RESEARCH TECHNICAL COMPLETION REPORT
PROJECT A-011-IDA

Detailed Ground Water Investigation Of Moscow Basin

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ABSTRACT

DETAILED GROUND WATER INVESTIGATION OF MOSCOW BASIN

Moscow basin, a 58 square-mile, U-shaped basin with a 12 square-mile central lowland underlain by basalt flows and sedimentary interbeds of the Columbia River Group, is a type area for the study of the small ground water basins underlain by basalt that are common in the Pacific Northwest. Because field pumping tests were not practical, mathematical models of the artesian aquifers were designed. Comparison of the performance of the model aquifers with that of the real aquifers indicates that, if no recharge is taking place, ground water in storage will meet the needs of the basin until 2050 or 2100. However, values of coefficient of transmissibility ("T") and coefficient of storage ("S") are very high in the no-recharge models. If the real values are significantly lower, then considerable recharge is taking place. No studies have been made of models that receive recharge. Model studies were used to demonstrate the feasibility of artificial recharge utilizing seasonal runoff of intermittent streams. High contents of iron in waters in parts of the artesian aquifers are the result of naturally recharging waters carrying in iron from weathered bedrock on the margins of the basin.

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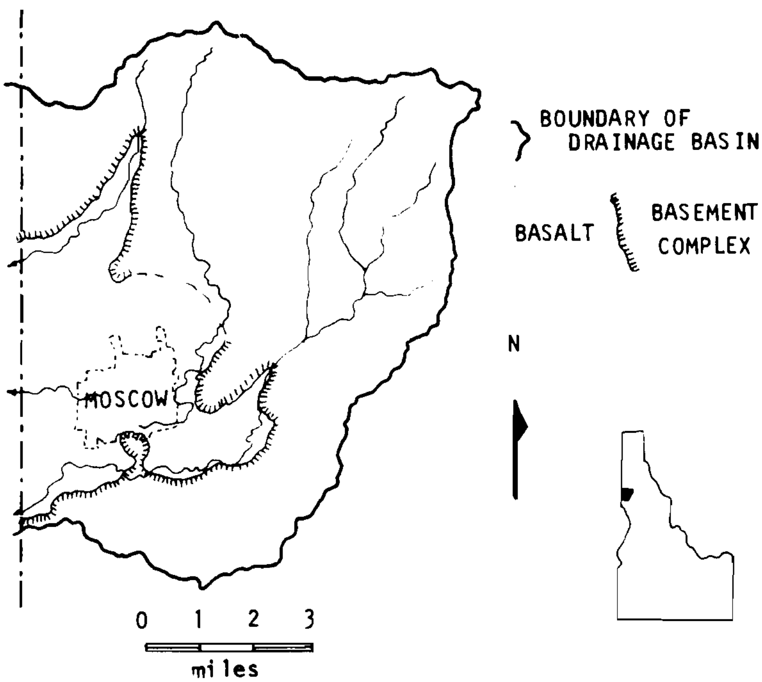

Figure 1. Location and index map of Moscow basin, Latah County, Idaho.

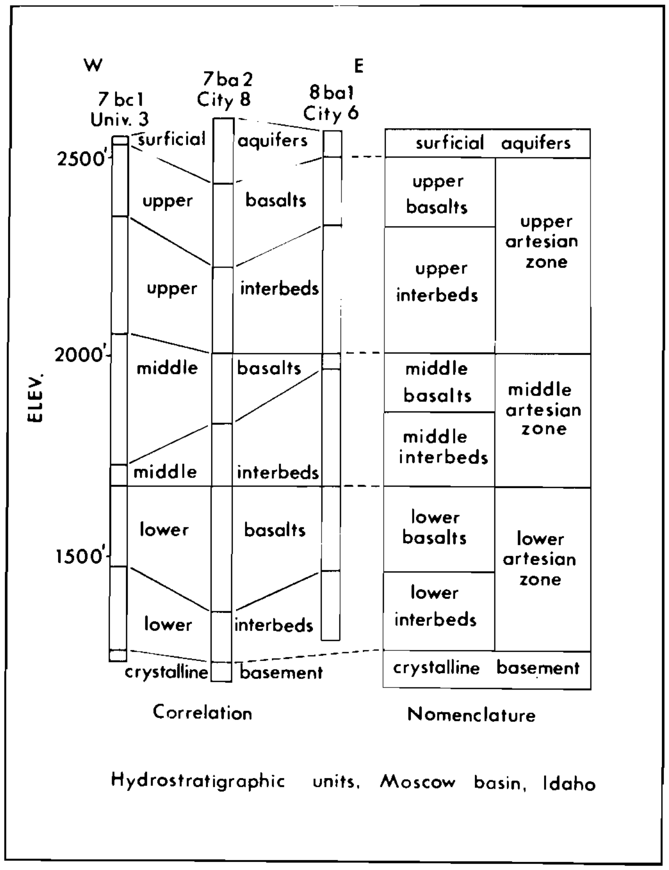

Figure 2. Hydrostratigraphic units, Moscow basin, Latah County, Idaho.

