Recommendations for Siting a Second Ground-Water Production Well at Black Pine Mine, Cassia County, Idaho

John A. Welhan

Staff Report 00-16
December 2000

Idaho Geological Survey
Morrill Hall, Third Floor
University of Idaho
Moscow, Idaho 83844-3014

Note: *This study was completed in 1995.*

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ABSTRACT

Black Pine Mining, Inc. operates a well to supply water for its mining operations. Because of increasing demand for waterand concern over the impacts of extended droughts on the well's future capacity, the company asked the Idaho Geological Survey to provide technical advice on the feasibility of siting a second well in the area. This report documents the recommendations arising from an examination of available hydrologic and geologic data near the current well.

A conceptual model of the hydrogeology in this area was created on the basis of the available information and discussions with mine personnel during a site visit on August 31, 1994. A two-dimensional analytical ground-water flow model was used to predict the drawdown effects of siting a second well in the vicinity of the first well. The conclusion of this study is that a second production well could be located near the existing well, and that both wells could pump continuously at 500 gpm with an acceptable increase in water level drawdown, if the wells were spaced 200-400 feet apart. In view of the limitations of the available well drawdown data and the limited knowledge of aquifer geology and boundary conditions near the existing well, it is strongly recommended that a controlled pumping test of this well be performed to corroborate the analysis of the existing data and to validate the model predictions.

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SUMMARY OF CONCLUSIONS

A conceptual model of the subsurface hydrology in the vicinity of Black Pine Mine's Project Well was constructed on the basis of information and data supplied by the company during a site visit on August 31, 1994. This model formed the basis for a two-dimensional analytical ground-water flow model that was used to predict the drawdown effects of siting a second well near the current production well which is known as the Project Well.

The overall conclusion of this study is that a second well could be located near the existing well, and that both wells could pump continuously at 500 gpm with an acceptable increase in water level drawdown, if the wells were spaced 200-400 feet apart.

Although this evaluation indicates that the short-term consequences of additional ground-water exploitation should be negligible, historic water level data from wells in the study area suggest that below-normal precipitation of the 1994 water year, coupled with the below-average recharge for the drought period 1987-1992, has reduced ground-water storage in the vicinity of the Project Well significantly, making long-term predictions of well drawdown less certain.

Two key components of the conceptual model will require verification before the predictions in this report can be used with confidence to design a new well:

1. The confined nature of the aquifer, its effective thickness, and hydraulic conductivity have been inferred from the yields of other wells in the area, from existing well test information, and from an examination of available data, and require confirmation.

2. Both the well's proximity to recharge and the nature of the recharge source are crucial to the predictions of aquifer drawdown response, and need to be better defined.

A constant-discharge pumping test should be conducted on the Project Well, ideally for a 3-day duration, with drawdown measured in both the Project Well and in the nearby monitoring well (the Monitor Well). Because no data are available on the drawdown response of the Monitor Well to Project Well pumping, such a test is crucial for confirming the validity of model predictions over a representative volume of the aquifer, and would provide a clear indication of the aquifer's ability to sustain multiple pumping wells. An alternative to a multi-day test is a short-term pumping test of 12 hours. Even such a relatively short test would corroborate existing well drawdown data and define the critical first 4 hours of pumping response in the Project Well and in the Monitor Well.

In the absence of such tests, the recommendations contained in this report on the suitability criteria for siting an additional well can only be considered general guidelines.

INTRODUCTION

Black Pine Mining, Inc. (a subsidiary of Pegasus Gold Corporation) operates a heap leach gold mine in Cassia County, Idaho. The mine is located east and south of the city of Burley. The company operates a well to supply water for its mining, heap leaching and personnel maintenance operations. The location of this well (the Project Well) is shown in Figure 1. This well had been sited and drilled on the basis of a hydrogeologic reconnaissance of site conditions (Morrison-Knudsen, 1988). After installation, the well was tested and deemed capable of supplying 500 gallons per minute (gpm) (Waste Engineering, 1992). Records show that the well has consistently produced more than 190 gpm (averaged over 13 months) with monthly mean production tending to have increased lately, up to 390 gpm in July 1994. Because of this increasing demand, projections of still greater future demand, and concern over the impacts of the current drought on this well's future capacity, the company asked the Idaho Geological Survey to provide technical advice on the feasibility of siting a second production well in the

