OREGON'S CRITICAL GROUND WATER AREAS:
A CASE STUDY INVESTIGATION

by

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ABSTRACT

Oregon's critical ground water area program was designed to protect the integrity of ground water supplies under conditions of sustainable yield. In areas where the demand for water exceeds the rate of natural recharge, wells experience declining water levels. If allowed to continue, this could eventually lead to severe social and economic disruption in the surrounding region. In 1955, the state legislature established the critical ground water area program as the legal framework for the protection of ground water supplies. Five critical ground water areas have since been established to correct problems of declining water levels. The control measures enacted for these areas are designed to restrict the rate of withdrawal to the rate of aquifer recharge, while protecting the appropriation rights of priority water users. By 1985, water levels had responded in most critical area wells and the control programs appear effective.
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INTRODUCTION

The demand placed on water in regards to municipal and industrial growth, power generation, irrigation, recreational use, and environmental preservation is constantly increasing. But the supply of water from surface and underground sources is often insufficient to satisfy all of these demands. In many instances ground water reservoirs are being overdrafted to meet the increased demand.

Although overdrafting can overcome short term drought conditions, problems arise when the practice is continued for the long-term. The mining of ground water supplies can result in land subsidence, saltwater intrusion into fresh water aquifers, reduced surface water flows, increased energy usage, and the disruption of social and economic institutions (Norton 1984).

The effective management of ground water is an important issue in areas where a large portion of the total water supply is comprised of ground water. The degree of dependence on ground water varies greatly from one locality to the next. Slightly more than 23 percent of the fresh water withdrawal in the United States represents water supplied from underground sources. In the nine western water resource regions the use of ground water for irrigation accounts approximately for 56 percent of the total water consumption (Solley 1980).

Management strategies used to correct problems of ground water decline generally involve the following three alternatives: (1) replacing ground water use from declining reservoirs with other water sources, (2) restricting water withdrawals to the rate of natural
recharge, or (3) allowing appropriations to continue at current levels until the supplies are exhausted. The first two alternatives may be combined in a water management program. Each of these alternatives would incur various degrees of social and economic costs, but the third alternative would be the most devastating to the surrounding region.

Federal policy makers have traditionally left the matter of ground water management to individual state governments (Dunbar 1983). State ground water management programs are generally limited to regulating ground water withdrawals and water use. Forms of intensive management usually do not occur until an area has been faced with long-term ground water overdraft problems.

After 1958 the state of Oregon implemented a program of establishing critical ground water areas to correct problems of ground water overdraft. The designation of these areas represents a form of intensive management in which strong corrective control provisions are implemented to protect ground water resources. The purpose of this paper is to examine the five critical ground water areas established in Oregon in terms of the need, reasoning, and effectiveness of the control measures.

A LEGAL RIGHT TO WATER USE

The Right to Appropriation

Oregon statutes declare all waters within the state to belong to the public. Individuals who have complied with the legal requirements of the State Surface Water Code or the Ground Water Act may appropriate these waters for beneficial use. Waters not available for appropriation
would include those claimed under existing rights or set aside by legislative action (OWRD Pamphlet). The legal framework for the administration of both surface and ground water appropriations in Oregon can be summarized into three key concepts: (1) "Beneficial use without waste within the capacity of available sources shall be the basis, measure, and limit of all rights to the use of water in this state" (ORS 537.525), (2) first in time is first in right, and (3) a water right is appurtenant to the place of use for which it was established.

The 1955 Ground Water Act (ORS 537.505 to 537.795) established the legal framework for the regulation of ground water appropriations in Oregon (Appendix 1). Provisions of the act provide a means whereby people previously using ground water could register legal claims to continue withdrawal and establish their priority of use.¹ Also contained in the act are provisions for the protection of ground water supplies from overuse and degradation.

**Establishing Critical Ground Water Areas**

An important administrative tool used to protect ground water supplies in Oregon is the designation of critical ground water areas. Under the program, the Director of the Water Resources Department may impose restrictions on ground water appropriations from designated aquifers to help remedy any present or impending ground water problems.²

When control measures are needed to protect ground water supplies the Water Resources Department initiates proceedings to determine if a critical ground water area should be established. Evidence for such designation must be presented by all interested persons at a public hearing. If the director concludes that sufficient evidence exists a
critical ground water area will be established. Ground water reservoirs that entirely or partially overlay one another may be included within the same critical area. Once the boundaries have been established, the director issues a control order designed to correct the situation (Appendix II).

