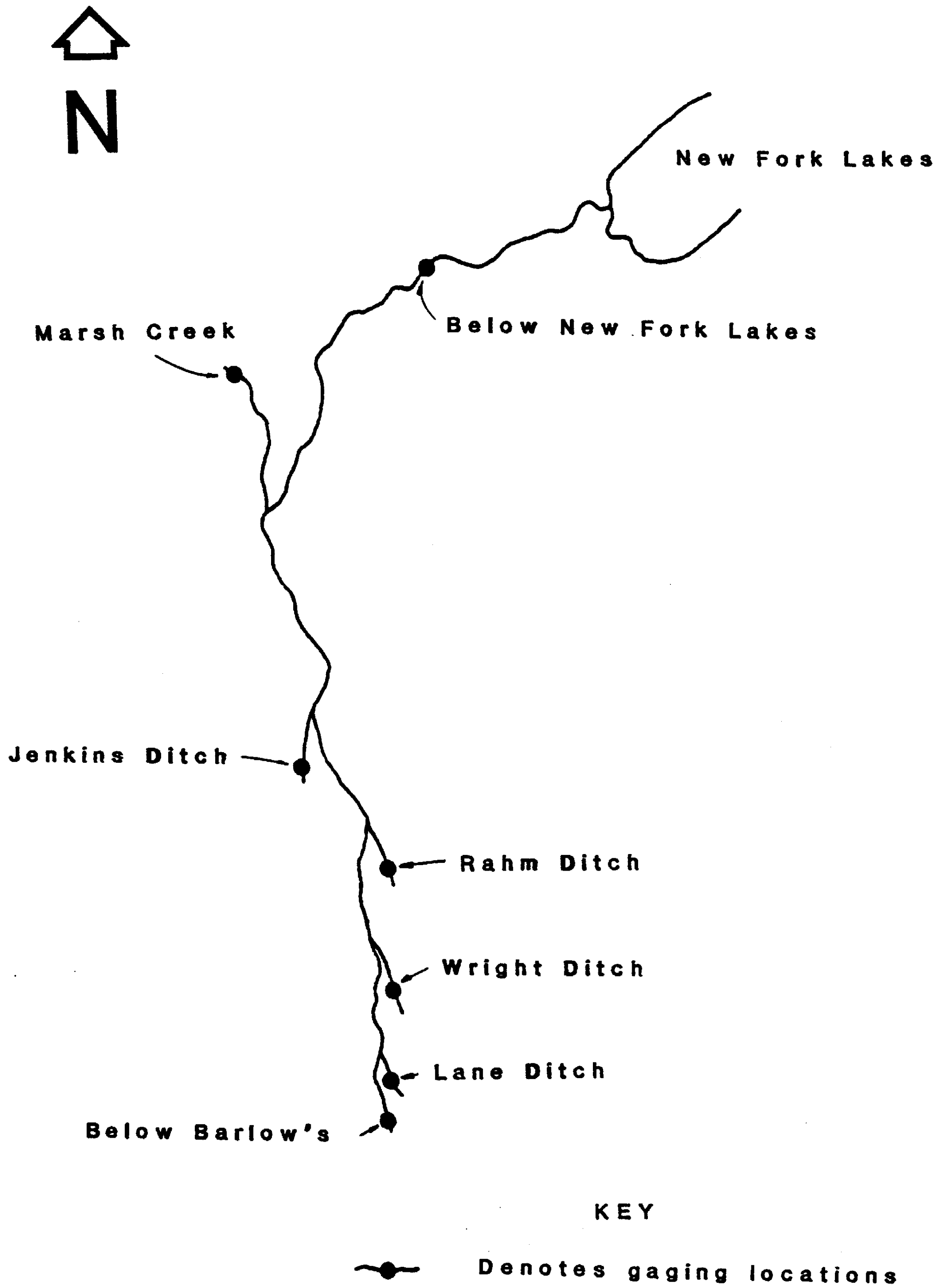

Figure 5. New Fork River Study Area

Method of Data Analysis

The hydrologic budget approach was used in the analysis of the collected streamflow data. This method required a comparison of the quantities of inflow and outflow in order to determine conveyance losses. In general terms, the water budget relationship can be written as

$$O = I - D + G \qquad (3.1)$$

where O is the surface flow out of the system

I is the surface flow into the system

D is the surface flow diverted out of the system

and G is the gain or loss in the flow in the entire system.

In the above equation, the 'G' term is a lumped variable which contains the effects of groundwater flow and all sources of loss, such as surface evaporation, evapotranspiration, etc., and can be either positive or negative in sign. All of the rivers discussed in this paper were gaining at the time of the data collection so the 'G' term was considered to be positive in the analysis. However, if a stream is losing, the approach discussed here is still applicable.

In order to determine the total losses in a gaining stream, extensive instrumentation would be needed to quantify all of the sources of gains and losses that comprise the 'G' term in Equation 3.1. An approach of this type would be very expensive, and the results would not be without errors. For these reasons, this study did not attempt to measure total river losses, but those incremental losses due to a reservoir release. In this case, incremental losses have been defined as the decrease in the gains or the increase in the losses during an increase in surface flow.

Incremental losses can be solved for by manipulating Equation 3.1 into the following form.

$$G_1 - G_2 = [I_2 - I_1] - [D_2 - D_1] - [O_2 - O_1] \qquad (3.2)$$

where subscript 1 represents the flows before the release and subscript 2 represents the flows during the release.

Equation 3.2 can be simplified further to the following equation.

$$L = [\Delta I - \Delta D] - \Delta O \qquad (3.3)$$

where L is the incremental loss due to the release

ΔI is the increase in the surface inflow due to the release

ΔD is the increase in diversions during the release

and ΔO is the increase in the surface outflow due to the release.

All of the components of Equations 3.1, 3.2, and 3.3 are in the same units; i.e., c.f.s. or acre-feet.

Equation 3.3 provides a simple means for determining the losses associated with a reservoir release based solely on surface flow records. With this relationship, losses can be computed either in terms of the flow rate or the volume of the reservoir release by solving Equation 3.3 in units of c.f.s. or acre-feet, respectively. Some adjustments may have to be made to account for travel times. If the engineer is concerned with the volume of release water available for storage at a point downstream, he may wish to use the volumetric approach. On the other hand, if he is concerned with the rate of flow available for diversion, he may find the flow rate approach more applicable. The shapes of the inflow and outflow hydrographs will determine whether or not the two approaches yield similar results.

Certain limitations exist on the use of Equation 3.3. In the first place, the use of the ΔD term in the equation removes any losses due to increases in diversions from the calculations. This is acceptable if the increase is intentionally caused by the appropriator. If this is not the case, the ΔD term should be removed from the equation so that inadvertent diversions are included in the total loss.

Secondly, all sources of loss are lumped together into one value. Included in this value are losses due to bank storage, channel storage, a reduction in the groundwater contribution, and an increase in surface evaporation and evapotranspiration. Determination of each of these separate losses would require more field data than was collected in this study.

Use of Equation 3.3 is limited to time periods when meteorological conditions are fairly consistent. Precipitation and its effect upon the surface and subsurface flows are not accounted for in this relationship. In most of the cases studied, there was negligible rainfall during the study periods so this was not a problem.

Perhaps the most important limitation on the use of Equation 3.3 pertains to the stability of the study area. Since this relationship determines the change in gains during a reservoir release, it is necessary that the flow regime in the study area is in a stable condition with relatively constant gains. This will insure that the calculated decrease in gains is mainly due to the introduction of additional water into the stream. Any large changes in activities, such as irrigation, during the study period could affect the amount of return flows which, in turn, could affect the gains measured before, during, and after the reservoir release.

Statistical Analysis

At each of the gaging locations, stage-discharge rating curves were developed using the least squares method in conjunction with the logarithms of the stage and discharge measurements. The resulting equations were than transformed into the general relationship shown below.

$$Q = KH^b \qquad (3.4)$$

where Q is the discharge, c.f.s.

K is a coefficient

H is the stage, ft.

and b is an exponent.

Using their respective rating curves, the continuous-stage records were converted into continuous-discharge records (i.e., hydrographs) which formed the basis for the determination of the conveyance losses. However, it became apparent that the measured losses were small enough to be affected by the degree of accuracy that could be expected with the established rating curves.

In an ideal situation, the current meter observations would fall directly on the stage-discharge curve. However, in practice, these points are scattered above and below the curve, due principally to the uncertainty in the current meter observations, the uncertainty in stage measurement, the instability of the station control, changing conditions in the channel due to scour or accretion, and to seasonal changes in the river regime (Herschy, 1978).

For example, a single determination of discharge, following the procedure outlined by Herschy, may be expected to be within ±7 percent of the actual value at the 95 percent confidence limits. A measurement error of this extent could have a large effect on the accuracy of the rating curves

In an attempt to quantify the accuracy of the conveyance losses that were calculated, 95 percent confidence limits were placed on the rating curves using the following equation given by Herschy.

$$X_{rd} = (S_{mr}^2 + b^2 X_h^2)^{1/2} \tag{3.5}$$

where X_{rd} is the uncertainty in the recorded discharge, in %,

S_{mr} is the standard error of the mean relation at the 95 percent confidence level in %,

b is the exponent from Equation 3.4

and X_h is the uncertainty in the stage measurement, in %.

The standard error of the mean relation, S_{mr}, in Equation 3.5 was calculated using

$$S_{mr} = \left| \frac{\sum \left| \frac{Q_m - Q_c}{Q_c} \times 100 \right|^2}{N-2} \right|^{1/2} \left| \frac{1}{N} + \frac{(H_K - \bar{H})^2}{\sum (H_i - \bar{H})^2} \right|^{1/2} (t) \tag{3.6}$$

where Q_m is the measured flow at a stage of H_i, in c.f.s.

Q_c is the calculated flow from the rating curve at a stage of H_i, in c.f.s.

N is the number of gaging points

H_k is the stage at which X_{rd} is being calculated, in ft.

$\bar{H}$ is the average stage of the N gaging points, in ft.

H_i is the stage at gaging point i, in ft.

and t is the Student's t correction at the 95 percent level for N gagings.

The uncertainty in the stage measurement, X_h, in Equation 3.5 was calculated using

$$X_h = \frac{100}{H-a} (E_g) \tag{3.7}$$

where a is the stage at which there is zero flow, in ft.

and E_g is the uncertainty in the stage reading, in ft.

In the above equation, E_g was set equal to 0.01 feet for all rating curves.

The 95 percent confidence limits placed on the rating curves, using the above relationships, represent ranges in which the actual stage-discharge relationships could be expected to fall. A typical rating curve with confidence limits is shown in Figure 6. The rating curves established by the State did not lend themselves to this analysis, so a constant uncertainty of 5 percent was used in those cases. These limits were applied to the hydrograph records to develop ranges for the recorded data. Maximum and minimum conveyance losses were then calculated using the upper and lower limits placed on the actual data in conjunction with Equation 3.3.

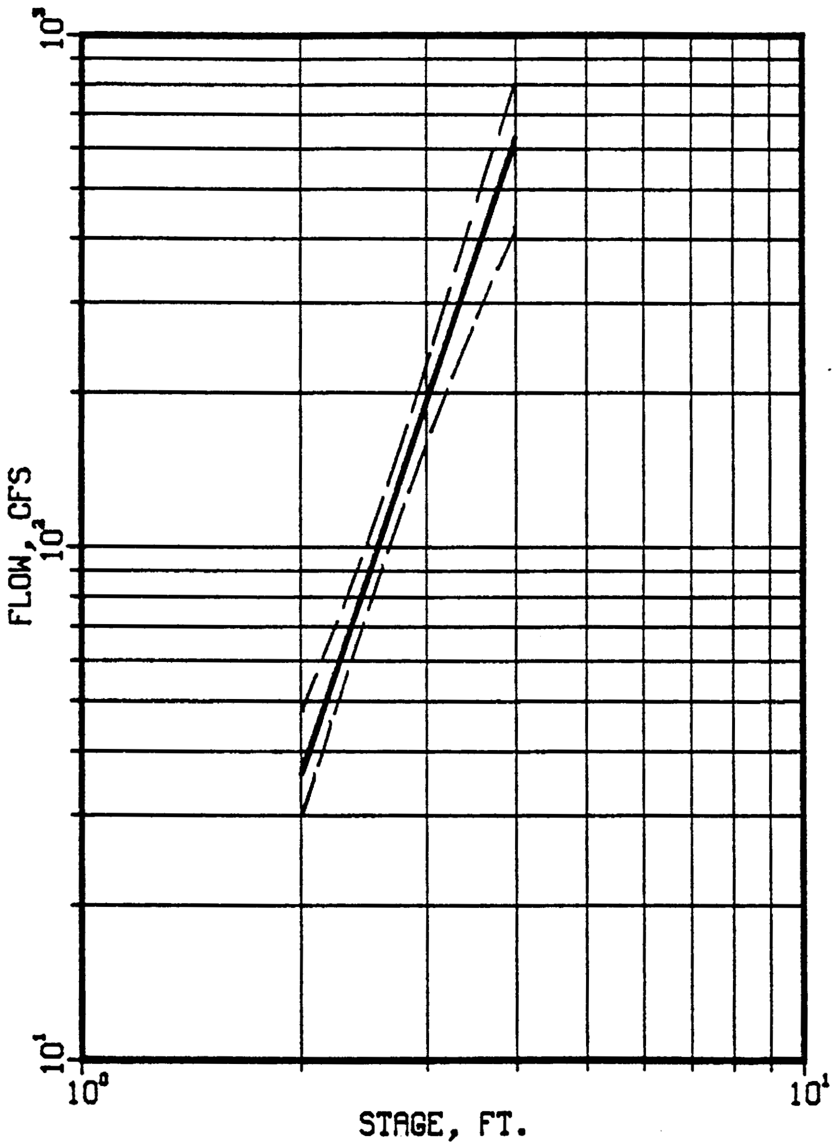

Figure 6. Typical Rating Curve with 95 Percent Confidence Limits

CHAPTER IV

DISCUSSION OF RESULTS

A discussion of the data collected at each of the study sites and the results of the analyses performed on these data is contained in this chapter. Topics to be covered include: (1) Piney Creek Study Area; (2) Laramie River Study Area; (3) New Fork River Study Area; and (4) Comparison of the Results.

Piney Creek Study Area

During the summer of 1984, two separate reservoir releases were made on Piney Creek for study purposes. The data and the results for each of these events are discussed below. In addition to this data, the past ten years of flow records were obtained and analyzed. These results are also included in the discussion.

First Release

For this portion of the study, flows in the Piney Creek area were monitored from August 9 to September 2, 1984. The data that was collected at this time are plotted on Figure 7 in the form of hydrographs. The data are also listed in Appendix A. On Figure 7, the inflow hydrograph represents the flow measured at "Piney Creek below Lake DeSmet" gaging station, and the outflow hydrograph is that flow measured at "Piney Creek at Ucross, Wyoming (06323500)." The diversion hydrograph is the mathematical sum of the water diverted by the nine irrigation ditches in the study area. None of these hydrographs were adjusted for travel time.

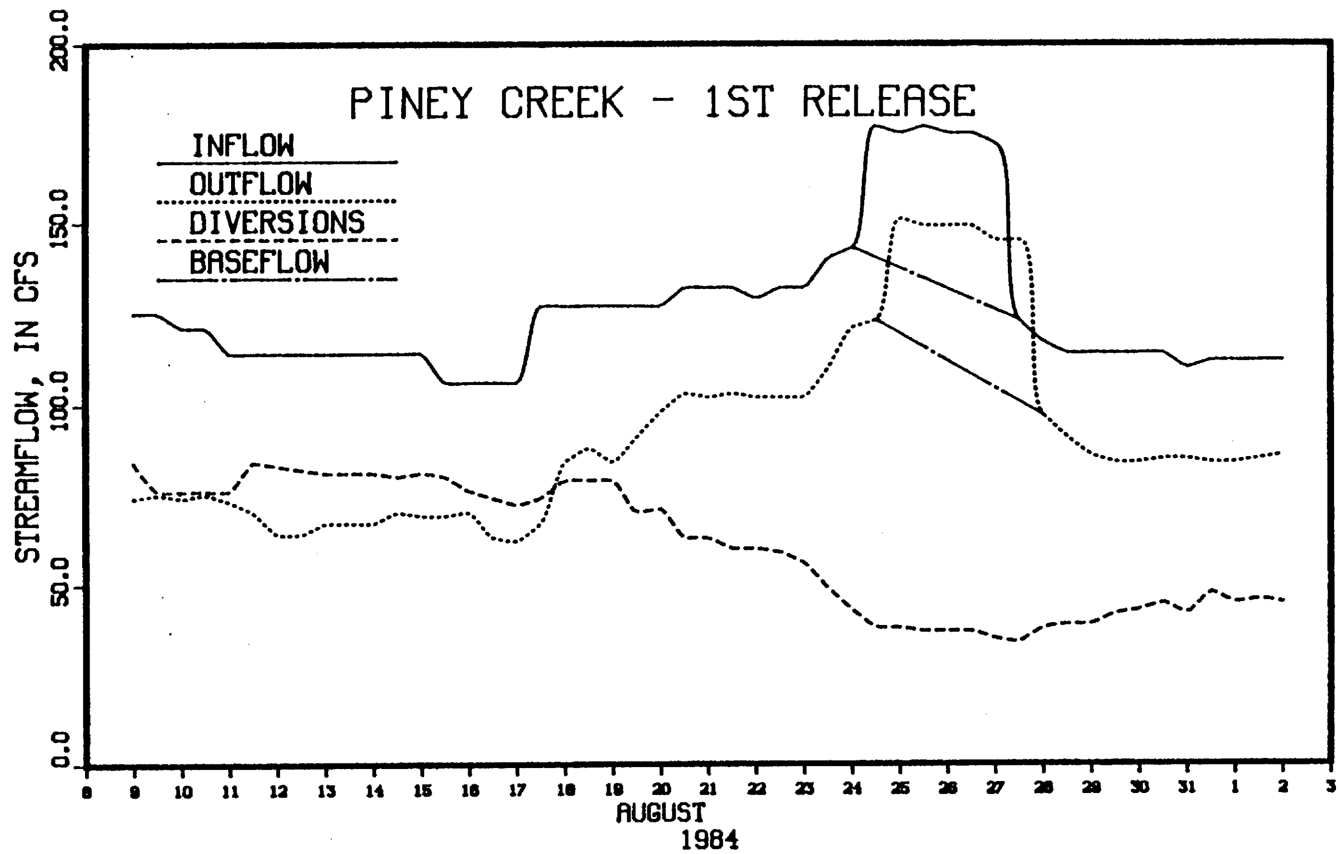

Figure 7. Piney Creek Inflow, Outflow, and Diversions, 1st Release

In order to make this data more understandable, the diversion hydrogrpah was subtracted from the inflow hydrograph to create a net inflow hydrograph. Before this procedure was performed, it was necessary to adjust the diversion hydrograph for travel time, which was done using a technique similar to the "time-offset method" described by Jens and McPherson (1964). The net inflow and outflow hydrographs are plotted on Figure 8. This plot is easier to read, and it clearly shows the relatively constant gains that existed in the system prior to the reservoir release. As discussed earlier, a stable system with constant gains is one of the prerequisites for the analysis technique used. After examining the hydrographs, it is obvious that there were some fluctuations in the flows due to the changes in the natural flow, in the discharges from Lake DeSmet, and in the irrigation activities. However, the degree of stability maintained during the study period appeared to be acceptable.

With the stability of the system confirmed, Equation 3.3 was utilized to estimate the conveyance loss associated with the first release. Since the change in the diversions during the release was negligible, the ΔD term was set to zero The ΔI and the ΔO terms were defined as that amount of additional flow in and out of the system, respectively, due to the reservoir release. To determine quantities for these terms, it was first necessary to estimate the base flows that would have existed had there been no release. This was accomplished using the most simple base flow separation technique which results in a straight line on the hydrograph connecting the flow prior to the release to the flow following the release (See Figure

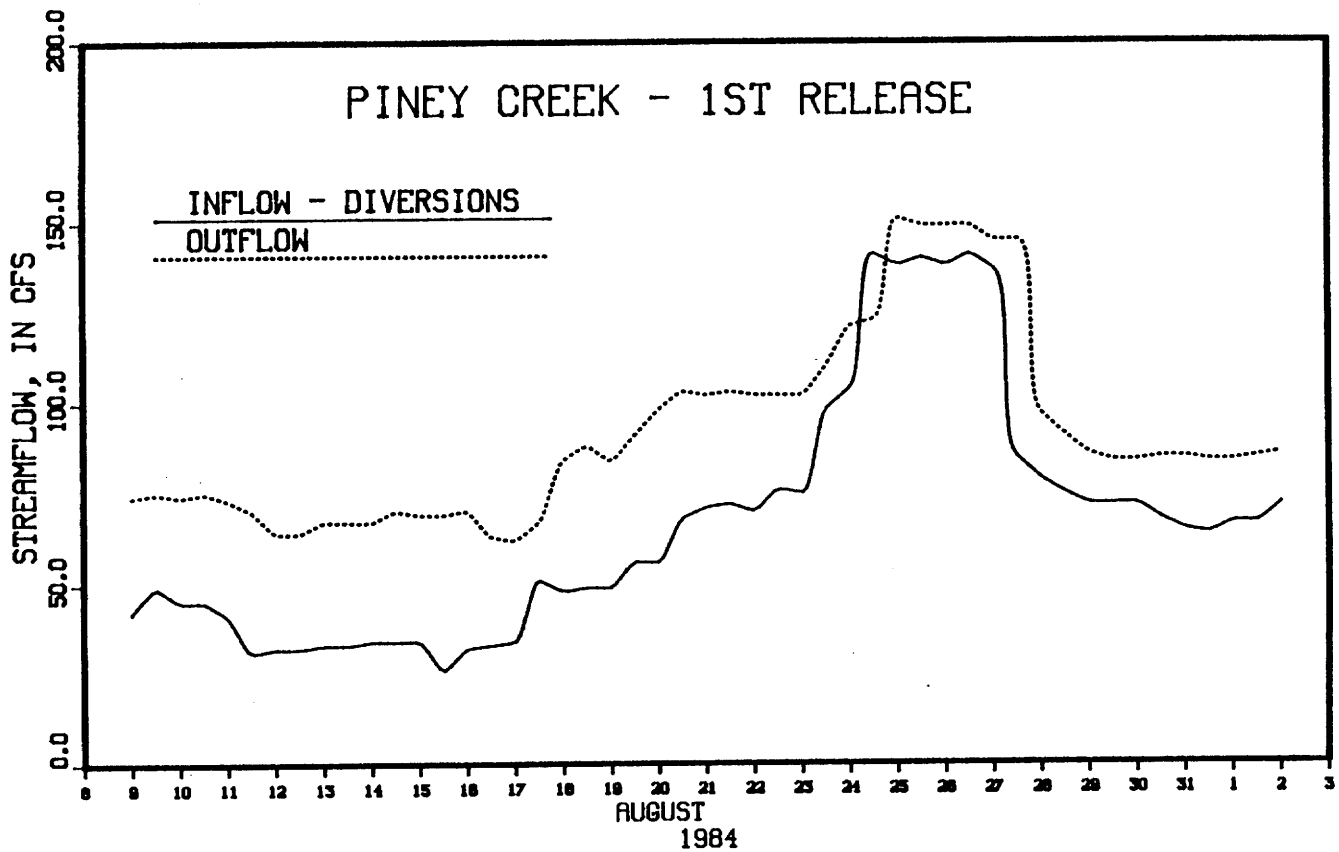

Figure 8. Piney Creek Net Inflow and Outflow, 1st Release

7). The flow above these lines was then used to determine values for ΔI and ΔO. Losses were determined in terms of flow rate and volume.

Following the techniques described above, the increase in the inflow was calculated to be an average of 41.8 c.f.s. for a period of approximately 3 days, or a total volume of 248 acre-feet. The increase in the outflow was 34.8 c.f.s. for a period of approximately 3 days, or a total volume of 207 acre-feet. From Equation 3.3, the conveyance loss was calculated to be 7.0 c.f.s. or 41 acre-feet. This converts into an average loss of 16.53 percent or 0.76 percent per mile of river. The conveyance loss calculations were repeated using the 95 percent confidence limits placed on the hydrographs. Use of these limits resulted in a range of possible losses from 0.00 percent to 1.49 percent per mile of river. The results of these calculations are summarized in Table V.

The majority of the calculated loss was due to bank storage and reduction in the groundwater inflow. It is assumed that the other factors had a negligible effect on the loss. During the release, the stage of the river rose an average of 0.18 feet. This minor increase temporarily forced water into the banks and reduced the groundwater inflow, effectively reducing the gains to the creek. Since the stream is still gaining during the release, bank storage losses were assumed to be small in comparison to losses due to a reduction in groundwater inflow.

TABLE V

SUMMARY OF CONVEYANCE LOSS RESULTS

Study Area	Year	Average Increase of Inflow, c.f.s.	Average Increase in Stage, feet	Loss % per mile	Upper 95% Confidence Limit, % per mile	Lower 95% Confidence Limit, % per mile
Piney Creek	1984	41.8	0.18	0.76	1.49	0.00
	1984	84.6	0.47	1.66	1.99	1.31
Laramie River Lower Reach	1984	114.6	1.02	0.34	1.03	*
Upper Reach	1984	91.3	0.35	*	*	*
	1981	289.5	1.01	0.01	**	**
	1978	171.9	0.88	1.05	**	**
	1974	88.3	0.49	0.87	**	**
	1972	158.5	0.79	0.42	**	**
New Fork River	1984	203.3	1.26	0.85	3.27	*

* Results showed an increase in gains
** Confidence limits not calculated

Second Release

A second reservoir release on Piney Creek was analyzed utilizing data collected from October 1 to October 15, 1984. This data is plotted in the form of hydrographs on Figure 9, with the inflow, outflow, and diversion hydrographs representing the flows measured at the same points discussed in the first release. The data are also listed in Appendix A. All of the flows shown on Figure 9 were calculated from continuous stage records, except those given for the diversions. These values were estimated based upon two field inspections made during the study period. The estimated diversion hydrograph was then subtracted from the inflow hydrograph, with the results plotted on Figure 10. This plot clearly shows the high degree of stability that existed in the system at this time. It is also easy to visualize the amount of conveyance loss that was experienced in the system.

Determination of the conveyance loss associated with this release involved the same techniques used for the first release. However, the ΔD term in Equation 3.3. was not equal to zero since there was a measurable increase in the amount of water diverted during the release. Since the ditches were not continuously monitored and the flows are based upon estimates, it is not known if this increase in the diversions was due to the increased head on the diversion structures or due to an adjustment in the headgates. For these reasons, this additional flow in the ditches was not classified as an inadvertent diversion loss and, therefore, was not included in the total conveyance loss value.

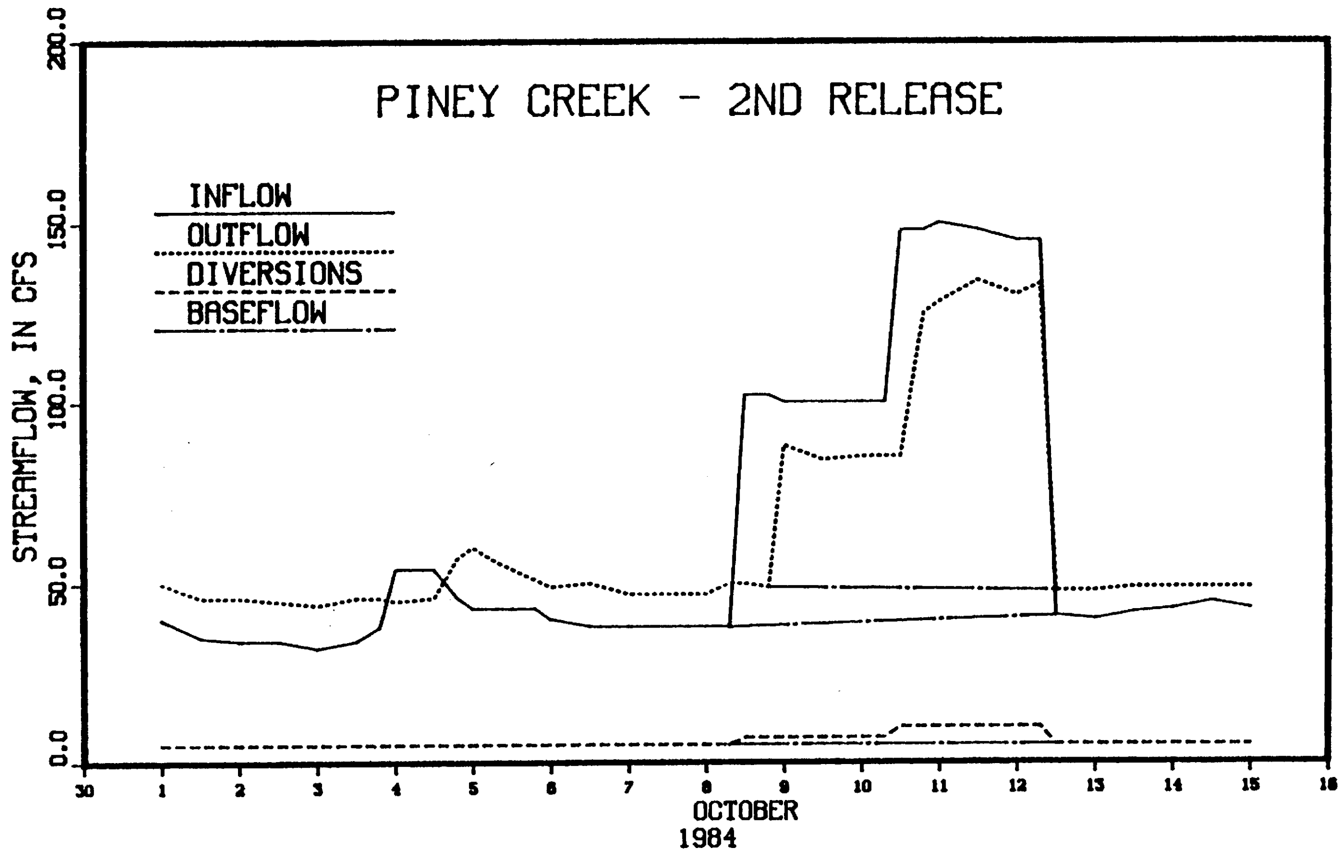

Figure 9. Piney Creek Inflow, Outflow, and Diversions, 2nd Release

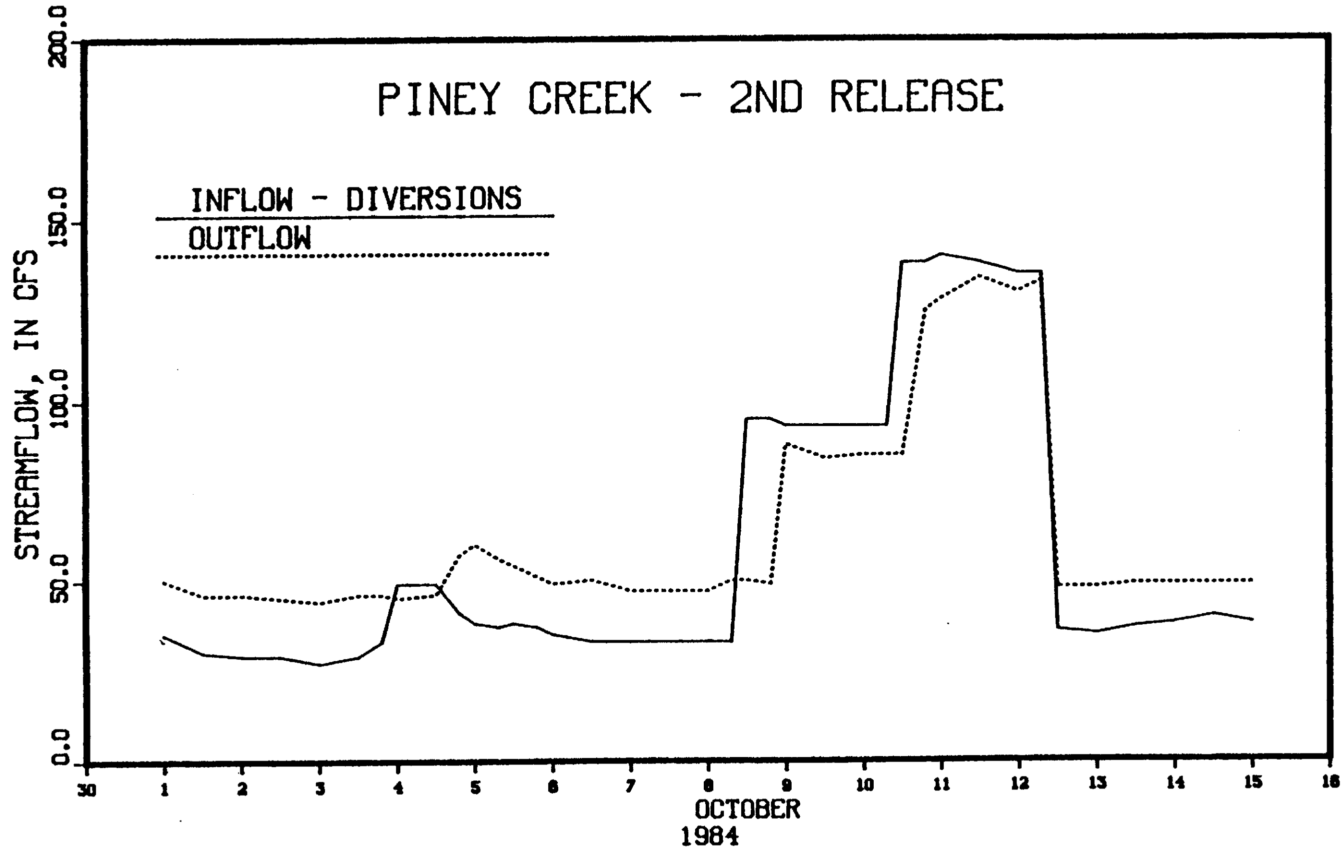

Figure 10. Piney Creek Net Inflow and Outflow, 2nd Release

The values of the terms in the conveyance loss equation were computed by separating out the base flows from the measured flows for each of the hydrographs (See Figure 9). Using this approach, the increase in the inflow was calculated to be an average of 84.6 c.f.s. for a period of approximately 4 days, or a total volume of 670 acre-feet, while the average increase in the outflow was calculated to be 56.3 c.f.s. for a period of approximately 3.66 days, or a total volume of 408 acre-feet. The average increase in the diversions was estimated to be 3.7 c.f.s. for a period of approximately 4 days, or a total volume of 30 acre-feet.

With these values, the average conveyance loss was calculated to be 24.6 c.f.s. or 232 acre-feet. These loss figures were then converted to a percentage of the net inflow; i.e., the inflow minus the diversions. Due to the difference in the time bases of the inflow and outflow hydrographs, the volumetric loss was larger than the loss based upon the flow rate, with values of 1.66 percent per mile and 1.39 percent per mile, respectively. Using the volumetric approach, the conveyance loss calculations were repeated, with the 95 percent confidence limits placed on the hydrographs. Use of these limits resulted in a range of possible conveyance losses from 1.31 percent to 1.99 percent per mile of river. The results of these calculations are summarized in Table V.

As with the first release, the majority of the measured loss in the second release was assumed to be due to bank storage and a reduction in the groundwater inflow. During the second release, the stage of the river rose an average of 0.47 feet, approximately three times more than the increase experienced during the first release.

This increase temporarily forced water into the banks and prevented the surrounding groundwater from entering the creek. As the hydrographs on Figure 10 show, the creek became influent during the release, losing water to the subsurface system. However, near the end of the release, the losses to the stream approached zero. This suggests that the stream would have reached a condition where the losses were negligible had the duration of the release been of sufficient length.

Past Records

It is common knowledge that stream losses will vary with time due to changes in the many factors that influence losses. Fluctuations in the groundwater levels, antecedent moisture conditions in the stream bed, and weather conditions can have a large effect upon the losses experienced in a reach. Because a system is constantly changing, no two losses measured at different times will be exactly the same. Therefore, the losses that were calculated during 1984 are only representative of the losses that could be expected to occur under similar conditions.

Water records from 1973 to 1983 were collected for the purpose of computing losses that occurred in the past. However, analysis of the records did not yield reliable conveyance loss values, since fluctuations in the stream and diversion flows affected the stability of the gains to the system. Figure 11 shows an example of flows in Piney Creek during an unstable period.

