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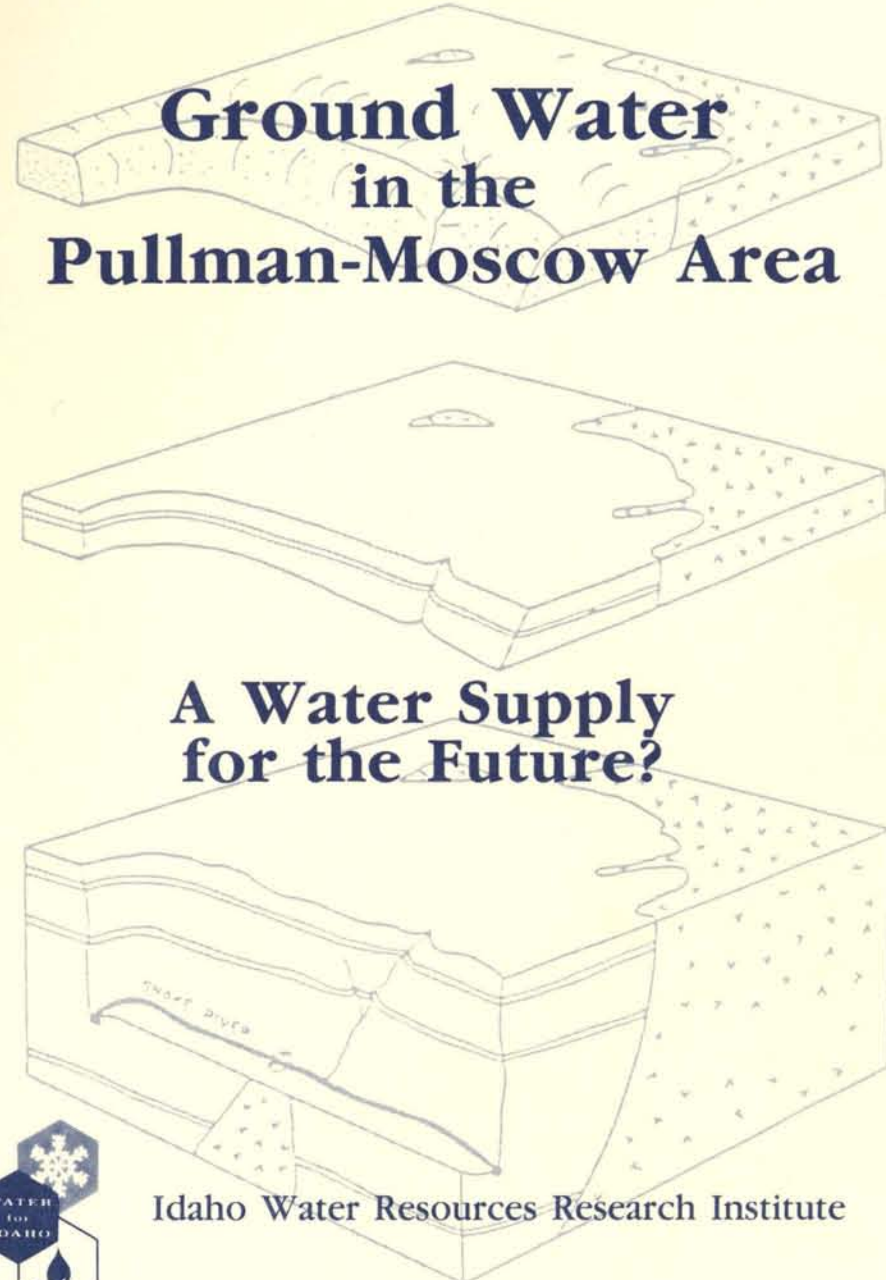
Ground Water in the Pullman-Moscow Area



A Water Supply for the Future?

WATER for IDAHO

Idaho Water Resources Research Institute

The research on which this report is based was financed in part by the United States Department of the Interior as authorized by the Water Research and Development Act of 1978 (P.L. 95-467).

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Ground Water Is Our Present Supply Source

All of the water supply within the Pullman-Moscow area is derived from ground water (figure 1). Water supply wells range up to 1,400 feet in depth and yield as much as 2,500 gallons per minute. The quality of water is excellent with a low potential for contamination from land uses.