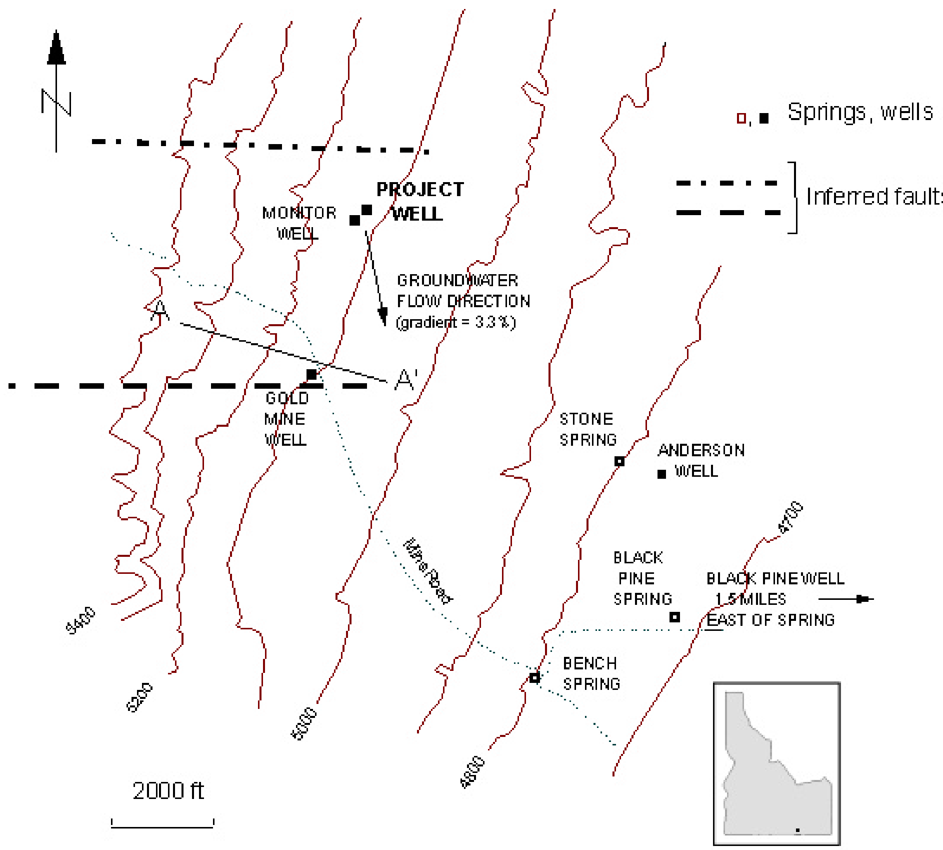


Figure 1. Locations of wells and springs near Black Pine mine. Ground water flow direction was determined from water level data collected December, 1990 at the Project Well, Gold Mine Well, and Anderson Well. Cross-section A-A' is shown in Figure 2.

area. This report documents the recommendations arising from an examination of the hydrologic and geologic data that were available as of August 31, 1994.

SCOPE AND DATA SOURCES

Recommendations in this report are based on a consideration of the hydrogeology in the immediate vicinity of the current production well (hereafter known as the Project Well) and a pair of piezometers located 440 feet (134 meters) southwest of the Project Well (the deepest of which hereafter will be referred to as the Monitor Well). The geographic scope was purposely limited primarily by the paucity of hydrogeologic data outside the immediate mine vicinity, and by the fairly good database that is available on the Project Well and the Monitor Well. Extrapolation of the geologic and hydrologic interpretations of this report to areas outside of the immediate Project-Monitor Well vicinity is not recommended.

Data on regional hydrogeologic conditions were obtained from a report on the Curlew Valley drainage basin (Baker, 1974). Site-specific information was obtained from reports and unpublished data provided by Black Pine Mining.

Data that were utilized in this analysis included lithologic and geologic information from the deep Monitor Well and Project Well drilling logs and exploration drill hole data; well yield information obtained during development of the Project Well, Monitor Wells and a nearby stock watering well (Gold Mine Well); and historic ground-water level records available for these wells for the period November 1990 to July 1994. Interviews with Mssrs. D. Ryzak and C. Scott and an examination of the site in the immediate vicinity of the Project-Monitor Wells were also conducted to obtain information on the history and current conditions of the mine's ground-water supply.

