

A WATER RIGHTS TRANSFER EVALUATION PROCEDURE
WITH APPLICATIONS FOR WESTERN ENERGY DEVELOPMENT

by

John H. Gerstle
and
David H. Marks, Principal Investigator

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ABSTRACT

A WATER RIGHTS TRANSFER EVALUATION PROCEDURE

WITH APPLICATIONS FOR WESTERN ENERGY DEVELOPMENT

This report deals with questions of water supply for coal development in the semiarid western United States. A method is developed to evaluate yields of water rights in "appropriation" or "permit" systems of water administration. Water rights are characterized in terms of location, priority, decreed maximum diversion, actual diversion in periods of low flow, and consumptive use. Transfers of water rights are evaluated in this method by using institutional procedures as a framework for analysis. A case study is performed on the North Fork of the Powder River, Wyoming, in which institutional considerations are discussed, and water rights are evaluated for a hypothetical facility.

This procedure is not limited to energy facilities, but may be used in most cases of water rights transfers. The method is designed for use with easily obtained data in order to facilitate its use in practice.

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Chapter 1

INTRODUCTION

1.1 Overview

It has become clear in the last decade that the importance of coal as a source of energy in the United States is likely to increase, resulting in an enlarged rate of extraction and exploitation from present levels. Because a major portion of the coal resource of the United States lies in the west, and because these western coal deposits are typically relatively inexpensive to exploit and yield coal with desirable qualities, a large portion of the increase in coal extraction is expected to occur in the western states.

The extraction and conversion of coal require a variety of direct and indirect inputs, one of the most important of which is water. Water is necessary for both direct requirements such as feed water for coal gasification plants, cooling water, and water used in surface mine rehabilitation, and in indirect requirements such as water for a population increased by the addition of a labor force connected with coal extraction. The amount of water required at any single location will clearly depend upon the specific facilities and operations to be found there, but it is clear that the annual water requirements of some facilities will range up to the thousands of acre-feet level in a semi-arid region.

The sources of water required by these coal conversion facilities are of concern primarily because of their relative magnitude compared to existing reliable sources of water. One of the most important

sources of water supply is expected to be water transfers from existing uses, the most significant of which is irrigation. There are several institutional aspects involved in the transfer of water, and these must be considered together with the physical availability of water in any planning for water supplies involving transfers. This thesis develops a model and procedure for the analysis of water transfers which takes natural streamflow and institutional considerations into account and indicates reliability and quantity in water yields.

1.2 General Approach

The general approach in this research is to evaluate the yields of water rights under low flow conditions with respect to water diversion and consumption. Transfer yields are then assessed with respect to institutional constraints. This method is designed for use in areas where water is administered under appropriation or permit doctrine, so that the basis of water ownership is characterized by well-defined rights.

The reliability of water supply associated with each right is analyzed by the use of a stream simulation model with differing low flows. The existing diversion rules are taken into account in this evaluation. A similar process is used in the evaluation of the transfer, with iterations made in an automatic process until all institutional demands are satisfied.

A brief discussion is included of the major institutional considerations involved with the large-scale allocation of water resources in the Northern Great Plains to uses in energy development. Additionally, comments on the alternative water sources of the necessary

magnitude are made. A case study using the procedure developed in this thesis, and incorporating the institutional aspects, is made of a specific river system.

1.3 Literature Survey

Much has been published on the subject of energy development in the western United States, and only slightly less attention has been paid to questions of water supply for the development.

Projections of coal development and descriptions of several facets involved can be found in Anderson and Fritz (1976), BLM (1974), DoI (1973), FEA (1974), Freudenthal et al. (1974), Harza (1976), MRBC (1975), Radian (1975), Synfuels Interagency Task Force (1975), USDA et al. (1974), WPA (1976), and Wyoming WRRI (1973, 1974). A large number of reports and assessments have been published on aspects of water supply and energy development interaction. Some which review the general situation in the western states are WRC (1974), DoI (1976), National Petroleum Council (1973), Western U.S. Water Plan (1975), and Bureau of Reclamation (1976).

Other reports deal with specific areas, primarily the Upper Colorado River Basin and the Missouri River Basin. Publications concerned with the Upper Colorado River Basin include Bishop and Naryanan (1978), DoI (1973), DoI (1974), and USGS (1976a,b). An idea can be gained of the situation in the Missouri River Basin by reviewing Alvarez (1976), Bureau of Reclamation (1977), Hudson (1978), NDSWC (1968), DoI (1974), Corrigan (1975), Montana DNRC (1975), MRBC (1975a), NGPRP (1974a,b,c), COE (1974), USGS (1975), Wyoming WRRI (1973). More specific reports

regarding the Yellowstone River Basin situation include Montana DNRC (1977, 1976), DoI (1975), Madsen (1975), MRBC (1976, 1975b, 1975c), OWRC (1976), Bureau of Reclamation (1974), DoI (1975), Wyoming SEO (1976, 1972a,b; 1974, 1973).

Publications specifically concerned with the Powder River Basin include USDA et al. (1968), BLM (1974), USGS (1974, 1975a, 1956), Wyoming WRI (1974), Wyoming SEO (1973, 1972a, 1972b, 1974).

Some concepts of water management factors and other institutional considerations can also be found in Goslin (1975), Thomas and Anderson (1976), Trelease (1976), Riggs (1975), Hartman and Seastone (1963, 1965), Corrigan (1975), Wyoming (1971), Smith and Castle (1964), Kneese and Smith (1966), and Garrity and Nitschke (1968).

Much less effort has been made in the determination of optimal water distribution and allocation taking multiple objectives into account. There have been several attempts to model the problem as a regionally aggregated supply and demand model, exemplified by Brill et al. (1977) and Whitlatch (1977). These work on a basis of minimizing the total cost of supplying coal and water to coal conversion plants, as well as minimizing the costs of transporting the product to its point of use. Typically, the coal gasification plants are considered in terms of unit size, and the output of the model is in terms of the conversion plant capacity to be located at various points. Linear programming is used to minimize the costs associated with each major resource input and expense. Another group of methods have used various techniques to evaluate facilities siting and water supply problems on a relatively highly aggregated level, as in Cohon and Church (1976),

King et al. (1972), and Bishop and Naryanan (1978).

A major problem lies in that water sources for any single facility are not usually obtained according to the results obtained by such highly aggregated models. Although the results give an indication of regions in which facilities might be constructed for optimal system-wide operation, most decisions are in fact made not by a central planning authority, but by officers of a single company. The objectives of the private company are frequently much different from those of a central planning authority. Although both parties may have a multiobjective problem for which an optimum solution is desired, the objectives will in many cases differ significantly.

An additional problem in most existing regional planning models lies in their assumption of an inflexible static situation with respect to water supplies and coal supplies. While this may be appropriate on the highly aggregated level at which the models operate, a far different situation exists in individual cases when a single company is evaluating the optimum sources of inputs for its facility. Typically, a specified coal field produces coal for use in the planned facility, which places significant limits on the location options. A number of instances exist in which it appears possible that several plants from different companies may be located in the same region; in such cases, the consequences for water supplies will be significantly different if the plants act in a cooperative venture to secure a water supply or in a competitive manner to obtain water.

It should be noted that in most cases, an ideal, perfectly competitive market does not exist in the commodity of water when it is

handled on the level of magnitude implied in this discussion. The limited supply on any single stream and large demand, combined with the time-varying levels of supply and demand, causes a situation in which single transactions alter the market. The operation of this market is guided by the physical and social consequences of major changes in local water resources. It is these changes, both physical and social, that form the basis of need for multiobjective consideration of the sources of water supply for new facilities. Some of the different objectives that should be considered in the analysis are discussed in the section dealing with institutional considerations. Other considerations include those of the organization building and operating the facility, some of which might be profit maximization and risk minimization.

Because the transfer of water rights plays such a central role in the considerations, a method is needed to assess the consequences of such transfers. Developed in this thesis is a model and procedure which is designed to fill this need.

1.4 Description of This Report

This thesis is divided into four chapters, including this introduction. Chapter 2 presents a description of desired characteristics of a procedure evaluating water rights transfers and includes the development of the proposed model.

Chapter 3 discusses the case study of the Powder River - Gillette, Wyoming area. The institutional aspects of water supply are presented, and results of the procedure are shown for a hypothetical water requirement.

Chapter 4 provides a summary and conclusion. Possible improvements to the model and some new applications of the model are suggested.

Chapter 2

MODEL JUSTIFICATION AND DESCRIPTION

2.1 Introduction

Any strategy of water supply must be formulated and operated within a set of "institutional considerations." Consisting of the legal, political, social, economic and administrative apparatus by which water resource management decisions are made, institutional considerations form a framework upon which different water management options may be constructed. The institutional procedures have developed along different approaches and to varying degrees for the many aspects which are involved. For example, well-defined procedures delineate the mode by which water rights are owned and transferred in the Northern Great Plains. However, procedures dealing with the assessment of the environmental, social, and economic consequences of such transfers are, in most cases, not defined with such clarity. Thus, the problem must be handled carefully in order to ensure that the solution remains viable in all pertinent aspects. The following aspects form a portion of the "institutional considerations" pertaining to water management:

- (1) Interstate Compact Requirements
- (2) Intra-state Water Law
- (3) Intra-state Water Policy
- (4) Federal Reserve Rights and Federal Water Policy
- (5) Environmental Considerations
- (6) Local, Regional, and State Socio-political-economic considerations.

(7) Federal Water Policies

2.2 Water Administration

Water law in the states of interest to this study is based on the "permit" or "appropriation doctrine" which developed in the arid portions of the United States in the 19th Century as settlement occurred and it became obvious that the common law of the eastern, more humid states, based upon the Riparian Code, was not suitable. The principle of the Appropriation Doctrine lies in its treatment of water as property which may be owned by individuals or groups and transferred among them, subject to certain restrictions. Contrary to Riparian Doctrine, the diversion of water from the natural water body is encouraged, and in some cases required in order to maintain a water right.

In general, the priorities of various "water rights" are determined by the rule of seniority, commonly expressed as "first in time, first in right." Essentially, this means that the oldest water right has priority over junior rights, in that the senior right is able to divert its full amount before the junior right is allowed to divert any water at all.

All rights have, as part of their description, a definition of the amount, point of diversion, and the use of the water, along with the date of appropriation. However, several other factors typically play a significant role in the determination of the actual characteristics of a water right. These are based upon one of the foundations of water law as practiced in these states: that each user is entitled the maintenance of water in the same condition as that which existed

at the time of his date of appropriation. This is an extremely important idea, because it implies that junior water rights are protected against adverse effects resulting from the manipulation of senior rights.

On this basis, any water right is effectively specified in terms of several aspects not listed above. These include:

- (1) The historical timing of diversions
- (2) The historical point of return flow
- (3) The historical fraction of diverted flow consumptively used
- (4) The historical amount actually diverted

The foundation for these additional qualifications lies in the precept governing the notion of a water right: the actual water used is the measure, basis, and the limit of a water right. Thus, it is clear that, if there is a discrepancy between the recorded characteristics of a water right and its historical pattern of use, the historical use is the measure by which that water right is evaluated.

This logic provides the foundation for the notion of a prescriptive right. Although this varies among the states, prescriptive rights may be acknowledged as proper (or "perfected") after the necessary procedure has been followed. A prescriptive right is one that is based upon the idea of "squatter's rights." Essentially, this is the process of establishing a legal water right on the basis of having used the water of a number of years without enjoying legal title to it. The terminology typically used in such cases speaks of situations in which an undecreed water right "ripens" into a prescriptive right.

