Research Technical Completion Report

HYDROLOGIC AND LEGAL ASSESSMENT OF GROUND WATER MANAGEMENT ALTERNATIVES FOR IDAHO

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ABSTRACT

This report is a hydrologic and legal assessment of conjunctive management of surface and ground water with emphasis on the water resources of the upper Snake River Basin in Idaho. The first portion of the report is the development of a hydrologic management classification of basins tributary to the upper Snake River. The last part of the report is a legal examination of the uncertainties and complexities of conjunctive management of surface and ground water under the appropriation doctrine.

Eleven basins tributary to the upper Snake River were selected for detailed study based upon existing data: Little Lost River, Big Lost River, Big Wood River-Silver Creek, Camas Prairie, Portneuf River, Michaud Flats, Rockland, Raft River, Rock Creek- Goose Creek, Salmon Falls Creek and Blue Gulch. The basins are classified based upon the following four factors: 1.) the ratio of annual basin discharge to total flow of the Snake River, 2.) the ratio of annual comsumptive pumpage to annual basin discharge, 3.) the ratio of annual water yield to basin area, and 4.) the distance that surface water and ground water must flow before discharging into the Snake River.

Most of the south side tributary valleys have either existing or potential overdevelopment problems.

Calculation of time lag estimates between pumpage in a tributary basin and impact on the Snake River are based upon lag times within the individual basins as well as the Snake Plain aquifer, if appropriate. Several basins have estimated lag times of more than 100 years.

The legal uncertainties and complexities of conjunctive management examined as part of this study include: 1.) questions involving the magnitude and timing of the impact of junior tributary diversions upon supplies in the main source, both in private litigation between water users and in administrative regulation of water use; 2.) selection of junior tributary diversions for closure when senior appropriators on the main source are not recieving their full supplies; 3.) questions of burden of proof both in private litigation and in administrative regulation; and 4.) the influence of policy objectives upon conjunctive management decisions. A number of more or less technical legal issues are identified and discussed. Where Idaho law gives little guidance, comparison is made to legal developments in Colorado. The study also focuses on a fundamental and difficult policy issue that may arise in a number of conjunctive management situations, namely, potential conflict between the policies of protecting senior vested rights and optimum development.

INTRODUCTION

This report provides the results of a combined research effort of the College of Mines and Earth Resources and the College of Law at the University of Idaho focused on conjunctive management of surface and ground water resources. The hydrologic aspects of the research are directed toward the ground water resources of the upper Snake River Basin in Idaho. The legal research is based upon Idaho laws and cases with correlation to other western states. The project was conducted under funding by the Idaho Water and Energy Resources Research Institute.

The report is presented in two major parts. The hydrologic aspects of conjunctive management of surface and ground water are presented first. Particular emphasis is placed on classifying selected basins tributary to the upper Snake River with respect to the magnitude of discharge, extent of development and estimated time lag between ground water pumpage and reduced discharge to the Snake River.

The legal aspects of conjunctive management are presented as the second major section. Issues addressed include the magnitude and timing of impacts on junior diversions, selection of junior diversions for closure, burden of proof and policy objectives.

PART I.

HYDROLOGIC ASPECTS OF CONJUNCTIVE MANAGEMENT OF SURFACE AND GROUND WATER

by

Dale R. Ralston and Roxane Broadhead

HYDROLOGIC ASPECTS OF CONJUNCTIVE MANAGEMENT OF SURFACE AND GROUND WATER

Introduction

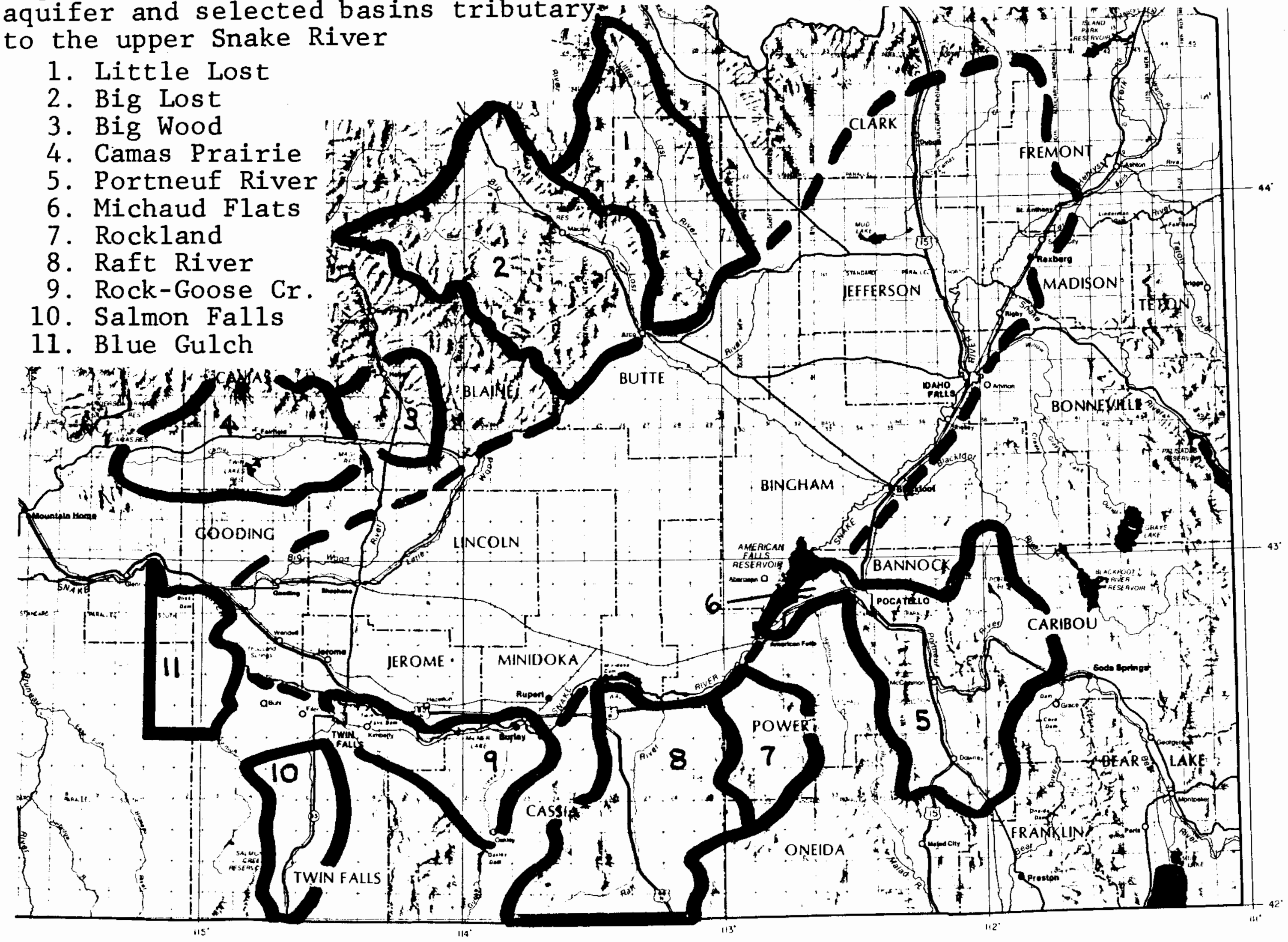
Statement of the Problem

The water resources of the upper Snake River basin support a vital part of the economy and lifestyle of southern Idaho. The upper Snake River Basin includes the Snake River, the Snake River Plain, and the basins tributary to the Snake River (Fig. 1). Until recently, the general attitude of the population was that sufficient quantities of water were available in the upper Snake River Basin to fill the needs of all existing and anticipated domestic, agricultural, and industrial users. In the 1980's there has been has been a growing awareness that restrictions were in place limiting new development of specific streams and ground water basins; however, unappropriated water was deemed available in many areas. Concurrently, there has been a greater consciousness of the complexities of combined management of surface water-ground water systems such as the upper Snake River Basin.

An intregal factor in management of a large drainage basin, such as the upper Snake River Basin, is conjunctive management. Conjunctive management includes: 1.) management of the main and tributary

Fig. 1 Location map for Snake Plain aquifer and selected basins tributary to the upper Snake River

1. Little Lost
2. Big Lost
3. Big Wood
4. Camas Prairie
5. Portneuf River
6. Michaud Flats
7. Rockland
8. Raft River
9. Rock-Goose Cr.
10. Salmon Falls
11. Blue Gulch



basins as one interrelated system as opposed to management of each basin as a separate unrelated area, and 2.) management of surface water and ground water as a single interrelated resource.

The Idaho Code dictates that water rights are granted under the Appropriation Doctrine, which states that "first in time is first in right." Therefore, a senior appropriator's water right is protected from all junior appropriators in a given management area whether they be on surface water or ground water resources. The complexity of conjunctive management of surface and ground water resources in a basin such as the upper Snake River Basin stems in part from the fact that almost all ground water rights are junior to almost all surface water rights. Also important are problems of physically, legally, and administratively defining the interrelationships of the two resources.

Hydrologic factors that are important with respect to a comprehensive conjunctive management plan include: hydrogeologic characteristics of individual basins; surface water and ground water interrelationships; hydrologic relationships between basins; and impacts of water resource development on the entire system. Once the hydrologic factors are understood, criteria can be established to guide management of the water resources of an area in an equitable manner while providing the fullest benefit to the greatest number of users.

This portion of the paper outlines the physical and hydrologic aspects of selected basins tributary to the Snake River, east of King Hill, Idaho. A classification of tributary basins is developed as a preliminary effort for detailed conjunctive management of the Snake River Basin.

Purpose and Objectives

The purpose of this study is to describe the hydrogeologic characteristics of selected tributary basins and to evaluate the impact that ground water development has on the flow of the Snake River in southern Idaho.

The general objective is to develop a hydrologic management classification of basins tributary to the upper Snake River. Specific objectives are as follows:

1. Review and compile existing hydrogeologic data on selected tributary basins.
2. Describe mechanisms of ground water and surface water flow in selected tributary basins.
3. Classify selected tributary basins according to magnitude of discharge and extent of ground water development.
4. Estimate time lag between ground water pumpage in selected tributary basins and reduced

discharge to the Snake River.

Previous Investigations

The first extensive study of ground water resources in the upper Snake River Basin was conducted by Stearns and others (1938). Mundorff and others (1964) in an extensive study regarding ground water for irrigation in the Snake River Basin, describe physical and hydrologic characteristics of tributary basins and the Snake Plain aquifer. Numerous reports have been published concerning hydrologic aspects of the tributary basins and are mentioned with the individual descriptions of selected basins. Kjelstrom (1984) published estimates of water yield and surface and ground water discharge from tributary basins. Kjelstrom's estimates are used where previous data are unavailable.

A study considering the effects of artifical recharge on the Snake Plain aquifer was conducted by Norvitch and others (1969). Moreland (1976) developed a digital model to analyze the effect of water use alternatives on spring discharge in Gooding and Jerome Counties. A computer model characterizing the response of the Snake Plain aquifer was developed by deSonneville (1974).

Idaho ground water law and its application to ground water management is discussed in publications by Grant (1975, 1980), Ralston (1974), and Ralston and others (1974). Ralston and others (1983) published a report on ground water management alternatives for Idaho that proposes an initial ground water management classification. Regional management considerations of ground water resources of layered volcanics is presented by Brown (1983).

In addition to previous reports, numerical models of the Snake River Plain are currently being developed by the U. S. Geological Survey and the Idaho Department of Water Resources in cooperation with the University of Idaho Agricultural Extension Station. Estimates published by Kjelstrom (1984) will be used as input for the U. S. G. S. model.

Methods of Study

Data regarding the hydrogeology of selected basins were assembled from existing reports concerning the upper Snake River Basin. An initial classification of the tributary basins according to the magnitude of discharge and the extent of ground water development was developed from information obtained from previous investigators. The Idaho Department of Water Resources supplied information regarding current management practices of the upper Snake River Basin.

Time lags between basin pumpage and the Snake River were computed by analytical methods. Calculations were compared with historic flow data at Thousand Springs and previous studies concerning artifical recharge to the Snake Plain aquifer and hypothetical pumpage effects on spring discharge in Gooding and Jerome Counties. The basins were then classified according to time lags.

Water Budget

Availability of water within a tributary basin was evaluated by use of a water budget based upon existing data. A water budget is essentially an accounting technique developed by identifying recharge-discharge characteristics of a basin.

Water input or recharge to a basin includes precipitation and water imported from outside the basin. The term water yield is used to describe the amount of water available for surface water and ground water use in a basin. Although, water yield is defined in a variety of ways, a general definition is the total water input minus evapotranspiration by native vegetation.

Water output or discharge from a basin includes evapotranspiration by native vegetation, surface and ground water consumptively used, and surface and ground water discharge from the basin. Consumptive use is commonly defined as water transpired by irrigated crops and water consumptively used for domestic, municipal and stock purposes.

Methods of estimating data such as precipitation, natural evapotranspiration, water yield, ground water discharge and consumptive pumpage vary according to sources. Ground water discharge, for example, is often estimated by use of a water budget or by multiplying hydraulic gradient, outflow area and aquifer hydraulic conductivity. Consumptive use of ground water is frequently estimated by assuming the water use efficiency of local crops.

A water budget is an average annual approach to the hydrologic regime of a basin and does not account for time dependent effects such as precipitation, average runoff and evapotranspiration. A water budget also assumes equilibrium conditions, therefore, there is no accounting for changes in ground water storage.

Hydraulic Principles of Ground Water Pumpage

Every acre-foot of water consumptively used in basins tributary to the Snake River ultimately reduces the flow of the Snake River. The process by which ground water pumpage affects the flow of the Snake River is distinctly different than the process by which surface water diversions affect the flow of the Snake River. Surface water diversions directly reduce surface flow into the Snake River.

Ground water pumpage creates a decline in hydraulic potential that spreads radially outward. This can be thought of as a ground water pressure wave. This concept is significant since the rate of an individual molecule of water movement is much slower than the rate of pressure wave movement through an aquifer.

The speed of response of an aquifer to pumpage is primarily dependent on whether the aquifer is confined or unconfined. When a well is pumped in a confined aquifer, water released to the well comes from expansion of water by reduced fluid pressures and compaction of the aquifer by increased effective stress. The release of water from storage is assumed to be nearly instantaneous. Water level responses to pumpage in a confined aquifer thus spread quickly over large areas.

When water is pumped from an unconfined aquifer, hydraulic gradients are induced to the well causing a drawdown cone in the water table. Water released to the well arises from gravity drainage of water from the aquifer. Water level responces to the pumpage from an unconfined aquifer are thus much slower than from a confined aquifer.

Both streams and impermeable boundaries affect the response of an aquifer to pumping. Interconnected streams act as a recharge source to the pumping well. The entire well yield is derived from the stream if pumping continues for a long enough period of time.

Major decreases in hydraulic conductivity such as occur at contacts between alluvial material and older metamorphic rocks act as no-flow boundaries. Such boundaries affect the size and shape of the cone of depression from a pumping well.

Analytical methods are available to estimate the response of an aquifer to pumpage. The Theis (1935) radial flow solution models the responses of an ideal aquifer to pumpage. The Theis solution may be used to model various types and shapes of boundaries utilizing effects by image wells theory. The Jenkins (1968) stream depletion solution models the affect of ground water pumpage near an interconnected stream. The Jenkins solution can be used to predict lag time response between ground water pumpage and a given rate from stream depletion of a local stream.

Regional Hydrology and Hydrogeology

The Snake River Plain is a broad undulating plain which extends from Ashton in southeastern Idaho into eastern Oregon. The plain ranges from 30 to 75 miles wide. The Snake River Plain is divided into two portions based on geology. The portion east of Bliss, Idaho is termed the upper Plain (Fig. 1) and the portion west of Bliss, Idaho is termed the lower Plain. This report deals only with basins tributary to the upper Snake River Plain.

The Snake River extends along the length of the Snake River Plain. The Snake River flows in a wide shallow channel from Ashton to American Falls. The river flows in a narrow canyon 50-150 feet deep downstream from American Falls to Milner Dam. Downstream from Milner Dam to Bliss, the canyon is as much as 400 feet deep. The Snake River receives all surface and ground water discharge from the Snake River Plain and associated tributary basins.

Most tributary basins in the upper Snake River Basin are broad valleys bordered by mountains that range in elevation from 7,500 to 12,000 feet above sea level. The ranges trend north to northwest and are fault block mountains related to the Basin and Range province. The mountain ranges are composed of low hydraulic conductivity rocks and act as both surface and ground water divides between tributary basins (Mundorff and others, 1964). The mountains receive greater precipitation than adjacent lowlands. Runoff from mountains supply flow to streams and recharge alluvial aquifers. Water that discharges from tributary basins enters the Snake River either directly as surface water outflow or as ground water discharge such as the Thousand Springs.

Ground water outflow from many of the tributary basins recharges the Snake River Plain aquifer. The Snake Plain aquifer is a large aquifer composed of basalt flows interlayered with sedimentary beds. Individual basalt flows are approximately 50 feet thick.

The basalts may be several thousand feet thick near the center of the Plain and thin towards the margin (Whitehead, 1984). Ground water discharge from the Snake Plain aquifer to the Snake River occurs predominantly from springs issuing from the walls of a basalt canyon in an area known as Thousand Springs near Hangerman, Idaho

Summary of the Water Resources Systems in Basins Tributary to the Snake River

Sixteen surface water and ground water basins or areas contribute flow directly or indirectly to the Snake River between Rexburg and King Hill gaging stations. Eleven of the sixteen tributary basins have been selected for detailed study (Fig. 1). Basins located to the north side of the upper Snake River Plain include: Little Lost River, Big Lost River, Big Wood River - Silver Creek, and Camas Prarie basins. Basins or areas located on the south side of the upper Snake River Plain include: Portneuf River, Michaud Flats, Rockland, Raft River, Rock Creek - Goose Creek, Salmon Falls Creek, and Blue Gulch basins. Basins studied were selected primarily on the basis of amount of hydrologic information available. Some tributary basins lack sufficient hydrologic data for indepth study. The

Henrys Fork Basin is not included because of the complex nature of surface and ground water response.

The information necessary for the evaluation of the effects water usage in tributary basins has on the flow of the Snake River includes: size and extent of the basin; major aquifers and their geologic properties; transmissivity and storativity values of aquifers; surface water-ground water interconnection; annual water yield; ground water pumpage; and surface and ground water discharge. Hydrologic descriptions of each basin were compiled from previous studies conducted by various investigators.

Little Lost River Basin

Little Lost River Basin is located on the north side of the Snake River Plain, with the mouth of the basin located at Howe, Idaho. The basin occupies approximately 800 square miles and is bounded by the Lost River Range, the Lemhi Range, and the Snake River Plain (Fig. 1). The basin averages 50 miles long and 20 miles wide. The valley floor averages 7 miles wide.

Two extensive studies on the hydrologic resources of Little Lost River Basin have been published. Mundorff and others (1960) published a report on the general hydrology of the basin. Clebsch and others (1974) published a report on availability of water in Little Lost River basin. A brief survey of the basin was written by Mundorff and others (1964) as part of a study on the Snake River Basin. Much of the information contained in this description of the Little Lost River Basin was obtained from the Mundorff and Clebsch reports.

Primary aquifers in the basin consist of late Tertiary to Recent unconsolidated alluvial deposits. Mundorff and others (1964) suggest that alluvium may be more than 3000 feet thick near the center of the valley. The depth of alluvium was estimated by projecting the slopes of the surrounding mountain ranges beneath the valley. Alluvial materials are more permeable toward the center of the valley. Silt and clay content increases downvalley. Basalt of the Snake River Group is interlayered with silt and clay in the vicinity of Howe. Ground water levels in the alluvial deposits north of Howe are nearly 200 feet higher than ground water levels in the Snake River Plain due to "damming effects" of silts and clays.

The mountains and hills surrounding the basin and the bedrock beneath the basin are composed of jointed Paleozoic sedimentary rocks and Tertiary volcanic rocks. Most of the sedimentary and volcanic rocks are virtually impermeable. Significant quantities of ground water occur where limestone deposits are present in the surrounding mountains.

Ground water in the alluvial deposits occurs primarily under unconfined conditions. Perched and artesian zones have not been indentified but may be present where basalt interfingers with alluvium at the mouth of the valley.

Transmissivity values of the alluvial aquifer have been estimated by both Mundorff and others (1964, 1963) and Clebsch and others (1974). Clebsch and others (1974) estimate transmissivity in the upper portion of the basin to be approximately 20,000-27,000 feet^2/day The transmissivity in the middle portions of the basin is reported to be 33,000-40,000 feet^2/day Clebsch and others (1974) estimate storativity for the upper and middle portions of the basin at .2. Average transmissivity and storativity in the vicinity of Howe are estimated at 67,000 feet^2/day and .15, respectively (Clebsch and others, 1974). Data reported by Clebsch and others (1974) provide the most complete characterization of the alluvial deposits and are used for calculations for this paper.

Surface and ground water are closely interconnected throughout the Little Lost River Basin. Most of the streams infiltrate into alluvial fans at the mountain fronts before reaching the Little Lost River. Many springs and seeps discharge near the confluence of Sawmill and Summit Creeks, which form the Little Lost

River. Downstream from the confluence of Little Lost River for 7 to 8 miles, surface water percolates to the ground water system. Downstream from Badger Creek, many springs and seeps discharge into the river. This pattern of recharge and discharge continues to the north edge of Sec. 28, T. 7 N., R. 28 E. where the water table intercepts land surface because of the low permeability of the silts and clays. Downstream from the constriction, the water table drops and a large portion of the surface flow infiltrates into basalt aquifers.

Water yield for the Little Lost River Basin is estimated to be from 160,000- 424,000 acre-feet/year (Table 1). Clebsch and others (1974) suggest that 271,000 acre-feet/year is the best estimate of average water yield. Water yield as defined by Clebsch and others (1974) is the average precipitation minus the consumptive use of nonphreatophyte vegetation.