DATA AND ANALYSIS

The Project Well and Monitor Wells are located in SE1/4 NW1/4 sect. 36, T.15S., R.29E. This area is on the northwestern margin of a thick sequence of Quaternary and Tertiary (Salt Lake Group) sediments comprising clay- and silt-rich gravel. On the basis of gravity data, the thickness of these sediments has been mapped in excess of 3,000 feet (915 meters) in the center of the basin (Baker, 1974). Approximately two miles east of the Project Well site, a structurally complex assemblage of folded and faulted Mississippian to Permian marine sedimentary rocks outcrops in the Black Pine Mountain Range. Several E-W trending vertical faults extend from the Range eastward and are believed to underlie the basin-filling sediments near the wells, including two inferred faults that may extend just north and south of the Project Well (D. Ryzak, pers. comm., 1994). Ground-water recharge likely originates in the Black Pine Range about five miles to the west and is possibly enhanced by outcropping bedrock lithologic contacts, such as that between the Manning Canyon Shales and Middle Plate Limestones just west of the range summit (D. Ryzak, pers. comm., 1994).

The immediate area around the Project Well shown in Figure 1 indicates the locations of these bedrock faults as inferred from exploration drill hole data. Figure 2a is a composite lithologic cross-section through A-A' of Figure 1, constructed with lithologic data from the Gold Mine Well and exploration drill hole data (C. Shaw, written comm., 1994), showing the general thickness of Quaternary/Tertiary sediments overlying Paleozoic bedrock in the vicinity of the Project Well. The lithologic logs for the Project Well and the deep Monitor Well corroborate this general picture, indicating that sediments north of Section A-A' near the Project Well are at least 420 feet (128 meters) thick, over limestone bedrock (Figure 2b). The position of the piezometric surface in the Project Well relative to the inferred water-bearing gravel and rock near the base of the well and the clayey, possibly confining upper beds suggests that confined aquifer conditions may prevail around this well. However, the piezometric surface defined by the deeper Monitor Well screen suggests unconfined conditions cannot be ruled out solely on the basis of lithology.

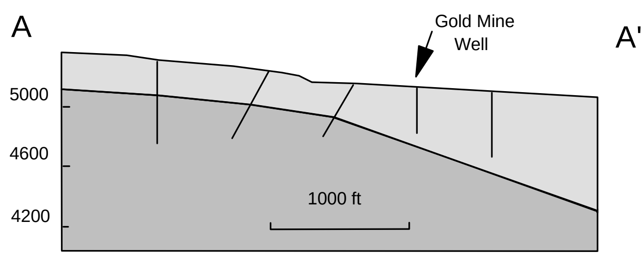


Figure 2a - Cross-section A-A' constructed from exploration drill holes and Gold Mine Well lithologic logs (after C. Shaw, written comm., 1994). Upper sedimentary unit described as Qal; lower unit as Permian bedrock. No vertical exaggeration.

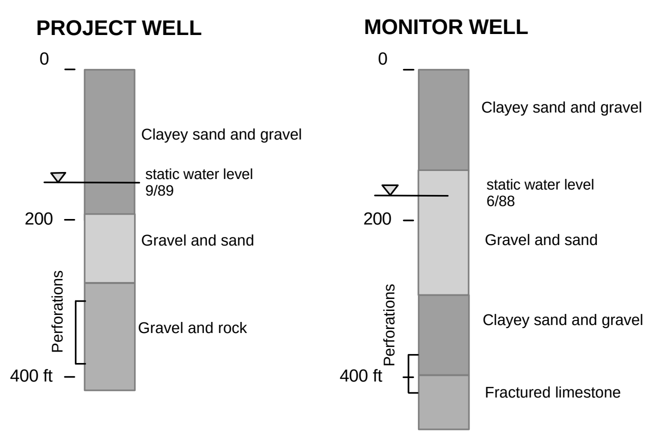


Figure 2b - Generalized lithologic logs of Project and Monitor Wells.

The region receives moderate to low amounts of precipitation annually, averaging 35 inches per year (0.89 meters/year) at Black Pine Peak to less than 16 inches per year (0.4 meters/year) at the Project Well (Baker, 1974). Precipitation data collected by Black Pine Mine at a site approximately 1.5 miles (2.4 kilometers) west of the Project Well showed that in 1992 (a drought year), only 8.5 inches (0.22 meters) fell, whereas in 1993 (a near-normal water year), 15.2 inches (0.39 meters) was recorded. Figure 3 summarizes monthly precipitation data at the mine site.