There are four major users within the area: the cities of Pullman, Washington and Moscow, Idaho plus Washington State University and the University of Idaho. Average ground water pumpage by these four users for the period of 1980-85 was about 2.5 billion gallons per year.

Ground water pumpage in the basin historically has been increasing at a rate of about 1 to 2 percent per year. Major questions have been raised as to how long ground water will serve as the primary water supply source for the area. Surface water supply sources are not available in the immediate area without significant developmental costs.

Present Ground Water Problems

Ground water levels have been declining in the Pullman-Moscow area at a rate of about 1 to 2 feet per year (figure 2). These rates of water level decline have been occurring for a number of years with the total decline approaching 90 feet.

Water level decline is a common phenomenon associated with development of any ground water basin. Prior to well development, the ground water system in the Pullman-Moscow area was in a state of equilibrium with a balance between natural recharge and natural discharge. Operation of water wells disrupted the natural balance resulting in a decline in water levels.

Management questions for ground water basins typically focus on the rate of water level decline. How long the decline will go on? Will the basin come into a new equilibrium because water level declines cause increased natural recharge or decreased natural discharge? These are the questions that are pertinent to the Pullman-Moscow ground water system.

Answering these questions requires a detailed knowledge of the basin, and the use of a computer ground water model as a predictive tool.