More than two-thirds of the irrigation wells in Little Lost River Basin are located in the vicinity of Howe. The remaining one-third of the irrigation wells are located in the middle and upper basin. Clebsch and others (1974, p. 41) report average consumptive use by crops irrigated with ground water to be 40,000 acre-feet/year.

Estimates of surface water and ground water discharge out of the basin have been reported by various authors (Table 1). Ground water discharge from the basin directly recharges the Snake Plain aquifer. All surface water discharge eventually evaporates or infiltrates as recharge to the Snake Plain aquifer; no surface flow reaches the Snake River. The Little Lost River channel ends at the Lost River Sinks but only in years of high flow does surface water reach the Sinks.

Basin water yield and outflow estimates computed by Clebsch and others (1974) are used in calculations for this paper. These data provide the most recent estimates of water yield and outflow available.

Big Lost River Basin

The Big Lost River Basin is located west of the Little Lost River Basin on the north side of the Snake River Plain, with the mouth of the basin located at Arco, Idaho. The basin includes approximately 1400 square miles and is bounded by the Lost River Range, the Boulder Mountains, the Pioneer Mountains, and the Snake River Plain (Fig. 1). The basin averages 50 miles long and 30 miles wide. The valley floor averages 5 miles wide.

Hydrologic studies concerning the Big Lost River Basin are limited. Mundorff and others (1964) conducted a brief study of the basin as part of a publication on ground water in the Snake River Basin. The most extensive study was conducted by Crosthwaite and others (1970). Much of the information contained in this description of the Big Lost River Basin was obtained from the Mundorff and Crosthwaite reports.

The primary aquifer occurs in late Tertiary to Recent consolidated and unconsolidated alluvial deposits. Geophysical studies conducted under the direction of Crosthwaite and others (1970) indicate that alluvial deposits range in thickness from 0-400 feet. Alluvium becomes progressively thinner south of Leslie where it begins to interfinger with basalt of the Snake River Group and eventually thins out entirely. Near the mouth of the valley, alluvium and basalt sequences may extend to depths greater than 2500 feet (Crosthwaite and others, 1970). Snake River basalt acts as the major aquifer in transmitting water out of the basin.

Much of the Big Lost River Basin is underlain by Paleozoic carbonate rocks. Large springs in the basin discharge from carbonate rocks suggesting that carbonate deposits receive significant amounts of recharge in mountainous areas and transmit water to the valley. Cemented alluvial deposits and other noncarbonate rocks occur in the surrounding mountains but exhibit low hydraulic conductivity and are probably insignificant as aquifers.

The principal aquifer, located in alluvial deposits, is unconfined with artesian and perched conditions existing locally. A weak artesian system may be present west of Chilly Buttes (Crosthwaite and others, 1970). Water is perched above the main water table southwest of Moore. In the vicinity of Arco, basalt interfingers with alluvium creating at least five different aquifers.

The transmissivity of the principal aquifer is estimated by Crosthwaite and others (1970, p. 81) to be 53,000 feet^2/day based upon specific capacity data obtained from 20 wells drilled in alluvium. Specific yield is assumed by Crosthwaite and others (1970) to be .2 in the upper 100 feet of saturated alluvium. The transmissivity of the the basalt near Arco is estimated by Mundorff and others (1964, p. 14) to be 98,000 feet^2/day

Surface water and ground water are interconnected throughout the reach of the river. Many streams originating in the mountains percolate into the alluvium and never reach the Big Lost River as surface flow. The Big Lost River is formed by the confluence of the East Fork Big Lost River and the North Fork Big Lost River, 60 miles upstream from the mouth of the basin. The reach of the Big Lost River between the confluence and Howell Ranch loses surface water to ground water. There is also a net loss of surface water to ground water between Howell Ranch and Mackay Reservoir. A large part of the loss occurs at Chilly Sinks, causing the main river channel to be dry 8-9 months out of most years between Chilly Sinks and Mackay Reservoir. Many of the smaller streams that discharge into Mackay Reservior receive large inflows from ground water. Large losses occur below Mackay Reservoir at the Darlington Sinks with a portion of the water returning to the river a few miles below the Sinks. Considerable losses of surface water to ground water occur between Moore Canal Heading and the gaging station near Arco. The water table drops well below the river bed downstream from Arco with continued losses of surface water to ground water.

Water yield estimates for the Big Lost River Basin range from 330,000 to 480,000 acre-feet/year (Table 1). Water yield as defined by Crosthwaite and others (1970) is the total average precipitation minus natural evapotranspiration occurring before the water has become a part of stream flow or ground water.

Ground water pumpage in the Big Lost River Basin occurs predominantly below Mackay Reservior. Approximately 200 acres above the reservoir and 8,300 acres below the reservoir are irrigated completely with ground water. Most supplemental pumping also occurs below the reservoir. Crosthwaite and others (1970, p.

81) estimate total consumptive pumpage in the basin to be 16,000 acre-feet/year.

Estimates of surface water and ground water discharge from the basin have been reported by various authors (Table 1). All surface outflow eventually evaporates or infiltrates as recharge to the Snake Plain aquifer with no surface flow reaching the Snake River. The Big Lost River channel ends about 25 miles east northeast of Arco at the Lost River Sinks. It is believed that a portion of the discharge at Thousand Springs is from the Big Lost River Basin.

Water yield and basin outflow estimates of Crosthwaite and others (1970) are used in calculations for this paper. Although Kjelstrom's (1984) discharge estimates are the most recent data available, Crosthwaite's (1970) data are used as they represent discharge at Arco rather than at Mackay. Substantial ground water pumpage occurs between Mackay and Arco, which decreases total outflow at Arco.

Big Wood River-Silver Creek Basin

The lower Big Wood River-Silver Creek basin is located on the north side of the Snake River Plain. The basin area occupies approximately 84 square miles and is bounded by the Pioneer Mountains, the Picabo and Timmerman Hills and an unnamed range of mountains to the west; the southern boundary is the Snake River Plain

Table 1. Estimates of water yield and basin discharge for selected tributary basins north of the upper Snake River.

Basin	Source	Water Yield (ac-ft/yr)	Surface Water Discharge (ac-ft/yr)	Ground Water Discharge (ac-ft/yr)
Little Lost River Basin	Clebsch and others (1974)	424,000	--	--
	Clebsch and others (1974)	271,000	--	--
	Clebsch and others (1974)	224,000	--	--
	Clebsch and others (1974)	--	10,000	157,000
	Mundorff and others (1963)	185,000	55,000	110,000
	Mundorff and others (1964)	160,000	50,000	100,000
	Kjelstrom (1984)	230,000	52,000	152,000
Big Lost River Basin	Mundorff and others (1964)	330,000	44,000	--
	Crosthwaite and others (1970)	470,500	54,000	308,000
	Kjelstrom (1984)	480,000	228,000	72,000
Big Wood River-Silver Creek Basin	Smith (1959)	470,500	320,000	38,000
	Castelin and Chapman (1972)	650,000	326,000	38,000
	Mundorff and others (1964)	478,000	320,000	50,000
Camas Prairie	Mundorff and others (1964)	--	127,000	--
	Walton (1962)	--		20,000
	Young (1978)	--	138,000	--

(Fig. 1). The study area includes the lower portion of the Big Wood River Basin below Hailey and the Silver Creek Basin. The Big Wood River flows from the southwestern outlet of the area directly into the Snake River. Silver Creek flows from the southeastern outlet of the basin and is tributary to the Little Wood River.

Hydrologic studies concerning the Big Wood River-Silver Creek Basin include reports by Smith (1959), Castelin and Chapman (1972), and Moreland (1977). Much of the information contained in this description of the Big Wood River Basin is obtained from these previous studies.

The primary aquifer occurs in Pleistocene fluvioglacial sediments which comprises the major portion of the valley fill. Recent alluvium underlies the Big Wood River channel and flood plain. The estimated maximum thickness of fluvioglacial and alluvial deposits is approximately 300 feet and 10 feet, respectively. The northern portion of the study area consists predominantly of coarse sand and gravel. South of Baseline Road, fine-grained sediments increase significantly. Extensive basalt flows of the Snake River Group occur at the southeast and southwest corners of the area between Gannett and Picabo. Estimated thickness of the basalt is 50-250 feet. Pre-Tertiary sedimentary rocks underlie and surround the Big Wood

River Basin area. The sedimentary rocks generally have low hydraulic conductivity and transmit water through fracture zones which is discharged at local springs. Pre-Tertiary granitic rocks and Tertiary volcanic rocks border portions of the study area.

The principal aquifer in fluvioglacial deposits is under both confined and unconfined conditions. Ground water flows southward in the unconfined aquifer in northern portions of the area. Some ground water flows beneath the confining silt and clay beds causing artesian pressures in southern portions of the basin. The remainder of the ground water continues to flow through the upper coarse grained materials in the unconfined aquifer. Basalt flows interfinger with unconsolidated sediments in the vicinity of Picabo, near the southeastern outlet of the basin. The high hydraulic conductivity of the basalt and sediment sequences provide the primary means for groundwater outflow.

Transmissivity values of aquifer materials have been estimated by various methods including pump test and specific capacity data. Transmissivity of the aquifer materials varies within the basin area. Smith (1959, p. 23) estimates transmissivity values in the basin to range from 106,000-294,000 feet^2/day. Castelin and Chapman (1974) suggest that transmissivity values for the unconfined aquifer are in the lower part of Smith's estimate. Moreland (1977, p. 14) estimates a range of transmissivity values from 7,000-30,000 feet^2/day.

Surface water and ground water are interconnected throughout the basin. Many mountain streams percolate into the valley fill before reaching the Big Wood River. Both surface water and ground water flow into the study area at Hailey. The reach of the Big Wood River from Hailey to Glendale Bridge gains flow from ground water. Surface water is lost from the river channel to ground water in the braided reach from Glendale Bridge to four to five miles downstream. The river channel is often dry for a few months out of the year below Glendale Bridge because of diversions into Bypass Canal. Downstream from the braided reach of the river to the southwestern edge of the basin area, the channel gains significant amounts of ground water.

A ground water divide is present roughly paralleling U.S. Highway 93 (Castelin and Chapman, 1970). Ground water east of the divide discharges into Silver Creek or leaves the southeastern outlet as underflow. Ground water west of the divide discharges into the Big Wood and various creeks and a small amount leaves the southwestern outlet as underflow.

Total inflow and precipitation for the lower Big Wood River-Silver Creek area have been estimated to range from 472,500 to 650,000 acre feet/year (Table 1). Castelin and Chapman (1982, p.36) estimate total evapotranspiration to be 286,000 acre-feet/year but do not distinguish between natural evapotranspiration and consumptive use. Total water yield is assumed to be 450,000 acre-feet/year.

Moreland (1977) provides the most recent data regarding consumptive use of ground water. Although, he only considers pumpage in the basin south of Bellevue, his estimates are considered within a reasonable range for purposes of this study. Moreland (1977, p. 15) estimates total pumpage from the unconfined aquifer to be approximately 17,000 acre-feet/year for 1974-75. Total water flow from artesian wells and total domestic and municipal use in 1975 is estimated at 12,000 acre-feet/year and 250 acre-feet/year, respectively (Moreland, 1977, p. 15-18). Assuming 50 percent consumption of water obtained from irrigation wells, the total consumptive use of water pumped in the Big Wood-Silver Creek Basin is 14,500 acre-feet/year.

Estimates of surface water and ground water discharge out of the basin that have been reported by previous investigators are reported in Table 1. The Big Wood River flows directly into the Snake River north of

Hagerman. Silver Creek flows directly into Little Wood River. Ground water outflow recharges the Snake Plain aquifer. The water yield and basin outflow estimates of Castelin and Chapman (1972) are used in calculations for this paper. The estimates computed by Castelin and Chapman (1972) are the most recent and complete data available.

Camas Prairie

The Camas Prairie is located on the north side of the Snake River Plain in Camas County and parts of Elmore, Gooding and Blaine Counties. The basin occupies approximately 730 square miles and is bounded by the Soldier Mountains, Mount Bennett Hills and the Snake River Plain (Figure 1). The drainage basin averages 40 miles long and 24 miles wide.

Hydrologic studies concerning Camas Prairie are limited. Walton (1962) conducted a preliminary study on the ground water resources of Camas Prairie for the U.S. Geological Survey. The most recent report was completed by Young in 1978. Most of the information contained in this description of Camas Prairie is obtained from the Walton and Young reports.

Major aquifers occur in Pleistocene valley fill deposits and basalt flows. Valley fill consists of alluvium deposited when lava flows blocked the eastern outlet of the basin during the Pliocene and Pleistocene ages. Well logs indicate the average depth of alluvial fill is 300-500 feet with depths up to 1,125 reported in the vicinity of Corral. The alluvium consists of sand and gravel with interbedded clay layers. A clay unit, approximately 90 feet thick, exists at an average depth of 120-210 feet below land surface. Pleistocene basalt flows of the Bruneau Formation are present near the eastern outlet of the basin.

Consolidated sedimentary and igneous rocks ranging in age from Carboniferous to Quaternary surround and underlie Camas Prairie. The sedimentary and igneous formations yield small to moderate amounts of water to wells and springs from joint and fracture zones. The hydraulic conductivity of the bedrock underlying the valley is very low.

Principal aquifers, located in the basalts and fluvial deposits, are under both unconfined and confined conditions. The unconfined aquifer occurs in the upper 40 feet of valley fill. Two distinct confined aquifers occur below the 90 foot clay layer. The average thickness of the "upper" and "lower" artesian aquifers is 50 feet and 85 feet, respectively. Both aquifers consist of sand and gravel with thin clay interbeds. Artesian conditions also exist where clay layers overlie basalt.

The transmissivity values of the alluvium and basalt have been estimated by Walton (1962, p. 19). A pump test conducted at well site 1S-14E-9adb1 in the "lower" artesian aquifer indicated a transmissivity value of 4,000 $feet^2$/day. Walton (1962, p. 19) estimated the combined transmissivity of the confined aquifers to equal 9,000 $feet^2$/day. Storativity is assumed to range from .001 to .00001. The transmissivity of the upper Snake River basalt aquifer at the eastern outlet of the prairie is estimated to be 27,000 $feet^2$/day from specific capacity data obtained from wells 1S-15E-16db1 and 1S-15E-21ad1 (Walton, 1962, p. 19).

Surface water and ground water are interconnected throughout the basin. Many of the streams originating in the mountains percolate into the alluvium before reaching Camas Creek. Upward vertical leakage also occurs from the confined to the unconfined aquifers. General ground water movement is southeast from Soldier Mountains and northeast from Mount Bennett Hills toward Camas Creek. Camas Creek loses flow to the alluvial aquifer and gains flow from the basalt aquifer.

Total water yield data are unavailable. Young (1978) estimates average annual runoff from mountainous areas to be approximately 120,000 acre-feet/year. Young

(1978, p. 13) also estimates annual recharge to artesian aquifers to equal 37,000 acre-feet/year.

Ground water pumpage in 1977 consisted of twenty-nine irrigation wells and two municipal wells. Young (1978, p. 22) estimates total irrigation pumpage for 1977 at 9,400 acre-feet/year and total municipal pumpage at 100 acre-feet/year. Ralston and others (1983, p. 21) report total pumpage at 9,800 acre-feet/year for 1982. Assuming a 50 percent efficiency of irrigated crops, the total consumptive use of ground water is approximately 4,700 acre-feet/year.

Estimates of surface water and ground water discharge out of the basin are reported by various authors. Surface water discharge near Blaine is estimated to be 127,000 acre-feet/year (Mundorff and others, 1964) and 138,000 acre-feet/year Young (1978, p. 10) (Table 1). Camas Creek discharges into the Little Wood River, which is tributary to the Snake River. Ground water discharge out of the basin is estimated by Walton (1962, p. 20) to be 20,000 acre-feet/year. According to Walton (1962, p.20)"...most of the underflow from the prairie discharges into Camas Creek or Magic Reservoir in Tps. 1-2S, R17E."

Young's (1978) estimate of 138,000 acre-feet/year for surface discharge from the basin is used for this report. It is assumed that an additional 15,000 acre-feet/year discharges from ground water to surface water east of Blaine. The assumption of 15,000 acre-feet/year is derived from Walton's (1962) estimate of 20,000 acre-feet/year ground water discharge minus the additional ground water pumpage which has occurred since 1957 when Walton estimated pumpage.

Portneuf River Basin

The Portneuf River Basin is located on the south side of the Snake River Plain in Bannock County (Fig. 1). The basin occupies approximately 1160 square miles and is bounded by the Pocatello and Bannock Ranges on the west and the Chesterfield Range and Soda Springs Hills on the east. The Portneuf Range, located in the center of the basin, separates Marsh Creek Valley from Portneuf and Gem Valleys. The total length of the basin is approximately 70 miles.

No extensive studies regarding the hydrologic characteristics of the Portneuf River Basin have been conducted. Mundorff and others (1964) include a brief discussion of the basin in a report concerning ground water resources of the Snake River Plain. Norvitch and Larson (1970) conducted a reconnaissance study of the water resources of the basin. Kjelstrom (1984) published estimates of recharge and discharge characteristics of the basin as part of a study regarding water yield to the Snake River Plain. Other investigators have included geology and hydrology of the basin in reports on other areas.

Major aquifers occur in the Tertiary Salt Lake Formation and Quaternary basalt and alluvium. The Salt Lake Formation overlies a Pre-Tertiary consolidated sedimentary formation. The Salt Lake Formation consists of clastic sedimentary rocks, calcareous clay and volcanic tuff. Little is known about the water producing capabilities of the formation in the Portneuf Basin but the formation is known to be a productive aquifer in other areas. Quaternary basalt overlies the Salt Lake Formation. Basalt is the primary aquifer in the southern half of the Portneuf Valley and the northern half of Gem Valley. Quaternary alluvium and colluvium mantle the valley and stream channels. Alluvium underlies basalt and overlies the Salt Lake Formation in portions of the basin. Alluvial deposits are a major source of water in the northern portion of the Portneuf Valley and Marsh Creek Valley.

Aquifers in the basin are under confined and unconfined conditions. Artesian wells are present in the vicinity of Hatch. Evidence from Twiss (1939) and Norvitch and Larson (1970) indicate that confined aquifers are present in the Arimo area. No information is available regarding the formation in which the confined aquifers occur. Most of the wells in the area penetrate unconfined aquifers present throughout the basin. Major hot springs supply water to the recreation sites of Downata and Lava Hot Springs.

Estimates of transmissivity for aquifers in the basin are limited. A pump test conducted on well 8S-39E-10ada1 indicates transmissivity of the basalt aquifer at 400,000 $feet^2$/day (Norvich and Larson, 1970, p.21). Specific capacity data are available for wells in the Portneuf Basin but without more information it is difficult to calculate accurate transmissivty values.

Surface water and ground water are interconnected in Portneuf and Marsh Creek Valleys. Intermittent streams flow out of the mountains and lose most or all of their flow to alluvial deposits at the base of the mountains. The water table is at or near land surface in the reach of the river from Portneuf Reservoir to about six miles downstream causing marshy areas along the river. The Portneuf River continues to gain ground water from seeps and springs as it flows through the Portneuf Gorge. Marsh Creek, which flows northward from Red Rock Pass to the confluence with the Portneuf River near Inkom, gains a large part of its flow from seeps and springs. Marshy areas occur along the flood plain of Marsh Creek where the ground water table is at or near land surface.

Precipitation and water yield in the basin have been estimated by previous investigators. Norvitch and Larson (1970) estimate total precipitation on the basin equals 1.2 million acre-feet/year. Mundorff and others (1964, p. 96) estimate precipitation to be approximately 1.1 million acre-feet/year for the Portneuf River Basin plus the area extending from Portneuf Gorge to Pocatello (an area larger than that studied by Norvitch and Larson). Additional recharge to the basin includes ground water underflow from the Bear River Basin which is estimated to be about 56,000 acre-feet/year (N.P. Dion, oral communciation to Norvitich, 1969). Ground water inflow is suspected at Tenmile Pass near Soda Point but data are not available to confirm this theory. An estimated 14,000 acre-feet/year is imported as irrigation water from Bear River Basin through Soda and West Branch Canals (Norvitch and Larson (1970). Approximately 4,000 acre-feet/year is diverted annually from Portneuf River Basin into Bear River Basin (Norvitch and Larson, 1970). Kjelstrom (1984) estimates total water yield above Pocatello to be 334,000 acre-feet/year (Table 2). Water yield as defined by Kjelstrom (1984) is total discharge without any water development within the basin. Evapotranspiration and consumptive use values have not been determined.

Total average consumptive pumpage for irrigation in the Portneuf River Basin is 14,800 acre-feet/year (Norvitch and Larson, 1970). The net pumpage above Topaz is approximately 10,400 acre-feet/year and below Topaz is approximately 4,400 acre-feet/year. Total municipal use of water derived from wells and springs is 1,400 acre-feet/year. Pumpage estimates for domestic use are not known.

Surface and ground water discharge out of the northern end of the basin. The Portneuf River discharges into the Snake River at American Falls Reservoir (Table 2). Mundorff and others (1964) and Kjelstrom (1984) estimate annual discharge of the river at Pocatello to total 187,500 acre-feet/year and 193,000 acre-feet/year, respectively. Ground water outflow is believed to discharge into American Falls Reservoir. Norvitch and Larson (1970) and Kjelstrom (1984) suggest that 63,000 acre-feet/year discharges from the basin as underflow. The discharge estimates of Norvitch and Larson (1970) and Kjelstrom (1984) are used for this paper as they are the most recent and complete data available.

Michaud Flats

Michaud Flats is located on the south side of the Snake River Plain in eastern Power and northwestern Bannock Counties. The area studied is an artificially

Table 2. Estimates of water yield and basin discharge for selected tributary basins south of the upper Snake River.