There are, in principle, two kinds of water rights; these are direct flow diversion rights, and storage (reservoir) rights. Although they both follow the description given above, differences between them are significant. Generally, storage occurs (storage rights are exercised) in the season when direct flow diversions put their smallest demand upon the river. In many cases, diversion periods are stated in the official decree of the storage water right. Additionally, storage water can generally be released at the direction of its owner, without regard to downstream rights.

Of interest is the trend in the United States towards the increasing use of the appropriation system with respect to water administration. The mode of water administration is decided by the individual states, of which the seventeen western states and Alaska, Hawaii, Mississippi, and Florida recognize the Appropriation Doctrine to some degree (Garrity and Nitschke, 1967). It can thus be seen that a model based on the appropriation system does indeed have a significant area of pertinence.

2.3 Existing Techniques of Water Transfer Evaluation

The need to evaluate the yield of a water right as the point of diversion is transferred along the river in order that no adverse impact is felt by other rights has been demonstrated in the previous sections. In this section, the method historically used for such evaluations is described.

To set the procedure in the correct perspective, it must be noted that usually a water resource engineer is hired as a consultant to

perform this analysis, unless in-house engineering talent is available. The engineer then typically uses all files available from other jobs in the same area, and from records of whatever sources he can find in order to evaluate the historical yield of the water right of interest in its current point of diversion. In most cases, the best record is the field notebook kept by the water commissioner responsible for that district. This notebook, however, is often incomplete, and the information shown is not always very satisfactory.

Frequently, entries are made in the commissioner's field books only as to the dates of diversion and extremely rough approximations or guesses with respect to areas irrigated. Thus, it is seen that the main source of information regarding the use of water is relatively inaccurate and in many cases, unreliable.

These notes are used in order to calculate the historical yield of a water right, and its return flow is also evaluated partially on the basis of these records, supplemented by site visits. By subtracting from total diversions the calculated return flow, the consumptive use is evaluated. Additionally, independent consumptive use calculations are made.

The records are then examined to determine when other water rights diverting water from the same stream were "called out" (e.g. not permitted to divert) relative to the water right under question. With the history of consumptive use and water calls along the river, a determination is then made of the amount of water which can be transferred without damage to any of the existing water rights. In principle, only the consumptive water use may be transferred relative to senior

rights.

Because a new approval or decree must be obtained for the transfer to become completely effective, the new priority, point of diversion, amount of flow, and mode of use must all be specified. In most cases, the priority remains the same as before, and the major change is in maximum permitted flow diversion.

This procedure is valid, and well-accepted by the administrative and judicial system. However, because of the time and effort involved in an evaluation of the type described in this chapter, it is an expensive proposition merely to study a system of proposed water rights, even without going through the entire administrative procedure to certify a transfer. For this reason, there is usually very little opportunity for optimization of water supply strategy when purchase of existing water rights is a large part of the strategy. Generally, an off-the-cuff decision is made to acquire certain water rights, and negotiation starts at that point.

Generally, far more water is acquired than is actually needed, for several reasons. Chief among these are security, expansion capability, and purposes of investment, and, in some cases, the necessity of purchasing "all or none" of a large water right.

Security, as used in the preceding paragraph, involves the belief that owning rights to larger quantities of water results in greater assurance of adequate water supply in times of low flow. This may have some validity, depending on the individual circumstances surrounding each case.

The purchase of additional water to ensure capabilities of future expansion is necessarily affected by the plans and expectations of the water purchasers. Because of the nature of the water commodity, and the increasing competition for reliable supplies, the decision to leave options open is frequently made by the acquisition of large amounts of water. This problem is ideally suited for capacity-expansion analysis; however, it is not often used in cases of the type discussed here.

The practice of acquiring more water than needed, and keeping the surplus merely as an investment is found occasionally. Although this is rarely the only purpose for the purchase of large amounts of water, it certainly provides an attractive supplementary aspect.

In many cases, the necessity arises of buying "all or none" of a large water right. An example of this situation repeatedly found in western water management occurs in the purchasing of irrigated crop or pasture land together with the water rights used on that land by an entity seeking to transfer the use to another purpose. It is often necessary to purchase the entire farm in order to obtain the water, and then one obtains all the water as well.

It should be realized that the conservative practices of those involved in the purchase of water rights are not likely to change with the advent of a system permitting a more efficient analysis of water rights manipulations. Although it is possible that a more efficient analysis may be used in the investigative portion of the transfer procedure, the inherent tendency towards conservatism indicates that no rapid changes will take place in the official presentation of information.

2.4 The Need for a Model

In any region with limited water supplies and relatively great demands for water, it is probable that the available water supplies will be used intensively. The nature of water resources, however, tends to be such that the actions of the users with respect to the water resource will frequently have consequences for other uses of the resource. For this reason, there has evolved in most areas with such hydrologic characteristics a water management system which closely controls activities having an effect on the water resource.

The nature of water management systems varies widely among regions, societies, cultures, and governments. However, they tend to have a number of similar characteristics. Among them, in the administration of surface water flow, is the recognition, expressly or tacitly acknowledged, that some uses of water take priority over other uses, and that some users of water have precedence over other users in times of scarcity. As river flow tends to be the most frequently varying facet of a water resource because of its "flow" rather than "stock" character and its relatively fast response and dependence upon meteorological and climatological characteristics, the water administration usually has a fast response to changes in the river flow.

In situations where the water use picture is rather static and unchanging, the mode of water use tends to become well-established and accepted by reasons of tradition. There is little need to assess consequences of changes in water use, because they happen rarely. However, in cases where the water use picture is more dynamic, i.e., changes in water use take place more frequently, the ability to assess the

consequences of such a change in an efficient manner becomes necessary.

2.5 Water Supply Objectives

An integral feature of the planning for an energy conversion facility in the Northern Great Plains lies in the consideration of water supply questions. Typically, there is a great deal of feedback in the planning process, in the sense that planners will respond to water supply features in several ways. These include changing the site, reconsidering the water requirement for the facility, changing the process to be used in the facility, and changing the scale of the facility, among others.

It is at this planning level that the use of the procedure presented in this chapter is most appropriate. The general source of water will have been identified at this point, and it will be known whether transfers of water rights are necessary. There are several aspects to the water supply which play a role in these considerations, and they will be discussed here.

The quantity of water available for the facility must be evaluated with respect to both diversion and consumptive use. Diversion quantity is that total amount of water required to run through the process under question, some portion of which may not be used up, but may be returned to the river or passed on to somebody else. The consumptive use is the amount of water which is actually consumed, or used up, in a process, and lost to the system by evaporation. Because of the difference under the necessities of western water management, a clear distinction is maintained in the procedure set forth here.

The reliability of water supply is another factor which is of importance in arid areas where great variability is found in surface water supplies over different time periods. As discussed in the preceding section, the basis of priority is used to determine the relative dependability of any water right, in the sense that senior water rights must be entirely satisfied before junior rights receive water. In this system, it is possible to determine the relationships between rights as to their relative dependability of water supply. This plays an important role in the method developed here.

The quality of water must also be considered in any analysis of water supply alternatives. While not taken into account in the procedure presented here, it must certainly be evaluated at an early point in the planning process.

In many situations, the decision is made on the source of the water supply with very little analysis. There are two important contributing factors to this situation. The first is that the cost of water supply frequently plays a relatively small role in the overall cost of the production, so that a big difference in the cost of water supply does not significantly affect the cost of plant construction and operation. Thus, a significant incentive is removed for careful analysis. The second reason is that planning and evaluating water resources is a task requiring a good deal of expertise, time, and money for satisfactory results. The lack of a well-defined procedure for water rights evaluation increases the problem to the point where sufficient water planning frequently does not occur. A determination of an adequate water supply is made and carried out without ensuring that it is the

most effective and desirable one available from whatever viewpoints are considered.

2.6 General Model Description

The model developed here permits the systematic evaluation of yields from water rights in terms of dependability, diversion amounts, and consumptive use amounts. The yield is determined first for in-place, or "in situ" water rights, and is subsequently evaluated for transfer to any designated point. This aids in the determination of optimum facility location along a river, as well as assessment of the water rights most suitable for transfer in use and location.

The most suitable water rights for transfer may be determined by using a number of objectives and constraints. These are explicitly determined and used. For example, the maintenance of minimum streamflow, the minimization of land lost from irrigation, and the minimization of total water rights acquired are all objectives which might be used.

The framework of the procedure follows the appropriate code of water administration in its evaluation of water yields under varying conditions. The prevailing principle is that no adverse impact may be felt by other water rights on the river, both upstream and downstream, senior and junior.

Two basic ways exist in which injuries may be caused by the transfer of water rights. They may be classified as follows:

- (1) Injuries to downstream rights. These may occur when the return flow from the decree being transferred was used as a portion of the available flow for downstream water

rights. Both senior and junior downstream rights may not have their supply diminished in this manner.

- (2) Injuries to junior upstream rights. These occur when a relatively senior right is transferred, removing a large call on the river and removing a call downstream of a junior right. In this case, the junior right relied on the senior downstream call to ensure flows in the river for the upstream junior right. The junior right which is able to divert water and put its return flow in the river enough to satisfy the senior right is thus adversely impacted by a transfer of the senior downstream right to a point upstream of the junior right.

Typically, water rights are purchased by the state in cases where minimum streamflow maintenance is desired, and then left in the river instead of being diverted. This represents a significant departure from previous water diversion practice, in which diversion of water from the watercourse was required in order to establish and maintain a water right.

Also, a factor in water rights transfers is the matter of state water policy and preferred uses. These become important because most states have an established ranking of preferred uses which tends to encourage transfer to a use with higher preference. In fact, some states permit condemnation of water rights for transfer to a preferred use.

2.7 Data Requirements

For reasons described in Section 2.5, limiting the use of data to that which is readily available is of considerable importance in any model intended for widespread use. Accordingly, the data required for the model is easily acquired from several sources — most commonly the United States Geological Survey and state water administration officials.

Flow data for the river under study is obtained from USGS which has an extensive flow-gaging network for the entire country. This data is obtained in the form of computer printouts which show graphically the plots of low flow versus recurrence interval for durations of various periods from 1 to 90 days. Such plots are available for all gages in the USGS system and are available at no charge from local USGS offices.

Water rights records are generally available from state water administration officials. There are essentially two levels of record keeping in most of the states of concern here. At the statewide level, records of official decrees, dates of priority, legal locations, and uses are kept and efficiently tabulated. Records of actual diversion histories are kept by a local water commissioner in a generally less organized and easily usable form. It is these records, however, which give the most accurate picture of the actual use and water supply of any decree. With the assistance of the local water official, or commissions, or with field observations, it is possible to construct a "straight-line diagram." This is simply a schematic diagram of the river and the water rights supplied from it and while necessary for the procedure described here, it is also useful in achieving an overall

view of the situation.

From this description it can be seen that no extraordinary demands are made on the analyst as far as data requirements are concerned. An important point with respect to data, however, is that the more one knows about the situation, i.e., the more pertinent data is available, the better and more reliable the analysis will be.

2.8 Interaction with Decision-Makers

An important input lies in the determination of the minimum acceptable quantities and reliabilities of water supply. The determination is made by interaction of the water planner with the decision-makers in an iterative process. The ideal interaction for the model described here is for the decision-maker (DM) initially to provide the water planner with an estimate of the water supply requirements. The planner then presents the optimum modes of satisfying this requirement to the DM, and if unsatisfactory, the DM can modify the requirements in such a way that the water planner may make a new determination of the optimum mode of supplying the modified requirement.