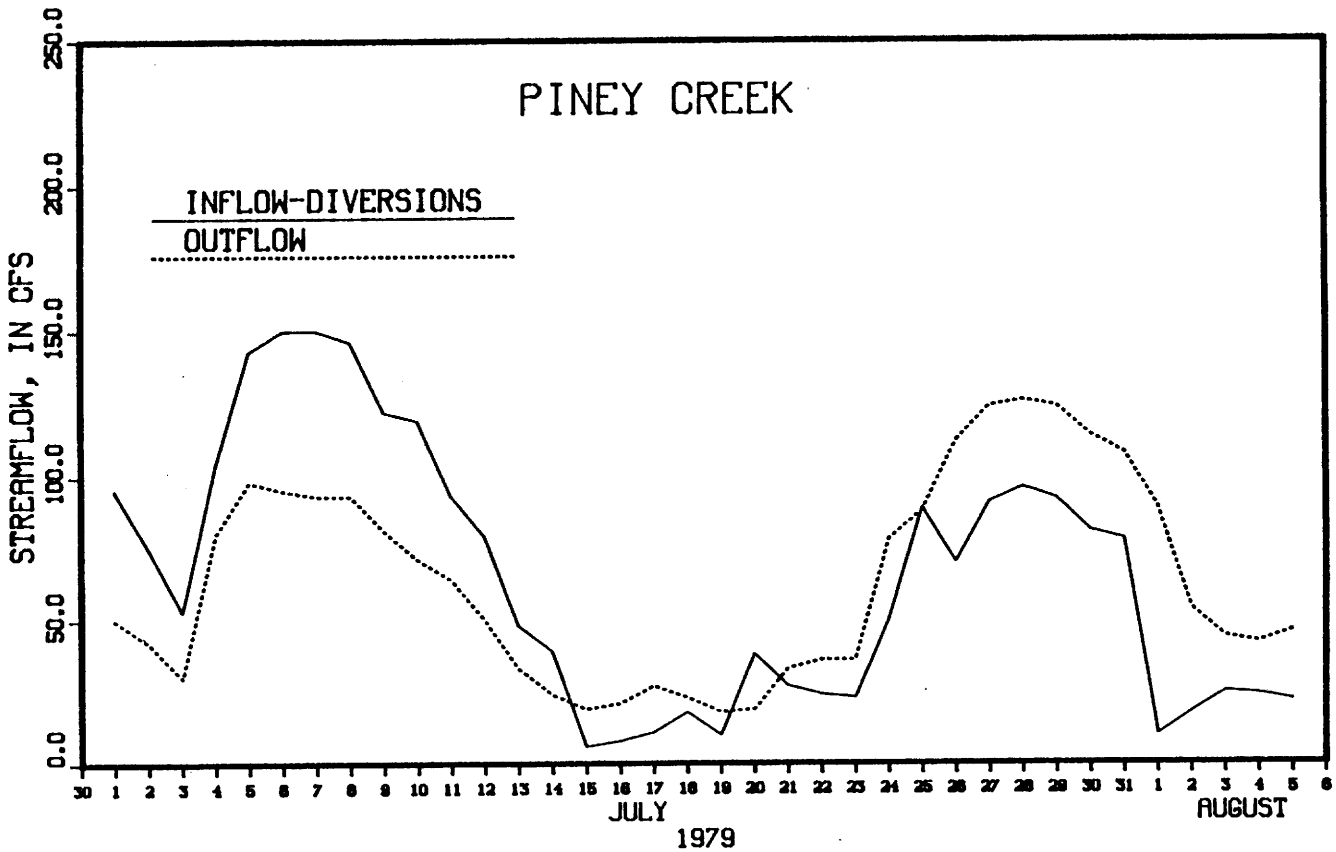

Figure 11. Piney Creek Net Inflow and Outflow during Unstable Period

Laramie River Study Area

During the fall of 1984, water was released from Wheatland Reservoir No. 2 in order to decrease the volume of water being stored. Unusually high amounts of runoff over the past two years prompted this action. The flow records collected during this time were analyzed, with the results discussed below.

Due to the changing geologic conditions, the river was divided into two reaches, which will be discussed separately. The upper reach extends from Wheatland Reservoir No. 2 to the Cramer Ditch. In this reach, the Laramie River traverses through a wide alluvial valley for approximately 10 miles. The river then enters a narrow canyon and flows for approximately 27 miles. The lower reach, which traverses through a narrow alluvial valley for approximately 14 miles, extends from the Cramer Ditch to the confluence of the Laramie River and Sybille Creek.

The past ten years of flow records were also analyzed. These results are included in the discussion below.

Upper Reach

The flows in this reach of the Laramie River were monitored from September 19 to October 23, 1984. The data collected during this period are plotted on Figure 12 in the form of hydrographs. The data are also listed in Appendix A. In Figure 12, the inflow hydrograph represents the flow measured by the "Wheatland Reservoir No. 2 Outflow" and "No. 3 Outflow" gaging stations, and the outflow hydrograph is that flow measured at "Laramie River above Cramer Ditch." The diversion hydrograph is the flow diverted by the

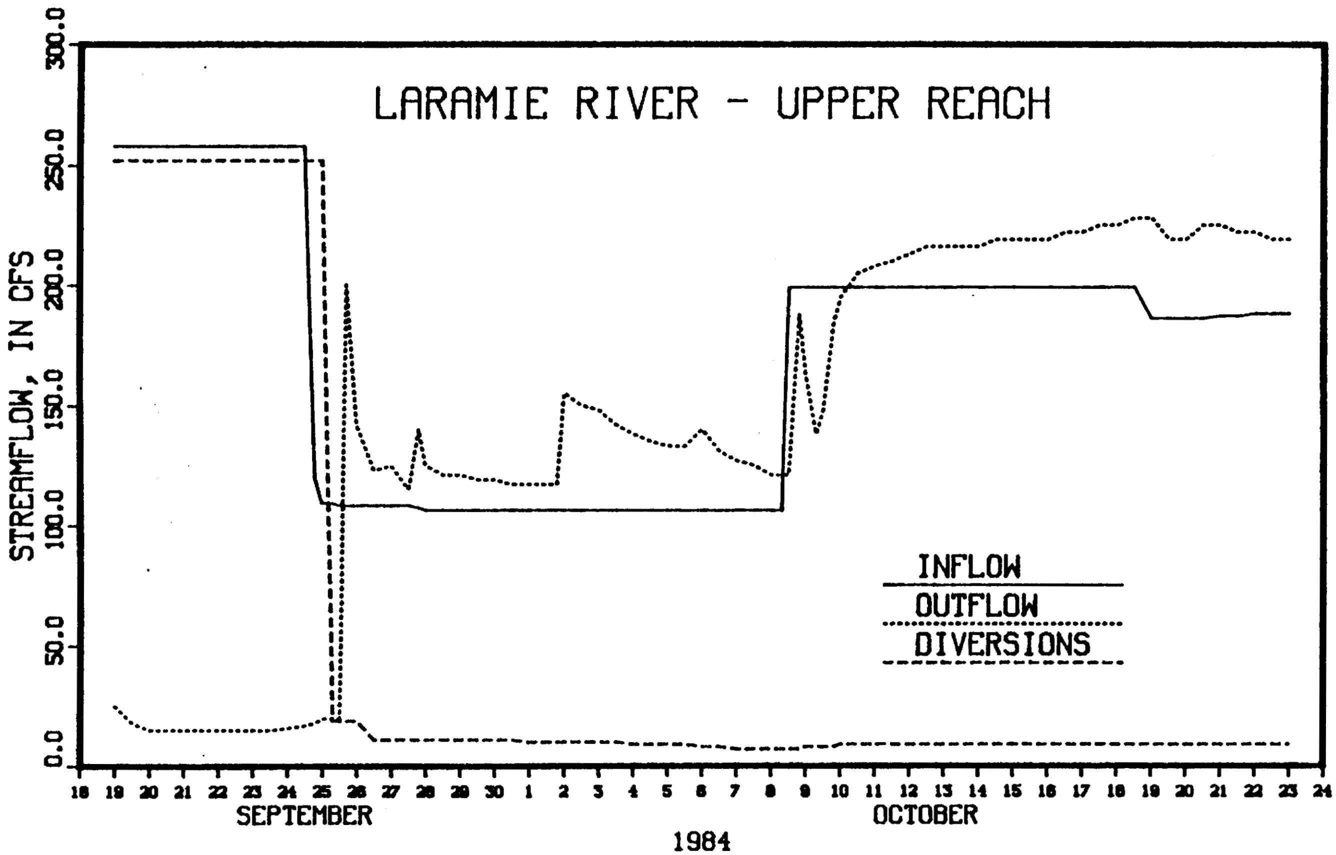

Figure 12. Laramie River Inflow, Outflow, and Diversions, Upper Reach

Wheatland Tunnel. During the larger flows on the river, the "Laramie River below Wheatland Tunnel" gaging station's Parshall flume was washed out, preventing the collection of any useful data. In this reach, there are several springs and small creeks that flow into the river. Due to the rugged terrain, these flows were not gaged. Their contribution to the flow was assumed to be constant during this study.

Figure 13 presents the flow hydrographs in a more understandable form in which the inflow and the diversion hydrographs were combined to create an "inflow minus diversion hydrograph" or net inflow hydrograph. In comparing the two hydrographs on Figure 13, the gains to the river in this reach are readily noticeable. It is also obvious that there is no decrease in the gains during the release but, rather, a sporadic increase. This lack of stability in the system at this time was due, in part, to runoff from several precipitation events during the course of the study. Because of this condition, no conveyance losses could be determined in the Upper Reach.

Lower Reach

The data collected in this reach are plotted on Figure 14 in the form of hydrographs. The data are also listed in Appendix A. In Figure 14, the inflow hydrograph represents the flow measured by the "Laramie River above Cramer Ditch" gaging station, and the outflow hyrograph is that flow measured at "Laramie River above Sybille Creek." During this period, the thirteen irrigation ditches on this reach were not diverting water.

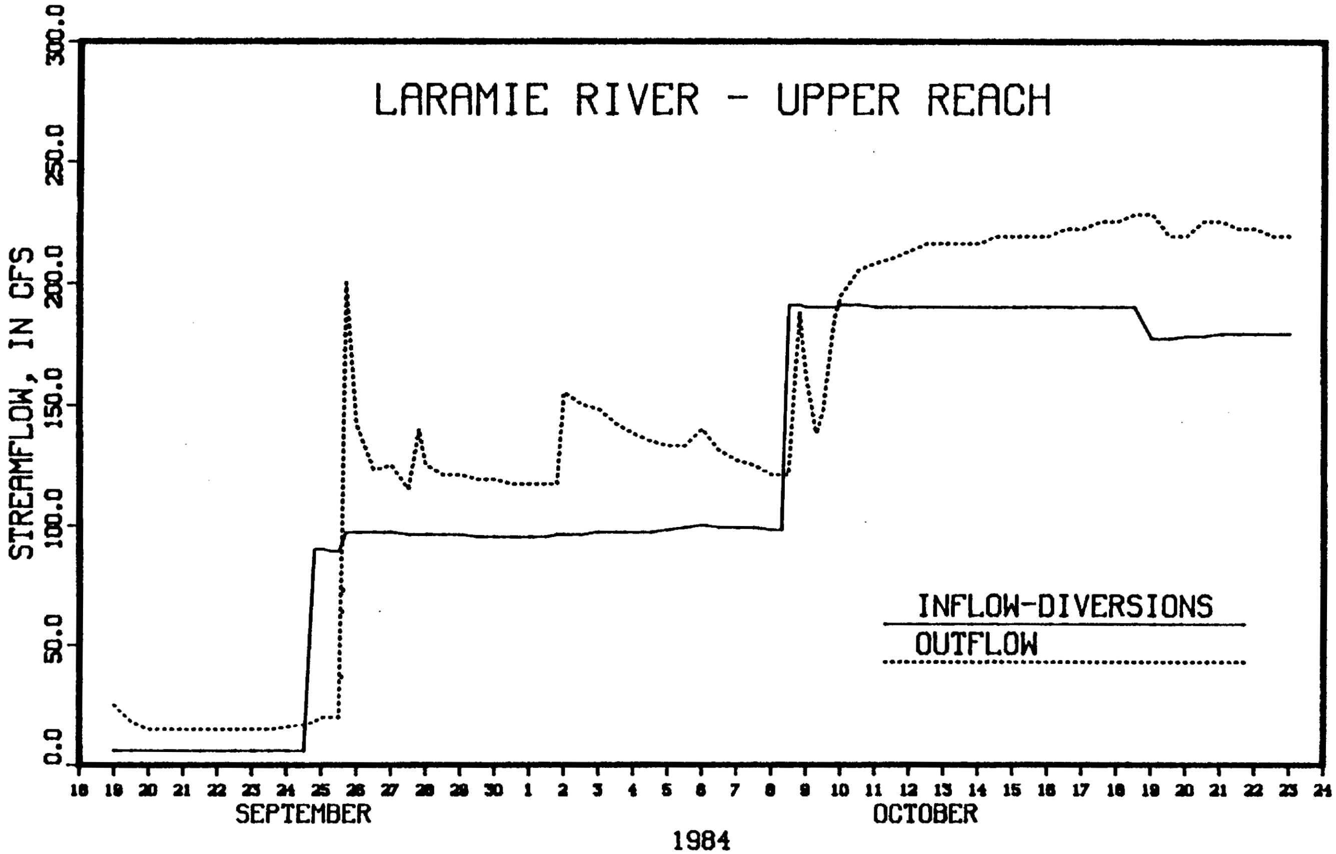

Figure 13. Laramie River Net Inflow and Outflow, Upper Reach

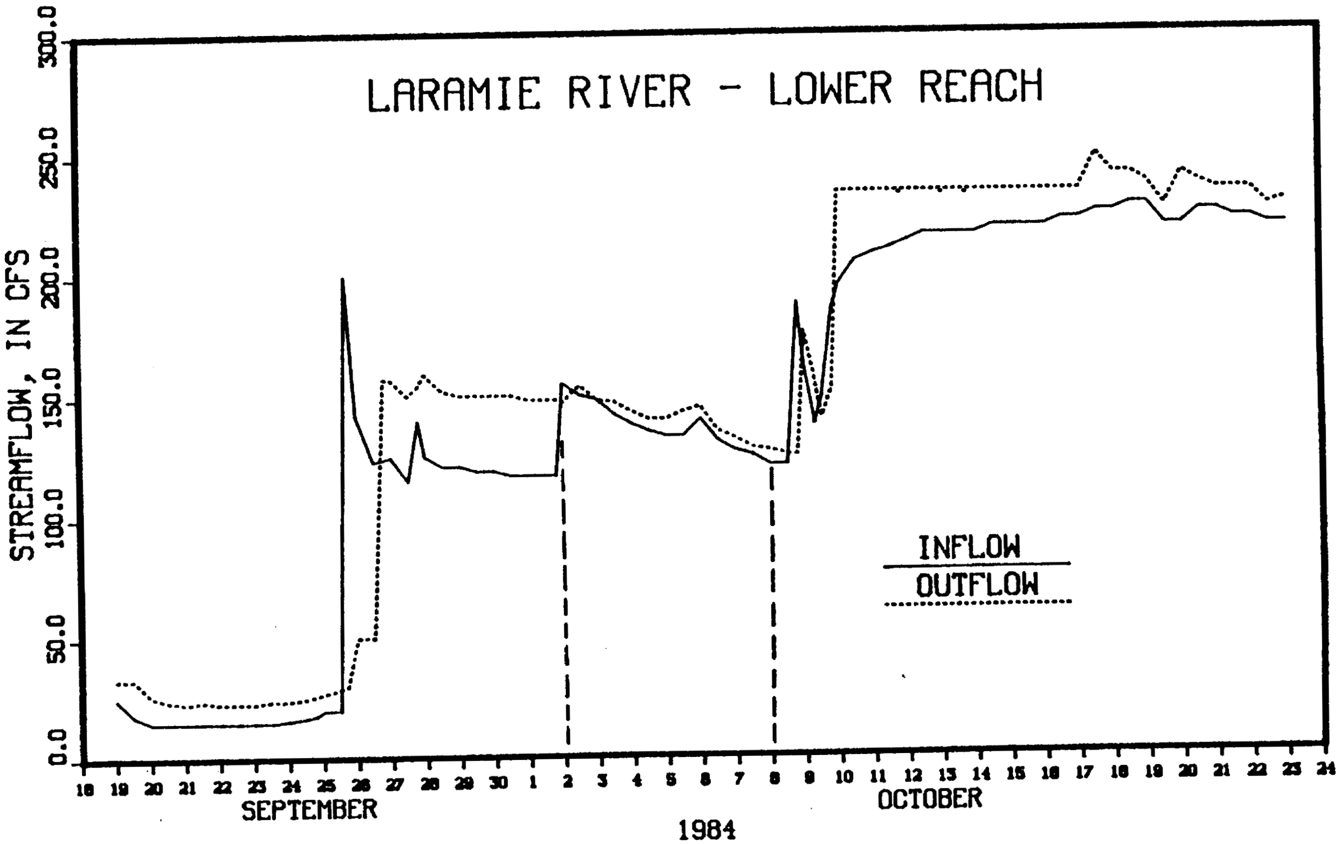

Figure 14. Laramie River Inflow and Outflow, Lower Reach

Prior to any increase in flow, the system was stable with constant gains to the river. However, once additional water was passing through the system, the inflow hydrograph became very sporadic due to runoff from rainfall. The outflow hydrograph does not reflect some of the variations in the inflow due to instrumentation difficulties. From September 26 to October 2 and from October 8 to October 17, the stage data collected at the "Above Sybille Creek" gaging station was unreliable. The large increases in the flow during these periods caused a rapid rise in the recorder's float system and disconnected the float from the recorder. The only reliable outflow data was collected from October 2 to October 8.

Problems also existed in the inflow record collected by the State Engineer's Office. Large shifts in the rating curve were experienced at this location due to the unusually high flows of the past two years. Based upon two current meter measurements, there was a +0.13 foot shift in the curve in September and a -0.13 foot shift in October. A shift of -.13 in the rating curve was used, since this measurement was taken at a time near the period when reliable data was collected at the outflow station.

For the reasons stated above, conveyance losses were determined only for the period of record from October 2 to October 8. Since there was no recession in the release hydrographs, the base flow separation technique used with the Piney Creek releases was not directly applicable to the Laramie River Study. With no recession, the increases in the inflow and the outflow could not actually be calculated in terms of the volume; so the flow rate approach was the only one used.

During the period of reliable data, the inflow increased an average of 114.6 c.f.s., and the outflow increased an average of 109.0 c.f.s. Use of these values in Equation 3.3 resulted in an average loss of 5.6 c.f.s. or 0.34 pecent per mile of the river. A range of possible losses from less than 0.00 percent to 1.03 percent per mile of the river was calculated using the 95 percent confidence limits on the hydrographs. The calculation results for this study area are summarized in Table V.

As with the Piney Creek study, the majority of the measured losses on the Lower Reach of the Laramie River was assumed to be due to bank storage and a reduction in the groundwater inflow. During the release, the stage of the river was raised an average of 1.02 feet. This increase temporarily forced water into the banks and reduced the groundwater flow into the river, effectively reducing the gains to the river. Since the stream is still gaining during the release, bank storage losses were assumed to be small in comparison to losses due to a reduction in groundwater inflow.

Past Records

Ten years (1973-1983) of water records for the Upper Reach of the Laramie River were collected for the purpose of computing losses that occurred in the past. The portions of the Upper Reach that were studied in this analysis extended from the "Wheatland Reservoir No. 2 Outflow" or "Dodge Ranch" gaging stations to "Laramie River below the Wheatland Tunnel" depending upon which records were available. From these records, eight situations were found that had the degree of stability needed to utilize the methodology discussed in Chapter III. The analyses of four of the releases resulted in flow rate losses that ranged from 0.01 percent to 1.05 percent per mile. The results of the analyses are summarized in Table V. The analyses of the other four releases showed an increase in gains during the release rather than a loss; therefore, these results were not included in the summary.

The high degree of variation that the analysis of these eight releases show is probably due to the complexity of the Upper Reach. Since there are several ungaged creeks that contributed water in this reach, the stability of the river was in question, which, in turn, jeopardized the applicaiton of the methodology discussed in Chapter III. Due to the unreliable nature of the losses calculated using the historical records, no confidence limits were computed.

New Fork River Study Area

During the summer of 1984, water was released from the New Fork Lakes for irrigation purposes. The data collected during this time are plotted on Figure 15 in the form of hydrographs. The data are also listed in Appendix A. In Figure 15, the inflow hydrograph represents the sum of the flows measured by the "New Fork River below New Fork Lakes" and the "Marsh Creek" gaging stations, and the outflow hydrograph is that flow measured at "New Fork River below Barlow's." The diversion hydrograph is the sum of the water diverted by the four irrigation ditches in the study area.

Figure 16 presents the flow hydrographs in a more understandable form in which the inflow and the diversion hydrographs were combined to create an "inflow minus diversions" hydrograph or net inflow hydrograph. This plot is easier to read, and it clearly shows the

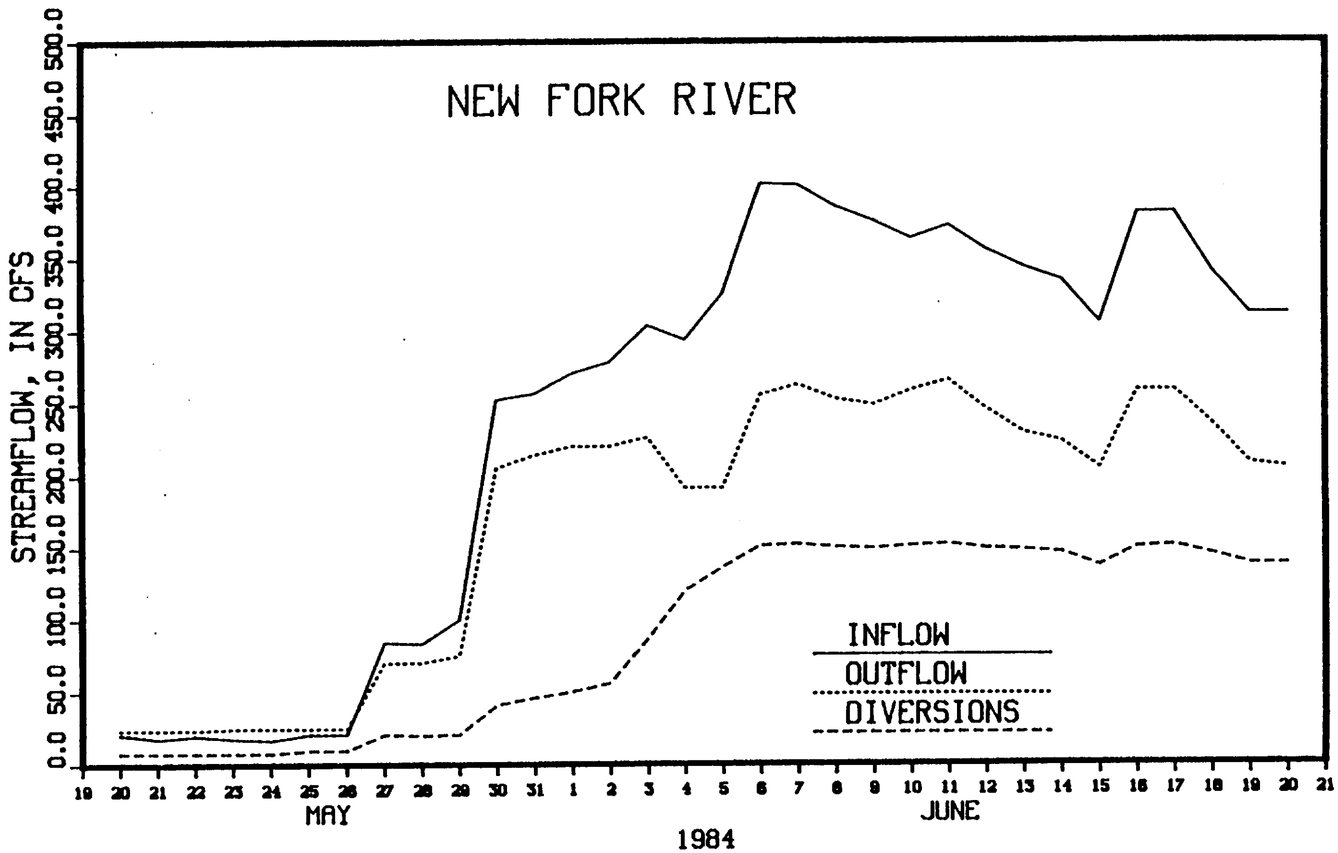

Figure 15. New Fork River Inflow, Outflow, and Diversions

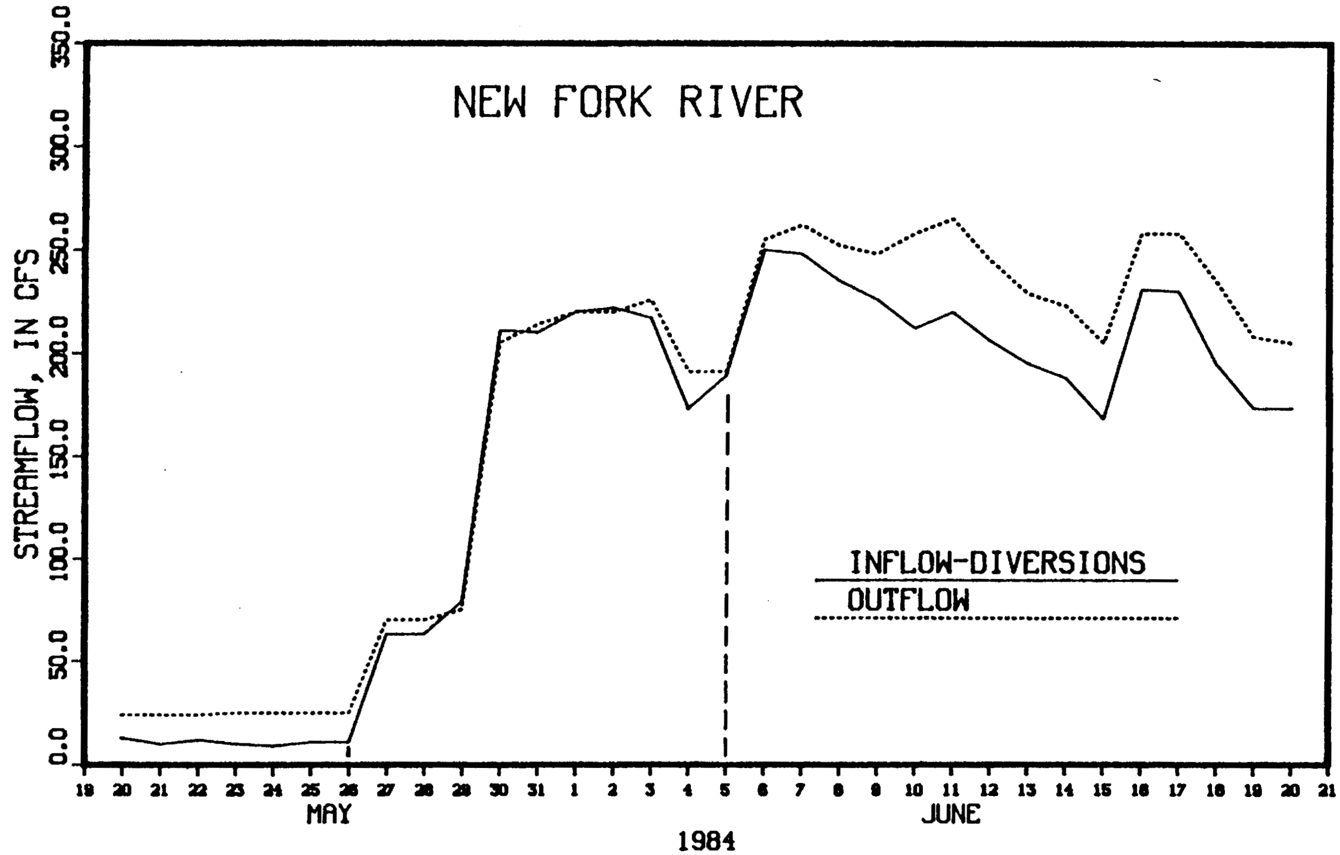

Figure 16. New Fork River Net Inflow and Outflow

constant gains that existed in the system prior to the reservoir release. As discussed in Chapter III, any decrease in these gains constitutes a conveyance loss. During the period from May 26 to June 5, a decrease in the gains was measured. After this time, the gains to the river gradually increased and exceeded the gains that were experienced prior to the release. This was the result of an increase in the irrigation activities in the area. For this reason, a conveyance loss was determined only for the period of record from May 26 to June 5.

As with the other study areas, Equation 3.3 was used to calculate losses. Since there was no recession in the hydrographs, the computations were performed in tems of the flow rate, using the values discussed below. The average increase in the inflow, ΔI, was computed to be 203.3 c.f.s., and the average increase in the outflow, ΔO, was computed to be 157.2 c.f.s. During this period, the increase in the diversions, ΔD, was 49.8 c.f.s. However, this increase in diversions could not be classified as a conveyance loss. Since the sole purpose of the reservoir release was to provide irrigation water to the ditches in the study reach and other ditches farther downstream, an increase in diversions would be expected; and, as such, the increase should not be considered a loss. These values resulted in a conveyance loss of 10.6 c.f.s. or 0.85 percent per mile of the river. Use of the 95 percent confidence limits gave a range of possible conveyance losses from 3.27 percent to less than 0.00 percent per mile of the river. The calculation results are summarized in Table V.

The majority of the measured loss on the New Fork River was assumed to be due to bank storage and a reduction in the goundwater inflow. During the release, the stage of the river rose an average of 1.26 feet. This increase temporarily forced water into the banks and reduced the goundwater flow into the river, effectively reducing the gains to the river. The hydrographs on Figure 15 show the reduction in gains that occurred from May 26 to June 5. Following this period, there ceased to be any losses to the subsurface system.

It should be noted that the conveyance loss was measured during an unstable period in which return flows were changing due to the increase in irrigation. During this time, the groundwater table was rising due to percolation from irrigation, which effectively reduced the amount of water allowed to enter bank storage from the river. Had this condition not existed, it is anticipated that the conveyance loss might have been larger than that which was measured during this study.

Comparison of the Results

With all of the releases that were studied, it was assumed that evapotranspiration and channel storage had a minimal effect on the measured conveyance losses. This assumption agrees with the results obtained by Livingston (1973) in his study of the Arkansas River. Bank storage and reductions in the groundwater inflow were considered to be the major sources of losses in the streams discussed in this paper.

These losses are shown in the data collected at each of the study areas. However, the losses are best exemplified with the Piney Creek data, due to the reliability of the results. The data that were collected on the Laramie River and the New Fork River were affected by problems associated with the instrumentation and the systems' instabilities and, as such, are not as reliable as the Piney Creek data.

The data collected for the Piney Creek study area demonstrated the high rate of loss that is typically experienced at the beginning of a reservoir release. However, in a perennial stream such as Piney Creek, the rate at which water is lost will decrease with time. As the groundwater table rises in response to the release, it is possible for the losses to become negligible. With this in mind, it can be stated that the longer the duration of a release in a perennial stream, the smaller will be the conveyance loss. This is not necessarily true in ephemeral streams where the groundwater table may be several feet below the stream bed.

The water that was considered to be lost due to the releases in Piney Creek, the lower reach of the Laramie River, and the New Fork River was not actually lost to the systems, but was merely detained in the alluvial materials bordering these streams. Nevertheless, the detention of the water did result in noticeable reductions in the inflow hydrographs and was, therefore, viewed as a loss. In the case of Piney Creek, it was assumed that most of the detained water returned to the river following the recessions of the release hydrographs. However, since the hydrographs showed little evidence of this actually occurring, it was assumed that the stored water was released at a rate which was initially high (small compared to total flow), but rapidly decreased with time. A similar observation was made by Livingston (1973).

With no reductions in the monitored flows on the lower reach of the Laramie River and the New Fork River, it was not possible to examine the hydrograph recession characteristics particular to these streams. However, the geological conditions that exist on these two reaches are similar to those on Piney Creek; so it is expected that the hydrograph recession characteristics would also be similar. If this is the case, there was a minimal amount of actual losses to any of these reaches. Any actual losses that existed would have been due to an increase in deep percolation to other groundwater formations, evapotranspiration, etc. It is felt that no water in these three reaches was lost through deep percolation. However, the geologic conditions that exist on the upper reach of the Laramie River prevent this assumption from applying to its situation. Nevertheless, a portion of the detained water that was assumed to return in each of the study areas could be considered to be lost, since the accuracy of present measurement techniques is not sufficient enough to account for its existence at the low flows.

The data collected in 1984 at the three study areas resulted in loss values ranging from 0.34 to 1.66 percent per river mile. These results are average losses for the particular stream reaches. It is expected that the incremental losses, in percent per mile, were high at the upper end of the reaches, but decreased as the releases traveled downstream since stream losses gradually reduced the amount of the increase and, consequently, the amount of the incremental losses.

In comparison to those losses measured in Colorado, which ranged from 0.02 to 0.35 percent per river mile, the average incremental losses measured at the three study areas are rather high. Several factors could have accounted for the difference in the results.

In the first place, the durations of the releases in the Colorado studies were generally longer than those reported in this paper. As stated earlier, the longer the duration of the release, the smaller the loss in terms of percentages.

Secondly, a difference in geologic conditions between the Wyoming and the Colorado study areas could have accounted for the contrast in the results. For example, the hydraulic characteristics of the material surrounding a study reach can have a large influence on the rate at which water from the stream will enter the banks during a release.

Another reason for the dissimilarity between the results could be the fact that the study reaches in Colorado were several times longer than the Wyoming reaches. In general, a short reach will experience a smaller total loss of water than will a long reach. Since the accuracy of many gaging stations' records is in the neighborhood of ±5 percent, any small losses in this range will be difficult to detect. The larger losses in the longer reaches will be affected to a lesser degree by uncertainties in the gaging stations' records. As such, the data collected from studies of long reaches will probably yield more reliable results. This makes it difficult to compare the results from studies of short reaches to those of long reaches. The effect that the uncertainties in the flow records have on the conveyance loss results from short study reaches can be large, as shown with the 95 percent confidence limits listed in Table V.

As discussed in Chapter II, the Board of Control, in its approval of water tansfers, has assigned total losses ranging from 0.2 to 0.9 percent per mile. However, due to the difference between water transfers and reservoir releases, it is difficult to compare these values to the incremental losses reported in this paper.

In the case of a water transfer, there is no "sudden" increase in streamflow as there is with a reservoir release. Without the sudden increase in flow, no water is lost due to bank storage and a reduction in groundwater inflow, these being the major sources of loss for a reservoir release. The main sources of incremental loss for a water transfer are water surface evaporation and evapotranspiration. With a release, evaporation and evapotranspiration losses are usually very small in comparison to other losses.

Because of these differences, incremental losses due to reservoir releases cannot be applied directly to water transfer cases. A total loss approach may be more appropriate, where the water transfer shares in a portion of the total river losses. This is currently the view that the Board of Control has taken with transfers. However, the determination of total losses can be rather expensive, and the process is not without errors.

In the review of transfers, the Board of Control must also examine the effects the transfer may have on the historic return flows. The Wyoming state statutes declare that a water transfer shall not decrease the historic amount of return flows. Following a transfer, a portion of land will no longer be irrigated and, as a result, there will be a reduction in return flows from that land. To prevent this reduction from occurring, additional losses may have to be assigned to the water transfer.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conveyance losses in streams are highly variable since they are influenced by a multitude of factors. Measurement of the losses due to each of these factors can be difficult, if not impossible. The methodology that was presented in this paper greatly simplified the problem. With the use of this methodology, conveyance losses were determined for three streams in the State of Wyoming. The conveyance loss results for these reaches ranged from 0.34 to 1.66 percent per mile. These results were rather high compared to those measured from previous studies in Colorado.

The approach taken in this study is applicable to other streams; however, certain limitations exist with its use. The system being studied must be in a stable condition in order to obtain reliable results. Even so, stability does not insure accurate results. When taking into account the uncertainty in the gaging stations' rating curves, a large range in the actual losses is possible.

Conclusions

Several conclusions can be drawn concerning conveyance losses based on the results obtained from this study and from the several previous studies included in the literature review. These conclusions are:

1. Incremental losses in a gaining perennial stream can be divided into five sources of loss: evapotranspiration, inadvertent diversions, channel storage, bank storage, and a reduction in groundwater inflow. The extent to which each of these sources contribute to the loss is dependent upon the conditions in the stream reach in question.
2. Water lost due to bank storage and a reduction in groundwater inflow is not a true loss to the system since the water is merely stored in the alluvium during an increase in flow. Following a decrease in the flow, most of this water may return to the river. However, its contribution to the system may become very small with time, making it difficult for this water to be accounted for by the hydrographer.
3. The value of the conveyance loss in a given reach is dependent upon the amount and duration of the reservoir release. It is also influenced by the flow in the stream, the moisture conditions in the banks, the gains to the stream prior to the release, and the hydraulic characteristics of the stream and the alluvium..
4. The limited accuracy of the gaging stations' rating curves contributes to the uncertainty of the calculated conveyance loss as illustrated with the 95 percent confidence limits reported in this paper. However, the degree of uncertainty can be minimized by insuring that the conveyance loss is larger than the inaccuracy of the rating curves. This can

be achieved by releasing a sufficient quantity of water into a long stream reach. Nevertheless, as techniques for the measurement of surface flow improve, so will the reliability of conveyance loss calculations.

