IMPACT OF LEGAL CONSTRAINTS ON GROUND-WATER RESOURCE DEVELOPMENT IN IDAHO

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Dale Roger Ralston

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Major Professor Donald F. Haber Date Aug. 27, 1974

Committee Members Edgar L. Michalson Date Aug 27, 1974

Roy E. Williams Date Aug 27, 1974

Douglas L. Grant Date Aug 27, 1974

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Department Head R. L. Schuster Date Oct. 10, 1974

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ABSTRACT

Ground-water management in Idaho is based on the appropriation doctrine of water law. Legislative phrases such as "full economic development...reasonable ground-water pumping levels...(and) reasonably anticipated average rate of future natural recharge" are the basis for ground-water administration. This thesis provides an analysis of possible administrative actions utilizing a mathematical model of a selected water resource system.

Five basic decisions are outlined for the administration of ground water under the constraints set forth in the Idaho Code: 1) selection of the management tool, 2) definition of the concept, 3) selection of the size of the administrative units and the length of the administrative period, 4) selection of the reasonable pumping lift or recharge value or values for each administrative area and 5) application of the selected value to junior users within the administrative area.

The mathematical model of the water resource system in the Raft River Basin in southern Idaho was used to evaluate the impact of different combinations of management decisions. Operation of the mathematical model indicated that the senior users at the designated reasonable pumping levels received little benefit from closure of juniors under any of the management schemes.

The degree of maintenance for a senior's means of diversion is only partially measured by his water right priority. The extent of protection is also dependent on his location both in the basin and with respect to other users and the relative priority of the surrounding users.

It is concluded that effective ground-water management may occur in Idaho by the development of adequate definitions and techniques of administration under the two main concepts of reasonable ground-water pumping levels and reasonably anticipated average rate of future natural recharge.

CHAPTER I

INTRODUCTION

Purpose and Scope of the Study

The appropriation doctrine of water law is the basis for ground-water administration in a number of western states. The broad statements presented in individual state statutes are the guidelines for control of the development and location of new wells and the continued operation of existing wells. These guidelines have generally been satisfactory for the period of time when the ground-water resource was being developed. However, many states are now facing conditions of well interference, declining water levels and basin overdraft which require administrative management decisions. The broad guidelines must be interpreted and quantified for resource administration . This thesis presents an analysis of ground-water management alternatives possible under the broad guidelines of the appropriation doctrine as expressed in the legal code for Idaho.

Legislative phrases such as "full economic development...reasonable ground-water pumping levels...(and) reasonably anticipated average rate of future natural recharge" are the basis for ground-water administration in Idaho. Each of these phrases is subject to a wide range of interpretation. Questions also arise in the application of these regulatory concepts to a particular basin. At least five levels of decision are required to administer the ground-water resource in a particular basin under the legislative phrases presented in the Idaho Code. Many alternative management schemes are thus possible for resource administration. This thesis provides an analysis of possible administrative actions and their respective impacts on a selected water resource system.

Statement of the Problem

Ground water is one of the most important natural resources present in the western United States. Problems of management of the resource have proven to be almost as large and complex as the resource itself. These problems have resulted primarily from man's development of the resource.

Ground water is part of the hydrologic cycle, the world's water distribution system. Recharge is from precipitation; discharge is mostly to lakes, streams, oceans and the atmosphere. Although ground water moves under the same general physical laws as surface water, it possesses some characteristics that make management of the resource very unique. Water is generally considered to be a renewable resource. Ground water, however, possesses some of the characteristics of a non-renewable mineral resource. The occurrence of ground water is tied very closely with the geologic environment in which it is found. Water movement is slow, generally measured in terms of feet per year. The resource has both the characteristics of a pipeline and a storage system.

The development of ground water is generally accomplished by the construction and operation of wells. From an operator's point of view, a well is a diversion point similar to a headgate on a stream. From a ground water point of view, it is a vertical line sink with the discharge dependent largely on the hydraulic characteristics of the aquifer system.

Management of the ground-water resource must include consideration of a number of factors. Physical factors include the hydrogeologic environment, the location and characteristics of man-made discharge points, and the relation of the resource to other phases of the hydrologic cycle. Management of the resource is bounded by the existing legal framework. The management guidelines presented in the state code must be followed along with any administrative regulations. The field of economics is necessary to provide a measure of the value of legal and physical certainty of an individual right and the cost of administrative decisions. Ground water is a common pool resource with all the associated problems of economic externalities. Management decisions must also consider the social costs of alternative administrative plans. In short, ground-water management should be the trend toward optimum utilization of the resource within the physical, legal, economic and social constraints.

The appropriation doctrine is a water resource development plan presented as a series of general concepts. The individual water user has some degree of certainty to the continuation of his use of water under this doctrine. The measure of his certainty is the date of his first use of the water or his priority. Ownership of the resource, however, is held by the state; the individual user can only obtain a right to the use of the water. Administration of the resource is placed with the individual state. The state legal code usually contains a limited description of the prior appropriation doctrine with a few general statements intended as guides for management of the resource. Use of the resource is regulated based upon court cases and upon administrative interpretation of the law. A wide range of management plans is possible under such legal guidelines.

Many of the western states that apply the doctrine of prior appropriation are now becoming concerned with detailed management of the ground-water resource. This study is designed to provide a reference for ground-water administration under the doctrine of prior appropriation by the detailed examination of legal constraints presented in the legal code for the state of Idaho.

Objectives

The general objective of the study is to provide a quantitative assessment of the alternatives for ground-water management expressed in the Idaho Code and the court interpretation of that code. The specific objectives are:

1. to evaluate the impact of a water rights adjudication on the utilization of the ground-water resource.

2. to determine the effectiveness and alternative methods of application of the concept of "reasonable ground-water pumping levels" for the management of ground water.

3. to determine the effectiveness and alternative methods of application of the concept of "reasonably anticipated average rate of future natural recharge" as a limit to ground-water development.

4. to determine the relative value of a ground-water right under the appropriation doctrine.

5. to evaluate the effectiveness of the appropriation doctrine as a development plan for ground-water resources.

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CHAPTER II

GROUND-WATER MANAGEMENT - SCOPE OF THE LITERATURE

Introduction

The word management is defined as the "judicious use of means to accomplish an end" (Merriam, 1971). Synonyms for the word include regulation, control, surveillance, protection and stewardship (Dutch, 1966). The wide range of meaning of these synonyms is borne out in the wide range of approaches to resource management. This section of the report provides a review of the literature pertaining to resource management with special emphasis toward ground water. Most of the literature is included in the three general disciplines of hydrology, economics and law.

Hydrologic Equilibrium

The basic components of input to and output from a basin may be presented in an equation of hydrologic equilibrium. This equation is simply an expression of the law of conservation of mass; For any specified area and interval of time, the total inflow of water must equal the total outflow, with proper correction for changes of storage within the area. The equation takes the following form (Todd, 1959, p. 203):

Surface inflow + subsurface inflow +
precipitation + imported water +
decrease in surface storage + decrease
in ground-water storage
=
Surface outflow + subsurface outflow +
consumptive use + exported water +

increase in surface storage + increase in ground-water storage.

If a basin is chosen such that the boundaries coincide with the surface water and ground-water divides and water is neither imported nor exported, the equation of hydrologic equilibrium may be rearranged and written in the following form:

Precipitation
=
Surface outflow + subsurface outflow + consumptive use + change in storage (both underground and surface).

The primary source of water in any basin is thus precipitation. Water is discharged from the basin by surface or subsurface outflow or by consumptive use. The ground-water portion of the equation may be written as follows:

Recharge = discharge $\pm$ changes in storage

The ground-water resource, prior to development by man, was in a state of equilibrium. Recharge was equal to discharge considered within the context of long-term climatic fluctuations. Man utilizes the resource by applying it to some consumptive or non-consumptive use. That part of the water consumptively used is an additional discharge applied to the recharge-discharge equilibrium described above. The sum of the natural and artificial discharges from the aquifer then exceed the natural recharge. This additional demand on the resource is initially satisfied by a decrease in ground-water storage. This storage change is shown by a decrease in water levels. If enough time is allowed and the artificial discharge is not too great, a new equilibrium condition will be achieved. Piper and Thomas (1958, p. 12-13) present an excellent description of the state of hydrologic equilibrium in a ground-water basin.

> "The hydrologic concept of ground-water reservoirs is that nature maintains an essential balance between recharge and discharge; as the rate of recharge rises or falls, the storage in the reservoir increases or decreases until the natural discharge (by springs, evapotranspiration, seepage to streams, and perhaps flow to other aquifers) again balances the recharge. Every modification by man to develop and use water necessarily induces changes toward a new equilibrium on the part of nature. The water produced by wells is not 'new' water, but merely water that has been diverted from its natural course. If a well had not taken the water, it would have been discharged naturally into a stream or a spring, or dissipated by evaporation from areas of high water table or by transpiration by native vegetation. The taking of ground water through wells is comparable to the diversion of surface water from streams, except that it is easier to trace the course the stream water would have followed if it had not been diverted. It is a natural corollary that every well must be expected to modify the natural movement of ground-water - it may reduce the quantity of water available to salt grass, or greasewood, or willow, or to a shallow water area subject to evaporation; it may reduce the flow of a spring or the discharge of a stream fed in part by ground water; it may also diminish the yield of other wells in the vicinity by lowering the ground water level."

The time required for this new equilibrium to occur varies depending on the hydrologic conditions of the basin and the pattern of resource development.

Development and use of the ground-water resource by man must necessarily result in some net decline in water level. The primary questions for resource management include: 1) how far can we afford to allow the water level to decline, 2) how can we differentiate between a water-level decline that will lead to a new equilibrium and one that indicates that a new equilibrium cannot be achieved, 3) what is the maximum yield that can be obtained from a basin without permanently upsetting the equilibrium? The total available and permissible water yield within a particular basin is of major concern in the development and use of the ground-water resource. Walker and others (1970 p. 33) defined water yield as:

> "the total quantity of the average annual water input to the basin that is available for use by man, either flowing in surface channels or moving through the formations underground. Water yield, therefore, is the total long-term input (precipitation) minus the total long-term average annual quantity evaporated at the surface and transpired by native vegetation (natural evapotranspiration) prior to the water becoming stream flow or a part of the ground water body."

This type of definition is very difficult to quantify for use as a management tool.

The term "safe yield" has been used to indicate an upper limit on usable water yield from a basin. This term is defined as "the amount of water which can be withdrawn from a ground-water basin annually without producing an undesired result" (Todd 1959 p. 200). This definition has been expanded considerably in a publication by the

American Society of Civil Engineers (1961 p. 53). Four alternative concepts of basin yield are presented:

> <u>Maximum sustained yield</u> - maximum rate at which water can be withdrawn perennially from a particular source.
>
> <u>Permissive sustained yield</u> - maximum rate at which water can economically and legally be withdrawn perennially from a particular source for beneficial purposes.
>
> <u>Maximum mining yield</u> - total volume of water in storage in a particular source that can be extracted and utilized.
>
> <u>Permissive mining yield</u> - maximum volume of water in storage in a particular source that can economically and legally be extracted and utilized for beneficial purposes, without bringing about some undesired results.

The two categories of sustained yield are measured as an annual rate of use; the two types of mining yield are expressed as a volume irrespective of time.

The maximum sustained yield is that obtained if all natural outputs are diverted for beneficial use. It would be calculated by the equation of hydrologic equilibrium for a designated area. The only limitations on the maximum sustained yield are those presented by the physical storage and pipeline properties of the aquifer system.

The maximum mining yield is simply a measure of the total volume of water in usable storage within the designated aquifer system. Only that water held by molecular forces against the force of gravity would be excluded under this classification. Both of these maximum yield categories represent the upper limit of the resource that may be developed by man. Physical, economic and legal constraints limit man's use of the resource below these levels.

Permissive sustained yield is the concept most nearly equal to the term safe yield. It is usually less than the maximum sustained yield even in the absence of economic and legal constraints because of the physical limitations of the actual pattern of development. Well construction by individual users almost always results in a less optimum distribution of artificial discharge. The permissive sustained yield is always less than the maximum sustained yield because of the objective of preventing undesirable results. The limitations are generally in the form of economic or legal restrictions. The A.S.C.E. publication lists four such restrictions (1961 p. 57):

> 1. Lowering of water levels in wells so far that the cost of well construction or pumping becomes uneconomical.
>
> 2. Intrusion of water of undesirable quality from the ocean, saline lakes or brines in adjacent aquifers; or other deterioration in the quality of the ground water.
>
> 3. Interference with established and recognized water rights.
>
> 4. Interference with economic use of overlying land.

The permissive sustained yield may change with time because of changing economic or social conditions.

The permissive mining yield is that part of the maximum mining yield that is "of economic quality, with economic pumping lifts, obtainable through economic pumping patterns, and legally available" (A.S.C.E., 1961, p. 67).

Several problems are obvious with the above definitions. From an administrative point of view, the criteria of "undesired results" is vague and defined only qualitatively. From a resource management point of view, the problem lies in the attempt to assign some single, average value for the amount of annual withdrawal. It is well known that an equilibrium can be established in an aquifer at different levels of development and annual withdrawal (Bear and Levin, 1967, p. 202). The definitions of safe yield and permissive sustained yield are thus non-workable from this point of view also. A number of authors have noted that the concept of safe yield is no longer usable. Thomas (1961) says that safe yield is no longer a usable term because the water withdrawn must either deplete the storage or deplete the supply somewhere else. We do not have a "no-impact" alternative. If we decide to pump ground water at a particular location, we are in fact deciding that this use has greater benefit than existing or alternative uses of that water. Corker (1971) noted several problems with the use of the term "practical sustained yield":

1. Undesirable effects to whom?, Where?

2. If the limits are to long-term recharge, how long is long term?

3. Can practical sustained yield be forecast when all of the factors upon which it is based will change? and

4. It is difficult to delineate the economic and legal aspects in order to get at the actual value.

The term "safe yield", however, is still noted in the water codes of several states as a major criteria for resource management.

Ground Water in Total System Management

The concepts of water yield noted above consider utilization of the ground-water resource only as a source of water. Several authors have suggested that the resource has a more complex role in a total water resource system. Banks (1966) notes that a ground-water basin has three primary resources: 1) naturally occurring ground water, 2) underground storage capacity, and 3) transmission capability.

Moulder (1966) said that ground water had four major roles in water management:

1. Primary role - ground water as the primary source of water.

2. Interim role - ground water as the primary source of water while pumping continues at a rate beyond rate of replenishment; ground water is thus an interim exhaustable supply.

3. Regulation role - regulation of total water supply by artificial recharge of the ground-water resource with pumping during high demand periods.

4. Conservation role - artificially recharging ground water during high flow periods to conserve the total supply.

Moulder thus supports Banks' thoughts on underground resources. Both of these authors have worked extensively in California. The pattern of water use in that state is different from most of the remainder of the west. Moulder's list provides a historical summary of basin management in several southern California basins. Ground-water management has been tied very closely with water import.

Bear and Levin (1967) presented a list of uses of ground-water aquifers. These uses include:

1) Renewable sources of water.

2) Large storage reservoirs.

3) Controls for spring and river flow.

4) Conduits and distribution systems

5) Filters for injected water in quality control.

Each of these authors emphasize the importance of including ground water in total water resource system management. Ground water is managed with surface water in most areas only when a conflict between uses exists. Ground water must be included as an element of total system management if we are to approach optimum use of the water resources.

Bear and Levin (1967) introduced the concept of optimum yield as an alternative to the yield concepts discussed in the previous section. Optimum yield is defined as an optimum operating policy for total system management. This policy is based on the probabilistic nature of the input and the natural storage of the aquifer.

Ground-Water as a Renewable or Nonrenewable Resource

Ground water occurs under widely different hydrologic and geologic conditions. The resource is present in humid areas where there is considerable recharge and in arid areas where there is little or no replenishment of the resource. Similarly, ground water occurs in a wide range of geologic environments under confined, partially confined and unconfined conditions. Although many generalizations may be made concerning the occurrence of ground water, two are of particular importance in the context of this discussion.

First, water artificially discharged from an aquifer system must deplete the total resource by that amount; water consumptively pumped from a well must be derived from either increased recharge to the aquifer, decreased discharge from the aquifer or from a decrease of water in storage. Prior to development by man, the ground-water resource was generally in a state of equilibrium; recharge approximately equaled discharge. Artificial discharge from wells alters this equilibrium. The additional discharge is initially satisfied by a decrease of ground water in storage. If enough time is allowed and the artificial discharge is not too great, a new equilibrium results with the well discharge being balanced by an increased rate of recharge or a decreased rate of discharge. The time required for this equilibrium to occur varies depending on whether the system is under confined or unconfined conditions. The effect of pumping a well in an unconfined aquifer is much more local than the effect of pumping a well in a confined aquifer of similar thickness and permeability because of the difference in the storage coefficient. Theis (1940) noted that the cone of depression in a confined aquifer grows roughly 100 times as fast an an unconfined aquifer. A new state of equilibrium is thus achieved much faster in a confined aquifer than in a similar unconfined system.

The second generalization concerning ground water states that the annual rate of recharge to a ground-water system is only a small percentage of the total resource in storage. This statement is true in most ground-water basins in arid regions and is also true in many basins in more humid areas. The statement is obvious in arid areas where large aquifer systems receive only small quantities of recharge. For example, the Ogallala Formation in Texas, Kansas, Oklahoma and Colorado contains an estimated 369 million acre-feet of water but receives only an estimated 0.27 million acre-feet of recharge each year (Bekure, 1971). The statement is also true in many ground-water basins in humid regions. Walton (1970) described several shallow aquifer systems in Illinois in which the estimated rate of recharge was less than one percent of the total resource in storage. Thus, for these types of basins, only a small percentage of the ground-water resource is renewed or replaced in any particular year. For ground-water development to be stabilized on a perennial basis, however, the pumpage must be limited to this renewable portion of the resource.

Ground water may be said to have the characteristics of both a renewable and nonrenewable resource. Resources are defined as flow or renewable resources "if different units become available for use in different intervals of time", and as stock or nonrenewable resources "if their total physical quantity does not increase significantly with time" (Ciriacy-Wantrup, 1968, p. 35-37). The flow component of ground water may be defined as the rate of recharge to the aquifer system. By this definition, the flow part of the ground-water resource can be altered by man through artificial changes in the recharge to the aquifer. The remainder of the resource is in storage and fits Wantrup's definition of a stock resource. The stock portion of ground water is thus that percentage of the resource in excess of recharge that is in storage in the aquifer. In the areas where the second generalization is true, most ground water may be defined as stock with only a small percentage designated as a flow resource.

Several problems are inherent in the division of ground water into flow and stock portions. The most serious is the lack of physical meaning since all of the water is in movement. The classification of a unit of ground water as either flow or stock is impossible; there is no direct analogy to a dry streambed for a ground-water system. The flow-stock aspects of ground water are important, however, with respect to resource management. The importance of the stock or nonrenewable aspect of ground water is shown by a primary problem facing resource administrators. This problem is not the availability of water but the protection of the means of diversion. Because of the stock characteristics of most ground-water basins, wells are not dry when the flow or renewable component of the resource is exceeded. Additional well development just results in a lower water level.

Only the flow portion of ground water may be developed if utilization of the resource is to be enjoyed over an infinite period. Maximum long term yield from the ground-water system is obtained when the rate of recharge is maximized and the natural discharge is minimized or eliminated. This requires a general decline in water levels. Here again, a major difference is evident between confined and unconfined aquifers. However, in both cases, some of the stock portion of the resource must be mined in order to approach the objective of extracting the full flow portion.

Bagley (1961) suggested that seven factors be considered in the decision of using only the flow portion or mining the stock. These include:

> 1. The size of the stock in comparison to the perennial yield.
>
> 2. The physical effects that withdrawal from the stock will have on the flow.
>
> 3. The use that is being made of the perennial flow.
>
> 4. The use that may be made of the stock.
>
> 5. What the water (both flow and stock) will be worth at various points in time.
>
> 6. What the costs of pumping will be at various rates of withdrawal and at various points in time.
>
> 7. What the appropriate discount rate will be.

Bagley's first two considerations are concerned with the physical system. His next two are qualitative factors concerning use. His last three items are economic in nature. How do we choose whether we mine the resource or not? Several more concepts will be discussed before we address that question directly.

Thomas (1951) noted that three general types of ground-water problems occur: 1) basinwide problems, 2) pipeline problems and 3) surface water-ground water problems. The basinwide problem is when more water is pumped and consumptively used in a basin than is being replenished. The flow part of the resource is being exceeded basinwide.

The physical result is a decline of water levels. The primary questions for management include: 1) Do we allow the continued utilization of the resource in the basin at a rate greater than the flow component and thus mine the resource? 2) If so, what is the economic maximum rate at which the resource should be utilized? and 3) Should existing users in the basin have any protection and, if so, how shall this protection take place?

The second type of problem, the pipeline problem, is also characterized by declining water levels. In this case, production is less than the total recharge to the aquifer system, but withdrawals from local areas have created areas of water-level decline. The problem is associated with the ability of the geologic material to transmit water. Management questions include protection of means of diversion, basin or area administration and well spacing.

The surface water - ground water problem is normally characterized by a decline in surface flow of a stream which has hydrologic interconnection with the ground-water system. This decline is caused by ground-water pumpage from the aquifer system. Management questions include the combined administration of surface and ground water, the protection of means of diversion and the extent and timing of the interference.

Ground-water as a Common Pool Resource

A common property or pool resource is one which is limited in supply but is accessible to many and is owned or claimed by no single one (Friedman, 1971). The common pool problem is the tendency toward overproduction that arises when competitors seek to exploit an exhaustible resource in which no one has adequately defined and protectable rights. It is basically a problem of externality, a divergence between the private and social cost of exploitation (Friedman, 1971). Ground water fits the definition of a common pool resource. In a single ground-water basin, all of the water under ground is hydrologically interconnected. The dominant factor in the production of a common pool resource is the rule of capture. Ownership is not achieved until the material is pumped to the surface and "captured".

The common pool problem may be divided into two parts: 1) ownership competition and 2) lift-cost allocation. Friedman notes that the ownership competition could be solved by a scheme for dividing the content of the pool between overlying producers so that each producer has a protectable property right in a prescribed volume of the underground mineral. This apportionment creates a nightmare of bookkeeping and administrative problems when the resource is as ill defined as most ground-water systems. Much more basic data would have to be gathered in order to administer effectively on this basis. The lift-cost problem is related to increasing costs with time. A particular user may have a unit of the resource reserved for his use, but yet have its value decline with time because of the withdrawal of units by other users. Extraction costs would tend to direct users to pump at a suboptimal rate by pumping early. This problem could be solved by some sort of incremental lift cost. Again, costs of administration of such a plan would be extremely high.

Common pool problems may be divided into two groups on the basis of whether the stock was replenishable or nonreplenishable. If some recharge to the system occurred, then an additional right would have to be placed on shares of recharge to the system.

The common pool problem is of prime importance for ground-water management particularly when economic controls are utilized. Bagley (1961) says that the economic best use of water is based on the maximization of aggregated discounted returns. This best use of water cannot be achieved until equality is achieved between social and individual costs of using water.

Water Rights as a Water Policy

Legally, water is not available for man's use until society recognizes his right to use it. Laws that control water rights are based on traditions of use and on public attitudes. A basic change in this attitude occurred in the United States from the early days of exploration and development where ownership included a wide range of freedom of use, to modern times where the trend is toward more restrictions on the exercise of ownership.

A water right under the Appropriation Doctrine is defined as real property; it cannot be taken without due process of law. It does not give the owner the title to the water itself but title to a right to use the water. The concept of a water right as real property is different from land as real property; water is dynamic and not stationary and only a use right may be obtained and not ownership.

The primary attribute of a water right is security or the assurance to the owner of a use of water. The value of a water right can vary widely. It has major value in the case where a right gives marked advantages in the cost of obtaining water.

In the United States, a water right may be based on land ownership, on appropriation for beneficial use, on preferential use, on Spanish or Mexican grants, or on prescription or adverse use. The rights may include limitations on rate of diversion, total quantity of diversion, quality rate and place of return flow, period of use and percent of consumptive use.

A water policy may be defined as actions of governments at various levels in various branches affecting the development (increase in quantities of water available for distribution and use) and allocation (distribution of given quantities of water among different uses and among users) of water resources (Ciriacy-Wantrup, 1968). A water policy is less concerned with markets and prices and more with laws, regulations and administrative structures. A water rights system is thus a water policy.