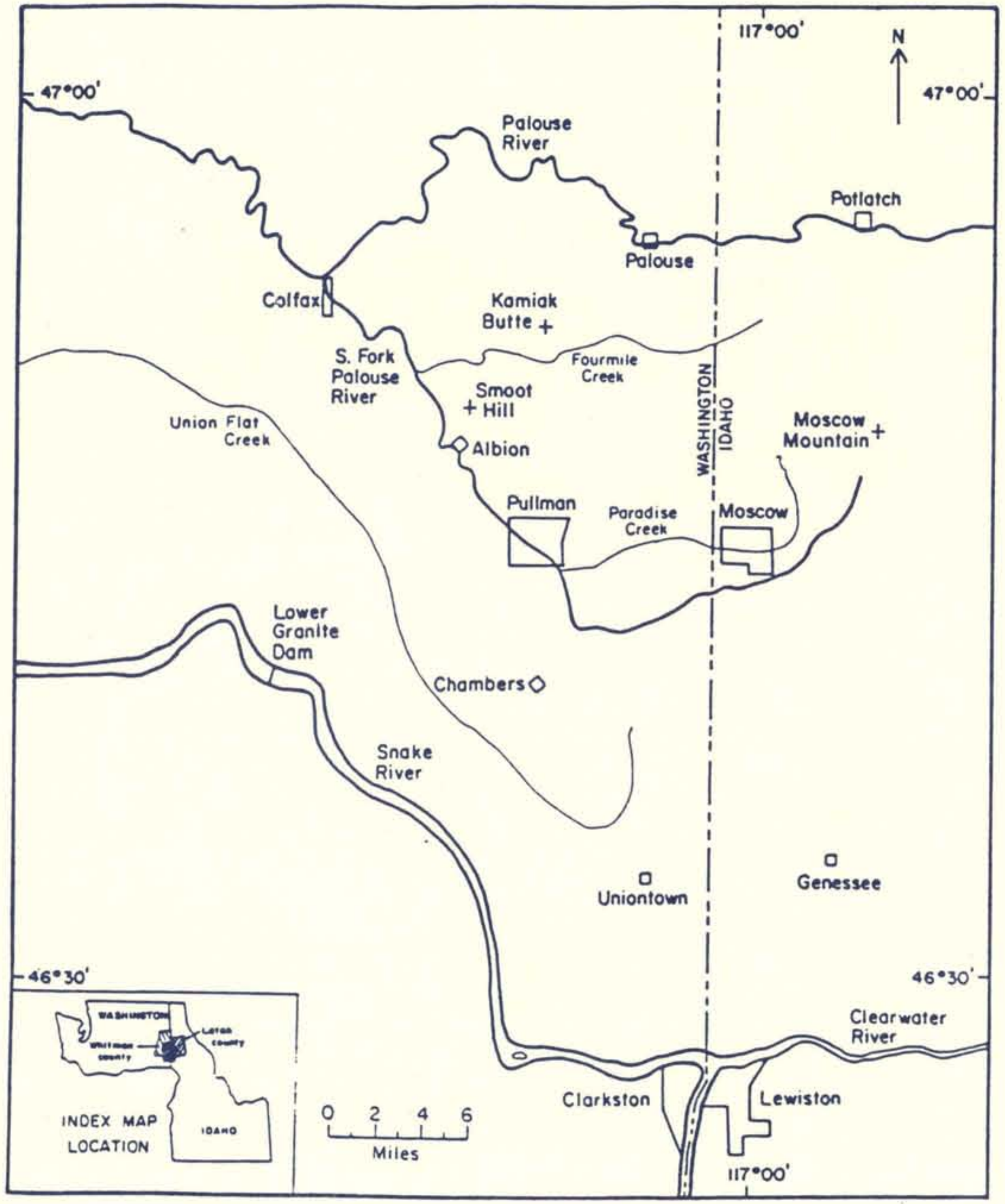

Figure 1. Location map of the Pullman-Moscow region.

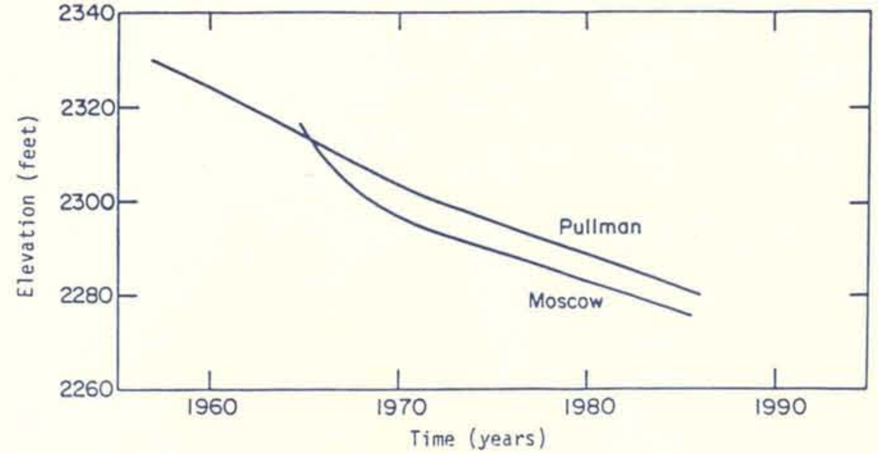

Figure 2. Hydrographs showing ground-water level declines at Pullman-Moscow.

Recent Ground Water Study

In 1984, the four major water users in the area, with matching monies from the United States Geological Survey (U.S.G.S.), funded a study of the ground water resources in the area leading to the construction of a computer management model. The research was conducted jointly by investigators from the U.S.G.S. and the University of Idaho.

The results of the study were presented in a report by John Smoot and Dale Ralston published in 1987 through the Idaho Water Resources Research Institute. A U.S.G.S. report is in review and will be published. This brochure provides a summary of the research results.

What Are Characteristics Of The Ground Water System?

Highly productive ground water zones or aquifers occur in basalt rock that underlies the Pullman-Moscow area. The basalt is underlain by much less permeable granitic rock. The basalt was deposited in layers in the ancestral granitic basin. The surface contact of the basalt and the granite forms the boundary of the ground water system on the east (figure 3). Except for isolated hills made up of the older rock, the basalt extends to the west on into the Columbia Plateau.