5. The approach taken in this paper dealt with sudden increases in flow for short periods of time. In the case of a water transfer, there is not necessarily a sudden increase in flow; and the water that is transferred may be conveyed in the stream for long periods of time. For these reasons, the incremental approach may not be directly applicable to water transfers unless water stored in reservoirs is involved. Total losses may be more usable; however, their determination would require a considerable monitoring network. The cost of such a project would be large, and the quantity of water that is saved may not warrant this approach.

Recommendations

Several recommendations can be made concerning future work with conveyance losses and with the use of the methodology presented in this paper. These recommendations are:

1. In order to reduce the uncertainty in the flow records and increase the reliability of the study results, it is desirable to take numerous flow measurements for the establishment of the gaging stations' rating curves.

2. It may be helpful to maintain the reservoir releases for a longer period of time in order to better understand the factors influencing the losses.

3. Additional research concerning the relationship between evapotranspiration and the depth to the water table would provide useful information for future conveyance loss studies.

4. Application of the computer model developed by Luckey and Livingston (1975) may be useful in future conveyance loss studies dealing with reservoir releases.

5. It may be helpful to perform future studies examining total losses rather than incremental loss. It appears that the total loss approach may be more appropriate for determining water transfer losses.

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A P P E N D I C E S

APPENDIX A

FLOW RECORDS FOR PINEY CREEK, LARAMIE RIVER AND NEW FORK RIVER STUDY AREAS

APPENDIX A-1

PINEY CREEK FLOW RECORDS

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/9/84	2:00 AM	125.0	74.1	84.5
		125.0	72.8	84.3
		125.0	72.8	84.2
		125.0	72.8	79.9
		125.0	74.1	76.7
		125.0	75.4	76.5
		122.9	75.4	76.5
		120.7	75.4	76.4
		120.7	75.4	77.2
		120.7	75.4	77.0
		120.7	75.4	77.0
8/10/84	12:00 AM	120.7	74.1	76.3
		120.7	72.8	76.0
		120.7	72.8	74.4
		120.7	74.1	73.5
		120.7	75.4	76.5
		120.7	75.4	76.3
		120.7	75.4	76.2
		120.7	74.1	76.1
		120.7	72.8	76.4
		114.4	72.8	76.3
		114.4	72.8	76.2
		114.4	72.8	76.2
8/11/84	12:00 AM	114.4	72.8	76.2
		114.4	72.8	75.3
		114.4	70.3	73.8
		114.4	69.1	74.0
		114.4	70.3	84.2
		114.4	70.3	84.1
		114.4	70.3	84.1
		114.4	64.3	83.6
		114.4	64.3	83.0
		114.4	63.2	82.9
		114.4	64.3	82.7
		114.4	64.3	82.7

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/12/84	12:00 AM	114.4	64.3	82.7
		114.4	64.3	82.4
		114.4	63.2	82.4
		114.4	63.2	82.4
		114.4	64.3	82.4
		114.4	64.3	82.4
		114.4	64.3	82.3
		114.4	65.5	82.3
		114.4	64.3	82.2
		114.4	65.5	82.2
		114.4	66.7	82.2
		114.4	66.7	81.2
8/13/84	12:00 AM	114.4	66.7	81.2
		114.4	66.7	81.5
		114.4	66.7	81.4
		114.4	66.7	80.8
		114.4	66.7	81.4
		114.4	66.7	81.4
		114.4	66.7	81.4
		114.4	66.7	81.4
		114.4	66.7	81.4
		114.4	65.5	81.3
		114.4	65.5	81.3
		114.4	66.7	81.0
8/14/84	12:00 AM	114.4	66.7	81.0
		114.4	69.1	80.4
		114.4	69.1	80.4
		114.4	69.1	80.2
		114.4	69.1	80.2
		114.4	69.1	80.2
		114.4	70.3	80.4
		114.4	70.3	80.2
		114.4	69.1	80.2
		114.4	67.9	80.2
		114.4	67.9	80.7
		114.4	69.1	80.9

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/15/84	12:00 AM	114.4	69.1	80.9
		114.4	69.1	80.7
		114.4	69.1	80.5
		114.4	69.1	80.5
		114.4	69.1	79.9
		106.3	69.1	80.2
		106.3	69.1	80.0
		106.3	69.1	79.9
		106.3	69.1	79.9
		106.3	69.1	79.3
		106.3	70.3	78.3
		106.3	70.3	77.1
8/16/84	12:00 AM	106.3	70.3	76.5
		106.3	64.3	74.2
		106.3	63.2	74.1
		106.3	63.2	75.3
		106.3	63.2	73.8
		106.3	63.2	73.8
		106.3	63.2	73.9
		106.3	63.2	73.8
		106.3	63.2	73.3
		106.3	62.1	73.1
		106.3	62.1	73.1
		106.3	62.1	73.1
8/17/84	12:00 AM	106.3	62.1	72.5
		106.3	62.1	72.4
		106.3	63.2	72.6
		106.3	64.3	72.1
		127.2	64.3	72.3
		127.2	64.3	72.5
		127.2	66.7	73.6
		127.2	66.7	73.8
		127.2	65.5	75.0
		127.2	66.7	75.3
		127.2	70.3	76.7
		127.2	82.1	78.9

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/18/84	12:00 AM	127.2	83.5	78.9
		127.2	83.5	79.0
		127.2	84.9	79.2
		127.2	84.9	79.2
		127.2	84.9	79.3
		127.2	87.7	79.1
		127.2	87.7	78.9
		127.2	86.3	78.9
		127.2	84.9	78.6
		127.2	84.9	78.7
		127.2	84.9	78.7
		127.2	84.9	78.7
8/19/84	12:00 AM	127.2	83.5	78.7
		127.2	83.5	78.5
		127.2	83.5	78.7
		127.2	83.5	78.7
		127.2	84.9	78.7
		127.2	89.2	68.3
		127.2	90.7	70.1
		127.2	101.6	70.4
		127.2	101.6	71.4
		127.2	103.3	71.4
		127.2	100.0	71.4
		127.2	98.4	71.4
8/20/84	12:00 AM	127.2	98.4	71.4
		127.2	98.4	71.4
		127.2	98.4	70.4
		127.2	98.4	70.4
		127.2	98.4	70.4
		127.2	103.3	65.1
		131.6	103.3	63.0
		131.6	103.3	63.0
		131.6	101.6	63.0
		131.6	101.6	63.0
		131.6	101.6	63.1
		131.6	101.6	63.1

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/21/84	12:00 AM	131.6	101.6	63.0
		131.6	100.0	62.6
		131.6	100.0	62.6
		131.6	101.6	62.6
		131.6	101.6	60.2
		131.6	104.9	60.2
		131.6	103.3	60.1
		131.6	103.3	59.9
		131.6	101.6	59.8
		131.6	101.6	59.6
		131.6	101.6	59.6
		129.4	101.6	59.6
8/22/84	12:00 AM	129.4	101.6	59.6
		129.4	101.6	59.1
		131.6	101.6	59.1
		131.6	101.6	58.4
		131.6	101.6	59.5
		131.6	101.6	59.4
		131.6	101.6	59.3
		131.6	100.0	59.3
		131.6	98.4	59.4
		131.6	101.6	55.7
		131.6	101.6	55.7
		131.6	101.6	55.7
8/23/84	12:00 AM	131.6	101.6	55.7
		138.4	103.3	56.3
		138.4	103.3	56.4
		140.7	103.3	56.4
		140.7	106.6	56.6
		140.7	106.6	48.8
		147.7	110.0	48.8
		147.7	111.8	48.9
		147.7	120.8	49.7
		145.3	118.9	49.7
		143.0	118.9	49.6
		140.7	120.8	49.5

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/24/84	12:00 AM	140.7	120.8	49.5
		143.0	120.8	48.8
		143.0	117.1	48.3
		143.0	117.1	48.3
		177.4	115.3	43.6
		177.4	118.9	33.6
		177.4	122.6	34.2
		177.4	128.4	34.7
		177.4	124.5	35.6
		177.4	151.1	37.6
		174.8	153.4	37.9
		174.8	151.1	37.7
8/25/84	12:00 AM	174.8	151.1	37.6
		177.4	151.1	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		177.4	149.0	37.1
		174.8	149.0	37.0
		174.8	149.0	37.0
8/26/84	12:00 AM	174.8	149.0	37.0
		177.4	149.0	37.0
		177.4	149.0	37.0
		177.4	149.0	37.0
		177.4	149.0	37.0
		177.4	151.1	37.0
		177.4	151.1	36.9
		174.8	149.0	36.9
		172.3	146.8	37.5
		172.3	144.7	37.6
		172.3	144.7	37.0
		172.3	144.7	36.6

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/27/84	12:00 AM	172.3	144.7	35.4
		172.3	144.7	35.4
		172.3	144.7	35.4
		172.3	144.7	35.4
		125.0	144.7	35.4
		125.0	144.7	34.4
		122.9	144.7	33.6
		122.9	128.4	33.5
		122.9	101.6	38.8
		120.7	98.4	38.4
		120.7	96.8	38.4
		120.7	96.8	38.4
8/28/84	12:00 AM	116.5	96.8	38.4
		114.4	95.3	37.9
		114.4	95.3	37.9
		114.4	95.3	37.9
		114.4	93.7	37.9
		114.4	90.7	39.4
		114.4	90.7	39.2
		114.4	90.7	39.2
		114.4	87.7	39.3
		114.4	87.7	39.1
		114.4	87.7	39.1
		114.4	86.3	39.1
8/29/84	12:00 AM	114.4	86.3	39.1
		114.4	86.3	39.1
		114.4	86.3	39.1
		114.4	83.5	39.1
		114.4	83.5	42.6
		114.4	83.5	42.6
		114.4	83.5	42.5
		114.4	82.1	42.5
		114.4	82.1	42.6
		114.4	83.5	42.6
		114.4	83.5	42.6
		114.4	83.5	42.6

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
8/30/84	12:00 AM	114.4	83.5	42.6
		114.4	83.5	42.2
		114.4	83.5	42.1
		114.4	83.5	42.0
		114.4	84.9	45.1
		114.4	84.9	45.3
		114.4	84.9	45.3
		114.4	82.1	45.5
		114.4	82.1	46.8
		114.4	82.1	42.1
		114.4	82.1	42.1
		110.3	83.5	42.1
8/31/84	12:00 AM	110.3	84.9	42.1
		110.3	84.9	41.8
		112.4	84.9	41.8
		112.4	84.9	44.7
		112.4	83.5	48.5
		112.4	83.5	48.4
		112.4	83.5	48.3
		112.4	83.5	48.4
		112.4	80.7	48.4
		112.4	80.7	45.4
		112.4	80.7	45.4
		112.4	82.1	45.8
9/1/84	12:00 AM	112.4	83.5	45.4
		112.4	83.5	44.5
		112.4	83.5	44.5
		112.4	83.5	44.5
		112.4	83.5	45.8
		112.4	84.9	45.8
		112.4	84.9	45.8
		112.4	83.5	45.6
		112.4	83.5	45.7
		112.4	84.9	45.8
		112.4	86.3	45.8
		112.4	86.3	45.0

PINEY CREEK 2 HOURLY FLOW RECORDS -- 1ST RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	DIVERSIONS C.F.S.
9/2/84	12:00 AM	112.4	86.3	44.9
		112.4	86.3	40.2
		112.4	87.7	40.2
		112.4	87.7	40.1
		112.4	87.7	40.2
		112.4	87.7	40.4
		112.4	93.7	40.3

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/9/84	2:00 AM	8.7	2.7	3.4	0.5	6.5
		8.7	2.7	3.4	0.5	6.5
		8.7	2.7	3.4	0.5	6.5
		5.5	2.7	3.1	0.5	6.5
		3.5	2.8	1.8	0.5	6.5
		3.5	2.7	1.7	0.5	6.5
		3.5	2.7	1.7	0.5	6.5
		3.4	2.7	1.7	0.5	6.5
		3.4	2.7	1.7	0.5	7.4
		3.4	2.7	1.7	0.5	7.4
		3.4	2.7	1.7	0.5	7.4
8/10/84	12:00 AM	2.6	2.7	1.7	0.5	7.4
		2.5	2.7	1.7	0.5	7.2
		1.0	2.7	1.7	0.5	7.2
		1.0	2.7	1.7	0.5	7.2
		3.9	2.7	1.7	0.5	7.2
		3.9	2.7	1.7	0.5	7.2
		3.9	2.7	1.7	0.5	7.2
		3.9	2.7	1.7	0.5	7.2
		3.9	3.1	1.7	0.5	7.2
		3.8	3.1	1.7	0.5	7.2
		3.7	3.0	1.7	0.5	7.2
		3.7	3.0	1.7	0.5	7.2
8/11/84	12:00 AM	3.7	3.0	1.7	0.5	7.2
		3.7	3.0	1.7	0.5	7.1
		3.7	3.0	1.7	0.5	7.1
		3.8	3.1	1.7	0.5	7.1
		3.8	3.1	1.7	0.5	7.1
		3.7	3.1	1.7	0.5	7.1
		3.7	3.0	1.7	0.5	7.1
		3.7	3.0	1.7	0.5	7.1
		3.7	3.0	1.7	0.5	7.1
		3.7	3.0	1.7	0.5	7.1
		3.7	3.0	1.7	0.5	6.9
		3.7	3.0	1.7	0.5	6.9

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/12/84	12:00 AM	3.7	3.0	1.7	0.5	6.9
		3.7	3.0	1.7	0.5	6.9
		3.7	3.0	1.7	0.5	6.9
		3.7	3.0	1.7	0.5	6.9
		3.7	3.0	1.7	0.5	6.9
		3.7	3.0	1.7	0.5	6.9
		3.6	3.0	1.7	0.5	6.9
		3.6	3.0	1.7	0.5	6.9
		3.5	3.0	1.7	0.5	6.9
		3.5	3.0	1.7	0.5	6.9
		3.5	3.0	1.7	0.5	6.9
		2.5	3.0	1.7	0.5	6.9
8/13/84	12:00 AM	2.5	3.0	1.7	0.5	6.9
		2.5	3.1	1.7	0.5	6.9
		2.5	3.1	1.7	0.5	6.9
		1.8	3.1	1.7	0.5	6.9
		2.4	3.1	1.7	0.5	6.9
		2.4	3.1	1.7	0.5	6.9
		2.4	3.1	1.7	0.5	6.9
		2.4	3.1	1.7	0.5	6.9
		2.4	3.1	1.7	0.5	6.9
		2.3	3.1	1.7	0.5	6.9
		2.3	3.1	1.7	0.5	6.9
		2.0	3.1	1.7	0.5	6.9
8/14/84	12:00 AM	2.1	3.1	1.7	0.5	6.9
		1.8	3.1	1.7	0.5	6.9
		1.8	3.1	1.7	0.5	6.9
		1.7	3.1	1.7	0.5	6.9
		1.7	3.1	1.7	0.5	6.9
		1.6	3.1	1.7	0.5	6.9
		1.6	3.1	1.7	0.5	6.9
		1.6	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/15/84	12:00 AM	1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.5	3.1	1.7	0.5	6.9
		1.4	3.1	1.7	0.5	6.9
		1.4	3.1	1.6	0.5	6.9
		1.3	3.1	1.6	0.5	6.9
		1.3	3.1	1.6	0.5	6.9
		1.3	2.9	1.6	0.5	6.9
		1.3	2.9	1.6	0.5	6.3
		1.3	2.9	1.6	0.5	6.3
8/16/84	12:00 AM	1.3	2.9	1.6	0.5	6.3
		1.2	2.9	1.6	0.5	6.3
		1.2	2.9	1.6	0.5	6.3
		2.5	2.9	1.6	0.5	6.3
		2.8	2.9	1.6	0.5	6.3
		2.8	2.9	1.6	0.5	6.3
		2.8	2.9	1.5	0.5	6.5
		2.8	2.9	1.5	0.5	6.5
		2.7	2.8	1.5	0.5	6.3
		2.7	2.8	1.5	0.5	6.2
		2.7	2.8	1.5	0.5	6.2
		2.7	2.8	1.5	0.5	6.2
8/17/84	12:00 AM	2.7	2.8	1.5	0.5	6.2
		2.7	2.8	1.6	0.5	6.3
		2.7	2.9	1.6	0.5	6.5
		2.8	2.9	1.5	0.5	6.6
		2.8	2.9	1.5	0.5	6.6
		2.8	2.9	1.5	0.5	6.6
		3.2	3.1	1.5	0.5	6.6
		3.2	3.1	1.5	0.5	6.6
		3.2	3.1	1.6	0.5	7.2
		3.2	3.1	1.6	0.5	7.2
		3.2	3.1	1.6	0.5	7.2
		3.2	3.1	1.6	0.5	7.2

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/18/84	12:00 AM	3.2	3.1	1.6	0.5	7.2
		3.2	3.1	1.4	0.5	7.2
		3.2	3.2	1.4	0.5	7.4
		3.2	3.2	1.4	0.5	7.4
		3.2	3.2	1.4	0.5	7.5
		3.1	3.2	1.4	0.5	7.4
		3.1	3.2	1.3	0.5	7.2
		3.1	3.2	1.3	0.5	7.2
		3.0	3.1	1.4	0.5	7.2
		3.3	3.1	1.4	0.5	7.1
		3.3	3.1	1.4	0.5	7.1
		3.3	3.1	1.4	0.5	7.1
8/19/84	12:00 AM	3.3	3.1	1.4	0.5	7.1
		3.3	3.1	1.3	0.5	7.1
		3.3	3.1	1.3	0.5	7.2
		3.3	3.1	1.3	0.5	7.2
		3.3	3.1	1.3	0.5	7.2
		3.3	3.2	1.3	0.5	7.2
		3.3	3.2	1.5	0.5	7.5
		3.3	3.2	1.4	0.5	7.5
		3.3	3.2	1.5	0.5	7.4
		3.3	3.2	1.5	0.5	7.4
		3.3	3.2	1.5	0.5	7.4
		3.3	3.2	1.5	0.5	7.4
8/20/84	12:00 AM	3.3	3.2	1.5	0.5	7.4
		3.7	3.2	1.3	0.5	7.4
		2.8	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.5
		2.7	3.2	1.3	0.5	7.5
		2.7	3.2	1.3	0.5	7.5
		2.7	3.2	1.3	0.5	7.5
		2.7	3.2	1.3	0.5	7.5
		2.7	3.2	1.3	0.5	7.5
		2.6	3.2	1.3	0.5	7.5
		2.6	3.2	1.3	0.5	7.5

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/21/84	12:00 AM	2.6	3.2	1.3	0.5	7.5
		2.6	3.2	1.3	0.5	7.5
		2.6	3.2	1.3	0.5	7.5
		2.6	3.2	1.3	0.5	7.5
		2.6	3.2	1.3	0.5	7.5
		2.5	3.2	1.3	0.5	7.5
		2.5	3.2	1.3	0.5	7.5
		2.5	3.2	1.3	0.5	7.4
		2.5	3.2	1.3	0.5	7.2
		2.5	3.2	1.3	0.5	7.2
		2.5	3.2	1.3	0.5	7.2
		2.5	3.2	1.3	0.5	7.2
8/22/84	12:00 AM	2.5	3.2	1.3	0.5	7.2
		2.5	3.2	1.3	0.5	7.4
		2.5	3.2	1.3	0.5	7.4
		1.7	3.2	1.3	0.5	7.4
		2.8	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
		2.7	3.2	1.3	0.5	7.4
8/23/84	12:00 AM	2.7	3.2	1.3	0.5	7.4
		2.6	3.2	1.4	0.5	7.7
		2.6	3.2	1.4	0.5	7.7
		2.3	3.3	1.4	0.5	7.7
		2.3	3.3	1.4	0.5	7.7
		2.3	3.3	1.4	0.5	.0
		2.3	3.3	1.4	0.5	.0
		2.3	3.3	1.4	0.5	.0
		2.3	3.3	1.2	0.5	.0
		2.3	3.3	1.3	0.5	.0
		2.2	3.3	1.3	0.5	.0
		2.2	3.3	1.2	0.5	.0

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/24/84	12:00 AM	2.2	3.3	1.2	0.5	.0
		2.1	3.3	1.2	0.5	.0
		2.1	3.3	1.2	0.5	.0
		2.1	3.3	1.2	0.5	.0
		2.1	3.3	1.2	0.5	.0
		2.5	3.5	1.2	0.5	.0
		2.5	3.5	1.3	0.5	.0
		2.4	3.5	1.3	0.5	.0
		2.4	3.5	1.4	0.5	.0
		2.3	3.5	1.4	0.5	.0
		2.3	3.5	1.4	0.5	.0
		2.3	3.5	1.3	0.5	.0
8/25/84	12:00 AM	2.2	3.5	1.3	0.5	.0
		2.1	3.5	1.3	0.5	.0
		2.1	3.5	1.3	0.5	.0
		2.1	3.5	1.3	0.5	.0
		2.1	3.5	1.3	0.5	.0
		2.1	3.5	1.3	0.5	.0
		2.0	3.5	1.3	0.5	.0
		2.0	3.5	1.3	0.5	.0
		2.0	3.5	1.3	0.5	.0
		2.0	3.5	1.3	0.5	.0
		2.0	3.5	1.3	0.5	.0
		2.0	3.5	1.3	0.5	.0
8/26/84	12:00 AM	2.0	3.5	1.3	0.5	.0
		2.0	3.5	1.2	0.5	.0
		2.0	3.5	1.2	0.5	.0
		2.0	3.5	1.2	0.5	.0
		2.0	3.5	1.2	0.5	.0
		2.0	3.5	1.2	0.5	.0
		1.9	3.5	1.1	0.5	.0
		1.8	3.5	1.2	0.5	.0
		2.5	3.5	1.2	0.5	.0
		2.7	3.5	1.2	0.5	.0
		2.6	3.5	1.2	0.5	.0
		2.6	3.5	1.2	0.5	.0

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/27/84	12:00 AM	2.5	3.5	1.2	0.5	.0
		2.5	3.5	1.2	0.5	.0
		2.5	3.5	1.2	0.5	.0
		2.5	3.5	1.2	0.5	.0
		2.5	3.5	1.2	0.5	.0
		1.8	3.2	1.2	0.5	.0
		1.7	3.0	.8	0.5	.0
		1.7	2.9	.9	0.5	.0
		1.7	2.9	1.0	0.5	.0
		1.7	2.9	1.0	0.5	.0
		1.7	2.9	1.0	0.5	.0
		1.7	2.9	1.0	0.5	.0
8/28/84	12:00 AM	1.6	2.9	1.0	0.5	.0
		1.5	2.9	1.0	0.5	.0
		1.5	2.9	.9	0.5	.0
		1.5	2.9	.9	0.5	.0
		1.5	2.9	.9	0.5	.0
		3.2	2.9	.9	0.5	.0
		3.2	2.8	.8	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
8/29/84	12:00 AM	3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.8	0.5	.0
		3.2	2.8	.8	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0
		3.2	2.8	.9	0.5	.0

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
8/30/84	12:00 AM	3.2	2.8	.9	0.5	.0
		2.8	2.8	.9	0.5	.0
		2.7	2.8	.9	0.5	.0
		2.7	2.8	.8	0.5	.0
		2.7	2.8	.8	0.5	3.1
		2.6	2.8	.8	0.5	3.4
		2.6	2.8	.8	0.5	3.4
		2.6	2.8	.8	0.5	3.6
		2.6	2.8	.9	0.5	4.8
		2.6	2.8	.9	0.5	.1
		2.6	2.8	.9	0.5	.1
		2.6	2.8	.9	0.5	.1
8/31/84	12:00 AM	2.6	2.8	.9	0.5	.1
		2.4	2.8	.8	0.5	.1
		2.4	2.8	.8	0.5	.1
		2.4	2.8	.6	0.5	3.1
		2.4	2.8	.6	0.5	3.1
		2.3	2.8	.6	0.5	3.1
		2.3	2.8	.6	0.5	3.1
		2.3	2.8	.6	0.5	3.1
		2.3	2.8	.7	0.5	3.1
		2.3	2.8	.7	0.5	.1
		2.3	2.8	.7	0.5	.1
		2.3	2.8	.6	0.5	.1
9/1/84	12:00 AM	1.8	2.8	.6	0.5	.1
		1.0	2.8	.6	0.5	.0
		1.0	2.8	.6	0.5	.0
		1.0	2.8	.6	0.5	.0
		2.3	2.8	.6	0.5	.0
		2.3	2.8	.6	0.5	.0
		2.3	2.8	.6	0.5	.0
		2.3	2.8	.6	0.5	.0
		2.3	2.8	.6	0.5	.0
		2.3	2.8	.7	0.5	.0
		2.3	2.8	.7	0.5	.0
		2.1	2.8	.6	0.5	.0

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	SENFF C.F.S.	UPPER FLYING E C.F.S.	LOWER FLYING E C.F.S.	MAVERICK C.F.S	STURDEVANT C.F.S.
9/2/84	12:00 AM	2.1	2.8	.6	0.5	.0
		2.1	2.8	.6	0.5	.0
		2.1	2.8	.6	0.5	.0
		2.0	2.8	.6	0.5	.0
		2.1	2.8	.6	0.5	.0
		2.3	2.8	.6	0.5	.0
		2.3	2.8	.5	0.5	.0

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/9/84	2:00 AM	2.3	11.3	14.9	34.3
		2.3	11.3	14.7	34.3
		2.3	11.3	14.5	34.3
		2.3	11.1	14.5	33.7
		2.3	11.1	14.5	33.7
		2.3	11.1	14.5	33.7
		2.3	11.1	14.5	33.7
		2.3	11.1	14.5	33.7
		2.3	11.0	14.5	33.7
		2.3	10.8	14.5	33.7
		2.3	10.8	14.5	33.7
8/10/84	12:00 AM	2.3	10.8	14.5	33.7
		2.3	10.8	14.5	33.7
		2.3	10.7	14.5	33.7
		1.4	10.7	14.5	33.7
		1.5	10.7	14.5	33.7
		1.5	10.6	14.5	33.7
		1.5	10.4	14.5	33.7
		1.5	10.3	14.5	33.7
		1.5	10.3	14.5	33.7
		1.5	10.3	14.5	33.7
		1.5	10.3	14.5	33.7
		1.5	10.3	14.5	33.7
8/11/84	12:00 AM	1.5	10.3	14.5	33.7
		1.5	10.3	14.3	33.2
		.0	10.3	14.3	33.2
		.0	10.3	14.3	33.2
		10.2	10.3	14.3	33.2
		10.2	10.3	14.3	33.2
		10.2	10.3	14.3	33.2
		10.2	10.3	14.3	32.7
		10.2	10.3	14.3	32.1
		10.2	10.3	14.3	32.1
		10.2	10.3	14.3	32.1
		10.2	10.3	14.3	32.1

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/12/84	12:00 AM	10.2	10.3	14.3	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
		10.1	10.3	14.1	32.1
8/13/84	12:00 AM	10.1	10.3	14.1	32.1
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
		10.1	10.3	13.7	32.7
8/14/84	12:00 AM	10.1	10.3	13.7	32.7
		10.1	10.3	13.3	32.7
		10.1	10.3	13.3	32.7
		10.1	10.3	13.3	32.7
		10.1	10.3	13.3	32.7
		10.1	10.3	13.3	32.7
		10.2	10.3	13.3	32.7
		10.2	10.2	13.3	32.7
		10.2	10.2	13.3	32.7
		10.2	10.2	13.3	32.7
		10.2	10.2	13.3	33.2
		10.2	10.2	13.5	33.2

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/15/84	12:00 AM	10.2	10.2	13.5	33.2
		10.2	10.0	13.5	33.2
		10.2	10.0	13.3	33.2
		10.2	10.0	13.3	33.2
		10.2	9.5	13.3	33.2
		10.2	9.8	13.3	33.2
		10.2	9.8	13.3	33.2
		10.2	9.8	13.3	33.2
		10.2	9.8	13.3	33.2
		10.1	9.6	13.3	33.2
		9.7	9.5	13.3	33.2
		9.7	8.8	12.9	33.2
8/16/84	12:00 AM	9.7	8.5	12.6	33.2
		9.7	8.4	12.6	31.1
		9.7	8.3	12.6	31.1
		9.7	8.3	12.6	31.1
		9.7	6.3	12.6	31.1
		9.7	6.3	12.6	31.1
		9.7	6.3	12.6	31.1
		9.7	6.2	12.6	31.1
		9.7	6.2	12.4	31.1
		9.7	6.2	12.4	31.1
		9.7	6.2	12.4	31.1
		9.7	6.2	12.4	31.1
8/17/84	12:00 AM	9.7	5.6	12.4	31.1
		9.7	5.0	12.6	31.1
		9.7	5.0	12.6	31.1
		9.7	4.4	12.6	31.1
		9.9	4.4	12.6	31.1
		9.9	4.4	12.7	31.1
		9.9	4.4	12.7	31.6
		9.9	4.4	12.9	31.6
		10.4	4.4	12.9	31.6
		10.4	4.6	12.9	31.6
		10.4	4.6	13.9	32.1
		10.4	4.6	13.9	34.3

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/18/84	12:00 AM	10.4	4.6	13.9	34.3
		10.4	4.4	13.9	34.8
		10.4	4.4	13.9	34.8
		10.4	4.4	13.9	34.8
		10.4	4.4	13.9	34.8
		10.4	4.4	13.9	34.8
		10.4	4.4	13.9	34.8
		10.4	4.4	13.9	34.8
		10.4	4.4	13.7	34.8
		10.4	4.4	13.7	34.8
		10.4	4.4	13.7	34.8
		10.4	4.4	13.7	34.8
8/19/84	12:00 AM	10.4	4.4	13.7	34.8
		10.4	4.2	13.7	34.8
		10.4	4.2	13.7	34.8
		10.4	4.2	13.7	34.8
		10.4	4.2	13.7	34.8
		1.0	4.2	13.7	33.7
		1.0	4.2	14.5	34.3
		1.0	4.2	14.5	34.8
		1.0	4.2	14.5	35.9
		1.0	4.2	14.5	35.9
		1.0	4.2	14.5	35.9
		1.0	4.2	14.5	35.9
8/20/84	12:00 AM	1.0	4.2	14.5	35.9
		.9	4.0	14.5	35.9
		.9	4.0	14.5	35.9
		.9	4.0	14.5	35.9
		.8	4.0	14.5	35.9
		.8	4.0	14.5	30.6
		.8	4.0	14.5	28.5
		.8	4.0	14.5	28.5
		.8	4.0	14.5	28.5
		.8	4.0	14.5	28.5
		.8	4.0	14.7	28.5
		.8	4.0	14.7	28.5

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/21/84	12:00 AM	.7	4.0	14.7	28.5
		.6	3.7	14.7	28.5
		.6	3.7	14.7	28.5
		.6	3.7	14.7	28.5
		.6	3.7	14.7	26.1
		.6	3.7	14.7	26.1
		.6	3.7	14.7	26.1
		.6	3.7	14.7	26.1
		.6	3.7	14.7	26.1
		.6	3.7	14.5	26.1
		.6	3.7	14.5	26.1
		.6	3.7	14.5	26.1
8/22/84	12:00 AM	.6	3.7	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	26.1
		.2	3.5	14.5	22.4
		.2	3.5	14.5	22.4
		.2	3.5	14.5	22.4
8/23/84	12:00 AM	.2	3.5	14.5	22.4
		.2	3.5	14.5	22.8
		.2	3.5	14.5	22.8
		.2	3.5	14.7	22.8
		.2	3.5	14.9	22.8
		.2	3.5	14.9	22.8
		.2	3.5	14.9	22.8
		.1	3.5	15.1	22.8
		.1	3.5	15.1	23.7
		.1	3.5	15.1	23.7
		.1	3.5	15.1	23.7
		.1	3.5	15.1	23.7

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/24/84	12:00 AM	.1	3.5	15.1	23.7
		.0	3.5	14.9	23.3
		.0	3.5	14.9	22.8
		.0	3.5	14.9	22.8
		.0	3.5	10.2	22.8
		.0	3.5	1.5	21.0
		.0	3.5	1.5	21.5
		.1	3.9	1.5	21.5
		.1	3.9	1.5	22.4
		2.1	3.9	1.5	22.4
		2.1	3.9	1.5	22.8
		2.1	3.7	1.5	22.8
8/25/84	12:00 AM	2.1	3.7	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
8/26/84	12:00 AM	2.1	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.2	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		2.1	3.4	1.5	22.8
		1.4	3.5	1.5	22.8
		1.2	3.5	1.4	22.8

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/27/84	12:00 AM	1.1	2.4	1.4	22.8
		1.1	2.4	1.4	22.8
		1.1	2.4	1.4	22.8
		1.1	2.4	1.4	22.8
		1.1	2.4	1.4	22.8
		1.1	2.4	1.4	22.8
		1.0	2.4	1.4	22.8
		.9	2.4	1.4	22.8
		.9	2.4	8.5	21.0
		.9	2.4	8.5	20.6
		.9	2.4	8.5	20.6
		.9	2.4	8.5	20.6
8/28/84	12:00 AM	.9	2.4	8.5	20.6
		.9	2.4	8.5	20.2
		.9	2.4	8.5	20.2
		.9	2.4	8.5	20.2
		.9	2.4	8.5	20.2
		.9	2.4	8.4	20.2
		.9	2.4	8.4	20.2
		.9	2.4	8.4	20.2
		.9	2.4	8.4	20.2
		.9	2.4	8.2	20.2
		.9	2.4	8.2	20.2
		.9	2.4	8.2	20.2
8/29/84	12:00 AM	.9	2.4	8.2	20.2
		.9	2.4	8.2	20.2
		.9	2.4	8.2	20.2
		.9	2.4	8.2	20.2
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
8/30/84	12:00 AM	.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
8/31/84	12:00 AM	.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	23.7
		.9	2.4	8.2	27.5
		.9	2.4	8.2	27.5
		.9	2.4	8.2	27.5
		.9	2.4	8.2	27.5
		.9	2.4	8.2	27.5
		.9	2.4	8.2	27.5
		.9	2.4	8.2	27.5
		.9	2.4	8.2	28.0
9/1/84	12:00 AM	.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.9	2.4	8.2	28.0
		.3	2.4	8.2	28.0

PINEY CREEK 2 HOURLY DIVERSION RECORDS -- 1ST RELEASE

DATE	TIME	WJD C.F.S.	ATHORPE ROGERS C.F.S.	DUNLAP C.F.S.	PRATT & FERRIS #1 C.F.S.
9/2/84	12:00 AM	.3	2.4	8.2	28.0
		.3	2.4	8.2	23.3
		.3	2.4	8.2	23.3
		.3	2.4	8.2	23.3
		.3	2.4	8.2	23.3
		.3	2.4	8.2	23.3
		.3	2.4	8.2	23.3

PINEY CREEK 2 HOURLY FLOW RECORDS -- 2ND RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	ESTIMATED DIVERSIONS C.F.S.
10/1/84	2:00 AM	39.6	48.7	5.0
		38.4	47.8	5.0
		37.2	46.9	5.0
		36.1	46.0	5.0
		36.1	46.0	5.0
		35.0	46.0	5.0
		33.8	46.0	5.0
		33.8	46.0	5.0
		33.8	46.9	5.0
		33.8	46.9	5.0
		33.8	46.9	5.0
10/2/84	12:00 AM	33.8	46.0	5.0
		33.8	46.0	5.0
		33.8	46.0	5.0
		35.0	46.0	5.0
		35.0	46.0	5.0
		35.0	45.1	5.0
		33.8	45.1	5.0
		33.8	45.1	5.0
		33.8	45.1	5.0
		33.8	44.2	5.0
		32.8	44.2	5.0
		31.7	44.2	5.0
10/3/84	12:00 AM	31.7	44.2	5.0
		31.7	45.1	5.0
		32.8	46.9	5.0
		32.8	46.9	5.0
		33.8	46.9	5.0
		33.8	46.9	5.0
		33.8	46.0	5.0
		33.8	46.0	5.0
		33.8	46.0	5.0
		38.4	45.1	5.0
		43.2	44.2	5.0
		48.4	44.2	5.0

PINEY CREEK 2 HOURLY FLOW RECORDS -- 2ND RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	ESTIMATED DIVERSIONS C.F.S.
10/4/84	12:00 AM	53.8	45.1	5.0
		53.8	45.1	5.0
		53.8	46.0	5.0
		53.8	46.0	5.0
		53.8	46.0	5.0
		53.8	46.0	5.0
		53.8	46.0	5.0
		49.7	50.6	5.0
		45.8	56.6	5.0
		45.8	56.6	5.0
		44.5	57.7	5.0
		44.5	58.8	5.0
10/5/84	12:00 AM	43.2	59.8	5.0
		43.2	59.8	5.0
		43.2	59.8	5.0
		43.2	55.6	5.0
		43.2	54.6	5.0
		43.2	53.6	5.0
		43.2	53.6	5.0
		43.2	52.6	5.0
		43.2	50.6	5.0
		43.2	50.6	5.0
		42.0	50.6	5.0
		40.8	50.6	5.0
10/6/84	12:00 AM	39.6	48.7	5.0
		38.4	50.6	5.0
		38.4	50.6	5.0
		38.4	50.6	5.0
		38.4	50.6	5.0
		38.4	50.6	5.0
		38.4	49.7	5.0
		38.4	48.7	5.0
		38.4	47.8	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0