In law, protection means protection against unlawful acts of others and is subject to legal uncertainty. This legal uncertainty may be divided into rule uncertainty and fact uncertainty. In economics, security means protection against physical uncertainty and tenure uncertainty (Ciriacy-Wantrup, 1968). Physical uncertainty in water resource utilization is the variability over time of the quantity of water usable under the right due to seasonal or annual variability of "natural" runoff. This uncertainty is fairly low for ground water because of the predominance of stock ground water in most systems. Tenure uncertainty is the variability over time of the quantity of water usable under the right due to the lawful acts of others. Absolute security cannot be provided under water law. Different water-right systems, however, provide different degrees of security.

The primary problem of ground-water management for any water rights system is the conflict between certainty of established uses and full development of the resource: A conflict between security and flexibility in resource use. Hoskin (1965) noted that the conflict is not about the availability of water but rather the protection of the means of diversion. Who will pay for the alteration or replacement of diversion works made obsolete when subsequent users lower the water level?

Water Rights Doctrines as Applied to Ground Water

Four major water rights doctrines control the utilization of ground water in the United States: absolute ownership, reasonable use, correlative rights and prior appropriation. Thomas (1961, p. 2) divided these into two broad groups: rights based upon ownership of land and rights based upon actual use of water.

> "Rights based upon ownership of land include riparian rights of land bordering streams or lakes, and equivalent rights to springs or to water wells that are located upon the landowners property. The water right is appurtenant to the land and exists whether the landowner uses the water or not: ...As might be expected, this doctrine of water rights developed at places where, and in times when, water supplies were more than enough to meet the requirements of the people - it developed chiefly in England and in the humid regions of the Eastern United States and it and its variations constitute the common-law doctrines." (Thomas, 1961, p. 2)

The absolute ownership doctrine is a strict adherence to the original riparian concept. It is founded on the idea that a landowner should have dominion over the percolating ground water which underlies his land in much the same sense that he has dominion over the other elements in his subsoil (Sax, 1968). The theory thus follows the rule of capture. This water right doctrine has been tempered in many states to the concept of reasonable use. The overlying landowner may take ground water freely, even though he deprives an adjoining landowner of the use of water, as long as the use made is a reasonable one. The primary question for the user in this case is to estimate what the court will hold as reasonable. The correlative rights doctrine is a further extention of the reasonable use doctrine that in time of shortage, each user may only use his reasonable share. Under the reasonable use doctrine, one owner may be permitted to take all the water; the correlative rights doctrine requires that the water be equitably apportioned. Texas is the primary state that applies the absolute ownership doctrine. The correlative rights doctrine was developed and is applied only in California. Most of the eastern states follow the reasonable use doctrine in some form. In many cases, administrative regulations have been added to provide for more efficient control of the resource. Oregon and Washington follow the reasonable use doctrine in the more humid western part of the states.

Water rights under the appropriation doctrine are based upon actual water use. "By this doctrine, the first in time of beneficial use is the first in right, and the right is maintained only by use" (Thomas, 1961, p. 2). A priority date is assigned to the right depending on the initial application of water to beneficial use or the completion of some state statutory permit requirement. Beneficial use is generally considered to be the measure of the right. The appropriation doctrine of water rights was developed and is presently applied in the more arid western states.

None of the water right doctrines are entirely satisfactory. The appropriation right is generally more secure against tenure uncertainty than rights under common law doctrines because of the priority system. On the other hand, the strict adherence to a priority system does not allow the flexibility required for efficient basin management.

> "In the humid regions there is increasing urge to give more emphasis to actual use of water as a basis of a water right in order to protect the investments of those who have actually developed and are using the water resources. In fact many people in the east regard enviously the appropriation system that has been developed in the western states" (Thomas, 1961, p. 3).

Application of the Appropriation Doctrine to Ground Water

Although the application of the appropriation doctrine to the administration of surface water has been reasonably satisfactory, its direct application to ground water has been less successful. The doctrine is designed for the allocation of a perpetual but fluctuating flow of water among competing users. It does not provide guidelines for the allocation of a stock resource. As mentioned previously, most ground water in the arid west must be considered as stock with only a small portion renewed each year. A right under the appropriation doctrine gives the user the legal availability of water on a perpetual basis or until he ceases to put it to beneficial use. A perpetual right cannot be granted to a stock resource.

Ground water is intended to be administered under the appropriation doctrine as a flow or renewable resource. This is shown by key phrases in state water codes which provide the limit for resource development. These include: normal annual rate of replenishment (Colorado), safe yield and recharge rate (Kansas), safe annual yield of ground water as measured by the recharge of the area (Montana), safe sustaining yield (Washington), current recharge rate (Wyoming), and reasonable anticipated average rate of future natural recharge (Idaho) (Hoskin, 1965).

Many of the state water codes include the objective of "full economic development" of the ground-water resource. However, in the same statutes protection is provided for the means of diversion. These include: maintainence of reasonable pumping lifts (Idaho), yield water within a reasonable or feasible pumping lift (Montana), right does not include the right to have the water level or artesian pressure at the appropriators point of diversion maintained at any level higher than that required for maximum beneficial use (Wyoming), maintain legally equitable and efficient diversions (Colorado), reasonable raising or lowering of the water level (Kansas), reasonable lowering of the static water level (Nevada), and reasonable or feasible pumping lift (Washington)(Hoskin , 1965). Oregon and South Dakota are the only states applying the appropriation doctrine to ground·water that do not use language indicative of full development. Most of the western states have thus compromised on the conflict between protection of established uses and full development.

The extent of protection given senior water right holders against declining water levels is a major problem with the appropriation doctrine. The alternatives for action range between: 1) protecting the method of diversion of the senior by maintaining water levels at the level originally tapped regardless of waste or inefficiency, and 2) allowing full development of average annual recharge to the basin regardless of the water-level situation of the senior. Hoskin (1965) suggests that full development under the appropriation doctrine means that the appropriator is protected against decreasing pressures and water levels only to a point where his personal interest and the public interest coincide.

Most of the problems with the application of the appropriaton doctrine to ground water area based on the stock characteristics of the resource. Several authors have presented what they believe to be dominant problems pertaining to the administration of ground water under the appropriation doctrine. Bagley (1961) noted the following problems:

1. No user can have a perpetual supply.

2. All users must accept falling water levels, higher pumping costs and lower yields.

3. Junior appropriators can operate while the supply lasts without depriving senior appropriators of water.

4. Stocks can be depleted at various rates.

Bagley's discussion was directed to the ground-water mining situation in the southwestern states. Flint (1968) presented problems with the appropriation doctrine in a discussion of water law and development in New Mexico.

1. What is the importance of priority when all users are in a common supply?

2. How is impairment determined and measured?

3. Are there legal differences in administration of tributary and nontributary basins?

4. How can you apply the same system to basins with and without recharge?

5. What is impairment in a ground-water basin - does it result from merely lowering the water level?

6. If existing uses have a water supply for less than perpetuity, will a new

use constitute impairment as a matter of law?

7. How do you determine if there is unappropriated water in a ground-water basin?

8. Can you administer on economic factors or must you stick to physical availability of water?

9. Can ground-water rights be transferred?

10. Can the type of use be changed - extent?

What is the value of an individual right under the appropriation doctrine? What protection does the law provide? Since the basic purpose of a water right is to provide security, these are very important questions. Certainly the law is ineffective if it denies the administrator the flexibility he needs for management but yet does not provide security for the individual. A water right under the appropriation doctrine supposedly provides an option to divert water for an infinite period of time (given continued beneficial use) with a given level of security based on priority. The system works fairly well with surface water because it is a definable flow resource. Ground water, however, is neither a flow resource nor is the quantity readily defined. If the flow in a surface stream is low, junior rights are shut down to provide water for downstream seniors. It is difficult, if not impossible, to determine when the flow portion of a ground-water resource is being exceeded. As Flint (1968) asked, does impairment of a right result from merely lowering the water level? If so, how far? One could conclude that a right for the diversion of ground water under the appropriation doctrine has no value. This perhaps is carrying the arguement too far. As will be shown later, the value of a water right for ground water might be in the classification of an individual either in the group of users or in a group of non-users. All rights that are valid might be of the same value.

Other questions may be asked concerning the administration of ground water under a given law. Flint (1968) noted that the following factors would provide uncertainty for the resource administrator:

1. Physical complexity of hydrologic problems.

2. Varying adequacy of data.

3. Diverse and changing needs of people.

4. Variety of existing and potential water institutions.

Piper and Thomas (1958) said that a lack of positive action on the part of administrators might be based on the following fears: 1) that the available facts would not support or sustain an order for a reduction in pumpage, or 2) that statutory procedure would not recapture the status of the arlier appropriators. Because of this uncertainty, little action has taken place in administration of ground water under the appropriation doctrine.

Corker (1971) presents what is probably the most complete analysis of ground-water management problems in his book entitled "Ground-Water Law, Management, and Administration". He notes what he feels are the most pressing questions concerning ground-water management.

1. To what extent shall stored water be used in excess of inflow (recharge) to storage?

2. How is mining to be restricted to prolong the life of the ground-water resource?

3. Is mining to be permitted when existence of substantial recharge makes an alternative to mining available, but water demand clearly exceeds any quantity that can be supplied from long term recharge?

4. What is the permissible risk, and how may it be described, in permitting new or continued uses of stored water?

5. Should criteria for permitting a new appropriation of ground water be the same as the criteria for deciding when an established but junior use of ground water should be terminated?

6. Is a ground water right to be protected, and, if so, to what extent and how shall protection be defined, in accress to water?

7. May water be artificially stored in a basin which underlies land which is now owned by the storer?

8. To what extent and by what means is it possible to forego determination of hundreds, sometimes thousands, of individual water rights and to manage a ground-water resource, or ground water and surface water sources

conjunctively, in the common interest of all the beneficiaries?

9. What are the goals of ground-water management?

Corker's first question is relatively easy to answer with respect to a basin that has little or no recharge. Man must mine the resource to gain any benefit. We have made this decision with respect to oil, gas and minerals. The question becomes more complex in a basin where significant recharge occurs. Corker presents this situation in question number three. In one sense, mining of ground water must occur if we are to develop the resource. Initially, any new point of discharge is satisfied by a decrease of water in storage. This results in a change of hydraulic gradient and a shift toward a new equilibrium. A new equilibrium will be established when the additional discharge is balanced by a decrease in natural discharge or an increase in recharge to the system. A net loss of water in storage will have occurred, however. The question is more realistically stated: Do we limit the well development to a level where a new equilibrium can feasibly occur? We may have already passed that point in most basins where this question has been raised.

How do we restrict the mining to prolong the life of the basin if we know we have a mining situation? Several states have chosen a specific life for the resource. In New Mexico, a 40-year life was chosen for a basin while in Colorado, a period of 25 years was selected (Corker, 1971). Even in these areas, unappropriated water was found for selected small uses. In Texas, the absolute ownership doctrine is applied to an area of ground-water mining on the high plains. While individual wells are not under state control, an effective conservation plan has evolved. Efficient water use is stressed along with artificial recharge operations. Frank Rayner (1973, personal communication), manager of High Plains Conservation District Number 1, claims that better water use is achieved in his district than in the similar area just across the New Mexico-Texas state line where the appropriation doctrine is applied.

The fourth question deals with the risk of new or continued uses of stored water. Corker notes that "if the junior is using stored water,...there is usually no present physical neccessity to shut off anybody's water. The senior user insists that water be shut off because the junior user is withdrawing that water needed by the senior next year, or the years thereafter. The junior user says that next year the rains will return, that all water users never simultaneously use their full entitlement, and besides, this is not for anyone a risk free universe" (p. xiii). How much risk do we permit for the senior water right holder? Can he insist that the storage exists solely for his benefit? The states have said the senior is not entirely risk free by stating that he is protected in his means of diversion only at a "reasonable pumping lift".

Should criteria for permitting a new appropriation of ground water be the same as the criteria for deciding when an established but junior use of ground water should be terminated? How rigorous do we apply the rules of the appropriation doctrine? If the resource acted as a flow resource, it might be much easier to answer the question affirmatively. Unappropriated water may, however, exist in a basin that has major decline depending on the administrative base period we consider. It may take tens to hundreds of years for the impact of a well at one end of a basin under water table conditions to be felt on a well located at the other end of the basin. It is quite possible for the court to find that unappropriated water is available in a basin where a senior has undergone water level decline. This flexibility adds a new dimension to an individual right in a ground-water system. The location of the well in the basin may be equally as important as relative priority under the appropriation doctrine.

Is a ground-water right to be protected? A primary question facing many administrators of ground water is not the availability of the resource, but the protection of the means of diversion. Many of the major aquifer systems extend in depth beyond what may be termed as an economic limit for pumpage. The value of a right in this situation is the protection it gives for the means of diversion or the pumping level. As was noted, many of the state statutes give some statement on the extent to which levels may be drawn down. In almost all cases, however, the limits have not been quantified.

Full protection of pumping levels would eliminate much of the potential for development of the ground-water resource. The courts have recognized this in several cases by requiring a reasonable means of diversion. Considerable question still exists, however, concerning the extent of risk assumed by the senior. Hoskin (1965, p. 410) noted that:

> "the doctrine of prior appropriation was designed to facilitate maximum development of the waters of the west, but ironically in practice it has acted to inhibit full development. Priority was intended as a means of furthering the economy of an area, not as end in itself. By providing such a high degree of protection to a prior user's means of diversion, the courts seem to have excluded the competition of all but the most affluent subsequent developers...Thus the protection of seniors, generally small users, often results in depriving other small users of an equal opportunity at economic success."

May water be artificially stored in a basin which underlies land which is not owned by the storer? Corker (1971) notes that the answer to this question is "yes" in most states. Questions still exist as to the liability of the storer for damage. Several districts in California have initiated pump taxes for the basis of recovery of water artificially recharged into the ground-water system.

To what extent and by what means is it possible to forego determination of hundreds -- sometimes thousands -- of individual water rights and to manage a ground-water resource, or ground-water and surface water sources conjunctively, in the common interest of all the beneficiaries? Adjudication of water rights is a long and costly process. It is necessary, however, to have a court definition of the individual rights before administration of the resource can occur under the prior appropriation system. In a small basin with 20-30 users, the process is not too difficult. In a major basin with a large number of users, the process is consuming in both time and money. In large areas where the resource is used intensively, it may prove less costly and more efficient to achieve a system of public ownership than to perform the tedious task of administration under the priority system. The question is then how to achieve the public management. Examples of central management exist in the form of several water districts in southern California. Both the Central and West Coast Basin and the Orange County Water District have achieved a high level of water management. In the former district, rights were adjudicated. These rights, however, affect only the cost of the water and not how much may be used. In the Orange County district, rights were not adjudicated. No water user is given any cost advantage depending on his right or historical use (Corker, 1971). The key to operation of each of these districts is the importation of water. No users are required to shut down. The availability of water is guaranteed; Only the cost of the water is variable. Central management of the water resource in a basin is a must for optimum use of the resource under any rights system. Corker (1971, p. xxi) noted that "the existence of a management entity with financial, technical, and political capcity to provide water service is a primary goal of water management."

Corker's last question concerns the goals of ground-water management. It is very important that the goals of ground-water management be the same as for surface water management. Surface water and ground water are usually physical alternatives. Goals for water management may be divided into economic goals and administrative goals. Bagley (1961) noted that the economic best use of water is the maximization of aggregate discounted net returns. Net benefits are all benefits in excess of costs, where costs include opportunity costs. Corker says that administrative goals are all goals other than economic. The question of ground-water use is time dependent. How much of the resource do we leave for the next generation? An economic analysis would indicate that present use of the water would give the maximum return using a reasonable interest rate. However, largely undefined administrative goals do have impact on resource management. Resource management includes the concept of stewardship. Man is given the opportunity to use the natural resources, but he is also given the responsibility for the care and preservation of those same resources. An administrative goal of management might be the preservation of a significant part of the resource for future generations of plant and animal species, including man.

CHAPTER III

ALTERNATIVES FOR GROUND-WATER MANAGEMENT IN IDAHO

Introduction

Idaho follows the appropriation doctrine of water law and applies it to both surface water and ground water. Controlling legislation for ground water was passed in 1951 and modified in 1953, 1961, and 1963. Water law in Idaho has historically followed the appropriation doctrine. The reasonable use doctrine and the correlative rights doctrine were both suggested for the state of Idaho in early cases but were rejected in more recent times. The legislation enacted in the early 1950's in Idaho was typical of many western states. It was designed to provide protection for the individual ground-water users but yet provide for the full development of the resource. The statutes reflect this conflict between certainty of individual uses and full development.

Application of the Appropriation Doctrine to Ground Water in Idaho

The appropriation doctrine was designed for the allocation of a perpetual but fluctuating flow of water among competing users. The system is reasonably applicable to surface water and serves as the basis for water rights in a number of western states. In some of these states, including Idaho, the doctrine has been applied to ground water.

The important aspects of the Idaho Code with respect to ground water are as follows:

Sec. 42-226

> "It is hereby declared that the traditional policy of the state of Idaho, requiring the water resource of this state to be devoted to beneficial use in reasonable amounts through appropriation, is affirmed with respect to the ground water resources of this state as said term is hereinafter defined; and, while the doctrine of '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 Administration as herein provided. All ground water in this state are declared to be the property of the state, whose duty it shall be to supervise their appropriation and allotment to those diverting the same for beneficial use. All rights to the use of ground water in this state however acquired before the effective date of this act are hereby in all respects validated and confirmed."

Sec. 42-233a

> "Critical ground water area' is defined as 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 amy be determined and designated, from time to time, by the Director of the Department of Water Administration.
>
> Upon the designation of a 'critical ground water area' it shall be the duty of the Director of the Department of Water Administration to conduct a public hearing in the area concerned to apprise the public of such designation and the reasons therefor. Notice of the hearing shall

be published in two (2) consecutive weekly issues of a newspaper of general circulation in the area immediately prior to the date for hearing.

In the event an area has been designated as a 'critical ground water area' and the Director of the Department of Water Administration desires to remove such designation or modify the boundaries thereof, he shall likewise conduct a public hearing following similar publication of notice prior to taking such action.

In the event the application for permit is made with respect to an area that has not been designated as a critical ground water area the Director of the Department of Water Administration shall forthwith issue a permit an accordance with the provisions of section 42-203 and section 42-204 provided said application otherwise meets the requirements of such sections.

In the event the application for permit is made in an area which has been designated as a critical ground water area, if the Director of the Department of Water Administration from the investigation made by him on said application as herein provided, or from the investigation made by him in determing the area to be critical, or from other information that has come officially to his attention, has reason to believe that there is insufficient water available subject to appropriation at the location of the proposed well described in the application, the Director of the Department of Water Administration may forthwith deny said application; provided, however, that if ground water at such location is available in a lesser amount than that applied for the Director of the Department of Water Administration may issue a permit for the use of such water to the extent that such water is available for such appropriation."

Sec. 42-247 a-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 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. To assist the Director of the Department of Water Administration in the administration and enforcement of this act, and in making determineations upon which said orders shall be based, he may establish a ground water pumping level or levels in an area or areas having a common ground water supply as determined by him as hereinafter provided. 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..."

The statues call for the "full economic development" of the resource with the restriction that "reasonable ground water pumping levels" be maintained. The total development is limited to the "reasonably anticipated average rate of future natural recharge". Recognition is given that excessive declines in water levels may occur and some protection is noted for the means of diversion. It is difficult to determine if the statement concerning full economic development refers to the use of the resource beyond the flow component. No guidelines are given for the use of stock ground water except as an elevator to help maintain reasonable pumping levels.

Ground-water administration in Idaho has been limited to the designation of five critical ground water areas. This designation closes the area to the future applications to appropriate ground water but does not affect any of the existing pumpers or those holding valid outstanding permits.

Ground-Water Management Under the Idaho Code

Two levels of resource management are allowed under the Idaho statutes. It is possible for the Director of the Department of Water Administration to deny a permit for a new user in a ground water basin on the basis that unappropriated ground water is not available. The Director may indicate that unappropriated ground water is not available in an area by the declaration that the area is a critical ground-water area. This designation serves as a notice to new users that applications for permits will either be denied or approved in reduced quantities. The recent decision in the case of State ex rel. Tappen v. Smith indicates that the Director of the Department of Water Administration does have sufficient power to create critical ground-water areas and to prevent new uses of ground water on the basis that unappropriated ground water is not available. Because of this case, it is assumed for this study that the Director of the Department of Water Administration has sufficient power to close areas to future appropriation.

Two main restrictions are presented in the Idaho Code that could result in closure of wells with valid water rights. These are noted as the recharge limitation and the pumping lift limitation. The recharge limitation is the limit on development to the "reasonably anticipated average rate of future natural recharge." The pumping lift limitation is the protection that the individual user has in the maintenance of "reasonable ground water pumping levels".

What is a reasonable ground water pumping level? The concept of reasonable ground-water pumping levels was introduced into the statutes to provide a degree of protection for the individual user. It was envisioned that the individual user should not be allowed to prohibit full development of the area but should be protected in the maintenance of a depth to water that will allow him to continue his operation.

Major questions are apparent in the selection of a reasonable ground water pumping lift. Young and Ralston (1971) examined the concept of reasonable ground water pumping levels and suggested specific values for each ground-water basin within the state of Idaho. Their study was based upon four assumptions.

> 1. The calculation of reasonable pumping lifts is based upon irrigation usage of water. It is assumed that persons using water for other purposes, such as industrial and domestic, can afford to pay more for each unit of water used.
>
> 2. The reasonable pumping lift is based upon cost per unit of water being the limiting factor for an average or "typical" irrigator in each basin. The irrigator can be considered typical in that he grows the types of crops that are

> ordinary to his area, has average yields, applies irrigation water in a reasonably efficient manner and pays an average price for each unit of water he pumps.
>
> 3. Administration of the use of ground water based upon reasonable pumping lifts is for the purpose of maintaining the water rights of the individual rather than maximizing profits on a community-wide scale (the general public).
>
> 4. Hydrologic, geologic, and water quality aspects are not the limiting factors in well yield or water usage. Among other considerations, this assumes that the aquifer thickness is sufficient to allow wells to obtain water at the reasonable pumping level for the area.

Young and Ralston base the reasonable pumping lift or pumping lift limitation on the typical irrigator farmer in a basin. A large, more efficient farm can logically afford to pump water from a greater depth than a small, less efficient farm. The Young and Ralston report would suggest that an average farm size should be selected as the basis for the pumping lift calculations. Water users range in management abilities from very poor to very good. Again, Young and Ralston assumed a farmer with average managerial abilities. A wide range of questions may be asked concerning the selection of a reasonable pumping lift value. 1) Should the pumping lift be selected with maximum economic development as an objective? 2) Should the pumping lift be selected on the basis of maximum physical development? 3) Should the pumping lift be a specific value or a range of values? 4) Should the pumping lift be based on a reasonable drawdown value? 5) Should the pumping lift be modified on the basis of topographic features? 6) Should the reasonable pumping lift be based not only on a depth to water but a reasonable rate of decline?

Along with these questions are questions of application of the reasonable pumping lift restriction. 1) Must the pumping limit be applied as a single value to the entire basin? 2) Is it possible to have small units? 3) Is it possible to have administrative units only near the areas of decline? 4) Is it possible to apply pumping lift only within a given radius from the problem area?

The intent of the recharge restriction is to provide for long term or perennial development and usage of the resource. It is based on the concept that ground water is a flow resource in similar fashion as surface water. The wording in the statute indicates that the legislature approached some of the questions with respect to selection of a recharge value. The statute reads as follows: "... shall not exceed the reasonably anticipated average rate of future natural recharge". "Reasonably anticipated" provides some measure of probability but needs further clarification. "Future recharge" needs definition. Does this refer to recharge induced by present development or by changes in land use? "Natural" recharge also needs definition. Does this necessarily exclude artificial recharge? Finally, does the statute refer only to ground-water recharge or to the total water available in the surface water-ground water system? Walker and others (1970) estimated the water yield of the Raft River Basin. Water yield has been assumed by some to be synonimous with recharge to the ground-water system. This is not necessarily so. The legislature probably intended to limit development to a level which would allow perennial use of the resource. If this was the intent, then the restriction should be translated to mean that amount of the natural recharge to a basin which can be recovered by man. The only way that man can fully utilize the recharge to a ground-water system on an indefinite basis is to eliminate all of the natural discharge from the system. In most cases, it is impossible to eliminate all of the natural discharge without causing very major water-level declines. The concept of "reasonably anticipated average rate of future natural recharge" is thus difficult to quantify. Can the recharge restriction be applied on less than a basinwide program; Also, does the recharge restriction have any time aspect of impact? These questions must be answered prior to the selection of a recharge limitation for the administration of a ground-water unit.