The interaction with DM's has been one of the weakest links in previous multiobjective methods, and it continues to be so here. However, with the relatively clear tradeoffs resulting from this model it is hoped that this problem will be decreased.

The requirements of water supply to be made by the DM's are in terms of continuous direct flow — for example, units of cubic feet per second (cfs), and in terms of the maximum permissible interruption in delivery.

There is a variety of ways in which the required supply reliability can be stated. If stated in terms of duration and recurrence interval, this aspect is easily compared with the USGS low flow records. For example, it might be decided that the maximum permissible interruption in supply is 7 days every 10 years, exactly the same terminology as that used in USGS records.

2.9 Simulation of The Water Rights System

The actual evaluation of yields, both in-place and transferred, takes place within a simulation model. The framework is based upon a straight-line (schematic) representation of the river and water right system. The simulation may be as elaborate as desired; frequently, however, the assumption of conservative flow with consumption occurring only during diversion periods will provide sufficient accuracy for the purpose at hand.

A matrix is used for each of the aspects of the water rights in order to handle the analysis of water yield, with location and seniority used as the common characteristic of all matrices. With these, it is possible to evaluate the senior downstream call on water, the upstream senior consumptive use, and the return flow of each right. By manipulation, the in-place water yield of each right is determined. For a given low flow, the following descriptors are used:

For any water right at location L, with priority S:

the maximum decreed diversion = Q_{LS}

the actual flow diverted = D_{LS}

the proportion of instantaneous return flow to $D_{LS} = R_{LS}$
the consumptive use = $CU_{LS} = D_{LS} - [(R_{LS})(D_{LS})]$

The available flow at any location A for the priority B is obtained by subtracting the total consumptive use of senior rights upstream of A:

$$\text{Available Flow} = \text{AFLOW}_{AB} = \text{FIN} - \sum_{S=1}^B \sum_{L=1}^{A-1} \text{CU}_{LS} - \sum_{S=1}^{B-1} \text{CU}_{AS} \quad (1)$$

where FIN is the gauge flow upstream of all water diversions at location 0.

Another available flow calculation is performed on the basis of flow in the stream from return flows due to the actual diversion of senior upstream water rights, in an iterative procedure at each location. The AFLOW(L,S) value used is the larger of the results of these two methods.

The downstream senior demand at any location A, for the priority B, is obtained by a decision which is iterated at each downstream water right senior to B, and works its way up to the location A.

$$\text{Senior Downstream Demand} = \text{SDSD}_{AB} \quad (2)$$

$$\text{If } (\text{SDSD}_{AB} + \text{CU}_{AB}) > Q_{AB}, \text{ then} \quad (3)$$

$$\text{SDSD}_{(A-1)B} = \text{SDSD}_{AB} + \text{CU}_{AB}. \quad (4)$$

If

$$(\text{SDSD}_{AB} + \text{CU}_{AB}) \leq Q_{AB}, \text{ then} \quad (5)$$

$$\text{SDSD}_{A-1,B} = Q_{AB} \quad (6)$$

The model assumes that instantaneous return flow is a function of the instantaneous diversion of that water right, an assumption discussed in another section. This permits an assessment of the diversion permitted any water right provided both the available streamflow and the senior downstream demand are known, by the following process:

$$\text{Flow available for consumptive use} = \text{IPWA}_{LS} = [\text{AFLOW}_{LS} - \text{SDSP}_{LS}]$$

$$\text{If } \text{IPWA}_{LS} \geq [Q_{LS} - (R_{LS})(Q_{LS})], \quad (7)$$

$$\text{then } D_{LS} = Q_{LS} = \text{Maximum Decreed Diversion} \quad (8)$$

$$\text{and permitted consumptive use} = \text{CU}_{LS} = [D_{LS} - (R_{LS})(D_{LS})] \quad (9)$$

$$\text{However, if } 0 \leq \text{IPWA}_{LS} < [Q_{LS} - (R_{LS})(Q_{LS})] \quad (10)$$

then the yield of the maximum permitted diversion is:

$$D_{LS} = \left[\frac{\text{IPWA}_{LS}}{1-R_{LS}} \right] \leq Q_{LS} \quad (11)$$

and the maximum permitted consumptive use is

$$CU_{LS} = IPWA_{LS} \quad (12)$$

If

$$IPWA_{LS} \leq 0$$

then the yield is

$$D_{LS} = 0$$

and the maximum permitted consumptive use is

$$CU_{LS} = 0$$

When this analysis is performed for each right on the river, a matrix can be formed of the in-situ water yields for each decree at each location. After appropriate analysis by the planner, those rights which appear most promising may be studied further for possible transfer.

In order to evaluate the transferability of water rights, the effects in terms of water loss to other rights must be determined. The model has the capability of determining the amount transferred by shifting the system to allow for the transfer, and then determining the in-site water yields in the new situation. A comparison is made with the historic situation, and successive reductions in the portion of water

transferred are made until all historic demands are satisfied. The remaining portion may then be considered the amount transferrable to the new location by using that water right.

For reasons described elsewhere, it may be desirable to put some objectives, such as maintenance of a minimum streamflow or diversion limitations associated with a river compact, into the model. This is accomplished by putting the objectives into the model as constraints, and performing the sensitivity analysis while varying these constraints.

The maintenance of minimum streamflow is treated as a constraint by requiring the streamflow at each location to be greater than a certain amount (the designated flow), and putting a call on the river (shutting down junior water rights) whenever the flow falls below that level at any location. If it is desired to evaluate the effects of using different priorities for minimum streamflow maintenance, the call on the river may be given a priority relative to other rights on the river.

Compact obligations typically involve a required system outflow, or, in other words, a required streamflow at the location furthest downstream. This is handled by placing the highest priority on the required downstream flow.

2.10 Assumptions

The assumptions made in this model may be categorized as belonging in two major groups: those which are central to the formulation of the procedure, and those which can be modified without forcing significant changes in the procedure. It is expected that many of the assumptions can be significantly altered with the effect of increasing the reliability and accuracy of the model.

One of the most basic assumptions, one upon which the principle of the model relies, is that all decrees desire their maximum permitted diversions at the period of low flow being studied. The validity of this assumption will vary with the individual cases to which the procedure is applied. However, for a large number of instances, the assumption is good, because of the predominance of water diversions used for purposes of irrigation. Typically the irrigation season in the western states runs from May through October, with the demand for irrigation water most strongly felt in August and September. The natural, or virgin, flow characteristics of most of the streams in this area are such that the major portion of the annual flow occurs in April, May, and June, from the winter snowmelt which is the most significant source of streamflow. The virgin flow then diminishes sharply, and in August, September, and October tends to be at its lowest levels before winter precipitation begins to occur, somewhat replenishing the supply. Thus, we see that virgin low flows may occur at any time between July and April, but those of interest normally take place in July, August, and September.

It is significant that the gauge which is used as the primary source of flow data will not always measure the virgin flow. If there are diversions above the gauge, they will alter the flow measured by the gauge, and their seniority must therefore be evaluated. However, no explicit accounting for them is required, because they will have been historically "called out" if warranted, and their priority will be implicitly accounted for in the gauged low flow records.

At this point, a note should be made about "futile calls." These occur in the following situation: When the senior right is so far

downstream that stream losses would prevent any water from reaching that location even if all upstream junior rights are prevented from using any water, then a "futile call" situation exists. In such cases, the water administrator permits the junior upstream users to divert water, even though none reaches the senior downstream decree, in order that some beneficial use be made of the existing water. No allowance is made for such a situation in the currently used simulation of the stream, because of the assumption of a conservative streamflow. In later incarnations of the model it is expected that more realistic streamflow simulation will be used, and the case of futile calls will be brought up. It is possible to incorporate an assessment of that problem in the model.

In the current version of the procedure, no allowance is made for consideration of the possibility of on-stream reservoir storage, or major offstream storage. The effect of a major upstream water storage facility on the stream is to render the gauged low flow data useless without some analysis of the reservoir release data with respect both to physical release records and the users for whom the releases are made.

Related to the question of reservoir storage is the assumption that an analysis has been made of the water storage potential or auxiliary sources of water supply for the facility for which the water rights are being evaluated. Essentially, it is anticipated that this is considered by the DM in the analysis of the required supply dependability and quantity. It is expected that the presence of facility water storage or auxiliary water supply will have the effect of reduc-

ing the required supply dependability or altering the duration of the low flow of concern.

The low flow recurrence intervals calculated by the USGS are based upon an assumption of stationarity in the hydrologic process. Because of the relatively small scale of the watersheds under consideration, it should be noted that stationarity cannot always be relied upon and that some objective consideration should be given the validity of this assumption in all model applications.

The relationship of return flow to diversions is relatively complicated for most uses. Typically, return flow is dependent upon the diversions for the preceding several months for most cases of irrigation use, and does not return to the stream at a single point. Instead, it returns to the stream over a long period of time and distance along the creek. In its present form, however, the model presents a system with immediate return flows having a flow rate proportional to instantaneous diversions, and occurring immediately downstream of the diversion. Although this approximation is extremely crude, it may be improved with later versions of the model. Closely tied to the assumption of an instantaneous conservative streamflow, its alteration would necessitate major changes in the simulation model altogether by the introduction of time-dependent factors.

The model is based upon the concept that the priority system is strictly adhered to in terms of both quantity and priority. This means that the actual amount diverted at each location is as close to the maximum decreed amount as possible, and that the rule of priority diversion is satisfied, in that no inappropriate junior diversion take place. In reality, there are frequently significant differences between the

actual diversions and their decrees. Frequently, the decreed diversion amounts are far in excess of the highest possible actual diversion structure capability, and often there are informal and unwritten agreements between water users regarding temporary changes in water use.

With field trips, it is possible to gain an improved idea of what is actually the situation. It is difficult, however, not to use the numbers appearing in the decrees, because owners of decrees typically guard jealously their property, and will not officially acknowledge that they do not use their full decreed amounts.

Finally, it should be noted that all of the assumptions listed above can be improved upon with further model development, and case study analysis. Whether this is appropriate depends upon the desired level of accuracy, a factor which must be kept in mind at all times in going through the procedure.

It should be recognized that this procedure is designed only to give very rough ideas of which possible water transfers are worth further investigation with conventional methods. In that sense, the procedure may be regarded as a screening model, and effort must be made to keep its use as inexpensive as possible.

2.11 General Procedure and Model Use

In order to consider both hydrologic and institutional aspects in planning for water transfers, the proposed model has been developed. In its present form it is capable of evaluating the yield of a water right at a predetermined river flow rate for both in-place use, and transfers along the river. Yields are determined in terms of the di-

version capability and the consumptive use capability of each transferred right.

Sensitivity analysis can be performed in order to assess the consequences of making changes in the transfer program. The model can incorporate such objectives as the maintenance of minimum streamflows and the implementation of water quality objectives simply by specifying them as constraints in iterations of the procedure.

The first step involves determination of the objectives of the DM, and of the required supply quantity and reliability. In this first iteration, the supply conditions should be the most stringent necessary. In subsequent iterations, the requirements may be relaxed in order to assess the consequences in a systematic manner.

The next step is relating the desired supply reliability to the USGS low flow data in order to obtain a corresponding flow. This flow is used in the following step as an input flow to the system.