PINEY CREEK 2 HOURLY FLOW RECORDS -- 2ND RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	ESTIMATED DIVERSIONS C.F.S.
10/7/84	12:00 AM	38.4	46.9	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
		39.6	46.9	5.0
		39.6	46.0	5.0
		39.6	46.0	5.0
		38.4	46.9	5.0
		38.4	46.9	5.0
10/8/84	12:00 AM	38.4	46.9	5.0
		38.4	48.7	5.0
		38.4	48.7	5.0
		38.4	49.7	5.0
		102.4	49.7	7.5
		102.4	49.7	7.5
		102.4	49.7	7.5
		102.4	48.7	7.5
		102.4	48.7	7.5
		102.4	48.7	7.5
		102.4	46.9	7.5
		100.4	83.5	7.5
10/9/84	12:00 AM	100.4	87.7	7.5
		100.4	87.7	7.5
		100.4	87.7	7.5
		100.4	87.7	7.5
		100.4	83.5	7.5
		100.4	83.5	7.5
		100.4	83.5	7.5
		100.4	83.5	7.5
		100.4	83.5	7.5
		100.4	84.9	7.5
		100.4	84.9	7.5
		100.4	84.9	7.5

PINEY CREEK 2 HOURLY FLOW RECORDS -- 2ND RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	ESTIMATED DIVERSIONS C.F.S.
10/10/84	12:00 AM	100.4	84.9	7.5
		100.4	84.9	7.5
		100.4	84.9	7.5
		100.4	84.9	7.5
		147.7	84.9	10.0
		147.7	84.9	10.0
		147.7	84.9	10.0
		147.7	84.9	10.0
		147.7	84.9	10.0
		147.7	124.5	10.0
		147.7	126.4	10.0
		147.7	130.3	10.0
10/11/84	12:00 AM	150.0	128.4	10.0
		150.0	128.4	10.0
		150.0	128.4	10.0
		150.0	130.3	10.0
		150.0	132.3	10.0
		150.0	134.3	10.0
		147.7	134.3	10.0
		145.3	134.3	10.0
		145.3	132.3	10.0
		145.3	132.3	10.0
		145.3	132.3	10.0
		145.3	130.3	10.0
10/12/84	12:00 AM	145.3	130.3	10.0
		145.3	130.3	10.0
		145.3	132.3	10.0
		145.3	132.3	10.0
		40.8	132.3	5.0
		40.8	72.8	5.0
		40.8	53.6	5.0
		39.6	50.6	5.0
		39.6	49.7	5.0
		39.6	48.7	5.0
		39.6	48.7	5.0
		39.6	48.7	5.0

PINEY CREEK 2 HOURLY FLOW RECORDS -- 2ND RELEASE

DATE	TIME	BELOW LAKE DESMET OUTLET C.F.S.	UCROSS, WYO. STA. NUMBER 06323500 C.F.S.	ESTIMATED DIVERSIONS C.F.S.
10/13/84	12:00 AM	39.6	47.8	5.0
		40.8	47.8	5.0
		40.8	47.8	5.0
		40.8	47.8	5.0
		40.8	47.8	5.0
		42.0	47.8	5.0
		42.0	48.7	5.0
		42.0	48.7	5.0
		42.0	48.7	5.0
		42.0	48.7	5.0
		42.0	48.7	5.0
		42.0	48.7	5.0
10/14/84	12:00 AM	43.2	48.7	5.0
		43.2	48.7	5.0
		44.5	48.7	5.0
		45.8	48.7	5.0
		45.8	48.7	5.0
		45.8	48.7	5.0
		44.5	48.7	5.0
		44.5	48.7	5.0
		44.5	48.7	5.0
		44.5	48.7	5.0
		44.5	48.7	5.0
		43.2	48.7	5.0

APPENDIX A-2

LARAMIE RIVER FLOW RECORDS

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
9/19/84	2:00 AM	153.0	105.0	262.0	25.2	32.7
		153.0	105.0	262.0	22.8	32.7
		153.0	105.0	262.0	21.0	32.7
		153.0	105.0	262.0	20.0	32.7
		153.0	105.0	262.0	19.0	32.7
		153.0	105.0	262.0	18.0	32.7
		153.0	105.0	262.0	17.0	32.7
		153.0	105.0	262.0	16.5	30.9
		153.0	105.0	262.0	16.0	29.2
		153.0	105.0	262.0	15.6	28.1
		153.0	105.0	262.0	15.2	26.5
9/20/84	12:00 AM	153.0	105.0	262.0	15.2	25.9
		153.0	105.0	260.0	14.8	25.9
		153.0	105.0	260.0	14.8	25.4
		153.0	105.0	260.0	14.8	24.9
		153.0	105.0	260.0	14.8	24.4
		153.0	105.0	260.0	14.8	24.4
		153.0	105.0	260.0	14.8	24.4
		153.0	105.0	260.0	14.8	23.9
		153.0	105.0	260.0	14.8	23.9
		153.0	105.0	260.0	15.2	23.4
		153.0	105.0	260.0	16.0	23.4
		153.0	105.0	260.0	15.6	23.4
9/21/84	12:00 AM	153.0	105.0	260.0	15.2	22.9
		153.0	105.0	257.0	15.2	22.9
		153.0	105.0	257.0	15.2	22.9
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.9
		153.0	105.0	257.0	15.2	24.4
		153.0	105.0	257.0	15.2	23.9
		153.0	105.0	257.0	15.2	23.9
		153.0	105.0	257.0	14.8	23.4
		153.0	105.0	257.0	14.8	22.9
		153.0	105.0	257.0	14.8	22.9
		153.0	105.0	257.0	14.8	22.9

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
9/22/84	12:00 AM	153.0	105.0	257.0	14.8	22.9
		153.0	105.0	257.0	14.8	22.9
		153.0	105.0	257.0	15.2	22.9
		153.0	105.0	257.0	15.2	22.9
		153.0	105.0	257.0	15.2	22.9
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.4
		153.0	105.0	257.0	15.2	23.4
9/23/84	12:00 AM	153.0	105.0	257.0	15.2	23.4
		153.0	105.0	252.0	15.2	23.4
		153.0	105.0	252.0	15.2	23.4
		153.0	105.0	252.0	15.2	23.4
		153.0	105.0	252.0	15.2	23.4
		153.0	105.0	252.0	15.2	23.9
		153.0	105.0	252.0	15.2	23.9
		153.0	105.0	252.0	15.2	23.9
		153.0	105.0	252.0	15.6	23.9
		153.0	105.0	252.0	15.6	24.4
		153.0	105.0	252.0	15.6	24.4
		153.0	105.0	252.0	15.6	24.4
9/24/84	12:00 AM	153.0	105.0	252.0	15.6	24.4
		153.0	105.0	252.0	16.0	24.4
		153.0	105.0	252.0	16.0	24.4
		153.0	105.0	252.0	16.5	24.4
		153.0	105.0	252.0	16.5	24.4
		153.0	105.0	252.0	16.5	24.9
		153.0	105.0	252.0	16.5	24.9
		153.0	105.0	252.0	16.5	24.9
		153.0	105.0	252.0	17.5	25.4
		14.7	105.0	252.0	17.5	25.9
		14.7	105.0	252.0	18.5	26.5
		4.2	105.0	252.0	19.0	26.5

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
9/25/84	12:00 AM	4.2	105.0	252.0	19.5	26.5
		3.0	105.0	19.0	19.5	26.5
		3.0	105.0	19.0	20.0	27.0
		3.0	105.0	19.0	20.0	27.0
		3.0	105.0	19.0	20.0	27.0
		3.0	105.0	19.0	20.0	27.0
		3.0	105.0	19.0	20.0	28.6
		3.0	105.0	19.0	210.0	28.6
		3.0	105.0	19.0	200.0	29.2
		3.0	105.0	19.0	185.0	29.2
		3.0	105.0	19.0	168.0	29.8
		3.0	105.0	19.0	152.0	49.9
9/26/84	12:00 AM	3.0	105.0	19.0	142.0	49.9
		2.7	105.0	10.9	135.0	49.9
		2.7	105.0	10.9	131.0	49.9
		2.7	105.0	10.9	129.0	49.9
		2.7	105.0	10.9	125.0	49.9
		2.7	105.0	10.9	123.0	49.9
		2.7	105.0	10.9	123.0	49.9
		2.7	105.0	10.9	121.0	49.9
		2.7	105.0	10.9	131.0	49.9
		2.7	105.0	10.9	135.0	157.1
		2.7	105.0	10.9	129.0	157.1
		2.7	105.0	10.9	125.0	157.1
9/27/84	12:00 AM	2.7	105.0	10.9	125.0	157.1
		2.2	104.0	10.6	121.0	158.9
		2.2	104.0	10.6	121.0	155.3
		2.2	104.0	10.6	119.0	153.5
		2.2	104.0	10.6	117.0	150.0
		2.2	104.0	10.6	115.0	150.0
		2.2	104.0	10.6	115.0	150.0
		2.2	104.0	10.6	117.0	148.3
		2.2	104.0	10.6	117.0	146.5
		2.2	104.0	10.6	140.0	146.5
		2.2	104.0	10.6	133.0	146.5
		2.2	104.0	10.6	129.0	146.5

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
9/28/84	12:00 AM	2.2	104.0	10.6	125.0	158.9
		2.2	104.0	10.6	123.0	158.9
		2.2	104.0	10.6	123.0	158.9
		2.2	104.0	10.6	121.0	157.1
		2.2	104.0	10.6	121.0	155.3
		2.2	104.0	10.6	121.0	151.8
		2.2	104.0	10.6	121.0	151.8
		2.2	104.0	10.6	121.0	151.8
		2.2	104.0	10.6	121.0	151.8
		2.2	104.0	10.6	121.0	151.8
		2.2	104.0	10.6	121.0	151.8
		2.2	104.0	10.6	121.0	150.0
9/29/84	12:00 AM	2.2	104.0	10.6	121.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	119.0	150.0
9/30/84	12:00 AM	1.7	104.0	10.6	119.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	150.0
		1.7	104.0	10.6	117.0	148.3
		1.7	104.0	10.6	117.0	148.3

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/1/84	12:00 AM	1.7	104.0	10.6	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	148.3
		1.7	104.0	10.3	117.0	146.5
		1.7	104.0	10.3	117.0	146.5
		1.7	104.0	10.3	117.0	146.5
10/2/84	12:00 AM	1.7	104.0	10.3	155.0	146.5
		1.7	104.0	9.7	155.0	146.5
		1.7	104.0	9.7	152.0	153.5
		1.7	104.0	9.7	152.0	153.5
		1.7	104.0	9.7	150.0	153.5
		1.7	104.0	9.7	150.0	153.5
		1.7	104.0	9.7	150.0	153.5
		1.7	104.0	9.7	148.0	153.5
		1.7	104.0	9.7	148.0	150.0
		1.7	104.0	9.7	148.0	150.0
		1.7	104.0	9.7	148.0	150.0
		1.7	104.0	9.7	148.0	150.0
10/3/84	12:00 AM	1.7	104.0	9.7	148.0	148.3
		1.7	104.0	9.1	145.0	148.3
		1.7	104.0	9.1	145.0	148.3
		1.7	104.0	9.1	142.0	146.5
		1.7	104.0	9.1	142.0	146.5
		1.7	104.0	9.1	142.0	146.5
		1.7	104.0	9.1	142.0	146.5
		1.7	104.0	9.1	142.0	144.8
		1.7	104.0	9.1	140.0	144.8
		1.7	104.0	9.1	138.0	143.1
		1.7	104.0	9.1	138.0	143.1
		1.7	104.0	9.1	138.0	143.1

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/4/84	12:00 AM	1.7	104.0	9.1	138.0	143.1
		1.7	104.0	9.1	135.0	141.4
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
		1.7	104.0	9.1	135.0	139.8
10/5/84	12:00 AM	1.7	104.0	9.1	133.0	139.8
		1.7	105.0	7.7	135.0	139.8
		1.7	105.0	7.7	135.0	139.8
		1.7	105.0	7.7	135.0	141.4
		1.7	105.0	7.7	135.0	143.1
		1.7	105.0	7.7	133.0	144.8
		1.7	105.0	7.7	133.0	143.1
		1.7	105.0	7.7	135.0	143.1
		1.7	105.0	7.7	133.0	143.1
		1.7	105.0	7.7	140.0	143.1
		1.7	105.0	7.7	140.0	144.8
		1.7	105.0	7.7	140.0	144.8
10/6/84	12:00 AM	1.7	105.0	7.7	140.0	144.8
		1.7	104.0	6.7	131.0	141.4
		1.7	104.0	6.7	131.0	139.8
		1.7	104.0	6.7	131.0	138.1
		1.7	104.0	6.7	131.0	138.1
		1.7	104.0	6.7	131.0	136.5
		1.7	104.0	6.7	131.0	134.8
		1.7	104.0	6.7	131.0	134.8
		1.7	104.0	6.7	131.0	134.8
		1.7	104.0	6.7	129.0	134.8
		1.7	104.0	6.7	127.0	136.5
		1.7	104.0	6.7	127.0	133.2

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/7/84	12:00 AM	1.7	104.0	6.7	127.0	131.6
		1.7	104.0	6.7	127.0	130.0
		1.7	104.0	6.7	125.0	130.0
		1.7	104.0	6.7	125.0	130.0
		1.7	104.0	6.7	125.0	130.0
		1.7	104.0	6.7	125.0	130.0
		1.7	104.0	6.7	125.0	128.4
		1.7	104.0	6.7	125.0	128.4
		1.7	104.0	6.7	123.0	126.9
		1.7	104.0	6.7	121.0	126.9
		1.7	104.0	6.7	121.0	126.9
		1.7	104.0	6.7	121.0	126.9
10/8/84	12:00 AM	1.7	104.0	6.7	121.0	126.9
		1.7	104.0	7.7	121.0	126.9
		1.7	104.0	7.7	121.0	126.9
		1.7	104.0	7.7	121.0	125.3
		1.7	104.0	7.7	121.0	125.3
		95.0	104.0	7.7	121.0	125.3
		95.0	104.0	7.7	121.0	125.3
		95.0	104.0	7.7	121.0	125.3
		95.0	104.0	7.7	119.0	125.3
		95.0	104.0	7.7	188.0	125.3
		95.0	104.0	7.7	182.0	125.3
		95.0	104.0	7.7	172.0	164.4
10/9/84	12:00 AM	95.0	104.0	7.7	162.0	175.9
		95.0	104.0	9.1	152.0	175.9
		95.0	104.0	9.1	142.0	166.3
		95.0	104.0	9.1	138.0	157.1
		95.0	104.0	9.1	133.0	150.0
		95.0	104.0	9.1	131.0	144.8
		95.0	104.0	9.1	148.0	139.8
		95.0	104.0	9.1	168.0	138.1
		95.0	104.0	9.1	180.0	134.8
		95.0	104.0	9.1	185.0	151.8
		95.0	104.0	9.1	190.0	170.1
		95.0	104.0	9.1	192.0	198.2

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/10/84	12:00 AM	95.0	104.0	9.1	195.0	234.1
		95.0	104.0	8.5	198.0	234.1
		95.0	104.0	8.5	200.0	234.1
		95.0	104.0	8.5	200.0	234.1
		95.0	104.0	8.5	202.0	234.1
		95.0	104.0	8.5	205.0	234.1
		95.0	104.0	8.5	205.0	234.1
		95.0	104.0	8.5	205.0	234.1
		95.0	104.0	8.5	205.0	234.1
		95.0	104.0	8.5	205.0	234.1
		95.0	104.0	8.5	205.0	234.1
		95.0	104.0	8.5	208.0	234.1
10/11/84	12:00 AM	95.0	104.0	8.5	208.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	210.0	234.1
		95.0	104.0	9.0	213.0	234.1
		95.0	104.0	9.0	213.0	234.1
		95.0	104.0	9.0	213.0	234.1
		95.0	104.0	9.0	213.0	234.1
10/12/84	12:00 AM	95.0	104.0	9.0	213.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/13/84	12:00 AM	95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	216.0	234.1
10/14/84	12:00 AM	95.0	104.0	9.0	216.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
10/15/84	12:00 AM	95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	219.0	234.1

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/16/84	12:00 AM	95.0	104.0	9.0	219.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	222.0	234.1
10/17/84	12:00 AM	95.0	104.0	9.0	222.0	234.1
		95.0	104.0	9.0	225.0	236.5
		95.0	104.0	9.0	225.0	238.9
		95.0	104.0	9.0	225.0	241.3
		95.0	104.0	9.0	225.0	243.8
		95.0	104.0	9.0	225.0	246.2
		95.0	104.0	9.0	225.0	248.7
		95.0	104.0	9.0	225.0	248.7
		95.0	104.0	9.0	225.0	251.2
		95.0	104.0	9.0	225.0	248.7
		95.0	104.0	9.0	225.0	241.3
		95.0	104.0	9.0	225.0	241.3
10/18/84	12:00 AM	95.0	104.0	9.0	225.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	104.0	9.0	228.0	241.3
		95.0	103.0	9.0	228.0	238.9
		95.0	103.0	9.0	228.0	238.9
		95.0	91.0	9.0	228.0	236.5

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/19/84	12:00 AM	95.0	91.0	9.0	228.0	236.5
		95.0	91.0	9.0	219.0	234.1
		95.0	91.0	9.0	219.0	234.1
		95.0	91.0	9.0	219.0	236.5
		95.0	91.0	9.0	219.0	231.8
		95.0	91.0	9.0	219.0	229.4
		95.0	91.0	9.0	219.0	227.1
		95.0	91.0	9.0	219.0	229.4
		95.0	91.0	9.0	219.0	231.8
		95.0	91.0	9.0	219.0	234.1
		95.0	91.0	9.0	219.0	236.5
		95.0	91.0	9.0	219.0	238.9
10/20/84	12:00 AM	95.0	91.0	9.0	219.0	241.3
		95.0	92.0	9.0	225.0	238.9
		95.0	92.0	9.0	225.0	238.9
		95.0	92.0	9.0	225.0	238.9
		95.0	92.0	9.0	225.0	238.9
		95.0	92.0	9.0	225.0	238.9
		95.0	92.0	9.0	225.0	236.5
		95.0	92.0	9.0	225.0	236.5
		95.0	92.0	9.0	225.0	236.5
		95.0	92.0	9.0	225.0	236.5
		95.0	92.0	9.0	225.0	236.5
		95.0	92.0	9.0	225.0	234.1
10/21/84	12:00 AM	95.0	92.0	9.0	225.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	222.0	234.1

LARAMIE RIVER 2 HOURLY FLOW RECORDS

DATE	TIME	WHEATLAND RES. NO. 2 C.F.S.	WHEATLAND RES. NO. 3 C.F.S.	TUNNEL DIV. C.F.S.	ABOVE CRAMER DITCH C.F.S.	ABOVE SYBILLE CK. C.F.S.
10/22/84	12:00 AM	95.0	93.0	9.0	222.0	234.1
		95.0	93.0	9.0	219.0	231.8
		95.0	93.0	9.0	219.0	229.4
		95.0	93.0	9.0	219.0	229.4
		95.0	93.0	9.0	219.0	229.4
		95.0	93.0	9.0	219.0	227.1
		95.0	93.0	9.0	219.0	227.1
		95.0	93.0	9.0	219.0	227.1
		95.0	93.0	9.0	219.0	229.4
		95.0	93.0	9.0	219.0	229.4
		95.0	93.0	9.0	219.0	229.4
		95.0	93.0	9.0	219.0	229.4

APPENDIX A-3

NEW FORK RIVER FLOW RECORDS

NEW FORK RIVER AVERAGE DAILY FLOW RECORDS

DATE	BELOW NEW FORK LAKES C.F.S.	MARSH CREEK C.F.S.	JENKINS DITCH C.F.S.	RAHM DITCH C.F.S.
5/20/84	8.4	12.5	0.1	1.0
5/21/84	8.4	10.0	0.1	1.0
5/22/84	8.4	11.9	0.1	1.0
5/23/84	8.4	9.6	0.1	1.0
5/24/84	8.7	8.3	0.1	1.0
5/25/84	8.7	12.5	1.9	1.0
5/26/84	17.6	17.0	2.1	1.0
5/27/84	74.4	10.0	8.8	1.0
5/28/84	75.6	7.0	8.8	1.0
5/29/84	94.2	5.5	9.7	1.0
5/30/84	246.0	6.4	11.5	1.0
5/31/84	246.0	10.0	16.3	1.0
6/1/84	255.0	14.9	20.5	1.0
6/2/84	270.0	8.3	27.5	1.0
6/3/84	293.0	9.6	43.8	13.1
6/4/84	283.0	9.6	40.4	43.6
6/5/84	307.0	17.8	40.1	44.0
6/6/84	390.0	10.9	43.8	44.0
6/7/84	385.0	14.9	44.1	44.0
6/8/84	377.0	7.6	44.4	44.0
6/9/84	369.0	5.5	44.4	44.0
6/10/84	356.0	7.0	44.7	44.0
6/11/84	348.0	24.1	45.3	44.0
6/12/84	345.0	9.6	44.7	44.0
6/13/84	337.0	5.5	44.4	44.0
6/14/84	329.0	4.6	44.1	44.0
6/15/84	297.0	5.5	43.8	43.2
6/16/84	373.0	8.0	45.9	44.0
6/17/84	373.0	8.0	46.2	44.0
6/18/84	333.0	7.3	44.1	44.0
6/19/84	304.0	7.3	42.4	44.0
6/20/84	304.0	7.0	42.4	44.0

NEW FORK RIVER AVERAGE DAILY FLOW RECORDS

DATE	WRIGHT DITCH	LANE DITCH	BELOW BARLOW'S
5/20/84	6.8	0.1	23.7
5/21/84	6.8	0.1	23.7
5/22/84	6.8	0.1	23.7
5/23/84	6.6	0.1	24.5
5/24/84	6.8	0.1	24.5
5/25/84	6.8	0.1	25.3
5/26/84	6.8	0.1	25.3
5/27/84	7.5	3.5	69.8
5/28/84	7.9	2.5	69.8
5/29/84	8.2	2.3	75.2
5/30/84	11.0	17.2	205.0
5/31/84	11.0	17.2	214.0
6/1/84	10.7	17.5	220.0
6/2/84	10.6	17.2	220.0
6/3/84	10.3	18.5	226.0
6/4/84	21.9	14.4	191.0
6/5/84	37.0	14.7	191.0
6/6/84	42.0	21.4	255.0
6/7/84	41.6	21.8	262.0
6/8/84	40.7	21.1	255.0
6/9/84	40.3	20.7	248.0
6/10/84	40.7	21.1	258.0
6/11/84	41.1	21.4	265.0
6/12/84	40.3	20.0	245.0
6/13/84	39.4	20.0	229.0
6/14/84	38.6	18.9	223.0
6/15/84	34.3	15.6	205.0
6/16/84	38.2	21.8	258.0
6/17/84	38.6	21.8	258.0
6/18/84	37.0	20.0	235.0
6/19/84	34.7	16.9	208.0
6/20/84	34.3	16.9	205.0

APPENDIX B

CORRESPONDENCE FROM STATE AGENCIES AND ENGINEERING FIRMS

Water-Resources Report

Number Twenty-Eight

ARIZONA STATE LAND DEPARTMENT
Obed M. Lassen, Commissioner

ANTICIPATED CHANGES IN THE FLOW REGIMEN CAUSED BY THE ADDITION OF WATER TO THE EAST VERDE RIVER, ARIZONA

By
H. W. Hjalmarson and E. S. Davidson

Prepared by the Geological Survey
United States Department of the Interior

Phoenix, Arizona
November 1966

CONTENTS

ILLUSTRATIONS

ANTICIPATED CHANGES IN THE FLOW REGIMEN CAUSED BY THE ADDITION OF WATER TO THE EAST VERDE RIVER, ARIZONA

By

H. W. Hjalmarson and E. S. Davidson

ABSTRACT

The East Verde River drains about 320 square miles of granitic and sedimentary rocks in northwestern Gila County, Ariz. The river heads in the Mogollon Rim and flows southwestward to discharge into the Verde River. The average annual streamflow from October 1961 to September 1964 was about 850 acre-feet near the head and about 13, 500 acre-feet near the mouth. The streamflow increased from 1. 2 cfs (cubic feet per second) near the headwaters of the river to 4. 7 cfs near the mouth, or about 3. 5 cfs from the head to the mouth during low-flow periods; the maximum decrease during a sustained low-flow period was 0. 5 cfs.

About 30 cfs of water is to be added to the river near the head of the East Verde River basin. The expected losses of the added water to seepage into the ground and evapotranspiration are small. The geometry of the river channel is not expected to change, and the erosion along the river course is not expected to increase markedly.

INTRODUCTION

The study of the East Verde River basin defines the present hydrologic regimen, insofar as present data allow, and anticipates the effect on the regimen of an addition of about 30 cfs (cubic feet per second) of water at the head of the basin to the natural flow of the river. The additional water will be transported from a reservoir 20 miles northeast of Pine on East Clear Creek.

The East Verde River drains about 320 square miles of heavily wooded land in northwestern Gila County and is typical of many small tributary streams heading in the Mogollon Rim region of central Arizona. The river heads at an altitude of 7,300 feet in the Mogollon Rim about 15 miles north of Payson, flows 43 miles southwestward, and discharges at an altitude of 2,500 feet into the Verde River a few miles south of Childs.

The basic data used to appraise the present stream regimen were provided by three stream-gaging stations, three partial-record sites, and a field reconnaissance of the drainage basin. The gaging stations have been operated since the fall of 1961 and are referred to in this report as the Pine, Payson, and Childs gages. The Pine gage is near the headwaters of the river, the Childs gage is near the mouth, and the Payson gage is 10-1/2 miles upstream from the Childs gage (fig. 1). The partial-record sites are numbered from 1 to 3 in downstream order.

PHYSICAL ENVIRONMENT OF THE EAST VERDE RIVER DRAINAGE BASIN

The East Verde River flows southwestward toward the Verde River from a headwaters area in the escarpment of the Mogollon Rim. The Mogollon Rim is a serrated cliff that extends northwestward across the State and separates the plateaus to the northeast from the basins and ranges to the southwest. The altitude of the plateau north of the rim in the area of the East Verde River is slightly more than 7,000 feet; the plateau slopes northward and is underlain by sedimentary rocks. South of the rim are many ridges and mesas at an altitude of about 5,000 feet. The ridges and mesas are separated by 200- to 500-foot-deep canyons. The area south of the rim is underlain by granitic, sedimentary, and volcanic rocks.

The upper 12 miles of the 43-mile-long East Verde River channel is on gently dipping sedimentary rocks, which consist chiefly of limestone and sandstone. The lower 31 miles is on crystalline granitic rocks and, to a minor extent, on semiconsolidated beds of sand and silt (fig. 1). In places the river flows on bedrock, and in other places the river channel and flood plain are underlain by deposits of unconsolidated sand and gravel that probably are not more than 30 feet thick.

The topography of the drainage basin is rugged, and the river is in a steep-walled V-shaped canyon incised several hundreds of feet below the tops of ridges and mesas in the basin. The flood plain generally is less than 200 or 300 feet wide; the gradient is about 410 feet per mile in the upper 5 miles and about 70 feet per mile in the lower 38 miles. Because the deeply incised steep-walled canyons are composed of rocks that are

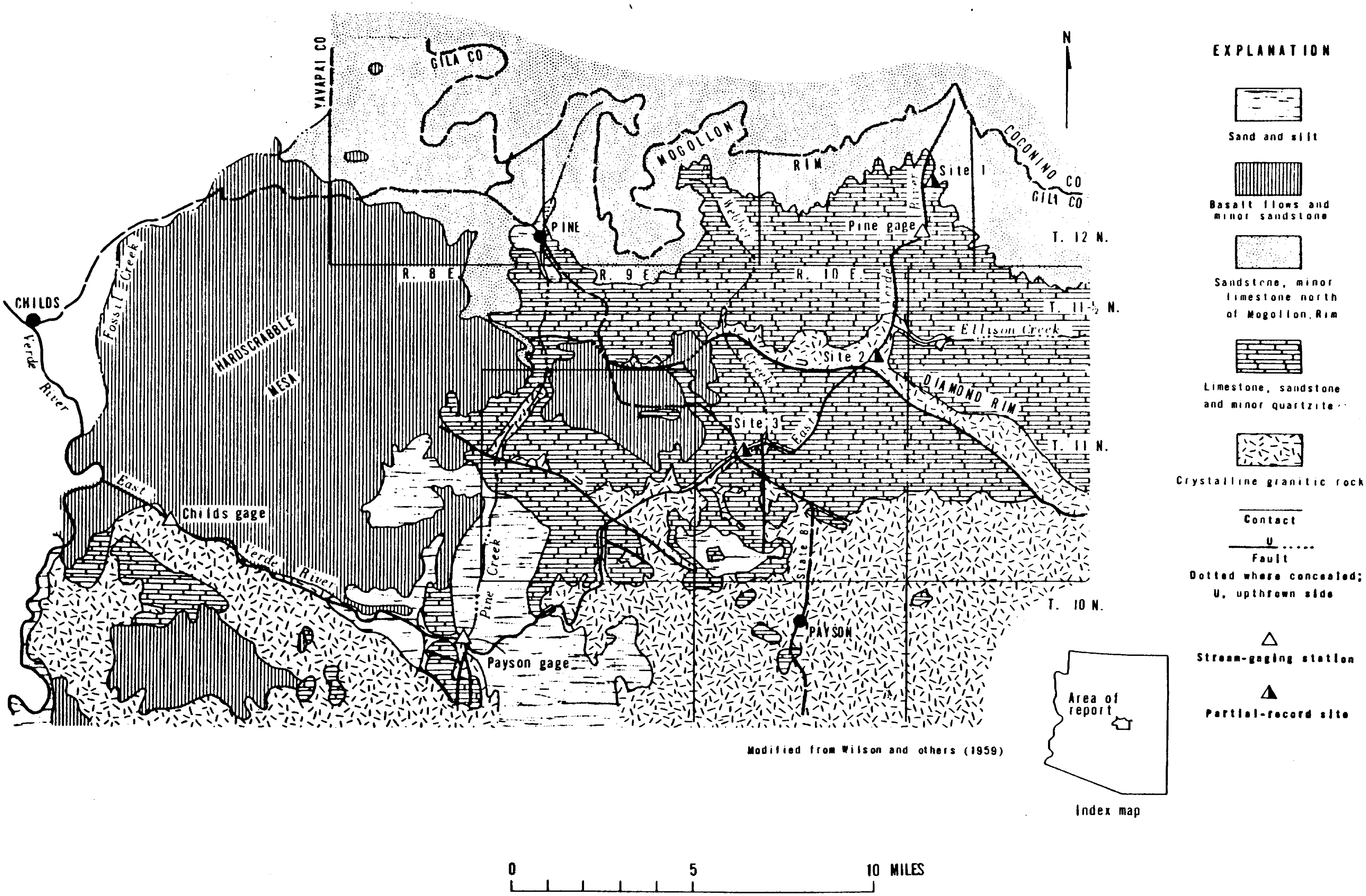

Figure 1.--Rock types, location of gaging stations, and partial-record sites.

resistant to erosion, the river's course is stable, and little material is eroded during periods of low flow.

The vegetation in the East Verde drainage basin changes from chaparral at the mouth of the river to pine at the head of the river. About 50 percent of the drainage basin is covered by chaparral, 25 percent by pinyon and juniper, and 25 percent by white and ponderosa pine.

HYDROLOGIC SYSTEM

The surface-water and ground-water drainage divides of the East Verde River coincide, except along the Mogollon Rim. The Mogollon Rim is the surface-water divide; the ground-water divide is 2 to 3 miles north of the escarpment of the rim. Ground water flows southward from the escarpment area along the rim and feeds the many springs (Feth and Hem, 1963) that emerge on the steep slopes below the rim. Thus, the area of ground-water contribution to the East Verde River is slightly larger than the 320 square miles of the surface-water drainage basin.

The flow of the East Verde River is dependent on precipitation within the bounds of the ground-water divide. Precipitation occurs as rainfall in the summer and as snowfall and rainfall in the winter. The normal annual precipitation in the drainage basin ranges from 20 inches at the Childs gage to 35 inches in the highest parts of the Mogollon Rim area; slightly more than half the precipitation—12 to 23 inches—falls from October through April (University of Arizona, 1965). The normal annual precipitation at the U.S. Forest Service ranger station in Payson is 20.6 inches. The annual precipitation at the ranger station during the period when data were collected for this study was 19.5 inches in 1961, 16.7 inches in 1962, 20.7 inches in 1963, and 16.8 inches in 1964. The total amount of precipitation that falls on the drainage basin is slightly more than 400,000 acre-feet per year. The average annual discharge into the Verde River is about 13,500 acre-feet, which is equivalent to slightly more than 3 percent of the mean annual precipitation.

The amount of precipitation that is converted into runoff in the East Verde drainage basin is dependent mainly on the degree of prior saturation of the rocks in the northern part of the basin. When these rocks are saturated to levels above the tributary streams, most of the precipitation that infiltrates into the ground will appear in nearby springs and will accumulate as flow in the tributary streams. When the rocks are not saturated and the regional ground-water levels are low, the spring flow and tributary flow will decrease. Thus, even if there were no use by plants, tributaries, such as Ellison Creek, Webber Creek, and Pine Creek, would not flow as much in response to rainfall in dry seasons as they would in wet seasons.

The average annual streamflow for 3 water years, October 1961 to September 1964, was 850 acre-feet at the Pine gage, 9, 200 acre-feet at the Payson gage, and 13, 500 acre-feet at the Childs gage. During the 3 years of record, eight peaks of more than 30 cfs occurred at the Pine gage, seven peaks of more than 400 cfs occurred at the Payson gage, and nine peaks of more than 300 cfs occurred at the Childs gage. The maximum peaks were 264 cfs at the Pine gage, 9, 950 cfs at the Payson gage, and 11, 400 cfs at the Childs gage. The surface-water drainage areas upstream from the gaging stations are 7 square miles for the Pine gage, 272 square miles for the Payson gage, and 320 square miles for the Childs gage. During the period of record, there was always streamflow at the Payson and Childs gages; however, periods of no flow occurred in the summer at the Pine gage.

Streamflow increases from the Pine gage to the Childs gage except during hot, dry periods when natural losses and diversions are large. The average annual increase in streamflow per unit increase in drainage area is 32 acre-feet per square mile between the Pine and Payson gages and 90 acre-feet per square mile between the Payson and Childs gages. The average precipitation over both drainage areas is nearly uniform; the reason for the disproportionate increase in streamflow is not known, but it may be due to a more efficient transport of rainfall and snowmelt from Hardscrabble Mesa to the river and, to a lesser extent, to the many diversions above the Payson gage.

Water is diverted from the East Verde River for domestic, agricultural, and recreational purposes. Most of the diversions are upstream from the Payson gage. The amount of water diverted probably reaches a maximum during the summer and sometimes exceeds the flow at the Payson gage. The total amount of streamflow diverted is not known, and much of the water diverted is returned to the river. As much as 3 cfs was measured at a diversion about 3 miles above the Payson gage.

Streamflow gains and losses during periods of low flow.-- The streamflow of the East Verde River is evaluated by an accumulative plot of the average gains and losses between successive gaging stations and partial-record sites. The average gains and losses are computed from 30 sets (U.S. Geological Survey, 1963) of streamflow measurements, each set made on the same day during periods of low flow. The measurements were selectively made during periods of no, or very minor, surface runoff from snowmelt or rainfall.

An average of about 0.6 cfs of streamflow is lost by seepage into the ground between site 1 and the Pine gage, and about 4.1 cfs is gained below the Pine gage (fig. 2, curve A). The greatest streamflow gain per mile of river channel is between the Pine gage and site 2. Flow from Ellison Creek to this reach is the cause of the gain. The average net gain of streamflow between site 1 and the Childs gage is 3.5 cfs. Because gains and losses of streamflow are regulated partly by manmade diversions, the average net streamflow gain of 3.5 cfs for the river is lower than the natural gain would be if no streamflow were diverted by man.

For the period of record, the average low flow at site 1 was 1.2 cfs, and the average low flow at the Childs gage was 4.7 cfs. The average gain in low flow of 3.5 cfs between site 1 and the Childs gage was about three times the average flow of 1.2 cfs at site 1.

The maximum measured net loss of streamflow during the period of record is shown in curve B (fig. 2). The measurements were made on June 18, 1963, and were preceded by a 2-month dry period. A gain of 0.6 cfs was measured between the Pine gage and site 2, but from site 1 to site 3 the river lost 0.6 cfs. A gain of 0.1 cfs was measured in the lower 30 miles from site 3 to the Childs gage. Natural losses and diversions exceeded inflow, causing a net loss of 0.5 cfs.