Basin	Source	Water Yield (ac-ft/yr)	Surface Water Discharge (ac-ft/yr)	Ground Water Discharge (ac-ft/yr)
Portneuf River Basin	Mundorff and others (1964)	--	187,500	--
	Norvitch and Larson (1970)	--	--	63,000
	Kjelstrom (1984)	334,000	193,000	63,000
Michaud Flats	Goldstein (1981)	--	--	180,000
	Jacobson (1982)	--	--	309,000
Rockland Basin	Mundorff and others (1964)	--	13,000	37,000
	Bezan (1974)	43,000	14,000	--
	Williams and Young (1982)	85,000	16,500	51,000
Raft River Basin	Nace and others (1961)	185,000	10,000	130,000
	Mundorff and others (1964)	184,000	10,000	130,000
	Walker and others (1970)	140,000	17,000	83,000
		--	1,900 (1966 Ave.)	80,000 (1966 Ave.)
	Nichols (1979)	--	3,800	13,000
	Kjelstrom (1984)	100,000	--	82,000
Rock Creek-Goose Creek Basin	Crosthwaite (1969)	140,000	13,000	94,000

Table 2. Continued.

Basin	Source	Water Yield (ac-ft/yr)	Surface Water Discharge (ac-ft/yr)	Ground Water Discharge (ac-ft/yr)
Salmon Falls Creek Basin	Fowler (1960)	167,000	--	--
	Crosthwaite (1969)	320,000	--	110,000
	Harper and others (1982)	--	115,000	--
	Kjelstrom (1984)	--	100,000	--
Blue Gulch Basin	Ralston and Chapman (1970)	--	--	7,300

selected area and is not a topographic basin. The area occupies approximately 50 square miles and is bounded by American Falls Reservoir, Portneuf River, and the foothills of Deep Creek Mountains and Bannock Range (Fig. 1).

U. S. Geological Survey hydrologic investigations include a water supply paper by Stewart and others (1951), an open file report by Jacobson (1982) and Kjelstrom (1984). Kjelstrom's (1984) study reports recharge and discharge characteristics of creeks and ground water outflow in the area. An unpublished Master's thesis by Goldstein (1981) describes the hydrogeology and water quality of 38 square miles of Michaud Flats. Much of the information contained in this description of Michaud Flats is obtained from these previous investigators.

Primary aquifers occur in the Starlight Formation, the Quaternary pediment gravels, and the Big Hole basalt. The Tertiary Starlight Formation consists of bedded ryholitic tuffs and basalt flows. Thickness of the formation exceeds 800 feet locally. Quaternary pediment gravels overlie the Starlight Formation and are more than 125 feet thick. Quaternary Big Hole basalt overlies pediment gravels and may be as thick as 170 feet.

Minor aquifers include the Quaternary Sunbeam Formation consisting of alluvial deposits and Quaternary Michaud gravels consisting of sand and gravel flood plain deposits. The Michaud gravels average 50-80 feet thick. American Falls lake bed deposits overlie the Sunbeam Formation and Big Hole basalt and act as a confining layer for underlying aquifers.

Ground water occurs under both confined and unconfined conditions. Aquifers in the Sunbeam Formation, the Big Hole basalt, the pediment gravels, and the Starlight Formation are confined. The aquifer in the Michaud gravels is unconfined.

Goldstein (1981) conducted a pump test to determine the transmissivity and storativity of the confined sand and gravel aquifer. Values of transmissivity range from 227,000-281,000 ft^2/day using the Theis and Jacob methods of solution. The calculated storativity value is .002. The results may be in error as neither the Theis or Jacob solutions account for leakage from the overlying confining layer. No other estimates of transmissivity or storativity are available.

Goldstein (1981) estimated average annual precipitation for 1977-78 at 11.6 inches and total evapotranspiration at 7.4 inches. Therefore, total average precipitation and evapotranspiration over the 50 square mile area is approximately 31,000 acre-feet/year and 20,000 acre-feet/year, respectively. Additional recharge to the area includes 162,000 acre-feet/year from irrigation losses and underflow from Bannock Creek and Portneuf River (Goldstein, 1981). Irrigation losses are from water originating from the Snake River. Total water yield is approximately 173,000 acre-feet/year. Goldstein (1981) estimates the total ground water withdrawal for irrigation to be 44,700 acre-feet/year. Assuming 50 percent consumptive use by irrigated crops, annual ground water consumptive use totals 22,400 acre-feet/year.

Surface water and ground water in Michaud Flats flow toward the Snake River. Ground water discharges into both the Snake River and the Portneuf River. Goldstein (1981) and Jacobson (1982) estimate total discharge from the area to be 180,000 acre-feet/year and 309,000 acre-feet/year, respectively. Discharge estimates reported by Goldstein (1981) are used for this paper as they are the most recent and complete data available.

Rockland Basin

Rockland Basin is located on the south side of the Snake River Plain in Power County, Idaho. The basin occupies approximately 320 square miles and is bounded by the Sublett Range, the Deep Creek Mountains and the

Snake River Plain (Fig. 1). The basin is approximately 30 miles long.

Hydrologic studies concerning Rockland Basin are limited. Mundorff and others (1964) conducted a brief study of the basin as part of a publication on ground water in the Snake River Basin. An extensive study was conducted by Williams and Young (1982) through the U. S. Geological Survey. Recharge and discharge characteristics of the basin are estimated by Kjelstrom (1984). A University of Idaho Master's thesis (Bezan, 1974) reviews the geology and hydrology of the basin. Much of the information contained in this description of the Rockland Basin is obtained from the Williams and Mundorff reports.

Primary aquifers occur in valley fill deposits. Tertiary sedimentary deposits, consisting primarily of gravel, sand, and silt, form the major aquifer in the central and southern portion of the basin. Total thickness of the Tertiary sediments are unknown. Quaternary-Tertiary volcanic rocks, consisting of olivine basalt flows, crop out in the northern portion of the basin. Mundorff and others (1964, page 91) suggest "the basalt may be correlative with Snake River basalt". Individual basalt flows are generally less than 100 feet thick. Basalt flows and interbedded sand and gravel deposits comprise the major aquifer in the northern portion of the basin. Pleistocene gravels flank the mountain fronts and may be greater than 100 feet thick in places. Pleistocene windblown deposits, consisting of calcareous silt, cover much of the valley and exceed 100 feet in thickness. Holocene alluvial deposits, consisting of sand, silt and clay are present along stream channels. Maximum thickness of the alluvium is 50 feet. Local aquifers occur in alluvial sand lenses. Pre-Tertiary sedimentary rocks, consisting chiefly of limestones and dolomites, comprise mountainous portions of the basin and are believed to underlie the valley fill. These rocks are believed to have low hydraulic conductivity.

Principal aquifers in the basin are unconfined. Artesian conditions exist locally in Tertiary sedimentary deposits in the southern part of the basin. Perched aquifers exist locally between contacts of Pleistocene gravels and Tertiary sedimentary deposits and maintain perennial flow to springs in the northern half of the basin.

Estimates of transmissivity values for Teritary sedimentary rocks and Quaternary-Tertiary volcanic rocks are given by William and Young (1982, p. 35). Transmissivity values calculated from specific capacity data for Tertiary sedimentary deposits range from 100-10,000 ft^2/day. Additional data indicate an average transmissivity value of the sedimentary aquifer to equal 6,000 ft^2/day. The range of transmissivity values for basalt in the northern portion of the basin is from 4,000- 48,000 ft^2/day. A value of 20,000 ft^2/day is assumed to be representative of the basalt in the northern end of the basin.

Surface water and ground water are interconnected throughout the basin. Much of the mountain runoff percolates into gravels at the base of the mountains and discharges as springs into creeks and streams on the valley floor. Rock Creek is a gaining stream throughout most of the basin.

Average annual water yield for Rockland Basin is estimated to be 85,000 acre-feet/year (Williams and Young, 1982, p. 15) (Table 2). Water yield as defined by Williams and Young (1982) is the total average precipitation minus natural evapotranspiration. Williams and Young (1982, p. 42) estimate consumptive pumpage for irrigation in 1979 to equal 3,500 acre-feet/year. The amount of ground water used for municipal and domestic use is minimal and most stock water is obtained from surface flow. Consumptive use of water for 1979 is believed to be typical of a normal water year.

Estimates of surface water and ground water discharge from the basin have been reported by both

Williams and Young (1982) and Mundorff and others (1964). Average annual surface discharge is estimated at 16,500 acre-feet/year (Williams and Young, 1982, p. 20), 13,000 acre-feet/year (Mundorff and others, 1964, p. 91) and 14,000 acre-feet/year (Bezan, 1974, p. 75). All surface discharge is from Rock Creek to the Snake River below American Falls. Average annual ground water discharge is estimated at 51,000 acre-feet/year (Williams and Young, 1982) and 37,000 acre-feet/year (Mundorff and others, 1964). Ground water outflow from the basin enters the Snake Plain aquifer. Values estimated by Williams and Young (1982) are used for calculations in this paper as they are the most recent and complete values available. Kjelstrom's (1984) estimates of water yield and discharge agree closely with Williams and Young's (1982) estimate.

Raft River Basin

The Raft River Basin is located on the south side of the Snake River Plain, in Cassia, Onieda, and Power Counties, Idaho and Box Elder County, Utah. The basin occupies approximately 1530 square miles and is commonly divided into three subbasins: the Raft River subbasin, the Elba subbasin, and the Yost-Almo subbasin. The basin is bounded by the Albion, Goose Creek, Black Pine and Sublett Ranges and the Raft River Mountains. The Elba and Yost-Almo subbasins are separated from the Raft

River Subbasin by the Cotterell (Malta) Range (Fig. 1). The valley floor of the Raft River Basin averages 12 miles wide.

Numerous hydrologic studies concerning the Raft River Basin have been published. The two most extensive studies are by Nace and others (1961) and Walker and others (1970). Nichols (1979) published results of a simulation anaylsis of the unconfined aquifer in the Raft River Basin. Kjelstrom (1984) published water yield and basin discharge as part of a water budget for the Snake River Plain. Much of the information contained in this description of the Raft River Basin is obtained from previous investigators.

Major aquifers occur in Pre-Tertiary consolidated sedimentary and metamorphic rocks, Salt Lake Formation, Raft Formation, Snake River basalt and valley alluvium. Pre-Tertiary consolidated sedimentary rocks form the mountainous area and are relatively impermeable except for open joints and solution cavities. The Salt Lake Formation, of Pliocene age, consists primarily of sedimentary and volcanic rocks. Three units are defined in the Salt Lake Formation having an aggregate thickness of 2500 feet. The upper unit is the most productive aquifer of the formation and consists of sandstone and conglomerate interbedded with layers of clayey silt. The Raft Formation, of Pleistocene age, consists primarily of lake and stream deposits. Thin layers of clay are abundant with coarse-grained material increasing southward. Average thickness of the formation is 200 feet. Basalt of the Snake River Group crops out in the northern part of the basin. Basalt interfingers with sediments of the Raft Formation southward. Alluvium, consisting of silt, sand, and gravel, is widespread on the valley floor. The Raft Formation, Snake River basalt and alluvium are generally considered as one aquifer. The thickness of the combined aquifer is as great as 1000 feet.

Ground water in the Raft River Basin occurs under both confined and unconfined conditions. The main aquifers are unconfined with semi-confined conditions occurring in deeper wells. Confined aquifers occur at a few places along the margins of the valley. Several wells in the southern portion of the basin yield hot water under artesian pressure. Perched aquifers occur locally above interbedded lenses of silt and clay during the irrigation season. Some perched aquifers remain for several months following irrigation.

Aquifer transmissivity and storativity values have been estimated by previous investigators. Nace and others (1969, p. 88) report transmissivity to range from 20,000-27,000 ft^2/day. Morilla and Ralston (as reported by Nichols, 1979, p. 31) estimate transmissivity to range from 3,000-74,000 ft^2/day. Nichols (1979) suggests that transmissivity values from previous reports are over estimated by as much as an order of magintude. Nichols (1979, p. 31) used transmissivity values of 1,000-12,000 ft^2/day as input in his computer model. These values were consistent with values estimated by Nichols (1979) from specific capacity data. Nichols' (1979) transmissivity data are used in calculations for this paper, as they are the most recent data available.

Surface water and ground water are interconnected throughout the basin. Surface flow from most of the streams entering the valley never reaches the Raft River due to diversions for irrigation, infiltration to ground water, and evapotranspiration. Ground water movement in the basin is generally parallel to surface stream flow. Nace and others (1961, p. 51) report that "the loss-and-gain regime of the river is variable, not only from reach to reach at a given time but also in a single reach at different times". Flow in the Raft River disappears between Bridge and Malta and generally remains dry nearly to Yale. Springs and seeps along the lower 15 miles of the river channel are fed mainly by underflow from upstream areas of the valley.

Water yield estimates for the Raft River Basin range from 100,000-185,000 acre-feet/year (Table 2).

Water yield as defined by Nace an others (1961) and Walker and others (1970) is the total average precipitation minus natural evapotranspiration occuring before water has become a part of stream flow or ground water flow. Kjelstrom (1984) defines water yield as total basin discharge without any upstream water development.

Consumptive ground water pumpage in 1966 was 141,000 acre-feet/year (Walker and others, 1970, p. 76). Ground water pumpage in 1966 was high due to a very dry year.

Surface and ground water discharge estimates are reported by previous investigators (Table 2). Walker and others (1970) estimate average surface water discharge to be 17,000 acre-feet/year and ground water discharge to be 83,000 acre-feet/year. Kjelstrom (1984) estimates average ground water discharge to be 82,000 acre- feet/year and no surface water discharge. Virtually all discharge from Raft River Basin is as ground water. Any surface water discharge from the basin enters the Snake River at Lake Walcott. A portion of ground water discharge from the basin enters the upstream part of Lake Walcott. Evidence indicates that a portion of ground water outflow passes beneath the river and joins the Snake Plain aquifer, eventually discharging into the Snake River downstream from Milner Dam (Nace and others, 1961).

Water yield and outflow estimates of Kjelstrom (1984) are used for this paper as they are the most recent and complete data available. An estimate of 141,000 acre-feet/year is used as the average consumptive pumpage of ground water. The Walker and others (1970) estimate of basin discharge for 1966 is similar to Kjelstrom's (1984) estimate of average basin discharge.

Rock Creek-Goose Creek Area

The Rock Creek-Goose Creek area is located on the southern side of the Snake River Plain in eastern Twin Falls and western Cassia Counties. The area described is an artifically selected area and is not a topographic basin. The area occupies approximately 1630 square miles and is bounded by the Albion Range, Rock Creek Hills, and the Snake River (Fig. 1). The southern portion of the Goose Creek drainage lies in northeast Nevada and northwest Utah. Approximately 630 square miles of the area is gently rolling plain with the remaining 1000 square miles mountainous terrain. The average length of the basin from north to south is 17 miles.

Mundorff and others (1964) conducted a limited study on the Lower Goose Creek Valley and the Dry Creek region as part of a study of the Snake River basin. Crosthwaite (1969) conducted a detailed study of the area for the U.S. Geological Survey. Much of the information contained in this description of the Goose Creek-Rock Creek area is obtained from the Mundorff and Crosthwaite reports.

Four major aquifers are present in the area. Paleozoic sedimentary and igneous rocks, of unknown thickness are present in the Albion Range, the South (Middle) Mountains and the Rock Creek Hills. Limestone deposits yield large quantities of water to wells along a fault zone at the northeastern edge of Rock Creek Hills. Small springs discharge from joints and fractures within the consolidated units.

Pliocene Idavada Volcanics consisting of ash flows, bedded tuffs, sand and gravel, are reportedly greater than 2500 feet thick. The Idavada Formation is present in the surrounding mountain ranges and hills and underlies the northern portion of the area. Small to large well yields are obtained from the Idavada Volcanics in the southern and central portions of the area. Many springs arise from volcanics in Rock Creek Hills and help maintain baseflow in local streams.

Holocene to Pleistocene basalt of the Snake River Group, are reportedly 0-600 feet thick. Snake River basalt overlies the Idavada Volcanics and underlie and interfinger with alluvial deposits in the northern portion of the basin. The basalt is one of the most productive aquifers in the area. Holocene to Pleistocene alluvial deposits are between 0-300 feet thick. Alluvial deposits blanket the entire valley floor.

Ground water in the area occurs under confined, unconfined, and perched conditions. Aquifers within the Idavada Volcanics are generally confined by interlayered beds of clay, silt and fine-grained ash beds. Unconfined aquifers occur in the Snake River Basalt and the alluvium. Perched aquifers occur in alluvial deposits near the Burley Irrigation District. Values of transmissivity and storativity have not been estimated by previous authors.

Surface water and ground water are interconnected throughout the area. Many mountain streams percolate into alluvial deposits before reaching the valley floor and discharge as springs and seeps. Seepage losses from canals and fields in the Burley Irrigation District recharge aquifers in the unconfined alluvial deposits. Seepage losses in the Milner Low Lift and Twin Falls South Side Projects recharge underlying basalt and alluvial aquifers. The Oakley Reservoir, located in the center of the basin, stores flow from Goose and Trapper Creeks and part of the flow from Birch Creek. Most streamflow in the basin is used entirely for irrigation except for Rock and Dry Creeks which flow out of the basin in periods of high runoff.

A preliminary estimate of average annual water yield in the Goose Creek-Rock Creek area is 140,000 acre-feet (Crosthwaite, 1969, p. 23) (Table 2). Water yield is defined by Crosthwaite to equal precipitation minus evapotranspiration by native vegetation. This estimate does not include seepage into the area from the Milner Low Lift and Twin Falls South Side Projects. Water imported to the northern portion of the area from Snake River Irrigation projects is estimated to be 500,000 acre-feet/year. Approximately 155,000 acre-feet/year of the additional recharge is evapotranspired by crops and 345,000 acre-feet/ year recharges ground water (Crosthwaite, 1969, p. 25).

Most irrigation wells within the basin are located north of Rock Creek Hills and south of Burley Irrigation District. Total ground water pumpage averaged 185,000 acre-feet/year between 1961 and 1965 (Crosthwaite, 1969, p. 32). Assuming 50 percent efficiency, total annual consumptive pumpage is approximately 93,000 acre-feet/year.

Estimates of surface water and ground water discharge out of the basin are limited. Crosthwaite (1969, p. 23) estimates average surface discharge from

Rock Creek and Dry Creek combined is 13,000 acre-feet/year. Total ground water outflow is difficult to estimate due to seepage from irrigation projects. Crosthwaite (1969, p. 62) suggests "the total quantity of water recharged to aquifers from precipitation in the Goose Creek - Rock Creek Basins annually averages about 94,000 acre-feet". Ground water recharge from the Snake River by way of irrigation projects is estimated at 345,000 acre-feet/year (Crosthwaite, 1969, p. 25). Natural ground water discharge from the basin (excluding water contributed by Snake River Irrigation projects) is estimated by assuming total discharge equals total recharge. Therefore, ground water discharge from the Rock Creek-Goose Creek Basin is estimated to be 94,000 acre-feet/year. Ground water outflow from the basin enters the Snake River Plain aquifer and discharges to the Snake River downstream from Milner Dam.

Salmon Falls Creek Basin

Salmon Falls Creek area is located on the south side of the Snake River Plain in Twin Falls County. The area occupies approximately 600 square miles and is bounded by Salmon Falls Creek, Rock Creek Hills, and High Line Canal (Fig. 1). The area is roughly 25 miles long and 25 miles wide. The area studied is an artificially selected area and not a topographic basin.

Hydrologic studies concerning the Salmon Falls Creek area include a preliminary report on ground water resources by Fowler (1960). Crosthwaite (1969) also published a report on the water resources of the basin. Much of the information contained in this report is obtained from the Fowler and Crosthwaite reports.

Primary aquifers in the area include the Idavada Volcanics and Pliocene or Pleistocene basalt. Idavada Volcanics, of Pliocene age, underlie the entire area and consist of silicic volcanic rocks with associated clay, silt, sand and gravel deposits. Hydraulic conductivity of the unit is highly variable. Large water yields are obtained from joint and fracture zones and moderate yields are obtained from sand and gravel beds. Pliocene or Pleistocene basalt underlie much of the basin. Thickness of olivine basalt flows ranges from 5 to 75 feet with fine grained sedimentary beds separating some flows. Hydraulic conductivity is variable and moderate water yields are obtained from the unit.

Minor aquifers in the area include Quaternary or Tertiary lake bed deposits and Quaternary basalt and alluvium. The Tertiary and Quaternary deposits yield small to moderate quantities of water locally but are limited in areal extent. Windblown deposits mantle the valley but are above the water table.

Confined, unconfined and perched aquifers occur within the area. Confined aquifers are located between Hollister and Rock Creek Hills. Perched aquifers are located in alluvial deposits near Deep Creek. Unconfined aquifers occur throughout the area.

Transmissivity values for individual aquifers are unavailable. Fowler (1960, p. 12) estimates a transmissivity value of 2,000 $feet^2$/day based upon specific capacity data collected from wells throughout the basin.

Interconnection of ground water and surface water is poorly understood. Fowler (1960, p. 7) suggests that ground water underflow above Roseworth Crossing is "prevented from discharging into the nearby parallel canyon (Salmon Falls Creek) by some barrier". Fowler (1960) further states that ground water may discharge into Salmon Falls Creek downstream from Roseworth Crossing. All other streams in the area except Deep Creek are ephemeral and loose water by downward percolation or are diverted for irrigation. Deep Creek discharges directly into the Snake River.

Water yield for Salmon Falls Creek area is estimated by Crosthwaite (1969, p. D19) to equal 320,000 acre-feet/year Water yield as defined by Crosthwaite (1969) is the total amount of water leaving the basin annually. Total precipitation is estimated by Fowler

(1960, p. 9) to be 167,000 acre-feet/year and annual consumptive use is estimated to be 30,000 acre-feet/year.

The majority of irrigation wells are located along the eastern side of the basin. Crosthwaite (1969, p. D16) estimates total pumpage in 1960 was 6,000 acre-feet/year for irrigation use and 2,000 acre-feet/year for municipal domestic, and stock use. Assuming 50 percent crop efficiency, the total consumptive use for the basin is estimated to be 5,000 acre-feet/year.