A simulation model of the river is then used to evaluate the yield of each water right on the river under the input flow conditions. The rules for diversion in this model follow the priority rules found from state water administration records, the constraints imposed by various objectives, and a major assumption that all water rights will divert their maximum possible flows during the low flow period under study. This assumption permits a simplification of the simulation model which makes possible the evaluation with the minimum data.

The results of the simulation model are used to gain information on the in-place yield of water rights. If a location has been selected to which it is desired to transfer water, the transfer yield of the

water right under consideration may be evaluated for that location. This is accomplished by satisfying the historic demands of both the junior and senior rights as well as supplying the priorities in the new arrangement of water rights.

With this information it is possible to interact with the DM and assess changes in the supply requirements which the DM finds desirable upon viewing the consequences of his previous requirements.

A case study using the model described above is presented in Chapter Three.

Chapter 3

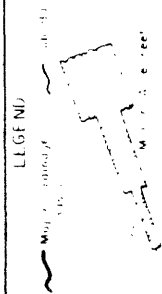
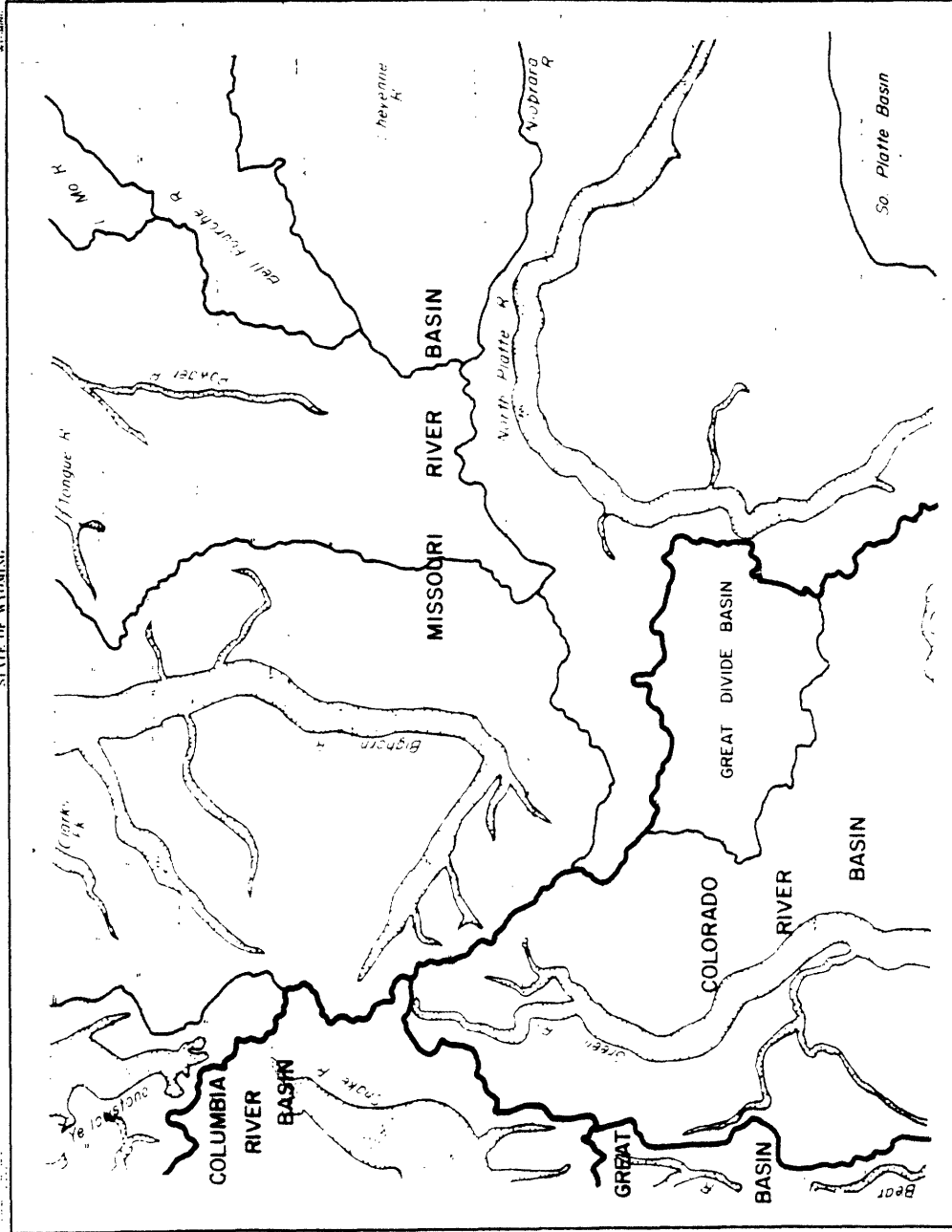
CASE STUDY OF THE UPPER POWDER RIVER

3.1 Introduction

The coal mined in the Gillette and Powder River area will meet any of several possibilities. These include:

- (1) Transportation to point of use by train.
- (2) Transportation to point of use by coal slurry pipeline.
- (3) Local conversion to alternative forms of energy, such as:
 - a. Electric generation
 - b. Synthetic pipeline gas
 - c. Synthetic oil
- (4) Local conversion to desired products, such as dyes, fertilizers, fibers, etc.

Of concern to this thesis is the fact that all of these processes except the first, transportation by train, require substantial amounts of water. It is apparent that a large increase in the number of facilities involved in the conversion of coal, and by extension, requiring significant amounts of water, is to be anticipated. This is an important matter in the coal area of the Northern Great Plains, because of the relative scarcity of water and the correspondingly high level of its utilization. In other words, there is not much water, and what little does exist in the immediate area is used to a high degree. The average annual flows can be seen in Figure 3-1 (Wyoming Framework Water Plan, May 1973 Summary). The water is currently used largely for agricultural purposes, with small portions going to municipal and industrial uses, a situation



(from 1973 Summary, Wyoming Framework Water Plan)

Average Annual Streamflow

Figure 3-1

unchanged for about a century. There exist only a few possibilities for sources of large amounts of water which are required in most scenarios of coal development in the Northern Great Plains. These are:

- (1) Development of groundwater.
- (2) Transfers of water from reliable sources such as rivers with large flows, or previously constructed reservoirs.
- (3) Construction of storage facilities on streams with highly variable flows.
- (4) Transfers of water from existing uses.

The development of groundwater is appealing for several reasons. It frequently gives the impression of being "new" water, which would otherwise go unused. In some instances, however, groundwater is hydraulically connected to surface streams, which means that pumping groundwater will have an effect upon stream flows. Groundwater is often a very reliable source, less subject to the flow and quality variability which plagues surface water sources. Additionally, groundwater can often be obtained at the point of use, thus eliminating transportation costs. However, groundwater in desired amount and quality is frequently not available. The Madison Aquifer remains a potential groundwater source in the area.

The transfer of water from reliable sources refers primarily to the possibility of the construction of aqueducts from the Yellowstone River, Missouri River, and the Green River to the point of use. There exist several reservoirs along these rivers which would be used in a scheme of this type. A study of proposed aqueducts has been published by the Bureau of Reclamation (1972) in which the water sources

Investigated include the Yellowstone River, Missouri River, Bighorn River and the Green River. It is significant to note that these aqueducts appear to present a meaningful alternative only for very large magnitudes of water delivery, i.e., sufficient to meet the water requirements of several coal conversion plants. This is because of the large economies of scale inherent in the costs of aqueducts with the range of capacities under consideration.

The construction of water storage facilities has been investigated in detail with several studies (Bureau of Reclamation 1972, Wyoming SEO). Sites investigated range from those on relatively small streams to those on the Yellowstone River. This course of action is one which appears to be quite likely, due to the requirement of increasing the reliable supplies of water, a necessity in a region where water supplies are characterized by extreme seasonal and long-term flow variations. In some cases the local water supplies are already highly developed, and the construction of additional storage capacity would be only marginally useful. In other instances, additional storage capacity would be very effective in providing increased reliable sources of water. It should be noted that there already exists a large amount of storage which is not currently fully utilized in reservoirs on the Bighorn and Missouri Rivers. This storage capacity plays an important role in the aqueducts mentioned above.

The final possibility for water sources to supply new coal conversion facilities in the Northern Great Plains lies in the possibility of transferring water from existing users to new users. This will take place to some degree in all plans for water supply, because any alteration

in the management of a water resource with a high level of current use necessarily includes changes in the manner and nature of that use. The procedure by which changes in the use of water are accomplished are discussed in Section 3.2.1, and form the heart of this study.

As has been described above, the different sources of water of the region have all been investigated in some depth, and several projects have entered various stages of planning. However, it is also clear that some manipulation will be required of the local direct flow water rights which are currently being used for agricultural purposes.

The "Campbell, Johnson and Sheridan County" area of coal development in the vicinity of Gillette, as shown in Figure 3-2, includes two significant river systems, the Belle Fourche River and the Powder-Tongue River. Both legally and hydrologically, these are distinct entities, and for reasons described below, transfers of water from one to the other are institutionally complicated.

The case study performed here does an analysis of water transfer possibilities on the North Fork of the Powder River. No out-of-basin transfers are considered and it is assumed that the existing modes of water management incorporated into the model are the framework upon which all water supply alternatives must be evaluated.

The model will give an evaluation of the in-site water supply characteristics of each water right located within the segment of interest. It will also indicate the yield of selected water rights when transferred to a selected point.