The records that form the basis for this report do not include any data for prolonged periods of drought. The streamflow loss along the East Verde River during a prolonged drought, when precipitation is not sufficient to maintain channel saturation, probably would be more than the maximum loss observed during the period of record.

Evapotranspiration losses from the East Verde River are not expected to differ in the same proportion as the variation in streamflow; the streamflow is confined to the channel, which has very small storage capacity along the entire length of the river, and there is usually sufficient water available to satisfy the demands of vegetation regardless of the amount of streamflow. The difference in seasonal evapotranspiration losses is shown by the correlation of seasonal streamflow at site 1 and at the Pine gage (fig. 3). Downstream from the Pine gage, the variation in unmeasured diversions was great enough to distort graphs designed to show the seasonal correlation. Although the correlation of streamflow at the downstream stations was poor, the trend was similar to that between site 1 and the Pine gage. The average streamflow from April through August, when evapotranspiration is high, is about 0.3 to 0.4 cfs lower than in September

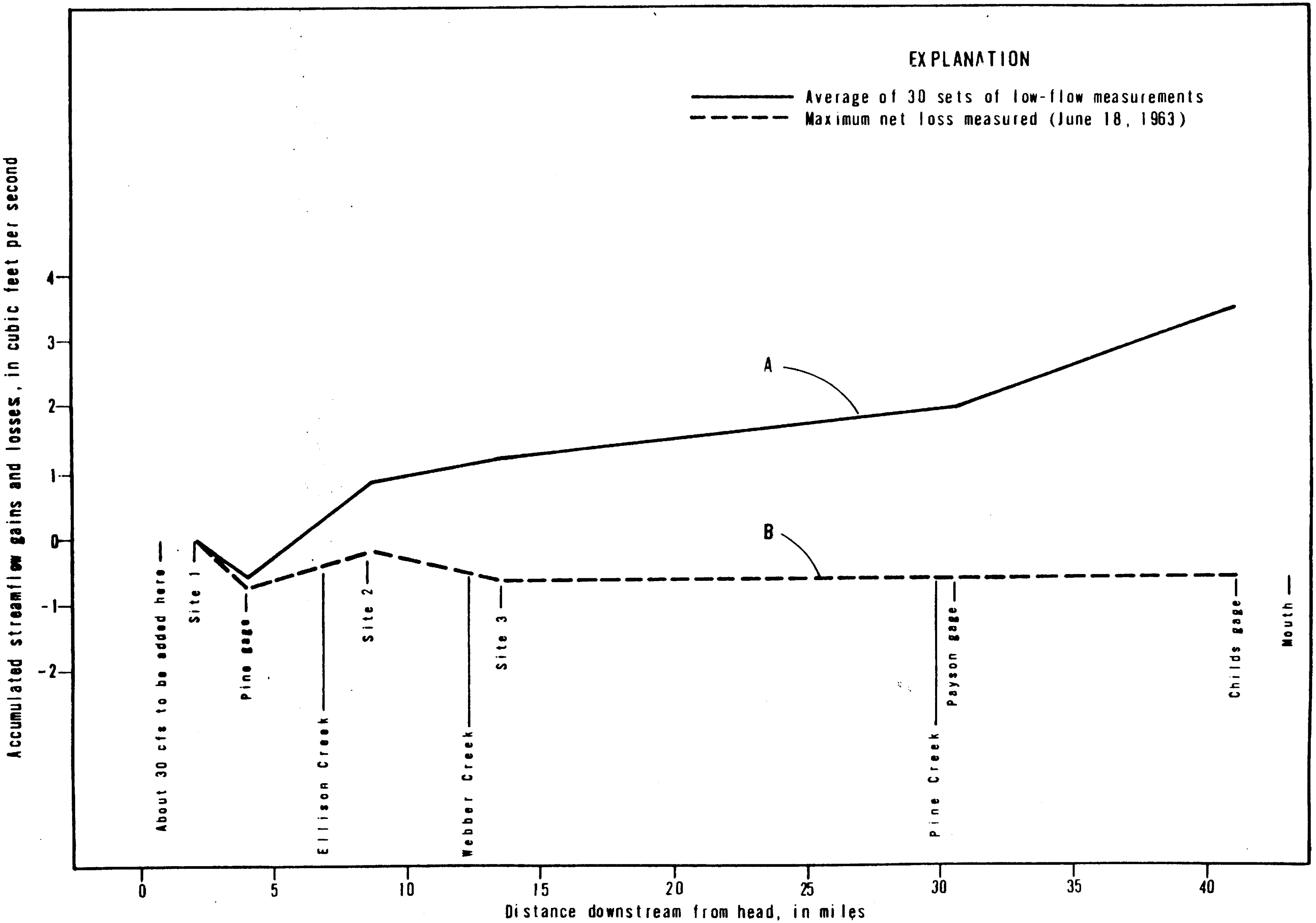

Figure 2.--Average and maximum net streamflow gains and losses.

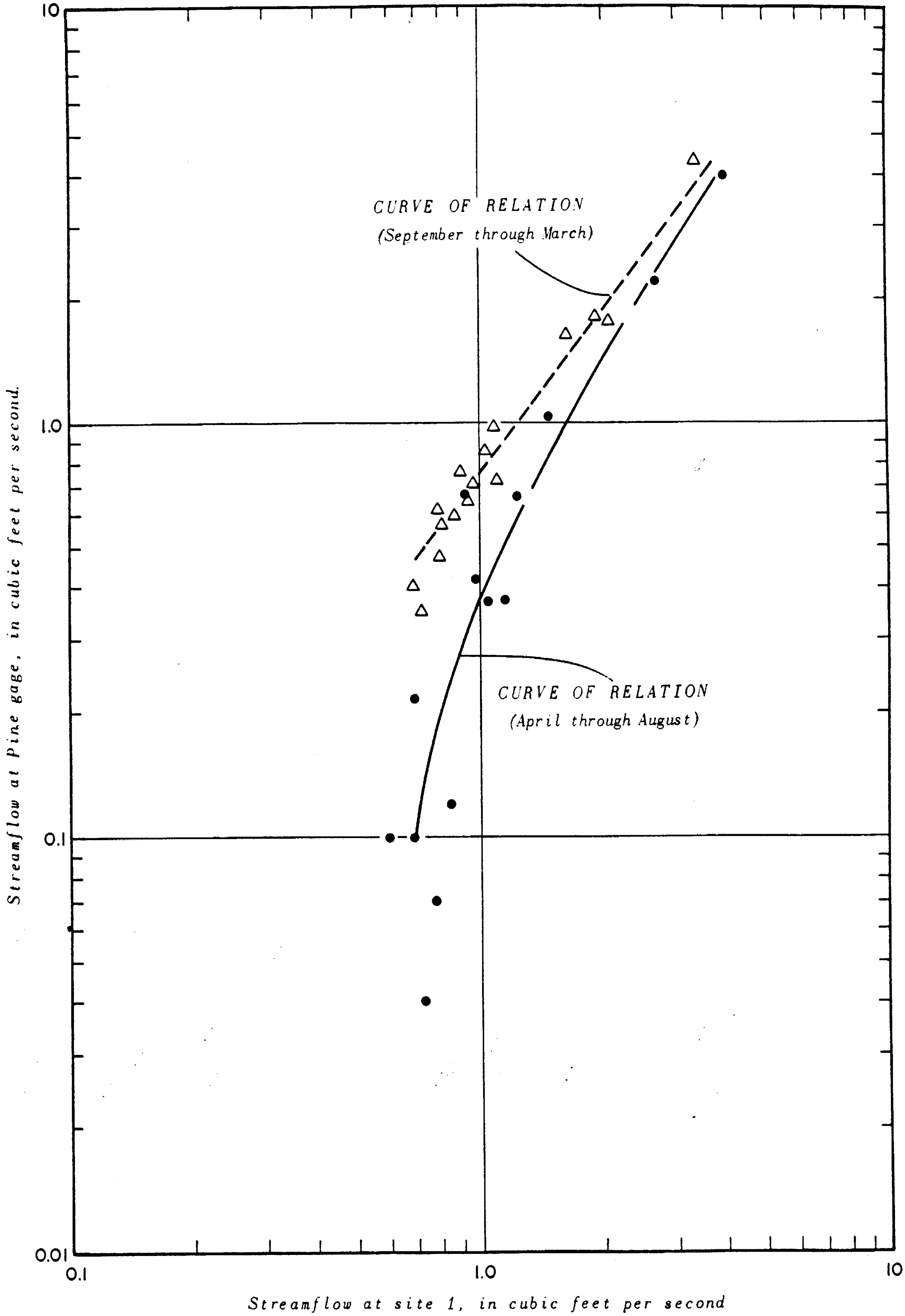

Figure 3.--Correlation of streamflow at site 1 and the Pine gage.

through March, when evapotranspiration is low (fig. 3). The streamflow difference between periods of high and low evapotranspiration is constant for the range of streamflow measured. Evapotranspiration losses, therefore, do not differ significantly despite rather large variations in streamflow and are not expected to increase significantly with the addition of water at the rate of about 30 cfs.

Physical changes of the river system due to the addition of water. --Addition of water to the East Verde probably will not change the channel course nor increase degradation of the channel. The river is entrenched deeply in bedrock, which is resistant to erosion; in the past, peak flows far greater than the amount of flow to be added have not changed the river course. Therefore, the river course is expected to remain stable. The water introduced into the river at the head of the basin will be free of sediment and will have high sediment-carrying and scouring capacities. Some degradation of the channel probably will take place in the unconsolidated alluvial areas as the river channel adjusts to the flow conditions. Degradation of the channel will be limited by the erosion-resistant bedrock, and adjustment of the channel to the added flow probably will be minor. Deposition or channel filling along the East Verde is expected to be minor, because of the present relatively steep gradient and the high scouring capacity of the river.

SUMMARY AND CONCLUSIONS

The average streamflow in the East Verde River increased from 1.2 cfs near the headwaters to 4.7 cfs near the mouth, or 3.5 cfs from the head to the mouth during low-flow periods; the maximum measured decrease during a sustained dry period was 0.5 cfs.

Evapotranspiration losses do not change significantly despite rather large variations in streamflow, because the flow is confined in the channel and the channel is usually saturated. Losses due to seepage into the ground are minor because the rocks along the stream generally are saturated and contribute to the streamflow.

About 30 cfs of water is to be added to the river near the head of the East Verde River basin from the East Clear Creek reservoir. The expected losses of the added water to evapotranspiration and seepage into the ground are small. The geometry of the river channel is not expected to change, and the erosion along the river course is not expected to increase markedly.

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RICHARD D. LAMM
Governor

1201H

JERIS A. DANIELSON
State Engineer

OFFICE OF THE STATE ENGINEER
DIVISION OF WATER RESOURCES

1313 Sherman Street-Room 818
Denver, Colorado 80203
(303) 866-3581

September 22, 1983

Mr. Victor R. Hasfurther
Professor, Civil Engineering Department
College of Engineering
University of Wyoming
Laramie, WY 82071

Dear Mr. Hasfurther:

This is to acknowledge receipt of your letter of August 9, 1983 requesting information on channel conveyance losses used in water transfer cases in Colorado. According to the Colorado water law, the State Engineer can charge any person or company requesting an exchange or transfer of water from one point to another for reasonable transportation and evaporation losses.

Conveyance losses are determined from the knowledge and experience of the stream system, any available studies or models, and/or from seepage measurements. It is quite complex to use models, especially in cases where the stream-aquifer system is highly influenced by well pumping, to calculate transit losses. Some models are available from the U. S. Geological Survey and the Colorado State University.

In general, we utilize data gathered from transit loss field measurements made by our hydrographers during reservoir releases and apply these losses to water transfer cases. In some circumstances, the proponent may conduct a study to substantiate a lesser value.

Please find enclosed some references on the subject matter and a court decree. If you have any further questions, feel free to contact Mr. Hal Simpson of my office.

Sincerely,

Jeris A. Danielson
State Engineer

JAD/DRS:ma

Enclosure

A. Evans

Ground Water - Surface Water Relationships

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DOCUMENTATION OF FINITE-DIFFERENCE MODEL

FOR

SIMULATION OF THREE-DIMENSIONAL GROUND-WATER FLOW

By

Peter C. Trescott

U.S. Geological Survey Open File Report 75-438

September 1975

ACKNOWLEDGMENT

The efficiency of the program has been improved significantly by Steven P. Larson who added the option of storing input arrays on disk and modified the solution routine to use only single-subscript arrays.

Requests for copies of this documentation and the card deck should be directed to:

Ralph N. Eicher, Chief
Office of Teleprocessing, M.S. 805
U.S. Geological Survey
→ Reston, Virginia 22092

CONTENTS

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WATER FORUM '81
ASCE/San Francisco, CA/August 10-14, 1981

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Ram

MODELING FOR MANAGEMENT OF A STREAM-AQUIFER SYSTEM

by

H. J. Morel-Seytoux*, M. ASCE
T. H. Illangasekare*, A.M. ASCE, and
A. R. Simpson*

ABSTRACT

Perspective

In the early stages of development the groundwater models were conceived to predict the physical (hydrologic) behavior of a river-aquifer system under a certain pattern of development and use. The coupling of the hydrologic model with an economic model and eventually with a management model was not a consideration in the design of the groundwater model. Today, on the contrary, the groundwater model is designed as a satellite subservient to the management model.

Methodology

Be it for purposes of optimization (best management) of the decision variables (how much to pump, when and where to pump, where to recharge, how much to import, etc.) or analysis of the stochastic structure of the outputs given the inputs, it is fundamental, for large scale systems, that the relationship between the gigantic sets of input and output variables be explicit so that the efficient tools of mathematical programming for optimization and of statistical distribution theory for the assessment of risk can be utilized. Techniques suited to the task include (1) the classical Green's functions of the theory of partial differential equations, (2) the theory of integral equations, (3) the theory of analytic continuation and naturally (4) extensive and efficient computer usage. These ideas have led to practical techniques and concepts referred to in the literature as the "discrete kernels" (influence coefficients or response functions), "reach transmissivity", "sequential reinitialization" and "moving grids". The basis and particularly the practical applicability of these techniques to solve management problems is discussed.

Case Studies

Applications of the computer models to 2 case studies will be briefly discussed: (1) the lower South Platte river in Colorado (a management study of legal strategies under drought conditions), and (2) the Rio Grange-Conejos system (a study for the prevention of water-logging near the confluence of the two rivers)

* Department of Civil Engineering, Colorado State University, Ft. Collins, CO

BACKGROUND

Water quality tends to deteriorate as a result of use. Population increases place a corresponding increased demand on this water of an already impaired quality. Both factors demand careful management of the meager water resources in many of the semi-arid regions of the United States and in many parts of the world.

Current modeling technology and computer availability makes it possible in principle to simulate (model) in great detail the behavior of a basin wide system consisting of a river and a connected aquifer. To study the effect of different management strategies one must be able to predict accurately the response of the system on a daily basis (for operational realism) over long periods of time (as much as 10 or 20 years for serious planning and study of environmental impacts) with fine spatial resolution (for legal and institutional realism). Though the technology was available during the sixties, it was still expensive and few water agencies or users associations at the state or local level of government have made use of it. Primarily with OWRT support, our HYDROWAR research team in active cooperation with the Colorado Water Resources Research Institute has explored quite successfully avenues to develop cost-effective models without (significant) loss of prediction accuracy. These techniques based on classical mathematical theory are briefly reviewed in the next section. In a later section some results of studies carried out with the operational methodology dating back to the period 1975-1977 are briefly presented. Methodology has been improved since.

METHODOLOGY

Green's Functions

To the extent that the linear form of the Boussinesq equation characterizes appropriately the behavior of a water table aquifer, then the classical theory of Green's function applies. Thus one can immediately write that drawdown, s_w at *observation* point w, due to withdrawal (pumping) or replenishment (recharge) activities at various *excitation* points (or lines or areas) is of the form:

$$s_w(t) = \sum_{e=1}^{E} \int_0^t k_{we}(t-\tau)\, Q_e(\tau) d\tau \qquad (1)$$

where t is (observation) time, E is the total number of excitation points, $k_{w,e}(.)$ is the Green's function (also known as the (unit impulse) kernel), $Q_e(.)$ is the (algebraic) excitation rate (positive for an acutal withdrawal) and τ is mathematically a dummy variable of integration and physically the excitation time. For heterogeneous aquifers, of complex shape, etc., the kernel cannot be found analytically but it can be obtained by numerical procedures. There are several and good reasons why this approach is superior to the standard numerical procedures (1,3).

Integral Equation Technique

The aquifer return flow to a stream depends upon pumping rates in the aquifer. It can be shown (2,3) that the return flow rate in reach r, $Q_r(t)$ is related to the pumping rates at various pumping points p by the system of Fredholm's integral equations of the first kind:

$$Q_r(t) + \Gamma_r \sum_{\rho=1}^{R} \int_0^t Q_\rho(\tau) k_{r\rho}(t-\tau) d\tau = -\Gamma_r \sum_{p=1}^{P} \int_0^t Q_p(\tau) k_{rp}(t-\tau) d\tau \qquad (2)$$

where Γ_r is the reach transmissivity (3,4), R is the total number of reaches and P is the total number of wells. Linear integral equations theory tells that there exists a *resolvent* kernel, $k^*_{rp}(\ )$ such that:

$$Q_r(t) = \sum_{p=1}^{P} \int_0^t k^*_{rp}(t-\tau) Q_p(\tau) \qquad (3)$$

or equivalently in discrete form:

$$Q_r(n) = \sum_{p=1}^{P} \sum_{\nu=1}^{n} \varepsilon_{rp}(n-\nu+1) Q_p(\nu) \qquad (4)$$

where $Q_r(n)$ is the return flow in reach r during the nth period and the $\varepsilon_{rp}(\ )$ are the *discrete kernels* of return flow responses due to pumping excitations. The mathematically inclined reader may recognize that the resolvent kernel in Eq. (3) is a simple transform of the Green's function of the Boussinesq equation for a radiation boundary condition along a line (the river). The same reader may also recognize that the technique of solution of the discrete (finite) form of the system of Eq. (2) which leads to a numerical evaluation of the $\varepsilon_{rp}(.)$ in Eq. (4) by Morel-Seytoux' technique (the Boundary Integral Discrete method or B.I.D.) is essentially the same as the B.I.E.M. (Boundary Integral Equation Method) or F.E.B.I. (Finite Element Boundary Integral method) and antedates (3) the use of either in groundwater problems.

Analytic Continuation

Once the discrete kernels have been generated the discrete form of the solution for Eq. (1) for drawdowns is:

$$s_w(n) - s^i_w = \sum_{e=1}^{E} \sum_{\nu=1}^{n} \delta_{we}(n-\nu+1)\ [Q_e(\nu) - Q^i_e] \qquad (5)$$

where s^i_w is the initial drawdown and Q^i_e is an *artificial* excitation rate which had it been exerted steadily since Genesis times would have led to the drawdown distribution s_w^i at time zero. The finite difference form of the Boussinesq equation under steady state conditions given the value of the s_w^i leads to an explicit linear equation for each Q_e^i in terms of the initial drawdowns at point e and (usually) at four neighboring points. Symbolically one can write:

$$Q_e^i = \sum_{g=1}^{G} \gamma^*_{eg} s_g^i \qquad (6)$$

In Eq. (6) only a small number of γ^*_{eg} (usually 5) are non zero. Once the γ^*_{eg} have been obtained (and saved), then the Q_e^i can be calculated for any values of the initial drawdowns and Eq. (5) can be used to predict the future evolution of the water table elevation. That Eq. (5) is the solution of the problem follows from the uniqueness of the solution of the boundary value problem since Eq. (5) satisfies the initial condition and the $\delta_{we}(\ )$ satisfy *(a finite difference form of)* the differential equation and the boundary conditions.

Sequential Reinitialization

The use of Eq. (5) becomes costly for large n . One cost effective technique consists of using Eq. (5) for a few periods say n=1,2,3,4,5 then consider $s_w(5)$ as a *new* initial condition. Then Eq. (6) can be used to recalculate the Q_e^i and the process is repeated. In this case the same few $\delta_{we}(\ )$ are used repeatedly namely $\delta_{we}(1)\ldots\delta_{we}(5)$. Only these therefore have to be generated.

Moving Grid System

Since with sequential reinitialization the $\delta_{we}(\ )$ have to be generated for a few periods, it is not necessary to consider the large aquifer, which may be several hundred miles long, but only a small grid subsystem centered about the excitation point. The size of the subsystem is chosen such that over a few periods of time the effect of the central excitation is insignificant beyond the boundaries of the subsystem. The small moving grid scans the big complete system to generate successively unit pulse responses due to excitations through the entire system (8).

SOUTH PLATTE DROUGHT MANAGEMENT STUDY

A 100-mile reach of the South Platte was studied (5,6,7). Different strategies (lining canals, improving farm irrigation efficiency, allowing groundwater pumping beyond current legal practice, etc.) were investigated. Calculations were performed on a *weekly* basis for a *ten year* period for 1000 grid point, each finite difference cell being 1 mi. by 1 mi. Figure 1 displays the effect of different management strategies on South Platte outflow discharge from the system at the Colorado-Nebraska border. Figure 2 displays the effect of the same strategies on the degree of satisfaction of irrigation requirements for the Sterling No. 1 irrigation area.

A major conclusion of the study was that the area can withstand a drought as severe as that of the fifties by proper management of the aquifer. With increased withdrawals the stream-aquifer reaches a new equilibrium and the aquifer is not mined indefinitely. This should not be construed as a license to put more agricultural land into production and draw further from the aquifer

RIO GRANDE-CONEJOS WEDGE STUDY

In this study (9) the concern was waterlogging in the wedge between the Rio Grande and the Conejos rivers near their confluence.

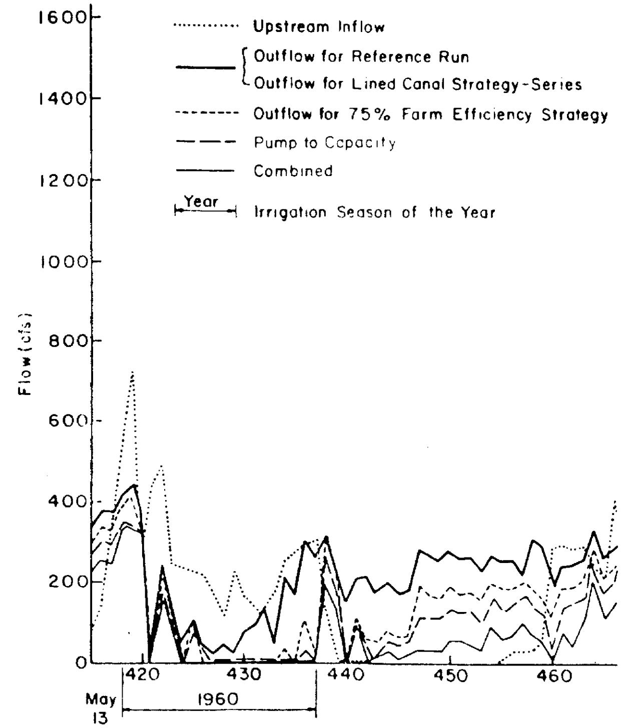

Fig. 1. River inflow into the South Platte study area and river outflow at Julesburg during and following the 1960 irrigation season.

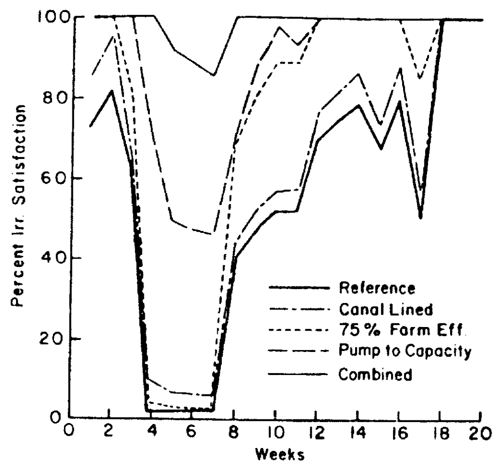

Fig. 2. Percentage degree of satisfaction of irrigation requirement in a typical year for different management strategies in the Sterling No. 1 irrigation area.

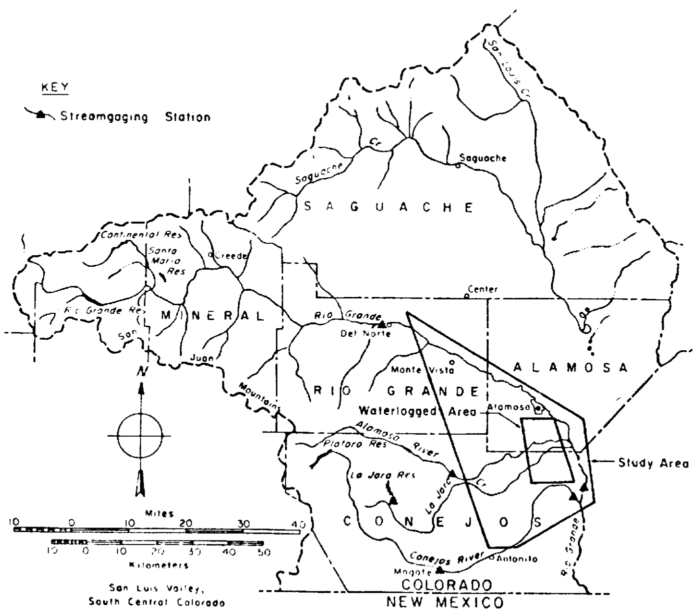

Fig. 3. Location map of study area, San Luis Valley, Southern Colorado

Figure 3 shows the general study area, whereas Fig. 4 shows the reduction in waterlogging as a result of a strategy which reclaims an area by drawing heavily from the aquifer with center-pivot irrigation. The strategy is quite effective from a hydrologic standpoint. However the economic merit of the strategy has not been explored yet.

CONCLUSIONS

This article is too succinct to pretend to be conclusive. The interested reader should consult the references to draw its own conclusions.

ACKNOWLEDGMENTS

This study was partially supported by funds provided by the U. S. Department of Interior, Office of Water Research and Technology as authorized under the Water Resources Research Act of 1964, Agreement 14-34-0001-6211-C-7144, B-199-Colorado Agreement 14-34-0001-9109 and by the Ministry of Agriculture and Water, Kingdom of Saudi Arabia through the U. S. Department of Agriculture, Office of International Cooperation and Development (Agreement No. 58-319R-8-134). The financial support of these sponsors is gratefully acknowledged.

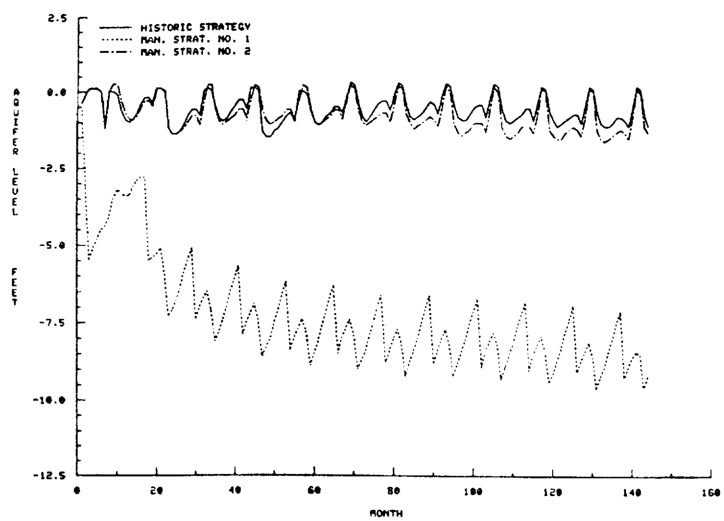

Fig. 4. Comparison of strategies - aquifer level at caln. cell no.11.

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RECEIVED
AUG 24 1983
WATER RESOURCES
STATE - ENGINEER
COLO.

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Orlyn Bell

DISTRICT COURT, WATER DIVISION NO. 5, STATE OF COLORADO

Case No. 82CW107

JUDGMENT AND DECREE

IN THE MATTER OF THE APPLICATION FOR WATER RIGHTS OF BATTLEMENT MESA, INC., IN GARFIELD COUNTY

This matter having come before the Court upon the application of Battlement Mesa, Inc. for water rights, change of water rights and approval of a plan for augmentation, and the Court having considered the pleadings, the files herein, the stipulations submitted by the parties, and the evidence introduced at the hearing in this case, does find as follows:

1. Application. An application for water rights, change of water rights and approval of a plan for augmentation was filed by Battlement Mesa, Inc., a Delaware corporation (hereinafter the "Applicant"), on May 13, 1982.

2. Jurisdiction. All notices required by law have been fulfilled, and the Court has jurisdiction over this application.

3. Objectors and Entrants. Statements of opposition to the application were timely filed by Union Oil Company of California ("Union"), the Colorado River Water Conservation District (the "River District"), the State Engineer, John W. Savage ("Savage"), Middle Park Water Conservancy District ("Middle Park") and the City and County of Denver acting by and through its Board of Water Commissioners ("Denver"). In addition, entries of appearance were filed by Pitkin County and the City of Aspen. No other statements of opposition or entries of appearance were filed herein and the time for filing such statements or entries has now expired.

4. Augmented Water Rights. Applicant is the owner of the following described water rights and conditional water rights to be augmented (collectively hereinafter the "Augmented Water Rights"):

(a) 20 cfs of the Dow Pumping Plant and Pipeline decreed in the District Court in and for the County of Garfield, State of Colorado, in Civil Action No. 4914 for a total of 178 cfs. The decreed source of this conditional water right is the Colorado River (and Green Mountain Reservoir) with a January 24, 1955 appropriation date, and a November 10, 1966 adjudication date. By decree of the District Court in and for Water Division No. 5 (hereinafter the "Water Court"), entered in Case No. 79CW350, the uses of this water right were changed to include municipal, domestic, industrial, commercial, irrigation, sewage treatment and other beneficial uses in connection with the Battlement Mesa Planned Unit Development. The original decreed point of diversion for the Dow Pumping Plant and Pipeline is located at a point on the Northerly bank of the Colorado River, whence the East quarter corner of Section 6, Township 7 South, Range 95 West, 6th P.M. bears North 13° 17' East 753 feet. In addition to the original decreed diversion point, the Dow Pumping Plant and Pipeline has various alternate points of diversion pursuant to decrees of the Water Court entered in Case Nos. W-2786, W-2560 and 79CW350. Moreover, by terms of the instrument whereby Applicant obtained title to the subject 20 cfs of the Dow Pumping Plant and Pipeline, Applicant's interest therein is subordinate in priority to the balance of the 178 cfs decreed to said water right. The effect of this conveyance was to sever into two distinct priorities the Dow Pumping Plant and Pipeline. The subject matter of this application is the subordinate, or most junior 20 cfs decreed to said water right. Nothing herein affects the 158 cfs not the subject of this conveyance.

(b) The following described conditional water rights decreed by the Water Court in Case No. W-2560 for 0.22 cfs (100 gpm) each for municipal, domestic, irrigation and industrial purposes, with an appropriation date of March 1, 1974, all of which derive their source of water from the Colorado River alluvium:

(1) Atlantic Richfield Well No. 1A, State Engineer Permit No. 20065-F, located in the SE¼ NE¼ of Section 13, Township 7 South, Range 96 West, 6th P.M., at a point 2300 feet South of the North line and 800 feet West of the East line of said Section 13.

(2) Atlantic Richfield Well No. 2A, State Engineer Permit No. 20066-F, located in the SE¼ NE¼ of Section 13, Township 7 South, Range 96 West, 6th P.M., at a point 2300 feet South of the North line and 600 feet West of the East Line of said Section 13.

(3) Atlantic Richfield Well No. 3A, State Engineer Permit No. 20067-F, located in the SE¼ NE¼ of Section 13, Township 7 South, Range 96 West, 6th P.M., at a point 2300 feet South of the North line and 1000 feet West of the East line of said Section 13.

(4) Atlantic Richfield Well No. 4A, State Engineer Permit No. 20068-F, located in the SE¼ NE¼ of Section 13, Township 7 South, Range 96 West, 6th P.M., at a point 2400 feet South of the North line and 1250

feet West of the East line of said Section 13.

(5) Atlantic Richfield Well No. 5A, State Engineer Permit No. 20069-F, located in the SW¼ NE¼ of Section 13, Township 7 South, Range 96 West, 6th P.M., at a point 2600 feet South of the North line and 1450 feet West of the East line of said Section 13.

(c) Atlantic Richfield Well B, State Engineer Permit No. 18746-F, decreed by the Water Court in Case No. W-2560 for 1.10 cfs (500 gpm) conditional for municipal, domestic, irrigation and industrial purposes, with an appropriation date of March 1, 1974. The decreed location of this well is in the NE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 2200 feet North of the South line and 2500 feet East of the West line of said Section 7, and its source is the Colorado River alluvium. On April 20, 1981 the State Engineer cancelled the well permit for this undrilled well, and in its place issued well permits granting Applicant the right to divert the water right associated with the Atlantic Richfield Well B at the following new wells:

(1) Battlement Mesa Well No. B1, State Engineer Permit No. 25264-F, permitted for 100 gpm, located in the NE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1960 feet North of the South line and 2200 feet East of the West line of said Section 7.

(2) Battlement Mesa Well No. B2, State Engineer Permit No. 25265-F, permitted for 200 gpm, located in the NE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1745 feet North of the South line and 2165 feet East of the West line of said Section 7.

(3) Battlement Mesa Well No. B3, State Engineer Permit No. 25266-F, permitted for 200 gpm, located in the NE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1720 feet North of the South line and 2360 feet East of the West line of said Section 7.

(d) Battlement Mesa Well No. B4, located in the NE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1465 feet North of the South line and 2185 feet East of the West line of said Section 7. The source of this well is the Colorado River alluvium. The amount claimed is 300 gpm conditional for municipal (including fire protection), domestic, commercial, irrigation, industrial, sewage treatment, recreation and all other beneficial uses, with an appropriation date of May 11, 1981.

(e) Battlement Mesa Well No. B5, located in the SE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1180 feet North of the South line and 2100 feet East of the West line of said Section 7. The source of this well is the Colorado River alluvium. The amount claimed is 300 gpm conditional for municipal (including fire protection), domestic, commercial, irrigation, industrial, sewage treatement, recreation and all other beneficial uses, with an appropriation date of November 11, 1981.

(f) Battlement Mesa Well No. B6, located in the NE¼ SW¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1440 feet North of the South line and 2475 feet East of the West line of said Section 7. The source of this well is the Colorado River alluvium. The amount claimed is 300 gpm conditional for municipal (including fire protection), domestic, commercial, irrigation, industrial, sewage treatment, recreation and all other beneficial uses, with an appropriation date of November 11, 1981.

(g) Battlement Mesa Well No. B7, located in the NW¼ SE¼ of Section 7, Township 7 South, Range 95 West, 6th P.M., at a point 1735 feet North of the South line and 2700 feet East of the West line of said Section 7. The source of this well is the Colorado River alluvium. The amount claimed is 300 gpm conditional for municipal (including fire protection), domestic, commercial, irrigation, industrial, sewage treatment, recreation and all other beneficial uses, with an appropriation date of November 11, 1981.

(h) Eaton Pipeline No. 2, decreed in the District Court in and for the County of Garfield, State of Colorado, in Civil Action No. 4954 for 10 cfs for irrigation, manufacturing, industrial and domestic uses, with a December 18, 1956 appropriation date. By supplemental decree entered in Civil Action No. 4954, 4.25 cfs of this water right was made absolute while the remaining 5.75 cfs was continued as a conditional right. The decreed point of diversion of the Eaton Pipeline No. 2 is located at a point on the left bank of the Colorado River, whence the West quarter corner of Section 7, Township 7 South, Range 95 West, 6th P.M. bears North 40° 44' West 3711.5 feet, and derives its source from the Colorado River.

5. Permit Applications. Applications for permits to construct the Battlement Mesa Wells Nos. B4, B5, B6 and B7 have been filed with the Colorado Division of Water Resources, Office of the State Engineer. The permit application for Well B4 was filed with the State Engineer's office on or about August 11, 1981, and the permit applications for Wells B5, B6 and B7 were filed on or about June 23, 1982. All well permit applications are currently pending and have yet to be acted upon by the State

Engineer. Since over six months have elapsed since these permit applications were filed with the State Engineer, pursuant to C.R.S. 1973, § 37-92-302(2) this matter is now ripe for decision.

6. Augmentation Contract Rights. To augment the water rights described in paragraph 4 above, Applicant proposes to utilize the following described water rights:

(a) Ruedi Reservoir, decreed in the District Court in and for the County of Garfield, State of Colorado, in Civil Action No. 4613, for domestic, municipal, irrigation, industrial, generation of electrical energy, stockwatering and piscatorial uses, with an appropriation date of July 29, 1957. By subsequent order of the Water Court entered in Case No. W-789-76 the decreed amount of this reservoir has been fixed at 102,369 acre feet. Ruedi Reservoir is located in Sections 7, 8, 9, 11 and 14 thru 18, Township 8 South, Range 84 West, 6th P.M., in Eagle and Pitkin Counties, and derives its water supply from the Fryingpan River. By Water Service Agreement dated May 13, 1982, between Applicant and the United States Bureau of Reclamation, Applicant has the right to call for the release of up to 1250 acre feet per year from Ruedi Reservoir for augmentation and other purposes. The term of this Water Service Agreement extends until September 30, 2019, and may be extended at Applicant's option for an additional forty years.