Surface water and ground water discharge from the basin is along the northern boundary of the study area. Fowler (1960, p. 16) suggests total outflow from the basin ranges between 70,000-160,000 acre-feet/year. Salmon Falls Creek and Deep Creek discharge into the Snake River. The average discharge of Salmon Falls Creek near Hagerman (Harper and others, 1982, p. 143) is estimated to be 115,000 acre-feet/year. The average discharge of Deep Creek is unknown. Ground water discharges into Salmon Falls Creek downstream from Roseworth Crossing and/or into the Snake River and the Snake River Plain.

Water yield as estimated by Crosthwaite (1969) is used in calculations for this paper as it is the most recent value available. It is difficult to determine total surface water and ground water outflow. Maximum ground water outflow is estimated to be 110,000 acre-feet/year. Ground water outflow is estimated from Crosthwaite's (1969) estimate of total ground water recharge (115,000 acre-feet/year) less consumptive use of ground water (5,000 acre-feet/year). Total surface water discharge of Salmon Falls Creek is a combination of surface water and ground water discharge from the east and west sides of the river. Average surface water discharge near San Jacinto, Nevada is 100,000 acre-feet/year (Kjelstrom, 1984) and is considered the total surface water discharge for the basin. This value is used as a rough estimate of total surface water discharge to Salmon Falls Creek from the Salmon Falls Creek Basin.

Blue Gulch Area

The Blue Gulch area is located on the south side of the Snake River Plain in western Twin Falls and eastern Owyhee Counties. The Blue Gulch area occupies approximately 300 square miles and is bounded on the north by the Snake River and on the south by the line common to Township 10 and 11 South. The western boundary of the area is the line common to Range 10 and 11 East and the eastern boundary is Salmon Falls Creek and the Snake River (Fig. 1). The area averages 18 miles long and 16 miles wide. The area studied is an artificially selected area and is not a topographic basin.

Few hydrologic studies of the Blue Gulch area have been published. Crosthwaite (1963) published a report on the Sailor Creek area, which included the Blue Gulch area and the area west of Blue Gulch to the Bruneau River. Ralston and Chapman (1970) conducted a detailed study of the ground water resources of the Blue Gulch area as defined in this study. Information included in this description of the Blue Gulch area is derived from the Crosthwaite and Ralston reports.

Primary aquifers in the Blue Gulch area occur in Idavada Volcanics and Banbury basalt. Early Pliocene Idavada Volcanics consist of tuff, welded ash and lava flows. The volcanics are exposed in the southern half of the area and underlie the entire area. Thickness of the formation exceeds 1700 feet. Pliocene Banbury basalt overlie Idavada Volcanics. The Banbury basalt consists of three members. The lower basalt member is several hundred feet thick. Fractures and joints are filled with secondary mineralization and alteration products causing the member to be a poor aquifer. The middle member consists of clay, silt, sand, and fine gravel layers with a maximum known thickness of 600 feet. The upper member consists of basalt with a maximum known thickness of 650 feet. The upper basalt member is the most important aquifer in the southeastern portion of the area.

The Glenn's Ferry Formation consists of a basalt and a sedimentary member exceeding 2700 feet thick. The formation, of Pleistocene age, is exposed in the northern portion of the area. Early Pleistocene Tuana gravel and Recent alluvium overlie the Glenn's Ferry Formation and are not important as aquifers except along the Snake River.

Most of the aquifers in the Blue Gulch area are under slight artesian pressure, although unconfined zones exist locally. Wells penetrating the Idavada Volcanics are generally under artesian pressure and yield warm water. Ralston and Chapman (1970) suggest that the water is from movement through fault zones at greater depths. Shallow unconfined aquifers occur along the Snake River which are believed to be recharged from infiltration from irrigation.

Transmissivity values of aquifers in the study area are given by Ralston and Chapman (1970, p. 13). Specific capacity data indicate the transmissivity of Idavada Volcanics is greater than 13,000 feet^2/day at many locations. Specific capacity data also indicate transmissivity values for the upper basalt and middle sedimentary members of the Banbury basalt at 8,000-50,000 feet^2/day and 500-2,800 feet^2/day, respectively. Pump test data obtained from well 9S-12E-29db1, located in the upper basalt member of the Banbury Basalt yield a tranmissivity value of 8,000 feet^2/day which is consistent with the values based on specific capacity data.

Total annual water yield and detailed discharge estimates have not been calculated. Natural evapotranspiration is believed to be minimal due to the great depth to water. Total pumpage from irrigation wells in 1969 was 26,500 acre-feet/year (Ralston and Chapman, 1970, p. 22). Ralston and Chapman (1970, p. 22) note that "over 75 percent of the estimated discharge is from well development in the area". Consumptive use of ground water is estimated to equal 13,000 acre-feet/year, assuming 50 percent crop efficency.

Discharge of ground water to Salmon Falls Creek totals approximately 7,300 acre-feet/year (Ralston and Chapman, 1970, p. 22). Ground water may discharge as underflow to the Snake River although no springs or seeps have been observed. Total ground water discharge from the basin is assumed to be 10,000 acre-feet/year. The total discharge includes 7,300 acre-feet/year discharged to Salmon Falls Creek plus any additional discharge to the Snake River by ground water or surface water.

Classification of Selected Basins

Conjuctive surface and ground water management requires a knowledge of physical and hydrologic characteristics of each basin and of the relationship of individual basins to the larger interconnected system. A thorough understanding of the physical and hydrologic characteristics of a basin includes the nature of surface and ground water, recharge and discharge characteristics of surface and ground water, and impacts of ground water development.

Important considerations in a conjunctive use management classification for the upper Snake River Basin are: 1.) the amount of water each tributary basin contributes to the flow of the Snake River; 2.) the amount of water available in each tributary basin; 3.) the degree of ground water development as compared with water availability; and 4.) the distance between the discharging edge of each tributary basin and the point of recharge to the Snake River. A classification of the hydrologic interreaction of the system provides a physical basis from which to develop legal and administrative guidelines.

Physical Descriptions of Selected Basins

An accurate hydrologic assessment requires knowledge of the physical characteristics of a basin. Brief physical descriptions of each basin are presented in Table 3. Significant physical and hydrologic aspects of a basin include: area and length of the drainage basin; aquifer geology and type; major surface water drainages; and ground water-surface water interconnection.

Area and length of a drainage basin are important factors in estimating time response of ground water impacts on surface water flow. Aquifer geology and type (confined or unconfined) are important factors in determining the characteristic ground water response to pumping. An understanding of ground water-surface water interconnection in each basin is necessary to access general flow mechanisms and to determine the manner in which pumping affects basin discharge. The information presented is only a brief summary of the physical aspects of each basin.

Impacts of Ground Water Development Within Selected Basins

Ground water development in a tributary basin may affect both surface water and ground water discharge. Lowered water levels from pumping can decrease ground water discharge from the basin and also decrease surface water discharge by depleting streams and decreasing spring discharge. Table 4 summarizes the impacts of ground water development in basins tributary to the upper Snake River Plain.

Table 3. Hydrologic and physical summaries of selected basins tributary to the upper Snake River.

Basins	Area (miles)	Length (miles)	Aquifer Geology	Type of Aquifer	Major Surface Water Drainages	Ground Water-Surface Water Interconnection
Little Lost River Basin	800	50	Alluvium and basalt	Unconfined	Little Lost River flows through the length of the basin	Interconnected throughout the basin
Big Lost River Basin	1,400	50	Alluvium and basalt	Unconfined	Big Lost River flows through the length of the basin	Interconnected throughout the basin
Big Wood River-Silver Creek Basin	84	30	Alluvium	Unconfined; confined in southern part	Big Wood River flows along the west side of the valley; Silver Creek flows southeastward	Interconnected throughout the basin
Camas Prairie	730	40	Alluvium and basalt	Unconfined and confined	Camas Creek flows through the southern portion of the basin	Interconnected throughout the basin
Portneuf Basin	1,160	70	Sedimentary basalt and alluvium	Unconfined with confined aquifers locally	Portneuf River flows through the northern portion of basin; Marsh Creek flows through southern portion of basin	Interconnected throughout the basin
Michaud Flats	50		Alluvium and basalt	Unconfined and confined	No surface drainage	Does not apply
Rockland Basin	320	30	Alluvium and basalt	Unconfined and confined	Rock Creek drains the basin	Interconnected throughout the basin
Raft River Basin	1,530	35	Consolidated Sedimentary and igneous rocks	Unconfined with confined in deeper wells	Raft River flows in the southern and northern portions of the basin	Interconnected in the southern and northern portions of the basin

Table 3. Continued.

Basins	Area (miles)	Length (miles)	Aquifer Geology	Type of Aquifer	Major Surface Water Drainages	Ground Water-Surface Water Interconnection
Rock Creek-Goose Creek Basin	1,630	17	Sedimentary and igneous rocks	Unconfined and confined	Rock, Goose, and Dry Creek only tributary to Snake River during high flow	Interconnected throughout the basin
Salmon Falls Creek Basin	600	25	Idavada Volcanics and basalt	Unconfined with confined locally	Salmon Falls Creek flows along the western edge of the basin	Salmon Falls is interconnected with ground water downstream from Roseworth Crossing
Blue Gulch Basin	300	18	Idavada Volcanics and basalt	Confined	Salmon Falls Creek flows along the eastern edge of the basin	Details unknown

Table 4. Impacts of ground water development in selected basins tributary to upper Snake River.

Basin	Rate Water Level Decline	Ground Water Effects on Surface Water
Little Lost River Basin	No long term declines have been observed.	Interference will occur in upper and middle portions of the valley; effect of pumping would be minimal in lower portion of valley since river is perched above ground water table.
Big Lost River Basin	No long term declines have been observed.	Withdrawal of ground water will affect surface water due to interconnection north of Arco.
Big Wood River-Silver Creek Basin	No long term declines have been observed.	Withdrawal of ground water will affect surface water due to interconnection.
Camas Prairie	Thirty feet of decline in the artesian aquifer have been observed in the Corral Creek area (1957-1977); 5-10 foot declines have been observed in the basalt portion of artesian aquifer.	Ground water pumpage may reduce discharge of springs in basalt aquifer and thus reduce streamflow.
Portneuf River Basin	No long term water level changes have been noted.	No data are available that indicate stream depletion by ground water pumping.

Table 4. Continued.

Basin	Rate Water Level Decline	Ground Water Effects on Surface Water
Michaud Flats	No long term water level decline has been noted.	No local surface water systems are present.
Rockland Basin	No long term water level decline has been noted.	Stream depletion occurs in the basin.
Raft River Basin	North of Malta, total declines exceed 100 feet; well 11S-27E-29aa1 has an average decline of 2.7 ft/yr. A general lowering of the water table has occurred throughout the northern two-thirds of the valley.	Stream depletion occurs in the southern and northern portions; ground water pumpage decreases spring flow into the Raft River near the northern boundary of the basin.
Rock Creek-Goose Creek Basin	The declines are as follows: Big Cedar-Buckhorn area, 22 ft/yr; Golden Valley, no change; Oakley area, shallow aquifer, 1 to 2 ft/yr; Murtaugh, a few ft. to a few tens of ft.; Kenyon, 3 ft/yr; Artesian area, up to 2 ft/yr; Basin area, no significant change.	Effects are unknown.

Table 4. Continued.

Basin	Rate of Water Level Decline	Ground Water Effects on Surface Water
Salmon Falls Creek Basin	Locally, artesian wells have stopped flowing; a large rise of water table has occurred in the vicinity of the Twin Falls South Side Project.	Effects are unknown.
Blue Gulch	The average decline is 3 to 17 ft/yr; a general rise in water level has occurred in the northern portion of basin by Magic Reservoir Water Co.	Effects are unknown.

Seasonal water level declines occur when water is pumped during the irrigation season but full water level recovery occurs before the next irrigation season. Short term water level decline occurs when a number of years are required to have the water resource system come into equilibrium after the initiation of pumpage. Long term water level declines occur when pumping rates exceed total recharge for an extended period of time. Water is pumped from aquifer storage causing a continual lowering of the water levels. Some basins exhibit only seasonal water level declines, whereas, others exhibit short or long term water level declines (Table 4).

Neither the Rockland Basin, Portneuf Basin, or Michaud Flats nor any of the selected north side tributary basins have had any significant declines in ground water levels. Significant water level declines have been observed in the other basins located along the south side of the Snake River Plain. Recognition of declining water levels is significant since a change in the quantity of water in storage changes the recharge-discharge characteristics of a basin. Declining water levels may also cause pumping lifts to be great enough that ground water pumpage decreases due to economic factors.

Interference of surface water from ground water pumpage occurs by lowered ground water levels causing decreased streamflow or decreased discharge from Tributary springs. Stream depletion predominates in areas where surface water and ground water are interconnected. Table 4 lists only stream depletion effects on major rivers and streams within a basin, not on tributary streams and creeks. Few studies have been conducted on stream depletion in the Tributary basins. Many of the effects described in the table are inferred from knowledge of ground water-surface water interconnection within the basin. It is difficult to quantitatively describe stream depletion because the amount and rate of depletion changes depending upon rate of pumping, distance of the pumping well from the stream, and length of pumping time. Transmissivity and storativity of aquifer materials also are controlling factors in stream depletion calculations.

Recharge-Discharge Characteristics of Selected Basins

A water budget technique is used to evaluate the availability of water within selected basins. Specific areas of interest in developing a management classification are water yield, surface and ground water discharge, and consumptive use of ground water (Table 5). Water yield represents recharge to the basin available for development. Water discharge and consumptive use represent discharge from the basin by both development and natural outflow.

Table 5. Water input and output characteristics of selected basins tributary to the upper Snake River.

Basin	Basin Input			Basin Output		
	Precipitation (ac-ft/yr)	Water Imported to Basin (ac-ft/yr)	Water Yield (ac-ft/yr)	Surface Water Discharge (ac-ft/yr)	Ground Water Discharge (ac-ft/yr)	Consumptive Pumpage (ac-ft/yr)
Northside Basins						
Little Lost River Basin	---	None	271,000	---	167,000	40,000
Big Lost River Basin	1,520,000	None	470,500	---	362,000	16,000
Big Wood River-Silver Creek Basin	236,000	414,000	450,000	26,000	38,000	14,500
Camas Prairie	---	---	120,000	153,000	---	4,700
Southside Basins						
Portneuf Basin	1,200,000	66,000	34,000	193,000	63,000	16,200
Michaud Flats	31,000	162,000	173,000	---	180,000	22,400
Rockland Basin	295,000	---	85,000	16,500	51,000	3,500
Raft River Basin	1,280,000	---	100,000	---	82,000	141,000
Rock Creek-Goose Creek Basin	---	500,000	140,000	13,000	94,000	93,000
Salmon Falls Creek Basin	---	---	320,000	100,000	110,000	5,000
Blue Gulch Basin	---	---	---	---	7,300	13,000

- Data not available.

Data regarding water input and output in tributary basins were compiled from various sources. Inherent discrepancies that exist in data include available information, definition of terms, time frame of data collection, and method of estimating data.

Definitions of water yield often vary according to the author. Water yield is commonly defined as total recharge minus evapotranspiration by native vegetation. Water yield values presented are only rough approximations of total available water and cannot be compared in detail.

Basin discharge is presented as both ground water discharge and surface water discharge. Basins that have little or no surface water discharge directly entering the Snake River are the Little Lost River Basin, Big Lost River Basin, Raft River Basin, Michaud Flats and Blue Gulch area. Ground water discharge values presented for these basins include all water outflow from the basin. Camas Prairie has both surface and ground water discharge. It is believed that all ground water discharge eventually replenishes Camas Creek or Magic Reservoir and that no ground water enters the Snake Plain aquifer. In this case, all basin discharge is presented as surface water discharge.

Consumptive use data were obtained from previous studies when available. A crop efficiency of 50 percent is assumed when consumptive use data are unavailable and only total pumping values are known. Consumptive water use for domestic, municipal, and stock purposes are assumed to be 100 percent. Only consumptive use data of irrigated crops are provided in some basins and all other uses are disregarded. Values listed on Table 5 are approximations and correlation of data between basins should be done cautiously because of the inconsistancy of the data.

Management Classification of Tributary Basins

A comprehensive ground water management plan requires classification of tributary basins according to some criteria based upon legal guidelines and hydrologic factors. The classification proposed in this section is intended as a first step in the formulation of a conjunctive surface - ground water management program for the upper Snake River Basin. Four factors are selected from which to evaluate the existing and potential impacts of ground water development. The four factors are: 1.) a ratio of annual basin discharge to total flow of the Snake River; 2.) a ratio of annual consumptive pumpage to annual basin discharge, 3.) a ratio of annual water yield to basin area; and 4.) the distance that surface water and ground water must flow before directly discharging into the Snake River. An initial classification of tributary basins is presented in Table 6.

The first factor in the classification is the ratio of annual basin discharge to total annual flow of the Snake River at the King Hill gaging station. This factor provides an indication of the amount of water a tributary basin supplies to the Snake River. The King Hill gaging station is used to represent total flow of the Snake River. Most of the water from the Snake Plain aquifer discharges into the Snake River above King Hill. Therefore, the total flow at King Hill includes the discharge of both surface water and ground water from the upper Snake River Basin. Basins that contribute less than one percent to the flow at King Hill may be considered as non-tributary. The one percent criteria was chosen because a contribution of less than one percent has an insignificant impact on the flow of the Snake River. The Blue Gulch, Rock Creek-Goose Creek and Rockland basins all contribute less than one percent and may be considered initially as non-tributary basins.

The second factor is a ratio of annual consumptive pumpage within a basin to annual basin discharge (Table 6). This factor provides an indication of long term water level declines. This is the case when the ratio of consumptive pumpage to total basin discharge exceeds 100 percent. Short term water level declines occur when

Table 6. Potential and existing impacts of ground water development in selected basins tributary to the upper Snake River.

Basin	Total Discharge Flow at King Hill[1] (%)	Consumptive Pumpage/ Total Discharge (%)	Water Yield (acre-ft/ acre)	Ground Water Discharge		Surface Water Discharge	
				Location	Distance (miles)	Location	Distance (miles)
Little Lost River Basin	2.0	25	.53	1000 Springs	150		
Big Lost River Basin	4.7	4.4	.53	1000 Springs	110		
Big Wood River-Silver Creek Basin	4.7	4.0	8.4	1000 Springs	50	North of Hagerman North of Hagerman	60 50
Camas Prairie	2.0	3.1	.26	Magic Reservoir	0		
Portneuf River Basin	3.3	6.3	.45			American Falls Reservoir	10
Michaud Flats	2.3	12	5.4	American Falls Reservoir	5	None	
Rockland Basin	.87	5.2	.42	N. edge of area			
Raft River Basin	1.1	172	.10	Lake Walcott Thousand Springs	5 85	Lake Walcott below American Falls Reservoir	0
Rock Creek-Goose Creek Basin	.77	344.22	.13	Snake River in study area	0	N. edge of area	0
Salmon Falls Creek Basin	2.7	2.4	.83	Salmon Falls Creek Snake River	10	High Line Canal	15
Blue Gulch Basin	.09	178	--	N.E. corner of study area	0	1000 Springs	0

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[1] Total average flow at King Hill--7,781,000 ac-ft/yr (Harper and others, 1982).

the ratio of consumptive pumpage to total basin discharge is less than 100 percent. Short term water level declines of this type can continue in a basin for several decades as the ground water system adjusts to a new condition of equilibrium between recharge and total discharge. The Blue Gulch, Rock Creek-Goose Creek and Raft River basins all have a factor greater than 100 percent indicating long term water level declines are occurring.

The third factor is a ratio of annual water yield to the drainage area of the basin (Table 6). This factor indicates the amount of water available per unit area within a basin and provides a preliminary base from which to evaluate the level of development the water resources of the area can support. The Rock Creek-Goose Creek area and the Raft River Basin have an average of less than .2 feet of water per year available for every acre of land, whereas the Big Wood-Silver Creek area has an average of 8.4 feet of water per year available for every acre of land. The south side tributary valleys are much more prone to over development.

The fourth factor is the distance that surface water and ground water must flow before discharging into the Snake River (Table 6). This factor is used to identify the time lag between basin development and impacts on the Snake River. The distances presented are approximate distances from the mouth or discharging edge of the basin to where surface water directly enters and ground water is assumed to enter the Snake River.

Current Status of Water Resource Management

Surface water and ground water management in the state of Idaho is under the jurisdiction of the Idaho State Department of Water Resources. Surface water resources in basins tributary to the Snake River east of Bliss are managed as one water district, with the exception of the Portneuf River Basin. The Portneuf River Basin is managed as a separate water district and historically has been managed as a nontributary basin. Currently, all of the tributary basins, including the Portneuf River Basin are managed as tributary to the Snake River.

Surface water and ground water rights in Idaho are granted under the appropriation doctrine. Most of the surface water resources in the Snake River and associated tributary basins are fully appropriated during the peak irrigation season. Unappropriated water is still available in some areas during May and June (Norm Young, oral communication, 1984).

Two types of ground water management designations currently exist: "critical" ground water management areas and "designated" ground water management areas. "Critical" ground water management areas are basins where ground water pumpage exceeds recharge and water levels are steadily declining. No additional ground water permits are issued once an area is declared "critical" (Norm Young, oral communication, 1984). Tributary basins that are designated "critical" in the upper Snake River Basin are the Blue Gulch area, the Raft River Basin, and specified areas of Rock Creek-Goose Creek area. The "designated" ground water management area classification is assigned to basins where there is concern that an overdraft of the ground water resource may occur. Once a "designated" ground water management is declared, additional ground water permits will not be issued without specific information that unappropriated water is available. The state can also require existing water users to specify their exact quantity of ground water useage. "Designated" ground water management areas east of King Hill are the Banbury area and the Twin Falls (Highline Canal) area. The areas are listed as "designated" management areas because of concern over geothermal water resources (Norm Young, oral communication, 1984). Both areas are located along the fringe of the Snake River Plain and are not located within the boundary of any of the tributary basins.

The Idaho Department of Water Resources operates on the assumption that unappropriated ground water exists in most of the basins east of King Hill with the exception of the areas previously discussed. Ground water permits may be difficult to obtain in areas where ground water pumpage interferes with previously appropriated surface water rights according to administrative policy. These areas include the Big Lost River Basin, the Portneuf River Basin, and Camas Prairie near Fairfield (Norm Young, oral communication, 1984).