ACKNOWLEDGMENTS

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STATEMENT OF THE PROBLEM

In the seventy-year period in which water was derived from the upper artesian zone, water levels declined drastically(Fig. 3). The first wells drilled in the lower parts of the basin flowed; by the mid- 1920's, water levels stood about elevation 2510, some 50 feet below land surface. Water levels continued to decline; increased pumpage in the 1950's caused a marked increase in the decline, and water levels were at about elevation 2450, (110 feet below land surface) in the early 1960's when pumpage was shifted to the deeper wells. Water levels in the upper artesian zone have been rising ever since pumpage ceased; levels in an observation well (7dd1) were about elevation 2488 in December, 1965, and have continued to rise, reaching elevation 2497 in the first week of April, 1969.

The continuous decline in water levels in the upper artesian zone caused concern that the pumpage in the basin might be in excess of recharge. In several studies (see Ross, 1965, p. 29-35) estimates were made of the recharge based on studies of precipitation, evaporation, and runoff. All of the estimates indicated that recharge is greatly in excess of pumpage, yet the water levels continued to decline. In 1965, Crosby and Chatters attacked the problem from a different approach--they determined the age of the waters of the various artesian zones by radiometric methods. Their results indicate that the waters of the artesian zones in Moscow basin are 15,000 to 30,000 years old. They interpret their data to indicate that recharge is only about one tenth of the pumpage. Pumpage in Moscow basin averaged about 660 million gallons a year during 1961-1965. Pumpage is expected to increase, and will probably average 1130 million gallons a year for the period 1965-2000.

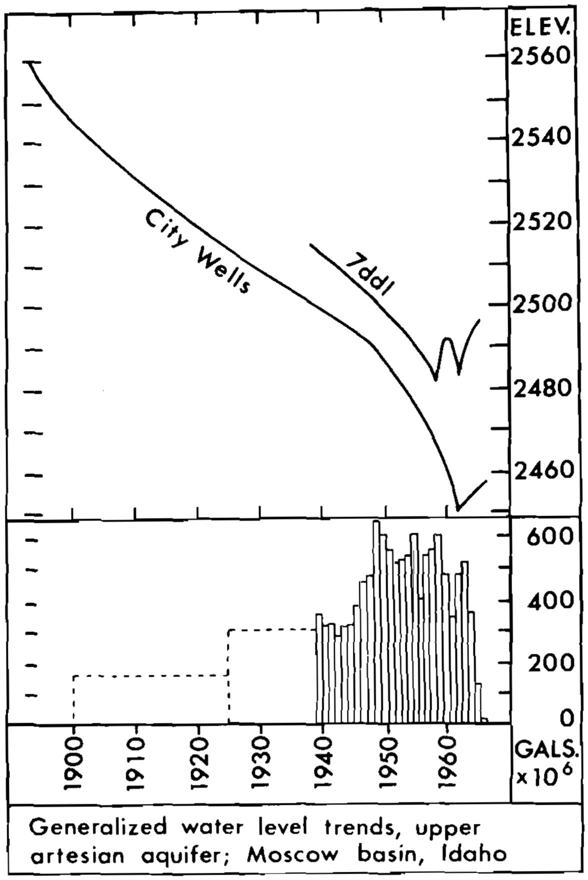

Figure 3. Water level trends (generalized) and water pumped, 1896-1965, Moscow basin, Latah County, Idaho.

PURPOSES OF THE PROJECT

Because the University of Idaho is in Moscow basin, the area is a convenient outdoor laboratory for the study of certain types of ground water problems. The basin is rather small, all recharge originates within the basin, and the basin is underlain by a sequence of artesian aquifers in basalts. The hydraulic properties of the artesian aquifers were unknown at the beginning of the study, but considerable data on pumpage and water level fluctuations were in the files of the University of Idaho and the City of Moscow. These data had never been analyzed. The aquifers are fairly heavily pumped, and the pumpage is expected to increase. Therefore, Moscow basin is a type area for the study of small ground water basins with limited recharge that are underlain by basalt. Basins of this sort are common in the Pacific Northwest.