OREGON'S CRITICAL GROUND WATER AREAS

As of December 1984, the state of Oregon has established five aquifer regions as critical ground water areas (Figure A). In each case the reason for designation has been the overdraft of ground water reservoirs. The hydrogeology of an aquifer region and the pattern of ground water use determines, to a large extent, the nature of the control measures used to correct overdraft problems. The remainder of this section will review the general hydrogeologic and use patterns of the five critical ground water areas and will describe the central features of the control orders.3

The Cow Valley Critical Ground Water Area

The first critical ground water area designation was a 41 square mile region of northern Malheur County known as Cow Valley. The valley is an upland basin formed by folding and faulting of the underlying rock formation. The climate is arid with an annual precipitation rate of approximately 15 inches. Cow Creek is the main tributary that drains the basin, but during periods of normal runoff the creek sinks into the ground within a few miles from where it flows out of the mountains.
The most productive water-bearing zones are located in the volcanic rocks and associated sediments, however, the coarse gravel strata in the alluvial deposits also serve as an important source of ground water. These aquifer zones appear to be hydraulically interconnected. This interconnection allows the area to be managed as a single hydrologic unit. Ground water production is primarily limited to the upper 700 feet with little yields from deeper depths.

The ground water reservoir is recharged by infiltration of the precipitation in the area and by runoff derived from the spring snowmelt in the hills and mountains bordering the valley. By using data on the storage capacity of the reservoir and the amount of water table rise attributed to recharge, the annual recharge was calculated to be 4,500 acre-feet per year.

Annual water level measurements taken from selected wells between 1949 and 1958 showed a steady decline in water levels as the amount of water withdrawn each year exceeded the natural rate of replenishment. State officials recognized that without corrective controls the water table may have continued to decline until appropriators would not have been able to withdraw the water to which they were legally entitled. In April of 1956 and July of 1959 public hearings were held to gather testimony and document evidence. And on November 12, 1959, a control order was issued for the Cow Valley Critical Ground Water Area.

Regulations in the control order apply to all the water-bearing zones underlying the critical area. The amount of allowable withdrawal was limited to the volume set forth in the ground water right certificates and permits existing prior to the order (estimated at between 4,255 and 5,422 acre-feet per year). No further appropriations
are to be allowed for non-exempt purposes. The restrictions imposed on ground water use were intended to reduce the rate of water level decline. Existing water users were not restricted in their water use because state officials recognized that more exact information was needed to arrive at an accurate estimate of annual recharge. In response to this need for information, the control order included provisions requiring records on the amount of withdrawal from each well to be kept by appropriators who must then furnish this data annually to the Oregon Water Resources Department. These records are then examined to determine if changes in the amount of allowable withdrawal should be made.

State officials reported water level declines of five to seven feet per year prior to the establishment of the 1959 control order. By 1982, it was reported that twelve operating wells in the basin were withdrawing approximately 4,000 acre-feet of ground water. Water levels in the majority of wells in the area have now stabilized while others are experiencing declines of less than 0.7 feet per year (OWRD 1982 b). No changes in the control orders are expected in the foreseeable future (Lissner 1984).

The Dalles Critical Ground Water Area

The second critical ground water area identified was a 20 square mile area of The Dalles in northern Wasco Country. The Dalles Critical Ground Water Areas was established on December 30, 1966. The water-bearing material of the area creates three distinct ground water reservoirs: The Dalles Ground Water Reservoir, the aquifers of The Dalles formation, and the Threemile Ground Water Reservoir. Each of
these aquifers has a different potential for ground water development and require individualized control measures.

The deepest and most widespread aquifer zone is located in the Columbia River basalt formation. This formation may exceed 2,000 feet in thickness in parts of the Dalles area. An exceptionally permeable zone of about 20 to 40 feet in thickness occurs between 350 to 400 feet below the top of the formation. This zone is referred to as the Dalles Ground Water Reservoir and supplies most of the irrigation wells in the area. Ground water in this reservoir is recharged by subsurface leakage from surrounding ground water reservoirs. They are, in turn, recharged from precipitation or leakage from other reservoirs.

Ground water level measurements collected from representative wells in the Dalles Ground Water Reservoir show evidence of a small decline during the period from 1951 to 1966. If the downward trend had continued, insufficient water to fulfill all of the legally permitted withdrawals would have resulted.