Conflicts have arisen within the past five years between Idaho Power Company's water rights at Swan Falls Dam and irrigators water rights in the Snake River Plain and associated tributary basins. At this time (1984), the Idaho Department of Water Resources is not issuing any new surface water or ground water permits in the upper Snake River Basin because of uncertainty caused by the Swan Falls conflict.

Time Lag Estimates

Ground water pumpage in a basin tributary to the Snake River reduces discharge from the basin and ultimately reduces the flow of the Snake River. Conjunctive management of water resources in the upper Snake River Basin requires an understanding of how and when pumpage in tributary basins affect the flow of the Snake River. Important considerations when identifying the effects of ground water pumpage include 1.) the magnitude of impact to the Snake River, and 2.) the time lag between when pumpage is initiated and when the effects of pumping impact the Snake River. The magnitude of impact may be determined if the pumpage quantity and consumptive use are known. The time lag between pumpage and impact on the Snake River is more difficult to determine. Many variables control the time lag between pumpage in a tributary basin and reduced flow in the Snake River.

The purpose of this section is to estimate the time lag between the initiation of pumpage at specific locations in the selected tributary basins and the reduction of flow in the Snake River. The discussion is divided into estimation of the time lags for pumpage in individual basin to impact the mouth of the basin or deplete the basin's stream and estimation of the time lag in the transmission of that impact to the Snake River via either the Snake Plain aquifer or the particular surface stream. A classification of tributary basins is developed based upon estimates of the length of time required for ground water pumpage to reduce recharge to the Snake River by both ground water depletion and stream flow depletion.

Tributary Basins

The tributary basins selected for lag time determinations represent the full range of pumping responses in the upper Snake River Basin. Tributary basins that do not have previous estimates of aquifer transmissivity and storativity values are not included in this portion of the analysis. Tributary basins with complex aquifer characteristics are not included as it is difficult to determine lag times by analytical methods in these areas. The construction of a numerical model of each of the selected tributary basins for time lag analysis was beyond the scope of this study.

Two simple models were developed upon which to base the analysis of impacts that ground water pumpage in a tributary basin has on basin discharge. The first model assumes that pumpage intercepts ground water that would have discharged to the Snake Plain aquifer and on to the Snake River. Therefore, the time lag is dependent on the rate at which a cone of depression spreads from the well to the edge of the basin. The time lag for flow through the Snake Plain aquifer is then added to the time lag within the basin to determine the total time lag.

The second model assumes that pumpage depletes the flow of the major stream within the basin. Therefore, factors affecting time lag are: the time span for a given rate of stream depletion to occur; the time span for the river or stream to flow from the point of depletion to the discharging edge of the basin; and the time span for the river or stream to flow to the Snake River. The second model is modified for the case of the north side tributaries that flow to the Lost River Sinks and recharge the Snake Plain aquifer. In these cases, the time lag includes infiltration to the Snake Plain aquifer plus flow through the aquifer to the Snake River. Both of the models are simplifications of actual field conditions.

In the case of the second model, the time lags for the stream depletion to occur and the ground water movement in the Snake Plain aquifer from the Lost River Sinks to the Snake River are are much larger than the times for the surface flow in streams and the vertical movement of water down to the Snake Plain aquifer. The latter two terms are thus considered insignificant and are not included. The rate of stream flow is a significant time factor in basins where stream depletion occurs in hours or days. However, time lags of less than three months are not considered in the study.

A number of different combinations of input parameters were evaluated by Broadhead (1984) as part of this research effort. For the Theis method, these included three different ratios of pumping rate to drawdown for five different pumping centers within each basin. For the Jenkins method, three different ratios of stream depletion to pumping rates were utilized for four different well to stream distances within each basin. Detailed results are available in Broadhead (1984).

Lag times are presented for each basin based upon the Theis and Jenkins methods where appropriate. A number of assumptions are inherent in the results presented. Streams were assumed to flow in a straight line down the center of each basin. Average values of transmissivity and storativity were used in all lag time calculations. Calculations were based upon a single pumpage center discharging at an assigned rate for an infinite period. All assumptions required for the theis method were assumed satisfied. In addition, the analytical methods were applied in the absence of boundary conditions. The consideration of boundary conditions reduces the magnitude of the time lags compared to a simple Theis solution without boundary conditions. A comparison of the drawdown values predicted using the Theis method without boundaries with a solution with boundaries is presented in Table 7. The digital model developed by Prickett and Vorhees (1981) was used to model a situation where parallel no-flow boundaries are located at distances of three and four miles from the pumping well. The boundary configuration represents the linear pattern of the tributary valleys. Values of drawdown are presented in Table 7 depicting

Table 7. Comparison of drawdown estimates predicted without boundary conditions (Theis analytical solution) and with boundary conditions (Prickett and Vorhees numerical solution).

Distance of Pumping Well from Discharging Edge of Basin (miles)	Drawdown at Edge of Basin Predicted By Theis Method[1] (feet)	Drawdown at Edge of Basin Predicted By Prickett and Vorhees Method[1,2] (feet)
5	1	0.97
10	1	2.6
25	1	4.1

[1] Aquifer parameters T = 67,000 ft^2/day, S = 0.15; pumping rate of 50 cfs.

[2] Parallel boundary conditions three and four miles from the pumping center.

basin boundaries 5, 10 and 25 miles down valley from the pumping well. The Theis results are more in error as the length of the valley increases.

Time lags calculated using the Theis method are presented in Table 8 for seven of the tributary valleys. These values represent the time required for a pumpage rate of 50 cubic feet per second to cause a one-foot decline in water levels at the noted distance. For example, a time lag of one year would elapse before the pumpage of 50 cfs (cubic feet per second) at a pumpage site in the Little Lost River Basin would cause one foot of water level decline at the basin boundary with the Snake Plain aquifer five miles away. The 50 cfs pumping rate was arbitrarily chosen to represent the ground water pumpage in the tributary valleys. The time lag is four years if the pumping rate is only 10 cfs (Broadhead, 1984). The one-foot decline in water levels was chosen to represent the first decrease in ground water discharge from a basin.

The lag times shown on Table 8 are generally small for the northside basins and large for three of the four southside basins. This results from the ratio of transmissivity to storativity and the distance from the pumpage center to the basin boundary. A large value of the ratio means that the ground water system responds quickly to pumpage. This is evident in the short lag

Table 8. Estimated intra-basin time lags for selected basins tributary to the upper Snake River based upon the Theis and Jenkins models.

			Theis Model		Jenkins Model	
Basin	Transmissivity (ft^2/day)	Storativity	Distance to Boundary of Basin (miles)	Time Lag for a One-Foot Decline to Occur at Basin Boundary With a Pumping rate of 50 cfs (years)	Distance to the stream (miles)	Time Lag for a Stream Depletion Rate of 10% of Pumpage (years)
Little Lost River	67,000	0.15	5	1	2	<.25
Big Lost River	53,000	0.20	5	1.5	2	<.25
Camas Prairie	9,000	0.001	15	<.25	-	-
Michaud Flats	270,000	0.002	10	<.25	-	-
Raft River	24,000	0.18	15	20	-	-
Rockland Basin	5,700	0.15	15	40	2	1.5
Salmon Falls Creek	2,000	0.08	15	50	-	-

time for the Michaud Flats area. A small value of the ratio indicates that the system responds slowly to pumpage; the best example is the Salmon Falls Creek Basin. The calculated lag times are greater for the three southside tributaries because of the high storativity values and the relatively low transmissivity values. The Raft River, Rockland and Salmon Falls basins have time lags of greater than 20 years.

Calculated lag times for stream depletion using the Jenkins method are also presented on Table 8. The results selected for presentation are based upon a ratio of stream depletion to pumpage of ten percent for a well located two miles from the stream. Other stream depletion ratios and well-stream distances are presented by Broadhead (1984). The calculated times lags are less than three months for the Little Lost and Big Lost Basins and 1.5 years for the Rockland Basin. Again, the slower reaction of the Rockland basin is due to the low ratio of transmissivity to storativity.

The lag times presented in Table 8 are used to calculate total lag time from the pumpage centers in the tributary basins to the Snake River. The following section deals with time lags associated with flow in the Snake Plain aquifer.

Snake Plain Aquifer

The Snake Plain aquifer consists of a sequence of basaltic lava flows interlain with layers of pyroclastic and sedimentary material. The aggregate thickness of the aquifer is unknown but is believed to be on the order of several thousand feet thick in the center of the plain (Whitehead, 1984). Evidence indicates that confined and unconfined zones exist within the upper Snake Plain aquifer (Garth Newton, oral communication, 1984). Perched zones are reported in the area of Mud Lake, American Falls Reservoir, Rupert-Burley, and Bonanza Lake (Norvitch and others, 1969).

Transmissivity estimates vary by several orders of magnitude in the Snake Plain aquifer. Mundorff and others (1964) estimate an average transmissivity value of 700,000 feet^2/day as representative of the Snake River aquifer. Transmissivity values used in the computer model developed by Norvitch and others (1969) range from 700,000 to 14,000,000 feet^2/day Newton (1984) suggests a rough transmissivity estimate of 1,400,000 ft^2/day for the Snake Plain aquifer.

Storativity values are dependent on the type of aquifer, confined or unconfined. Mundorff and others (1964) report that the storativity value of the most productive water-bearing zone is .0001. However, they further state that after several days of pumping, most of the water is supplied by the overlying zone and storativity of the aquifer approaches that of the upper zone (.04). Norvitch and others (1969) estimate an average storativity of .15 for the aquifer west of the Mud Lake area. They state that artesian conditions exist in some places but that most of the pump test data indicate unconfined conditions. Moreland (1969) estimates storativity values ranging from .07 to .15 for the area nearest Thousand Springs.

The time lags associated with pumpage in the tributary basins must be added to the time lag of ground water movement in the Snake Plain aquifer where appropriate to obtain the lag time of impact on the river. The Theis solution is used to provide a time lag estimate between the reduction of ground water discharge from a tributary basin and reduced ground water discharge to the Snake River. Assumptions involved in applying the Theis solution to estimate time lags are: the pumping well is located at the discharging edge of the tributary basin; the calculated point of drawdown is located where ground water from tributary basins is believed to discharge into the Snake River (generally, the Thousand Springs); and the pumping rate is constant. Again, boundary conditions are not considered. Table 9 presents estimates of time lags for a pumpage center discharging 50 and 100 cfs located at various sites in the Snake Plain aquifer. Time lag estimates based on

Table 9. Estimated time lags for the Snake Plain aquifer based upon the Theis model.

Flow Distance	Time Lag for a One-Foot Water Level Decline to Occur at a Discharge Area With the Pumping Rates and Aquifer Parameters Given Below			
	50 Cubic Feet Per Second		100 Cubic Feet Per Second	
	T=700,000 ft^2/day S=0.04	T=1,400,000 ft^2/day S=0.15	T=700,000 ft^2/day S=0.04	T=1,400,000 ft^2/day S=0.15
miles	years	years	years	years
5	0.3	5	<.25	0.6
10	1.4	20	0.4	3
25	8	130	2.7	16
50	30	520	10	65
75	75	1,200	25	145
100	130	2,000	40	250
150	300	5,000	50	580

two ratios of storativity to transmissivity are presented to illustrate the effect a change in aquifer parameters has on the calculated results. Time lag results vary widely from the change in aquifer parameters.

Historical stream flow records and studies conducted by previous investigators provide evidence that substantiates the range of lag times estimated using the Theis model. Agricultural development of the Snake River Plain produced changes in spring discharge to the Snake River. Significant surface water irrigation on the Snake River Plain started in the early 1900's. Little flucuation in flow rates were recorded from 1902-1911. In 1912, spring flow began to increase from increased ground water recharge due to surface water irrigation. Diversions of surface water remained fairly constant from 1920-1940, but spring flow continued to increase through mid 1940. According to Moreland (1976, p. 9) the continued increase in spring flow was "presumably because of time required for recharge 'waves' to travel to the springs." Spring flow remained fairly constant from the mid 1940's to 1959, even though ground water pumpage became a significant irrigatio practice in the late 1940's. Increased ground water pumpage caused spring flow to decline between 1959-1962. Spring flow has remained relatively constant from 1962-1973. Recorded spring flow measurements indicate a 10-40 year lag time between major agricultural development on the Snake River Plain and a change in spring discharge.

The 10-40 year lag time reported from historic records corresponds with the time lags calculated by using a transmissivity value of 700,000 feet^2/day (Table 9). The lag times calculated using a transmissivity value of 1,400,000 feet^2/day are greater than indicated by historical flow records.

Effects of artificial recharge to the Snake Plain aquifer were simulated with an electrical-analog model developed by Norvitch and others (1969). Total simulated recharge over a ten year period was 3,700,000 acre-feet. Recharge was simulated in four different areas. The model indicated that 88 percent of the recharge went into aquifer storage and 12 percent was added to spring discharge. Norvitch and others (1969) constructed a contour map of water level rise after 10 years resulting from hypothetical artifical recharge. Distances were measured between recharge areas and two-foot contours of water level rise presented by Norvitch in order to estimate time lag. For example, the distance between hypothetical recharge wells in the Shelley-Firth area and the closest two feet water level rise contour is approximately 60 miles. Assuming a linear change in water level, a one foot rise in water level would occur 30 miles from the recharge well in ten years. The model developed by Norvitch and others (1969) cannot be directly related to the results obtained from the Theis solution. However, the results of the analog model suggest that a recharge rate of 93,500 acre-feet/year or 130 cfs would result in a one foot water level rise 30 miles away from the recharge well in 10 years. The Theis method predicts a water level rise of one foot under the same conditions in 3-14 years depending on the aquifer parameters used.

Moreland (1976) used a digital model to determine the effects of water use alternatives on spring discharge. Moreland evaluated the effects of six water use alternatives. Four alternatives studied the potential effects of increased pumpage in Lincoln, Jerome, and Gooding Counties on spring discharge to the Snake River. For example, in one alternative plan, ground water was withdrawn at a rate of 138 cfs near Shoshone over a five-year period. One foot of water level decline occurred at a distance of approximately 5-10 miles from the pumping well after one year and 8-20 miles after 5 years. These results are in general agreement with the Theis model results presented in Table 9.

Although previous models do not specifically predict the time lag between pumpage and aquifer response, they can be used to support values predicted from the Theis solution. Time lag effects in the Snake Plain aquifer based upon the Theis model compare favorably with results obtained from previous studies and historical spring flow measurements. Therefore, it is believed that data presented in Table 9 are reasonable estimates of time lag and can be used as preliminary management criteria.

Classification of Selected Tributary Basins

Time lag between ground water pumpage and reduced recharge to the Snake River is an intregal factor in the determination of pumpage impacts. Table 10 presents the approximate time lags between ground water pumpage in selected tributary basins and reduced discharge into the Snake River. A pumping rate of 50 cfs and a stream depletion to pumping ratio of .1 are assumed for all the selected basins. A pumping center is established in each tributary basin in order to evaluate the approximate time lag between basin pumpage and reduced discharge to the Snake River. The pumping centers are located at points where the majority of basin pumpage occurs or at the center of the basin when pumping is scattered thoughout the basin. Transmissivity and storativity values for the Snake Plain aquifer of

Table 10. Time lag estimates of flow reduction in the Snake River from pumpage in selected tributary basins.

Basin	Location of Discharge to Snake River	Approximate Distance from Basin Boundary (miles)	Estimated Time Lag in Snake Plain Aquifer Based Upon Theis Model[1] (years)	Estimated Time Lag in Basin Aquifer Based Upon Theis Model (years)	Estimated Time Lag in Basin Aquifer Based Upon Jenkins Stream Depletion (years)	Total Estimated Time Lag (years)
Little Lost River	1000 Springs area	150	50-300	1	<.25	50-300
Big Lost River	1000 Springs area	110	40-130	1.5	<.25	40-130
Camas Prairie	Via Big Wood River	-	-	<.25	-	<.25
Michaud Flats	American Falls Reservoir	5	0.3	<.25	-	<.5
Rockland Basin	American Falls Reservoir	5	0.3	40	1.5	1.5-40[2]
Raft River	a) Lake Walcott b) 1000 Springs area	5 85	0.3 25-75	20 20	-	20 45-95
Salmon Falls Creek	1000 Springs area	10	0.4-1.4	50	-	50

[1] For a pumping rate range of 50-100 cfs

[2] Range is via surface water and via ground water

700,000 feet^2/day and .04 respectively, are used for time lag calculations. Time lags and distances are approximate values and are intended only as a general framework from which to develop a management classification.

Tributary basins that indicate maximum lag times greater than 90 years between pumpage and impact on the Snake River include Little Lost River Basin, Big Lost River Basin, and Raft River Basins. Ground water flow through the Snake Plain aquifer appears to be the controlling mechanism of lag time for Little Lost and Big Lost River Basins. The time lag of ground water response through the Raft River basin is as significant as time lags in the Snake Plain aquifer. It is possible that many of the other southside basins exhibit the same time lag characteristics as the Raft River basin if ground water is tributary to the Snake Plain aquifer rather than directly to the Snake River. The time lag from pumpage in the Raft River Basin is largely dependent on where basin outflow discharges into the Snake River. If basin outflow enters Lake Walcott, then the time lag is substantially less than if basin outflow discharges at the Thousand Springs. The time lag in the Salmon Falls Creek Basin is a function of well location. Pumpage in the northern portions of the basin will impact the Snake River in less than five years, whereas, pumpage in southern portions of the basin will not impact the Snake River for over 130 years (Broadhead, 1984). Pumpage effects impact the Snake River with a maximum time lage of 40-50 years in the Rockland Basin and the Salmon Falls Creek Basin. Basins where pumpage effects will impact the Snake River in less than one year include Michaud Flats and Camas Prairie. Depletion of surface water within a basin generally will impact the Snake River much sooner than depletion of ground water in the Snake Plain aquifer.

Time Lag Classification As A Management Tool

Management areas can be delineated as accurate time lags of surface and ground water response are established. This type of classification enables management decisions to be based on how and when a junior water right interferes with a senior water right on a regional scale.

Most surface water rights in the Snake River Basin were obtained before ground water development was started. Therefore, under the appropriations doctrine, most surface water rights are senior to most ground water rights. Legally and/or administratively, the following question needs to be addressed. Should the time delay between basin pumpage and the resultant reduction of flow in the Snake River be a factor in determination of the legal definition of interference with surface water rights? If so, should a junior appropriator be shut down if closure of his well will not affect a senior appropriator's surface right for 100 years? A number of other similar questions must also be addressed.

Economic, legal and social considerations will all be determining factors in answering the above questions. The legal aspects of these questions are explored in the second portion of this paper.

Conclusions

Conjunctive surface water and ground water management of the upper Snake River Basin requires knowledge of the physical and hydrologic characteristics of each tributary basin and knowledge of the interrelationship between each tributary basin, the Snake Plain aquifer and the Snake River.

Eleven tributary basins were selected for detailed analysis. The eleven basins can be grouped according to surface and ground water discharge characteristics. Basins that contribute all or most of the ground water to the Snake River include: Big Lost River, Little Lost River, Michaud Flats, Raft River and Blue Gulch. Basins that contribute both surface and ground water to the Snake River include: Big Wood-Silver Creek, Portneuf River, Rockland, Rock Creek-Goose Creek and Salmon Falls

Creek. Camas Prairie only contributes surface water to the Snake River. Surface and ground water are interconnected in all of the basins.

A classification of tributary basins is presented as an initial step toward conjunctive management of the Snake River Basin. The first factor in the classification is a ratio of the quantity of water supplied by the tributary basins to the flow of the Snake River at King Hill. Basins contributing less than one percent of the flow of the river at King Hill include: Rockland, Rock Creek-Goose Creek, and Blue Gulch. The second factor is the occurrence of consumptive ground water pumpage in excess of basin recharge. Basins where this is occurring include: Raft River, Rock Creek-Goose Creek and Blue Gulch. The third factor is a ratio of annual water yield to the drainage area of a basin. This factor is indicative of the amount of water that is available per unit area of the basin. The Rock Creek-Goose Creek area and the Raft River Basin both have less than 0.2 feet of water available annually per acre of land. The fourth factor is the distance that surface water and ground water must flow to discharge into the Snake River. This factor is important in determination of the lag time between initiation of pumpage in a basin and depletion of the Snake River.

Time lags between basin pumpage and reduced flow of the Snake River vary significantly dependent upon whether stream depletion occurs within the tributary basin. Pumpage in basins where depletion occurs of streams tributary to the Snake River will impact the Snake River much faster than in basins where only ground water interception occurs. Time lags are also a function of well location, transmissivity and storativity of the aquifer, and the distance of the flow path to the Snake River.

Pumpage effects in the Little Lost River Basin, the Big Lost River Basin and the Raft River Basin have maximum estimated time lags between pumpage and impacts on the Snake River of greater than 90 years. The Rockland Basin and the Salmon Falls Creek area have estimated maximum time lags of 40 to 50 years. Pumpage in the Michaud Flats area and Camas Prairie probably impact the flow the Snake River within one year.

Legal and administrative questions need to be addressed before a detailed conjunctive management classification or plan can be established for the upper Snake River Basin. Knowledge of the physical and hydrologic nature of tributary basins and the interrelationship of each tributary basin to the Snake River provides the framework from which management decisions can be made.

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PART II.

LEGAL ASPECTS OF CONJUNCTIVE MANAGEMENT OF SURFACE AND GROUND WATER

by

Douglas L. Grant

LEGAL ASPECTS OF CONJUNCTIVE MANAGEMENT
OF
SURFACE AND GROUND WATER

In Idaho, the appropriation doctrine governs rights in both surface and ground water.[1] The key management tool of that doctrine is the principle that priority in time gives priority in right.[2] Under this principle, users are shut off in inverse order of priority when the supply is not sufficient for all. Water is withheld completely from those with junior priorities to supply fully those with senior priorities.