Because of the convenient location, Moscow basin is useful for the training of scientists in water resources studies. S.H. Ross was employed in the project and used her work for her Master of Science in Geology thesis at the University of Idaho. Her thesis has been published as an Open-File Report of the Idaho Bureau of Mines and Geology (Ross, 1965).

The City of Moscow and the University of Idaho have practical interest in water resources studies in Moscow basin because of the need of long-range planning to meet their future requirements. Part of the study was directed to determining availability of water to meet the needs of the City and University. This part of the study might serve as a guide for water resources studies in similar basins.

PROJECT OBJECTIVES

List of Objectives

1. Data Collection: to assemble and tabulate all existing records that were scattered in various offices of state, municipal, federal, and private organizations.
2. Well Inventory: to inventory all wells in Moscow basin.
3. Hydrogeology: to delineate the several aquifers and determine the hydraulic interconnections between them.
4. Hydraulic Properties of the Aquifers: to determine directions of movement of ground water and hydraulic properties of the aquifers.

5. Estimated Recharge and Storage: to obtain better estimates of recharge and storage.
6. Adequacy of Available Ground Water: to predict adequacy of water available for projected use.
7. Geochemistry of Ground Water: to investigate the origin and distribution of the dissolved chemical constituents in the water, especially the very large amount of iron.
8. Continuing Investigation: to develop a program of continuing study to check the results of the investigation.

Discussion of Achievements

1. Data Collection

Pumping records, water-level measurements, and well logs were obtained from the files of the City of Moscow, the University of Idaho, and the U.S. Geological Survey. The data are in print (Ross, 1965) or in press (Jones and Ross, 1969b).

2. Well Inventory

We were not able to obtain data on all wells in Moscow basin. Records are in print (Ross, 1965) or in press (Jones and Ross, 1969b) for about 230 wells, which we believe are about 80 percent of the wells in the basin as of the end of data collection in December, 1966.

3. Hydrogeology

In addition to our own efforts (Jones and Ross, 1969c), considerable knowledge of the hydrogeology of Moscow basin was obtained through studies by several workers at Washington State University (Crosby and Cavin, 1966; Chang-Lu, 1967). The sizes and shapes of the aquifers are now known in a general fashion, although many details are uncertain. Direct connection between the aquifers seems to be poor; we were unable to determine if the aquifers are leaky or non-leaky.

4. Hydraulic Properties of the Aquifers

Hydraulic properties of aquifers usually are determined by field pumping tests. We could not use field methods in Moscow basin because:

1. Too few wells pump from the deeper aquifers.
2. Aquifer boundaries are too close and have too great an effect on water levels to permit analysis of pump-test data by ordinary methods.
3. Drawdowns are small for high pumping rates and recovery so rapid that tests based on recovery of pumped wells were not satisfactory.

First approximations of coefficients of transmissibility for the artesian aquifers were obtained from specific capacity of wells. Other values of coefficient of transmissibility and values for coefficient of storage were obtained through studies of mathematical models of Moscow basin that assumed no recharge takes place. A paper on these studies is in press (Jones and Ross, 1969a).

5. Estimated Recharge and Storage

The mathematical model aquifers, which assume that no recharge is taking place in Moscow basin, indicate that the ground water in storage should meet the needs of the basin for the next 50 to 100 years. We were not able to make any direct contribution to the problem of ground-water recharge in Moscow basin. However, in order to develop mathematical models that would match the actual performances of Moscow basin aquifers under the assumption that there is no recharge at all, we had to use values of coefficient of transmissibility and coefficient of storage that are very large--perhaps unrealistically large. If it can be demonstrated that the actual values of aquifer constants in Moscow basin are significantly lower than those used in our no-recharge model studies, then the major source of the water pumped must be recharge.

In the event that water naturally in storage plus natural recharge should not be adequate to meet the needs of the basin, we investigated the feasibility of artifical recharge utilizing nearby intermittent streams. A paper has been published on the artificial recharge study (Jones, Ross, and Williams, 1968.)

6. Adequacy of Available Ground Water

If no recharge to the artesian aquifers is assumed, our model studies indicate that the ground water in storage in Moscow basin will meet the needs of the basin for the next 50 to 100 years. We have not studied the adequacy of supply if significant recharge is taking place.

7. Geochemistry of Ground Water

Chemical analyses were obtained for waters from about 42 wells. Specific conductance was measured for waters from about 200 wells and iron content was determined for waters from about 160 wells. The data have been analyzed and suggest that natural base exchange is taking place (Jones and Ross, 1969c) and that the iron is introduced into the artesian aquifers by waters percolating out of iron-bearing high-alumina clays at the margins of the aquifers (Ross, 1965, p. 83-88).