The recent case of <u>Baker et al. vs. Ore-Ida et al.</u> provides some guidelines for the application of the pumping lift and recharge limitations. The <u>Baker</u> case was concerned with ground-water development in a very limited artesian aquifer system which had been suffering a steady water level decline of about 20 feet per year. The court noted that both the recharge restriction and the reasonable pumping lift restriction were applicable in this particular case. The court chose to apply the recharge restriction and order closure of wells in reverse order of priority until pumpage was equal to the designated recharge rate. The pumping lift restriction could be applied if the decline continued down to a designated reasonable pumping lift value.

Ground-Water Administration Under the Pumping Lift Restriction

An outline of ground water administration under the criteria of reasonable ground-water pumping levels is presented in Figure 1. A number of decisions must be made in order to arrive at a management plan. The first level of decision involves the selection of reasonable ground-water pumping levels as the primary administrative tool. The second decision concerns the definition of the pumping lift concept. Reasonable ground-water pumping levels can be interpreted as 1) a limit on the depth to pumping water level or 2) a limit on the rate of water level decline plus a limit on the depth to pumping water level. If the pumping lift limitation is assumed to be the limit on the depth to pumping water level, then a decision must be made on the method of application of the pumping level restriction to the basin. The Idaho

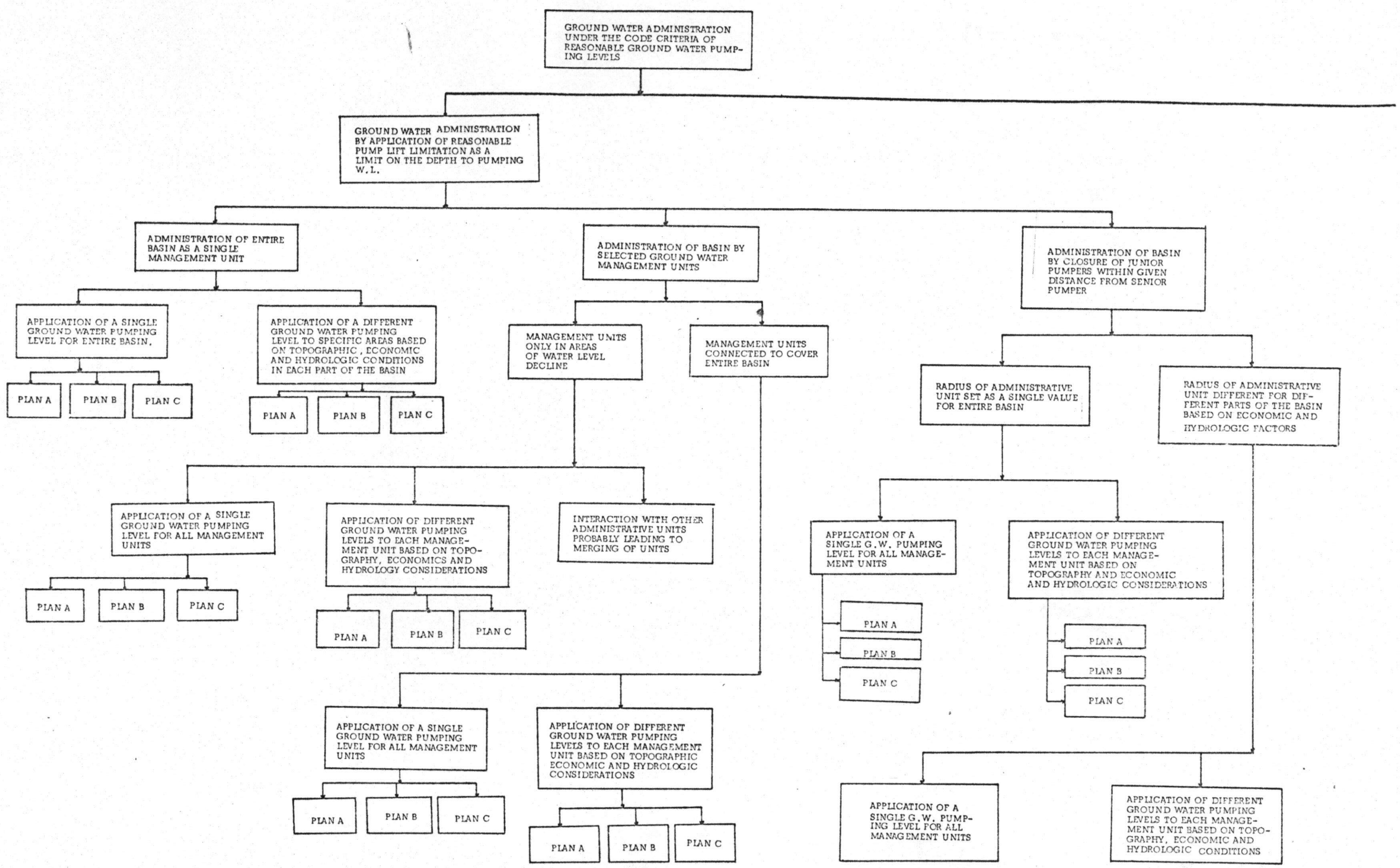


FIGURE I ALTERNATIVES FOR GROUND-WATER MANAGEMENT UNDER THE CONCEPT OF REASONABLE GROUND-WATER PUMPING LEVELS (A)

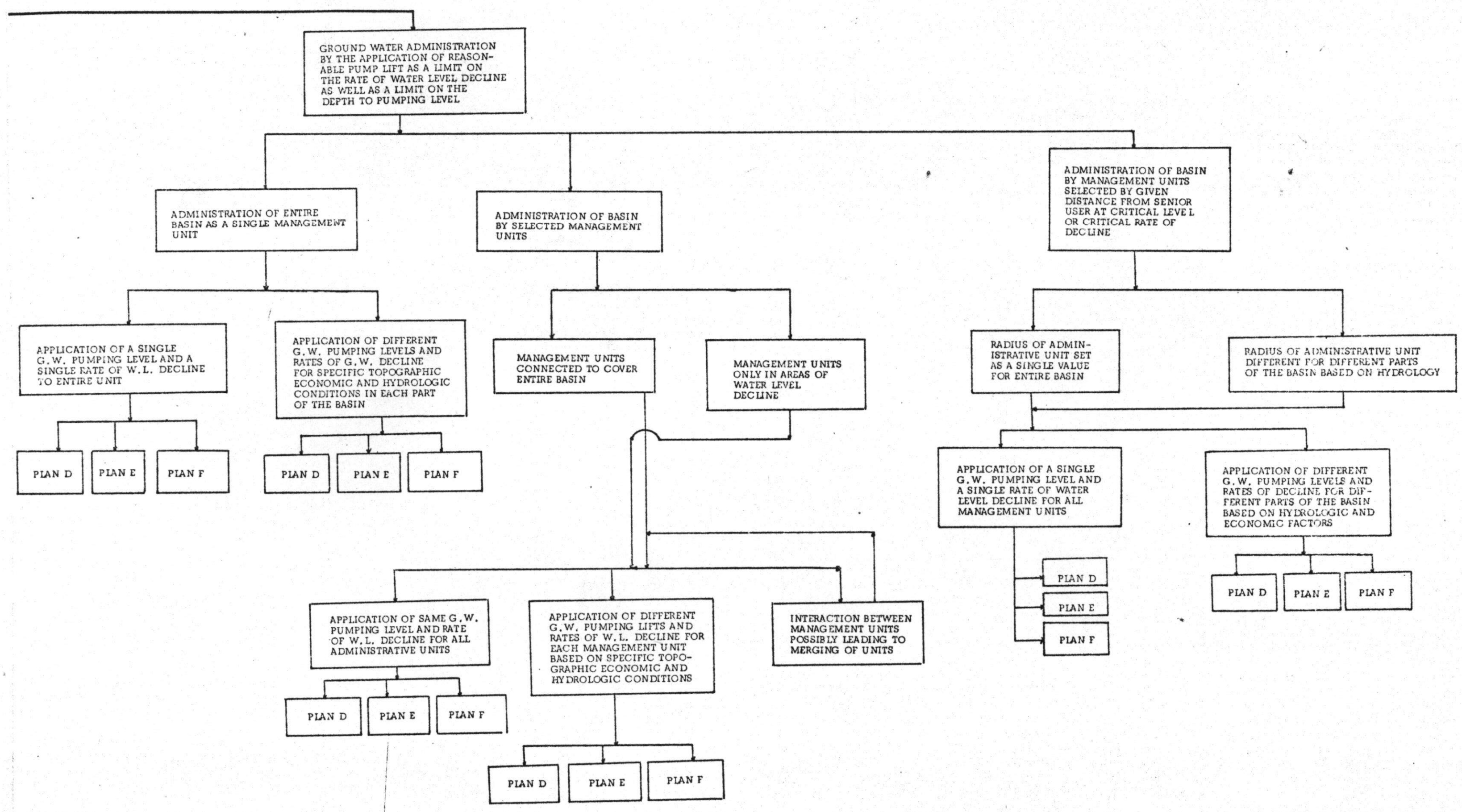


FIGURE I CONTINUED (B)

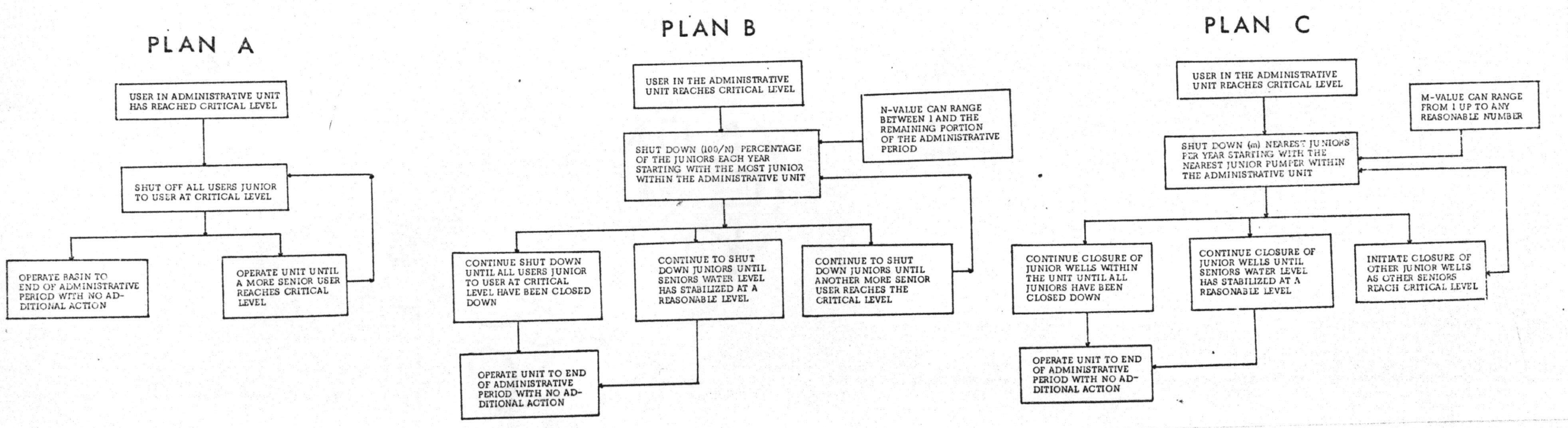


FIGURE I CONTINUED (C)

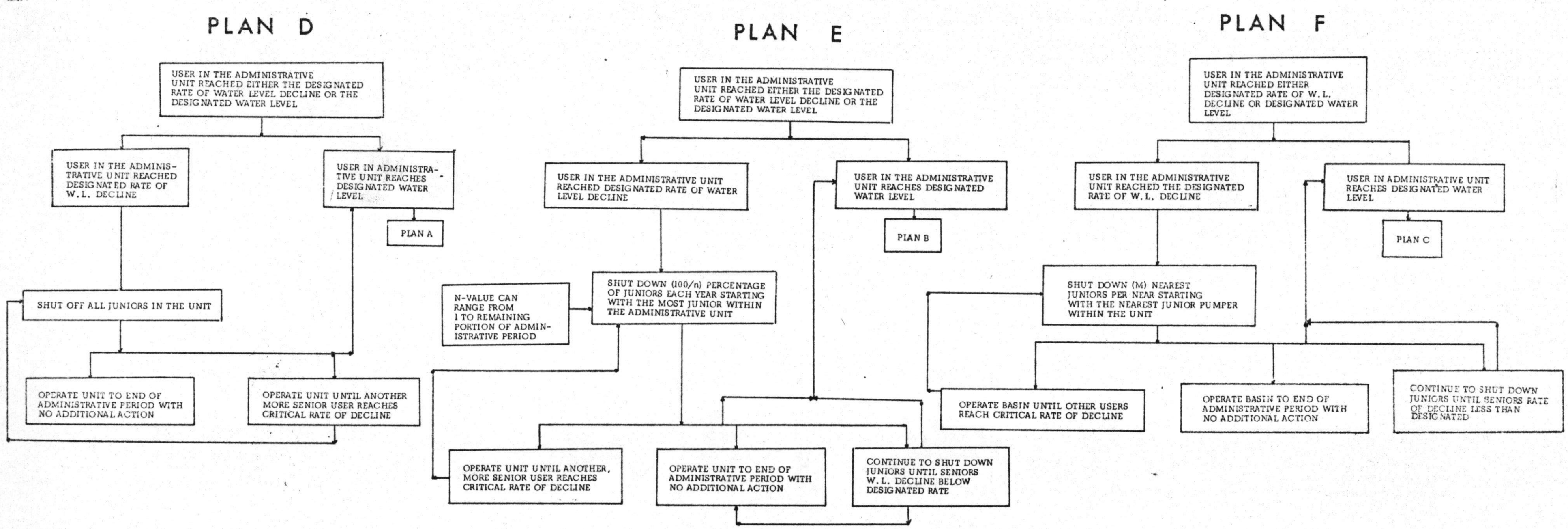


FIGURE 1 CONTINUED (D)

Code allows the designation of a critical ground-water area as part or all of a ground-water basin. It is thus possible to apply the reasonable ground-water pumping lift restriction to all or only part of the basin.

The first alternative, noted on Figure 1, is to apply the restriction to a single administrative unit that includes the entire basin. The restriction may also be applied to selected ground-water management units which may or may not include the entire basin. The restriction may be applied to units defined by a given distance from the senior pumper who has reached the critical level. The selection of the size of the administrative unit is very important in the application of the pumping lift restriction. Administration of ground water in the Raft River Basin has been limited to date to the declaration of the entire basin as a critical ground-water area. The basin is thus being treated at the moment as a single management unit.

Two primary alternatives are outlined for the selection of the reasonable pumping lift value for the basin. The first and simplest application of the reasonable pumping lift concept is the application of a single ground-water pumping level for the entire basin. Based on the assumptions noted by Young and Ralston (1971), the pumping level would be designed for a typical irrigator for the entire basin without reference to growing season and crop variations within the basin and differences in topographic features. The second major alternative in the application of reasonable pumping lifts to a single unit covering the entire basin is the application of different ground-water pumping levels in each part of the basin based upon specific topographic, economic and hydrologic conditions. Under this plan, a reasonable ground-water pumping level would better fit the conditions in each part of the basin. It would be difficult, however, to interface the ground-water pumping lift management scheme when conflicting users have different reasonable pumping lift values.

Once the reasonable pumping lift value is selected for the basin or for parts of the basin, considerable question exists on the application of that value to users within the basin. Three basic plans of application of the reasonable pumping lift value within the administrative unit are presented on Figure 1. These plans are repeated throughout the various alternatives noted on the diagram. Each of these plans is initiated when any user in the administrative unit has reached the designated critical level. Under plan A, the administrative official would shut off all users junior to that user that has reached the critical level. Thus, if the user at the critical level were the most senior user in the basin, all of the other users in the basin would be shut off.

However, if he were the second most junior user, only the most junior user would be shut off. Two basic courses of action are possible following this closure of juniors. The basin may be operated to the end of the administrative base period with no additional administrative action. However, if another user within the administrative unit reaches the designated critical level, all users junior to him would be shut off with administration following this general plan to the end of the administrative base period.

Plan B also would be initiated when a user in the administrative unit reaches the designated critical level. Under this plan the administrative officer for the state would shut down (100/n percentage) of the juniors each year starting with the most junior within the administrative unit. This would continue for (n) years with (n) being any number between 1 and the remaining number of years in the administrative period. Administration would follow this guidelines until either 1) all users junior to the user at the critical level had been shut down or 2) the senior's water level had been stabilized at the designated reasonable level. In either of these cases, administrative action would be terminated for the remainder of the administrative period. However, if another user reaches the critical level, administration action would include shutting off (100/n percentage) of the users junior to that user each year.

Plan C would be initiated when any user in the administrative unit reaches the critical level. Under this plan, (m) nearest juniors would be shut down per year starting with the nearest junior user within the administrative unit. The (m) value can range from 1 up to any reasonable number. The users to be shut down would be the nearest junior users so that all users junior to the pumper at the critical level would be grouped irrespective of priority. Administration under plan C would continue until either 1) all users junior to that user at the critical level have been closed down or 2) sufficient juniors have been closed down to stabilize the senior's water level at the designated reasonable level. Administration would then continue without further action to the end of the administrative period. However, if another user reaches the critical level within the administrative unit, administration would include the closure of (m) juniors per year near that senior user.

Plan A provides for the closure of a probable large number of users without examination of the positive benefit for the senior who has reached the critical level. This plan would be advisable only if the administrative unit were selected as a very small area. Plan B provides an important modification of plan A in that only a portion of the juniors would be shut down each year with this closure to continue until either all juniors are closed down or the senior has been protected as to his reasonable pumping level. However, this plan still ignores the importance of the location of each particular user. In a large administrative unit, a user at great distance may be shut down with no immediate benefit to the senior. This plan would also provide reasonable administrative action in small administrative units. Plan C would perhaps provide greatest protection for both the senior and junior users. The senior would be protected because those users closest to him would be shut down first. Conversely, all users junior to the user at the critical level would be assumed to have equal priority thus eliminating some of the value of the water right. Location would be an important factor in the certainty of water use.

The administrative unit may be selected as other then the entire basin. Administration of the ground-water resource in a basin may be performed in selected ground-water management units or in ground-water management units based on a given distance from a senior pumper who has reached the designated critical level (Figure 1). The selected administrative units may connect to cover the entire basin or may be located only in areas of immediate water-level decline. Selection and application of reasonable pumping lift value or values would follow the same course of action as described for management of the basin as a single unit. However, the complicating factor of interaction between selected administrative units would have to be considered. Closure of juniors under this application of the reasonable pumping lift concept would follow plan A, plan B, or plan C described previously.

The size of the administrative unit could be based on a given distance from the senior pumper who has reached the designated reasonable pumping lift. The radius of the administrative unit could be set either as a single value for the entire basin or modified for different parts of the basin based on hydrologic and economic factors. The application of selected reasonable pumping lift value or values would follow the format described previously with final application of the critical value under plan A, B, or C as described above.

Reasonable pumping lift has been discussed as a control on the depth to pumping level. It is also possible to interpret reasonable pumping level as a combination of control on the rate of water-level decline and control on the depth to pumping water level. As is shown on Figure 1, this interpretation provides a different set of alternatives for closure of junior users.

Plan D is initiated when a user in the administrative unit reaches either the designated rate of water-level decline or the designated pumping water level. If a user in the administrative unit reaches the designated rate of water-level decline, all users junior to him in the unit are shut off. This plan is directly parallel to plan A. Upon this action the unit would either be operated until another, more senior user reaches the critical rate of decline or operated until a user reaches the designated reasonable pumping lift. In the second case, all users junior to the second person reaching the critical rate of decline would be shut off. When a user reaches the designated reasonable pumping lift value, plan D then reverts directly to plan A.

Plan E is very similar to plan B. In this case when the user reaches the designated rate of water level decline (100/n) percentage of the junior users would be shut off each year starting with the most junior within the administrative unit. This operation would continue until 1) another more senior user reaches the critical rate of decline, 2) the first senior has his water-level decline reduced below the designated rate of water-level decline, or 3) a user in the area reaches the designated reasonable pumping lift value. Under the latter possibility, plan E would then revert to plan B.

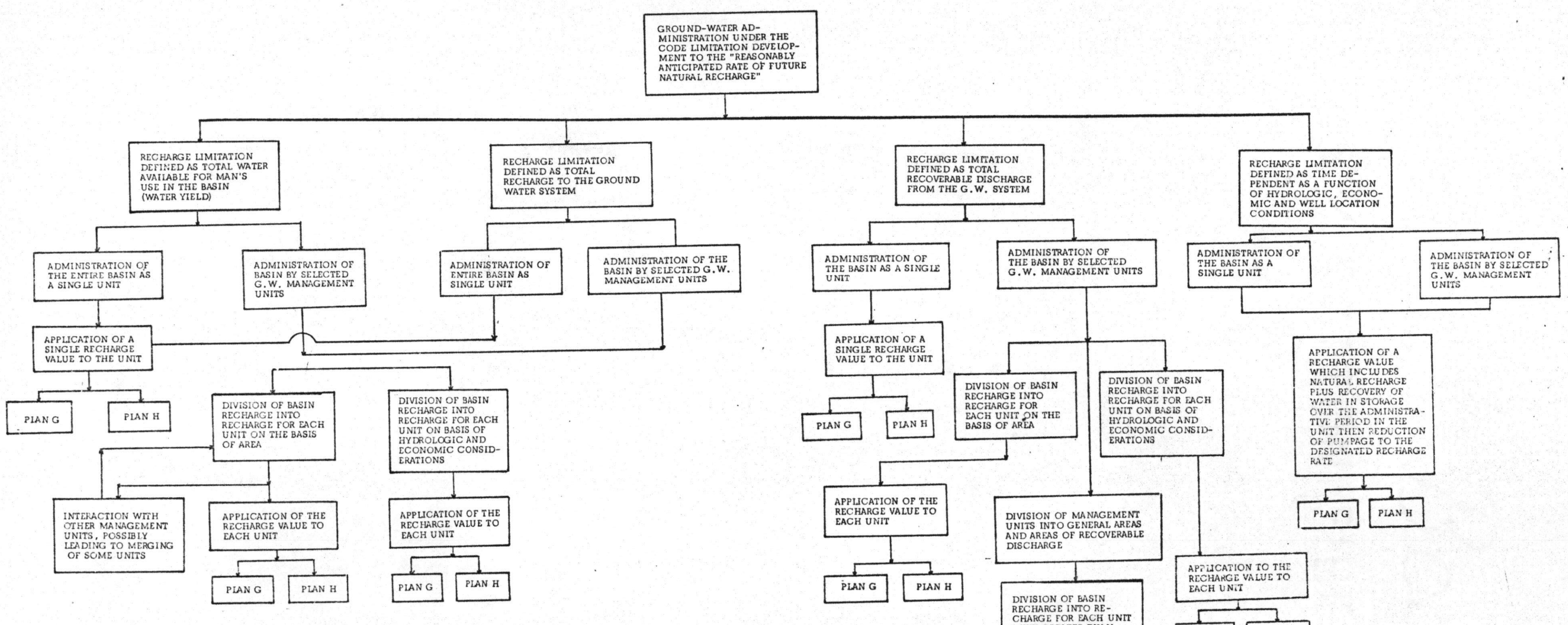
Under plan F, when a user in the administrative unit reaches the designated rate of water-level decline, (m) nearest juniors would be shut down each year starting with the nearest junior pumper within the unit. The basin would then be operated until either 1) other users reach the critical rate of decline, 2) the seniors rate of water-level decline is reduced until it is less then the designated rate of decline or 3) a user in the administrative unit reaches the designated reasonable pumping lift value. In the latter case, plan F would revert to plan C described previously.

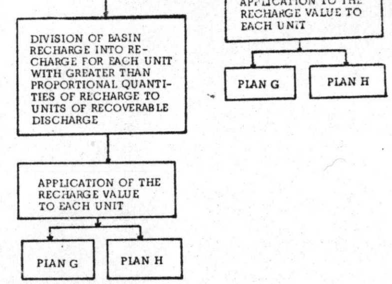
The outline of decisions under administration of reasonable pumping lift as a limit on the rate of water-level decline as well as a limit on the depth of pumping water level is similar to that discussed previously with the exception that the final plans of application of the reasonable pumping lift concept are plans D, E, and F, rather than A, B, and C.