Under such a system, conjunctive management of surface and ground water would seem initially to be a simple matter: Rights in physically interrelated surface and ground water supplies would be integrated into a unitary list of priorities and then administered in accordance with the priority principle. It turns out, however, that the matter is not so simple. A number of complexities and uncertainties quickly come into play. These are analyzed below. To facilitate the analysis, some basics of the appropriation doctrine are first discussed.

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[1] Idaho Code §§ 42-103, -201 (1977). A possible exception would be diffused surface water, which may be subject to a rule of capture. <u>See</u> King v. Chamberlin, 20 Idaho 504, 118 P. 1099 (1911).

[2] <u>See</u> Idaho Const. art. 15, § 3; Idaho Code § 42-106 (1977).

Basics of the Appropriation Doctrine

Early History

The appropriation doctrine for water rights originated in the customs of western settlers in the mid-nineteenth century.[3] Before long, the doctrine received governmental sanction throughout the West. In Idaho, this happened as early as 1881 when the territorial legislature passed a statute declaring that rights to use water flowing in rivers, creeks, or other streams could be acquired by appropriation.[4] Seven years later, the first reported water decision of the territorial supreme court impliedly rejected any role for the eastern doctrine of riparian water rights as against the claims of appropriators.[5]

When the state constitution was adopted and ratified in 1889, article 15, section 3 declared: "The right to divert and appropriate the unappropriated waters of any natural stream to beneficial uses shall never be denied. Priority of appropriations shall give the better right

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[3] 1 W. Hutchins, Water Rights Laws in the Nineteen Western States 159-80 (1971).

[4] 1881 Idaho Sess. Laws, p. 267, § 1. In 1887, the appropriation doctrine was codified as section 3159 of the Revised Statutes of Idaho.

[5] Malad Valley Irr. Co. v. Campbell, 2 Idaho 411, 18 P. 52 (1888). Later, the Idaho court indicated that while there is no role for riparian rights as against appropriators, a riparian landowner may have a right to the flow of water in a stream as against a stranger or intermeddler. Hutchinson v. Watson Slough Ditch Co., 16 Idaho 484, 101 P. 1059 (1909).

as between those using the water . . . ."[6] A statute enacted in 1889 declared: "The right to the use of the waters of rivers, streams, lakes, springs and of subterranean waters, may be acquired by appropriation."[7] This statue continues in force today, with the addition of language indicating a permit from the state is needed to make an appropriation.[8]

Notwithstanding the reference in the 1889 appropriation statute to subterranean waters, the legal system for ground water was unsettled for some time. In other states during the late nineteenth and early twentieth centuries, subterranean streams were governed by the same legal system as applied to surface steams. But other subterranean waters, often called percolating waters, were governed by any of several other legal systems. These systems, which went by the names of the absolute ownership doctrine, the reasonable use doctrine, and the correlative rights doctrine, all gave proprietary rights in percolating water to overlying landowners.[9] Against this background, it was argued that the 1899 Idaho statute adopting the appropriation doctrine for "subterranean waters" applied only to subterranean

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[6] In 1928, the first sentence of article 15, section 3 was amended by substituting a comma for the period and adding: "except that the state may regulate and limit the use thereof for power purposes."

[7] 1889 Idaho Sess. Laws, p. 380, § 2.

[8] Idaho Code § 42-103 (1977).

[9] See 2 S. Wiel, Water Rights in the Western States §§ 1039-66 (3d ed. 1911); Kirkwood, Appropriations of Percolating Water, 1 Stan. L. Rev. 1 (1948).

steams, not percolating waters. According to this argument, relatively static or slow moving percolating water was owned by an overlying landowner and thus could not be made subject by the legislature to the right of appropriation.[10]

The early ground water decisions of the Idaho Supreme Court, as later summarized by the court itself, "vacillated on the question of the appropriability of ground water."[11] Those decisions generally favored the appropriation doctrine,[12] with the major deviation coming in a 1922 decision that seemed to say the absolute ownership doctrine should govern percolating waters which are not tributary to any spring or stream.[13] By subsequent decisions in 1930 and 1931, the court reaffirmed its commitment to the appropriation doctrine for percolating waters, with the possible exception of percolating water underlying the land of a single owner and not tributary to any other source.[14]

In 1951, the Idaho Legislature passed legislation that, as currently amended, is the major source of the

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[10] See appellant's brief in Bower v. Moorman, 27 162, 165-66 (1915); Note, 80 U. Pa. L. Rev. 133 (1931).

[11] Baker v. Ore-Ida Foods, Inc., 95 Idaho 575, 580, 513 P.2d 627, 632 (1973). The uneven development is traced in detail in Grant, Selected Problems in Idaho Ground Water Law (Idaho Water Resources Research Institute 1975).

[12] See Remarks of R.P. Parry, 23 Idaho State Bar Proceedings 19 (1949).

[13] Public Utilities Comm'n v. Natatorium Co., 36 Idaho 287, 211 P. 533 (1922).

[14] Hinton v. Little, 50 Idaho 371, 296 P. 582 (1931); Silkey v. Tiegs, 51 Idaho 344, 5 P.2d 1049 (1931).

state's ground water law.[15] The Idaho Supreme Court has labeled that legislation the Ground Water Act.[16] Since its inception, the Ground Water Act has declared: "The right to the use of ground water of this state may be acquired only by appropriation."[17] It defines ground water as "all water under the surface of the ground whatever may be the geological structure in which it is standing or moving."[18] This would appear to include percolating water that is relatively stationary.

Initiation of Water Rights

Currently, Idaho has a mandatory permit system for initiating water rights.[19] With the exception of small

[continued on next page]

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[15] 1951 Idaho Sess. Laws, ch. 200. The ground water act currently is codified as Idaho Code §§ 42-226 to -229 (1977 & Supp. 1983).

[16] See Parker v. Wallentine, 103 Idaho 506, 650 P.2d 648 (1982); Briggs v. Golden Valley Land & Cattle Co., 97 Idaho 427, 546 P.2d 382 (1976); Baker v. Ore-Idaho Foods, Inc., 95 Idaho 575, 513 P.2d 627 (1973).

[17] Idaho Code § 42-229 (1977).

[18] Idaho Code § 42-230(a) (Supp. 1983).

[19] Idaho Code §§ 42-103, -201 (1977). For discussion of the constitutionality of the legislation mandating a permit, see Grant, The Idaho Water Plan: Two Threshold Constitutional Problems and Suggested Solutions, 15 Idaho L. Rev. 443, 474-507 (1979).

ground water appropriations for domestic use,[20] anyone desiring to make an appropriation must apply to the Department of Water Resources for a permit. The Department may deny an application on any of the following grounds:

> "(1) that [the proposed use] will reduce the quantity of water under existing water rights, or (2) that the water supply itself is insufficient for the purpose for which it is sought to be appropriated, or (3) where it appears to the satisfaction of the department that such application is not made in good faith, is made for delay or speculative purposes, or (4) that the applicant has not sufficient financial resources with which to complete the work involved therein, or (5) that [the proposed use] will conflict with the local public interest . . . ."[21]

This provision applies to all proposed appropriations, whether of surface or ground water.

In addition, ground water is subject to special provisions in the Ground Water Act that affect proposed appropriations. The Act establishes a procedure for the declaration of critical ground water areas.[22] A critical ground water area is defined as:

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[20] Idaho Code § 42-227 (Supp. 1983). Domestic use is defined as "Water for household use or livestock and water used for all other purposes including irrigation of up to one-half (1/2) acre of land in connection with said household where total use is not in excess of thirteen thousand (13,000) gallons per day," but not including "water for multiple ownership subdivisions, mobile home parks, commercial or business establishments." Idaho Code § 42-230(d) (Supp. 1983). Section 42-228 says no permit is needed for drainage wells or wells of owners of irrigatiion works which are operated solely to recapture seepage for further use on the land to which the water right is appurtenant, but it is doubtful such wells involve any new appropriation.

[21] Idaho Code § 42-203 (Supp. 1983).

[22] Idaho Code § 42-233a (Supp. 1983).

> "any ground water basin, or designated part thereof, not having sufficient ground water to provide a reasonably safe supply for irrigation of cultivated lands, or other uses in the basin at the then current rates of withdrawal, or rates of withdrawal projected by consideration of valid and outstanding applications and permits, as may be determined and designated from time to time, by the director of the department of water resources."[23]

If an application is filed for a permit to appropriate water from a designated critical ground water area, and if the Director of the Department of Water Resources has reason to believe that there is insufficient water available subject to appropriation at the location of the proposed well, he may forthwith deny the application.[24]

A recent amendment to the Ground Water Act adds a procedure for the designation of ground water management areas.[25] A ground water management area is defined as "any ground water basin or designated part thereof which the director of the department of water resources has determined may be approaching the conditions of a critical ground water area."[26] If a permit application is filed to appropriate water from a designated ground water management area, it may be approved only if the Director determines "on an individual basis that sufficient water is available and

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[23] Id.

[24] Id.

[25] Idaho Code § 42-233b (Supp. 1983).

[26] Id.

that other prior water rights will not be injured."[27]

After a permit has been issued, to obtain a water right the permittee must divert water from the source of supply and put it to a beneficial use in accordance with the terms of the permit.[28] Upon proof to the Department of Water Resources that this has been done, the Department will issue a water license.[29] A license is prima facie evidence of the existence of a water right.[30]

For many years prior to 1963 for ground water, and prior to 1971 for surface water, the permit system was optional rather than mandatory. A water right could be initiated simply by diverting water and putting it to a beneficial use without a permit.[31] Water rights initiated in this manner are often called constitutional method rights.[32] Although a permit is now mandated by statute, there is no question that rights previously initiated under the

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[27] Id.

[28] Hidden Springs Trout Ranch, Inc. v. Hagerman Water Users, Inc., 101 Idaho 677, 619 P.2d 1130 (1980). The diversion requirement is excused for minimum stream flow appropriations by certain state agencies. State, Dept of Parks v. Idaho Dept of Water Admin., 96 Idaho 440, 530 P.2d 924 (1974).

[29] Idaho Code §§ 42-217, -219 (Supp. 1983).

[30] Idaho Code § 42-220 (1977).

[31] See Silkey v. Tiegs, 51 Idaho 344, 5 P.2d 1049 (1931); Nielson v. Parker, 19 Idaho 727, 115 P. 488 (1911).

[32] See.e.g., Olson v. Bedke, 97 Idaho 825, 830, 555 P.2d 156, 161 (1976); Parke v. Bell, 97 Idaho 67, 69, 539 P.2d 995, 997 (1975); DeRousse v. Higginson, 95 Idaho 173, 174, 175, 505 P.2d 321, 322, 323 (1973).

constitutional method are still valid. Thus, Idaho has two types of appropriations based on the method of initiation, namely, constitutional method rights and permit system rights.

Limits on Exercising Water Rights

A water right is limited as to quantity, based on the amount of water the appropriator applied to a beneficial use during the initiation period.[33] The right is measured at the point of diversion,[34] but it includes allowance for reasonable loss in transporting water to the place of use.[35] Within the allowable maximum diversion, an appropriator is further limited at any particular time to diverting only the quantity of water he is then able to put to a beneficial use.[36] Thus, an irrigator may be entitled to divert less water during a wet period than during a dry one.[37]

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[33] Idaho Code § 42-219, -1402 (1977 & Supp. 1983); In re Robinson, 61 Idaho 462, 469, 103 P. 693, 696 (1940).

[34] Idaho Code § 42-110 (1977); Glenn Dale Ranches, Inc. v. Shaub, 94 Idaho 585, 588, 494 P.2d 1029, 1032 (1972).

[35] Hidden Springs Trout Ranch, Inc. v. Hagerman Water Users, Inc., 101 Idaho 677, 681w-82, 619 P.2d 1130, 1134-35 (1980).

[36] Caldwell v. Twin Falls Salmon River Land & Water Co., 225 F. 584, 595 (D. Idaho 1915); Glavin v. Salmon River Canal Co., 44 Idaho 583, 589, 258 P. 532, 534 (1927).

[37] In Caldwell, supra note 36, the court said: "[A]t any given time the extent of . . . [an approporiator's] reasonable need is the measure of the maximum amount he is entitled for the time being to divert from the stream . . . . [W]hat the farmer needs this year for the proper irrigation of his crops may be too much or too little for the coming year."

In addition to being limited as to quantity, water rights are limited as to their point of diversion, place of use, period of use, and nature of use.[38] A change in any of these latter characteristics of the right requires prior approval of the Department of Water Resources, and various statutory requirements must be satisfied to obtain approval.[39]

Perhaps most fundamentally, though, the exercise of water rights is limited by the priority principle. Each water right has a priority date.[40] For rights initiated under the permit system, the priority is the date of application for a permit.[41] For rights initiated under the constitutional method, the priority is the date water was first diverted and applied to a beneficial use.[42]

Practical Administration of Water Rights

Water rights may be asserted and enforced in private litigation between individual users. While such litigation

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[38] See Idaho Code §§ 42-202, -217, -219, -1410 (1977 & Supp. 1983). Old water decrees do not always expressly limit water rights as to point of diversion, place of use, etc. See, e.g., Harris v. Chapman, 51 Idaho 283, 5 P.2d 733 (1933)(noting that a decree entered in 1909 failed to state the place of use of a particular right). Nonetheless, such rights might be limited as to point of diversion, place of use, etc. by the historic pattern of their actual use. See Dunn v. Boyd, 46 Idaho 717, 722, 271 P.2d 2,4 (1928)(limitation as to period of use).

[39] Idaho Code §§ 42-108, -222 (Supp. 1983).

[40] See Idaho Code §§ 42-219, -1410 (Supp. 1983).

[41] Nielson v. Parker, 19 Idaho 727, 115 P. 488 (1911).

[42] Id.

is often important in specific instances, there is also a more comprehensive and far-reaching statutory structure for administrative regulation of the distribution of water among appropriators. Under that structure, the state is initially divided into three large water divisions.[43] The Department of Water Resources is charged with further dividing the state into water districts.[44] By statute, "each public stream and tributaries, or independent source of water supply, shall constitute a water district . . . [except that no district shall be established for] streams or water supplies whose priorities of appropriation have not yet been adjudicated . . . ."[45] If the distance between the extreme points of diversion on any stream or water supply is more than 40 miles, it may be divided into two or more water districts.[46]

Within a water district, day-to-day administration of water is handled by a watermaster. The watermaster is elected by water right holders in the district and acts under the supervision of the Department of Water Resources.[47] Watermasters are directed by statute to distribute water under the principle that priority in time gives priority

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[43] Idaho Code § 42-601 (1977).

[44] Idaho Code § 42-604 (1977).

[45] _Id_.

[46] _Id_.

[47] Idaho Code §§ 42-602 to -607 (1977 & Supp. 1983).

in right.[48] The statute adds, however, that any alleged constitutional method right that has never been adjudicated or decreed by a court shall be treated by the watermaster as subsequent to all adjudicated, decreed, permit, or licensed rights, regardless of the priority date claimed for the unadjudicated constitutional method right. Other legislation establishes procedures for the adjudication of water rights.[49]

Machinery exists for coordinating priorities between water districts. The Department of Water Resources is charged by statute with seeing that priorities are implemented throughout an entire water division, without regard to the water district in which a particular appropriation is located.[50] To accomplish this, all watermasters are required to make reports to the Department of Water Resources regarding water supply and demand within their districts. The Department must then ascertain whether any appropriators in the division are not receiving their proper supply of water.

For problems involving ground water, the Ground Water Act creates two special administrative processes. First, section 42-237a(g) empowers the Director of the Department of Water Resources to regulate the exercise of ground water rights by issuing summary orders that "prohibit or limit

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[48] Idaho Code § 42-607 (1977).

[49] Idaho Code §§ 42-1401 through -1415 (1977 & Supp. 1983).

[50] Idaho Code § 42-606 (1977).

the withdrawal of water from any well during any period that he determines that water to fill any water right in said well is not there available."[51] To assist in making such determinations, that section authorizes the Director to establish reasonable ground water pumping levels. It also declares:

> "Water in a well shall not be deemed available to fill a water right therein if withdrawal therefrom of the amount called for by such right would affect, contrary to the declared policy of this act, the present or future use of any prior surface or ground water right or result in the withdrawing the ground water supply at a rate beyond the reasonably anticipated average rate of future natural recharge."[52]

A companion statute affirms the traditional state policy that water resources be put to beneficial use in reasonable amounts through appropriation, and adds:

> "[W]hile the doctrine that 'first in time is first in right' is recognized, a reasonable exercise of this right shall not block full economic development of underground water resources, but early appropriators of underground water shall be protected in the maintenance of reasonable ground water pumping levels as may be established by the director of the department of water resources . . . ."[53]

Second, the Act establishes a local ground water board process. Anyone with a surface or ground water right who believes it is being adversely affected by the exercise of any ground water right of later priority may file a statement to that effect with the Director of the Department

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[51] Idaho Code § 42-237a(g) (Supp. 1983).

[52] Id.

[53] Idaho Code § 42-226 (Supp. 1983).

of Water Resources. The same is true of anyone with a ground water right who believes it is being adversely affected by the use of any other water right of later priority.[54] If the Director considers the statement sufficient, he sets the matter for a hearing before a local ground water board.[55] A board is created specially to hear the dispute and functions only until the matter is resolved.[56] The board consists of the Director, a qualified engineer or geologist appointed by the local district court judge, and a local irrigation farmer who is appointed by the other two members.[57]

The board conducts a hearing on the statement and any answer filed by the person or persons against whom the statement was directed. The board then determines the existence and nature of the respective water rights involved, and whether the junior right or rights affect the senior right contrary to the declared policy of the ground water act. The board can also issue a corrective order.[58] Any person dissatisfied with such an order, or with a summary order issued by the Director under section 42-237a(g),

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[54] Idaho Code § 42-237b (1977).

[55] Id.

[56] Idaho Code § 42-237d (1977).

[57] Id.

[58] Idaho Code § 42-237c (1977).

may seek judicial review.[59]

Foundation for Conjunctive Management

In Idaho, the conjunctive management principle of treating physically interrelated water sources as a single system finds support both in private litigation between water users and in the statutory structure for administrative management. Taking private litigation first, as long ago as 1888, the territorial supreme court ruled that priorities in a main stream and in a spring fed creek tributary thereto should be integrated into a unitary priority list.[60] The court enjoined a junior appropriator on the creek from interfering with the supply to a senior appropriator on the main stream. Over the years, the court has continued to apply the principle of a unitary priority list for interrelated surface water sources of supply.[61] In addition, the court has indicated that the same principle applies to private litigation between users of interrelated surface and ground water.[62]

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[59] Idaho Code § 42-237e (Supp. 1983).

[60] Malad Valley Irrigating Co. v. Campbell, 2 Idaho 411, 18 P. 52 (1888).

[61] Shaub v. District Court of the Fifth Judicial Dist., 96 Idaho 924, 539 P.2d 277 (1975), and cases cited therein.

[62] Martiny v. Wells, 91 Idaho 215, 419 P.2d 470 (1966)(quoting with approval broad language from Colorado cases); Union Central Life Ins. Co. v. Albrethsen, 50 Idaho 196, 294 P. 842 (1930)(water seeping through the gravelly subsurface of the Bellevue Flats treated as part of Silver Creek). See also McGlochlin v. Coffin, 61 Idaho 440; 103 P.2d 703 (1940)(further description of the hydrology of Bellevue Flats).

Turning to administrative management, it was noted earlier that section 42-237a(g) empowers the Director of the Department of Water Resources to issue summary orders prohibiting or limiting the withdrawal of ground water if such withdrawal "would affect, contrary to the declared policy of this act, the present or future use of any prior surface or ground water right . . . ."[63] That section goes on to empower the Director:

> "to determine what areas of the state have a common ground water supply and whenever it is determined that any area has a ground water supply which affects the flow of water in any stream or streams in an organized water district, to incorporate such area in said water district . . . ."

In addition, the local ground water board process applies to interference by a junior ground water right with any prior surface or ground water right, and to interference by any junior water right (apparently including junior surface water rights) with a prior ground water right.[64] Finally, the Director of the Department of Water Resources is authorized to initiate judicial proceedings to adjudicate the water rights of a "water system," which is defined to include "streams, lakes, ground waters, or any other body of water, tributaries and contributory sources thereto."[65]

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[63] See supra pp. 112-13.

[64] Idaho Code § 42-237b (1977).

[65] Idaho Code § 42-1406 (1977). Idaho Code § 42-1410 (Supp. 1977) contains a similar provision authorizing privately initiated adjudication of a water system.

Such adjudication would then facilitate integrated management of surface and ground water priorities.

Issues in Conjunctive Management

Various complexities and uncertainties affecting the conjunctive management of surface and ground water are discussed below. The focus, of course, is on Idaho law. When Idaho law is not well developed, reference is sometimes made to the law of Colorado. Colorado was chosen for comparison for two reasons. First, that state has experienced acute conjunctive management problems. Consequently, it has a more well developed body of law on conjunctive management than most, if not all, western appropriation doctrine states. Second, like Idaho, Colorado has a state constitutional provision guaranteeing that the right to appropriate the unappropriated waters of natural streams to beneficial use shall never be denied, and that priority of appropriation shall give the better right to use water.[66]

Magnitude and Timing of Impact of Junior Diversions

When junior diversions are made from a tributary source, issues can arise involving the magnitude and timing of their impact on the main source. These issues can arise in various ways. For example, the tributary might contribute only a small fraction of the total supply in the main source. Even if the tributary is an important contributor to the

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[66] Colo. Const. art. XVI, § 6; Idaho Const. art. 15, § 3.

main source, the junior diversions might be so small as to have little impact on the main source. Even if the tributary is an important contributor to the main source and the junior diversions are significant in amount, the tributary water might move through the ground toward the main source so slowly that the impact of the junior diversions will not be felt on the main source for many years. Furthermore, if the junior diversions are limited mainly to the the irrigation season and the movement of the tributary ground water is slow and diffuse, the impact on the main source may be spread throughout the year so that the impact at any given time is considerably reduced.