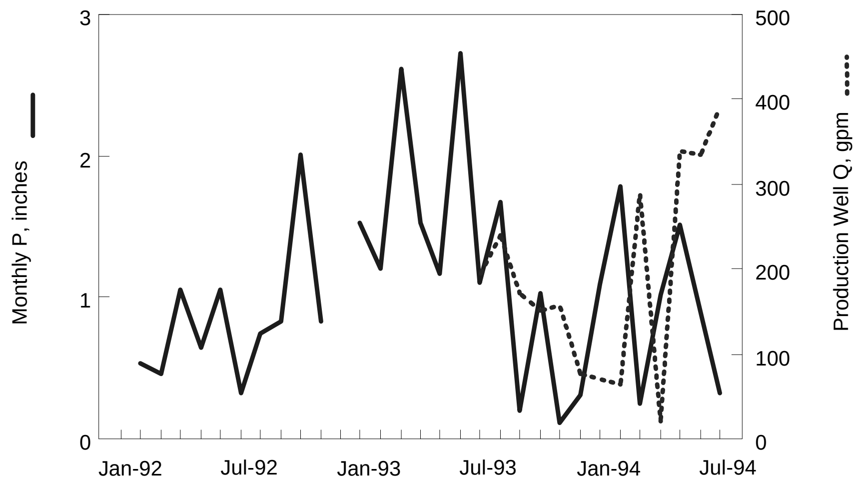


Figure 3 - Precipitation measured at the Black Pine Mine site;
Project Well's mean monthly discharge is shown for comparison.

Water level data for the Monitor Well, Black Pine #1 Well and the Gold Mine Well are summarized in Figure 4. Of the wells shown, Black Pine #1 is the farthest east and displays the lowest water elevations, consistent with a general west-to-east ground-water flow direction which would be consistent with topography (Waste Engineering, 1992). However, the substantial difference in ground-water elevation between the Monitor/Project Wells and the Gold Mine Well indicates that ground-water flow has a major southward component, a fact which has not been documented in previous studies. An analysis of well water levels collected in December, 1990 among the Project, Gold Mine and Anderson Wells indicates that the direction of ground-water flow between the inferred faults north and south of the Project Well is more southerly than easterly (Figure 1).

Water level variations in the wells shown in Figure 4 are 6.6 $\pm$ 1 feet (2 $\pm$ 0.3 meters) over the period of record. Black Pine Well #1 displays the largest variations; Gold Mine Well water levels varied by little more than 2.5 feet (0.75 meters) over all but the last three months of the period of record. Monitor Well water levels displayed a 5.6 feet (1.7 meters) variation, shown on an expanded scale in Figure 5.

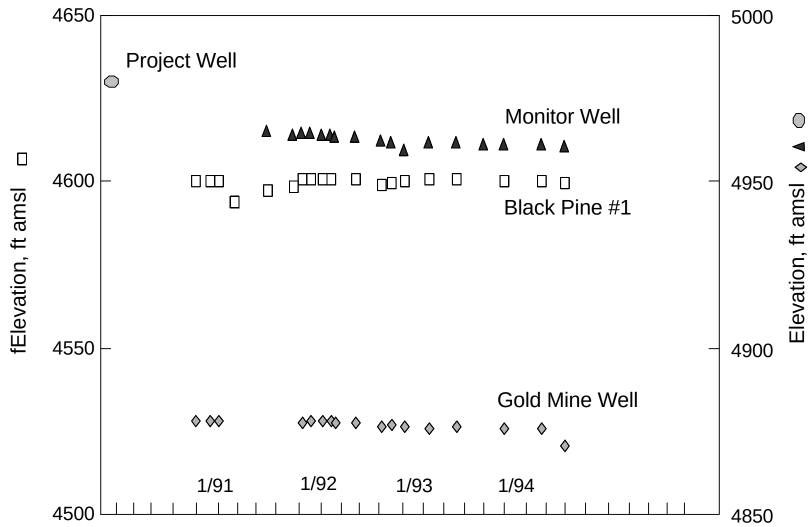


Figure 4 - Static water levels in site wells. No information available on Project Well water levels since 1990.