To reduce the water level decline in the Dalles Ground Water Reservoir, unauthorized withdrawals were stopped and authorized users were limited to their legal entitlements. All applications for appropriations made after the critical area was established in 1966 were not accepted. Any additional withdrawals were restricted to exempt uses only.

Overlying the Columbia River basalts is a series of semi-consolidated sandstone, sandy shale, conglomerate, tuff, and mud deposits that have been named the Dalles formation. This formation may exceed 1,000 feet in thickness in some parts of the critical area. The water-bearing material of this zone has a low permeability and is not
capable of supplying large or even moderate yields of water. As a result, this reservoir is developed primarily as a source of domestic water. Ground water levels in this formation have not shown any noticeable declines; consequently, ground water appropriations were allowed to continue. However, all wells must be constructed in a manner so that they do not allow leakage from the surrounding protected aquifers.

In the southeast corner of the critical area, the upper 100 feet of the Columbia River basalts contain interconnected water-bearing zones that are hydraulically separated from The Dalles Ground Water Reservoir. This zone is known as the Threemile Ground Water Reservoir and is classified as a perched aquifer. In his 1932 analysis of the reservoir, Piper noted that interference between wells would eventually cause serious ground water shortages. As predicted, water level records showed a steady decrease through 1965. As a consequence of that decline, several owners had to curtail their withdrawals for irrigation water while others had their wells fail completely.

The severe decline of the Threemile Ground Water Reservoir created a need for strict controls. State restrictions were designed to reduce the current withdrawals from the reservoir. Wells having a priority date later than 1932 had withdrawals restricted to stock and domestic uses only. All non-exempt wells in The Dalles Critical Ground Water Area are required to be equipped with control works and flow meters to regulate water usage. Monthly records of withdrawals from each well are maintained by well owners and supplied annually to the Water Resources Department.
In the last decade, water levels within the basin have stabilized. Some of the wells in the southern part of the city of The Dalles have recovered 60 to 70 feet since 1965 (OWRD 1982 a). This is due in large part to the restrictions associated with the critical ground water area designation. Today, most of the irrigation wells are no longer in use. After the area was declared critical, users formed an irrigation district to pump Columbia River water to most of the cropland to meet their irrigation needs (Paul 1984). The major uses of ground water today are for municipal and industrial purposes.

The Cooper Mountain-Bull Mountain Critical Ground Water Area

The third critical ground water area established is in the Cooper Mountain-Bull Mountain region of southeastern Washington County. This area occupies 41 square miles of the Tualatin Valley southeast of the cities of Beaverton and Tigard. The area is located in a humid region of the state and receives an average of 40 inches of precipitation each year. A large part of this precipitation is quickly lost as direct runoff to local streams, limiting natural recharge. Rising above the valley floor at elevations of 785 and 710 feet respectively are the upland areas of Cooper Mountain and Bull Mountain. These topographic highs have been created by sharp folding of the geological strata.

Two principal aquifer units have been identified within the area. The uppermost aquifers are contained in sedimentary formations composed of basin fill and alluvial detritus. Underlying the sedimentary material is the second and deepest aquifer unit identified as the Columbia River basalt formation.
The sedimentary deposits in the critical area are composed of sand, silt, and poorly sorted sandy gravel material. Ground water is generally encountered between 20 and 40 feet below the land surface. Wells constructed in this material usually have poor yields (2.5 to 4.0 g.p.m.) and are not capable of supporting large scale commercial or irrigation usage. Therefore, the majority of existing wells provide single family domestic water supplies.

The major ground water reservoir in the critical area is comprised of the individual layers of the Columbia River basalt formation. This formation is about 900 feet thick within the critical area. The weathered interflow zones, where saturated, form the most productive water-bearing units. It appears that the entire basalt aquifer underlying the critical area forms one ground water reservoir. All water pumped from the reservoir will affect the supply for other users. Water levels vary from a few feet below the surface near the valley floor to more than 500 feet below the land surface at the crest of Cooper Mountain. The deepest well on record within the area is 930 feet. Wells pumping water from the basalts are capable of producing higher yields (10 to 1,089 g.p.m.) and are used to satisfy municipal and irrigation needs.