3.2 Institutional Considerations of the Case Study

The reason for interest in this particular case study lies in the

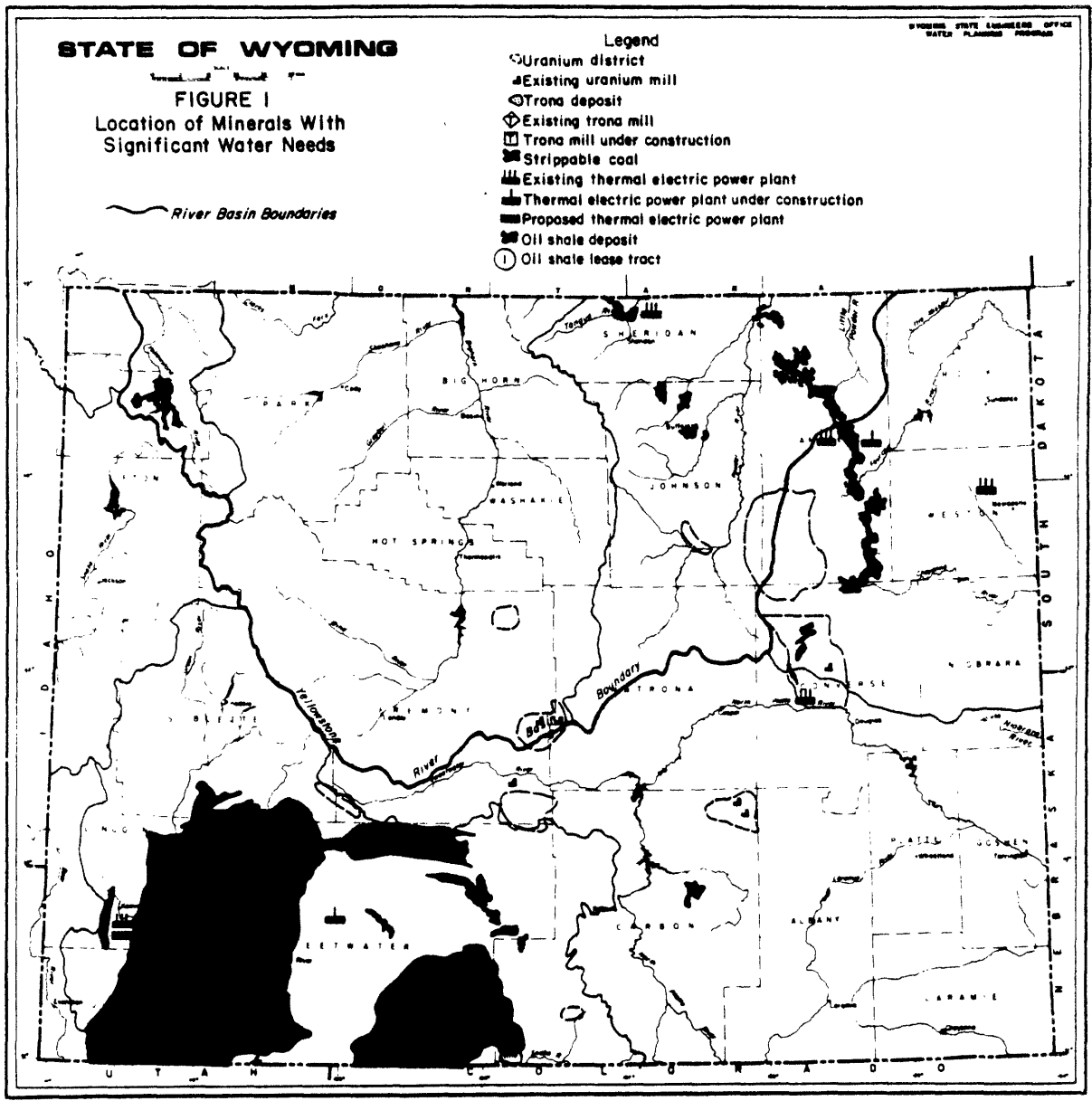


Figure 3-2 From "A Water Development Program for Wyoming," Wyoming State Engineer's Office, 1974

unique aspects given to it by the institutional considerations. Because the area of concern lies astride the drainage divide of two different river systems, river compacts play a large role in defining the permissible range of water management alternatives.

3.2.1 Intra-state Water Law

In Wyoming, the State Engineer and his staff administer the water rights for all types, including groundwater, direct diversion, and storage rights. An application for any change in the use of water is made to the State Engineer's office, and protests against such a change are also made to the State Engineer at this time. After consideration, the State Engineer's Office may deny or grant the permit for changes in use subject to any conditions deemed appropriate.

There are several aspects common to all water use changes which are evaluated by the State Engineer's Office. Among these, one of the most important is the right of existing water users to maintenance of conditions existing prior to the change. Typically, this is ensured through the mechanism of protests: if a water user senses any sort of adverse consequence of a change, he is likely to protest. Other water users are informed of proposed alterations in water use by means of a required publication of intentions, published early enough to give adequate time to react.

Another aspect considered by the State Engineer's Office is how the proposed change will fit in with whatever policy directives may have been made by the state legislature. This has a major effect upon the administration of water rights, for the state legislature is

essentially the ultimate decision-maker regarding the state's water resources. One of the clearest examples of the legislative influence on water administration is the matter of orders of preference in the use of water. In this order for Wyoming, the use of water for industrial purposes is preferred to agricultural uses, which has the effect of facilitating transfers to the more desired use (industrial) from the less desired (agricultural).

Another consideration of the State Engineer and the State Board of Control in making decisions on these changes in water use is based upon consequences to the interstate river compacts of concern. These compacts typically have an overriding priority. The State Engineer is responsible for ensuring the satisfaction of these compacts, and wide powers of discretion are granted him for that purpose.

3.2.2 Interstate Compact Considerations

There are two interstate river compacts which concern water supplies in the area of interest; these are Yellowstone River Compact and the Belle Fourche Compact. Before describing the specific effects of these compacts, it is well to give a brief description of the procedure in which such compacts are developed.

Generally, it becomes apparent to all states lying along a river in arid areas that some sort of allocation of river water among the states is necessary for reasons of development and investment planning. In many cases, external pressures, e.g., from the federal level of government, are involved. When the states agree upon a compact which delineates the manner in which the signatory states should act under different

situations, this draft compact, signed by the appropriate representatives from each state, is then presented to the U.S. Congress, and goes into effect after ratification by both houses and presidential approval. Any change in such compacts must be made using the same procedure, indicating the extreme difficulty in implementing such changes. Once in effect, such compacts have the force of law, and must be treated as such by the states.

Belle Fourche River Compact

The Belle Fourche River Compact concerns the entire drainage basin of the Belle Fourche River in Wyoming and South Dakota. The two states are participants in the compact, which divides the limited quantity of water in the basin between Wyoming and South Dakota.

While recognizing the existing water rights on the river, it strictly controls what use and facilities may occur in Wyoming after the signing of the pact. Generally, the Belle Fourche Compact does not appear to affect water development plans significantly, as it deals with relatively small amounts of water.

Yellowstone River Compact

In three northern states of the study area, Wyoming, Montana, and North Dakota, an interstate compact of major importance is the Yellowstone River Compact. Since the Yellowstone River and its tributaries represent the largest potential source of water in much of the Northern Great Plains Coal Area, the stipulations of this compact, signed in 1950, provide important guidelines for water supply possibilities. Four articles of this compact have particular bearing on the question of water

supply and are worth enumerating. These are Articles V, VII, VIII, and X.

Article V is concerned with the allocation of Yellowstone tributary water between Wyoming and Montana. This is performed on a percentage of available flow basis, and is relatively uncontroversial. Rights and diversions existing at the date of compact signing are recognized.

Articles VII and VIII deal with the permissibility of facility construction in one state for use of water in another state.

Article X is important because it treats the question of out-of-basin transfers of water from any of the Yellowstone River Drainage Basin. Essentially, it requires unanimous consent from the three signatory states before any out-of-basin diversions. This is a serious constraint on water resource development in the area, for the reason that some of the major easily-retrievable coal reserves lie just outside the Yellowstone Drainage Basin. As water supplies are particularly limited in the Belle Fourche River Basin, a likely possibility for a source of large-scale water importations would have been the tributaries of the Yellowstone River. However, the problems associated with gaining the requisite unanimous approval of the signatory states are sufficient to cause a serious (some believe insurmountable) obstacle to transferring the water from this source. This is currently being tested in court by the Intake Water Company vs. Yellowstone River Compact Commission case. Provision does exist in the Yellowstone River Compact for the transfer of water from one tributary of the Yellowstone River to another tributary, such that the water is not exported from the Yellowstone Basin.

Platte River

No Platte River Compact as such exists. Several court cases have been decided in the Supreme Court regarding the division of the North Platte River and its tributaries between Wyoming and Colorado. These decisions presently constitute the guidelines by which the North Platte River is divided between Wyoming and Colorado. There also exists a stipulation, approved by the Supreme Court, between the states of Nebraska, Colorado, and Wyoming regarding the allocation and use of Platte River water between them.

These documents result in a situation such that the water of the Platte River is almost fully allocated. This implies the potential sources of water required for energy use will be the following:

- (1) Purchase of existing agricultural rights
- (2) Construction of new storage facilities
- (3) Importation of water to the Platte River Basin

Because of the long history of litigation between Wyoming, Colorado, and Nebraska, each of the downstream states have often sued the upstream states to prevent actions which might remove too much water from the stream. Thus Nebraska might be expected to be the plaintiff in any action resulting from the construction of additional storage capacity on the Platte River in Wyoming for energy use.

3.2.3 Federal Water Policy and Considerations

An important factor in the consideration of the water supply possibilities in the area lies in the claims of the Federal Government for its reservations of different types. As discussed below the

Reserved Rights Doctrine allows the federal government to reserve sufficient water for whatever use is made of federally reserved lands, which include Indian Reservations and Bureau of Land Management land, among other types. Consequently, there has been considerable litigation to force the federal government to quantify these claims and file for them through the State Water Administrations, with limited success.

Federal Reserved Rights are based upon the notion that sufficient water from adjoining watercourses was reserved for whatever use the federal lands should be put to when the land was claimed by the federal government. Since many of these lands were put aside before private water development took place, the priority of the federally reserved water is better than most other water rights on the river. Generally, this concept has been tested in the courts and upheld firmly. The problem associated with the federally reserved water rights is that they have not been quantified or even identified, resulting in uncertainty on the part of other water users. Because the Indian Reservations fall into this category, and because they are the federally reserved lands most likely to be developed, much of the concern has focused upon them — hence the proliferation of court cases concerning them. There has been no resolution of this problem, and the uncertainty may well drag on for several years.

An outcome of the trials known as the "Eagle County Cases" and the McCarran Amendment of the 1952 U.S. Congress was the decision that federal claims to water would be made within the state systems for general adjudications of water rights. As a result of these cases, the federal government must move to establish its claims in the state

legislatures; however, this has been proceeding quite slowly because the government is seeking to determine the maximum use for any of the possible futures which might take place on its reservations. Some claims have been established in the Colorado River Basin; for example, the amount of water claimed for the Naval Oil Shale Reserves has been designated as 200,000 Acre-Feet, although the federal government in Colorado still does not agree that its claims under the Reserve Rights Doctrine must be quantified.

Another consideration of federal water policy is the development of the Wild and Scenic Rivers in the region of concern. When a river is designated as wild or scenic, development along the river is severely restricted in order to maintain the desirable condition of the river. Among the rivers being considered for designation are parts of the Yellowstone, Missouri, Green, Yampa, Dolores, and Colorado in the study area.

3.2.4 Environmental Considerations

Water transfers on the Powder River will affect the environment of the area in many ways, including both the natural and socio-economic facets. In general, attitudes range the entire gamut on practically every issue involved in this section. Often, though, some prevailing sentiments may be sensed toward several objectives. Two of the dominant objectives are:

- (1) Maintenance of minimum streamflows
- (2) Maintenance of the maximum possible agriculture

Since these objectives require water, there frequently arises a conflict over water use. Until now, the Powder River region has seen very few trade-offs between development interests and agricultural/

environmental interests; the water has gone to those who pay for it. The objective of minimum streamflows may be given more weight, however, if the current direction of action in the Wyoming State Legislature continues.

3.3 Data Acquisition

3.3.1 Flow Data

There are several gauges on the North Fork of the Powder River which are used by the USGS to measure streamflow as can be seen in Figure 3.3. The gauge with the longest period of record, 06311000, is near Hazelton, Wyoming, with record of 22 years beginning in September 1946.

The USGS low flow-recurrence interval information was received without cost after making one telephone call to the Wyoming office of the USGS. An example is shown in Figure 3.4. There is no special effort made in putting the data in this form.

3.3.2 Water Rights Data

Water rights data was acquired from two sources. The first, an official publication of the Wyoming State Board of Control, is the 1972 Tabulation of Adjudicated Water Rights of State of Wyoming - Water Division Number Two. In it are listed the official data regarding decrees, including Permit Number, Ditch Name, Appropriator, Priority, Use, Flow, Area Irrigated, and Location. Figure 3.5 shows the page containing information on the decrees on the North Fork of the Powder River.