Five basic levels of decision are described on Figure 1. First, the administrator must choose the particular management tool to apply to the basin. In this case, the choice is reasonable pumping lift. Secondly, the administrator must chose a definition of reasonable pumping lift. The definition may either be a limit on the depth to pumping water level or a limit on the rate of water-level decline plus a limit on the depth to pumping water level. Third, the administrator must chose the size of management unit and the length of management period. Fourth, he must select the pumping lift value or values and the rate of decline value or values to be applied in the management units. Fifth, he must select a method of application of the designated pump lift and rate of decline values to users in the administrative units.

Ground-Water Administration Under the Recharge Limitation

The Idaho Code limits development in a ground-water basin to the "reasonably anticipated average rate of future natural recharge." The decision diagram for this administrative alternative is presented in Figure 2. One of the





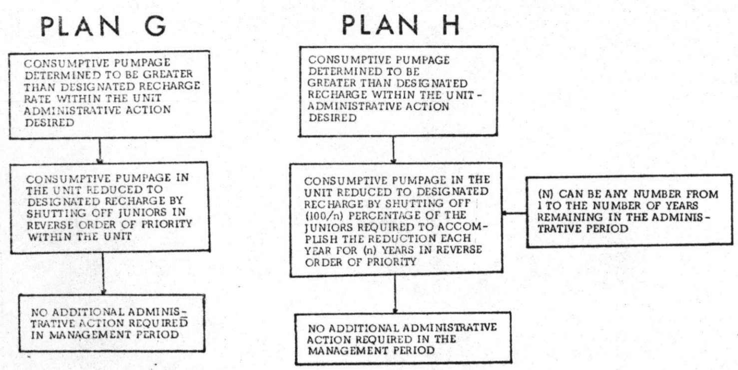


FIGURE 2 ALTERNATIVES FOR GROUND-WATER MANAGEMENT UNDER THE CONCEPT OF REASONABLY ANTICIPATED AVERAGE RATE OF FUTURE NATURAL RECHARGE

primary problems with administration of the resource under this criteria is the definition of the recharge limitation. Four alternative definitions are presented on Figure 2. First, the recharge limitation may be defined as the total water available for man's use in the basin (water yield). Second, the recharge limitation may be defined as the total recharge to the ground-water system. Third, it may be defined as equal to the total recoverable discharge from the ground-water system. Fourth, the recharge limitation may be defined as a time dependent function of the hydrologic, economic and well location conditions in the basin. The size of administrative units must be selected under any of these alternative definitions. A single administrative unit may cover the entire basin, or the basin may be administered through selected ground-water management units.

The application of a single recharge value to an administrative unit covering an entire basin would follow plan G or plan H, as shown on Figure 2. Under plan G, the consumptive pumpage in the unit would be reduced to the designated recharge value by shutting off juniors in reverse order of priority within the unit. It is envisioned that the well closure would occur all at once. Under plan H the consumptive pumpage in the unit would be reduced to the designated recharge by shutting off (100/n) percentage of the juniors required to accomplish the reduction each year for (n) years in reverse order of priority.

This alternative plan would spread the impact of the closure over a number of years.

A decision must be made on the division of the basinwide recharge value into recharge values for each specific unit if administration of the basin under the recharge limitation is to be performed in selected ground-water management units. As is shown on Figure 2, this division may be based on either the size of each administrative unit with respect to the total a rea in the basin or on the basis of hydrologic and economic considerations. In either case, the application of the selected recharge value to the users in each unit would follow either plan G or plan H described previously.

Administration of the resource under the recharge limitation defined as the total recharge to the ground-water system would follow the same pattern as described for the definition of the recharge limit as water yield. The only difference would be in the total magnitude of the defined natural recharge value.

Resource administration with the definition of recharge being recoverable discharge from the ground-water system would follow that described above with one exception. The division of the basinwide recharge into recharge for each ground-water management unit would be varied on the basis of recoverable discharge within each management unit. For example, management units near discharge points might be allowed greater unit recharge than other units of the same size within the basin.

Administration of the recharge limitation with a definition of recharge being time dependent as a function of hydrologic, economic and well location conditions could vary widely from administration under other definitions of the constraint. The application of a recharge value which included both natural recharge and recovery of water in storage over the administrative period would allow a greater immediate development of the resource. In this case, the length of the administrative period would be very important as the development would revert back to the designated natural recharge to the area at the end of the assigned administrative period. Closure of juniors within the unit would follow either plan G or plan H described previously.

Five levels of decisions are apparent in the application of the recharge restriction for basin management. First, the administrator would select the recharge limit as the management tool. Secondly, the administrator would define the recharge limit. Third, he would select the size of the administrative unit or units and select the length of the management period. Fourth, he would select the reasonable recharge value or values for each unit. Fifth, he would select the method of application of the recharge limits to users within each administrative unit.

Steps in Ground-Water Administration

The first indication of a ground-water problem is often excessive water-level decline. Some decline of water levels must necessarily result from man's development of the resource. The water-level decline must thus be interpreted as a water resource management problem. Under Idaho statutes, the probable, but not necessary, next step is the declaration of a critical ground-water area. This declaration prohibits new applications for permit to appropriate ground water in the area. The next logical, and very necessary step is an adjudication of the ground-water rights. Under this process, each user has his recorded or non-recorded water right established with respect to priority, quantity of water and location of water use. The product of an adjudication is a priority list noting valid water rights and giving the priority date, the quantity of water and the lands irrigated. Pumpage must be discontinued for those wells without valid water rights. The water-level decline may continue or the decline may be slowed or stopped as a result of this adjudication depending on the number of pumpers discontinued by the adjudication action. No further administrative action is required if the water levels stabilize.

If water-level decline continues, the next step is an evaluation of the physical aspects of the problem and a selection and application of a management tool. Four general classifications of physical problems may be outlined: 1) local water-level decline with total basin pumpage believed less than basin recharge. 2) general water-level decline with total basin pumpage believed less than basin recharge. 3) local water-level decline with total basin pumpage believed to be greater than basin recharge and 4) general water level decline with total basin pumpage believed to be greater than basin recharge. The selection of the management tool is based on the type of physical problem. The administrative decisions noted on Figures 1 and 2 then follow.

CHAPTER IV

MODEL OF A HYDROLOGIC SYSTEM

Introduction

The Raft River basin in southern Idaho was chosen as a study area for the analysis of the impact of legeal constraints on ground-water development. It is the largest of the five areas in Idaho presently declared as critical ground-water areas and the only one that may be considered as a hydrologic unit. A mathematical model of the water resource system in the basin was constructed as an aid in the evaluation of the legal controls for management. An existing finite difference program, developed by Pinder (1970) provided the basis for simulation. This program was modified to fit the objectives of the study and the particular characteristics of the Raft River Basin. The completed model allowed non-steady state analysis of the water resource system with individual well control.

Description of the Study Basin

The Raft River basin includes a drainage basin of approximately 1,510 square miles located in southern Idaho and northern Utah (Walker and others, 1970) (Figure 3). The area is composed of rugged mountains rising above aggraded alluvial valleys. The climate ranges from humid and subhumid in the higher mountains, to semiarid on the floor of the main Raft River Valley.

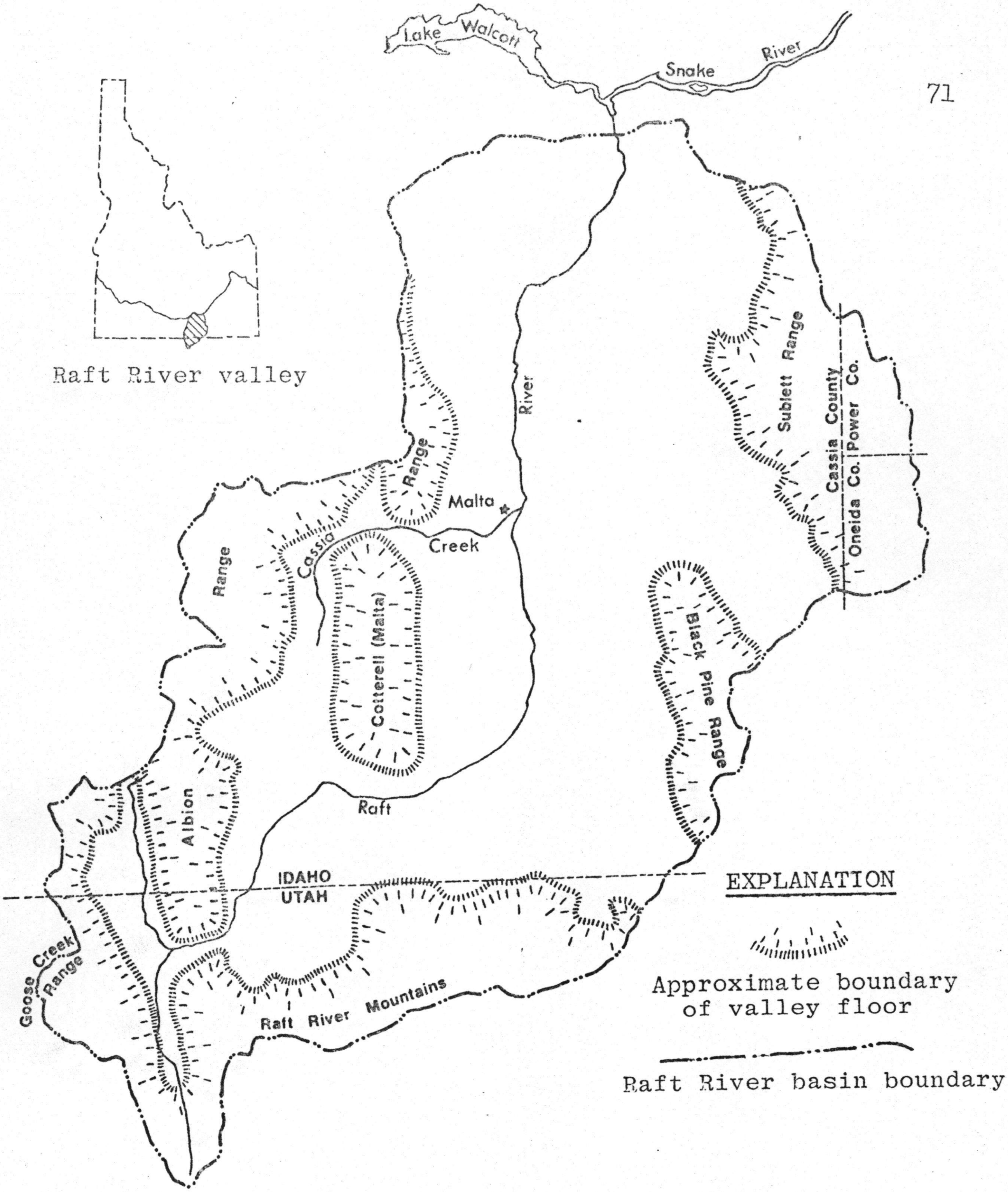


FIGURE 3 LOCATION MAP FOR THE RAFT RIVER BASIN

Precipitation ranges from less than 10 inches on the valley floor to more than 30 inches near the summits of several ranges. The streams in the basin are tributary to the Raft River which in turn flows north into the Snake River. The lower reaches of the streams are dry in the late summer during most years because of surface water diversion and ground-water pumpage.

The primary aquifers in the basin consists of gravel and sand of the Salt Lake Formation and the Raft Formation and recent alluvium. Basalt of the Snake River Group is also important as an aquifer in the northern part of the basin. The main body of ground water in the basin occurs under unconfined or water table conditions (Walker and others, 1970, p. 58). Perched ground water occurs beneath parts of the lowlands; artesian aquifers have been penetrated in several local areas. The depth to water varies from near land surface in the center of the main valley to greater than 400 feet. The known depth of the aquifer system is greater than 700 feet in most parts of the valley and greater than 1,400 feet in the area of greatest pumping.

An estimated 290 irrigation wells were in operation in the basin in 1963 with an increase to 330 in 1966 (Figure 4). The mean discharge from these wells is about 1,300 gallons per minute. The total pumpage in the area increased from approximately 14,000 acre feet

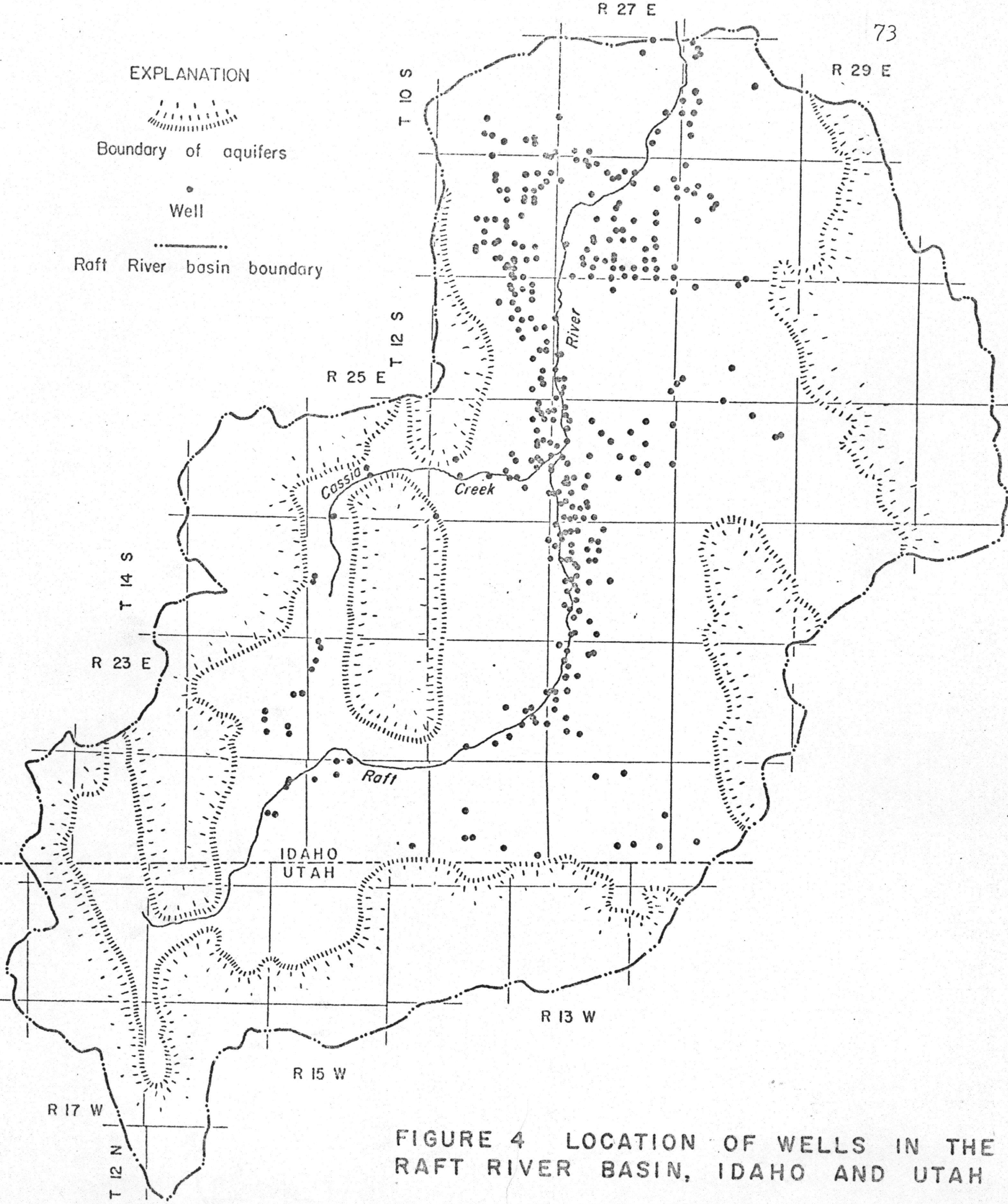


FIGURE 4 LOCATION OF WELLS IN THE RAFT RIVER BASIN, IDAHO AND UTAH

in 1950 to an estimated 235,000 acre feet in 1966. About 84,000 acres of land are presently irrigated in the basin. Much of the additional 340,000 acres that lie in the lowlands area could be irrigated if water were available. Walker and others (1970) calculated the total water yield of the basin to be approximately 140,000 acre feet per year. An estimated 9 million acre feet of water is in storage in the top 200 feet of the saturated aquifer in the main valley.

The entire Raft River basin was declared a critical ground-water area and closed to future applications to appropriate ground water in July 1963 because of declining water levels. Aside from changes in the critical designation for several small areas not directly related to the primary problem, the basin has remained closed for ground-water development.

Finite Difference Modeling Technique

The differential equation for the nonsteady flow of a compressible fluid in an elastic nonhomogeneous porous medium can be written as (Pinder and Bredehoeft, 1968):

$$\frac{\partial}{\partial x_i}\left(T_{ij}\frac{\partial h}{\partial x_i}\right) = S\frac{\partial h}{\partial t} + W(x,y,t)$$

T_{ij} = transmissivity tenser

h = hydraulic head

S = storage coefficient

t = time

w = volume flux per unit area

x,y = coordinates in the east-west and north-south direction

An approximate solution to this equation may be obtained through the finite difference approach. The continuous aquifer parameters are replaced by a set of discrete nodes. A finite difference form of the flow equation is written for each node in the system. The solution of the flow equation for any system requires the simultaneous solution of the equations for all nodes in that system.

Pinder (1970) developed a program to allow the solution of the finite difference equations of non-steady ground-water flow using the alternating direction procedure. This program was the basis for the mathematical model of the water resource system in the Raft River basin. Detailed information on the modification of Pinder's program and the construction of the model are presented by Goldman (1974).

Construction of the Model

The following information was needed for the construction of the model of the water resource system in the Raft River basin:

1. Hydraulic conductivity and thickness of the saturated geologic material.

2. Storage coefficient (equal to the specific yield for the basin).

3. Historical pumping data for each well in the basin.

4. Historical streamflow data and estimates of stream loss.

5. Estimates of basin water yield.

6. Elevation of water surface in wells.

Input data for the model were derived from field observation and from the following reports: Walker and others (1970), Haight (1964, 1965), Mundorff and Sisco (1963) and Nace and others (1961). Basic data on energy consumption for ground-water pumpage was obtained from Raft River Electric Cooperative and Intermountain Natural Gas Company.

A nodal array was selected with 105 nodes in the X direction (north-south) and 50 nodes in the Y direction (east-west) (Figure 5). A constant nodal spacing of one-half mile was used. The boundaries of the model were taken as the edge of the aquifer material as mapped by Walker and others (1970). The irregular shape of the aquifer was modeled by setting the aquifer parameters equal to zero for any nodes outside of the boundary.

The hydraulic conductivity array was developed from analysis of well logs in the basin and from known or inferred hydrogeology. The storage coefficient array was derived from specific yield values given by Walker and others (1970) The array of initial head values was developed from water level data given by Nace and others (1961) and Walker and others (1970). The pumpage array was developed for each year of model calibration from historic pumpage records and recorded streamflow. Ground-water pumpage was calculated from power consumption data using

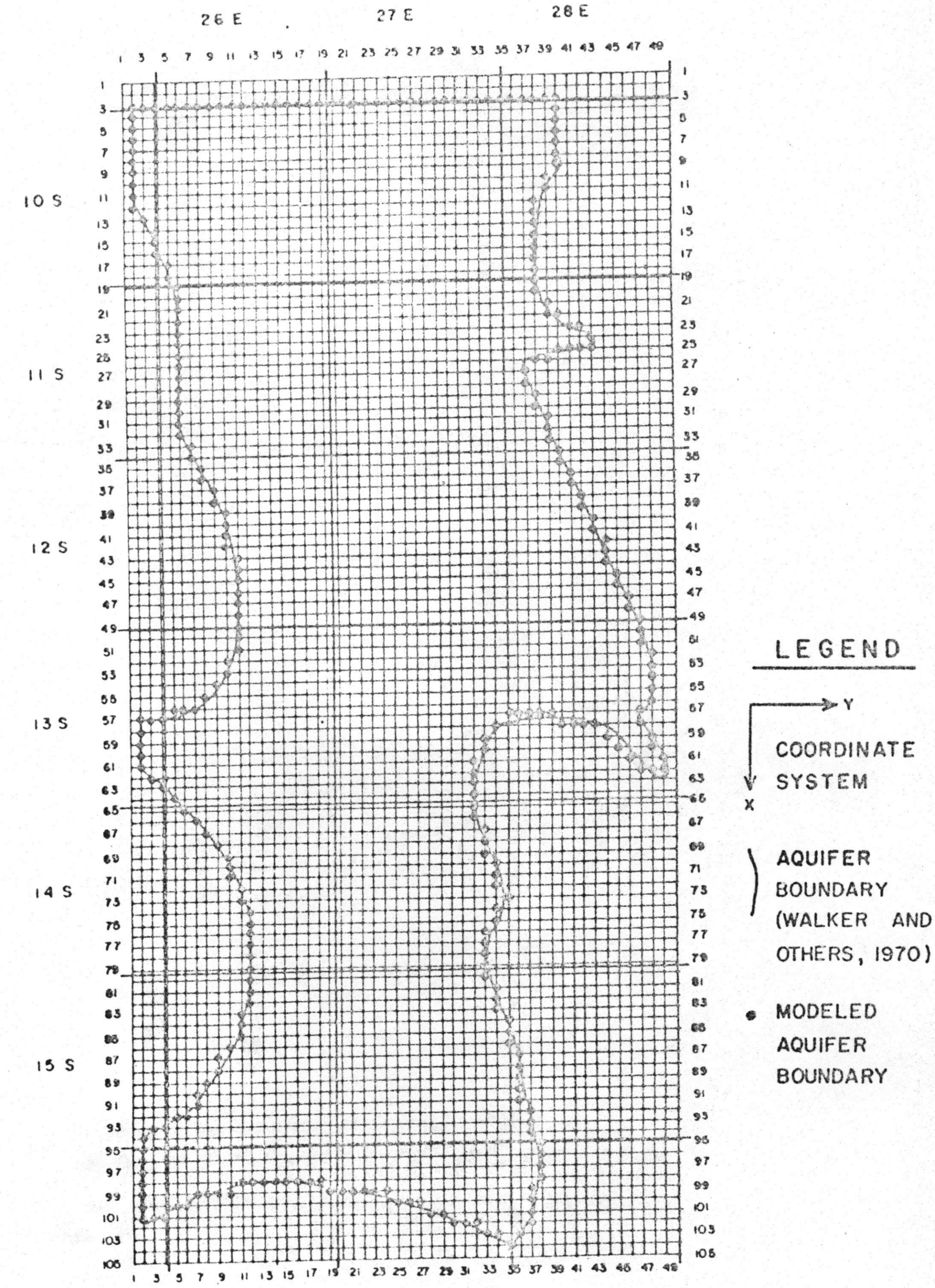


FIGURE 5 GRID SYSTEM SUPERIMPOSED ON PLAN VIEW OF MODELED RAFT RIVER VALLEY

energy per acre foot conversion factors for each irrigation well in the basin. The input from Cassia Creek and Raft River was modeled using recharge wells along the sections of the streams known to loose water to the ground water system. Streamflow data were used to determine loses to the ground-water system. Water input to the basin from small streams, overland flow and ground-water inflow was modeled by the use of recharge wells along the boundary of the aquifer system. The value of recharge applied at each well was determined from water yield data presented by Walker and others (1970). The water yield information was derived using a monthly water balance technique.

Field data presented by Mundorff and Sisco (1963), Haight (1964, 1965) and Walker and others (1970) plus data collected during this study were used to verify the model. Fall measurements of water levels during 1952 were used as the initial input on hydraulic head.

A three part procedure was adopted for verification of the model (Goldman, 1974, p. 35):

1. Simulation of a non-developed ground-water environment.

2. Simulation of the location and magnitude of water level changes for the period 1952-1965.

3. Simulation of the rate of water-level change during the period 1952-1965.

The model results do not show the local cones of depression to the magnitude as was observed in the field. However, the rate of water-level decline in most wells is similar to that recorded in the basin. The model was deemed suitable for the comparison between alternative management schemes.

Operation of the Model

Several changes in input data were required for the operation of the model for the evaluation of management alternatives. The well pumpage was held constant at the average rate for the 1960-1970 pumping period. Similarly, the stream loss was also held constant at the 1960-1970 average. Several subroutines, used for the calibration of the model, were removed for the operational runs to reduce computer costs.