Marine sedimentary deposits are encountered below the basalt formation (1,029 feet in some places). Ground water from within these marine deposits is of poor quality, containing about 43,700 parts per million of chloride. In areas of sharp folding and faulting, and in some deep wells in the Bull Mountain area, some mixing has occurred with the upper ground water zones.
Since the early 1960s there has been a steady increase in the population residing in and around the critical area. Ground water has traditionally been the chief source of supply for meeting municipal water needs, and as a result, high demands have been placed on a limited supply of ground water. The large yielding wells serving municipal, industrial, and irrigation water users have had the greatest effect on lowering water tables. Major pumping cones developed around the areas of heaviest pumping; the Beaverton, Aloha-Huber, and Tigard well fields. Within these areas water level declines of 6 to 10 feet per year occurred between 1960 and 1970. Recognizing the impending problems, local communities began to replace their ground water use with surface water supplies from outside the area in the early 1970s.11

Hearings were held in May, 1973, to determine the status of the Bull Mountain-Cooper Mountain ground water area. At that time the annual withdrawal from the basalt aquifer was estimated to be 6,000 acre-feet per year. It was further estimated that 3,100 acre-feet, or 52 percent of the withdrawal, represented water being removed from storage. If water level declines were allowed to continue at this rate, wells would continually have to be deepened until it became uneconomical to pump any further or until total well failure occurred. The decline of water levels might also cause contamination due to intrusion of saline water from underlying marine formations.

As a result of the information presented at the hearing, the Cooper Mountain-Bull Mountain Critical Ground Water Area was formally designated, and on May 17, 1974, a control order was issued by the State Engineer. The critical area includes all water contained in the ground water reservoirs of both the alluvial and basalt aquifers.
All applications for a permit to appropriate ground water from within the critical area that are filed after the effective date of the control order are approved only on the condition that no ground water be appropriated from the basalt aquifer system for non-exempt purposes. Appropriation of ground water from within the basalt aquifers has been restricted to existing wells being used for domestic and stock watering purposes exempt from filing permits under ORS 537.545. The distribution of water from wells located in the basalts is based on the relative date of priority and further limited to a maximum of 2,900 acre-feet per year.\textsuperscript{12}

All additional wells constructed in the basalt aquifer are restricted to single family domestic and stock water purposes on tracts of land not less than 10 acres. Ground water appropriated for stock use is to be piped to watering tanks equipped with control works and operated to prevent the overflow and waste of ground water.

Owners and operators of non-exempt wells must equip them with water flow meters and control valves and maintain an accurate monthly record of the amount of water withdrawn from each well. A copy of these records are given to the Oregon Water Resources Department within 30 days after the close of each calendar year.

To assure that annual appropriations are within the limits set by the control order, a special provision was enacted which requires all water right holders who desire to use ground water for the upcoming season to notify the watermaster of their intent prior to December 1 of each year. In the notice they identify the water right and list the date, quantity, use, and place of intended use for the upcoming year. On or before February 15 the watermaster will notify the parties authorized to use water for that year.
It appears the control orders have been effective in halting the decline of ground water levels. Water levels have stabilized in most of the observation wells in the area, and some wells north and west of Cooper Mountain have shown a rise of 10 to 40 feet above 1972 water levels. Between 1977 and 1982 everyone requesting ground water withdrawals within the critical area was allowed to exercise his water rights. In addition, the total annual withdrawal has remained within the 2,900 acre-feet per year limit (OWRD 1982 a). No changes in the control order are expected in the foreseeable future (Lissner 1984).

The Ordnance Critical Ground Water Area

The Ordnance ground water area was the fourth aquifer region to be designated as critical. Located along the Columbia River in northern Morrow and Umatilla Counties, the area has an arid to semi-arid climate. Precipitation rates range from 8 to 12 inches per year in the lowland areas with most of this coming during the winter months. The lack of precipitation combined with high rates of evapotranspiration (approximately 32 inches per year) create a condition where there is little water available for recharging the ground water reservoirs. In the northern part of the area some localized alluvial aquifers are recharged by the Columbia River. The aquifers of the Ordnance area are separated into alluvial and basalt ground water systems.

The alluvial aquifers occupy approximately 82 square miles and are referred to as the Ordnance Gravel Critical Ground Water Area. These stream and lake sediments overlie the Columbia River basalts and are primarily developed by shallow wells. The amount of acreage irrigated by wells developing water from these alluvial aquifers is more than

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double the acreage irrigated from the deep basalt wells in the area. Yields obtained from these gravels are generally very good (400 to 3,000 g.p.m.). Until 1976, well level declines in the alluvial sediments averaged 1.6 feet per year. At that time only 15 to 50 feet of saturated alluvium remained in most areas. In the spring of 1977, some well owners initiated a project to recharge the Lost Lake-Depot aquifer south of the Ordnance army depot.¹³ The water levels of wells have responded and the project seems effective (OWRD 1983 a).