The second source of data was the District Water Engineer's Office. It provided a straight-line diagram, and some information regarding the

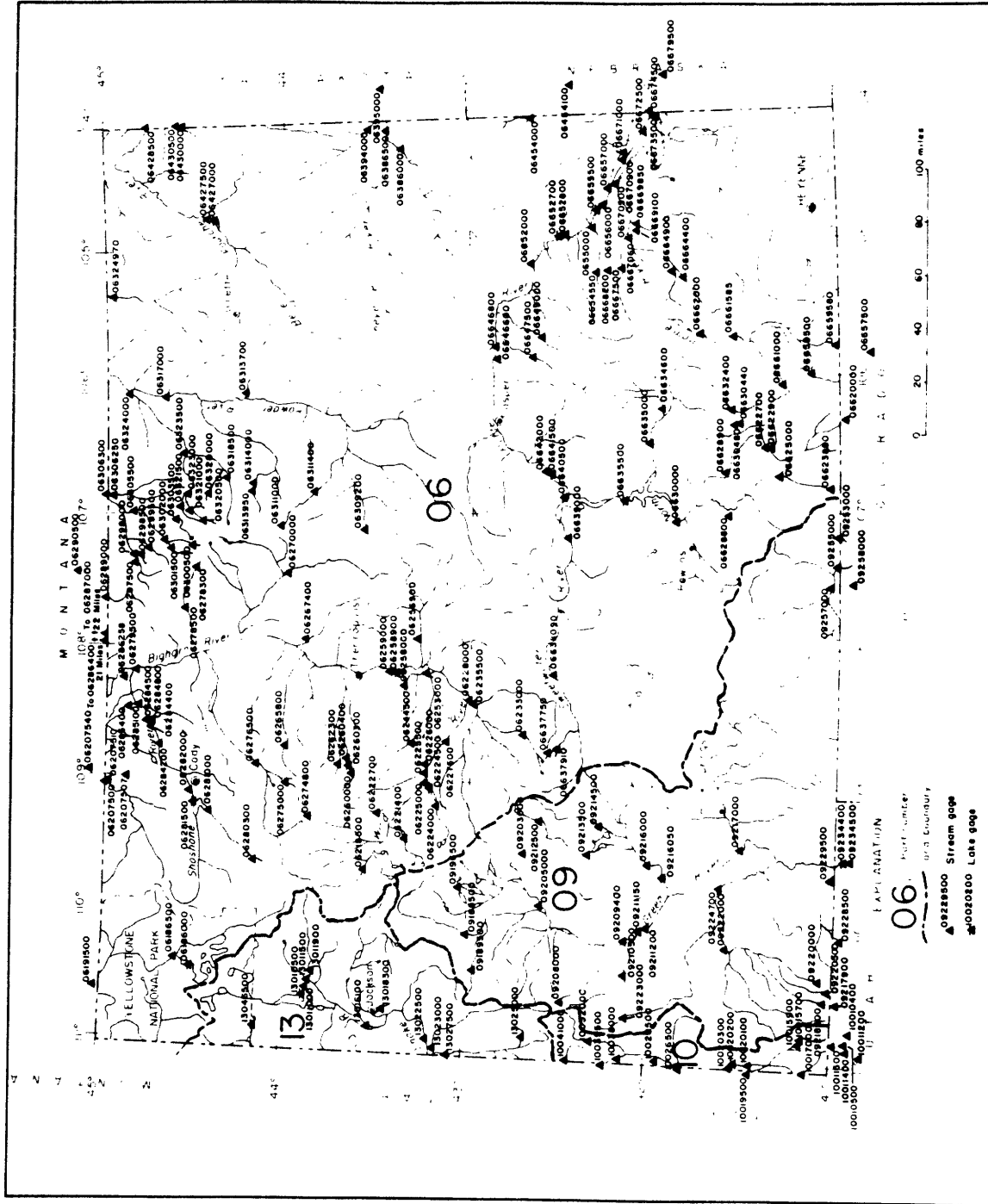


Figure 3.3 From USGS "Water Resources Data, Part 1, Surface Water Records"

STATION 06311000

N = 24

NORTH FORK POWDER R NR HAZELTON, WYO.

1948-1975, 12 MON PERIOD ENDING MARCH 31

1* DAY LOW VALUE

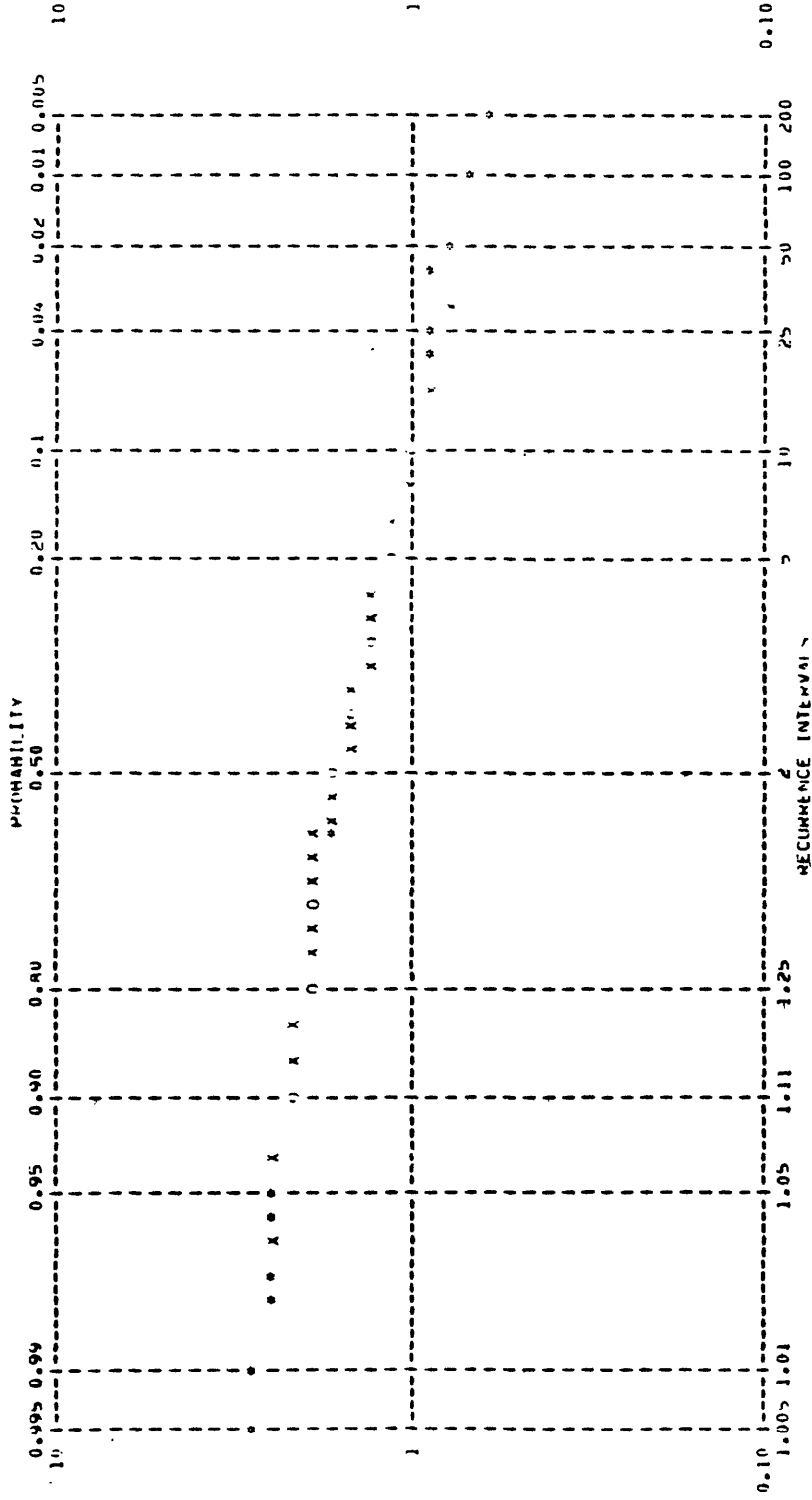


Figure 3.4 USGS Low Flow Recurrence Interval Data for Hazelton, Wyoming

THE FOLLOWING SYMBOLS MAY APPEAR IN THE PLOT
 X - AN INPUT DATA VALUE
 * - A CALCULATED VALUE
 U - A CALCULATED VALUE AND ONE DATA VALUE AT SAME POSITION
 C - TWO INPUT DATA VALUES PLOTTED AT SAME POSITION
 J - THREE INPUT DATA VALUES PLOTTED AT SAME POSITION
 A - A CALCULATED VALUE AND TWO DATA VALUES AT SAME POSITION
 B - A CALCULATED VALUE AND THREE DATA VALUES AT SAME POSITION

WATER DIVISION NUMBER TWO

BROWN DRAW, Tributary Aspelin Creek

Permit	DITCH	APPROPRIATOR	Priority	USE	C. F. S.	ACRES	H. G. Loc. S. T. R.	Present Owner
4651 SR	Brown Draw Stock Res.-----	Pine Mountain Livestock---- Co.	1- 8-1963	S	1.6 a.f.		34-35-88	