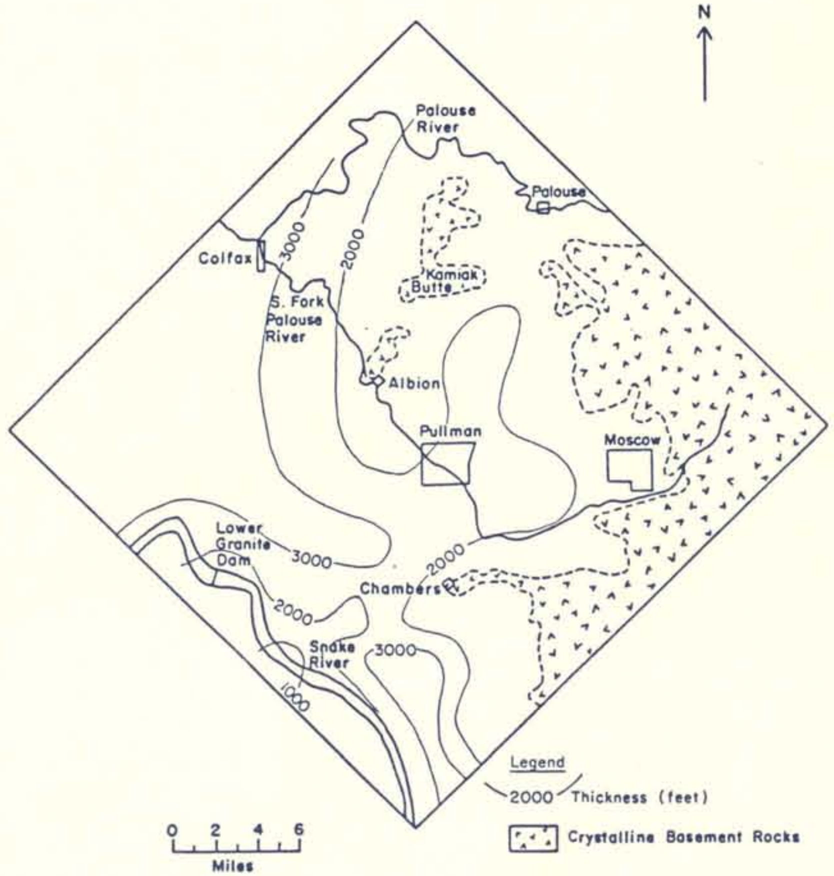

Figure 3. Thickness of the basalt (modified from Klein and others, 1987).

One of the objectives of the ground water study was to determine the thickness of the basalt system within the area. In Moscow, wells have been drilled through the basalt into the granite at depths of about 1,400 feet. A geophysical technique called magnetotullurics was used by the U.S.G.S. to prepare a map showing the thickness of the basalts (figure 3). The map shows the thickness of the basalts to range from zero east of Moscow to about 2,000 feet under Pullman and more than 3,000 feet near Colfax.

Ground water occurs in the basalt in fracture zones along the contacts between individual flows. The basalt flows are relatively flatlying in the Pullman-Moscow area. The productive aquifers in the basalt thus are flatlying. Production wells typically obtain water from a number of individual flow contact zone aquifers.

Geologists divide the basalts in the Pullman-Moscow area into two formations called the Wanapum Basalts and the Grande Ronde Basalt. A typical well in the Pullman-Moscow area would penetrate soil and the windblown sediments or loess that make up the Palouse hills, then enter basalt flows of the Wanapum formation, penetrate a thin sedimentary bed called the Vantage unit, then enter the Grande Ronde Basalts. The Grande Ronde Basalts make up the majority of the thickness of geologic material overlying the granite in the Pullman-Moscow area.

Most of the city and university production wells obtain water from the Grande Ronde Basalts. Most private wells and the older city wells in Moscow obtain water from the Wanapum Basalts. The ground water study focused on the Grande Ronde Basalts because of their importance for city and university water supplies.

How Much Ground Water Is Available For Development In The Basin?

Three aspects are important in answering the question of how much water is available for development. First, what are the characteristics and amounts of recharge to the ground water system? Second, how much water is in storage in the rock within reasonable distances of land surface? Third, what are the characteristics and amounts of natural discharge from the ground water system? A significant portion of the ground water study focused on answering these questions.

Recharge to the ground water system in the basalt in the Pullman-Moscow area occurs primarily from infiltration of water from precipitation of the overlying land surface. The non-patterned area on figure 3 shows the areal extent of the land underlain by basalt in the area of interest near Pullman and Moscow. Some water also recharges the basalt from streams that head on the mountain areas such as Moscow Mountain.

A recharge model was constructed and operated by the U.S.G.S. in order to quantify the amount of water that is believed to enter the ground water system underlying the Pullman-Moscow area. The model uses a daily water balance approach to calculate recharge based on subtracting evaporation, transpiration by plants and runoff from values of precipitation while accounting for soil moisture storage and the accumulation and melting of snow. Each input factor was analyzed based on the distribution of available data. The model was constructed to utilize input data for one-half mile squares of the Pullman-Moscow area for the 17-year period of 1960-1976. This period was selected based on the availablility of information. The results of the operation of the recharge model suggest that less than 4 inches of the average of 22 inches of precipitation infiltrates below the root zone of plants. About one inch of water on the average recharges the Grande Ronde Basalt, the primary aquifer unit. The results of the recharge model were used as input data for operation of the computer model of the ground water system.