The evaluation of management alternatives was achieved by the comparison of various management plans with a basis run. This technique of analysis reduced the impact of any error in the model representation of the resource system in the study basin.

CHAPTER V

ANALYSIS OF MANAGEMENT ALTERNATIVES FOR GROUND WATER IN IDAHO

Introduction

Management of ground water under the appropriation doctrine must first include an adjudication of water rights. A mock adjudication of ground-water rights in the study basin was performed because an actual adjudication had not been implimented. The second step in ground-water management is the development of administrative procedures based on the physical aspects of the basin and the alternatives outlined in the legal code. Alternatives for ground-water management in Idaho are presented in Chapter III. The third step in ground-water management is the application of the management procedures to the basin under consideration. In this study, management alternatives are examined utilizing the mathematical model of the water resource system in the Raft River Basin. The analysis of alternatives for ground-water management in Idaho is based on operation of the model under given sets of constraints.

Adjudication of Ground-Water Rights in the Study Basin

The adjudication of water rights is a necessary first step for the administration of ground water. Without an adjudication, non-recorded use rights must be treated as junior to all recorded rights, and thus not given their proper value. A water-rights adjudication involves the court determination of priority dates, quantities of water and locations of use for each diversion of water in the basin. The priority date may be established by one of two procedures. First, the date may be established by the receipt of an application for a permit in the office of the Idaho Department of Water Administration. If this permit is successfully matured into a license, the priority date set by the receipt of the application will be the priority date for the water right. Second, a water right may be obtained by the "constitutional" method of application of water to beneficial use. Under this method, the priority is established with the first beneficial use of water. Proof of beneficial use is presented to the court during the adjudication in the form of testimony or depositions. A claim procedure has been outlined in the Idaho Code to allow recording of the facts concerning constitutional appropriation of water. Water rights could be established under the "constitutional" method in Idaho only prior to a law which became effective on March 25, 1963. Persons who developed new uses of water after that date were required to follow the permit system.

Several procedures are outlined in the Idaho Code which allow for the voiding of a water right permit or license: 1) failure to complete application of water to beneficial use within the designated period. 2) abandonment of the right and 3) forfeiture of the right. The failure to complete application of water to beneficial use within the designated period voids the permit and thus prevents it from maturing into a license. The abandonment of a water right involves intent; the user must intend to abandon his use of water. The forfeiture of a water right involves nonuse for an extended period of time. The forfeiture period noted in the Idaho Code is five years or more.

The establishment of water-right priorities for ground-water users within the study basin was an important part of this study. Several sources of information were utilized to provide the basis for the assignment of water rights to ground-water users. Information on permits, licenses, claims and transfers were obtained from the files of the Idaho Department of Water Administration. These data were compared with energy consumption records for irrigation wells obtained from electric and natural gas suppliers. Additional information from Water Administration personnel were used to supplement the records.

Five basic assumptions were required for the establishment of water right priorities in the Raft River Basin. First, for the purpose of this study, the water rights adjudication was assumed to have been performed after the pumping season of 1970 and before the pumping season of 1971. This assumption was required because power consumption data, necessary for the calculation of well pumpage, was available only through the pumping season of 1970. Second, a valid water right with a given priority was assumed to give the user the opportunity to pump water the average annual quantity diverted during the period 1960 through 1970. This assumption was necessary because water rights give only the maximum rate of diversion and not the total volume of water applied. The annual volume of water pumped under a given right was calculated from the power consumption data. This total volume was applied uniformly over the pumping season.

Third, it is assumed that the priority established under this procedure gives the right to the full pumpage historically derived from the well. In some situations, well capacities were increased over time and later priorities were established for additional amounts.

Fourth, establishment of rights by the "constitutional" method were not considered prior to 1953 because of the absence of useable power consumption records. As a result, a larger than actual group of wells were assigned priorities of 1953. Some of these users would probably claim earlier priorities in an actual adjudication.

Eight specific assumptions were required for the establishment of water right priorities in the basin.

1. Priority is claimed on May 1 of the year that pumping first occurred for those wells where pumping was initiated on or before 1963 and for which no water right was filed.

2. Priority is claimed on May 1 of the first year of pumping even though a water right was established, when the pumping occurred before the priority date of the right.

3. The priority established by the water right is maintained even though more than five years lapsed between the application date and the first pumping on the basis that the licensed right indicates that an extension was granted.

4. A water right is lost by forfeiture if no water is pumped for a period of at least five years and the pumpage is not resumed prior to the adjudication.

5. A water right is not obtained through the use of a well for which pumping was initiated after 1963 and no water right was filed.

6. A water right is not lost by forfeiture if use of the water is resumed prior to the adjudication even though the water was not used for a period of five years or more.

7. Replacement wells are assumed where it is evident that a new power use was initiated in the same quarter section where a valid use was stopped.

8. Early water right priorities are no longer valid after very long periods of non-use in specific cases.

The first two assumptions refer to the constitutional method of obtaining a water right. Sufficient detail was not available from the power records to determine the specific date on which water was first pumped from a well. An arbitrary date of May 1 was chosen as the basis for a right obtained by the constitutional method. The second assumption indicates that obtaining a permit under the statutory system does not remove the opportunity to obtain a water right under the constitutional method. The fourth and fifth assumptions provide the basis for elimination of pumpers in the basin without valid rights. The forfeiture of a water right by non-use is considered in the fourth assumption. A right is assumed to be forfeited if no use is made of the well for a period of more than five years with no resumption of pumping prior to the adjudication. In this case, the date of the adjudication is very important. Assumption six allows the continuation of the right if pumpage is resumed prior to the adjudication. Abandonment is not considered in the assumptions because it involves an intent on the part of the user. The fifth assumption pertains to the development of the right under the statutory permit system. Legislation that became effective on March 25, 1963 provided the state with a mandatory permit system for ground water. Assumption five is the application of this mandatory permit system to the users in the study basin. It is assumed that those users that first pumped ground water in 1963 did so prior to the effective date of the act. A transfer form is not required when a water right is transferred from one well to another well in the same quarter section. The seventh assumption recognizes the transfer within the quarter section. The eighth assumption includes only a few wells where extreme lapses in time occurred between the date of the water right permit and the year of first pumpage. The decision on these cases would rest with the judge in an actual adjudication. Some ground-water pumpage occurred in the basin from wells equipped with gasoline or diesel motors. These users are not included in the analysis because of a lack of fuel consumption records. A total of 444 irrigation wells historically operated in the basin by 1970 based on power consumption records. Under assumptions one and two of the adjudication procedure, 127 of the wells would have priorities established under the "constitutional" method. Under assumption four, 40 wells would no longer be allowed to operate because of a forfeiture of the water right as a result of non-use for a period of more than five years with no resumption prior to the water right adjudication. Seventy-eight wells would no longer be allowed to operate because of the absence of valid water right under assumption five. The wells closed under assumptions four and five include about 16 percent of the wells that were in operation in 1970. The relative priorities, dates of priority and accumulated pumpage of wells with valid adjudicated water rights in the study basin are presented in Figure 6.

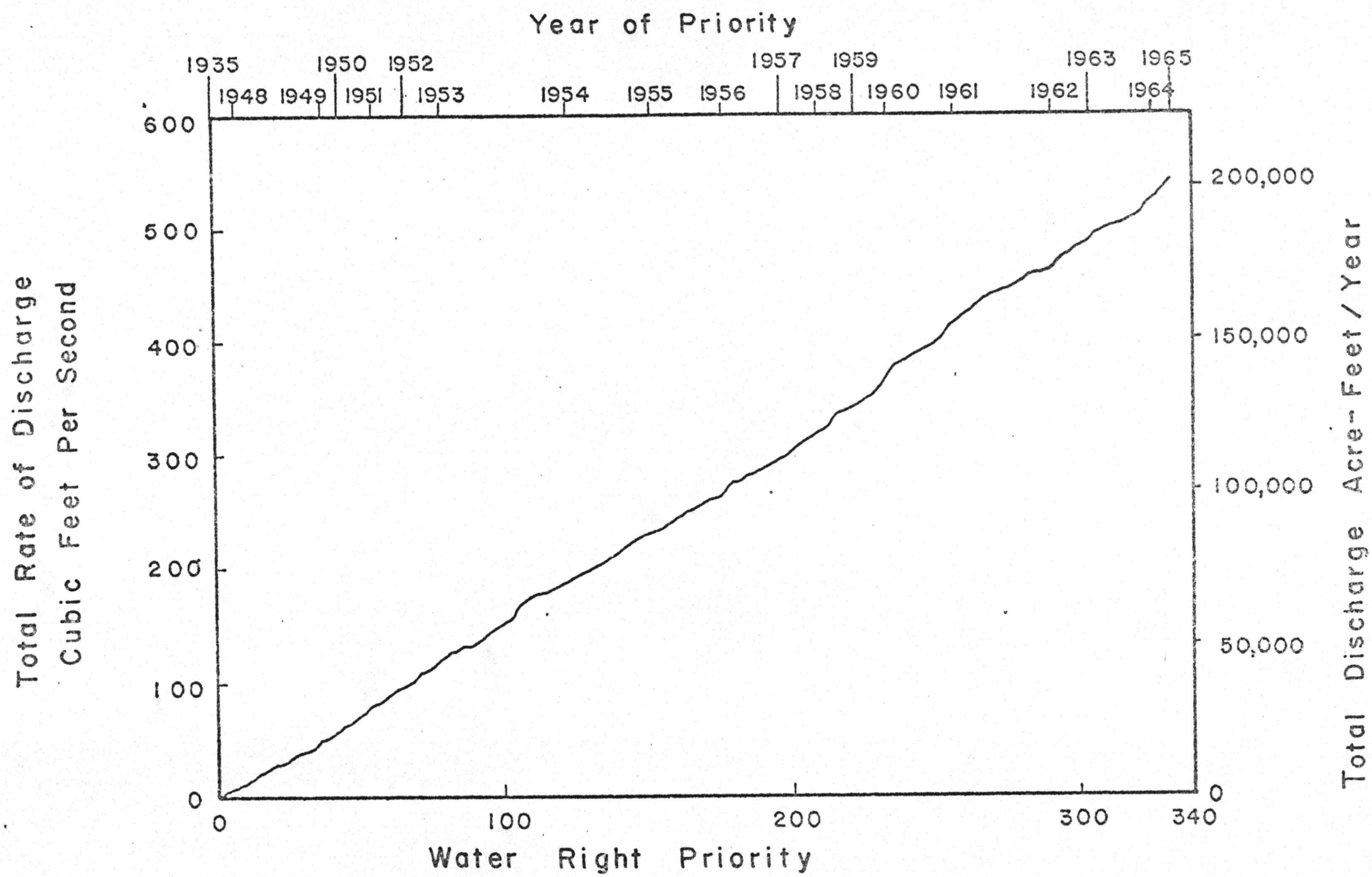


FIGURE 6 WATER RIGHT PRIORITIES AND TOTAL PUMPAGE FOR WELLS IN THE STUDY BASIN

Application of Management Alternatives to the Model of the Study Area

Management alternatives are evaluated using the model of the water resource system in the Raft River Basin by the control of pumpage from individual wells. Each well is identified by location and water right priority. Specific management plans include the operation or closure of wells based on priority and/or location

A Basis Run was designed to provide the standard for comparison of the impact of various management alternatives on the water resource system. The model was operated for this run for the period 1971-1990 with only those wells with valid water rights operating. Punched output was obtained of the water-level elevation at all nodes at the end of the pumping season each year. In addition, water-level data were punched at the start and end of the pumping season for all nodes where pumping wells are located. These data were utilized for hydrograph plots. Ground-water outflow from the basin was also calculated at the start and end of the pumping season for each year.

Basis Run

The Basis Run represents administration of the ground-water resource in the basin after the water rights adjudication without any closure of wells with valid rights. Considerable water-level change occurs in the basin during the period of 1971-1990. Areas of major decline coincide with concentrations of wells. The rate of decline is shown on Figures 7 and 8 for wells at nodes 4536 and 5437. The rate of decline is approximately constant for most wells. The ground-water outflow, as calculated by the model, steadily decreases with time as the impact of pumpage reaches the northern end of the basin.

Impact of the Adjudication of Ground-Water Rights in the Basin

The impact of the adjudication of ground-water rights in the basin is shown on Figure 9 as water-level changes from the Basis Run in 1975. All wells that historically pumped in the 1960-70 period were allowed to pump at the average rate for the ten year period regardless of water rights. The water rights adjudication in the study area resulted in the closure of 118 wells. Several areas of major water-level change may be seen on Figure 9 showing the impact of closure of the wells. Several major areas of decline are eliminated or reduced by the enforcement of the adjudication procedure.

Analysis of Reasonable Ground-Water Pumping Levels as a Tool for Resource Management

A number of administrative alternatives for management of ground water under the guideline of reasonable pumping levels are presented on Figure 1 (page 52). Five levels of decision are noted on that figure.

1. Selection of a management tool (reasonable pumping lift).

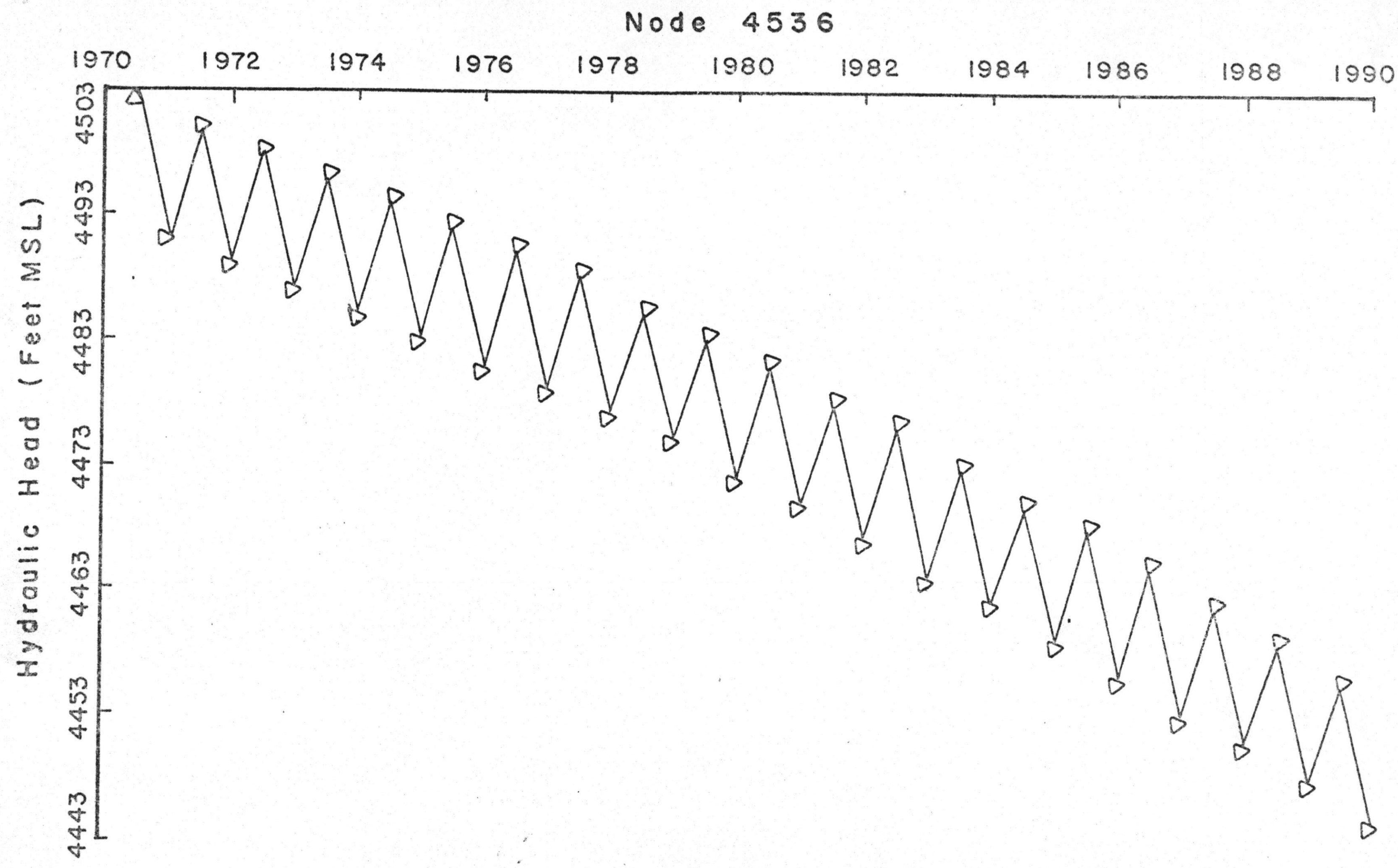


FIGURE 7 HYDROGRAPH OF THE WELL AT NODE 4536, BASIS RUN

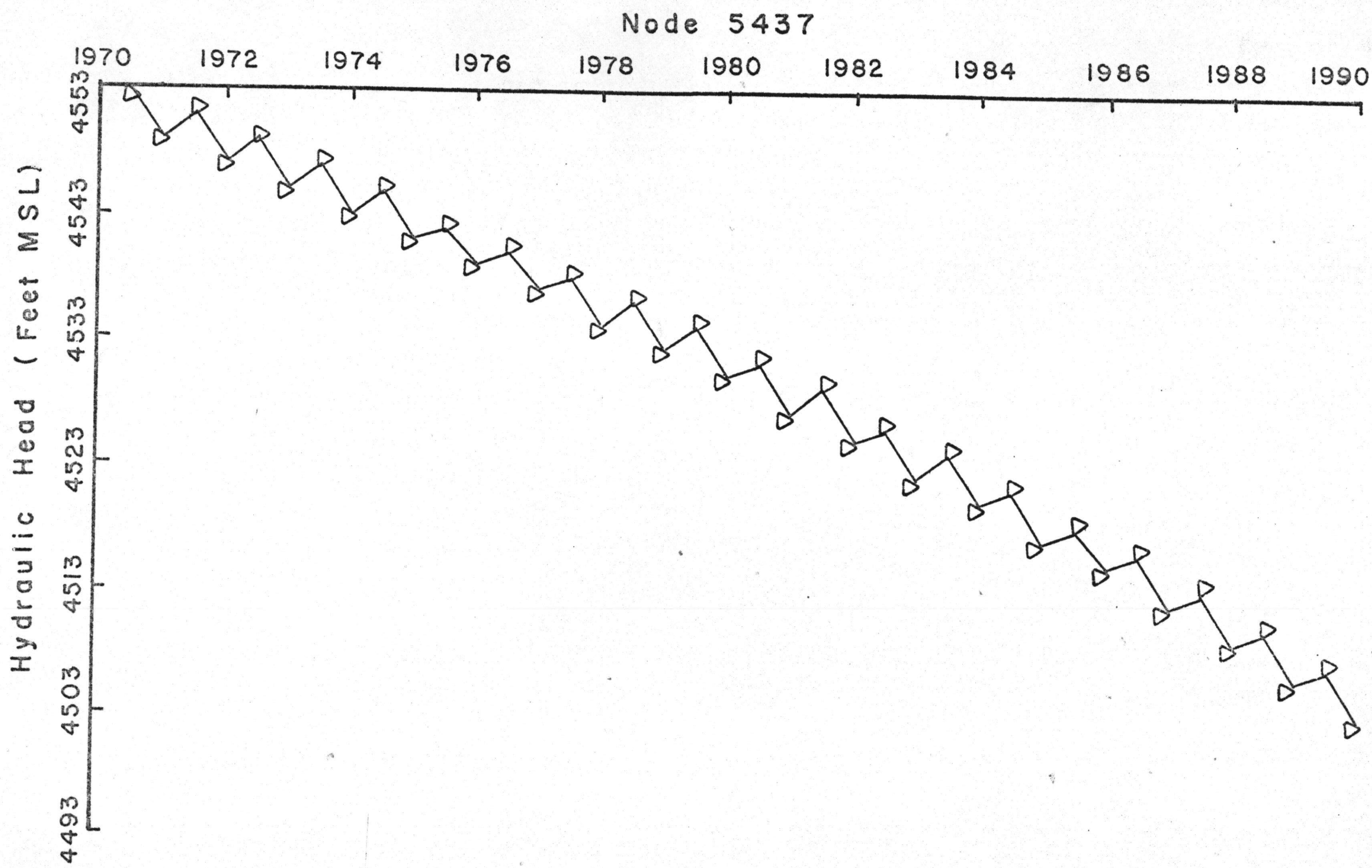


FIGURE 8 HYDROGRAPH OF THE WELL AT NODE 5437, BASIS RUN

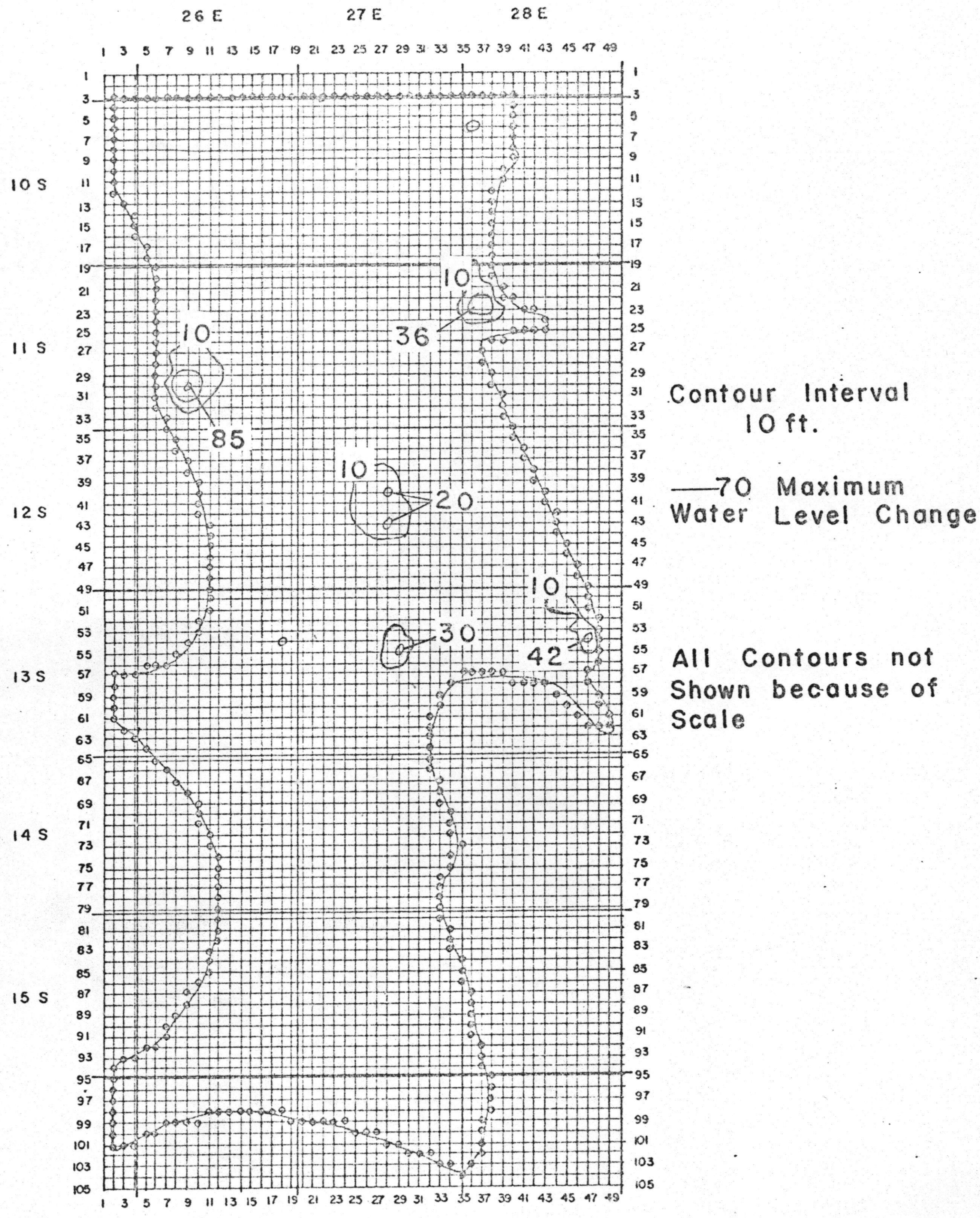


FIGURE 9 WATER-LEVEL CHANGES IN THE STUDY BASIN BY 1975 AS A RESULT OF THE WATER RIGHTS ADJUDICATION

2. Definition of the reasonable pumping lift concept.

   a. A limit on the maximum depth to pumping water level

   b. A combination limit on the maximum rate of water-level decline and the maximum depth to pumping water level.