Ground water in the alluvial sediments of the northern part of the area are in partial hydraulic connection with the Columbia River. As a result, ground water levels rise and fall in accordance to the river fluctuations, and control of appropriations is unnecessary.

The basalt formations of the Columbia River Group contain the most widespread aquifers in the Ordnance area. They are the result of individual lava flows, 10 to 150 feet thick, which poured out of numerous cracks and fissures, burying the previous land surface and forming a broad lava plain covering more than 50,000 square miles. This formation underlies the entire critical area.

Aquifers in the basaltic rocks usually exist as thin tabular bodies located in the fragmented contact zone between individual lava flows. Vesicles and interconnecting fractures provide thin permeable zones between some lava units. Sedimentary deposits as much as 100 feet thick sometimes occur between basalt flows. These sedimentary deposits were formed when local streams become impounded on the basalt surface, laying down local interbeds of clay, silt, sand, and gravel.¹⁴ Where these interbeds lie below the regional water table they form aquifers capable of yielding 1,000 g.p.m. or more. These porous layers often pinch out,
overlap, or terminate at the boundaries of individual basalt flows, creating discontinuous saturated zones.

By 1985, pumping lifts in the deepest wells were approaching 1,000 feet. Considering the estimated thickness of 2,000 feet and the tabular bedding of the basalts, it seems likely that additional aquifer zones may exist under presently developed aquifers. Removal of this water, however, would likely be expensive because of high pumping costs and the need for extensive casing. In some instances over 1,500 feet of casing might be required to separate presently used water-bearing zones from potential producing zones not yet tapped.

Tectonic structures such as folds and faults can serve to locally determine the depth and areal distribution of water-bearing layers. Folding and faulting may serve to depress or elevate the various water-bearing units. This may have the effect of either increasing or decreasing the movement of water into or through the aquifer.

The basalt aquifers are often compartmentalized both vertically and horizontally which limits recharge to the system. Carbon 14 dating indicates an age of at least 27,000 years since water from the deep basalt zone last made contact with the atmosphere. Water from the shallow basalt zone showed an age of 6,700 years, suggesting some seepage from overlying alluvial aquifers (Robinson 1971). Consequently, water being withdrawn from basalt aquifers is not being substantially replaced. Most of the recharge that does occur enters the system along the Blue Mountain front and flows downslope towards the Columbia River (Hicks 1984). The Umatilla structural basin is estimated to receive between 60,000 and 65,000 acre-feet of recharge to the alluvial and basalt aquifers. It has not been determined what percentage of this total recharge reaches the basalts (Norton 1984).
Between the early 1960s and late 1970s a serious water level decline occurred in the deep wells of the Ordnance area. Declines at the time of the 1976 control order were between 5 and 7 feet per year. Shallow wells (less than 400 feet) were experiencing declines of about 1.6 to 2.0 feet per year. To protect future rights and the public health, safety, and welfare, the Water Resources Department must determine and maintain stable ground water levels.

In 1966, the State Engineer conducted a hearing intended to declare the basalt and alluvial aquifers of the Ordnance area as a critical area. This resulted in a ruling to stop accepting applications for appropriations from the deep basalts. Then in February, 1976, a second public hearing was held to consider additional data. This resulted in the establishment of the Ordnance Critical Ground Water Area, and on April 2, 1976, control orders were issued for the area.

Provisions of the control order prohibited further development of the alluvial and basalt aquifers for non-exempt purposes. In addition, it was determined necessary to substantially reduce the amount of ground water withdrawn from shallow gravel wells in the Lost Lake-Depot sub area. This area had previously been experiencing the greatest rates of water level decline. In an effort to correct this situation, the average annual withdrawal was restricted to 9,000 acre-feet per year; an amount equal to the estimated rate of natural recharge. It is interesting to note that subsequent metered pumping data has shown the rate of recharge to be about 6,000 acre-feet, but water users are being allowed to continue appropriating 9,000 acre-feet on the condition that they supply recharge water from the Umatilla River to make up the difference (Bartholomew 1984).
An interesting part of the control order for the alluvial and basalt aquifers is that a specified season of irrigation was established (March 10 to October 15). No use of water for irrigating cropland is to occur outside this season without special permission by the Water Resources Department. The establishment of a specific season of use encourages the efficient use of water as well as providing a time when ground water level data can be accurately obtained.16