(b) Wildcat Reservoir, decreed by the Water Court in Case No. W-21 for 1140 acre feet for municipal, recreation, irrigation and industrial uses, with an appropriation date of September 28, 1968. The left dam abutment for this reservoir is located at a point whence the SW corner of Section 30, Township 9 South, Range 85 West, 6th P.M. bears South 53° 31' East, 6800 feet, Pitkin County, Colorado, and the reservoir derives its source from Wildcat and East Snowmass Creeks. By Lease with reservoir owner Robert Mosbacher dated January 1, 1980, Applicant has the right to call for the delivery of up to 200 acre feet annually from Wildcat Reservoir. The term of this lease extends until December 31, 1984, and may be extended at Applicant's option for an additional three years.

7. Augmentation Water Rights. Applicant is the owner of the following additional water rights which may be used for augmentation purposes:

(a) Mesa Lakes Nos. 1, 2, 3, 4, 5, 6, 7 and 8, decreed by the Water Court in Case No. 79CW349 for a total of 103.7 acre feet conditional, all with an appropriation date of December 26, 1979. These lakes are located in Sections 7 and 18, Township 7 South, Range 95 West, and Section 13, Township 7 South, Range 96 West, 6th P.M., Garfield County, Colorado, and all derive their source of water supply from the Colorado River, Monument Creek (a/k/a Monument Gulch) and unnamed gulches which flow into the eight lakes.

(b) Monument Reservoir No. 3, decreed by the Water Court in Case No. W-2013 for 500 acre feet conditional for irrigation, piscatorial, municipal, and domestic uses, with an appropriation date of July 24, 1973. This reservoir is located in Section 20, Township 7 South, Range 95 West, 6th P.M., Garfield County, Colorado, and derives its source from Battlement Creek and Monument Gulch. In addition, this reservoir is also entitled to be supplied from the Huntley Ditch - Monument Reservoir Enlargement decreed by the Water Court in Case No. W-2012 for 15 cfs conditional, with an appropriation date of July 24, 1973. This ditch derives its supply from Battlement Creek.

(c) Battlement Mesa Augmentation Reservoir, decreed by the Water Court in Case No. 81CW302 for 240 acre feet conditional for municipal, irrigation, domestic, and recreation uses, with a September 22, 1981 appropriation date. This reservoir is to be located in Sections 18 and 19, Township 7 South, Range 95 West, 6th P.M., Garfield County, Colorado and derives its supply from Battlement Creek, Monument Gulch and the Colorado River.

8. Application for Water Rights. By the subject application, Applicant seeks to adjudicate the conditional water rights for the Battlement Mesa Wells Nos. B4, B5, B6 and B7, more particularly described in paragraphs 4(d), 4(e), 4(f) and 4(g) above. Pursuant to the Pretrial Order entered in the above-captioned case on December 28, 1982, the Court determined that the parties had admitted and stipulated to the fact that, among other matters, the Applicant was entitled to a decree for these wells. Accordingly, the Court finds that Applicant should be granted conditional water rights for the Battlement Mesa Wells Nos. B4, B5, B6 and B7 as described herein.

9. Change of Water Rights. By this application, Applicant seeks the following changes with respect to its water rights:

(a) A change in use of all of the previously adjudicated water rights to be augmented and more particularly described in paragraph 4 above to include municipal (including fire protection), domestic, commercial, irrigation, industrial, sewage treatment, recreation and all other beneficial uses. While additional purposes are sought in connection with this change, the uses originally decreed to these water rights contemplates a level of consumptive use that precludes any notion that any greater demand on the stream will occur by reason of this change. Accordingly, injury to the vested water rights of other appropriators will not occur by virtue of this requested change in use.

(b) A readjudication of and correction of the clerical error made regarding the Mesa Lakes Nos. 1 through 8, more particularly described in paragraph 7(a) above, to include the right to store and use water from these lakes for municipal (including fire protection), domestic, commercial, irrigation, industrial, sewage treatment, augmentation, exchange, recreation and all other beneficial uses, with an appropriation date of December 26, 1979. This correction is sought inasmuch as the decree of the Water Court entered in Case No. 79CW349 which originally adjudicated the eight Mesa Lakes mistakenly omitted the decreed uses and date of appropriation for these water rights. This omission was the result of a clerical error, and thus no injury will occur by reason of this change.

(c) The right to use the Battlement Mesa Wells Nos. B1, B2 and B3 as alternate diversion points for the Atlantic Richfield Well B, and the right to use the Battlement Mesa Wells Nos. B1 through B7 as alternate diversion points for Applicant's Dow Pumping Plant and Pipeline up to the decreed and/or permitted capacity of such wells. As this change involves the movement of points of diversion relatively short distances, with usage and returns to the stream remaining the same, no injury will occur to the vested water rights of other appropriators by virtue of this requested change.

(d) The right to store water diverted under Applicant's Dow Pumping Plant and Pipeline and the Eaton Pipeline No. 2 in the Mesa Lakes Nos. 1 through 8, the Monument Reservoir No. 3 and the Battlement Mesa Augmentation Reservoir. Given the level of consumptive use contemplated by and decreed to these direct flow water rights, no injury will occur to the vested water rights of other appropriators by virtue of the request to store such water in the aforementioned reservoirs.

(e) A change in name of the Atlantic Richfield Wells Nos. 1A through 5A, more particularly described in paragraph 4(b) above, to the Battlement Mesa Wells Nos. 1A through 5A. This change is strictly a clerical matter which will not occasion any injury.

In view of the lack of injury resulting from any of the requested changes, the Court finds that all of the foregoing changes of water rights should be granted.

10. Plan for Augmentation. By Decree of the Water Court dated March 20, 1981, entered in Case No. 79CW351, Applicant obtained approval of a plan for augmentation regarding certain water rights to be used in connection with the new community of Battlement Mesa which is located on the south side of the Colorado River near the Town of Parachute. Among other aspects of the

Court approved augmentation plan, Applicant was awarded the right to make otherwise out-of-priority diversions of its Dow Pumping Plant and Pipeline priority up to the amount of 6 cfs. By the present application Applicant seeks the right to make out-of-priority diversions from the Dow Pumping Plant and Pipeline at all of its alternate points of diversion up to the full 20 cfs owned by Applicant. Moreover, Applicant seeks the right to make out-of-priority diversions from its Atlantic Richfield and Battlement Mesa Wells at such times as said wells are not being used as alternate diversion points for the Dow Pumping Plant and Pipeline. Finally, Applicant seeks the right to make out-of-priority diversions from the Eaton Pipeline No. 2. To permit such otherwise out-of-priority diversions, Applicant proposes to make contemporaneous replacement of resulting depletions from the water storage rights described in paragraphs 6 and 7 above.

11. Depletions. Depletions resulting from diversions and use of water from the Augmented Water Rights consist of the water actually consumed in the course of operating the Battlement Mesa central water and sewer system for municipal, domestic, commercial, irrigation, industrial, sewage treatment, recreation and all other beneficial uses occurring under the system. This depletion will be measured as the difference between raw water diversions from the Augmented Water Rights (all of which will be metered) and return flows discharged to the Colorado River after use. Return flows shall include metered discharges from Battlement Mesa's wastewater treatment plant (or a facility which by contract provides such treatment and metering of discharges) and irrigation return flows from lawns, gardens, parklands, golf courses and other identifiable return flows.

12. Depletion Formula. So as to assure the replacement of all out-of-priority depletions, the method of measuring water consumption and the formula for calculating required replacements of depletions approved by the Water Court in Case No. 79CW351 shall be employed in connection with the present augmentation plan. This depletion formula is as follows:

$$D=Q-P-.2(Q_{m-1}-HU_{m-1})$$

Where:

D equals depletion of water to Colorado River system on any given day expressed in acre feet.

Q equals rate of diversion in acre feet per day of the Augmented Water Rights.

P equals discharge in acre feet per day from the Battlement Mesa wastewater treatment plant.

HU equals the acre feet per day of water delivered to residences, office buildings, schools, and other structures for internal domestic and sanitary purposes, which, for purposes of this plan, is calculated as equalling the measured discharge of the Battlement Mesa wastewater treatment plant divided by 0.95, plus water delivered for industrial or other non-irrigation uses.

Q_{m-1} equals the average daily rate of diversion in acre feet per day of the Augmented Water Rights one month prior to the date for which the formula is being applied. Imposition of this delay factor is designed to account for the lag time from application of water until its return to the stream.

HU_{m-1} equals the average daily delivery of water, in acre feet, of water delivered to residences, offices, buildings, schools, and other structures for internal domestic and sanitary purposes which is calculated in the same way as provided above for HU but for one month prior to the date for which the formula is being applied, plus water delivered for industrial or other non-irrigation uses one month prior to the date for which the formula is being applied.

0.20 equals the increment of applied irrigation water which returns to the Colorado River by ground water percolation or tailwater. It represents the application of irrigation water over and above evapo-transpiration.

In addition to the foregoing depletion formula, Applicant shall account for any water introduced into the Battlement Mesa central water and sewer system which does not originate from the points of diversion described herein.

13. Stream Carriage Losses. By the subject application, Applicant seeks to fix the stream carriage charge imposed on releases of its Ruedi Reservoir contract water for augmentation purposes. In support of this request, Applicant submitted an extensive engineering report which calculated the extent of stream carriage losses resulting from the release of Ruedi Reservoir water for Applicant's augmentation purposes. In addition, Applicant entered into stipulations with the State Engineer, Middle Park, Savage, Union and the River District, the terms of which are more particularly described in paragraph 15 below, in which it was agreed that such stream carriage charges on Applicant's Ruedi Reservoir contract water should be fixed at a constant rate of 9.5% for the first 14 days of release after call initiation, and 0.4% for each day thereafter through termination of the augmentation release. The parties further stipulated that releases of augmentation water from Wildcat Reservoir and the water storage rights described in paragraph 7 above should be subject to such stream carriage charges as may reasonably be imposed by the Division Engineer for Water Division No. 5. In

view of the foregoing, the Court finds that releases of reservoir water for augmentation purposes shall be subject to such stream carriage charges as agreed to by the parties and set forth in the aforementioned settlement stipulations. Furthermore, such augmentation water shall be released at the direction of the Division Engineer for Water Division No. 5 so that releases can be effected in the most practicable way to fulfill the purposes of this augmentation plan.

14. Supplemental and Replacement Wells. In the event Applicant requires supplemental or replacement wells to provide an adequate water supply for those being supplied by the Battlement Mesa water system, the Court finds that such wells may be incorporated in the plan for augmentation subject to the same terms and conditions provided for in this decree; provided, however, that Applicant obtains the requisite replacement or supplemental well permit and a change of water right for any supplemental well.

15. Stipulations. Applicant entered into stipulations with the State Engineer, Middle Park, Savage, the River District and Union, in which the parties agreed to the following:

(a) The stream carriage charges imposed on the use of Applicant's Ruedi Reservoir contract water for augmentation purposes shall be fixed at a constant rate of 9.5% for the first 14 days of release after call initiation, and 0.4% for each day thereafter through termination of the augmentation release.

(b) Releases of augmentation water from Wildcat Reservoir, the Mesa Lakes, Monument Reservoir No. 3 and the Battlement Mesa Augmentation Reservoir shall be subject to such stream carriage charges as may reasonably be imposed by the Division Engineer for Water Division No. 5.

(c) On or before December 31 of each year during the period of the Court's retained jurisdiction, Applicant will provide the State Engineer with monthly estimates of application rates for irrigation within the service area of the Battlement Mesa central water system (service area) during the previous irrigation season. In a typical year, such irrigation season shall extend from April 15 until October 31; provided, however, the actual irrigation season in any given year may be longer or shorter depending on conditions. Such estimates shall be made available to each of the various objectors upon request, and shall be based upon and shall itemize the following information:

(1) Total monthly treated water, produced by the Battlement Mesa Treatment Plant both during the irrigation and non-irrigation seasons.

(2) Monthly estimate of treated water applied for irrigation based on a comparison of the irrigation and non-irrigation season treatment plant amounts (the estimate

shall be calculated by subtracting the average monthly non-irrigation season treated amount from the average monthly irrigation season treated amount).

(3) Monthly diversion records of any untreated water used for irrigation purposes.

(4) Estimate of acreage irrigated within the Battlement Mesa service area.

(5) The monthly consumptive use of irrigation water will be estimated using the Modified Blaney-Criddle method using the growth state coefficient curve for bluegrass for Denver attached hereto as Exhibit A. An additional loss of 5 percent of the applied irrigation water will be assessed for spray evaporation losses.

(6) A comparison on a monthly basis shall be made to determine if the amount of water applied for irrigation ascertained by adding the amounts calculated in paragraphs 15(c)(2) and 15(c)(3) above, exceeds by 20 percent the amount of water consumptively used as calculated in paragraph 15(c)(5) above.

(d) The Applicant shall make the reporting set forth in paragraph 15(c) above regardless of the amount of out-of-priority diversions it is making, or in other words, regardless of whether it is still operating within the limits of the Plan for Augmentation decreed in Water Court Case Nos. 79CW350 and 351. Furthermore, regardless of the time of entry of a decree in this matter, the Applicant shall make a reporting required by paragraph 15(c) above for the 1983 irrigation season.

(e) If in any given month during the period of retained jurisdiction the amount of water applied for irrigation each month does not equal or exceed 120 percent of the consumptive use estimated in paragraph 15(c)(5), then any party may file a notice with the Court during said period of retained jurisdiction and set a hearing on the issue of the amount of return flow from irrigation within the service area and whether any injury results to other water rights. Unless the Court modifies the decree pursuant to its retained jurisdiction, the amount of irrigation return flow shall be calculated by multiplying the monthly estimate of treated water applied for irrigation specified in paragraph 15(c)(2) above times 20 percent. This amount of water is assumed to reach the Colorado River thirty days after application, subject to the other provisions of this stipulation.

(f) It is the intent of the parties to preserve their present position on the issues set forth in the pretrial order paragraphs 3(a), 3(d), 3(e), 3(f), 4(a), 4(b), and 4(c) only insofar as they relate to the question of the extent and timing of Battlement Mesa irrigation return flows. Therefore, in the event any party files a notice pursuant to paragraph 15(e) above, the issues specified above as set forth in the pretrial order as limited herein shall be litigated in the same manner and procedure and with the same burdens as if they were litigated prior to any decree being entered in this case. It is not the intent of any party to waive any claim or defense or to shift any burden of proof on the issues set forth above by entering into this stipulation. Moreover, the consumptive use methodology employed in paragraph 15(c)(5) above shall have no precedential value in the event any party files a notice pursuant to paragraph 15(e) above.

(g) The period of the Court's retained jurisdiction in connection with the above-captioned case shall be no less than 5 years from the date of entry of any decree in this case.

(h) Any decree entered in this case shall contain the following or similar language: The stipulations between the Applicant and the various objectors are entered into on the basis of the facts of this case only, and are not controlling in any other case. Accordingly, the decree shall not by the operation of any of the doctrines of bar, merger, res judicata or collateral estoppel, prevent any party from litigating or contesting in another case any issue addressed in the stipulations between Applicant and the various objectors.

(i) The objectors agree to inclusion of the above provisions or those more restrictive to the Applicant in a consent decree or ruling of referee.

In addition, Applicant and Denver entered into a stipulation which differed from the above stipulations only insofar as Denver took the position that the State Engineer or his designated representative determines stream losses pursuant to C.R.S. 1973, § 37-83-101. Accordingly, paragraph 15(a) above was deleted from its stipulation with the Applicant.

16. Operation of Augmentation Plan. Since the operation of the subject plan for augmentation depends on a contemporaneous replacement of water to satisfy the actual depletions occasioned by any out-of-priority diversions, the Court finds that the Colorado River system will be made whole and that no injury to the water rights of others will be caused by operation of the plan for augmentation in accordance with this decree; provided, however, that this finding shall not limit the Court in making any subsequent revisions pursuant to paragraphs 19 and 20 below.

17. Out-of-Priority Diversions. On any day that a valid call upon the Augmented Water Rights exists, as determined by the Division Engineer for Water Division No. 5, the Applicant as a condition of this decree shall cause there to be made available to the Colorado River a full replacement of depletions associated

with any out-of-priority diversions from the Augmented Water Rights. Applicant shall be entitled to make such out-of-priority diversions, without curtailment for the benefit of more senior priorities, only when the sources of augmentation water identified above are released to the Colorado River system in satisfaction of depletions determined in accordance with this augmentation plan.

18. Weekly Accounting. In order to assure that the vested water rights of others are protected from injury and to assure proper administration of this decree, whenever the Augmented Water Rights are diverting out-of-priority Applicant shall provide the following information to the Division Engineer by a weekly accounting:

(a) The daily amount of water diverted from the Augmented Water Rights at the various alternate points of diversion;

(b) A daily calculation of depletions in accordance with the depletion formula set forth in paragraph 12 above; and

(c) The daily amount of water released from the reservoirs described in paragraphs 6 and 7 above to replace depletions.

Applicant, upon written request, will provide objectors with copies of such weekly accounting, provided that the requesting objector shall reimburse Applicant for any copying and mailing costs reasonably incurred. In addition to the foregoing accounting, Applicant shall comply with the accounting requirements stipulated between the parties and more particularly described in paragraphs 15(c) and 15(d) above.

19. Retained Jurisdiction. In order to assure that the vested water rights of others are not injured by change of water rights provided for herein and or by implementation of this plan for augmentation, the Court retains jurisdiction in this matter and upon proper petition the Court will reconsider its approval of the changes of water rights and the plan for augmentation. In the event the Applicant or any person or party petitions the Court for reconsideration on any of the changes or elements of the plan, the Court shall order appropriate notice to be given to all the parties hereto. Such petition shall be made in good faith, under oath, and shall set forth with particularity the factual basis upon which the requested reconsideration is premised, together with proposed decretal language to effect the petition. The party lodging the petition shall have the burden of going forward to establish the *prima facie* facts alleged in the petition. If the Court finds those facts to be established, the Applicant shall thereupon bear the burden of proof to show (a) that any

modification sought by Applicant will avoid injury to other appropriators, or (b) that modification sought by any other party or person is not required to avoid injury to other appropriators, or (c) that any term or condition proposed by Applicant in response to the petition does avoid injury to other appropriators. In the event any party files a petition with regard to the question of the extent and timing of Battlement Mesa irrigation return flows, then the provisions of the parties' stipulations with regard to this issue, more particularly described in paragraphs 15(e) and 15(f) above, shall control.

20. Period of Retained Jurisdiction. The Court determines that a period of five years will suffice to determine whether injury is in fact precluded or needs to be further remedied. The five-year period of retained jurisdiction shall begin to run on the date of this decree. If no petition for reconsideration is filed within five years from the date of this decree, the retention of jurisdiction for this purpose shall automatically expire.

It is therefore ORDERED, ADJUDGED and DECREED by the Court that (i) the application for conditional water rights for the Battlement Mesa Wells Nos. B4, B5, B6 and B7, more particularly described in paragraphs 4(d), 4(e), 4(f) and 4(g) above, and the application for change of water rights, more particularly described in paragraph 9 above, are hereby granted; and (ii) the plan for augmentation and stream carriage charges described herein are hereby approved, subject to the terms of the stipulations between the parties more particularly described in paragraph 15 above.

It is further ORDERED, ADJUDGED and DECREED that well permits for the Battlement Mesa Wells Nos. B4, B5, B6 and B7 be issued by the office of the State Engineer, and that an application for quadrennial finding of reasonable diligence shall be filed in _______ of 1987 and in ______ of every fourth calendar year thereafter so long as the Applicant desires to maintain the conditional water rights decreed herein, or until a determination has been made that said conditional water rights have become absolute by reason of the completion of the respective appropriations.

It is accordingly ORDERED that this judgment and decree shall be filed with the Water Clerk and shall become effective upon such filing, subject to judicial review pursuant to C.R.S. 1973, § 37-92-304, as amended, and the provisions of paragraphs 19 and 20 above.

It is further ORDERED that a copy of the judgment and decree shall be filed with the State Engineer and the Division Engineer for Water Division No. 5.

Done at the City of Glenwood Springs, Colorado this ______ day of ____________, 1983.

BY THE COURT:

____
Water Judge

APPROVED AS TO FORM AND CONTENT:

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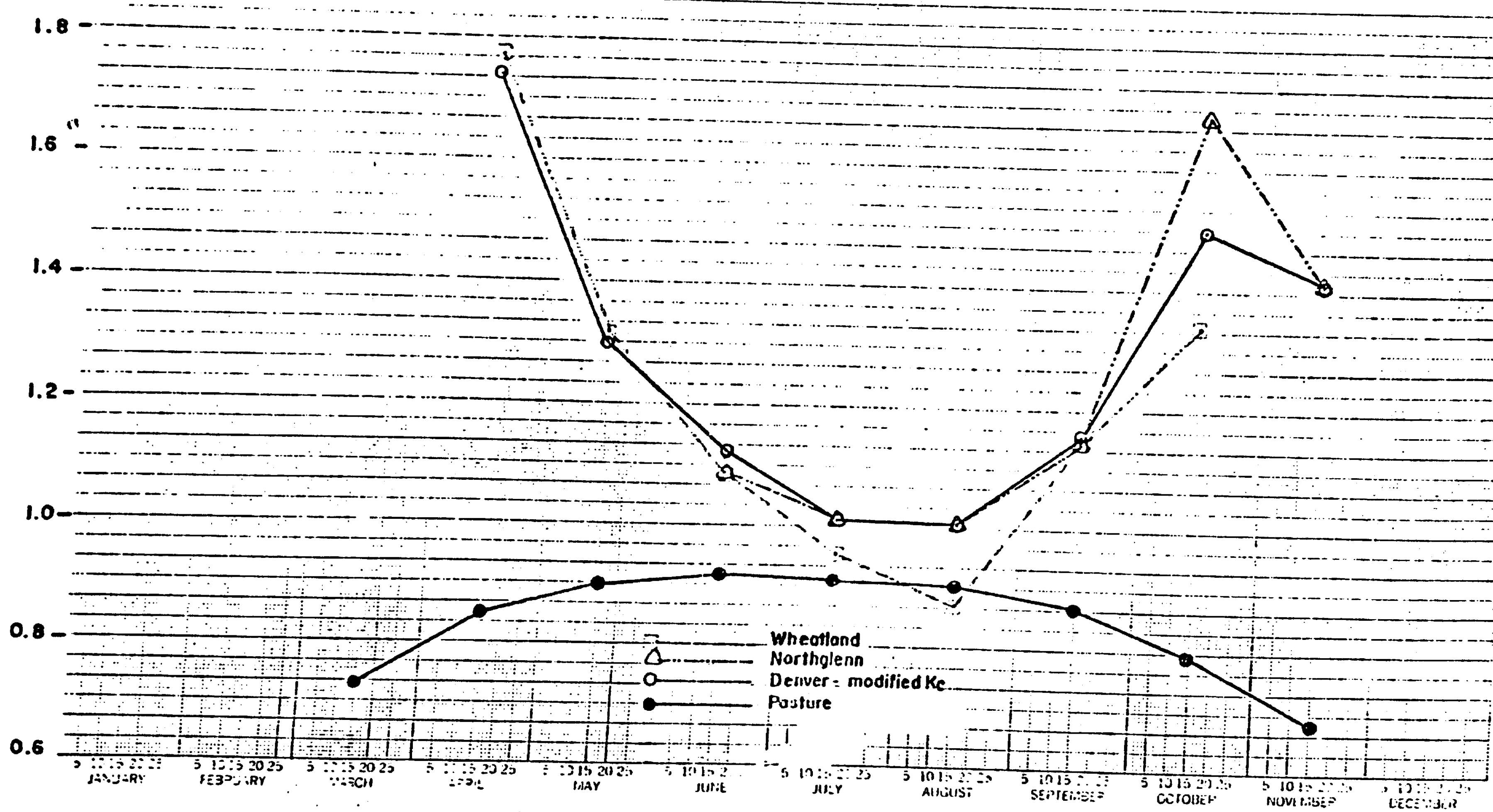
EXHIBIT A

K_c Bluegrass	Denver		1.74	1.30	1.12	1.01	1.01	1.16	1.50	1.41
	Northglenn				1.08	1.01	1.01	1.15	1.69	1.40
	Wheatland		1.74	1.32	1.08	.96	.87	1.15	1.34	
K_c Pasture		.73	.85	.90	.92	.92	.91	.87	.79	.67



RONALD K. BLATCHLEY
TED J. CAMPBELL, JR.
JAMES L. JEHN
JOE TOM WOOD
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January 17, 1984

Department of Civil Engineering
University Station Box 3295
University of Wyoming
Laramie, Wyoming 82071

Attention: Mr. Victor R. Hasfurther

Dear Vic:

In response to your letter of August 9, 1983, there are several items enclosed for your review and consideration. I started responding to your requests months ago. I hope this information, if still needed, will help.

First of all, the individual loss calculations in a ditch or canal are very difficult to define without specific measurements on the system. The one general rule of thumb, used in Colorado at least, is one percent loss per mile of main canal system. This rule of thumb assumes a mutual loss within the system. In other words, if the total system is 20 miles long, there would be a 20% loss applied to all water users on that system.

The Church Ditch, which diverts from Clear Creek near Golden, Colorado, has a step method for charging for losses from the headgate near Golden to a location called the Ketner Flume. an administrative charge of 20% loss is assessed. This particular reach is about 26 miles in length. Beyond the Ketner Flume a separate charge for losses is made. An analysis by Charles Fisk for the period 1934 through 1963 concluded the loss to the Ketner Flume averaged 12%. He did qualify this analysis stating he thought it was low. This was based on average flows of 11,940 af/year. In 1954, the lowest water supply in recent times, the analysis indicated a 50% loss. I have attached portions of his study.

An additional specific study was made by W.W. Wheeler and Associates in the Las Animas Consolidated Company Ditch transfer. I have attached herewith a copy of this letter which summarizes their results.

With respect to river losses, we have used a figure of 0.13% per mile for the South Platte River and its tributaries above Denver. This percentage was developed from averaging various charges which the State Engineer has been making for deliveries

Mr. Victor R. Hasfurther
January 17, 1984
Page 2

of water from the South Park area to the City and County of Denver and other water users. I do not know if the figures which were a part of this average were made on the basis of actual measurements or whether they were assumed figures that were accepted over the years of transfers. The State Engineer allows for a credit for exchanges upstream to points of storage or use when operated on an exchange basis.

When looking at the figures which the Wyoming State Engineer and the Board of Control have used in transfers downstream, I am quite amazed at the percentages that they charge. I suppose that these percentages would be indicative of large alluvial flood plains in the lower elevations of Wyoming. I would think that the validity of any of these numbers that could be used could be determined as to being accurate if an upstream transfer is made rather than a downstream transfer. If, for example, in an upstream transfer the Board would give a credit of 30%, then this would be an acceptable basis. I have always been of the opinion that any transportation charges receive the ultimate test by any objectors in asking for a credit for any upstream exchanges.

Not receive GAINS

Your investigations will be interesting to determine as to what might be acceptable in various areas. However, it would appear to me that you would have to classify them as to the type of stream on which the transfer is being made.

One study which I am aware of was conducted by Wright Water Engineers on the Arkansas River. It is my understanding they made this study for the Southeastern Colorado Water Conservancy District some eight or ten years ago. You may want to contact them concerning this.

Sincerely yours,

BLATCHLEY ASSOCIATES, INC.

Ronald K. Blatchley, P.E.
President

RKB/ph
Enclosures

Fisk Study

NET SUPPLY CAPABILITY

FRICO records indicate that during the 29-year period 1934 through 1962 Church Ditch diversions from Clear Creek averaged about 11,900 acre feet per year. During this same period, flow through the Ketner flume averaged about 6,500 acre feet per year (FRICO records). In 1963, 39% of the Church Ditch stockholders were located above the Ketner flume. These data indicate that net losses in the Church Ditch, between Clear Creek and the Ketner flume, probably averaged about 12% of the Church Ditch's Clear Creek diversion during years 1934 through 1963.

Estimate Of Average Losses In The Church Ditch

Item	Units	Amount
1-Church Ditch average diversion from Clear Creek,1934-62	Acre Feet	11,940
2-Church Ditch loss, Clear Creek to Ketner flume	%	12.0*
3-Church Ditch loss, Clear Creek to Ketner flume	Acre Feet	1,430
4-Church Ditch net supply (1-3)	Acre Feet	10,510
5-Delivery to stockholders above Ketner flume	%	39
6-Delivery to stockholders above Ketner flume	Acre Feet	4,100
7-Deliveries and losses above Ketner flume (3+6)	Acre Feet	5,530
8-Net flow at Ketner flume (1-7)	Acre Feet	6,410
9-Net flow at Ketner flume (FRICO records)	Acre Feet	6,470

*Computed from FRICO data in items 1,5,9.

This computed average ditch loss of 12% seems too low for the Church Ditch. This might be due to deliveries above the Ketner flume amounting to less than 39% of the net supply, or to substantial inflow from Ralston Creek, or to inaccurate measurements of the flow at Ketner flume.

In dry year 1954, FRICO's records indicate a diversion from Clear Creek of 4,236 acre feet and a flow through the Ketner flume of 1,292 acre feet. These data indicate a net ditch loss of 50% in 1954, which seems a little high. However, in 1954 the Church Ditch was shut off for 5 days in May, 6 days in June and 16 days in July. These shut-down periods substantially increase ditch losses.

In a report for Broomfield dated January 29, 1964 Wright Water Engineers mentioned a 20 percent loss in the Church Ditch, based on normal operating procedures.

> Wright: "Sixty-one percent of Church Ditch water is delivered to the Ketner flume, less a twenty percent ditch loss. Water loss in a ditch is due to seepage, evapoation, and the non-beneficial plant growth along the banks of the ditch. 20%
>
> "From interviews it is understood that the delivery of water to the Ketner flume is handled in the following manner. With 100 cfs of water being diverted into the ditch at the Clear Creek headgate, 61 percent of the diversion, less twenty percent loss, or 48.8 cfs would normally pass through the Ketner Flume. If the flow at the flume is less, the Farmers Irrigation and Reservoir Company adjusts the height of the upstream headgates so as to increase the flow at the flume. If the flow at the flume is greater than 48.8 cfs, upstream users may divert more water. Also, if the Farmers Irrigation and Reservoir Company learns that downstream users are not beneficially taking all of their water, it may divert this 'free water' into Standley Lake, which it also administers."

My current estimates of net losses in the Church Ditch to the Ketner flume are 20% for average weather conditions and 40% with recurrence of a very hot and dry year like 1954.

Average annual net water supply capability of the Church Ditch is estimated to be about 8,500 acre feet (10,600 x 0.80). The dependable annual net water supply capability is estimated to be about 2,500 acre feet (4,160 x 0.60). These estimates amount to net water supply capabilities of about 1.50 acre feet per inch share for average conditions and about 0.45 acre feet per inch share for very hot and dry conditions.

$\frac{1.5}{.8} = 1.88$ af.

$\frac{\$3000}{1.88 af} = \$1595/af$

W. W. WHEELER AND ASSOCIATES, INC.
WATER RESOURCES ENGINEERS
SUITE 201
770 WEST HAMPDEN AVENUE
ENGLEWOOD, COLORADO 80110
PHONE
761-4130

December 1, 1981

Mr. Duane Helton
Woodward-Clyde Consultants
2909 West 7th Avenue
Denver, Colorado 80204

Re: #664 Las Animas Consolidated

Dear Duane:

At our last meeting I promised to provide you with ditch loss measurements and 1966 diversion records. This information is enclosed.

The ditch loss measurements were made in 1979 under controlled conditions. From the Parshall flume near the headgate to the Parshall flume near the Purgatoire, no loss was indicated. The measured flow at the upper Parshall flume was 43.1 cfs and the measured flow at the lower Parshall flume was 43.4 cfs. Both Parshall flumes were operating properly and uniformly, so we would expect this measurement to be within the three percent (±) accuracy of a Parshall flume. Because of inaccuracies in defining the exact cross section for the other sections that current meter measurements were taken, the accuracy of these measurements are probably not as good as the Parshall flumes. In our opinion, based on these measurements, the ditch is very tight. On a percentage basis the percent loss with small flows is expected to be greater than for large flows. Overall, we would expect the ditch loss to be less than five percent as an upper limit. If you wish to see photographs showing the conditions during the ditch loss investigation, please advise.

In your report you estimated a project irrigation efficiency of 61 percent which was the result of losses estimated at 10 percent in the canals, 10 percent in the laterals and 25 percent on the farms. If five percent is used for losses in the canals and five percent for the laterals, the project irrigation efficiency becomes 67.7 percent or an increase of eleven percent. For our analysis we used 65 percent. Based on actual measurements, it remains our opinion that 65 percent is certainly a reasonable maximum allowable project irrigation efficiency and perhaps somewhat on the low side for dry year conditions. In wet years the consumptive use is controlled by acreage such that the overall actual average project irrigation efficiency is less than 65 percent.

During 1966 the water commissioner maintained daily records of how much water was diverted from the Consolidated Ditch into the Town Ditch. These quantities were subtracted from the Consolidated Ditch diversion records to obtain the corrected Consolidated diversions. The hand written copies are provided since it is impossible to make good copies from the copies we received from the Division of Water Resources. If you want to see our original copies, please advise.

Please call if you have any questions concerning this information.

Sincerely,

W. W. WHEELER AND ASSOCIATES, INC.

Raymond A Hogan

Raymond A. Hogan, P.E.

RAH:sk
Encl.
xc: Mr. Tim Flanagan
Mr. Fred Easton
Mr. John Patterson
Mr. Ron Blatchley

DETERMINATION OF DITCH LOSS

On November 7, Bill Mitchell, the Consolidated Ditchrider was contacted by telephone and agreed to close all turnouts diverting from the ditch and to keep them closed for November 8th & 9th. He also agreed not to change the headgate settings at the beginning of the ditch so that the flow in the ditch would remain constant.

On November 9, the flow in the ditch was measured at various points. The flow was determined either from the 7 & 12 foot Parshall flumes or calculated from velocity meter readings and measured flow areas. ("wet" ditch cross sections.)

These points along with the measured flows and percent loss or gain values are shown in Table 1.

TABLE 1

CONSOLIDATED DITCH FLOWS & LOSSES

Point of Flow Measurement Pt.#(1)	Description	Distance Downstream From Headgate @ River (Miles)	Measured Flow (cfs)	Percent Loss(3)	Percent Loss(4)
2.	Upper Parshall flume (flow varied from 41.3 to 44.9 cfs; avg. 43.1 cfs.	1.1	43.1		
3.	At Highway bridge	1.2	42.9	.5	.5
12.	Bridge in Section 18	4.3	40.3	6	7
18.	Bridge in Section 21	6.5	44.1	-9	-2
21.	Lower Parshall flume (flow varied from 42.1 to 44.7 cfs; avg. 43.4 cfs)	7.1	43.4	2	- .7
28.	Downstream of waste ditch to Purgatoire River	8.5	12.2	-	-
29.	Upstream end of siphon (2) (avg. of two measurements)	9.5	11.1	2	-
33.	Section 26 (2)	11.2	11.3	-1	-

(1) From field notes.

(2) Leakage of .3 cfs was observed at turnout about 200 feet upstream of the siphon.

(3) Percent of flow measured at 12 foot Parshall Flume near River lost between given and preceding point.

(4) Percent of flow measured at 12 foot Parshall Flume near River lost between given point and 12' Parshall Flume.

Leonard Rice Consulting Water Engineers, Inc.
(303) 455-9589 / 2695 Alcott Street / Denver, Colorado 80211

Leonard Rice
Leslie H. Botham
Gordon W. Fassett

August 19, 1983

Victor R. Hasfurther, Professor
Civil Engineering Department
University of Wyoming
University Station
Box 2395
Laramie, Wyoming 82071

RE: Water Research Center - Instream Flow Loss Project

Dear Vic:

Leonard Rice Consulting Water Engineers, Inc. (LRCWE) is in receipt of your August 9, 1983 letter concerning the Wyoming Water Research Center's project regarding the determination of instream flow losses within natural streams in Wyoming. We are pleased that you would consider us for assistance and hope that your project and the State can benefit from our experience and water right engineering expertise developed for Colorado and Wyoming. The project objectives outlined in your letter seem ambitious and you are fortunate to be involved with such an interesting water resource engineering study.

The problems associated with water right transfers, for which you propose gathering information, is a problem which has been addressed many times in specific water court proceedings within Colorado. Although a comprehensive analytical approach, as you propose, has not been completed, several individual studies and rules of thumb have been used and applied in water court transfers and for administration purposes. In several cases, specific streamflow loss factors have been assigned and charged to deliveries of water from raw water storage facilities to their place of ultimate use. These factors, and others used in water court proceedings, have ranged from 0.05 percent per mile up to 0.25 percent per mile in different studies and cases with which we are familiar.