NORTH FORK POWDER RIVER, Tributary Powder River

Terr.	Boughton-----	Chas. Waegala-----	9-25-1884	I,S	12.21	855	20-44-82	
Terr.	Dry Bob-Brock-----	Albert L. Brock, et al-----	9- -1884	I	6.26	440	36-45-83	
Terr.	Capitola-----	John J. Cash-----	4-15-1885	I	3.20	212	26-45-83	
Terr.	Frances-----	J. R. McDowell-----	10-14-1887	I	1.23	86	8-45-83	
Terr.	Morgareidge & Frances-----	J. O. Morgareidge-----	10- 1-1888	I	1.43	107	8-45-83	
Terr.	Morgareidge & Frances-----	Carl L. Sackett-----	10- 1-1888	I	1.61	113	8-45-83	
Terr.	Strickler & Rinker-----	Sullivan Bros.-----	10- -1888	I	5.64	396	26-45-83	
Terr.	Potts-----	J. K. Potts-----	11- 8-1888	I	2.10	115.9	7-44-82	
Terr.	Jim Blaine-----	John Landers-----	11- 8-1888	I,S,D	12.44	872	7-44-82	
Terr.	Jonas-----	G. J. Jonas-----	11- 9-1888	I,S,D	0.42	30	22-45-83	
Terr.	Cowan-----	Frank J. Cowan-----	11-25-1890	I	0.71	50	10-43-81	
619	Judd Ritter-----	Andrew J. Ritter-----	12- 9-1893	I	3.42	240	7-44-82	
117 E	Enl. Dry Bob-----	Alfred H. Brock-----	11- 9-1894	I	2.84	200	36-45-83	
916	Barratt-----	Crawford Gordon, et al-----	12-29-1894	I	1.00	70	16-45-83	
1013	G. J. & W. S. Jones-----	G. J. Jones-----	5-31-1895	I,S,D	0.71	49.78	22-45-83	
1013	G. J. & W. S. Jones-----	John J. Cash-----	5-31-1895	I	0.62	44.2	22-45-83	
1113	Roseberry-----	John Roseberry-----	8- 9-1895	I	1.91	134	1-44-83	
1047	Jarrard-----	James Jarrard-----	8-16-1895	I	0.42	100	29-44-81	
1223	Capitola No. 2-----	John J. Cash-----	5- 5-1896	I	0.21	15	26-45-83	
1649	Buck No. 1-----	Chas. Buck-----	9-12-1897	I	0.52	37	20-44-81	
1650	Buck No. 2-----	Jacob Affalter-----	9-27-1897	I	0.26	18.7	20-44-81	
2156	J. R. McDowell-----	J. R. McDowell-----	5-19-1899	I	0.34	25	8-45-83	
2140	Miles-----	Margaret A. Miles-----	5-27-1899	I	1.05	75	10-43-81	
558 E	Enl. Frame (Frances)-----	J. O. Morgareidge-----	10-13-1899	I	0.11	8	8-45-83	
558 E	Enl. Frame (Frances)-----	J. R. Morgareidge-----	10-13-1899	I	1.53	108	8-45-83	
2454	Affalter-----	Jacob Affalter-----	1-26-1900	I	1.83	129.1	18-44-81	
562 E	Enl. Jim Blaine-----	Martha J. Brown-----	5-31-1900	I	1.42	100	7-44-82	
3028	Canon-----	L. A. Webb-----	2- 8-1901	I	0.81	57.2	6-45-83	
720 E	Enl. Judd Ritter-----	Mrs. D. B. Ritter-----	10-19-1901	I	0.43	31.5	7-44-82	
743 E	Enl. Strickler & Rinker-----	Sullivan Bros.-----	11-13-1901	I	0.44	34.1	26-45-83	
3550	Burris-----	Zachariah Burris-----	11-14-1901	I	1.11	77.8	33-44-81	
863 E	Enl. Strickler & Rinker-----	Den D. Sullivan-----	1-18-1902	I	0.71	50	26-45-83	
864 E	Enl. Strickler & Rinker----- (Van Houten)	Jae. J. Sullivan-----	5-21-1902	I	2.05	144.1	26-45-83	
1001 E	Enl. Affalter No. 2-----	Jacob Affalter, et al-----	12- 9-1902	I	2.05	143.6	18-44-81	
5315	Coschy-----	L. A. Webb-----	2-12-1903	I	0.65	47	8-45-83	
1263 E	Enl. Jarrard-----	Jae. Jarrard, et al-----	10- 8-1903	I	0.65	46	29-44-81	
1141 E	Enl. Jones-----	James J. Jones-----	10-21-1903	I	0.09	6.4	22-45-83	
1839 E	Enl. Barrett-----	Tisdale & Sackett-----	9-12-1907	I	0.50	35.2	16-45-83	
8840	Webb & Perkins-----	C. H. Cash-----	12- 3-1908	I	0.40	28	11-46-83	
8840	Webb & Perkins-----	L. A. Webb-----	12- 3-1908	I	0.91	63.5	11-46-83	
8840	Webb & Perkins-----	Nannie L. Cash-----	12- 3-1908	I	0.80	56	11-46-83	
2433 E	Enl. Boughton-----	Martha Hibbard-----	4-29-1911	I	0.21	15	20-44-82	
2739 E	Enl. Strickler & Rinker----- (Van Houten-Sullivan)	The Brock Co., Inc.-----	1-11-1912	I	0.68	47.5	26-45-83	
2788 E	Enl. Dry Bob-Brock-----	The Brock Co., Inc.-----	5-16-1912	I	0.68	47.5	36-45-83	
2834 E	Enl. Webb & Perkins-----	Chas. H. Cash-----	8- 4-1913	I	0.07	5	11-46-83	
2834 E	Enl. Webb & Perkins-----	Nannie L. Cash-----	8- 4-1913	I	0.71	50	11-46-83	
2834 E	Enl. Webb & Perkins-----	L. A. Webb-----	8- 4-1913	I	3.02	211.5	11-46-83	
3888 E	Enl. Jarrard-----	Chas. Jarrard-----	4-15-1918	I	0.53	37	4-43-81	
3953 E	Enl. Frame-----	Ralph Donaldson-----	11-30-1918	I	0.42	29.57	8-45-83	
4166 E	Enl. Boughton-----	Mart O. Hibbard-----	10-14-1920	I,S	2.90	203	20-44-82	
16823	Jarrard-----	Charles Jarrard-----	6-18-1924	I	0.40	28	4-43-81	
4476 E	Enl. Miles-----	Robert Skiles-----	2-20-1926	I	2.56	179.25	10-43-81	
5863 E	Enl. Affalter-----	Metka Brothers-----	7-19-1956	I	Supply Ditch		18-44-81	
6800 R	Dull Knife Res.-----	North Fork Powder River----- Water Users Association	8-27-1959	I	4216.71 a.f.		22-47-85	
6915 R	Enl. Dull Knife Res.-----	North Fork Powder River----- Water Users Association	6-19-1967	I	128.51 a.f.		22-47-85	

¹Amended certificate issued to successors of O. C. Kilkenny, original appropriator for corrected land description. Point of diversion and means of conveyance changed to Frame (Frances) Ditch, 8-45-83 Original Survey, being Tract 51-45-83 under the Resurvey.
²Point of diversion and means of conveyance changed to Buck Revision Ditch, 20-44-81.
³Amended certificate issued for corrected land description; point of diversion and means of conveyance changed to Buck Revision Ditch, 20-44-81.
⁴Point of diversion and means of conveyance changed to Frame (Frances) Ditch, 8-45-83 Original Survey, being Tract 51-45-83 under the Resurvey.
⁵Supply ditch for Dry Creek Res., Permit 6339 R., from North Fork Powder River, Tributary Powder River and Dry Creek, Tributary North Fork Powder River.

NORTH FORK POWDER RIVER, Tributary Powder River
and
DRY CREEK, Tributary North Fork Powder River
(20-44-81)

6339 R	Dry Creek Res.-----	Metka Brothers-----	7-19-1956	I	171.95 a.f.		20-44-81	
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Figure 3.5 From 1972 Tabulation of Adjudicated Water Rights of the State of Wyoming - Water Division Number Two.

validity of the assumptions in the model — namely, that every decreed right on the stream is used for irrigation and that the strict order of priority diversion is in this case strictly followed. The straightline diagram can be seen in Figure 3.6.

It should be noted that the personnel in the District Engineer's Office are extremely helpful in situations met in attempting water transfers, because they realize that such activities are one of their most important duties.

3.4 Data Manipulation and Analysis

For the data described in the previous section to be useful, it must be arranged in a coherent manner. The model used in this case study requires that the information on water rights be displayed as a straightline diagram. Therefore, the information shown in Figures 3.5 and 3.6 must be rearranged in the manner shown in Figure 3.7.

The matrix formulation of the model permits several rights of differing priorities to be diverted at the same location. This situation is commonly found at irrigation canal headgates, where enlargements or appropriations have been made subsequent to the original appropriations. Another cause of this situation is that several ditches may share a joint headgate-point of diversion, separating only after the water has been diverted. The locations are numbered starting at the top of the segment of interest and going downstream. In the case study, location number 0 is the Hazelton USGS gauge, and the location number at the Miles Ditch is 44. Twenty-two separate points of diversion are found in the North Fork of the Powder River, and allowing a distinct location point between each

of these diversion points and one at the top and one at the bottom, we develop the number of points to which water can be transferred as 45.

With location number and priority number, each right is labelled, or subscripted, throughout the procedure. Separate matrices exist to organize the characteristics of each right in question.

The input flows to the model, taken from the graph, will depend on the reliability requirements of the planned facility. The static simulation model used in the procedure, however, implies that if a decree receives water under any input flow, then it will receive water for all flows greater than that flow. Thus, the input flow level to be analyzed should occur with the same frequency or probability that is the maximum frequency in which water supply interruptions can be tolerated.

In the case study presented here, a sample input flow of 25 cfs is used. This flow is enough to make the problem of optimal selection of water rights non-trivial. Although it is considerably larger than the low flows given in Figure 3.4 for low flow-duration intervals at Hazelton, Wyoming, stream gauge, it represents at least one of the flows which would be used to evaluate water yield under varying conditions. Ordinarily, sensitivity analysis using a broad range of flows would be performed to gain a "feel" for the situation.

With this hypothetical case, it is assumed that the required water supply is for 3 cfs diversion flow, and 50% consumptive use of the diversion flow. The desired location for this flow is between the Canon and Coachy Ditches, relatively high on the stream. It is assumed that the return flow enters with no delay to the stream directly below the point of diversion, upstream of the next diversion from the Coachy Ditch.

NORTH FORK - POWDER RIVER STRAIGHTLINE DIAGRAM

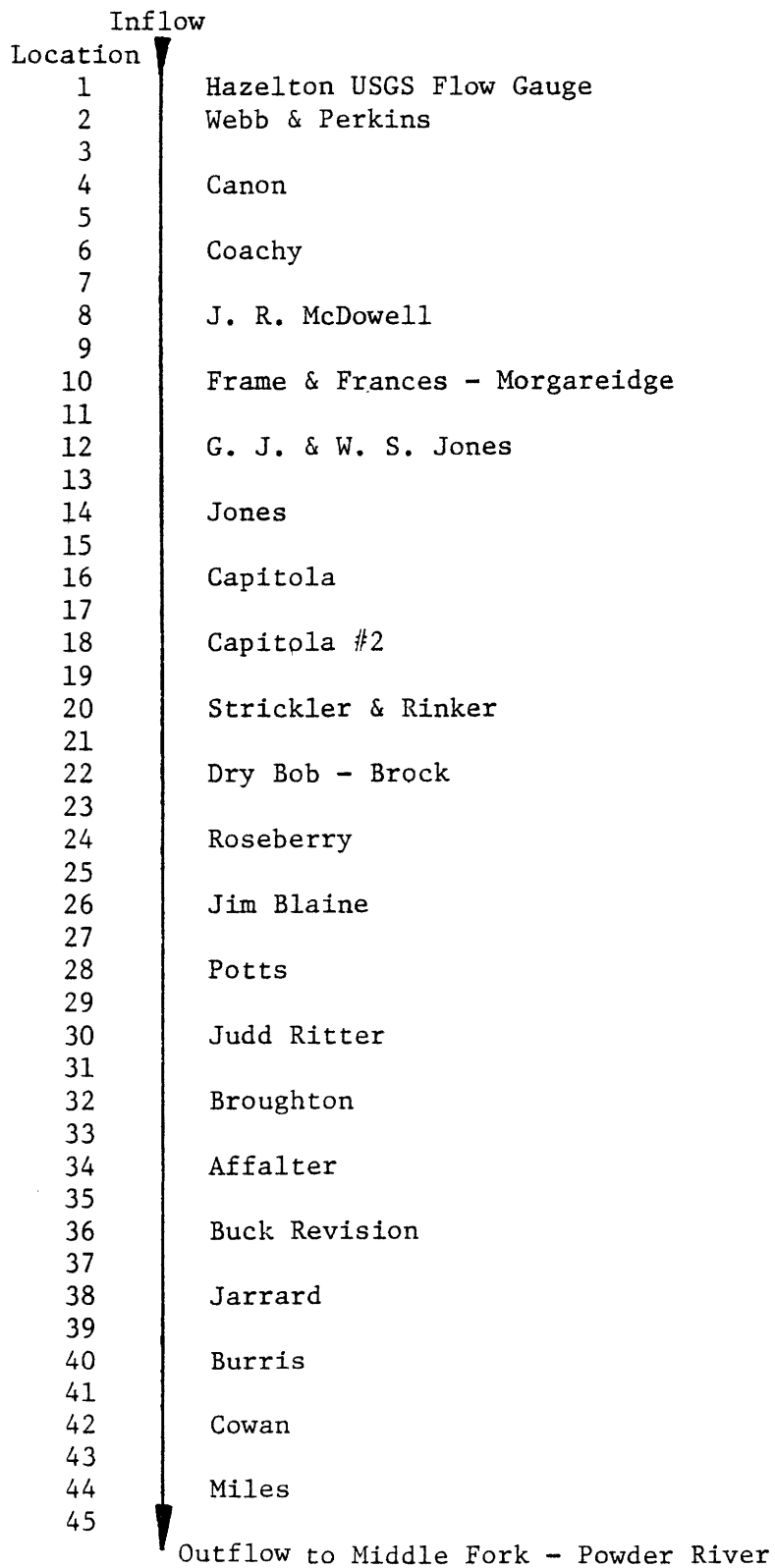


FIGURE 3.6

FIGURE 3.7(a)
 DECREED CHARACTERISTICS OF WATER RIGHTS ON THE NORTH FORK OF THE POWDER RIVER

<u>Location</u>	<u>Priority</u>	<u>Decreed Flow</u>	<u>Assumed Return Flow</u>
2	34	2.11	0.5
2	38	3.8	0.5
4	23	0.81	0.5
6	30	0.65	0.5
8	18	0.34	0.5
10	4	1.23	0.5
10	5	3.04	0.5
10	11	1.0	0.5
10	20	1.64	0.5
10	33	0.5	0.5
10	40	0.42	0.5
12	12	1.33	0.5
14	7	0.42	0.5
14	32	0.09	0.5
16	2	3.2	0.5
18	15	0.21	0.5
20	5	5.64	0.5
20	25	0.44	0.5
20	27	0.71	0.5
20	28	2.05	0.5
20	36	0.68	0.5