The Butter Creek Critical Ground Water Area

The Butter Creek Critical Ground Water Area is the most recently designated critical area.17 Situated along the eastern and southern borders of the Ordnance Critical Ground Water Area, it encompasses a 175,360 acre tract of land.18 The Water Resources Department has issued orders twice declaring the Butter Creek area critical. The first time was in February, 1976, and the second time was in May, 1978. Appropriators challenged the first two orders in the Court of Appeals, and the court remanded both on grounds of procedural error. A third hearing was held December 5, 1984. The attempt was successful and established the Butter Creek Critical Ground Water Area.

Ground water development in the area began in 1925, but little expansion took place until the 1950s. The period of greatest development was between 1967 and 1972. Most of the wells producing currently are located in the southern part of the area.

The dominant source of ground water is from aquifers contained in the Columbia River Basalt Group. Ground water found in shallow, localized sand and gravel deposits are of secondary importance. Alluvial aquifers along the flood plain of Butter Creek and the lower
portion of the Umatilla River are unreliable sources of ground water. The alluvial aquifers in the upper reaches of Butter Creek are incapable of sustaining stream flow during dry summer months.

Irrigation usage has the largest influence on changes in ground water supplies. As of July, 1984, the maximum allowable water usage would be over 91,000 acre-feet per year. Domestic and stock watering uses of ground water are estimated to take only 600 acre-feet annually.19

Water level data collected by an observation well network, set up between 1958 and 1972, shows a continual decline occurring since 1958 (Figure B). In the Spring of 1984, a monthly observation well network of 20 to 25 wells was established to provide accurate information on seasonal water fluctuations, pumping water levels, discharge rates, and power consumption information.

The state has long-term water level data for 53 wells in the Butter Creek area. Of these, 3 wells have total water level declines of greater than 300 feet, 5 wells have declines of between 200 and 300 feet, 19 wells have declines of 100 to 200 feet, 11 wells have declines of 50 to 100 feet, and 14 wells are experiencing declines of 0 to 50 feet. One well, which is located in an area partially separated from the rest of the aquifer by hydrogeologic structures, has shown a water level rise of 0.61 feet. Another well, which is located in an area that has not seen large development, is also experiencing a slight rise in the water level.

An examination of current well hydrographs for the Butter Creek area shows that water levels continue to decline, but at a decreasing rate relative to that occurring in the late 1960s and early 1970s.20
This trend suggests that the ground water system may be approaching a state of equilibrium. The decreased rate can be correlated with reductions of pumpage. Since 1977, there has been a decline in the annual withdrawal rate of over 12,000 acre-feet. Even with the reduction in withdrawal, the average annual recharge is insufficient to maintain stabilized ground water levels. Without an increase in annual recharge or a reduction in withdrawals, water levels will continue to decline until it becomes uneconomical or impossible to withdraw their ground water supplies.

Changes in irrigation practices (the reduction in the length of the irrigation season and a shift to low pressure sprinkler systems) are responsible for the reduction in the quantity of water used for irrigating crops. State figures indicate that 2,400 acres of farm land now being irrigated by a combination of surface and ground water or by surface water alone were previously irrigated with just ground water.

If agricultural growth and irrigation practices are to continue in the Butter Creek area, it will become necessary to import irrigation water from outside sources such as the Columbia and Umatilla Rivers. But with the high costs of construction and financing, and increased power costs, it is unlikely that a significant amount of water will be brought into the area by surface water projects in the near future.

CONCLUSION

Effective ground water management is needed to prevent the rapidly growing demand for water from overdrafting aquifer supplies. The complex hydrology and "hidden" nature of ground water creates special challenges to state water managers.
Oregon's ground water management program combines a system of continual collection and review of ground water data with an established framework for the regulation of ground water use. By implementing control measures in the early stages of ground water depletion the social and economic disruption that can result from aquifer overdraft may be avoided.