In 1888, in Malad Valley Irrigating Co. v. Campbell, when the territorial supreme court held that springs which were tributary to a stream were subject to priorities on the stream, the court noted that the springs constituted "the principal and immediate sources of supply for the stream."[67] The quoted language suggests the question of whether a tributary source might make either too insignificant a contribution to the main source or be too remote from it to be subject to priorities on the main source. Discussed below is the extent to which subsequent developments have dealt with that question, and with the related question of whether an individual diversion from a major tributary might be too insignificant to be integrated with priorities

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[67] 2 Idaho 411, 415, 18 P. 52, 54 (1888).

on the main source.

Issues regarding the magnitude and timing of impact can arise both in private litigation between senior and junior appropriators, and in administrative regulation of interrelated surface and ground water. Taking private litigation first, the question of magnitude of impact seems not to have been seriously disputed in any of the reported cases. However, in a 1924 decision, the court did declare: "An appropriator is entitled to have the full quantity of water called for by his appropriation flow in the natural stream, . . . and for any <u>material interference</u> with this flow of water, by which his right to its use is <u>substantially impaired</u>, he may maintain an action for damages."[68] Several years later, the court allowed the junior diversion and use of ground water tributary to Silver Creek because "such use in no <u>material way</u> interferes with the ultimate entrance of such water into Silver Creek, and in no way prejudices the . . . [senior appropriator]."[69] More recently, in <u>Martiny v. Wells</u>,[70] the court quoted with apparent approval the following language from a Colorado case:

> "It is probably safe to say that it is a matter of no moment whether water reaches a certain point by percolation through the soil, by a subterranean channel, or by an obvious surface channel.

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[68] Bailey v. Idaho Irrigation Co., 39 Idaho 354, 358, 227 P. 1055, 1056 (1924)(emphasis added).

[69] Union Central Life Ins. Co. v. Albrethsen, 50 Idaho 196, 207, 294 P. 842, 846 (1930).

[70] 91 Idaho 215, 419 P.2d 470 (1966).

> If by any of these natural methods it reaches the point, and is there appropriated in accordance with law, the appropriator has a property in it which cannot be divested by the wrongful diversion by another, nor can there be any substantial diminution."[71]

In Martiny, the court also said:

> "So long as the water from the springs and swamps, flowing in its natural channels, would reach Spring Creek in usable quantities, plaintiffs are entitled to enjoin defendant's interference therewith. The fact that some of the water would be lost by evaporation or percolation would not afford this defendant any right to divert it.[72]

Thus, in the context of private litigation, there is at least some indication that junior diversions with too insignificant an impact on senior rights will not be subject to the senior priorities. Perhaps, the question of how insignificant such impact must be would be answered by a "usable quantities" standard. At any rate, a junior appropriator cannot interfere with a senior's supply merely because his diversion and water use would involve less loss by evaporation or percolation.

The issue of delayed impact from junior diversions arose early in Idaho's history. In 1904, the court dealt with a suit by a senior appropriator from a creek to enjoin interference by junior appropriators, some of whom apparently

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[71] Id. at 217-18, 419 P.2d at 473, quoting from Ogilvy Irrigating & Land Co. v. Insinger, 19 Colo. App. 380, 75 P. 598, 599 (1904), which in turn quoted from McClellan v. Hurdle, 3 Colo. App. 430, 434, 33 P. 280, 282 (1893).

[72] Id. at 219, 419 P.2d at 474 (emphasis added).

were diverting from tributaries of the creek.[73] Juniors with land near the head of the stream argued that the early spring irrigation of their land benefited the senior because the irrigation water seeped into the ground and gradually found its way back to the stream, thus prolonging the life of the stream. The court said: "If the theory is true, the users at the lower end of the stream are certainly benefited. . . . If this contention of . . . [the junior appropriators] is true, it is certainly a good and sufficient defense to this action."[74] However, the court affirmed the finding in the court below that the contention was not true.

Later in 1904, a similar theory was advanced by junior appropriators in another case.[75] Again, however, the evidence was found insufficient to support it. Beyond these two cases, there does not appear to be discussion of the issue of delayed impact of junior diversions in the privately litigated cases.

Turning now to administrative regulation, Idaho Code § 42-233a contrasts with most of the Idaho water administration statutes. That section says an applicant for a permit to appropriate 10,000 acre feet or more per year of ground water can be required to undertake ground water recharge

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[73] Cartier v. Buck, 9 Idaho 571, 75 P. 612 (1904).

[74] _Id_. at 574, 75 P. at 613.

[75] Moe v. Harger, 10 Idaho 302, 77 P. 645 (1904).

efforts if the Director of the Department of Water Resources determines, inter alia, that the proposed withdrawal "will substantially and adversely affect the amount of water available for withdrawal from such basin or basins under existing water rights."[76] Generally, the statutes authorizing administrative regulation do not use words like "substantially." For example, a senior appropriator seeking to invoke the local ground water board process must allege that his right "is being adversely affected."[77] The statute does not say anything about the adverse effect having to be substantial. Similarly, section 42-237a(g) says the Director of the Department of Water Resources shall have power to determine what areas of the state have a common ground water supply, and "whenever it is determined that any area has a ground water supply which affects the flow of water in any stream or streams in an organized water district, to incorporate such area in said district."[78] There is no mention of the significance of the effect of the ground water supply on stream flow.

On the other hand, the key administrative statutes tend to be optional rather than obligatory---the Director "may" or the Director "shall have power"---and tend to be shaped by references to policy. For example, the water

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[76] Idaho Code § 42-233a (Supp. 1983)(emphasis added).

[77] Idaho Code § 42-237b (1977).

[78] Idaho Code § 42-237a(g) (Supp. 1983).

district provision just quoted empowers, but does not necessarily require, the Director to incorporate a tributary ground water source into a water district for a surface stream. Similarly, section 42-237a(g) says in part:

> "In the administration and enforcement of this act and in the effectuation of the policy of this state to conserve its ground water resources, the director of the department of water resources is empowered: . . . (g) To supervise and control the exercise and administration of all rights hereafter acquired to the use of ground waters and in the exercise of this power he may be [by] summary order, prohibit or limit the withdrawal of water from any well during any period that he determines that water to fill any water right in said well is not there available. . . . Water in a well shall not be deemed available to fill a water right therein if withdrawal therefrom of the amount called for by such right would affect, contrary to the declared policy of this act, the present or future use of any prior surface or ground water right . . . ."[79]

Arguably, perhaps, the declared policy of conserving ground cuts against closing a junior well if the water thereby left in the ground would be "wasted" in the sense that it would benefit a senior appropriator only insignificantly. If this stretches the concept of conservation too far, much the same argument can be made based on the court's recent decision in Parker v. Wallentine.[80] There the court said the Ground Water Act is a vehicle to implement a state

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[79] Id. (emphasis added). Regarding local ground water boards, Idaho Code § 42-237c (1977) empowers a board to determine "whether the use of the junior right affects, contrary to the delcared policy of this act, the use of the senior right.

[80] 103 Idaho 506, 650 P.2d 648 (1982).

policy of optimum development of water resources.[81] A policy of optimum development arguably cuts against closure of junior diversions if the benefit to senior rights would be too insignificant. Whether significance would be tested by the "usable quantities" standard of Martiny v. Wells remains to be seen.

Turning to administrative statutes that might bear on the issue of delayed impact, Idaho Code § 42-233a defines a critical ground water area as "any ground water basin, or designated part thereof, not having sufficient ground water to provide a reasonably safe supply . . . as may be determined and designated, from time to time, by the director of the department of water resources." The power to designate only part of a basin as critical may be explainable on several grounds. For example, it may have been intended to take care of cases where good hydrologic data regarding inflow and outflow is available for only part of a basin. Possibly, however, it was also intended to cover cases where one part of a basin is remote from another part, and withdrawals of water from the remote portion will not have any impact on the other part for many years.

An interesting limitation is found in Idaho Code § 42-233b, which deals with ground water management areas. That section says in part:

> "The director, upon determination that the

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[81] 103 Idaho at 512, 650 P.2d at 654. This policy is discussed infra p. 143-53.

> ground water supply is insufficient to meet the demands of water rights within all or portions of a water management area, shall order those water right holders on a time priority basis, within the area determined by the director, to cease or reduce withdrawal of water until such time as the director determines there is sufficient ground water. Such order shall be given only before September 1 and shall be effective for the growing season during the year following the date the order is given."

Technically, perhaps, the Director could issue a closure order before September 1 for the growing season the following year, even though the benefits will not be realized by senior appropriators for a several years or more. One wonders, however, whether the tenor of the statute is more short range.

Perhaps, the issue of delayed impact of tributary diversions upon the main source would be influenced by the general policy of optimum development of water. If closure of a junior diversion on a tributary would not add more water to the main source for, say, 100 years, the present value of the future benefits on the main source may be de minimis compared to the present value of the costs of immediate closure of the junior diversion. However, it remains to be seen whether such a consideration could in fact affect application of the priority principle in Idaho.

In sum, the Idaho statutes authorizing administrative regulation are problematic regarding the magnitude and timing of the impact of junior tributary diversions on senior appropriations from the main source. That being the case, it may be useful to consider developments in Colorado regarding the issues of magnitude and timing of impact.

Colorado law distinguishes between ground water that is tributary to a natural stream and ground water that is not.[82] Generally, tributary ground water is treated as if it were part of the main source, while nontributary water is subject to other rules.[83] By statute, tributary ground water consists of "that water in the unconsolidated alluvial aquifer of sand, gravel, and other sedimentary materials, and all other waters hydraulically connected thereto which can influence the rate or direction of movement of the water in that alluvial aquifer or natural stream."[84] In one case, permits were denied for two wells that would divert ground water which was hyrologically connected with an over-appropriated river thirteen miles distant. The ground water was moving toward the river at the rate of

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[82] See State v. Southwestern Colorado Water Conservation Dist., 671 P.2d 1294 (1983). Nontributary ground water is further classified according to whether or not it is within a designated ground water basin. Id.

[83] Tributary ground water is governed by the Water Right Administration Act of 1969, Colo. Rev. Stat. art. 92, tit. 37 (1973 & Supp. 1983). Nontributary ground water is governed by the Ground Water Management Act of 1965, Colo. Rev. Stat. art. 90, tit. 37 (1973 & Supp. 1983), except for a recent amendment to art. 92, tit. 37 regarding water court jurisdiction to adjudicate rights in nontributary ground water outside of designated basins.

[84] Colo. Rev. Stat. § 37-92-103(11) (1974); State v. Southwestern Colorado Water Conservation Dist., 671 P.2d 1294, 1300 n.2 (1983).

.3 mile per year, so that apparently the water would take about 40 years to reach the stream.[85]

In a later case, ground water in a particular area was moving at the rate of 175 to 300 feet per year toward two streams, one of which was eight miles away and the other of which was sixteen miles away. The court noted that if the water moved at an average rate of 237.5 feet per year, it would take the ground water 178 years to reach one of the rivers and 356 years to reach the other. The court held that the ground water was in effect nontributary. With reference to the statute defining tributary water as water which can "influence" the rate or direction of movement of water in the main source, the court said:

> "We cannot believe that the General Assembly was talking about water that could not influence the rate or direction of movement of a stream for over a century. By the time the rivers are affected by the pumping from this basin, we have little doubt but what scientific progress will have solved many of the problems cause by the failure of this water then to reach the stream."[86]

As noted earlier, the Colorado Constitution, like the Idaho Constitution, says the right to appropriate the unappropriated waters of any natural stream to beneficial use shall never

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[85] Hall v. Kuiper, 181 Colo. 130, 510 P.2d 329 (1973).

[86] Kuiper v. Lundvall, 187 Colo. 40, 529 P.2d 1328, 1331 (1974). A subsequent case added: "The fundamental consideration actually is the length of time in which use of the wells will affect the surface stream, not necessarily limited to a consideration of the length of time which the water upon being left undisturbed would reach the stream." District 10 Water Users Ass'n v. Barnett, 198 Colo. 291, 599 P.2d 894 (1979).

be denied, and priority of appropriation shall give the better right to use water.[87] The court held "that as to the water taking over a century to reach the stream, the tributary character is de minimis and that this is not a part of the surface stream as contemplated by our Constitution."[88] This suggests that the Colorado approach to delayed impact could be followed in Idaho without any constitutional difficulty.

Perhaps, though less clearly, that approach could be followed under the existing Idaho statutes. The statutory basis for distinguishing between tributary and nontributary ground water is more elaborate in Colorado, and the reasons for doing so are different,[89] but even in Colorado it was necessary to do some reading between the lines to conclude that ground water which will not influence the flow of a stream for over a century should not be treated as part of the stream. On the other hand, the Colorado court's rationale for a hundred year test seems to be based on optimism about "scientific progress" solving future water shortages. Whether that rationale would be persuasive to the Idaho court remains to be seen.

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[87] Supra note 66 and accompanying text.

[88] 529 P.2d at 1331.

[89] See generally State v. Southwestern Colorado Water Conservation Dist., 671 P.2d 1294 (Colo. 1983); Note, A Survey of Colorado Water Law, 47 Den. L.J. 226, 308-339 (1970).

Selection of Junior Diversions for Closure

Suppose a hundred wells tap a ground water basin that is tributary to an over-appropriated surface stream. Most of the surface appropriations are senior to most of the ground water appropriations. Under integrated administration of priorities, some of the ground water appropriations will have to be shut down. It will not be necessary, however, to shut down all of the wells. The problem is which juniors should be shut down.

The priority principle itself does not necessarily solve the problem. Suppose two dozen of the most junior wells are situated at the far end of the basin from the stream. Closure of these wells will eventually restore the streamflow to the required rate. However, due to the slow movement of the ground water, it will take twenty years for this to occur. Two dozen of the most senior wells are located close to the stream, and closure of these wells will restore the streamflow within a week or two. Farther back are wells of intermediate priority, and closure of about two dozen of these will restore the streamflow within some intermediate period of time.

If only the most junior, and remote, wells are closed, the senior stream appropriators probably will have long since gone bankrupt by the time the streamflow is restored. Even if they avoid bankruptcy by collecting damages from the junior well owners, their established water uses will have long since disappeared. If only the most senior, and nearby, wells are closed, the stream appropriators will get fairly prompt relief, but those wells may never be able to resume pumping, while the more remote, junior wells continue to operate every year. If all the wells are closed in the hope that eventually the more senior wells will be allowed to resume operation, the immediate result may be Draconian; and over the longer term, hydrologic issues may arise that are more expensive to solve than the answer is worth.

Recent Colorado experience is of interest in connection with this type of problem. Acting under a statute calling for integrated administration of surface and ground water rights under the priority principle, the Colorado Division Engineer ordered curtailment of 39 out of more than 1600 wells in the Arkansas Valley in order to satisfy surface priorities. In Fellhauer v. People,[90] the administrative action was held invalid, principally on the ground that the selection of wells for closure was arbitrary and thus violated the constitutional guarantee of equal protection of the laws. The court said that regulation of wells in the valley would have to comply with three requirements:

> "(1) The regulation must be under and in compliance with reasonable rules, regulations, standards and a plan established by the state engineer prior to the issue of the regulative orders.
> (2) Reasonable lessening of material injury to senior rights must be accomplished by the regulation of the wells.
> (3) If by placing conditions upon the use of

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[90] 167 Colo. 320, 447 P.2d 986 (1968).

> a well, or upon its owner, some or all of its water can be placed to a beneficial use by the owner without material injury to senior users, such conditions should be made."[91]

Following the Fellhauer decision, the State Engineer promptly issued regulations that took an innovative approach to enforcement of priorities. The regulations were to be effective only from August 8, 1969 to October 15, 1969. Wells were grouped into zones based on the time between withdrawal of water and initial effect on streamflow: Wells in Zone A were estimated to affect streamflow within 10 days; wells in Zone B within 10 to 30 days; and wells in Zone C within 30 to 75 days. A well was deemed to affect streamflow if it would have an impact on the river equal to 5% of the consumptive use of water appropriated by the well. Wells were to be closed only upon written demand of a senior surface appropriator, and no wells could be closed more than three days per week. As the end of the irrigation season approached, wells were to be allowed to resume full pumping by zone once pumping from that zone would not affect the river until after the end of the irrigation season. The rules were never implemented because of a trial court injunction, but subsequently the Colorado Supreme Court upheld the rules against attack on no less than twenty-

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[91] Id. at 334, 447 P.2d at 993 (1968).

four grounds.[92] Although the court upheld the zone approach, the State Engineer abandoned it in later regulations.[93]

In 1971, Colorado enacted a statute that says: "The state engineer may adopt rules and regulations to assist in, but not as a prerequisite to, the performance of [his] duties."[94] However, the constitutionality of that statute has never been squarely determined,[95] and administrative integration of priorities in Colorado has continued to proceed through the issuance of rules and regulations.

In Idaho, the Director of the Department of Water Resources has clear authority to administer priorities by issuing summary orders that prohibit or limit ground water withdrawals.[96] Whether the Director could proceed by issuing rules or regulations is less clear. The Department of Water Resources is directed by statute to "devise all needful rules for the distribution of water from the streams, as shall be necessary to carry out the laws in accordance with the priorities of the rights of the users thereof."[97]

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[92] Kuiper v. Well Owners Conservation Ass'n, 176 Colo. 119, 490 P.2d 268 (1971). The regulations are included in an appendix to the court's opinion.

[93] Hannay, Recent Developments in Colorado Groundwater Law, 58 Den. L.J. 801, 811; Hillhouse, Integrating Ground and Surface Water Use in an Appropriation State, 20 Rocky Mt. Min. L. Inst. 691, 713-19 (1975).

[94] Colo. Rev. Stat. § 37-92-501(1) (1973).

[95] Hannay, supra note 93, at 810 (1981).

[96] Idaho Code § 42-237a(g) (Supp. 1983).

[97] Idaho Code § 42-603 (1977)(emphasis added).

Arguably, at least, this statute authorizes the issue of rules not only for streams but for ground water sources that are tributary to streams.

Burden of Proof

The question of who has the burden of proof is highly important in conjunctive management of surface and ground water. In fact, one commentator went so far as to say:

> "The factual problems are sufficiently difficult that whoever has the burden of proof is likely to lose. The pumper of groundwater will lose if he must prove that he does not deplete a surface stream; the user of water from the stream will lose if he must prove that the pumper is depleting a stream. Although any court . . . should be able to take judicial notice that most ground water feeds a surface stream at some time and some place if its water is not earlier diverted, to determine where, when, and by how much, and which water users are affected remains a difficult matter."[98]

The burden of proof question can arise both in private litigation between senior and junior appropriators, and in connection with administrative regulation of interrelated surface and ground water.

Litigation between senior and junior appropriators in Idaho has been uneven regarding allocation of the burden of proof. The vacillation goes back to early cases dealing with surface water appropriations. In 1904, in Cartier v. Buck,[99] a senior appropriator at the lower end of a

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[98] C. Corker, Groundwater Law, Management and Administration 149-50 (1971).

[99] 9 Idaho 571, 75 P. 612 (1904). Apparently the case involved only surface water appropriators, since the court did not mention ground water or wells.

creek sought to enjoin diversion by junior appropriators from the creek and its tributaries. The court seemed to say the senior appropriator had the burden of proving the junior diversions interfered with his supply. A few months later, however, the court took the opposite approach in Moe v. Harger,[100] which was a suit to decree water rights in the Big Lost River and enjoin diversion except in accordance with priorities recognized in the decree. About 40,000 inches of water were decreed from the river, but the river carried only 9,000 inches at low water. Thus, it was clear no water would be available during low water for junior appropriators. The court noted that the situation was similar to Cartier. Yet, apparently without awareness of any inconsistency, the court also said:

> "Where prior appropriators have diverted the amount of water to which they are entitled and, for example, say one hundred inches, to which the next appropriator is entitled, is left in the stream and a settler above diverts a part or all of the remaining water, the presumption must at once arise that such diversion will be to the injury and damage of the prior appropriator entitled thereto. . . . The subsequent appropriator who claims that such diversion will not injure the prior appropriator below him should be required to establish that fact by clear and convincing evidence."[101]

In 1908, in Josslyn v. Daly,[102] which was another suit to adjudicate water rights, one issue on appeal was whether

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[100] 10 Idaho 302, 77 P. 645 (1904).

[101] 10 Idaho at 307, 77 P. at 647.

[102] 15 Idaho 137, 96 P. 568 (1908).

certain springs and a lake were tributary to a fully appropriated creek. The court remanded the case for trial on that issue, but offered the following comment:

> "[I]f these springs are in the gulch or valley through which [the creek] flows, and toward which their waters would naturally percolate and flow, then they must be in a sense and measure tributary to the stream; and the only further question that can arise is as to the amount of water that could reach the main stream from these springs or sources of supply. It seems self-evident that to divert water from a stream or its supplies or tributaries must in a large measure diminish the volume of water in the main stream, and where an appropriator seeks to divert water on the grounds that it does not diminish the volume in the main stream or prejudice a prior appropriator, he should, as we observed in Moe v. Harger, 10 Ida. 305, 77 Pac. 645, produce 'clear and convincing evidence showing that the prior appropriator would not be injured or affected by the diversion.' The burden is on him to show such facts."[103]

At this point, then, two out of three cases put the burden on juniors to prove no interference. Furthermore, those two cases indicated the proof must be by clear and convincing evidence.

In 1915, in Bower v. Moorman,[104] the court addressed its first case of alleged interference involving ground water appropriations. A senior with several artesian wells claimed that construction of a junior well reduced the flow from his wells. The court said no injunction could issue against the junior well unless the evidence conclusively proved that well caused the reduced flow from the senior

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[103] 15 Idaho at 148-49, 96 P. at 571-72.

[104] 27 Idaho 162, 147 P. 496 (1915).

wells. The next year, in Jones v. Ausdeln,[105] the court again dealt with alleged well interference. And again, the court said no injunction could issue in the absence of very convincing proof of interference by the junior well. These two cases, then, seem to say a senior appropriator of ground water has the burden of proving interference by a junior well, at least when the senior is seeking to enjoin diversion by the junior.