At this point, we have not had a chance to spend much of our time to thoroughly investigate resources available to us to address your requests. However, I have attached a copy of several pages of a specific document which I was able to easily extract from our water resource library. This study, which we have a full copy of, was one of the few completed for the Colorado State Engineer's Office and others dealing with this specific problem.

Dependent upon our personal time commitments and your timetable for gathering the desired background information, we would suggest and invite you or members of your staff working on this project to visit our offices in Denver, Colorado. At that time, we would be happy to meet with you to review and for you to obtain specific examples of information based on our previous efforts in Colorado. Your staff would also be welcome to look through our water resource engineering library and to review and copy any non-confidential legal or engineering studies which we may have relating to this subject matter.

We would also suggest that you contact the Colorado State Engineer's Office with respect to their administration procedures in this regard. I am not sure if that office has relied on "rule of thumb" criteria or have had commissioned specific hydrologic studies to water collect information concerning this problem. The Water Division Engineer for the seven water divisions within Colorado would also be a good data source regarding site-specific information or rules for certain streams within their divisions. Like Wyoming, Colorado's administration practices vary from district to district, depending upon the degree of appropriation, number of water users and general water supply concerning administration procedures (the east slope of Colorado is dealt with differently than some areas of the west slope).

Again, although we have not had a chance to research your needs extensively at this time, we felt that we would respond in a timely fashion to indicate our interest and willingness to assist with your study. I believe that information which we have, based on our experience or contained in documents in our library, would prove valuable to your research effort and look forward to the opportunity of assisting further in any way we can. Please let me know of your timetable and desires to pursue this matter.

With best regards,

LEONARD RICE CONSULTING WATER ENGINEERS, INC.

JEFF

Gordon W. Fassett
Vice President

GWF/sw
064BPR00

GLENWOOD SPRINGS OFFICE
P.O. BOX 219
GLENWOOD SPRINGS, COLORADO 81602
DENVER OFFICE
2420 ALCOTT STREET
DENVER, COLORADO 80211

WRIGHT WATER ENGINEERS, INC.
ENGINEERING CONSULTANTS
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KENNETH R. WRIGHT
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WILLIAM H. BELLIS
GARY L. BEACH
WILLIAM B. DeOREO

September 1, 1983

Dr. Victor R. Hasfurther
Professor
Civil Engineering Department
University of Wyoming
University Station/Box 3295
Laramie, WY 82071

Re: Instream Flow Loss Project

Dear Vic:

This is in response to your letter of August 9, 1983, requesting the experience of my firm and me on instream flow losses, conveyance losses, etc.

Wright Water Engineers has over 20 years experience in dealing with water losses and conveyance losses in Colorado.

By way of published information, Wright Water Engineers was employed by the State of Colorado to conduct conveyance losses on the Arkansas River. The U.S. Geological Survey followed up on the project and published Colorado Resources Circular No. 20, "Transit Losses and Travel Times for Reservoir Releases, Upper Arkansas River Basin, Colorado", by Russell K. Livingston, prepared for the Colorado Water Conservation Board, 1973.

The conclusion of these studies is that antecedent streamflow compared with the quantity of water to be conveyed considerably effects the amount of conveyance loss. For example, the conveyance loss for a 400 cfs reservoir release into a stream flowing 100 cfs is greater than the loss in conveying 100 cfs reservoir loss in a stream flowing 400 cfs before the release.

The U.S.G.S. report contains the documentation data. If you cannot get a copy of that report, please let me know, and I will copy one for you. If you desire, I can obtain a copy of the Wright Water Engineer's study for you.

decreased return flows
bank storage

The factors involved in river conveyance ~~losses include~~ increased evapotranspiration, effects on groundwater inflow/outflow, "inadvertent diversions", and others. The inflow from ~~tributary streams~~ must be accounted for and the diversions and returns from irrigation projects or other man's water uses must be measured in determining conveyance losses versus depletions of water from the river by man's activities.

I have personally been involved in several conveyance loss studies:

1. The Wheatland canal system. The USBR installed seep meters which attempted to put water under a head through the bottom of the canal to determine the loss rate. We also did inflow/outflow studies.

2. I have studied several ditches by inflow/outflow. The Bureau of Reclamation collected data on the Water Supply and Storage Company main canal in the Fort Collins area. This study, like the Wheatland study, showed that canals gain at times and lose at other times.

3. For the South Platte River reach from Henderson to Fort Lupton, Colorado, for CSU, I set up the following stream loss study:

a. Measured the flow at the Henderson streamgage and determined the velocity.

b. Using the determined velocity, we measured inflows/outflows at various distances downstream from the Henderson gage at the time that the Henderson water should have been flowing by those points.

c. We measured the outflow at the Fort Lupton gage.

d. We then calculated the gain or loss using the inflow/outflow equation and the data collected.

4. On the East Fork of the New Fork River, I participated with the U.S.G.S. in the streamgage measurements of the river gain/loss study and ditch loss study of water diversions in the East Fork River in 1966 through 68. The U.S.G.S. published an open file data report. I did the stream gain/loss and ditch gain/loss analysis. I believe the study and accompanying maps are still on file with the Wyoming Water Development Commission.

5. For the Casper Board of Public Utilities in 1980, I conducted a conveyance loss study on Middle Fork Casper Creek. A copy of our memorandum report is enclosed.

6. For a water rights transfer, we prepared a "paper study" based on inflow/outflow relationships. A copy of our analysis is enclosed. For this transfer our concept was that a variable quantity of water would be allowed to be transferred depending upon the month of the irrigation season from less than 1 cfs to 3.8 cfs during July. This transferred water would be the historic May, June, July, August, and September water that had been formerly being consumptively used which would now be allowed to flow down the river to the new use rather than being consumptively used by irrigation. The conveyance of this water would occur at times when the North Platte River flows from thousands of cfs down to normally around 400 to 500 cfs, but probably not lower than 300 cfs. We had to estimate the diversions and return flows by irrigation ditches and we had to estimate the inflows from tributaries. You can see from the report what our calculations showed.

From my experience, there are various problems in studying and determining conveyance losses. The studies I participated in sometimes gave unexpected results, yet if you think about it, they are probably predictable. Some of my thoughts follow:

1. Antecedent moisture conditions effect natural and conveyance losses considerably. My experience and the literature shows that conveyances of big quantities of water on small streams experience large losses, perhaps even when banks are wet, etc.

2. Losses do not necessarily increase in dry periods. If you have ever done irrigation diversion return flow studies and/or analyses of future conditions on river systems after a new project is implemented, you will find that there should be increased return flows in the river from the prior year new irrigation. The implication is that if there is a new irrigation system on a river, you may not find the same conveyance losses in high, average, or dry years that would have existed prior to the new project. This could be due not only to the the seasonal variation, but also to the lag from prior year return flows in the system that formerly had not been there. Of course, it may take some years for these return flows to build up, but there are now calculation techniques available such as promogated by Robert Glover and published in ASCE and by him. One reference is: "Transit Groundwater Hydraulics" by Robert E. Glover, Professor of Civil Engineering, CSU, January 1974.

3. Conveyance losses probably vary throughout an irrigation season and are probably different in the winter time for year around conveyance--again the result of anecedent moisture conditions, return flows, etc.

4. George Christopulos and other members of the Wyoming Board of Control say, "An appropriator is not entitled to river gains." Several of use who have proposed transfers or changes in systems respond that we are not asking for gains, we are only asking for recognition that there will not be increased losses and, therefore, charges for conveyance ought to reflect this condition.

5. In Colorado, water administration officials usually make inflow/outflow determinations or by some means determine conveyance charges or "shrink." They use the term "shrink" because it represents the fact that water cannot be administered to the "nth decree" even with full time Water Commissioners, reasonable sized river districts, and with all sorts of recorders, etc. The shrink recognizes that there is a cost in terms of water that is associated with the delivery of water.

For example, in Water Division 64, on the South Platte River between Sterling, Colorado and Nebraska, the Water Commissioner has figured the shrink from the Prewitt Reservoir downstream to various ditches. The shrink is greater with river distance because, of course, there is a greater "loss" the farther one travels. We have done extensive river regime studies for a continuing court case involving groundwater appropriators. We find that the river gains as one goes downstream. However, the reservoir releases are usually made when the river is low and the reservoir water does add to the bank storage as it flows downstream so that if a certain release is made, not all of the water will reach its destination even if all of the headgates are carefully controlled. The fact is that the reservoir water plus irrigation perculation adds to the South Platte River alluvial groundwater which returns to the South Platte River. Nowdays irrigation wells effect the water table and the flows that return back to the stream so that the Water Commissioner has trouble delivering the reservoir water to ditches. The fact is the reservoir is still added into the system and almost everyone who has a ditch also has wells. In fact batteries of wells are being used for augmentation to make up the depletion of wells in a somewhat complicated system. The point is that river conveyance is now almost impossible to measure, but shrink is based on historic conditions. In fact, reservoir water is now delivered down ditch systems not in the river to various water users.

6. In Colorado, for augmentation plans on the South Platte River and the Arkansas River, for example, where small quantities of water are involved for augmentation plans, the state recognizes that a very small quantity of water accurately measured into the stream for augmentation plans does put water into the stream system and does not appreciably change the river regime. Therefore, they allow conveyance of small quantities without charge.

This later point would be my primary point. If conveyance of a large quantity of water such as reservoir water in the North Platte system below Alcova Dam can be measured and shown to have an appreciable conveyance loss, after accounting for man's diversion and returns and tributary inflows, then that conveyance charge is appropriately made to the reservoir water users. If a small quantity of water is introduced to the same river and it is known that the small quantity of water is not going to raise the flow at headgates appreciably to cause increased inadvertent diversions nor is it going to increase the area appreciably to increase evaporation, nor is it going to increase the depth appreciably and affect bank storage, then I think it should be recognized that this small quantity of water should not be charged the same conveyance charge that the conveyor of the large quantity of water in the river has to bear.

In fact, I believe the biggest function you could perform would be to demonstrate some of these factors and provide education for water users and for water administrators. Your demonstrations could illustrate that there should be a shrink charge, but this shrink charge can be variable and yet fair to all the water users involved.

I am obviously quite interested in this subject. If I can be of any further assistance, please give me a call, perhaps I can provide additional data from my files for from the Company files. I would be glad to meet with you and your study teams sometime. Football Saturday mornings might make sense.

Best personal regards, and I look forward to be hearing from you.

Very truly yours,

WRIGHT WATER ENGINEERS

By Frank

Frank J. Trelease, Vice President

te

Enclosures

STATE OF NEBRASKA

ROBERT KERREY • GOVERNOR • J. MICHAEL JESS • DIRECTOR

August 30, 1983

IN REPLY REFER TO:

Victor R. Hasfurther, Professor
Civil Engineering Department
The University of Wyoming
Laramie, Wyoming 82071

Dear Professor Hasfurther:

Your letter of August 9, 1983, to Michael Jess, Director, in which you inquire about methods used in Nebraska to determine instream flow losses has been referred to me for reply.

I regret that we will not have much to contribute scientifically to your project, however, we will be very interested in the results of your study.

Transfers in the place of use of a water appropriation in Nebraska were not permitted until new legislation passed this year, and that law became effective on August 26, 1983. Enclosed is a copy of LB 21 which permits limited transfers in places of use.

We have approved many changes in point of diversion on a stream upon filing of proper petition and maps. In my recollection we have not considered losses for such changes in point of diversion. For the most part the changes were not great distances and would not adversely affect other appropriators.

In eastern and southern Nebraska we have occasions where stream channels are used to carry storage water from reservoirs and also to transport water from wells. We have been charging a 10 percent loss which is very arbitrary; however, it has been satisfactory to water users. Enclosed are copies of two Nebraska statutes pertaining to conducting water in natural stream channels.

DEPARTMENT OF WATER RESOURCES, BOX 94676, LINCOLN, NEBRASKA 68509-4676, PHONE (402) 471-2363

The Platte River system in Nebraska receives more attention to stream channel losses than do other streams in the state since we are annually involved in the segregation and distribution of natural flow and storage in that stream.

Enclosed are some data sheets used in our Bridgeport office showing transportation losses attributed to certain sections of the Platte and North Platte rivers during the irrigation season. I would suggest that you try to arrange a visit to our Bridgeport office and review details of these transportation losses. Stan Christensen is the Division Engineer in Bridgeport, and his telephone number is 308-262-0856.

We received a similar request from Wyoming for this type of information about ten years ago when response was from our Division Engineer at Bridgeport. I am enclosing a copy of our reply at that time.

I trust this information will be of some use to you, and I am sure you could benefit much more from a visit to our Bridgeport office.

Sincerely,

DEPARTMENT OF WATER RESOURCES

Robert F. Bishop

Robert F. Bishop
Chief, Operations Branch

RFB/jm
Enclosures
pc: Bridgeport Office

LEGISLATIVE BILL 21

Approved by the Governor February 25, 1983

Introduced by Schmit, 23

AN ACT to amend section 46-122, Reissue Revised Statutes of Nebraska, 1943, relating to surface water and irrigation; to modify provisions relating to certain water rights; to authorize a change of location; to provide duties; and to repeal the original section.

Be it enacted by the people of the State of Nebraska,

Section 1. That section 46-122, Reissue Revised Statutes of Nebraska, 1943, be amended to read as follows:

46-122. It is hereby expressly provided that all water distributed for irrigation purposes shall attach to and follow the tract of land to which it is applied, unless a change of location has been approved pursuant to section 6 of this act.

The ~~; Provided, however, the~~ board of directors may by the adoption of appropriate bylaws ~~by-laws~~ provide for the suspension of water delivery to any land in such district upon which the irrigation taxes levied and assessed thereon shall remain due and unpaid for two years. It shall be the duty of the directors to make all necessary arrangements for right-of-way for laterals from the main canal to each tract of land subject to assessment, and when necessary the board shall exercise its right of eminent domain to procure right-of-way for the laterals and shall make such rules in regard to the payment for such right-of-way as may be just and equitable.

Sec. 2. Any person having a permit to appropriate water for beneficial purposes issued pursuant to Chapter 46 who desires to transfer the use of such water appropriation to a different location within the same river basin than that specified in the permit shall apply for approval of such change to the Department of Water Resources.

Sec. 3. Upon receipt of an application filed under section 2 of this act, the Director of Water Resources shall cause a notice of such application to be published at the applicant's expense at least once a week for three weeks in at least one newspaper of general circulation in each county containing lands on which the water appropriation is or is proposed to be located and a newspaper of general circulation in Nebraska.

Such notice shall be published at least once a week for three consecutive weeks, and shall contain a description of the water appropriation, the number assigned such permit in the records of the department, the date of priority, a description of the lands to which such water appropriation is proposed to be applied, and any other relevant information.

The notice shall state that any person may in writing object to and request a hearing on the application at any time prior to the elapse of two weeks from the date of final publication.

Sec. 4. The department may hold a hearing on an application filed under section 2 of this act on its own motion, and shall hold a hearing if requested by any person.

Sec. 5. Any hearing held pursuant to section 4 of this act shall be conducted in accordance with sections 46-209 and 46-210.

Sec. 6. The Director of Water Resources shall approve an application filed pursuant to section 2 of this act if:

(1) The requested change of location is within the same river basin and will not adversely affect any other water appropriator and will not significantly adversely affect any riparian water user who files an objection in writing prior to the hearing;

(2) The requested change will use water from the same source of supply as the current use;

(3) The quantity of water to be transferred to the new location will not exceed the amount consumptively used under the current use;

(4) The water will be applied to a use in the same preference category as the current use, as provided in section 46-204; and

(5) The requested change is in the public interest.

The applicant shall have the burden of proving that the change of location will comply with subdivisions (1) to (5) of this section, except that the burden shall be on the riparian user to demonstrate his or her riparian status and to demonstrate a significant adverse effect on his or her use in order to prevent approval of an application.

In approving an application, the director may impose any reasonable conditions deemed necessary to protect the public interest. An approved change of location shall retain the same priority date as that of the original water right.

Sec. 7. That original section 46-122, Reissue Revised Statutes of Nebraska, 1943, is repealed.

46-252. Conducting of water into or along natural channels; withdrawal; rights; procedure. Any person may conduct water into or along any of the natural streams or channels of this state, and may withdraw all such water at any point without regard to any prior appropriation of water from such stream, due allowance being made for losses in transit to be determined by the Department of Water Resources. Subject to the exceptions hereinafter stated, before any person may conduct water into or along any of the natural streams or channels of the state, he shall first obtain the consent in writing of the majority of the residents and landowners bordering upon such stream or channel. He shall be liable for any damages resulting from the overflow of such stream or channel when water so conducted contributed to such overflow. Any person actually engaged in the construction or operation of any water power plant may, without such written consent upon payment of all damages, use any such stream or channel for a tailrace or canal; and may, whenever necessary, widen, deepen, or straighten the bed of any such stream. All damages resulting therefrom shall be determined in the manner set forth in sections 76-704 to 76-724.

Source: Laws 1919, c. 190, tit. VII, art. V, div. 3, § 8, p. 848; C.S. 1922, § 8458; C.S. 1929, § 46-608; R.S. 1943, § 46-252; Laws 1951, c. 101, § 94, p. 488; Laws 1955, c. 183, § 4, p. 516.

46-273. Stored floodwaters; United States may furnish to individuals; conditions and requirements. The United States of America is hereby authorized, in conformity to the laws of the State of Nebraska, to appropriate, develop, and store any unappropriated flood or unused waters, in connection with any project constructed by the United States pursuant to the provisions of An Act of Congress approved June 17, 1902, being an Act providing for the reclamation of arid lands (32 Stat. L. 388), and all acts amendatory thereof and supplemental thereto. When the officers of the United States Bureau of Reclamation shall determine that any water so developed or stored is in excess of the needs of the project as then completed or is flood or unused water, the United States may contract to furnish such developed, stored, flood, or unused water, under the terms and conditions imposed by Act of Congress and the rules and regulations of the United States, to any person who may have theretofore been granted a permit to appropriate a portion of the normal flow of any stream, if the water so appropriated, shall during some portion of the year, be found insufficient for the needs of the land to which it is appurtenant. The United States and every person, entering into a contract as herein provided, shall have the right to conduct such water into and along any of the natural streams of the state, but not so as to raise the waters thereof above the ordinary high water mark, and may take out the same again at any point desired, without regard to the prior rights of others to water from the same stream; but due allowance shall be made for losses in transit, the amount of such allowance to be determined by the Department of Water Resources. The department shall supervise and enforce the distribution of such water so delivered with like authority and under the same provisions as in the case of general appropriators. A certified copy of all such contracts for the furnishing of water by the United States, as herein provided, shall immediately upon their execution be furnished to the department; and the water superintendent and water commissioner of the district shall be notified of the time when such water shall be delivered.

Source: Laws 1919, c. 190, tit. VII, art. V, div. 3, § 28, p. 856; C.S. 1922, § 8478; C.S. 1929, § 46-628; R.S. 1943, § 46-273; Laws 1955, c. 183, § 5, p. 517.

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
SECTION BETWEEN MITCHELL AND MINATARE

INFLOW

PASSING MITCHELL Date ________ 19 ____
Sec.Ft.________

Increments

Fanning Seep ____
(1)Wet Spotted Tail ____ ____
(2)Tub Springs ____ ____
Scottsbluff Dr.#1 ____
(3)Winter Creek ____ ____
Gering ____
Scottsbluff Dr.#2 ____
Melbeta Drain ____
Total ____

Storage ____ % ____
Evap. ____ ____
Natural ____ % ____
Evap. ____ ____
Total(a) ____

(a) ____
Gain ____
Total ____

OUTFLOW

PASSING MINATARE on ________ (z) ____

Analysis of (z)

Storage ____ -s ____ = ____
Natural ____ -e ____ = ____ -n ____ = ____
Total(z) ____

Date ____ Enterprise Divs.

River (Sheet No. 4) ____
Morrill Drain ____
Dry Sp. Tail ____
Tub Springs ____
Winter Creek ____

Diversion ____

	Diversions Stor.	Nat.	Total
Minatare		____	____
Winter Cr.C. fr:			
North Platte		____	____
(3)Winter Creek		____	____
(3)Winter Cr.Lat.		____	____
Castle Rock		____	____
Central	____	____	____
Tri-State fr:			
(1)Wet Spt. Tail		____	____
(2)Tub Springs		____	____
Enterprise C. fr:			
(3)Winter Creek		____	____
(2)Tub Springs		____	____
Sub Total	(s) ____	(n) ____	____

____

Loss (e) ____
Total ____

Note: Number preceding increment indicates the source of the corresponding canal diversion

EVAPORATION LOSSES
(Commencing 5-1-62)

	May	June	July	Aug.	Sept.
Second-feet	25	29	30	24	19

Sheet No. 5

19____ Run No. ____

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES

SECTION BETWEEN TRI-STATE DAM AND MITCHELL

INFLOW

	Stor.	Nat.	Total
PASSING TRI-STATE DAM on ________19____	____	____	____

ANALYSIS

Storage____ %____
Evap. ____ ____
Natural____ %____
Evap. ____ ____

Total (a)____

Increments

Horse Creek ____
Sheep Creek ____
Dry Sp. Tail ____
(4)Morrill Dr. ____

Total ____

(a)____ ____
Gain ____
Total ____

OUTFLOW

PASSING MITCHELL on ________(z)

	Diversions		
	Stor.	Nat.	Total
Enterprise River *	____	____	____
(4)Morrill Dr.		____	____
Ramshorn		____	____
Totals	(s) ____	(N)____	____ ____

*Glendo Storage

Loss(e) ____

Total ____

ANALYSIS OF (z)

Storage ____ -s ____ = ____
Natural____ -e____ = ____ -N ____ = ____

Total (z) ____

EVAPORATION LOSSES
(Commencing 5-1-62)

	May	June	July	Aug.	Sept.
Second-feet	16	18	19	15	12

Sheet No. 4

19____Run No.____

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES

SECTION BETWEEN GLENDO DAM AND WHALEN

INFLOW

Natural

GLENDO INFLOW________ 19___ ______
Yesterday ______
Day before ______
GLENDO OUTFLOW_ _ _ _ _ _ _ _ _ _ _ Mean ______

Arbitrary Gain(+) __20__

Available Natural Flow at Whalen Dam ______

OUTFLOW

PASSING WHALEN DAM ________ ________

Interstate Canal ________
Ft. Laramie Canal ________
Total at Whalen Dam (z)________

Analysis of (z)

Storage ______
Natural ______

Total (z) ______

Sheet No. 2 19___ Run No. ____

Note: During 1960 season used 40 S.F. arbitrary gain July, August, September. For 1961 season use 40 S.F. arbitrary gain for 5 months, May-September. For 1962, '63 - '67 seasons use 20 S.F. gain (mean of trib meas) for 5 months, May-September.

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES

SECTION BETWEEN PATHFINDER AND GLENDO

INFLOW

DATE ________ 19__

MEDICINE BOW RIVER ________
NORTH PLATTE RIVER (Sinclair) ________
SWEETWATER RIVER ________
TRIBUTARIES ________

Natural Flow above Gray Reef ________

Daily inflow by months from tributaries in second-feet.

May	June	July	Aug.	Sept.
90	45	40	35	35

Storing* ________

Analysis GRAY REEF OUTFLOW ________

Natural ______ % ______
Evap. Loss ______ ______
Storage ______ % ______
Evap. Loss ______ (s) ______

Total ______

Gain ______

Total ______

OUTFLOW

INTO GLENDO RESERVOIR on______ (z) ______

Less (e) ______

Total ______

Analysis of (z)

Storage (s)______
Natural______-e______= ______+*______ = ______-PPL______ =** ______
Total (z)______

EVAPORATION LOSS

	May	June	July	Aug.	Sept.
Second-feet	43	61	70	61	45

**Show as Natural Flow into Glendo (Sheet No. 2) when storing above Gray Reef

Sheet No. 1 19____Run No.______

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES

SECTION BETWEEN LISCO AND LEWELLEN

PASSING LISCO Date ________ 19___

Natural ______

INFLOW

					Increments		
					to R.	div.	
Storage ____ %	____						
Evap.	____	____	Cold Water			____	
Natural ____ %	____		#Blue Creek	____ +	____ =	____	
Evap.	____	____			Total	____	
	Total (a)	____			(a)	____	____
					Gain		____
					Total		____

OUTFLOW

Analysis of (z)

PASSING LEWELLEN on ________ (z) ______

Storage ____ -s ____ = ____

Natural ____ -e ____ -n ____ = ____

Total (z) ____

	Diversions Stor.	Nat.	Total	
Midland-Overland	____	____	____	
Oshkosh	____	____	____	
#Union	____	____	____	
#Hooper	____	____	____	
#Blue Creek	____	____	____	
#Graf	____	____	____	
#Paisley	____	____	____	
Sub Total	(s) ____	(n) ____	____	____
			Loss (e)	____
			Total	____

EVAPORATION LOSSES
(Commencing 5-1-62)

	May	June	July	Aug.	Sept.
Second-feet	46	57	63	55	42

Sheet No. 8

19 ____ Run No. ____

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES

SECTION BETWEEN BRIDGEPORT AND LISCO
PASSING BRIDGEPORT Date ______ 19___

Sec. Ft.______

INFLOW

Analysis

Storage _____% _____
Evap. _____ _____
Natural _____% _____
Evap. _____ _____
_____

Increments

#Pumpkinseed Creek _____ _____
Silvernail Drain _____
*Cedar Creek _____ _____
Total _____
_____ (a) _____ _____
Gain _____
Total _____

OUTFLOW

PASSING LISCO on __________ (z)______

Analysis of (z)

Storage _____-s_____= _____
Natural____-e_____= _____-n_____= _____
Total (z)_____

	Canal Diversions Stor.	Nat.	Total	
#Court House Rock		_____	_____	
#Meredith-Ammer		_____	_____	
#Last Chance		_____	_____	
Lisco	_____	_____	_____	
Browns Creek	_____	_____	_____	
Beerline	_____	_____	_____	
*Belmont Feeder		_____	_____	
Totals	(s)_____	(n)_____	_____	_____
Loss (e)				_____
Total				_____

Note: Symbol preceding increment indicates the source of the corresponding canal diversion

EVAPORATION LOSSES
(Commencing 5-1-62)

	May	June	July	Aug.	Sept.
Second-feet	39	48	53	46	36

Sheet No. 7

19___ Run No.___

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
SECTION BETWEEN MINATARE AND BRIDGEPORT

INFLOW

PASSING MINATARE Date __________ 19 ____
Sec.ft. ______

Analysis

Storage ______ % ______
Evap. ______ ______
Natural ______ % ______
Evap. ______ ______
Total (a) ______

Increments

Nine Mile Drain ______
Cleveland Drain ______
*Bayard Drain ______ ______
#Red Willow ______ ______
Indian Creek ______
Upper Dugout Creek ______
Total ______
(a) ______
Gain ______
Total ______

OUTFLOW

Analysis of (z)

Storage ______ -s ______ = ______
Natural ______ -e ______ = ______ -n ______ = ______
Total (z) ______

PASSING BRIDGEPORT on __________ (z) ______

Diversions

	Stor.	Nat.	Total
Tri-State from:			
Alliance Drain	____	____	
Belmont	____	____	
Empire	____	____	
Chimney Rock ____	____	____	
Alliance from:			
*Bayard Drain	____	____	
#Red Willow	____	____	
Short Line	____	____	
Nine Mile	____	____	
(s) ____ (n) ____	____	____	____

Loss (e) ______
Total ______

EVAPORATION LOSSES
(Commencing 5-1-62)

	May	June	July	Aug.	Sept.
Second-feet	28	34	38	33	25

Sheet No. 6

19 ____ Run No. ____

SHEET 3 APPROPRIATION DATA

Prefered Rights Farmers D-918	40	?
Percent To Farmers A-660 (Approx. 5%)	4.2	?
Percent Allocated To Nebraska	75	?

SHEET 4 APPROPRIATION DATA TRI STATE – MITCHELL

Enterprise Canal From River	102	?

SHEET 4 EVAPORATION LOSS DATA

May	16	?
June	18	?
July	19	?
August	15	?
September	12	?

SHEET 5 EVAPORATION LOSS DATA MITCHELL – MINATARE

May	25	?
June	29	?
July	30	?
August	24	?
September	19	?

SHEET 6 EVAPORATION DATA MINATARE – BRIDGEPORT

May	28	?
June	34	?
July	38	?
August	33	?
September	25	?

SHEET 7 EVAPORATION DATA BRIDGEPORT – LISCO

May	39	?
June	48	?
July	53	?
August	46	?
September	36	?

SHEET 8 EVAPORATION DATA LISCO – LEWELLEN

May	46	?
June	57	?
July	63	?
August	55	?
September	42	?

ray Re

SHEET 9 KINGSLEY RESERVOIR LOSS FACTOR

(e)	40	?

SHEET 10 TRANSPORTATION LOSSES Keystone – Sutherland

---UNDER 400

May	19	?
June	23	?
July	27	?
August	24	?
September	19	?

---401 TO 800

May	26	?
June	30	?
July	36	?
August	31	?
September	25	?

---801 TO 1200

May	33	?
June	40	?
July	47	?
August	41	?
September	33	?

---1201 TO 1600

May	33	?
June	47	?
July	55	?
August	48	?
September	38	?

---OVER 1600

May	42	?
June	52	?
July	61	?
August	53	?
September	42	?

SHEET 10 APPROPRIATION DATA

North Platte Canal	201	?
Keith-Lincoln Canal	~~84~~ 79	?
Paxton-Hershey Canal	105	?

SHEET 11 TRANSPORTATION LOSSES *Sutherland – North Platte*

---UNDER 400

May	15	?
June	18	?
July	21	?
August	18	?
September	15	?

---401 TO 800

May	19	?
June	24	?
July	28	?
August	24	?
September	19	?

---801 TO 1200

May	25	?
June	31	?
July	37	?
August	32	?
September	25	?

---OVER 1200

May	29	?
June	36	?
July	42	?
August	36	?
September	29	?

SHEET 11 APPROPRIATION DATA

Suburban Canal	78	?

SHEET 12 TRANSPORTATION LOSSES (Top Set) *North Platte – Tri-County Diversion*

May	12	?
June	15	?
July	17	?
August	14	?
September	12	?

SHEET 12 TRANSPORTATION LOSSES (Bottom Set) *Tri-County Diversion – Brady*

May	13	?
June	15	?

July	20	?
August	16	?
September	12	?

SHEET 13 TRANSPORTATION LOSSES *Brady - Cozad*

May	32	?
June	41	?
July	52	?
August	40	?
September	31	?

SHEET 13 APPROPRIATIONS DATA

#1 (To Gothen)	12	?
#2 (To Dawson)	4	?
#3 (To Dawson)	405	?
#4 (To Dawson)	21	?
#5 (To Gothen)	218	?
#6 (To Six Mile)	17	?
#7 (To Cozad)	239	?
#8 (To Orchard-Alfalfa)	85	?
#9 (To 30 Mile)	250	?
#10 (To 30 Mile)	25	?
#11 (To 30 Mile)	49	?
#12 (To Dawson)	24	?
#13 (To 30 Mile)	5	?
#14 (To Dawson)	1	?
#15 (To Dawson)	18	?
#16 (To Dawson)	6	?
#17 (To Gothen)	14	?

SHEET 14 TRANSPORTATION LOSSES *Cozad - Overton*

May	36	?
June	45	?
July	58	?
August	45	?
September	34	?

SHEET 15 TRANSPORTATION LOSSES *Overton - Odessa*

May	20	?
June	24	?
July	32	?
August	24	?
September	18	?

xxxxxxxxxxxxx
xxxxxxxxxxxxx
Bridgeport, Nebraska
April 9, 1973

Paul A. Rechard, Director
Water Resources Research Institue
P. O. Box 3038, University Station
Laramie, Wyoming 82070

Dear Mr. Rechard:

I have at hand a copy of your letter to Mr. Dan S. Jones, Jr., Director of this Department wherein you request information as to our procedure for charging transportation loss to reservoir storage releases into natural stream channels.

This office has responsibilities in the administration of storage releases from reservoirs on the upper North Platte River in Wyoming and Kingsley Reservoir in Nebraska. Since the Wyoming State Engineer's Office is involved in administration of the Wyoming reservoirs I will ignore that portion of the system in this initial correspondence.

The North Platte River from Lewellen (Kingsley inflow) to Odessa, Nebraska, is divided into seven "sections" or "runs" with a gaging station on the main stem at the downstream point of each section. The river stations are spaced at intervals approximating 24 hours of travel. Diversion, tributary inflow and power returns are carefully accounted for in each section. A variable rate transportation loss is assessed proportionately to storage and natural flow upon entry into each section.

The transportation losses assessed are a product of "evolution" and subject to periodic challenge and refinement.

re: Transportation Loss to Reservoir
Storage Releases

The loss figures presently in use were adopted after giving due consideration to monthly temperatures, stage discharge relation to water surface area, measured evaporation rates and the expert and perhaps even inexpert opinion of numerous individuals.

We experience the usual loss in storage water in the initial release to a dry and thirsty river channel, "priming the river" as it is sometimes referred to. In this instance and in a river section that usually indicates a "gain", the losses are assessed to storage and an accumulative account is maintained. As the stage is lowered in the section and gains reappear, a portion of the gains are credited to the storage flow until it is balanced or until the end of the irrigation season when it ceases to be of significance.

The specific procedures and losses are determined administratively as provided in 46-252 R.R.S. Nebraska.

If the foregoing is insufficient for your purposes I will respond to any additional questions you may care to ask. A copy of the results of your investigation would be appreciated.

Very truly yours,

DEPARTMENT OF WATER RESOURCES

Stanley M. Christensen
Division Engineer

SMC:db
Enclosures
cc Dan S. Jones, Jr., Director
Lincoln

State of Arizona

DEPARTMENT OF WATER RESOURCES

99 E. Virginia Avenue, Phoenix, Arizona 85004

BRUCE BABBITT, Governor
WESLEY E. STEINER, Director

September 20, 1983

Victor R. Hasfurther, Professor
Civil Engineering Department
The University of Wyoming
University Station, Box 3295
Laramie, Wyoming 82071

Dear Professor Hasfurther:

This is in response to your August 9, 1983 letter requesting information relative to Arizona's handling of water transfers where a change of point of diversion may result in a conveyance loss.

Arizona has not been faced with many situations where water right transfers involve expected conveyance losses. The older water right decrees in the state are conspicuously silent on losses from use of channels to convey water stored in upstream reservoirs. The net effect being that downstream holders of natural flow water rights absorbed the total losses associated with the channel.

One project of significance in regard to channel losses involved a complex water exchange between the Phelps-Dodge Corporation and the Salt River Project. The project involves import of water to the Verde River Watershed, a tributary of the Salt River. In exchange, Phelps-Dodge diverts water from the Salt River upstream from the confluence of the Verde and the Salt Rivers. Two import diversions are involved. Exchange water is credited at 80 percent from one and 60 percent from the other.

Two studies relative to changes in flow regimes from the addition of new supplies to watersheds have been conducted in Arizona by the U.S. Geological Survey. One was used as a basis for the Phelps-Dodge/Salt River Project agreement. Enclosed for your information are copies of reports developed from these studies and the Salt River Project/Phelps-Dodge agreement.

There are no existing conveyance flow loss models available for streams in Arizona.

Sincerely,

Wesley E. Steiner
Director

WES:pj

Enclosures

P-D Exchange

A G R E E M E N T

THIS AGREEMENT, entered into the 23rd day of Feb, 1962, between SALT RIVER VALLEY WATER USERS' ASSOCIATION, a corporation organized under the laws of the State of Arizona, herein referred to as the "Association", SALT RIVER PROJECT AGRICULTURAL IMPROVEMENT AND POWER DISTRICT, a Political Subdivision of the State of Arizona, herein referred to as the "District", and PHELPS DODGE CORPORATION, a corporation organized under the laws of the State of New York, herein referred to as "Phelps Dodge".

R E C I T A L S :

(1) The shareholders of the Association consist of the owners of lands within the exclusion line of Salt River Project, said lands being sometimes referred to herein as "lands within Salt River Reservoir District". The Association was organized as the instrumentality of the shareholders for the storage, diversion and delivery to lands within Salt River Reservoir District of the normal flow and stored water of Salt River and Verde River to which such lands are entitled, together with water pumped from wells. In the performance of these functions the Association operates and controls, subject to the title or interest of the United States, four storage reservoirs on Salt River consisting in downstream sequence of Roosevelt Dam, Horse Mesa Dam, Mormon Flat Dam and Stewart Mountain Dam, and two reservoirs on Verde River consisting in downstream sequence of Horseshoe Dam and Bartlett Dam, all of which storage reservoirs are collectively referred to herein as the "Salt River Project reservoirs", diversion

dams below the confluence of Verde River with Salt River, canals and laterals for distribution of water to lands within Salt River Reservoir District, and various wells, pumping plants and facilities, all of which, including the Salt River Project reservoirs, are sometimes herein referred to as the "irrigation facilities".