Critical ground water area legislation has provided the Oregon Water Resources Department with a wide selection of possible control measures to utilize in the protection of ground water resources. It appears that the critical ground water area program has been successful. Aquifers administered under this program have experienced modest to substantial rates of water level recovery. States that have not yet developed a satisfactory system of ground water management may find Oregon's critical ground water area program to be a useful model.
NOTES

1. The priority date of a water right is the date the application for a water use permit is filed with the Water Resources Department.

2. Under chapter 537.730 in the Oregon Ground Water Act, the director may initiate a proceeding for the determination of a critical ground water area whenever the director has reason to believe that any of the following conditions exist: a) ground water levels in the area in question are declining excessively, b) the wells of two or more ground water claimants or appropriators interfere substantially with one another, c) the wells of ground water appropriators and the production of geothermal resources interfere with each other, d) the available ground water supply is being overdrawn, or e) the purity of the ground water has been or may become polluted to an extent contrary to the public welfare, health, and safety.

3. Much of the data used throughout this section was taken directly from the ground water reports and critical ground water area findings of fact issued by the Water Resources Department for the individual aquifer areas.

4. Exempt uses include "the use of ground water for stockwatering purposes, for watering of any lawn or noncommercial garden not exceeding one-half acre in area, for single or group domestic purposes in an amount not exceeding 15,000 gallons a day or for any single industrial or commercial purpose in an amount not exceeding 5,000 gallons a day. The use of ground water for any such purpose, to the extent that it is beneficial, constitutes a right to appropriate ground water equal to that established by a ground water right certificate issued under ORS 537.700." (ORS 537.545).

5. The watermasters of the individual districts are empowered to regulate the control works on wells, so that the rate and/or total quantity of ground water used does not exceed the legal rights to appropriation or an amount which can be put to beneficial use.

6. Often water is not used to the maximum amount filed for under usage permits and it is not always clear how much water may have been used in excess of, or without a permit. It is difficult to determine in advance the number of rights that can be served with a given annual withdrawal. After the installation of control works and water meters, and when most of the unlawful diversions have been eliminated, it becomes possible to more specifically determine safe yields.

7. The amount of water in aquifer storage was calculated to be declining by 2,200 acre-feet for each one foot drop in the Cow Valley aquifer.

8. In 1961 the largest quantity of water was withdrawn from the Cow Valley aquifer, 5,495 acre-feet.
9. The Columbia River basalt formation and The Dalles formation have both been deformed through folding and faulting. The structure of these rock units plays an important role in the occurrence of water in The Dalles area. Fault zones which break the continuity of water-bearing strata often form effective barriers to ground water movement.

10. A pumping cone develops when the seasonal withdrawal from any given well(s) is greater than the localized recharge rate. After withdrawal ceases, water begins to refill the locally overdrafted area. The seasonal interference caused by the pumping cones of adjacent wells can sometimes be as great a problem to an individual appropriator as the long-term decline in the general water table.

11. Based on reports submitted to the State Engineer's office by city water companies in Aloha-Huber, Tigard, and Beaverton, the total annual municipal use of ground water from the Bull Mountain-Cooper Mountain Critical Area increased from 1,509 to 3,894 acre-feet per year between 1967 and 1970 (+158%), and then decreased to 2,697 acre-feet by 1973 (-31.2%)

12. A six month extension on withdrawals was granted to a municipal well possessing a late priority right. It was determined that the district needed additional time to adopt a new source of water.

13. Artificial recharge requires pumping water from outside sources, usually uphill, and injecting it into the aquifer to be recharged. To recover the water it must be pumped back out of the aquifer to the land surface for use. This requires pumping the water twice, therefore, total pumping costs are high. Any water that can be directly applied for irrigation is more economical than lifting, injecting, and repumping water. But, where available surface storage sites are lacking, artificial recharge may be the only practical solution to utilizing excess water from winter season precipitation and spring runoff. However, not all aquifer systems are physically suitable for recharge projects.

14. These sedimentary interbeds are a common occurrence throughout the Columbia River basalts. Robinson (1971) estimated that these interbeds make up 4 to 30 percent of the total thickness of the basalt formation. In addition, the poorly permeable layer created by silt and clay strata sometimes creates confining layers for aquifer units.

15. The estimate of recovery was made by the United States Geologic Survey, and was based on a recent ground water model (Norton 1984).