3. Selection of administrative management units and selection of length of management periods.

4. Selection of the pump lift (or pump lift and rate of decline) values for the administrative unit or units.

5. Selection of method of application of reasonable pump lift values to junior users in the administrative units.

The concept of reasonable pumping levels was first evaluated as a limit on the maximum depth of pumping water level. Pump lift was determined for each operating well for each year of the 1970-1990 period using data generated from the Basis Run and an array of land surface elevations for well locations. The pumping lifts in wells in the basin in 1975 are presented in Figure 10. Most of the wells with pumping lifts greater than 250 feet are located around the margin of the basin. The distribution of pumping lifts in 1975, 1980, 1985 and 1990 are presented in Figure 11. The model pumping level increases from the range of 50-100 feet in 1975 to 100-150 feet in 1990. The mean pumping lift increased from 120 feet in 1975 to 144 feet in 1990.

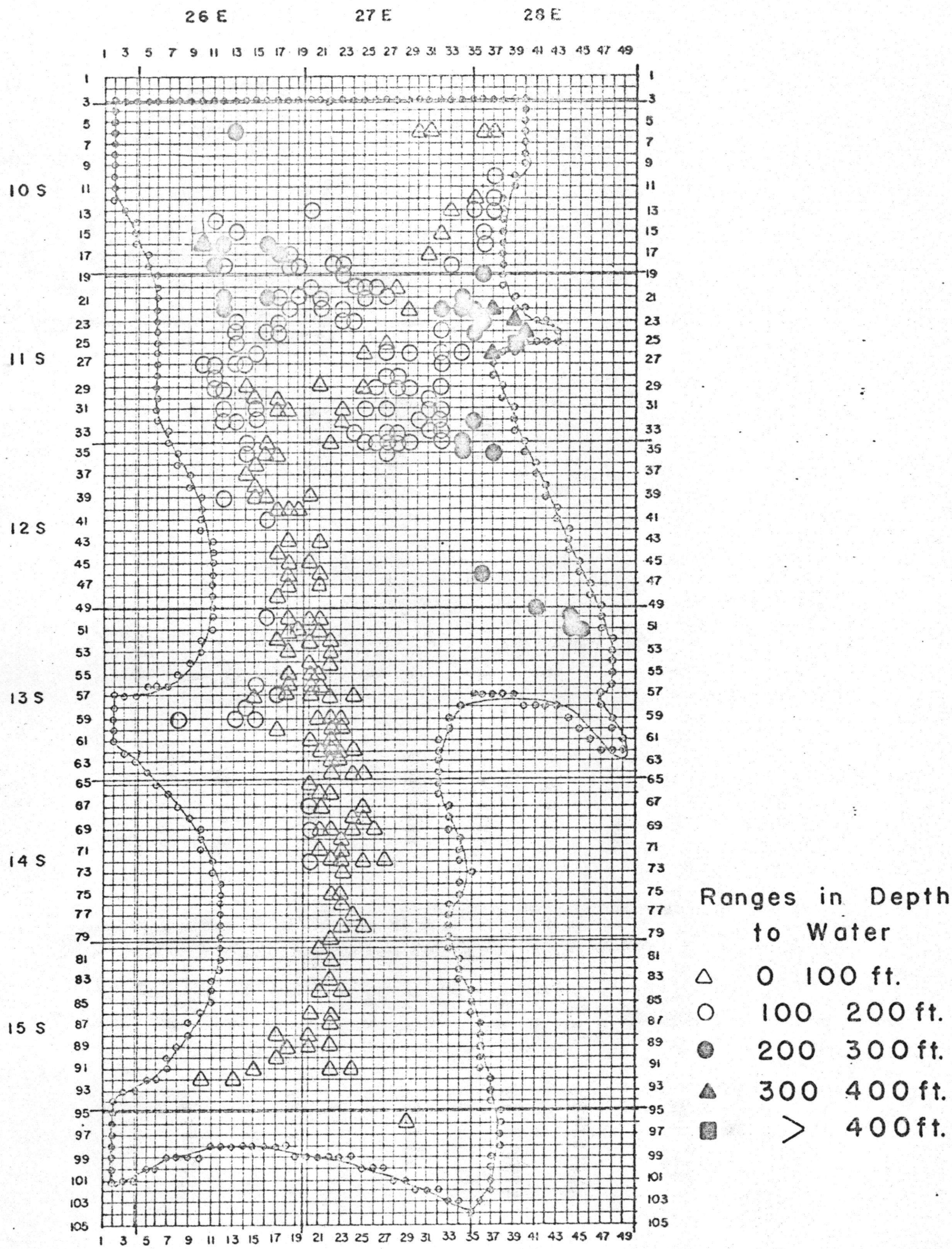
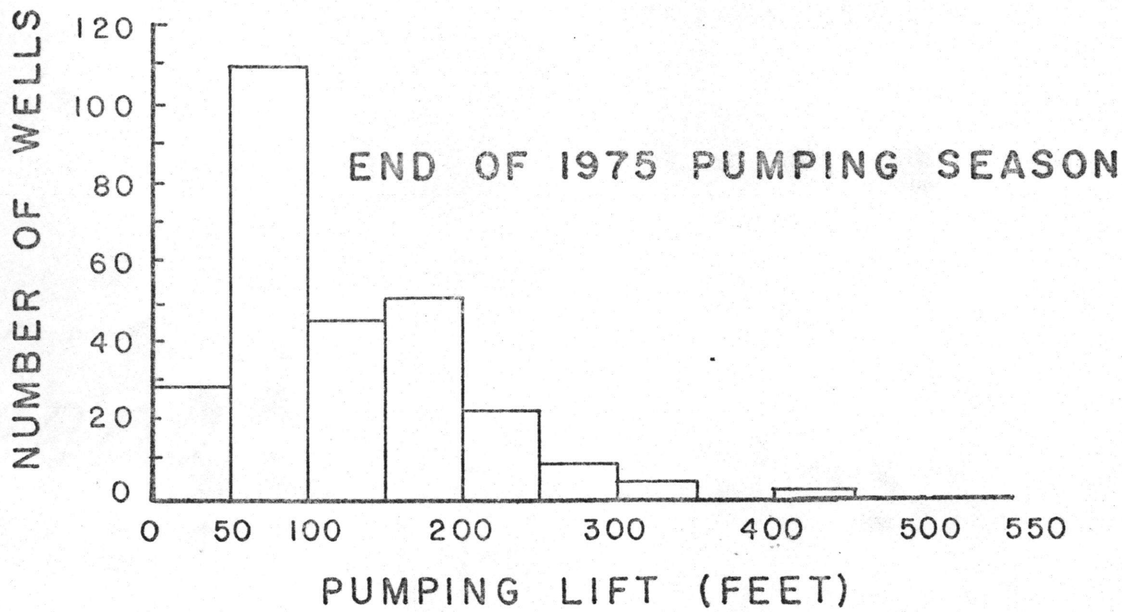
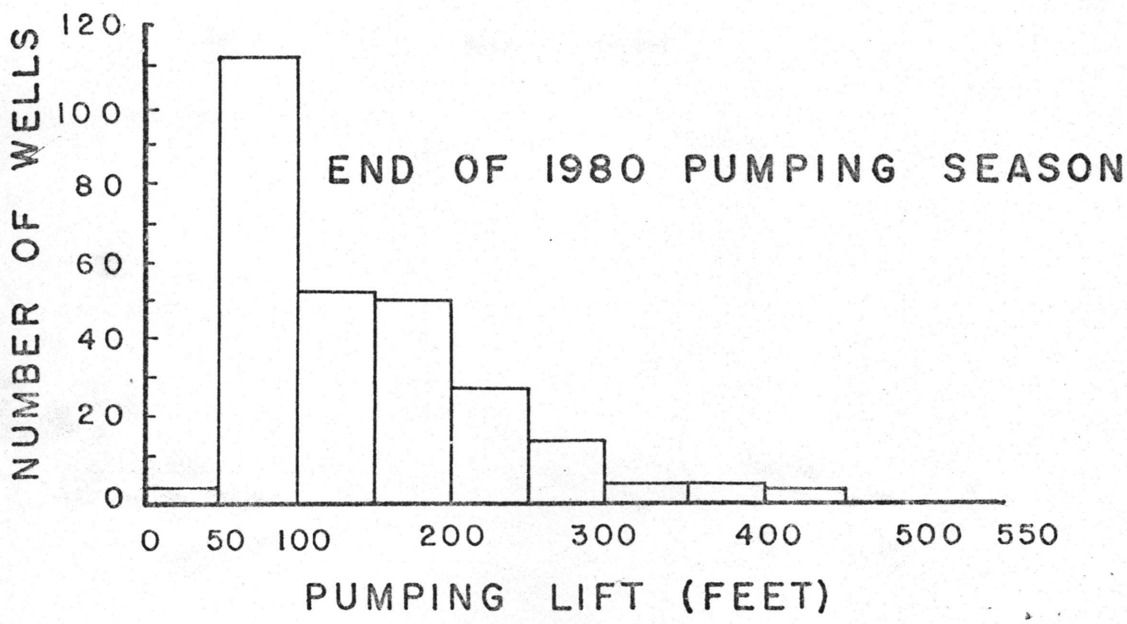


FIGURE 10 DEPTH TO PUMPING WATER LEVEL IN WELLS AT THE END OF THE PUMPING SEASON OF 1975, BASIS RUN



(A)



(B)

FIGURE 11 DISTRIBUTION OF PUMPING LIFT IN THE STUDY BASIN AT END OF PUMPING SEASON OF (A) 1975, (B) 1980, (C) 1985 AND (D) 1990

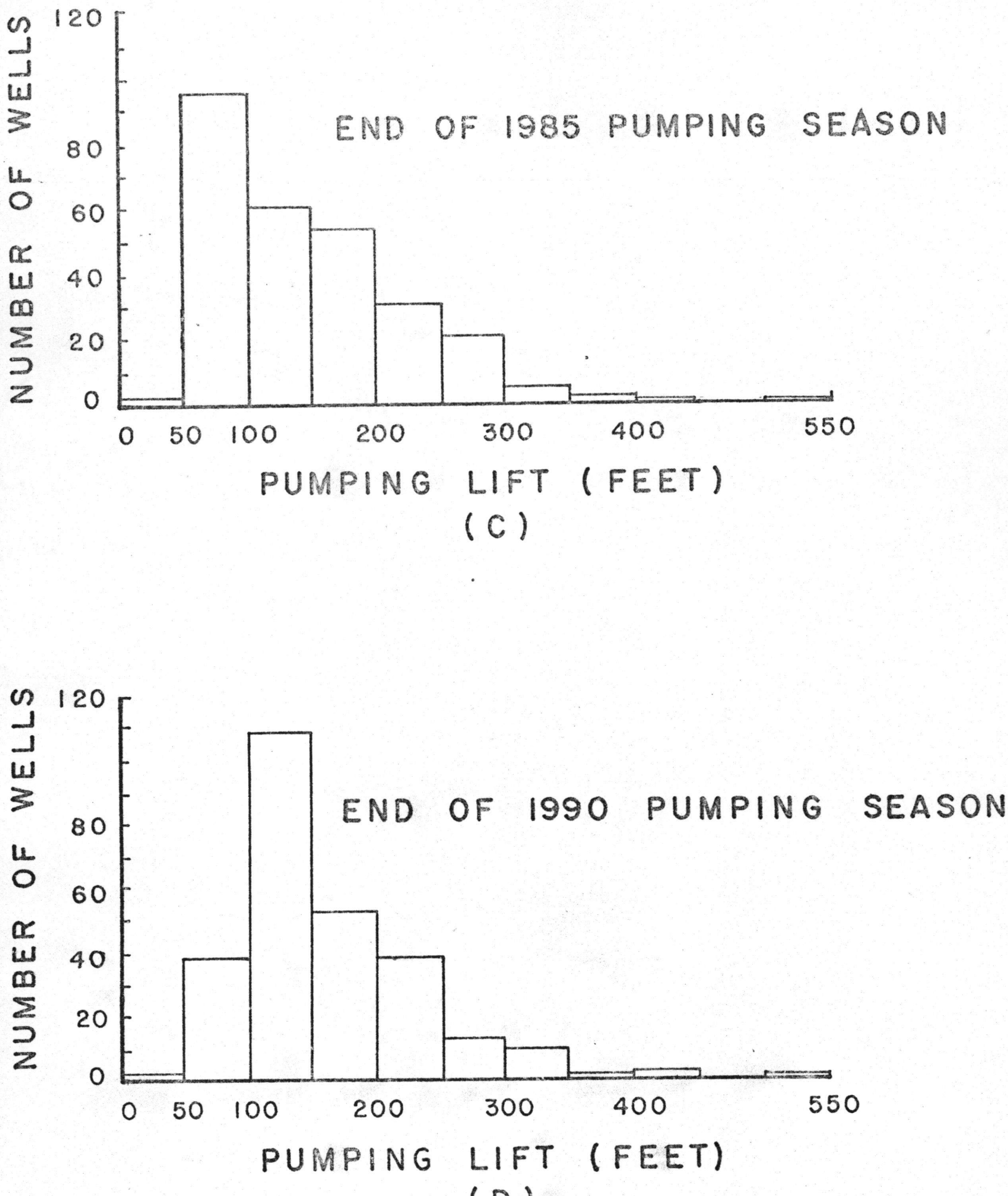


FIGURE 11 (CONTINUED)

The selection of reasonable ground-water pumping levels for a basin must be based on economic, social, physical, and political considerations. Young and Ralston (1971) present the only published estimates of reasonable pumping levels for the study basin. They note a range of 450-550 feet as a reasonable lift in the northern portion of the basin but suggest a lower but undefined lift for the southern portion of the area. The objective of this study is not the determination of a reasonable lift value but rather the determination of the impact of administration under this guideline. The number of wells per year that have pumping lifts equal or exceeding selected reasonable pumping lift values are presented in Table 1. If the reasonable pumping level were selected as 300 feet, three wells would already exceed that level in 1971. However, if the level were selected at 450 feet, administration would not be initiated until 1981 when one well reaches that level. It is assumed in this study that administration is automatically initiated when the level is reached. In actual basin administration, management action would probably not occur until a senior pumper registered a complaint and asked for action.

The first operational run for analysis of impact from resource administration under the reasonable pumping lift concept was based on the following decisions

Table 1. Number of Wells Per Year Equal or Exceeding Selected Reasonable Pumping Lift Values in Study Basin

PUMPING LIFT VALUE

Year	300 Feet	350 Feet	400 Feet	450 Feet	500 Feet
1971	3				
1972	3	1			
1973	4	1			
1974	4	1	1		
1975	5	1	1		
1976	5	1	1		
1977	5	1	1		
1978	5	3	1		
1979	5	3	1		
1980	5	3	1		
1981	5	3	1	1	
1982	8	3	1	1	
1983	8	3	1	1	
1984	8	3	1	1	1
1985	8	3	1	1	1
1986	10	4	3	1	1
1987	12	4	3	1	1
1988	13	4	3	1	1
1989	15	4	3	1	1
1990	17	4	3	1	1

(see Figure 1):

1. Reasonable pumping lift as the management tool.

2. Reasonable pumping lift defined as the maximum depth to pumping water level.

3. Entire basin selected as the administrative unit with administrative action continuing through 1990.

4. Reasonable pumping lift of 450 feet selected for administration.

5. Closure of junior users under plan A.

No administrative action would be required under this plan until 1981 when a single well reached the designated reasonable pumping lift. Resource administration would then be based on the priority and location of the control user at the critical level. The critical depth of 450 feet was reached by a well at node 2539 with a priority of 272. Under plan A, all users junior to the user at node 2539 would discontinue pumpage for the remainder of the administrative period. In this case, sixty users were shut off with a combined discharge of 97.8 cubic feet per second. The locations of these juniors are shown on Figure 12. The impact of this closure is shown on Figure 13 as water-level changes from the Basis Run by 1990. Most of the water-level change occurred in the center of the basin at some distance from the senior at the critical level. The senior received little benefit from this administrative

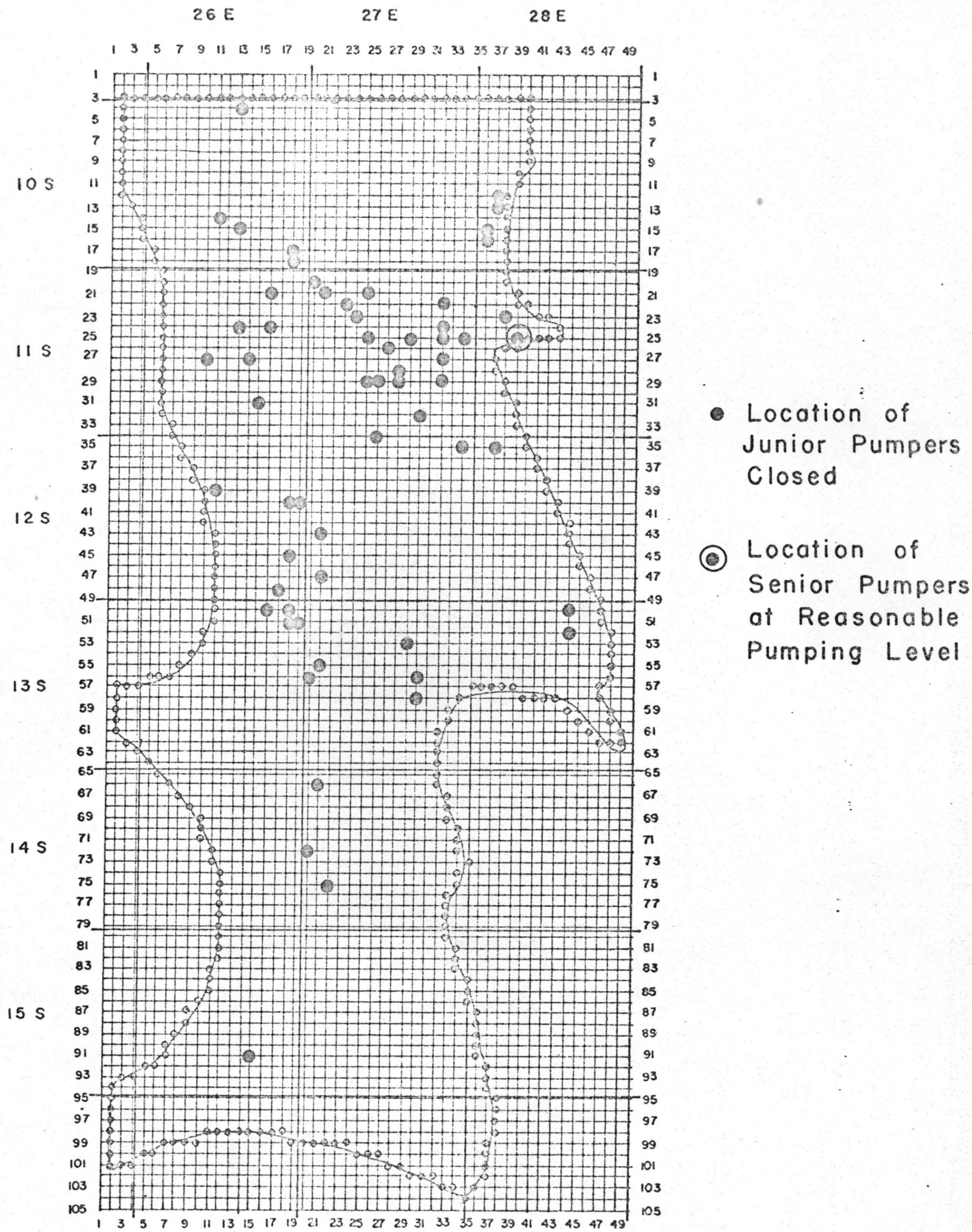
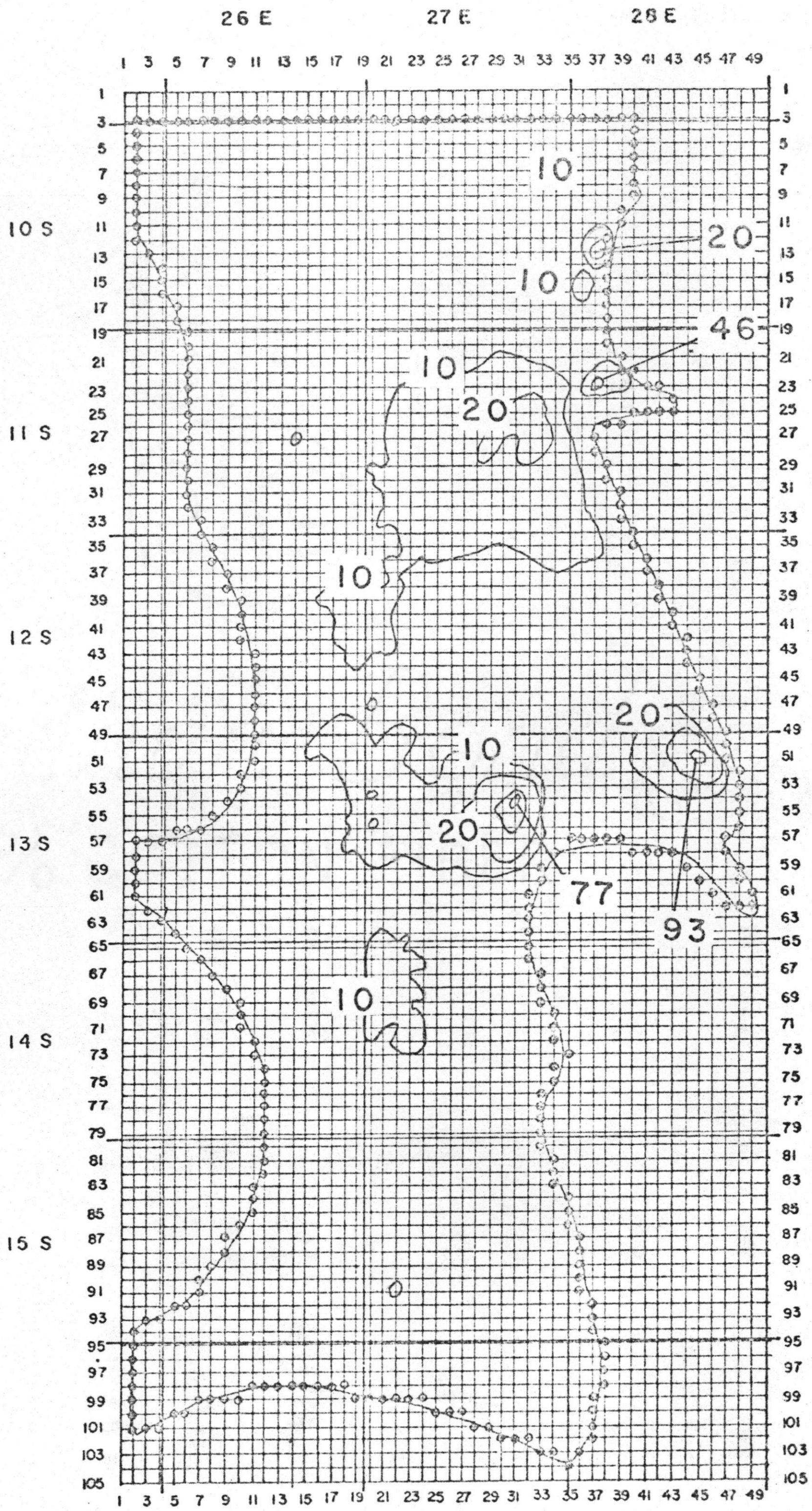


FIGURE 12 LOCATION OF JUNIOR PUMPERS NOT ALLOWED TO OPERATE UNDER PLAN A WITH CONTROL SENIOR AT NODE 2539



Contour Interval
10 ft.

—70 Maximum
Water Level Change

All Contours not
Shown because of
Scale

FIGURE 13 WATER LEVEL RISES BY 1990 BECAUSE OF CLOSURE OF JUNIORS UNDER PLAN A WITH THE CONTROL WELL AT NODE 2539 AS COMPARED TO THE BASIS RUN action, even though twenty percent of the pumpage in the basin was discontinued. The lack of benefit to the senior was a result of the location of the senior with respect to the juniors and the hydrologic characteristics of the ground-water system.