A very large quantity of water is in storage in the basalt that underlies the Pullman-Moscow area. Results from studies both within the Columbia Basin suggest that water occupies about one hundreth of one percent of the volume of saturated basalt in the area. This volume of water is equal to many times the annual rate of recharge.

Natural discharge from the ground water system in the Pullman-Moscow area is to streams in the area and to springs and seeps along the Snake River Canyon. Relatively little is known of the characteristics of these discharges. Data were gathered as part of the ground water study on stream flow gains during low flow periods. A portion of the Snake River Canyon wall also was examined to evaluate this discharge form.

Conversion Of The Conceptual Model To A Computer Model

The ground water system underlying the Pullman-Moscow area is too complex to analyze without the use of a computer model. The steps involved in the development of a computer model include formulation of a conceptual model of the actual system, formulation of a computer model based on the conceptual model, quantification of inputs for the computer model, calibration and verification of the model and finally operation of the computer model to analyze long term impacts from different pumpage patterns and amounts.

A simplified conceptual model of the ground water system underlying the Pullman-Moscow area is shown on figure 4. The model consists of three layers. The upper layer represents the sedimentary material that overlies the basalt. The second and third layers represent the Wanapum Basalt and Grande Ronde Basalt, respectively. The lateral boundaries of the conceptual model were modified to represent reasonable hydrologic boundaries for the computer model (figure 5). The eastern model boundary coincides with the edge of the basalts. The southwestern boundary was selected as the Snake River because the river canyon cuts deep into the basalts. The northern boundary was arbitrarily chosen as the Palouse River. The western and southeastern boundaries are lines drawn with no physical significance to represent continuations of the basalt aquifers in these directions. The computer was operated to test the significance of the selected boundaries.

The upper loess layer of the model incorporates recharge from precipitation, interconnection with streams and flow to and from the Wanapum layer. The second layer is interconnected with the loess layer, receives recharge from precipitation where the loess is missing, is interconnected with streams where they flow directly on the Wanapum and has flow to and from the Grande Ronde layer. The third layer, representing the Grande Ronde unit, is interconnected with the Wanapum layer, has limited areas of interconnection with streams and has a large discharge area along the deeper cut streams in the area, particularly the Snake River. The Grande Ronde layer also has most of the ground water pumpage.

Water is hydraulically moved within each layer and between layers based on the respective hydraulic heads or water levels and the input properties describing the water movement and storage within the rock. The terms hydraulic conductivity and transmissivity describe the ability of the geologic material to transmit water. The term storativity describes the storage characteristics of the rock. Vertical hydraulic conductivity is used to describe the ease of water movement between layers.

The factors of hydraulic head, transmissivity, hydraulic conductivity and storativity are necessary inputs to the development of a computer