8. Continuing Investigation

A program of continuing investigations was submitted to local authorities. No action has been taken on our program, but other local studies are continuing on various aspects of Moscow basin water supply.

RESEARCH PROCEDURES

Much of the research was conducted by standard methods for field investigations of ground water problems: well owners and well drillers were interviewed, water-level measurements were taken periodically, records were assembled and tabulated, water samples were analyzed, etc. The one aspect of the investigation that is unusual is the use of mathematical model aquifers to study availability of water and feasibility of artificial recharge (Jones, Ross and Williams, 1968; Jones and Ross, 1969a, 1969c).

For reasons listed above, we were not able to run the usual field pumping tests in Moscow basin. Therefore, we developed mathematical models of the aquifers using the Theis (1935) nonequilibrium equation (see Ferris and others, 1962, p. 92) and the method of image wells (Walton, 1962, p. 15-21; Ferris and others, 1962, p. 144-166).

Records of the City of Moscow and the University of Idaho provided data on the actual pumping rates and the actual drawdowns of the real aquifers. We designed mathematical models of the Moscow basin artesian aquifers using values of coefficient of transmissibility obtained from specific capacities of the real wells. We also used values of coefficient of transmissibility and coefficient of storage that have been reported elsewhere for the Columbia River basalts that make up the principal rock types in the Moscow basin aquifers as well as values reported for the Snake River basalt. We "pumped" the various model aquifers for the same amounts of time and at the same rates as the real wells pumped the actual aquifers, then compared the "drawdowns" of the model aquifers with those of the real aquifers. We presumed that, if a model aquifer had the same "drawdown" as the real aquifer for the same rate and duration of pumping, the coefficient of transmissibility and coefficient of storage of the model aquifer are the same as those of the real aquifer--provided that no recharge took place. Our study was limited to the case that little or no recharge is taking place in Moscow basin, a view that was advanced by Crosby and Chatters (1965) on the basis of their study of isotope ages of waters in the Pullman-Moscow basin.

The same kind of mathematical model aquifers were used to study the buildup of water levels by artificial recharge through wells. We "recharged" through wells at a rate and duration determined by the availability of water from intermittent streams. Water levels at the end of the recharge season were predicted in order to be sure that the aquifers would accept the amount of water needed and available during the recharge operation.

SIGNIFICANT RESULTS AND CONCLUSIONS

Results and conclusions that have applicability beyond the immediate problem of availability of water in Moscow basin include:

1. Mathematical models of aquifers can be used to study ground water problems in areas where field studies are not practical.
2. Iron in ground water need not originate in the aquifer from which the water is obtained.
3. Artificial recharge from seasonal runoff in intermittent streams in technically feasible and, under certain conditions, is cheaper than importation of surface water.

Mathematical Model Studies

The long-continued decline of water levels in Moscow basin led to speculation that recharge is inadequate to balance the discharge through wells. The conclusion of Crosby and Chatters (1965, p. 16) that recharge is only 10 percent of annual pumpage supported the concept. Therefore, we studied mathematical models of the Moscow basin that assumed that no recharge is taking place in order to predict the availability of ground water under the most unfavorable of conditions. The studies indicated that, as of 1965, between 126.2 and 349.5 billion gallons were in storage in the middle and lower artesian aquifers that are the principal suppliers to Moscow basin. Estimated consumption during the period 1965-2000 is 50.1 billion gallons, leaving a balance of 76.2 to 299.4 billion gallons in usable storage by the year 2000--this should be enough to last until at least 2030 and perhaps until 2100. (Jones and Ross, 1969a, 1969c).

However, in order for the mathematical models to duplicate the performance of the real aquifers, we had to use values of aquifer constants that are very high--and perhaps are unrealistically high. The range of values for the model aquifers that produced most nearly similar results to those of the real aquifers are: coefficient of transmissibility ("T"): 1.0×10^6 to 4.0×10^7 gallons per day per foot; coefficient of storage ("S"): 1.0×10^{-2} to 1.0×10^{-3} (dimensionless). These values are greater than those that we have seen reported from elsewhere in the Columbia River basalt. Foxworthy and Bryant (1967) reported T or 3.2×10^5 gallon per day per foot by recovery method and 1.0×10^6 by specific capacity method at The Dalles, Oregon. Price (1961) reported T of 3.7×10^5 and