FIGURE 3.7(b)

DECREED CHARACTERISTICS OF WATER RIGHTS ON THE NORTH FORK OF THE POWDER RIVER

<u>Location</u>	<u>Priority</u>	<u>Decreed Flow</u>	<u>Assumed Return Flow</u>
22	1	6.26	0.5
22	10	2.84	0.5
22	37	0.68	0.5
24	13	1.91	0.5
26	6	12.44	0.5
26	22	1.42	0.5
28	6	2.10	0.5
30	9	3.42	0.5
30	24	0.43	0.5
32	1	12.21	0.5
32	35	0.21	0.5
32	41	2.9	0.5
34	21	1.83	0.5
34	39	2.05	0.5
36	16	0.52	0.5
36	17	0.26	0.5
38	14	0.42	0.5
38	31	0.65	0.5
38	39	0.53	0.5
38	42	0.40	0.5
40	26	1.11	0.5
42	8	0.71	0.5
44	19	1.05	0.5
44	43	2.56	0.5

The instantaneous return flow for all other rights on the river is taken, for convenience, to be 50%. With study, this number could be further refined.

The straightline diagram describing the order of canal diversions along the river is shown in Figure 3.6, and the water rights characteristics according to their location and seniority are shown in Figure 3.7. We can see from the straightline diagram that the desired location for the 3.0 cfs water supply is at point 5, and we want that water right with the lowest flow and most recent seniority necessary to satisfy the flow. If we evaluate the optimum transfer under conditions of no required upstream flow and no downstream demand, it is seen that several transfers can supply the need, or close to it, and are worth further examination. These include the decrees at:

<u>Location</u>	<u>Seniority</u>	<u>Decree Flow (cfs)</u>	<u>Amount Transferable to Location 5 (cfs)</u>
10	5	3.04	2.28 to 3.04
16	2	3.20	2.4 to 3.2
20	5	21.27	4.23 to 5.64
22	1	6.26	3.13 to 6.26
26	6	12.44	9.95 to 12.44
32	1	12.21	4.89 to 7.33

This transfer would permit a continuation of the 50% consumptive use in the new location.

Results of the examinations at the inflow of 25 cfs show that the most junior rights with the necessary transfer potential are those of

seniority 5 and 6, at locations 10, 22 and 26. As explained previously, however, analysis would be performed with many inflows before any decision is made regarding the optimum strategy.

It is interesting to note that the imposition of a required minimum streamflow or a required outflow of the system plays an important role in the yield of water rights. For example, the water right at location 20, seniority 5, was examined for transfer potential to location 5 with streamflow and system outflow requirements. The results, shown in the following table, indicate that the yield falls quickly when such requirements are imposed.

<u>Location</u>	<u>Seniority</u>	<u>Minimum Streamflow (cfs)</u>	<u>Required Outflow (cfs)</u>	<u>Amount Transferable (cfs)</u>
20	5	0	0	4.23 to 5.64
20	5	5	0	4.23 to 5.64
20	5	0	5	1.41 to 2.82
20	5	5	5	0.0

This demonstrates the reason for the close examination of interstate compacts by all states concerned.

The input flows to the model, taken from the graph, will depend on the reliability requirements of the planned facility. The static simulation model used in the procedure, however, implies that if a decree receives water under any input flow, then it will receive water for all flows greater than that flow. Thus, the input flow level to be analyzed should occur with the same frequency or probability that is the maximum

frequency in which water supply interruptions can be tolerated.

Chapter 4

SUMMARY AND RECOMMENDATIONS

4.1 Summary

A description of institutional features of surface water allocation in the Powder River Basin has been developed. Based upon this analysis, an evaluation procedure has been presented which analyzes the water yield of the different water rights under low flows of the river.

Because the method is oriented towards projects of a relatively small scale, it handles institutional considerations, such as the appropriation system, as a framework upon which different supply alternatives can be considered, rather than treating institutional aspects as a variable in the process. The driving force in the procedure is the determination of water supply reliability of decrees characterized by location, seniority, and amount. Relying on the principle of adverse impact avoidance to other water rights, the characterization of water rights under transferred conditions is a significant part of the procedure developed here.

The basic model has been used in a case study, the North Fork of the Powder River near Gillette, Wyoming. This proved to be a setting well suited for the use of this model: all water rights are used for agricultural purposes, relatively good data exists regarding flows and water decrees, and there exists large interest in the water by those involved in local coal development. Water rights were evaluated for a hypothetical location to be supplied with water under certain flow and reliability conditions.

To date, the process has not been used in any real cases. It is hoped that with further development the approach presented here will be used in actual situations in a manner designed to enhance efficient and accurate water resource planning.

4.2 Utility of Model

The model presented here is designed primarily for use as a screening tool in the preliminary evaluation of water rights transfers. Although it was intended originally for use in energy development problems in the Western United States, it is applicable to a wide variety of situations lying outside the purview of the situation for which it was developed. For example, it may be used in many situations in which a change of water use (primarily direct flow rights) is desired in areas where some form of the appropriation doctrine is practiced.

Because no significant changes in the transfer procedure of states with appropriation doctrine are anticipated in the near future, it is not expected that the model presented here will be used as evidence or exhibits in the formal transfer proceedings. The traditional methods of water rights evaluation will probably continue to be the major source of information presented at such formal proceedings.

The parties which may use this procedure include those wishing to transfer water, those protesting the transfer, and those who are responsible for granting and administering the transfer. In the case study, this might include the energy development group, other river water users protesting the transfer, and the Wyoming State Board of

Control. Additional agencies such as the Bureau of Fish and Game, and the Department of Agriculture will also find the model useful.

One aspect of the water transfer process which would be well served by the model outlined here is that of the "horsetrading" between parties which occurs at unofficial meetings. Often, agreement can be reached during these direct meetings between the concerned parties, and the entire formal procedure thereafter is based on stipulation agreed to by all parties. In this use, the model would probably be run with a wide variety of input flows, giving a relatively comprehensive view of the consequences of a transfer under changing conditions.

In the assessment of minimum stream flow augmentation via the purchase and dedication to instream use of water rights, the model should be of value. By determining the results of the abandonment of certain water decrees, as well as assessing the consequences of keeping certain water rights in their existing uses, greater efficiency in the use of the river water, and increases in many objectives may be obtained.

4.3 Recommendations for Further Work

The model presented here should be considered as merely the barest outline of a method which can be developed to suit a variety of needs. There are several areas in which further work could be done which would have a significant effect upon the model results and permit further uses.

One of the most obvious improvements would be to alter the simulation portion of the model to account for time-dependent variations in the parameters of interest. The most important of these are the

assumption of conservative streamflow on an instantaneous basis, the relationship of return flow to diversion history, and the assumption of maximum diversion by all water decrees at the same time.

The inclusion of time-dependent considerations in a model of this type would make the generation of synthetic streamflows necessary in order to exhibit the system reaction to all types of possible inputs. Modeling of the physical system has been done before in such a manner, but no references have been found which speak of the analysis of water rights via the generation of synthetic data.

Additionally, the inclusion of more accurate return flow considerations, including time and location factors, should improve the model substantially. Models currently exist to provide synthetic streamflow data which require very few inputs — typically the statistical descriptors of the historical data. Thus, the inputs to the synthetic streamflow generator could be determined from a brief examination of USGS data.

Removal of the continuous diversion assumption will require analysis of water rights diversion histories at a level higher than is currently required in the model. Ideally, some synthetic generator of water rights diversions could be developed which, based on time-dependent statistical analysis of diversion histories, would yield a more realistic picture of direct flow diversions for different purposes. In fact, there are major difficulties involved with any modeling of this aspect. This is because several relationships may tie the diversion rate in subtle ways to the river flow. For example, the rate of diversion for irrigation may depend upon the amount of precipitation at any

one time, and the precipitation may affect the available stream flow also. Thus, any satisfactory stochastic diversion generator must take into account a considerable number of parameters. However, because the model is concerned with recurrences of low flows and the corresponding behavior of the water rights, the period of interest for water rights analysis is short. This simplifies the modeling requirements significantly.

Another alteration to the model which would broaden its area of usefulness considerably would be to take into account the possibilities of storage, both on- and off-stream. The analysis of storage consequences for water availability is affected by several considerations, including storage purpose, operating policy, and reservoir location and filling priority. The evaluation is facilitated by the formal differentiation in most appropriation law codes between direct flow diversion rights and storage rights. The analysis of storage consequences will, however, probably require the flow history approach suggested above.

With this capability, the model would be applicable to a much wider range of applications, because a significant number of rivers have storage capability which results in major consequences for the water right diversion possibilities.

A major extension of the model lies in the direction of fitting a formal optimization model to it, or integrating one into the procedure. Depending on the purpose for which the model is used, both for single and multiple objectives, several techniques could be used. In most cases, a large number of constraints might be used in order to model the priorities and diversion requirements. It seems that one way to

go about this problem might be to generate the results of many alternatives, and then use some sort of surface-search procedure to find optimal points.

4.4 Possible Applications for Immediate Study

There are a variety of problems in the water resources field which appear to lend themselves to the type of analysis for which the model is intended. Generally, these include problems falling in the category where evaluation is desired of the trade-offs involved in changing reliabilities and quantities of water supply.

A problem currently being viewed with some interest is that of evaluating the consequences of different modes of cooling for thermal-electric generation. Specifically of concern are the different required water supply characteristics for cooling pond systems and various other types of cooling systems. For example, it is known that cooling pond systems have a less stringent water reliability requirement than most cooling tower or once-through systems, but may require a greater land area for the pond.

Another type of problem which might be addressed with the use of this procedure would be to determine the expected consequences of alternative levels of development in river basins upon the existing water use picture. It would be possible to derive trade-off curves showing the effects of increasing levels of development on the current water situation by showing which water rights would be expected to be used first, in a series of sensitivity analyses performed on the model.

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