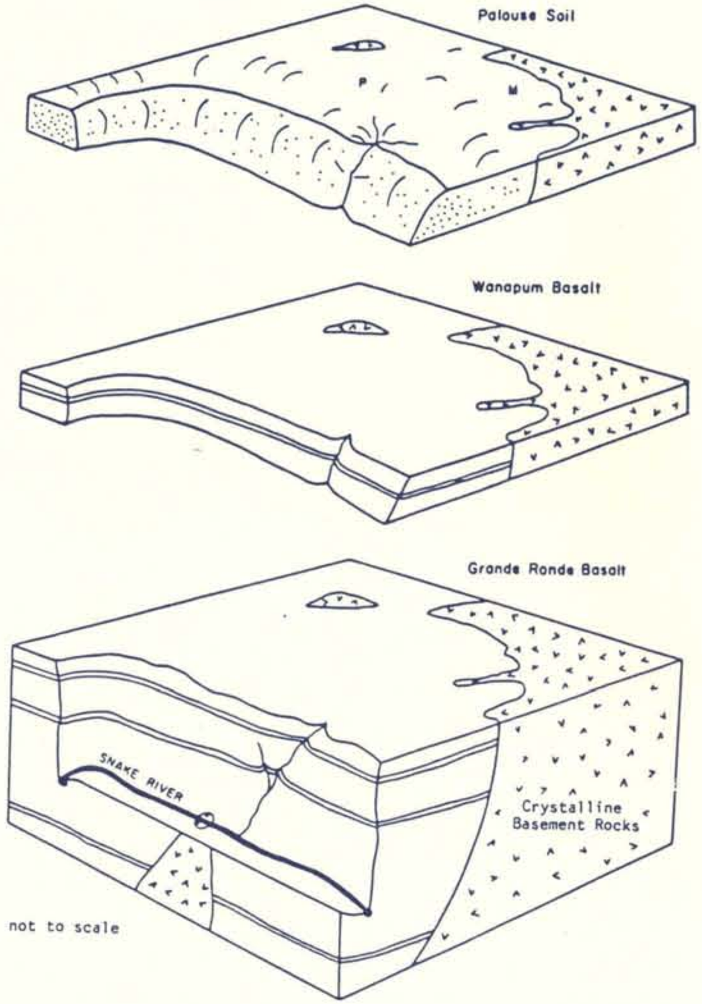

Figure 4. Three-dimensional perspective of the layered aquifer system, Pullman-Moscow area.

model of the ground water system. A field data collection program was initiated as part of the ground water study to obtain these data. Experience gained as a result of other ground water studies in basalt provided a guide for the magnitude of these input factors.

A computer ground water model consists of a program designed to handle large arrays of input data and solve equations representing ground water flow. A number of different computer models are available for this purpose. The model used for the Pullman-Moscow area was developed by McDonald and Harbaugh in 1984 and is known as the U.S.G.S. Modular Three Dimensional Ground Water Flow Model. This code was selected for use because of its suitability for this type of problem and its standard use by the U.S. Geological Survey.

A three layer computer model of the Pullman-Moscow area was constructed based on the conceptual model of the system. Each layer consisted of 2500 nodes in a 50 by 50 pattern with each node representing a one-half mile square. The model was jointly constructed and operated on the computer systems at the University of Idaho in Moscow and the U.S.G.S. in Tacoma.

The computer model was calibrated in a process of adjusting model inputs to allow the model generated water levels to match what has been historically measured in the area. The calibrated ground water levels for the Grande Ronde Basalt are shown on figure 5. Model calibration is critical to the development of a viable management tool. Considerable care was taken to create a mathematical model that matches the natural system to the greatest extent possible.

Results Of The Operation Of The Ground Water Computer Model

Once the computer model was constructed and calibrated, it was operated as a predictive tool to analyze alternative basin management options. Six different projections were examined in order to bracket potential future pumpage patterns. Three projections were based on stable pumpage rates at the 1985 rate, 25 percent above the 1985 rate and twice the 1985 rate. The other three projections were for continual growth in the pumpage rates at annual increases of one, two and three percent per year starting from the 1985 pumpage level. For reference, the 1985 pumpage rate was about 2.5 billion gallons per year; the ac-