Since 1919, the court has indicated in at least five cases that the burden of proof is on a junior appropriator to show no interference, rather than on a senior appropriator to show interference.[106] These cases appear not to be limited to circumstances like those in Moe v. Harger, where the senior appropriator's immediate source of supply was clearly over-appropriated. One of the cases even involved a dispute between senior and junior appropriators of ground water, and began as a suit to decree priorities and enjoin junior diversions in such manner as would deplete the senior wells.[107]

Turning to administrative regulation, there is virtually no specific guidance in Idaho law regarding allocation

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[105] 28 Idaho 743, 156 P. 615 (1916).

[106] Martiny v. Wells, 91 Idaho 215, 419 P.2d 470 (1966); Cantlin v. Carter, 88 Idaho 179, 397 P.2d 761 (1964); Silkey v. Tiegs, 54 Idaho 126, 28 P.2d 1037 (1934); Jackson v. Cowan, 33 Idaho 525, 196 P. 216 (1921); Neil v. Hyde, 32 Idaho 576, 186 P. 710 (1919).

[107] Silkey v. Tiegs, *supra* note 106; Silkey v. Tiegs, 51 Idaho 344, 5 P.2d 1049 (1931).

of the burden of proof. Of interest, though, is Hart v. Stewart,[108] which involved an appeal from a decision by a local ground water board. Senior appropriators had requested that a board be convened to determine if a junior appropriator was responsible for diminishing their supply of ground water. The court's opinion mentions that the board placed the burden of proof on the senior appropriators to show interference. However, the court disposed of the appeal on a technical ground without having to address whether the burden of proof had been properly allocated.

For contested cases, in which opportunity for a hearing is required,[109] a standard treatise on state administrative reports:

> "The state courts quite uniformly impose on agencies the customary common-law rule that the moving party has the burden of proof, including not only the burden of going forward but also the burden of persuasion. This means, of course, that when an applicant appears before an agency seeking to establish a claim or obtain a license, the burden is on him. Conversely, when the agency is the moving party, the burden is on it."[110]

The local ground water board's allocation in Hart is consistent with the rule quoted above, since the senior appropriators

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[108] 95 Idaho 781, 782, 519 P.2d 1171, 1172 (1974).

[109] Idaho Code § 67-5209 (1980) requires that all parties to a contested case be afforded an opportunity for hearing after reasonable notice. Unfortunately, the definition of a contested case is circular. Idaho Code § 67-5201(2) (Supp. 1983) defines a contested case as one in which an opportunity for a hearing is required before an agency determines the legal rights or duties of a party.

[110] Id. at 355.

clearly were the moving parties.

Identifying the moving party may not always be so clearcut.[111] For example, section 42-237a(g) says the Director of the Department of Water Resources may by summary order prohibit or limit the withdrawal of water from a well during any period that he determines water is not available. It says further that water shall not be deemed available for a well if its operation would affect, contrary to the policy of the ground water act, any prior surface or ground water right. Then it says:

> "[I]n the administration of ground water rights either the director of the department of water resources or the watermaster in a water district or the director of the department of water resources outside of a water district shall, upon determining that there is not sufficient water in a well to fill a particular ground water right therein by order, limit or prohibit further withdrawals of water under such right as hereinabove provided, and post a copy of said order at the place where such water is withdrawn . . . ."

The section says nothing about a prior hearing. If no prior hearing is held, however, companion legislation requires that any person dissatisfied with the order be afforded an opportunity for a hearing to contest it.[112] Even though such a contest would be initiated by the dissatisfied person, it seems that the proposed action is the closure of a well, rather than the withdrawal of the order of closure. If so, the proponent of the action would be the Director of

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[111] See generally 4 B. Mezines, J. Stein, J. Gruff, Administrative Law § 24.02 (1983).

[112] Idaho Code §§ 42-237e, -1701A(3) (Supp. 1983).

the Department of Water Resources or the watermaster.

Related to the burden of proof question in the administrative context is the issue of judicial review of agency findings. Idaho Code § 67-5215(g) speaks to that issue in contested cases:

> "The court shall not substitute its judgment for that of the agency as to the weight of the evidence on questions of fact . . . . The court may reverse or modify the decision if substantial rights of the appellant have been prejudiced because the administrative findings . . . are . . . (5) clearly erroneous in view of the reliable, probative, and substantial evidence on the whole record . . . ."

Also of interest regarding judicial review of agency findings is Keller v. Magic Water Company, where the court said:

> "[W]e ordinarily must vest the findings of the state engineer with the presumption of correctness. . . . Although such findings do not take from the court the power to grant relief to a party whose rights may have been infringed, it is seldom that a court will interfere with the discretionary action of the state engineer upon matters involving the administration of the water laws of the state. . . . As stated by Mr. Justice Holmes, the state engineer is 'the expert on the spot,'. . . and we are constrained to realize the converse, that 'judges are not super engineers.' . . . . The legislature intended to place upon the shoulders of the state engineer the primary responsibility for a proper distribution of the waters of the state, and we must extend to his determinations and judgment, weight on appeal."[113]

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[113] 92 Idaho 276, 282-83, 441 P.2d 725, 731-32 (1968). In the rule-making process in Colorado, the State Engineer's findings of fact are entitled to judicial deference, but the same is not true of questions of law such as the extent to which rules and regulations are supported by statutory authority. In re Rules and Regulations Governing Water Rights in the Rio Grande and Conejos River Basins, 674 P.2d 914 (Colo. 1984); Kuiper v. Well Owners Conservation Ass'n, 176 Colo. 119, 490 P.2d 268 (1971).

In Keller, the State Engineer[114] was not the moving party. He had acted on an application for a permit to appropriate and on petitions to extend the time to complete the appropriation. The court has not explicitly addressed whether the reasoning in Keller would apply fully if the agency itself is the proponent of action. However, a few months after Keller decision, the court did cite that case in upholding the State Engineer's decision, apparently without any formal prior hearing, to designate a large portion of the Raft River drainage basin as a critical ground water area.[115]

Allocation of the burden of proof was a central issue in a recent Colorado case, In re Rules and Regulations Governing Water Rights in the Rio Grande and Conejos River Basins.[116] As the result of a stipulation in litigation over an interstate water compact, it became necessary for Colorado to curtail water use in the San Luis Valley. Most of the senior water rights in the valley were surface rights, and most of the junior rights were ground water rights. To accomplish the necessary curtailment, the Colorado State Engineer issued proposed rules that, inter alia, integrated tributary ground water diversions into the priority

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[114] The position of Director of the Department of Water Resources was formerly called the State Reclamation Engineer. Idaho Code § 42-1801a (1977).

[115] State ex rel. Tappan v. Smith, 92 Idaho 451, 458, 444 P.2d 412, 419 (1968).

[116] 674 P.2d 914 (Colo. 1984).

system for surface streams. The rules were intended over a five-year period to prohibit ground water diversions unless individual well owners could prove that their wells did not injure senior rights or could provide substitute supplies to the seniors.

The rules were challenged before a Colorado water court. After taking evidence, the water court found that ground water in the valley was tributary to surface streams and that well diversions were reducing surface supplies. The court also found, however, that the impact of the ground water withdrawals had not been specifically quantified and had not been attributed to individual wells. The court then held that the rules to integrate surface and ground water priorities were invalid because they did not require proof that each individual well subject to curtailment materially interfered with a senior water right. The water court relied on a state statute that prohibited the curtailment of a diversion unless it caused "material injury" to senior rights, and also used language referring to "each case" and "each diversion."

On appeal, the Colorado Supreme Court disagreed. It said:

> "The purpose of the materiality of injury requirement is to prevent the futile curtailment of underground water diversions, not to erect a procedural roadblock to effective regulation of wells. . . .
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> "[W]here, as here, streams are over-appropriated and underground water diversions from an aquifer have been found to significantly affect stream flow, it may be presumed that each underground water diversion materially injures senior appropri-

> ators. The state engineer, therefore, will not be required to repeat for every well curtailed the painstaking analysis which led to the aquifer-wide determination of material injury. See Safranek v. Limon, 123 Colo. 330, 228 P.2d 975 (1951)(It is presumed that all water contributes to the stream.); cf. State v. Vickroy, 627 P.2d 752 (Colo. 1981)(Once a designated underground water basin has been established, a party asserting that certain underground water within the basin is not designated has the burden of proof.).

While there are differences between the statutory and case law of Idaho and Colorado, a parallel can be found between the above statement and language quoted previously from the early Idaho case of Moe v. Harger.[117] Again quoting that language, the Idaho court said:

> "Where prior appropriators have diverted the amount of water to which they are entitled and, for example, say one hundred inches, to which the next appropriator is entitled, is left in the stream and a settler above diverts a part or all of the remaining water, the presumption must at once arise that such diversion will be to the injury and damage of the prior appropriator entitled thereto. . . .The subsequent appropriator who claims that such diversion will not injure the prior appropriator below him should be required to establish that fact by clear and convincing evidence."[118]

Suppose the Director of the Idaho Department of Water Resources issues orders to close down junior wells to protect the supply to prior surface water rights. If Idaho were to adopt for such orders the Colorado approach to regulations, even though the Director is considered the moving party in the action, he would need to show only that the stream

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[117] See supra note 100 and accompanying text.

[118] 10 Idaho at 307, 77 P. at 647 (emphasis added).

is over-appropriated and that on an aquifer-wide basis, diversions of ground water are significantly affecting the stream flow. Then each individual junior ground water appropriator would have to prove that his well does not injure any senior surface water appropriator.

Policy Objectives

In Idaho's first reported water case, Malad Valley Irrigating Co. v. Campbell,[119] the court integrated priorities on physically interrelated surface sources. The court explained as follows:

> "If persons can go upon the tributaries of streams whose waters have all been appropriated and applied to a useful and legitimate purpose, and can take and control the waters of such tributaries, then, indeed, the sources of supply of all appropriated natural streams may be entirely cut off, and turned away from the first and rightful appropriators. To allow this to be done would disturb substantial vested rights, and the law will not permit it."[120]

The court's stated objective in integrating priorities was to protect substantial vested rights. If that is the only objective, simple integration of priorities accomplishes it well.

Modern state water policy, however, is not necessarily limited to protecting substantial vested rights. In 1964, the Idaho Constitution was amended by the addition of article 15, section 7, calling for the establishment of a state water resource agency with "power to formulate and implement

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[119] 2 Idaho 411, 18 P. 52 (1888).

[120] 2 Idaho at 415, 18 P. at 54.

a state water plan for optimum development of water resources in the public interest . . . under such laws as may be prescribed by the Legislature."[121] The next year, the legislature established such an agency and called it the Idaho Water Resource Board.[122] The constitutional amendment might be read narrowly as pertaining only to the water planning function of the Water Resource Board. However, the Idaho court has seemed to view it as stating a more far reaching policy of optimum development of water resources in the public interest.

In Baker v. Ore-Ida Foods, Inc.[123] the court commented as follows on the Ground Water Act:

> "Idaho's Ground Water Act seeks to promote 'full economic development' of our ground water resources. . . . We hold that the Ground Water Act is consistent with the constitutionally enunciated policy of promoting optimum development of water resources in the public interest. Idaho Const. art. 15, §7. Full economic development of Idaho's ground water resources can and will benefit all of our citizens."[124]

The court also discussed its earlier decision in Noh v. Stoner,[125] which had held that a senior appropriator is forever protected from any interference with his historic

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[121] The history of this amendment is discussed in Grant, The Idaho Water Plan: Two Threshold Constitutional Problems and Suggested Solutions, 15 Idaho L. Rev. 443, 444-47 (1979).

[122] 965 Idaho Sess. Laws, ch. 320, § 2, currently codified as Idaho Code § 42-1732 (Supp. 1983).

[123] 95 Idaho 575, 513 P.2d 627 (1973).

[124] Id. at 584, 513 P.2d at 636.

[125] 53 Idaho 651, 26 P.2d 1112 (1933).

pumping level. The court noted that the Ground Water Act protects only reasonable pumping levels for senior appropriators and volunteered the following: "We hold Noh to be inconsistent with the constitutionally enunciated policy of optimum development of water resources in the public interest."[126] In short, the court seemed to view the policy of article 15, section 7 as affecting more than just the water planning function of the Idaho Water Resource Board, and to view the Ground Water Act as incorporating much the same policy.

In Parker v. Wallentine,[127] the court concluded that prior to a 1978 amendment, a provision in the Ground Water Act protecting senior appropriators only in reasonable means of diversion did not apply to domestic wells. The court held that pre-1978 domestic wells were protected in their historic means of diversion. While this holding perpetuates (or revives) Noh v. Stoner in a limited context, the balance of the court's discussion reaffirms the existence of a broadly applicable policy of optimum development of water resources. After quoting the optimum development language of article 15, section 7, the court said: "The Ground Water Act was the vehicle chosen by the legislature to implement the policy of optimum development of water resources."[128] This statement perhaps reflects judicial

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[126] 95 Idaho at 583, 513 P.2d at 635.

[127] 103 Idaho 506, 650 P.2d 648 (1982).

[128] 103 Idaho at 511-12, 650 P.2d at 653-54.

eagerness to give article 15, section 7 broad effect, since the basic structure of the Ground Water Act was enacted more than a decade before the constitutional amendment was passed. The court went on to say: "[I]t is clearly state policy that water be put to its maximum use and benefit," citing inter alia article 15, section 7.[129] But the court also traced judicial recognition of the policy of maximum use back to 1915 case.[130] To harmonize protection of the historic pumping level of pre-1978 domestic wells with the policy of maximum development of water resources, the court held that a junior appropriator can lower the pumping level in a pre-1978 domestic well if he pays the domestic user's increased costs of diversion.

If modern state water policy is aimed not just at protecting vested rights but at optimum development of water resources in the public interest, conjunctive management might entail more than integration of priorities on physically interrelated sources of supply. Developments in Colorado illustrate what else might be involved. Those developments began with the Fellhauer case.[131] There the court considered the provision in the Colorado Constitution which, like Idaho Constitution article 15, section 3, says that the right to divert the unappropriated waters of natural streams

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[129] 103 Idaho at 513, 650 P.2d at 655.

[130] Id. The case was Bower v. Moorman, 27 Idaho 162, 147 P. 496 (1915).

[131] Supra note 90.

to beneficial use shall never be denied and that priority in time shall give the better right to use water. The court said:

> "It is implicit in these constitutional provisions that, along with *vested rights*, there shall be *maximum utilization* of the water of this state. As administration of water approaches its second century the curtain is opening upon the new drama of *maximum utilization* and how constitutionally that doctrine can be integrated into the law of *vested rights*."[132]

Thus, the court recognized dual policy objectives and potential tension between them.

Following *Fellhauer*, Colorado enacted legislation to guide the State Engineer in issuing rules and regulations to integrate priorities in surface water and tributary ground water. The Water Right Determination and Administration Act declares it to be state policy to integrate priorities "in such a way as to maximize the beneficial use of all the waters of this state."[133] At the same time, the Act says that previously vested rights "shall be protected subject to the provisions of this article."[134] A major feature in the Act's effort to reconcile these two objectives is the augmentation plan concept, under which a junior appropriator who would otherwise be closed down is allowed to continue to divert water if he augments the water supply

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[132] 447 P.2d at 994 (emphasis in original).

[133] Colo. Rev. Stat. § 37-92-102(1) (Supp. 1983).

[134] *Id.* at 37-92-102(2)(a) (1973).

so that senior appropriators receive the water to which they are entitled. The Act says:

> "'Plan for augmentation' means a detailed program to increase the supply of water available for beneficial use in a division or portion thereof by the development of new or alternate means or points of diversion, by a pooling of water resources, by water exchange projects, by providing substitute supplies of water, by the development of new sources of water, or by any other appropriate means."[135]

Thus, junior appropriators might provide senior appropriators with alternate points of diversion, substitute water, etc. For a plan of augmentation to be approved, the program must not injuriously affect any senior appropriator.[136] It has been suggested that the no injury criterion for augmentation plans is being applied less stringently than is a similar no injury rule that has long limited water right transfers under the appropriation doctrine.[137]

In Idaho, some analogies to the augmentation plan concept can be found. In Parker v. Wallentine,[138] to promote the policy of optimum development of water, the court held that a senior ground water appropriator with a protected means of diversion could not prevent a junior appropriator from lowering the water level at the senior well if the junior paid the senior's increased diversion expenses.

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[135] Colo. Rev. Stat. § 37-92-103(9) (Supp. 1983).

[136] Colo. Rev. Stat. 37-92-305(3) (1973).

[137] C. Meyers & A. Tarlock, Water Resource Managment 771 (2d ed. 1980).

[138] Supra note 127.

In addition, an Idaho statute authorizes water exchanges if the amount of water available to senior appropriators will not be diminished. These analogies, however, do not begin to approach the emphasis and role in Colorado given to plans for augmentation. Furthermore, even though the Idaho exchange statute could perhaps be applied to ground water as well as surface water, it is seriously limited by a requirement that consent must be obtained from each appropriator with whom the exchange is proposed to be made.

A major new development in Colorado's efforts to reconcile protection of vested rights with maximum use of water came in the recent decision in _In re Rules and Regulations Governing Water Rights in the Rio Grande and Conejos River Basins_.[139] As noted earlier, the proposed rules challenged in this case were intended over a five year period to prohibit well diversions in the San Luis Valley unless individual well owners could prove that their wells did not injure senior rights or could provide a plan for augmentation to replace water taken by their wells. In that case, the water court disapproved the well regulations because, _inter alia_, in some instances senior streams appropriators maybe should be required to drill wells to augment or replace their surface diversions before being entitled to curtail junior rights, and the State Engineer had not considered that possibility in developing the regulations. In concluding

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[139] _Supra_ note 116.

that senior surface water appropriators in some instances might properly be required to shift to ground water diversions, the water court relied on (1) the statutory requirement of integrating the administration of surface and ground water, (2) the state policy of maximum utilization of water, and (3) statutory and case law requiring a reasonable means of diversion.

The Colorado Supreme Court agreed and remanded the proposed rules to the State Engineer for consideration of whether, under the circumstances, the reasonable-means-of-diversion doctrine would provide a method of maximum utilization of water. However, the court added a cautionary comment:

> "We note that the policy of maximum utilization does not require a single-minded endeavor to squeeze every drop of water from the valley's aquifers. Section 37-92-501(2)(e) makes clear that the objective of 'maximum use' administration is 'optimum use.' Optimum use can only be achieved with proper regard for all significant factors, including environmental and economic concerns. See section 37-92-102(3), C.R.S. (recognizing the need to correlate the activities of mankind with reasonable preservation of the natural environment); Harrison & Sandstrom, supra, at 14-15 (An increase of well diversions at the expense of maintenance of a surface flow would increase the efficiency of irrigation at the expense of other environmental and economic values)."[140]

The court went on to say:

> "The water court observed that the state engineer's reconsideration might take the form of requiring senior appropriators to drill new wells before requiring curtailment of junior rights and listed a number of suggestions for increasing utilization.

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[140] 674 P.2d at 935.

> Similarly, the state engineer's reconsideration might result in assessment to junior appropriators of the cost of making those improvements to seniors' diversions which are necessitated by junior withdrawals. Selection among these and other possibilities, including retention of the scheme of the proposed rules, is a policy decision to be made by the state engineer, after consideration of all relevant factors."[141]

In comparing Idaho law, it is interesting that Idaho has (1) a state policy of maximizing water use, (2) something of a foundation in statutory and case law for integrating the administration of surface and ground water, and (3) statutory and case law requiring a reasonable means of diversion (except for pre-1978 domestic wells). The Idaho foundation for integrating surface and ground water has perhaps focused more on integrating priorities than on broader scale integrated administration. Nevertheless, there are enough similarities between Idaho and Colorado law that as pressures on available water supplies in Idaho increase, thoughtful consideration by Idaho legislators, judges, and administrators of approaches tried in Colorado would seem merited.

A discussion of policy objectives in conjunctive management of surface and ground water would not be complete without including another potential concern. When ground water diversions are located some distance from a stream to which the ground water is tributary and the rate of movement of the water through the ground is slow, numerous

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[141] _Id_.

wells may have been constructed and operated for many years before anyone realizes that the wells are going to interfere with the supply to senior surface water appropriators. During those years before the hydrologic connection was realized, the surface water and ground water will have been administered as separate sources of supply. A local economy will have developed dependent on ground water use. Once the hydrologic connection is discovered, integrated enforcement of priorities against junior wells may have a devastating effect on the local economy.

The problem is described well in the following passage from a recent Colorado opinion, even though the court happened to be talking about a situation other than conjunctive management of surface and ground water:

> "As a result of the doctrine of prior appropriation, local economies develop based on vested rights in appropriations, subject to the vagaries of nature, but with settled expectations---arising out of the pattern of development of a water source---as to how water is to be allocated. Under prior appropriation doctrine water is allocated according to chronology because such allocation has the effect of protecting historic patterns of use. . . . To . . . [re-sort] settled water rights on both . . . [sources of supply] into a single system of priorities based solely on dates of appropriation would reshuffle economies of the valley according to a chronology of events unrelated to settled expectations derived from historical patterns of use and reflected in independent priority systems."[142]

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[142] In re Rules and Regulations Governing Water Rights in the Rio Grande and Condjos River Basins, 674 P.2d 914, 923 (Colo. 1984).

In short, there is a dilemma. Hydrologic reality and the priority principle of the appropriation doctrine call for integration of surface and ground water priorities. However, junior ground water appropriators, like senior surface appropriators, may have settled expectations derived from long continued uses. To the extent that the priority principle is based on a policy of protecting expectations derived from historic patterns of use, application of that principle against long standing junior uses is troublesome.

Aside from whatever appeal a policy of optimum development of water resources has generally, that policy has a special appeal in the situation just described. Optimum development will give some protection to settled junior rights: With optimum development, more appropriators can divert and use water, and fewer juniors will have to be closed.

Conclusion

Idaho law on conjunctive management of physically interrelated surface and ground water is at an embryonic stage of development. The existing structure of statutory and case law has gaps that result in a number of more or less technical legal uncertainties and complexities. At a more fundamental level, however, lies the need to resolve potential conflict between the policies of protecting senior vested rights and optimum development of water resources. Those two policies will not conflict in all conjunctive management situations, but where they do, solutions are likely to be difficult and controversial.