4.0×10^5 gallons per day per foot and S of 2.0×10^{-4} at Walla Walla, Washington. Eddy (1969) reported permeability data for the Columbia Basin Irrigation Project that would indicate T of 1.0×10^4 gallons per day per foot under conditions similar to Moscow basin; he reported values of S ranging from 1.0×10^{-2} to 1.0×10^{-3}. Basalts can have very large aquifer constants; the upper range of values reported for the Snake River basalts of south Idaho are T of 1.0×10^4 to 1.0×10^7 gallons per day per foot and S of 1.0×10^{-1} to 1.0×10^{-3} (Mundorff, Crosthwaite, and Kilburn, 1964; Walton and Steward, 1959) Snake River basalts formed through a different mode of eruption than Columbia River basalts; therefore, origin of the primary permeability of the two units may be different and thus Columbia River basalts might not have as high values of aquifer constants as Snake River basalts.

If it can be shown that the actual values of aquifer constants for the real aquifers of Moscow basin are significantly less than those of the model aquifers that duplicate the performance of the real aquifers under no-recharge conditions, then some--or much-- of the water being pumped from the real aquifers is not coming from storage, but rather is coming from recharge. Extrapolations based on the no-recharge model aquifers will be valid only as long as recharge is in excess of discharge. When pumpage exceeds recharge the proportion of water pumped that is derived from storage will go up.

The Crosby and Chatters (1965, p. 16) conclusion that recharge to Moscow basin is small is based on their study of isotope ages of water. In contrast, studies of recharge based on the water-balance equation indicate that recharge in Moscow basin is large. Ross (1965, p. 30-35) summarized the various water-balance estimates and pointed out that all came to a similar conclusion: pumpage at the time of the study was about one-half of the ground-water recharge. (Ross also pointed out that the water-balance studies have wide margins of error.) A typical figure is that of Stevens (1960) who arrived at an annual recharge of 1303 million gallons. Estimated consumption in Moscow basin in the year 2000 is 1360 million gallons (Jones and Ross, 1968, p. 264). Therefore, if annual recharge is as large as estimated by Stevens, natural recharge should balance pumpage until the year 2000.

We have not attempted to design mathematical models of Moscow basin that include recharge. The procedure would be to combine two models, one a "pumping" model operating at real or projected pumping rates and the other a "recharging" model operating at various values of recharge. For such models to be valid, better data are needed on the aquifer constants of the real aquifers of Moscow basin. This is a study that merits investigation.

Origin of Iron in Ground Water in Moscow Basin

Although basalt is a rather iron-rich rock and although some of the cuttings from wells in Moscow basin show secondary pyrite in the basalt, much of the iron in the ground water apparently is not derived from the basalt. Distribution of most of the high concentrations of iron in water in the upper artesian zone is geographically related to a spur of weathered basement rock on the east edge of the basin (Ross, 1965, p. 83-88; Jones and Ross, 1969c). High alumina clays in the weathered rock contain about 5 percent iron oxides. Water percolating through the clay deposits picks up iron which is carried along across the recharge area on the east edge of the basin into the upper artesian zone. Iron content is small in waters from the middle and lower artesian zone.

Artificial Recharge

The possibility of depletion of the ground water supply of Moscow basin led to consideration of plans for importation of surface water. However, no satisfactory reservoir sites are close to the area and the nearest streams with dependable flow during the high-demand periods are over 20 miles away. Importing surface water would be very expensive.

Intermittent streams within the basin carry relatively large flows when the winter snow pack melts from February through May. We proposed a plan (Jones, Ross, and Williams, 1968) of artificial recharge of the upper artesian zone during the spring runoff season in order to hold water in temporary ground-water storage for utilization during the summer peak-demand season. No large reservoirs are necessary and pipelines are short. Potential yield of the system is from 400 to 960 million gallons annually, depending on the size of the artificial recharge plant. Projected demand for water in Moscow basin for the year 1970 is 840 million gallons; therefore, the system could meet the entire 1970 demand. However, by the year 2000 demand will increase to 1360 million gallons. If natural recharge is not sufficient to make up the difference between the year 2000 demand and the water available from artificial recharge, we suggest that artificial recharge of the treated effluent of the Moscow sewage treatment plant should provide the rest of the water needed. Our computations indicate that the cost of this project would be less than that of importation of surface water.

The artificial recharge study utilized a coefficient of storage of 1.0×10^{-4}, a value that is much smaller than the value of 1.0×10^{-2} indicated by the studies of the "pumping" of the mathematical models of the upper artesian zone. The buildup from recharge probably would be smaller than the figures given in our paper (Jones, Ross, and Williams, 1968). We have not recomputed the buildup using the larger values of coefficient of storage.

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