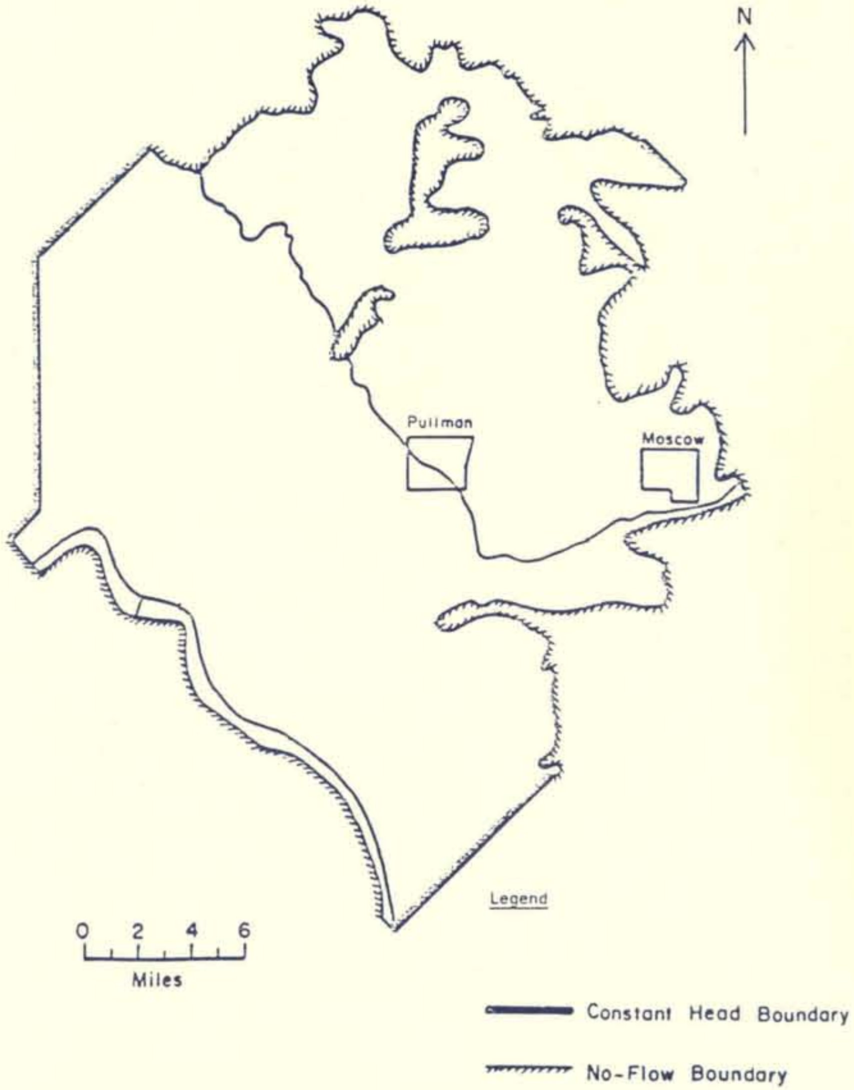

Figure 5. Model boundaries, Pullman-Moscow area.

tual rate of increase in pumpage has been about 1.7 percent per year since the 1940's.

Operation of the model suggests that ground water levels will stabilize if pumpage rates are held constant at any of the three rates. This conclusion is very important with respect to the long-term aspects of water supply in the area. The model results suggest that the ground water resource is capable of supplying the needs of the two cities and two universities into the forseeable future as long as pumpage rates are stabilized, even at rates twice that of 1985. Ground water levels will continue to decline for a period of time before reaching equilibrium conditions under any of the constant pumping alternatives evaluated. The lag time between pumpage stabilization and water level stabilization predicted by the model probably is less than will actually occur because of the single layer repesentation of the Grande Ronde Basalts. A time lag of ten to twenty years is possible before equilibrium conditions might be established under any pumping stablization program.

Results from operation of the model with annual increases in the pumping rate of one, two and three percent per year show continual water level declines into the future. The model runs of one and two percent per year increases in pumpage bracket the present pumpage pattern and show water level declines at rates similar to these presently measured in the area. The continued water level declines with annual increases in pumpage are to be expected from the ground water system in the area.

Limitations Of Model Predictions

The model incorporates many simplifying assumptions about treatment of the aquifer system that limit the applicability of the model results. Particularly important are the assumed model boundaries, the half-mile square areas represented by each node and the use of a single layer to represent the Grande Ronde Basalts. These limitations suggest that only general conclusions should be drawn from the model output. This does not lessen the value of the model but rather provides the proper perspective for interpretation of the predicted water level patterns.

Conclusions And Recommendations

The predictive runs of the model suggest that the cities and universities can rely on the existing ground water resource without extensive additional water level declines if pumpage rates are stabilized and held constant. Conversely, the model runs suggest that continued water level decline will accompany any continual pattern of increased annual pumpage.

The rates of future water level decline are directly related to the rates of increased ground water usage.

The model results do not suggest that the Pullman-Moscow area is in a situation where long term management decisions must be made immediately. However, the model results do illustrate the sensitivity of the resource to increased rates of pumpage. The model suggests that stabilization of water levels can occur at pumpage rates signficantly greater than 1985. This suggests that additional growth in pumpage is possible in the area without creating irreversible damage to the water resource system.

Model results suggest that several avenues of action are warranted in the Pullman-Moscow area. First, a continued effort is needed to upgrade the hydrogeologic knowledge of the area. A greater understanding is needed on the locations, controls for and magnitudes of both recharge and discharge. Second, the cities and universities should begin planning for measures to curtail continual water level decline in the region. Activities that are needed include water conservation, recharge enhancement, use of treated waste water and use of water from the Wanapum Basalts wherever possible.

Resource planning in the Pullman-Moscow area should continue to be a cooperative effort between all water users in the affected area. Past cooperation between the four major users has been excellent. Future planning and management efforts probably will require a formal agreement between the two states and the parties involved.