The model was next operated with the first four decisions equivalent in order to determine the impact of the fifth decision (the pattern of closure of junior pumpers) on the water resource system. Administration of the resource was achieved with the closure of juniors under plan B (Figure 1). In this case, (n) percentage of the juniors were shut down each year for (1/n) years in reverse order of priority. A total of 12 users were shut down in each of five years to accomplish the closure. Changes in water levels between closure by plan A and plan B were minimal in the basin. Closure of juniors over a period of time lessens the impact of administration on the economic and social condition of the basin. More time is allowed for changes in land use and life style.

Plan C for the closure of junior pumpers was also evaluated. This plan involves the closure of (m) juniors per year starting with the junior nearest the control senior. Closure is dependent on location rather than relative priority among the juniors. This alternative was analyzed by closing five juniors per year for three consecutive years. Water-level changes are more localized in the area of the senior pumper. However, the senior received little benefit from the closure. The economic and social impact of administration in the basin is more limited under plan C than plans A or B.

The impact of administration of the basin with different reasonable pumping lift values was also evaluated. A reasonable pumping lift of 350 feet was selected for examination. The 350 foot pumping level is first reached by the well at node 2539 in the pumping season of 1972 (see Table 1). Administrative action would be initiated by the closure of wells for the pumping season of 1973 under either plans A, B. or C. The only difference between this action and the one described earlier, is the length of the administrative period. Water-level changes would be similar to those presented previously.

The well at node 2539 is not representative of the majority of the wells in the basin (see Figure 11). It is located on the extreme eastern margin of the basin in a relatively thin section of the aquifer. The pumping lift is at least 50 feet greater than any other well in the study area. This well was temporarily removed from the analysis to determine the impact of administration based upon a different control senior.

The next wells to reach the designated reasonable pumping lift of 350 feet are located at nodes 2339 and 2440 in the pumping season of 1978. The priorities of the wells at nodes 2339 and 2440 are 270 and 271 respectively. They are located within one mile of the well at node 2539 with a priority of 272. The only difference between administration based on these wells and administration based on well 2539, is the closure of the well at node 2539. The water-level changes resulting from administration based on the wells at nodes 2339 and 2440 would be very similar to that described previously. If these wells are also removed from the analysis, administration would be based on the well at node 2237. This well reaches the critical level in the pumping season of 1986. The location and priority (262) of this control senior would result in a similar physical impact from administration as that described above.

Administrative action based upon the following decisions provide a single general impact upon the basin.

Decisions

1. Reasonable pumping lift as the management tool.

2. Reasonable pumping lift defined as the maximum depth to pumping water level.

3. Entire basin selected as the administrative unit with administration continuing from the time of administrative action through 1990.

4. Reasonable pumping lift selected as any value equal to or greater than 350 feet including or excluding the three users with the greatest lift.

5. Closure of juniors under plan A, B, or C.

Administration of ground water is controlled by a group of wells along the eastern margin of the basin. These wells have consecutive priorities which may indicate ownership by a single individual. Users junior to these wells are located throughout the basin. Closure of the juniors results in general water-level rise in the basin, but provides little improvement of the senior's pumping level. The depth to water in these wells is greater than other wells in the basin because of the location near the margin of the valley and the lower aquifer transmissibility. Given the decisions noted above, administration of the basin appears ineffective. Little protection is given to the senior user at the expense of closure of a large group of juniors.

The administrative action outlined above might benefit the senior user if the length of the administrative period is extended significantly. The analysis was limited to the period of 1970-1990 because of monetary limitations on the operation of the model. The length of the administrative period required to provide the senior with a measureable benefit could not be estimated from the available information.

The next series of operational runs were conducted with the following decisions:

Decisions

1. Reasonable pumping lift as the management

tool.

2. Reasonable pumping lift defined as the maximum depth to pumping water level.

3. Basin divided into two administrative units with the division line at node row I=37 with administration continuing from the time of administrative action through 1990.

4. Reasonable pumping lift of 450 feet selected for administration in the northern portion of the basin and a lift of 300 feet selected for administration in the southern portion of the basin.

5. Closure of junior users under plan A.

The division of the basin into two units has been suggested by Schatz (1974) on the basis of his analysis of economic return from irrigation by ground water. He noted that the northern portion of the basin has the potential for row crop agriculture while the southern portion of the basin is limited to lower return grain and pasture operations. The division of the basin at node row 37 follows Schatz's economic division of the basin. Young and Ralston (1971) noted different reasonable pumping lift values for the northern and southern portions of the basin. Their division line is similar to that suggested by Schatz. A reasonable pumping lift of 300 feet was suggested by Schatz (personal communication , 1974) for the southern portion of the basin on the basis of lower net returns from farm operation. The 450 foot reasonable pump lift value is that suggested by Young and Ralston (1971) as a minimum for the northern part of the basin.

The division of the basin into two administrative units limits closure of juniors to users within each unit. A senior user at the critical level in the northern portion of the basin may not force closure of a junior user in the southern portion of the basin.

Administrative action was initiated in the northern portion of the basin when the user at node 2539 reached the designated reasonable pumping lift of 450 feet in the pumping season of 1981. The first user to reach the designated level of 300 feet in the southern portion of the basin was at node 4941 in the pumping season of 1982. The water right for this well has a priority of 172. Under plan A, all users junior to priority 272 in the northern portion of the basin were closed in 1982 while all users junior to priority 172 in the southern portion of the basin were closed in 1983. Thirty-eight wells in the northern portion of the basin with a combined discharge of 58 cubic feet per second were not allowed to pump. An additional 61 wells totaling 103 cubic feet per second of discharge were not allowed to operate in the southern administrative unit. The locations of the wells are shown on Figure 14. The results of the administrative action is presented in Figure 15 as water-level change from the Basis Run by 1990. Extensive water-level change may be seen in the center of the basin. Little rise of water levels

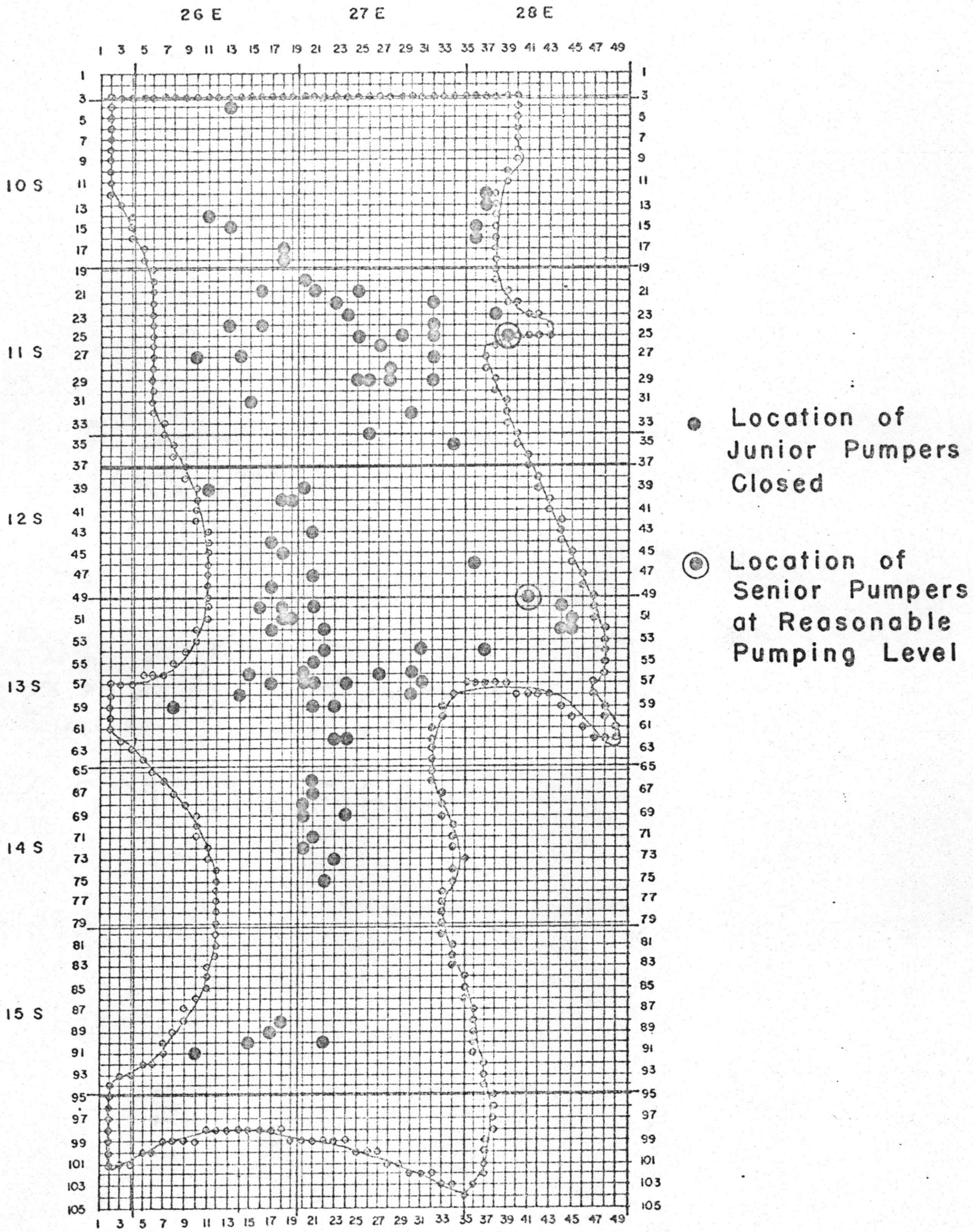
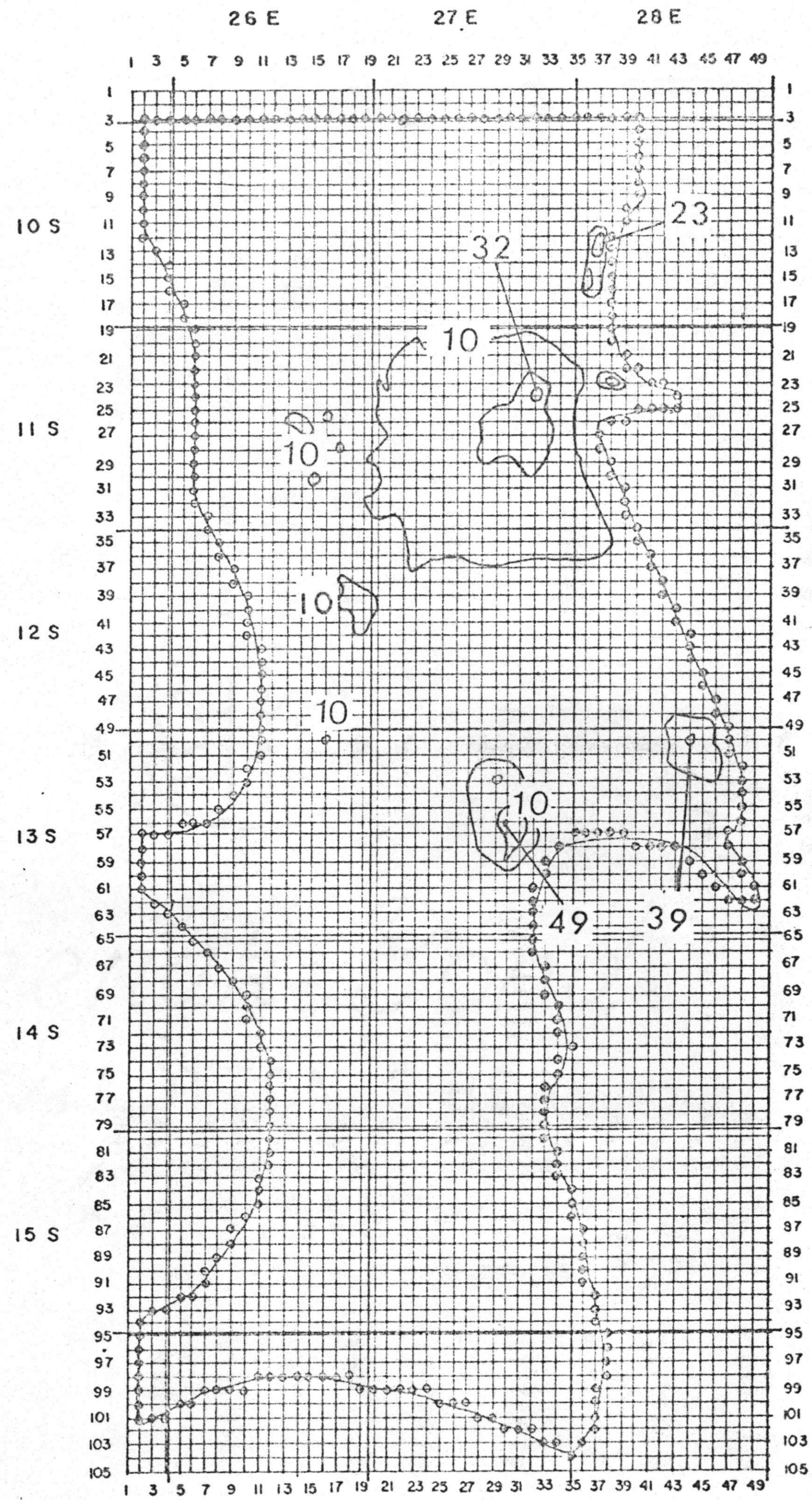


FIGURE 14 LOCATIONS OF JUNIOR PUMPERS NOT ALLOWED TO OPERATE UNDER PLAN A WITH BASIN DIVIDED AT I = 37 AND CONTROL SENIORS AT NODES 2539 AND 4941



Contour Interval
10 ft.

70—— Maximum
Water Level Change

All Contours not
Shown because of
Scale

FIGURE 15 WATER LEVEL RISES BY 1990 BECAUSE OF CLOSURE OF JUNIORS UNDER PLAN A WITH BASIN DIVIDED AT I = 37 WITH CONTROL WELLS AT NODES 2539 AND 4941 AS COMPARED TO THE BASIS RUN occurs near the northern control well. Some rise in water level is shown at node 4941, as a result of the closure of wells to the southeast. The decreased rate of water-level decline in well 4941 is shown in Figure 16.

Closure of juniors under plans B and C were evaluated in the next operational runs. Water-level changes by 1990 from closure of juniors under plan B were very similar to those for plan A. The water-level changes by 1990 from the Basis Run by closure of juniors under plan C is presented in Figure 17. The location of the wells is shown on Figure 18. Rises in water level are more localized to the areas of the control wells. The hydrographs from the well at node 4941 from the closure of juniors under plans B and C are similar to that for plan A. The senior in the southern unit is provided with the same benefit within the administrative period by the closure of 12 wells closest to him as by the closure of all 61 users junior to him in the administrative unit.

The division of the basin into two administrative units does not increase the protection given to the senior at the critical level but does increase the protection for the juniors from closure based on the water-level conditions of a well in the other end of the basin. The division allows for administration of the water resource in the basin on more than one reasonable pumping lift. The degree of protection given the senior by administrative

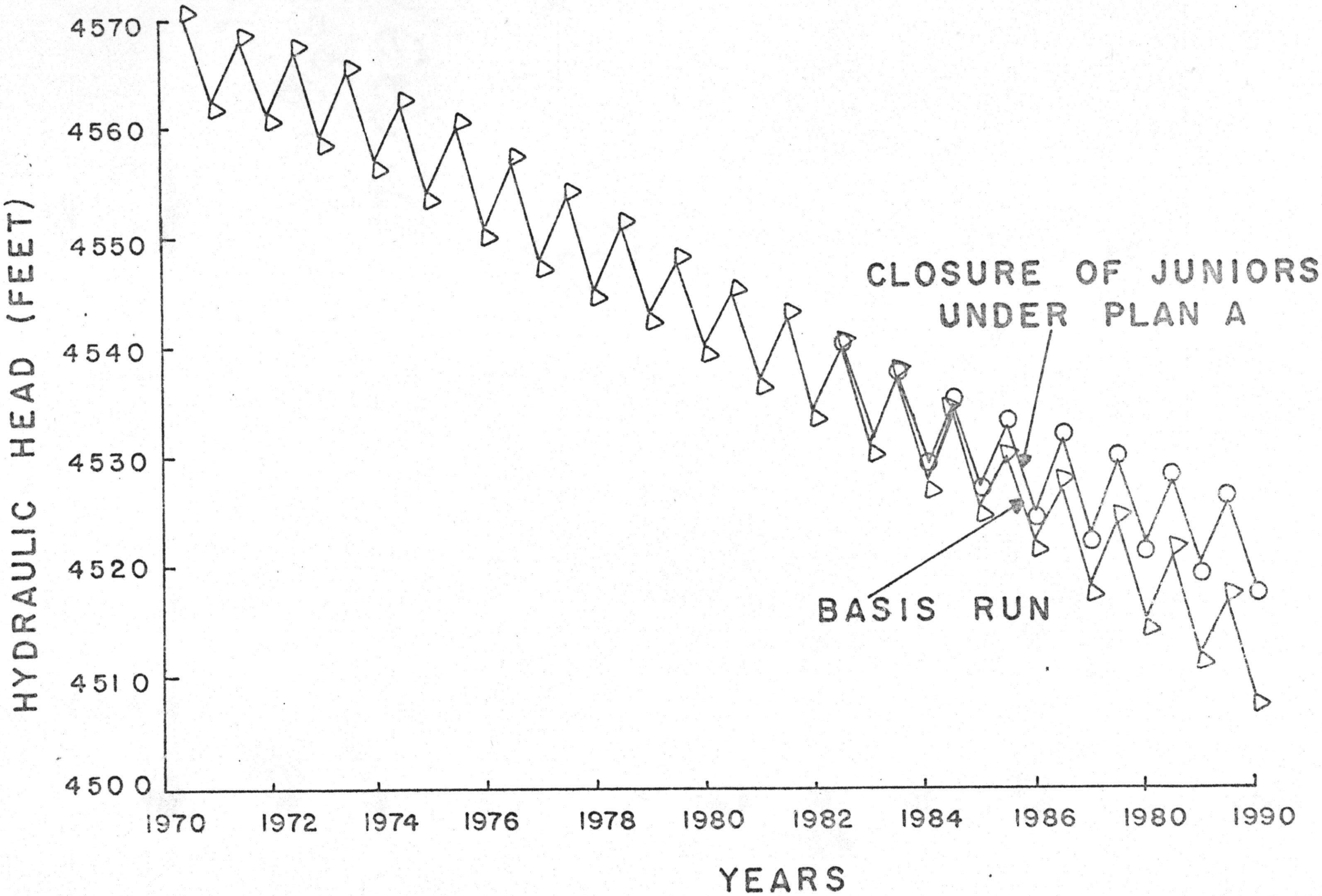
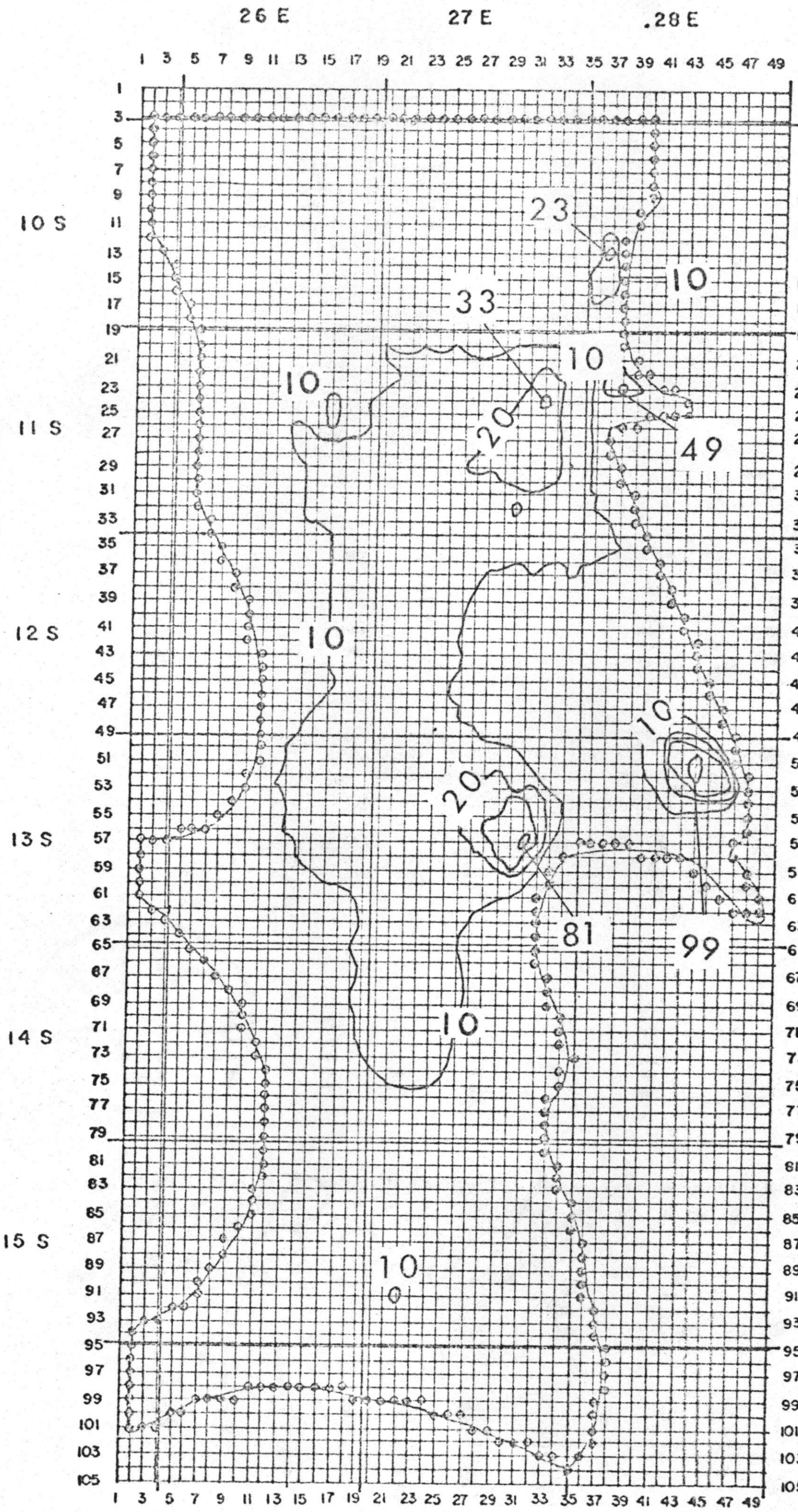


FIGURE 16 HYDROGRAPHS OF WELL AT NODE 4941 FROM BASIS RUN AND FROM OPERATIONAL RUN WITH CLOSURE OF JUNIORS UNDER PLAN.A WITH BASIN DIVIDED AT I=37



Contour Interval = 10 ft.