(2) The District, pursuant to a contract with the Association, controls and operates hydro-electric power plants at the dams on Salt River, together with steam generating plants and electric power distribution lines and facilities located in the Salt River Valley, by means of which there is generated electric power which is distributed in various areas and to various users in the State of Arizona.

(3) In the operation of the irrigation facilities and the delivery of water to lands within Salt River Reservoir District the Association commingles normal flow water, stored water and pumped water, delivering to the lands entitled to the same the quantity and quality of water to which said lands are entitled, within the limits of the available supply, without physical segregation of said waters as to source, it being recognized that the Association may substitute or exchange water from one source for water from another source provided the Association delivers to the lands within Salt River Reservoir District water equivalent in quantity and quality to that which such lands would have received if such substitution or exchange had not been made.

(4) Phelps Dodge is engaged, and intends to engage, in the mining and metallurgical treatment of ores. In the conduct

of such operations at Morenci, Arizona, and vicinity, and for domestic uses and other uses incidental to or in connection with such operations, Phelps Dodge requires quantities of water which exceed the quantities available to Phelps Dodge under appropriation water rights which it holds for water from San Francisco River and Eagle Creek, tributaries of Gila River. In order to provide sufficient water for its present operations at Morenci, Phelps Dodge diverts water from Black River, a tributary of Salt River, in exchange for other water delivered to the Association for use on lands within Salt River Reservoir District.

(5) Phelps Dodge anticipates that for many years in the future it will need to divert water from the Salt River drainage basin for use in its mining and metallurgical operations, and for domestic uses and other uses incidental to or in connection with such operations, and contemplates that diversions of water from the Salt River drainage basin for such uses will exceed the quantity which it is currently diverting from Black River.

(6) In order for Phelps Dodge to divert water from Black River as above set forth, or to divert water from any other stream within the Salt River drainage basin (except such water as Phelps Dodge may be entitled to divert from such source under appropriation water rights held by Phelps Dodge), it is necessary that Phelps Dodge make available to the Association, for delivery to lands within Salt River Reservoir District, water equivalent in quantity and quality to that which said lands would have received if Phelps Dodge had not made such diversions from the Salt River

drainage basin, and to compensate the Association for loss in hydroelectric power which would have been generated by water diverted by Phelps Dodge from the Salt River drainage basin above Roosevelt Reservoir and not replaced in Salt River, or its tributaries, above said Reservoir.

(7) As a means of providing the Association with water to replace diversions by Phelps Dodge from Black River, the Association and Phelps Dodge, together with Defense Plant Corporation, entered into an Agreement dated the 1st day of March, 1944, herein referred to as the "Horseshoe Contract", under the terms of which Phelps Dodge constructed Horseshoe Dam on Verde River and became entitled, for purposes of exchange, to the first 250,000 acre feet of surplus flood water developed and stored by this Dam. The aggregate quantity of surplus flood water developed and stored by Horseshoe Dam as of December 31, 1960, exceeded 250,000 acre feet, and as of said date Phelps Dodge had diverted from Black River 67,783 acre feet of water in exchange for a corresponding quantity of water developed and stored by Horseshoe Dam. In accordance with the provisions of the Horseshoe Contract, Phelps Dodge is entitled to divert from Black River the balance of 182,217 acre feet, less the quantity it has diverted under the Horseshoe Contract since December 31, 1960, at rates not exceeding 40 acre feet in any day or 14,000 acre feet in any year.

(8) As a further means of making water available to the Association to replace water diverted by Phelps Dodge from Black River, instead of diverting water under the Horseshoe Contract,

Phelps Dodge has constructed a dam on Show Low Creek, a tributary of Little Colorado River, and a pumping plant and pipeline for delivery of water developed by said dam over Mogollon Rim into Forestdale Canyon and thence by natural channel into Salt River above Roosevelt Dam. Since 1953 Phelps Dodge has delivered water from the reservoir created by Show Low Dam, herein referred to as "Show Low Reservoir", into Salt River which has replaced diversions made by Phelps Dodge from Black River to the extent water delivered from Show Low Reservoir reaches Carrizo Creek, a tributary of Salt River. The quantity of water delivered from Show Low Reservoir which reaches Carrizo Creek has been determined on behalf of the Association by the United States Geological Survey and represents an average of at least eighty per cent of the water delivered from Show Low Reservoir into Forestdale Canyon. By making delivery of water from Show Low Reservoir in exchange for water diverted at Black River, Phelps Dodge has reduced the annual draft under the Horseshoe Contract on the stored water available for delivery by the Association to lands within Salt River Reservoir District.

(9) Phelps Dodge, under the authority of a permit granted by the State Water Commissioner, has initiated construction of a dam and other facilities on East Clear Creek, another tributary of Little Colorado River, for the purpose of delivering additional exchange water into the drainage basin of Verde River, which constitutes a part of the Salt River drainage basin, said Verde River entering Salt River above the point of diversion of

water for use on lands within Salt River Reservoir District. It is the intention of Phelps Dodge to construct said dam so that the reservoir created thereby, herein referred to as "Blue Ridge Reservoir", will provide not less than 12,000 acre feet of initial effective storage capacity,* and to construct a pumping plant of approximately thirty cubic feet per second capacity for the diversion of water from said reservoir, a pipeline of suitable size for the delivery of water from said reservoir into East Verde River, and a hydro-electric power generation plant of sufficient size to provide the electric power required for operation of the pumping plant. Said facilities are herein referred to as the "Blue Ridge facilities".

(10) Under the provisions of Section 8 of Article VIII of the Articles of Incorporation of the Association, the Board of Governors of the Association may not sell, dispose of, distribute or deliver any of the waters of the Association to or for use upon any lands outside the exclusion line of the Salt River Project unless authorized by the prescribed vote of the shareholders of the Association. However, Phelps Dodge may, without the consent of the Association, divert from the Salt River drainage basin water which would otherwise be used on lands within Salt River Reservoir District to the extent Phelps Dodge makes available to the Association from the drainage basin of the Little Colorado River water which the Association may deliver to such lands without diminution in the quantity or quality of water which such lands would otherwise receive, subject to payment by Phelps Dodge to the District

* See attached amendment dated April 13, 1963

of compensation for loss of power which would have been generated by waters diverted by Phelps Dodge from the Salt River drainage basin above Roosevelt Reservoir and not replaced in Salt River, or its tributaries, above said Reservoir. The consent of the Board of Governors of the Association to use of Salt River Project reservoirs to the extent required for storage of water from the drainage basin of Little Colorado River prior to diversion by Phelps Dodge of the equivalent from the Salt River drainage basin is a condition precedent to use of such reservoirs for storage of such water.

(11) It is the mutual desire of the parties to agree upon the operation of the Blue Ridge facilities following completion of construction thereof, the operation of the Show Low facilities, the transportation and other losses to be deducted from water delivered from Blue Ridge Reservoir and Show Low Reservoir into Salt River drainage basin in exchange for water diverted by Phelps Dodge from such basin, the method of accounting for all such water, the compensation to be paid by Phelps Dodge for loss in hydro-electric power resulting from the diversion of water replaced by water from Blue Ridge Reservoir, and the eventual disposition of the Blue Ridge facilities.

A G R E E M E N T :

NOW, THEREFORE, in consideration of the respective rights, privileges and obligations of the parties hereinafter set forth, it is mutually agreed as follows:

ARTICLE I. BLUE RIDGE WATER

SECTION 1. Operation of Facilities. Upon construction of the Blue Ridge facilities, complete and ready for operation, and the obtaining by Phelps Dodge of all easements and rights of way required for delivery of water from Blue Ridge Reservoir into East Verde River, Phelps Dodge shall thereafter operate and maintain said facilities, or cause them to be operated and maintained, in an efficient manner.

SECTION 2. Manner of Operation. Phelps Dodge shall use its best efforts to deliver into East Verde River the maximum quantity of water which can be developed by and pumped from Blue Ridge Reservoir within the limits of the appropriative water rights held by Phelps Dodge and the physical capacities of the Blue Ridge facilities, subject to such interruptions in pumping as, in the reasonable judgment of the Association, will result in the conservation for mutual benefit of the maximum quantity of water practicable.

SECTION 3. Water Losses. Although Phelps Dodge may divert from streams within the Salt River drainage basin water equivalent to that which it makes available to the Association for delivery to lands within Salt River Reservoir District, it is recognized that water delivered into East Verde River, before the same is available to the Association for delivery to lands within Salt River Reservoir District, will be subject to greater losses than water in Black River. Accordingly, for accounting purposes, there shall be deducted from the gross quantity of water delivered from Blue Ridge Reservoir into East Verde River the following:

(a) Twenty per cent of such gross deliveries to cover losses in transit between the point of delivery of said water into East Verde River and its confluence with Verde River.

(b) An additional ten per cent of such gross deliveries to compensate for (i) credits to which the Indians of Salt River Reservation might become entitled under the agreement dated June 3, 1935, between the United States and the Association, and to compensate for credits to which the City of Phoenix might become entitled under the agreement dated November 22, 1946, between the City of Phoenix and the Association, such credits, in each case, arising out of the delivery of water from Blue Ridge Reservoir into East Verde River and/or the storage in Verde River reservoirs of water delivered from Blue Ridge Reservoir into East Verde River, and (ii) evaporation loss arising out of storage in Salt River Project reservoirs of Blue Ridge credit water, as hereinafter defined, or its equivalent.

40% of Blue Ridge Dv

(c) An additional ten per cent of such gross deliveries to compensate for any error in the above allowances and for other losses arising out of the transportation and storage of water delivered from Blue Ridge Reservoir into East Verde River.

SECTION 4. Measurement and Adjustment of Losses.

(a) For the purpose of determining whether the actual losses in transit referred to in subparagraph (a) of Section 3 above exceed twenty per cent of the water delivered from Blue Ridge Reservoir into East Verde River, the parties shall agree upon a program for the installation of such stream gauges and the making of measurements reasonably required to establish the average percentage of water delivered from Blue Ridge Reservoir into East Verde River that is lost in transit before reaching Verde River during the first five years of operation of Blue Ridge facilities, or such longer period as may be agreed upon, and if the parties are unable to so agree then the nature, extent and duration of such program shall be fixed by arbitration under Section 19 of Article V hereof. The program shall be conducted by or through the Association, it being contemplated that the Association will enter into a cooperative agreement with the United States Geological Survey for such purpose. The actual costs incurred by the Association in the conduct of this program, other than administrative, accounting or overhead expenses, shall be promptly reimbursed to the Association by Phelps Dodge following receipt by Phelps Dodge of statements for such costs.

(b) Upon completion of such program the parties shall endeavor to agree upon the percentage of loss, and if they are unable to so agree then such percentage shall be fixed by arbitration under Section 19 of Article V hereof. If the percentage of loss, either as fixed by agreement between the parties, or as fixed by arbitration if the parties are unable to agree, shall exceed thirty per cent of the water delivered from Blue Ridge Reservoir into East Verde River, then the deduction provided for in subparagraph (a) of Section 3 hereof shall be increased to the extent such percentage of loss exceeds thirty per cent, and adjustment for prior deliveries shall be made accordingly.

(c) In case of increased diversions by third persons from East Verde River which are deemed illegal by either party, the Association and Phelps Dodge will cooperate to prevent any such increase, and shall share jointly in the expense of any legal action necessary to prevent such increased diversions.

SECTION 5. Blue Ridge Credit Water. The water delivered from Blue Ridge Reservoir into East Verde River, after the deductions provided for in Sections 3 and 4 above, shall be credited to Phelps Dodge as water made available to the Association for delivery to lands within Salt River Reservoir District in exchange for water to be diverted by Phelps Dodge from the Salt River drainage basin, and shall be known as "Blue Ridge credit water". The Blue Ridge credit water shall be credited by the Association to a separate water account to be maintained by the Association which shall be known and is herein referred to as the "Blue Ridge Account". The Blue Ridge Account shall be debited with the following:

(a) Said Account shall be debited currently with the quantity of all diversions of water by Phelps Dodge from Black River so long as there is any balance remaining in the Blue Ridge

IF VERDE SYSTEM SPILLS

Account.

(b) In the event the storage capacity of Verde River reservoirs is filled and as a consequence water is spilled from the lowest of these reservoirs which is not diverted for use on lands within Salt River Reservoir District, any credit balance in the Blue Ridge Account at the time such spill occurs shall be reduced by the amount of spill not diverted for use on said lands.

ARTICLE II. SHOW LOW WATER

SECTION 6. Operation and Maintenance of Show Low Facilities. Phelps Dodge shall continue to operate and maintain the Show Low facilities or cause them to be operated and maintained.

SECTION 7. Delivery of Water. Phelps Dodge shall use its best efforts to deliver from Show Low Reservoir into Forestdale Canyon, at or below the outlet of the present pipeline, the maximum quantity of water which can be developed by and pumped from said reservoir within the limits of the appropriation rights to such water held by Phelps Dodge and the physical capacity of the Show Low facilities, but only at such times and at such rates as, in the reasonable judgment of Phelps Dodge, will result in the conservation for mutual benefit of the maximum quantity of water practicable and will not result in excessive erosion of the natural channel of Forestdale Canyon.

SECTION 8. Losses in Transit. Actual losses in transit of water delivered from Show Low Reservoir into Forestdale Canyon, between the outlet of the present pipeline and the confluence of Forestdale Canyon with Carrizo Creek, having been found by measurements during the years of operation of the Show Low facilities to be an average of not more than twenty per cent of the water delivered from Show Low Reservoir into Forestdale Canyon, it is agreed that twenty per cent of the gross quantities of water delivered into Forestdale Canyon shall be deducted to cover losses in transit between the point of delivery and the confluence of Forestdale Canyon with Carrizo Creek, provided that if a change shall occur in physical conditions which, in the opinion of either party, substantially affects such losses in transit, then the percentage of loss shall be redetermined by agreement of the parties, and if the parties are unable to so agree, then such percentage shall be fixed by arbitration under Section 19 of Article V hereof, and the amount as so agreed upon or fixed shall thereafter be deducted to cover said losses.

SECTION 9. Show Low Credit Water. The water delivered from Show Low Reservoir into Forestdale Canyon, after deduction of the losses in transit as provided in Section 8 above, shall be credited to Phelps Dodge as water made available to the Association for delivery to lands within Salt River Reservoir District in exchange for water to be diverted by Phelps Dodge from the Salt River drainage basin. Said water shall be known and is herein referred to as "Show Low credit water", and the quantities thereof, as delivered into Forestdale Canyon, shall be credited by the Association to a separate water account to be maintained by the Association which shall be known and is herein referred to as the "Show Low Account". The Show Low Account shall be debited with the following:

(a) Said Account shall be debited currently with the quantity of all diversions of water by Phelps Dodge from Black River in excess of quantities debited to the Blue Ridge Account, so long as there is any balance remaining in the Show Low Account.

(b) At the end of each calendar month, any credit balance then remaining in the Show Low Account shall be reduced by one per cent as compensation for evaporation losses of Show Low credit water, or the equivalent thereof, from reservoirs on Salt River.

Spill on Salt River Side

(c) In the event the storage capacity of all reservoirs on Salt River is filled and as a consequence water is spilled from the lowest of these reservoirs which is not diverted for use on lands within Salt River Reservoir District, any credit balance in the Show Low Account at the time such spill occurs shall be reduced by the amount of spill not diverted for use on said lands.

ARTICLE III. EXCHANGE WATER

SECTION 10. Diversions by Phelps Dodge. Phelps Dodge may divert water under this Agreement from Black River up to but not in excess of the balance in the Blue Ridge Account and the Show Low Account at the time of such diversion. Phelps Dodge shall measure with standard measuring devices all water delivered from Blue Ridge Reservoir into East Verde River and from Show Low Reservoir into Forestdale Canyon, and all water diverted by Phelps Dodge from the Salt River drainage basin, and shall maintain permanent records of such measurements. At the expiration of each eight day period, commencing with such date as the Association shall designate, or more frequently if required by the Association, Phelps Dodge shall furnish the Association with a statement of the quantities of water so measured during such period. Said measuring devices and records shall at all times be subject to inspection by representatives of the Association.

SECTION 11. Exchange Water to be Equivalent. The gross amount of water, less the deductions and reductions provided herein, delivered from Blue Ridge Reservoir and Show Low Reservoir into the Salt River drainage basin during any period beginning on the effective date of this Agreement and ending on any subsequent date, for use on lands within the Salt River Reservoir District, shall be at least equivalent in quantity and quality to that which Phelps Dodge has diverted, or has become entitled to divert, during such period under Section 10 above.

SECTION 12. Limitations on Phelps Dodge Diversions. Diversions of water by Phelps Dodge under Section 10 above shall be only from Black River for use in the conduct of mining and metallurgical operations, and for domestic uses and other uses incidental to or in connection with such operations, subject to modification of this limitation by mutual agreement to meet changed circumstances. The maximum rate of diversion from Black River, including diversions under the Horseshoe Contract, shall not exceed forty (40) cubic feet per second.

ARTICLE IV. HORSESHOE CONTRACT

SECTION 13. Horseshoe Contract not Affected. All of the rights and obligations of the parties under the terms and provisions of the Horseshoe Contract shall be and remain unchanged by this Agreement. Water diverted by Phelps Dodge from Black River shall not be charged against exchange water under the Horseshoe Contract so long as there is any balance remaining in the Blue Ridge Account or the Show Low Account in exchange for which Phelps Dodge shall be entitled to divert the equivalent from Black River.

ARTICLE V. MISCELLANEOUS

SECTION 14. Compensation for Power Loss. Phelps Dodge shall pay to the District compensation for loss of power revenues from the hydro-electric power plants on Salt River resulting from the diversion by Phelps Dodge of water debited to the Blue Ridge Account. In the case of all such water diverted by Phelps Dodge from the Salt River drainage basin above Roosevelt Dam, the yearly amount of such payments in lieu of lost power revenues shall be the product of the number of acre feet of water debited to the Blue Ridge Account for diversions of water by Phelps Dodge during such year times the gross revenues of the District from the sale of hydro-electric energy generated during such year at power plants located at the dams on Salt River divided by the total number of acre feet of water released from Stewart Mountain Reservoir during such year exclusive of spillway discharges. Gross revenues of the District from the sale of hydro-electric energy generated at power plants located at the dams on Salt River is herein defined as the gross power revenue of the District in any such year divided by the total kilowatt hours of power generated and purchased by the District in any such year, and the quotient obtained therefrom multiplied by the number of kilowatt hours generated by the hydro-electric power plants of the District at the dams on Salt River in any such year. There shall be included in the gross revenues of the District the value of the power used by the Association and the District for their own purposes, and the rate charged for such power for the purpose of this Agreement shall be the same as that charged other customers having like or similar loads.

SECTION 15. Transfer of Blue Ridge Facilities. Whenever Phelps Dodge determines that it no longer has any need for water from Blue Ridge Reservoir, Phelps Dodge shall offer in writing to transfer, without compensation from the Association, to the extent it then may legally do so, all of its right, title and interest in the Blue Ridge facilities, including rights to the waters to be developed thereby, to the Association for use of water from Blue Ridge Reservoir upon lands within the Salt River Reservoir District, but not for resale of such water to any third party, and Phelps Dodge shall thereupon be released of all obligations thereafter accruing under this Agreement with respect to such facilities. If, within ninety days following receipt of such offer the Association shall accept the same, but not otherwise, Phelps Dodge shall execute and deliver to the Association such instruments as may reasonably be required to effect such transfer.

SECTION 16. Cancellation of Balances. Phelps Dodge, at its option, may cancel at any time, or from time to time, all or any part of the balance then remaining or which may thereafter accrue in either the Blue Ridge Account or the Show Low Account, or both of said accounts, by giving notice in writing of such cancellation to the Association and, upon receipt of such notice, the Association shall reduce the balance in such accounts accordingly, provided that for the purpose of compensation for power loss under Section 14 above, but not otherwise, the quantity of water so cancelled in the Show Low Account shall be credited against the number of acre feet of water debited to the Blue Ridge Account for diversions of water by Phelps Dodge during the year in which such cancellation occurs and any subsequent year or years.

SECTION 17. Rental Charge for Use of Storage Facilities. Phelps Dodge shall not be subject to any charge for the storage of waters in Salt River Project reservoirs unless the Association or the District become subject to federal income tax or state income tax, or to other taxes differing in nature from any now imposed on either of them. In the event any such new taxes are imposed, Phelps Dodge shall pay to the Association, as compensation for the storage of water, sums equal to the total of such new taxes in each year multiplied by the ratio that the combined balance in the Blue Ridge Account and the Show Low Account at the close of such year bears to two million acre feet, the approximate gross capacity of the Salt River Project reservoirs; provided that the maximum storage charges hereunder per acre foot of water in the combined balance in the Blue Ridge Account and the Show Low Account at the close of any year shall not exceed one-half of the average charge per acre foot for water delivered to users within the Salt River Reservoir District during such year. If the combined balance in said accounts shall be reduced during any year as a result of spill or other cancellation of credits to either or both accounts, the storage charge computed as above shall be increased as compensation for part time storage of the quantity represented by such reduction, and such increase shall be the proportion of the storage charge on an equal quantity for the entire year which the period prior to such reduction bears to the entire year.

SECTION 18. Indemnity. Phelps Dodge shall at all times defend and hold harmless the Association from and against any claim of liability not otherwise provided for herein arising from the delivery of water from Blue Ridge Reservoir or Show Low Reservoir hereunder.

SECTION 19. Arbitration. Either the Association or Phelps Dodge may give notice in writing to the other that it desires to submit to arbitration any matter in dispute which is expressly provided in this Agreement as being subject to arbitration. Within two weeks after the giving of such notice, each such party shall appoint a person to act as its representative, giving written notice of such appointment to the other, and the two persons so appointed shall promptly select a disinterested third party to act as arbitrator, who shall be an engineer or a recognized authority with experience applicable to the matter to be arbitrated, and the arbitrator so appointed shall proceed to determine the matter in dispute. The arbitrator shall adopt his own rules of procedure. Each such party shall prepare and furnish through its representative to the arbitrator such data or other information available to such party as the arbitrator deems necessary to make a determination. Any determination under the provisions of this Section shall be rendered in writing, signed by the arbitrator, and delivered to the representative of each such party, and upon such delivery shall be deemed final and binding upon such party. The expenses of the arbitration, except for the compensation and expenses of the representative appointed by the Association and except as otherwise determined by the arbitrator, shall be borne by Phelps Dodge.

SECTION 20. Effective and Operative Dates. This Agreement shall be and become effective upon execution by the parties, but the same shall not become operative until

(a) The Secretary of the Interior has approved this Agreement.

(b) Completion of construction of the Blue Ridge facilities, in all respects.

(c) Any and all rights, permits, licenses, easements and privileges lawfully required for the operation of the Blue Ridge facilities hereunder and the delivery of water from Blue Ridge Reservoir into East Verde River have been obtained by Phelps Dodge.

SECTION 21. Termination. This Agreement shall be terminated, and shall be of no further force or effect, except as hereinbelow provided, (i) unless the Blue Ridge facilities have been constructed, completed and ready for operation, within five years from the date hereof, or (ii) at such time as Phelps Dodge determines that it no longer has any need for water from Blue Ridge Reservoir and offers to transfer, to the extent it may legally do so, all of its right, title and interest in the Blue Ridge facilities to the Association as provided in Section 15 of this Agreement. Following the making of such offer of transfer Phelps

Dodge may continue to divert water from Black River to the extent of the balance in the Blue Ridge Account and the Show Low Account.

IN WITNESS WHEREOF, the parties have caused these presents to be executed by their proper officers, thereunto duly authorized, as of the date first herein written.

SALT RIVER VALLEY WATER USERS' ASSOCIATION

By ______________________

Its President

Attest:

____

Its Secretary

SALT RIVER PROJECT AGRICULTURAL IMPROVEMENT AND POWER DISTRICT

By ______________________

Its President

Attest:

____

Its Secretary

PHELPS DODGE CORPORATION

By ______________________

Its PRESIDENT

Attest:

____

Its SECRETARY

APPROVED: January 21, 1953

____

Secretary of the Interior

COPY

April 18, 1963

Salt River Valley Water Users Association
Salt River Project Agricultural Improvement
and Power District
P. O. Box 1980
Phoenix, Arizona

Gentlemen:

With reference to the Agreement entered into by Phelps Dodge Corporation with you under date of February 23, 1962, and approved by the Secretary of Interior under date of January 21, 1963, it is contemplated that there will be substituted for the pumping plant, pipeline and hydroelectric power generation plant a tunnel through which there may be delivered water by gravity flow from said reservoir into East Verde River at a rate of approximately 30 cubic feet per second.

Accordingly, it is proposed that the above mentioned Agreement be hereby amended so as to define "Blue Ridge Facilities" as meaning such facilities as may be installed for the delivery of water from Blue Ridge Reservoir into East Verde River at a rate of approximately 30 cubic feet per second capacity.

It would be appreciated if you will indicate your approval of this amendment on the original and one copy of this letter and return the same at your early convenience in order that the Agreement may be deemed amended and the construction of the tunnel may proceed promptly.

Yours very truly,

PHELPS DODGE CORPORATION

By ______________________
Its President

Attest: ______________________
Its Secretary

APPROVED

SALT RIVER VALLEY WATER USERS ASSOCIATION
By ______________________
Its President
Attest: ______________________
Its Secretary

SALT RIVER PROJECT AGRICULTURAL IMPROVEMENT
AND POWER DISTRICT
By ______________________
Its President
Attest: ______________________
Its Asst. Secretary

TEXAS DEPARTMENT OF WATER RESOURCES
1700 N. Congress Avenue
Austin, Texas

Charles E. Nemir
Executive Director

August 30, 1983

Professor Victor R. Hasfurther
Civil Engineering Department
The University of Wyoming
Laramie, Wyoming 82071

Dear Professor Hasfurther:

Re: Request for Information Concerning Methods for Evaluating Conveyance Losses in Natural Channels as Pertains to Water Rights Transfers

In your recent letter, you inquired as to the methods used by the Texas Department of Water Resources for estimating flow losses in natural channels. The Department does not have a specific engineering method for evaluating losses in natural channels. Generally, Department hydrologic studies express water losses as flow rate percentages, which are based upon information provided by staff members of river authorities or other water distribution agencies.

In Texas, water delivery systems are not operated by the State, except in one instance. The one exception is the Department's Rio Grande Watermaster Office in the lower Rio Grande Basin of Texas. The Department, through the Watermaster Office, schedules daily flow releases from Amistad, Falcon and Anzalduas Reservoirs for water deliveries to irrigation districts along the river. Losses are expressed as a percent of the monthly flow and vary according to the month of the year (see attached table). The percentages of loss were derived based upon years of experience of the Watermaster staff. No analytical technique was used to derive these estimates. Should you wish to inquire further as to the Rio Grande Watermaster operations, please contact Mr. Dan Havelka, 811 E. Pike Blvd., Weslaco, Texas 78596, 1-512-968-5481.

Professor Victor R. Hasfurther
August 30, 1983
Page Two

Texas has no legal provisions which require an estimate of conveyance losses to a waterway when a change in the point of diversion is desired. The Texas Water Commission is charged with ensuring that water is put to a beneficial use and that existing senior or vested water rights are not impaired (Texas Water Code 11.134). When a change in a point of diversion is applied for which may impair other water rights, a public hearing must be held. [See Water Development Board Rule 156.04.10.001(f)]. Presumably, preparatory to the hearing, a water availability analysis will be done by the staff, especially if additional water is requested. Such analysis of water availability will include factors such as instream losses due to evaporation or percolation. However, there will be no specific estimate of conveyance loss and none is required either by statute or case law.

When an applicant seeks to change the place of use and there will be no increased use of state water or injury to other lawful users of state water, a public hearing does not need to be held. [See Texas Water Development Board Rule 156.04.05.001(d)]. Additionally, interjacent water users must be notified by certified mail of the proposed change in place of use and given two weeks to protest. [See Texas Water Development Board Rule 156.04.05.001(e)]. In such a case, a water availability analysis will not normally be done so long is there is no increase in the amount of water used or the diversion rate. And once again, there are no statutes, case law or rules which require an estimate of instream losses.

The Water Development Board has a rule regarding the conveyance of water stored in reservoirs to downstream users. The rule states that the bearer of transportation and evapotranspiration losses shall be the supplier unless the contract specifically states otherwise. [See Texas Water Development Board Rule 156.01.50.005(c)].

We regret that we cannot provide any further information for your study.

Sincerely yours,

Charles E. Nemir
Executive Director

cc: Dan Havelka

Table 1

ADDITIONAL RELEASES FROM ANZALDUS DAM TO COMPENSATE FOR CHANNEL LOSSES AND MEASUREMENT ERRORS

Month	Additional Release (%)
January	5
February	5
March	5
April	8
May	8
June	10
July	10
August	8
September	8
October	5
November	0
December	0

(f) The notice shall be mailed and first published not less than 20 days before the date set for the hearing.

Amended by Acts 1977, 65th Leg., p. 2207, ch. 870, § 1, eff. Sept. 1, 1977.

Derivation:
Former Section 5.131.

1. In general

Order granting permit to appropriate state water by construction of dam and reservoir on creek did not deny owner of riparian rights due process on theory that notice of hearing before the Water Rights Commission was inadequate, where owner had notice of the hearing and was represented by counsel at the hearing. Webster v. Texas Water Rights Commission (Civ. App.1975) 518 S.W.2d 607, ref. n. r. e.

§ 11.133. Hearing

At the time and place stated in the notice, the commission shall hold a hearing on the application. Any person may appear at the hearing in person or by attorney or may enter his appearance in writing. Any person who appears may present objection to the issuance of the permit. The commission may receive evidence, orally or by affidavit, in support of or in opposition to the issuance of the permit, and it may hear arguments.

Amended by Acts 1977, 65th Leg., p. 2207, ch. 870, § 1, eff. Sept. 1, 1977.

Derivation:
Former Section 5.132.

§ 11.134. Action on Application

(a) After the hearing, the commission shall make a written decision granting or denying the application. The application may be granted or denied in whole or in part.

(b) The commission shall grant the application only if:

(1) the application conforms to the requirements prescribed by this chapter and is accompanied by the prescribed fee;

(2) unappropriated water is available in the source of supply; and

(3) the proposed appropriation:

(A) contemplates the application of water to any beneficial use;

(B) does not impair existing water rights or vested riparian rights; and

(C) is not detrimental to the public welfare.

Amended by Acts 1977, 65th Leg., p. 2207, ch. 870, § 1, eff. Sept. 1, 1977.

Derivation:
Former Section 5.133.

Law Review Commentaries

Legal assurances of adequate flows of fresh water to maintain proper salinity levels. Corwin W. Johnson, 10 Houston L. Rev. 598 (1973).

Index to Notes

1. Construction and application

Water Rights Commission was not required to include findings of fact and conclusions of law in order granting permit for appropriation of state water. Webster v. Texas Water Rights Commission (Civ. App.1975) 518 S.W.2d 607, ref. n. r. e.

Where subsec. (b) of former § 5.133 authorizing Water Rights Commission to grant permit for appropriation of state water in certain circumstances did not require Commission to make written findings of fact, it would be presumed that all controverted fact issues were found by the Commission in favor of its order granting permit. Id.

2. Change in use of water

Under Vernon's Ann.Civ.St. art. 7880—4a (repealed; see, now, § 51.184), conservation and reclamation district could change the use of irrigation waters under its certified filing to municipal and domestic purposes as conditions changed, without filing an amendment to its certified filing and obtaining the approval of the Water Rights Commission, which was notified of the process of conversion over a period of 38 years before attempting cancellation, where the owners of 70% of the irrigatable land in

AMENDING WATER RIGHTS
156.04.05.001-.002

The following rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. APPLICATION FOR AMENDMENT. Only an application to amend an existing permit, certified filing, or certificate of adjudication which does not contemplate an additional use of state water or an increased rate or period of diversion and which, in the judgment of the Commission, has no potential for harming any other existing water right, is subject to amendment by the Commission without notice other than that provided to the record holder. Upon filing such an application, the Commission shall consider whether additional notice is required based on the particular facts of the application. Applications of the following descriptions have been found not to require additional notice:

(a) To correct errors inadvertently made in the preparation of a permit, such as in the name of the water right holder, boundary description, or other detail incorrectly transcribed.

(b) To cure ambiguities or ineffective provisions in a water right.

(c) To reduce an appropriation or rate of diversion.

(d) To change the place of use when there will be no increased use of state water and the change will not operate to the injury of any other lawful user of state water.

(e) To change the point of diversion when the existing rate of diversion will not be increased and there are no interjacent water users of record between the originally authorized point of diversion and the new one, or when interjacent water users agree in writing to the amendment. If written agreements are not obtained, interjacent water users will be notified of the proposed change by certified mail and given two weeks within which to protest. If no protest is received, further notice will not be required.

(f) To add additional points of diversion where the existing rate of diversion will not be increased and there are no water users of record between any originally authorized point of diversion and the new one to be added, or when interjacent water users agree in writing to the amendment. If written agreements are not obtained, interjacent water users will be notified of the proposed change by certified mail and given two weeks within which to protest. If no protest is received, further notice will not be required.

(g) To reduce or increase the authorized storage capacity of a reservoir where the change results from new or corrected data on the topography of the site.

.002. FILING. Applicant shall file an application prepared in the manner of an original application for a permit; however, the heading should be altered to reflect the fact that it is a request for an amendment.

AMENDMENTS TO WATER RIGHTS REQUIRING
MAILED AND PUBLISHED NOTICE
156.04.10.001-.002

The following rules are promulgated under the authority of Sections 5.131 and 5.132, Texas Water Code.

.001. APPLICATION TO AMEND. Unless authorized by Rule 156.04.05.001, applications for amendments to permits, certified filings, or certificates of adjudication must comply with requirements for a water permit. The applications of the nature described in this rule are as follows:

(a) To change the place of use when other users of state water may be affected;

(b) To increase an appropriation and/or rate or period of diversion;

(c) To change the purpose of use where the change would authorize a greater consumption of state water or would materially alter the period of time when state water could be diverted;

(d) To add points of diversion which would result in a greater rate of diversion or impair other water rights;

(e) To remove or modify the requirements or conditions of a water right which were included for the protection of other water rights;

(f) To change a point of diversion which may impair other water rights;

(g) To relocate or enlarge a reservoir; or

(h) To extend the period of duration of any term permit.

.002. FILING. Applicant shall file an application prepared in the manner of an original application for a permit; however, the title should be altered to reflect the fact that it is a request for an amendment.

proposed amendment's potential impairment of senior and superior water rights.

(2) The applicant shall pay appropriate fees in accordance with §§303.131-.140 (156.02.60.001-.010) of this title.

.005. SPECIAL REQUIREMENTS FOR DOWNSTREAM SALES OF WATER FROM STORAGE.

(a) If a contract which obligates a supplier to supply water from storage to a purchaser does not provide for or contemplate diversions of water by the purchaser from stream flows other than those resulting from releases of water from storage under the contract, the supplier shall make releases of water to the extent of the purchaser's downstream diversions within the limits of the supplier's contractual amendment or the contract, except as provided below:

(1) Nothing in these rules shall require a seller to release water to satisfy contractual obligations when such release would aggravate existing flooding conditions, and the purchaser may divert water during such conditions pursuant to the contract;

(2) The Executive Director shall recommend a condition to be included in the contractual amendment which

establishes stream flood stages for purposes of this rule. The Commission shall include such a condition in each contractual amendment which authorizes such a downstream sale of water from storage.

(b) If a contract which obligates a supplier to supply water from storage to a purchaser provides for or contemplates diversions of water by the purchaser from stream flows other than those resulting from releases of water from storage for the purchaser's use under the contract, and if neither the purchaser nor the supplier possesses a valid appropriative right authorizing such diversions:

(1) The purchaser shall obtain a regular, term or temporary permit to appropriate water to the extent of his maximum annual diversions of water not released from storage before the supplier's contractual amendment, if any, may be approved; or

(2) The supplier shall apply for a regular, term or temporary permit or a contractual amendment to appropriate water to the extent of the purchaser's maximum annual diversions of water not released from storage; provided that the contract specifies that the supplier shall have or shall apply for such permit or amendment and that the purchaser

shall divert water not released from storage only pursuant to such permit or amendment.

(c) If any contract required to be filed under this subchapter does not specify which party will bear transportation and evapotranspiration losses from a reservoir to a downstream point of diversion, the supplier shall bear such losses.

.006. SPECIAL REQUIREMENTS FOR DIVERSIONS OF WATER UPSTREAM OF A STORAGE RESERVOIR. If a contract provides that a purchaser may divert water upstream of a supplier's storage reservoir in a manner which impairs the supplier's water right:

(1) The purchaser shall obtain a term or temporary permit to the extent of his maximum annual diversions of water for the term of the contract; or

(2) The supplier shall obtain a term or temporary permit or a contractual amendment to the extent of the purchaser's maximum annual diversions of water for the term of the contract; provided that the contract specifies that the supplier shall apply for such permit or amendment and that the purchaser shall divert water only pursuant to such permit or amendment.

.007. EXISTING UNPERMITTED SUPPLY CONTRACTS. Within 90 days of the effective date of this subchapter, all suppliers of water