16. One way to help standardize the measurements taken from individual wells is to eliminate the effects of differential pumping rates on water levels. This can be done by collecting data during periods of non-use. Seasonal drawdown causes pumping cones to develop around areas of heavy withdrawal, but in the winter when irrigation use has ended some recovery or adjustment takes place as the pumping cones surrounding individual wells fill with water. Provisions for the
establishment of a specific season for irrigation are viewed as a valuable tool in ground water management (Norton 1984).

17. Control orders for the Butter Creek Critical Ground Water Area were still in preparation at the time of this writing.

18. The overall climate and hydrogeologic characteristics of the Butter Creek area are like those discussed for the Ordnance Critical Ground Water Area.

19. The estimate is based on an annual estimated average consumption of 1.0 acre-foot of water for each domestic well.

20. In 1982 almost 19,000 acre-feet of ground water were pumped. Of 20 wells measured in February of 1982 and 1983, 17 wells had lower water levels after the 1982 irrigation season. In 1983, approximately 15,000 acre-feet was withdrawn, down 4,000 acre-feet from the year before. Of twenty-six wells measured at the end of the 1983 season, slightly more than half showed declines. It should be noted that yearly precipitation rates recorded at Hermiston have been above the long-term average of 8.93 inches since 1978. In 1983 precipitation rates were 5.87 inches above the long-term average. This may have had the effect of reducing irrigation needs and providing some additional recharge to area aquifers.
Figure A. County base map showing the location of the five critical ground water areas in Oregon.
Figure B. State observation well network as of 1982 (OWRD 1982 a).
SELECTED REFERENCES


APPENDIX I

Sections of the 1955 Ground Water Act that particularly relate to ground water policy (537.525):

(2) "Rights to appropriate ground water and priority thereof be acknowledged and protected, except when, under certain conditions, the public welfare, safety, and health require otherwise

(3) Beneficial use without waste, within the capacity of available sources, be the basis, measure and extent of the right to appropriate ground water

(5) Adequate and safe supplies of ground water for human consumption be assured, while conserving maximum supplies thereof for agricultural, commercial, industrial, recreational, and other beneficial uses

(6) The location, extent, capacity, quality, and other characteristics of particular sources of ground water be determined

(7) Reasonably stable ground water levels be determined and maintained

(8) Depletion of ground water supplies below economic levels, impairment of natural quality of ground water by pollution, and wasteful practices in connection with ground water be prevented or controlled within practicable limits

(9) Whenever wasteful use of ground water, impairment of or interference with existing rights to appropriate surface water, declining ground water levels, interference among wells, overdraining of ground water supplies or pollution of ground water exists or impends, controlled use of the ground water concerned can be authorized and imposed under voluntary joint action by the Water Resources Director and the ground water users concerned whenever possible, but by the Director under the police power of the state when such voluntary joint action is not taken or is ineffective."
APPENDIX II

One or more of the following corrective control provisions may be included in a critical ground water area control order (ORS 537.735):

(1) A provision closing the critical ground water area to any further appropriation of ground water, in which event the Director shall thereafter refuse to accept any applications for permits to appropriate ground water located within such critical areas.

(2) A provision determining the permissible total withdrawal of ground water in the critical area each day, month of year, and insofar as may be reasonably done, the Director shall apportion such permissible total withdrawal among the appropriators holding valid rights to the ground water in the critical area in accordance with the relative dates of priority of such rights.

(3) A provision according preference, without reference to relative priorities, to withdrawal of ground water in the critical area for residential and livestock watering purposes first. Thereafter the Director may authorize withdrawals of ground water in the critical area for other beneficial purposes, including agricultural, industrial, municipal other than residential, and recreational purposes, in such order as the Director deems advisable under the circumstances, so long as such withdrawal will not materially affect a properly designed and operating well with prior rights that penetrates the aquifer.

(4) A provision reducing the permissible withdrawal of ground water by any one or more appropriators or wells in the critical area.

(5) Where two or more wells in the critical area used by the same appropriator, a provision adjusting the total permissible withdrawal of ground water by such appropriator, or a provision forbidding the use of one or more of such wells completely.

(6) A provision requiring the abatement in whole, or in part, or the sealing of any well in the critical area responsible for the admission of polluting materials into the ground water supply by dispersing polluting materials that have entered the ground water supply previously.

(7) A provision requiring and specifying a system of rotation of use of ground water in the critical area.

(8) Any one or more provisions making additional requirements as are necessary to protect the public welfare, health, and safety in accordance with the intent, purpose, and requirements of ORS 537.505 to 537.795.