—70 Maximum Water Level Change

All Contours not Shown because of Scale

FIGURE 17 WATER LEVEL RISES BY 1990 BECAUSE OF CLOSURE OF JUNIORS UNDER PLAN C WITH BASIN DIVIDED AT I = 37 WITH CONTROL WELLS AT NODES 2539 AND 4941 AS COMPARED TO THE BASIS RUN

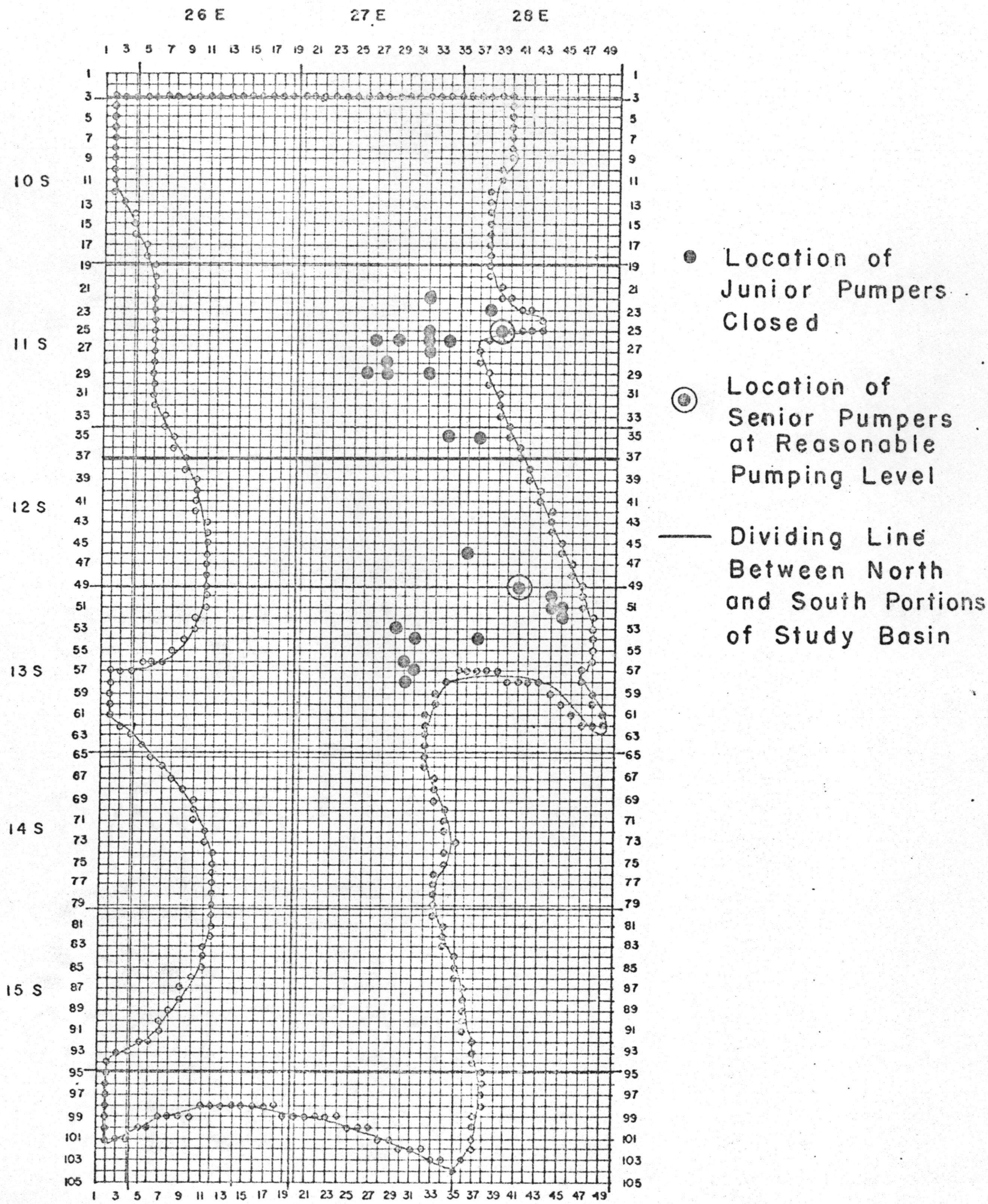


FIGURE 18 LOCATIONS OF JUNIOR PUMPERS NOT ALLOWED TO OPERATE UNDER PLAN C WITH BASIN DIVIDED AT I = 37 AND CONTROL SENIORS AT NODES 2539 AND 4941.

action is still more dependent on his location within the basin and with respect to other users than the relative priority of his water right. Closure of 58 users in the northern portion of the basin did not benefit the senior because none of the juniors were located near him. However, closure of 12 juniors in the southern portion of the basin benefited the senior because they were located near him.

The reasonable pumping levels criteria was next evaluated as a limit on the rate of water level decline and the maximum depth of pumping water level. The annual water-level change in each well in the basin was determined from the punched arrays of data generated from the Basis Run. The water-level change in wells from 1982 to 1983 (measurements at the end of the pumping season) is presented in Figure 19 as an example of these annual changes. The distribution of these changes is presented in Figure 20. The mean annual change in water level shown on the figure is 2.8 feet. Only eight wells have a water level drop greater than five feet per year. Only one well has an annual decline greater than 10 feet.

Schatz (1974) evaluated the impact of various rates of water-level decline on farm interprises in the study basin. He studied annual decline rates of 1, 2 , 3, 4, 5, and 10 feet and concluded that the lower rates have little economic significance on farm income in the area. Users have sufficient time to depreciate required changes in

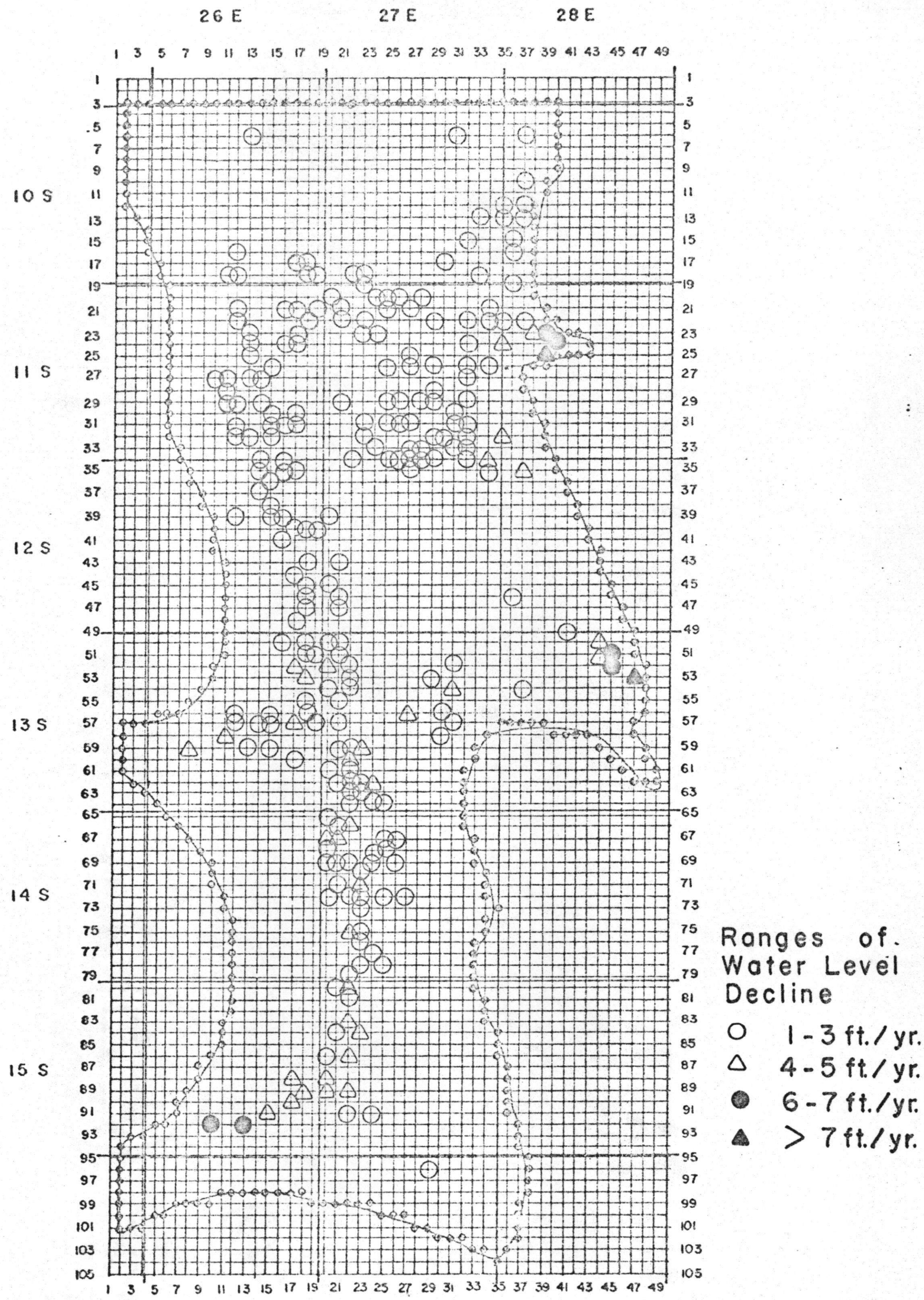


FIGURE 19 WATER LEVEL DECLINE IN WELLS FOR PERIOD 1982-1983, BASIS RUN

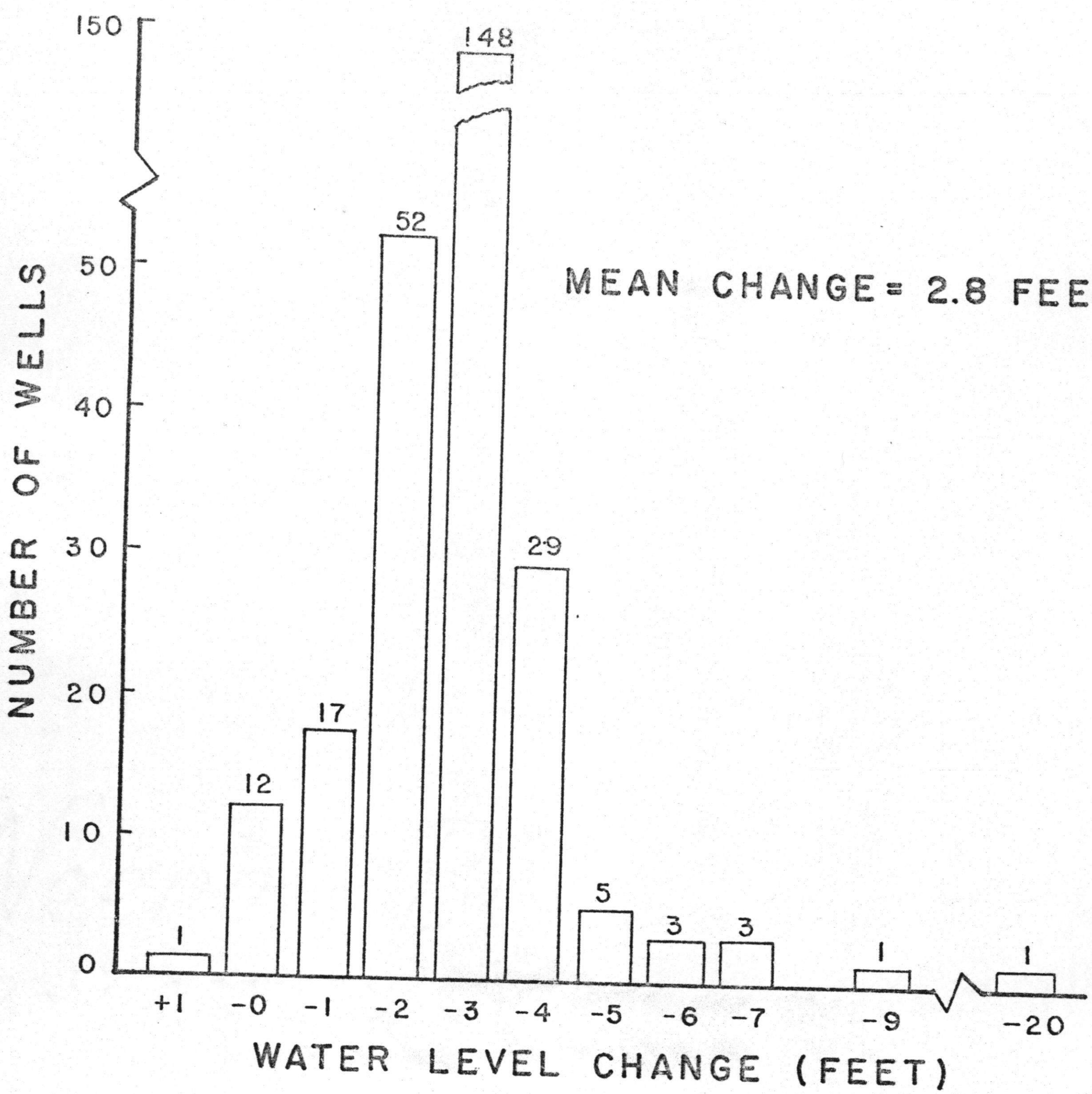


FIGURE 20 HISTOGRAM OF WATER-LEVEL CHANGES IN WELLS FROM 1982 TO 1983, BASIS RUN

well depth and pumping equipment to minimize the impact. Schatz did note that a water-level decline of ten feet per year or greater has a significant impact on the net return to the user. These rates of decline were found to be from an economic viewpoint as measured by the impact on farm income. Butcher and others (1971) concluded that a decline rate of ten feet per year is the maximum limit for continued irrigation using ground water.

Only one well in the basin has a consistent decline in water level of more than ten feet per year; the well at node 2539. This well also has the greatest depth to water and is the controlling well in the analysis based on reasonable pumping lift as the maximum depth to pumping water level. Administration of the ground-water resource based on rate of water-level decline using this well as control would be similar to that described previously. The only difference would be in the length of the administrative management period. In this analysis, administration would be initiated in 1972.

The well at node 5348 has an average rate of annual decline of 9.2 feet, the second greatest rate of decline in the area. The well at this node has a priority of 265 as compared to the priority of 272 for the well at node 2539. Basin wide administration under plans A and B would result in a similar water-level change as shown on Figure 13. The user at node 5348 would have little relief under this administrative action. The water-level decline in his well is primarily the result of his own withdrawal and his location near the edge of the aquifer system.

Protection of a reasonable rate of water-level decline is a function of the senior's location in the basin and the location and priority of nearby users as well as his own priority.

Analysis of the Recharge Limitation as a Tool for Resource Management

Administrative alternatives for management of ground water under the guideline of limiting pumpage to the "reasonably anticipated average rate of future natural recharge" are presented in Figure 2. Five levels of decisions are noted on that figure.

Decisions

1. Selection of a management tool (recharge limit).

2. Definition of the recharge limit concept
   a. Recharge limitation defined as the total water available for man's use in the basin (water yield).

   b. Recharge limitation defined as the total recharge to the ground-water system.

   c. Recharge limitation defined as equal to the total recoverable discharge from the ground-water system.

   d. Recharge limit defined as time dependent as a function of the hydrologic, economic and well location conditions in the basin.

3. Selection of administrative management units and selection of the length of management periods.

4. Selection of recharge value or values.

5. Selection of method of application of the recharge restriction to junior users in the administrative units.

Administration of a ground-water resource under this criteria does not depend on a cause-effect type of resource response. Junior users are not shut down to provide immediate relief for seniors but rather to provide some long term certainty of water availability. The mathematical model of the water resource system in the study basin was not suited to long term analysis of impact from administration because of the limited period of calibration and the high cost of operation. The model was used to provide short term information on the impact from administration under the recharge limitation.

The major problem with administration of the resource under the recharge limitation is the definition of the concept and its quantification. The "water-yield" of the study basin has been estimated in three separate studies. The yield estimates of the entire Raft River Basin, of which the modeled area is only a part, range from 140,000 acre-feet per year (Walker and others, 1970), to 320,000 acre-feet per year (Mundorff and Sisco, 1963). The third estimate was 183,000 acre-feet (Nace and others, 1960). Some difference occurs between the reports in the definition of the term water yield. If the highest estimate of water yield is adopted for administration, then no management action is warranted. Pumpage during the Basis Run was held at 203,000 acre-feet per year. Selection of the 140,000 acre-feet per year or the 183,000 acre-feet per year values would necessitate closure of a portion of the users in the basin. Ninety-seven users would be shut off with the former recharge value; thirty-four users would not be allowed to pump with the latter recharge estimates.

If the recharge limit is defined as the total recharge to the ground-water system, then a value less than the basin water yield would have to be used. Some water included in the water yield estimate is diverted and consumptively used for surface water irrigation. No estimates are available of the quantity of water annually recharged to the ground-water system. Direct recharge to the ground-water system was held at 74,000 acre-feet per year for the model operation. This figure is believed to be a conservative estimate of the recharge to the system. Pumpage would have to be reduced by about sixty-three percent if this value was selected as the basis for administration under the recharge limitation. Only the most senior 130 users would be allowed to pump in the basin.

The recharge limitation may be defined as equal to the total recoverable discharge from the ground-water system. It is often not possible to eliminate all natural discharge from the basin because of various physical, economic and social constraints. Well development must be limited to the portion of the discharge from the basin that is recoverable to have a long term equilibrium condition. Walker and others (1970) estimated that 29 percent of the natural discharge from the study basin was by consumptive use of riparian vegetation, 12 percent by surface water discharge and 59 percent by ground-water outflow. They noted that development by 1966 had resulted in a 50 percent reduction in the consumptive use of riparian vegetation, an 89 percent reduction in the surface water outflow and four percent reduction in the ground-water outflow. Walker further stated that a "reduction of the ground-water outflow by about half... would require lowering the water level several tens of feet in the area immediately north of the present areas of greatest water-level decline. The time required to effect the reduction would be very great, and very large additional quantities of ground water would be removed from storage". (Walker and others, 1970, p. 91). If half of the ground-water outflow is considered recoverable, then the recharge value (based upon the 140,000 acre-feet per year water yield estimate) would be 100,000 acre-feet per year. If none of the ground-water outflow is considered recoverable, then the recharge value would be only 60,000 acre-feet per year.

A wide range of equilibrium conditions between recharge, natural discharge and artificial discharge can occur in the basin depending on the extent to which the water level is allowed to decline. The recharge value may be defined as a rate of pumpage which will allow equilibrium conditions to occur. A relatively shallow reasonable pumping lift would prevent major water level decline and limit the recovery of natural discharge. Pumpage would be limited severely under these conditions. The recharge limit under this definition has not been estimated.

The short term impacts of basin wide administration under three defined recharge levels are presented to illustrate the impact of management under this constraint. The water-level change map presented in Figure 13 shows the impact of eight years of basin operation with a reduction of pumpage to 166,000 acre-feet per year. The impact of pumpage at a level of 143,000 acre-feet per year is shown on Figure 15 after seven years of administration. An additional run was made to show the impact of the extreme closure down to a pumpage level of 74,000 acre-feet per year after ten years of basin operation (Figure 21). Water-level rises are seen from all three figures. Sufficient data are not available to interpret the long term impact from such administration.

The selection of administrative management units and the selection of the administrative management period would be based upon the definition of the recharge limitation. These administrative tools could be used to achieve

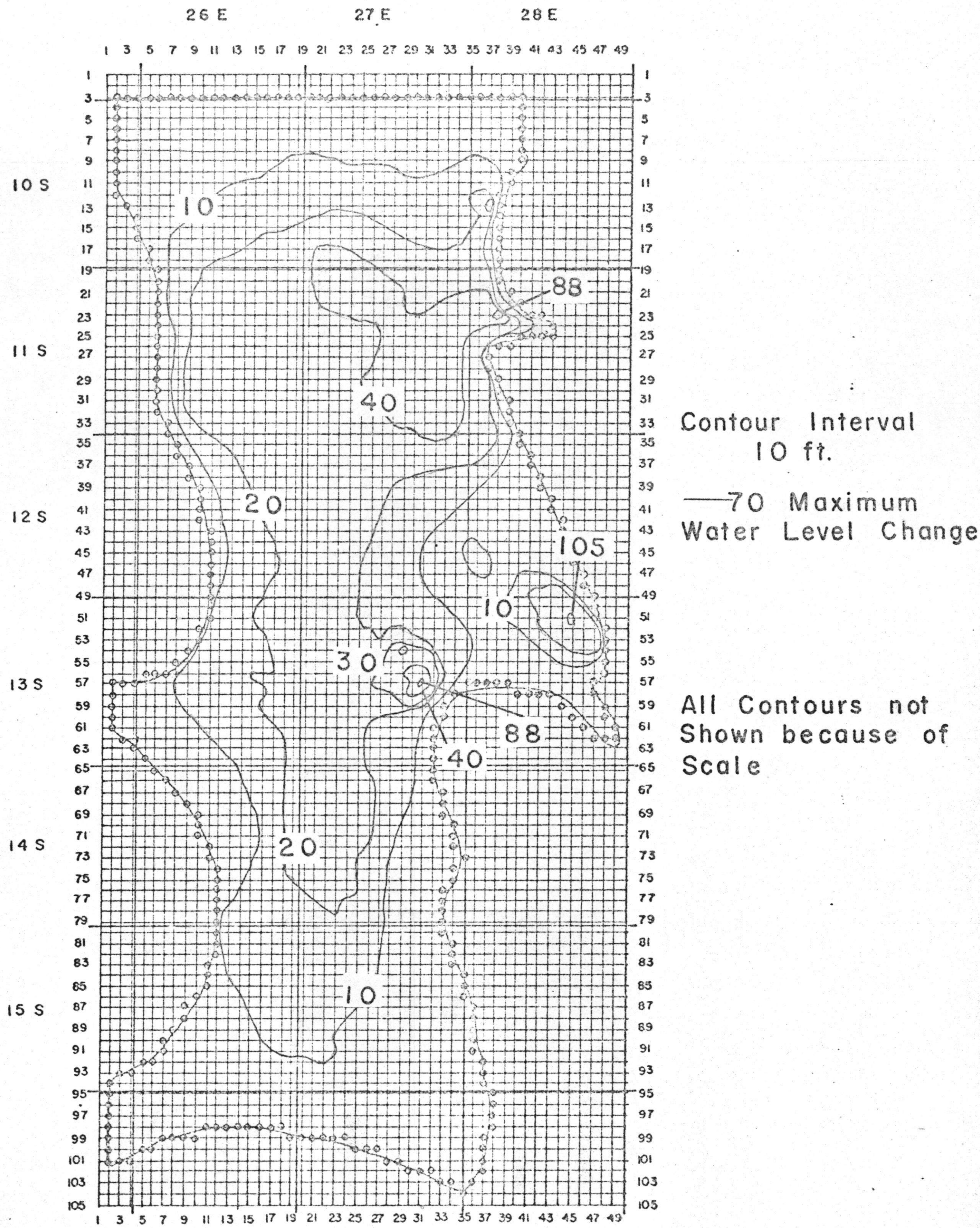


FIGURE 21 WATER LEVEL CHANGES BY 1990 FROM CLOSURE OF WELLS TO LIMIT PUMPAGE TO 74,000 ACRE-FEET PER YEAR, AS COMPARED TO THE BASIS RUN

the equilibrium condition with the maximum basin pumpage.

CHAPTER VI

CONCLUSIONS

1. Ground-water management in Idaho can be achieved by the administration of the resource under the state laws of water allocation.

2. The stock-flow relationship of ground water is an important factor affecting resource management under the appropriation doctrine.

3. Management of the ground-water resources in Idaho rests largely on the interpretation and application of two legislative phrases: 1) reasonably anticipated average rate of future natural recharge and 2) reasonable ground-water pumping levels. These phrases must be considered in light of the stated legislative intent of full economic development of the underground water resources.

4. Five basic decisions may be outlined for administration of ground water under the constraints set forth in the Idaho Code: 1) selection of the management tool, 2) definition of the concept, 3) selection of the size of the administrative units and the length of the administrative period, 4) selection of the reasonable pumping lift or recharge value or values for each administrative area and 5) application of the selected value to junior users within the administrative area.

5. The reasonable pumping lift concept is based upon a cause-effect relationship. This relationship is dependent on a number of factors. The impact on a senior's well of a

junior appropriator's well may be very limited because of the stock characteristics of ground water.

6. Operation of the mathematical model indicated that the senior users at the designated reasonable pumping levels received little benefit from closure of juniors under any of the management plans.

7. Alternative plans for the closure of junior appropriators under the reasonable pumping lift restriction had little impact on the ground-water levels in the vicinity of the senior user's well. The senior received equal or greater protection with lessened impact on the economy of the area by closure of juniors over extended periods or by closure of only those juniors nearest the senior.

8. Changes in the value of the pumping lift had little effect on the pattern of resource administration in the study basin.

9. Application of the constraint of reasonable ground-water pumping levels was based on senior appropriators who are located along the edge of the basin where the static depth to water is greater and the aquifer is thinner.

10. The division of the basin for resource administration had little impact on the protection given the senior appropriators.

11. The pattern of administration of the ground-water resource in the study basin was the same for either

definition of the reasonable pumping lift constraint.

12. The degree of maintenance for a senior's means of diversion is only partially measured by his water right priority. It is also dependent on his location both in the basin and with respect to other users and the relative priority of the surrounding users. The user who is surrounded by users with more senior rights receives little benefit from any plan of resource administration.

13. Administration of the ground-water resource under the recharge restriction is based upon long-term impacts and is not dependent on any direct cause-effect relationship.

14. The most important decision in the administration of ground water under the recharge restriction is the definition of the concept.

15. Administration of the resource under the recharge restriction must include consideration of the time required for the establishment of hydrologic equilibrium conditions and the relationship between the level of equilibrium the extent of ground-water mining.

16. Effective ground-water management may occur in Idaho by the development of adequate definitions and techniques of administration under the two major concepts of reasonable ground-water pumping levels and reasonably anticipated average rate of future natural recharge. Adminis-

trative plans must be designed for each basin within the general legal guidelines based on the specific hydrologic and geologic conditions and the pattern and extent of resource development. A sufficient range of alternatives is available in the concepts to allow efficient resource management in a wide range of situations.

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