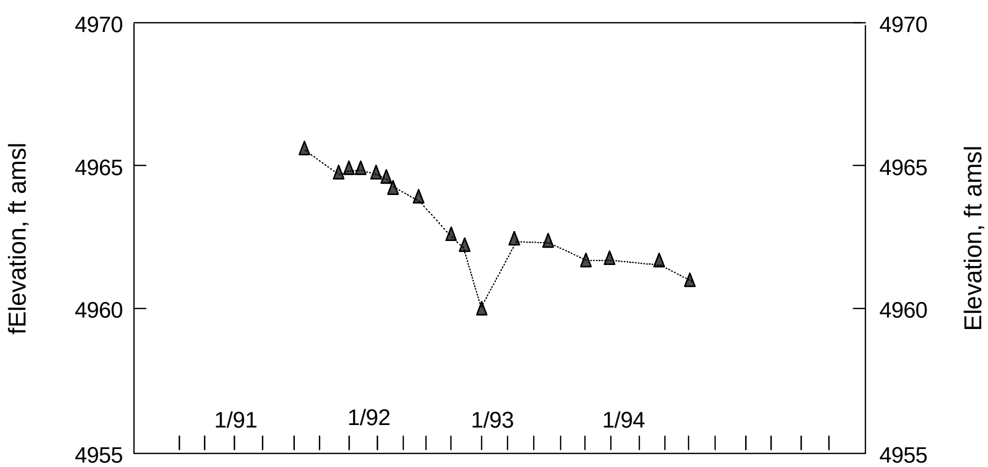


Figure 5 - Static water levels in Monitor Well, showing significant long-term and short-term water level variations.

At least some of this variation appears to reflect seasonal recharge, as suggested in Figure 6, where the Monitor Well's water level record is compared with monthly precipitation recorded at the mine site. If precipitation at the mine site is a subdued reflection of high-altitude precipitation in the recharge zone, then the increase in precipitation during the fall and winter of 1992/1993 at the mine site and the sudden increase in ground-water level in the spring of 1993 suggest that ground-water storage at the Monitor Well site is sensitive to recharge fluctuations.

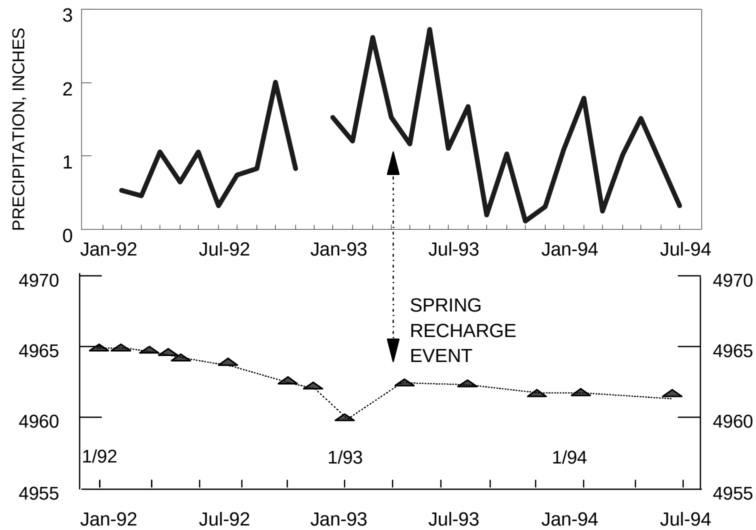


Figure 6 - Precipitation measured at the mine site, compared to ground water level changes in the Monitor Well. Note the large increase in water levels at the time of Spring, 1993 recharge.

Since snowpack in the winter of 1992/93 was near-normal, the data indicate that ground-water in the vicinity of the Project Well/Monitor Well site could respond favorably in years of normal precipitation and recharge. As indicated in Figures 5 and 6, however, a single normal water year (1993) appears to have had little impact on long-term declining ground-water storage in this area, indicating that protracted drought periods may have a deleterious influence on the Project Well's ability to sustain current yields.

Table 1 summarizes available specific capacity data for area wells, gleaned from drillers' logs and mine reports. Based on an assumed nominal 100-foot open interval in these wells and a storativity of 0.001, a hydraulic conductivity of approximately 10-20 feet/day (3-6 meters/day) can be crudely estimated for the aquifer materials in the study area. This estimate has more than an order-of-magnitude of uncertainty, because of the approximate nature of the conversion of specific capacity data and because the observed range in specific capacities in Table 1 spans three orders of magnitude. The Project Well's data, (obtained under controlled conditions that best represents long-term drawdown), provides the best estimate of long-term well capacity and local hydraulic conductivity. Based on a perforated interval of 80 feet, the estimated hydraulic conductivity of the aquifer in the vicinity of the Project Well is estimated to be approximately 170 feet/day (52 meters/day).

Information on the drawdown-time response of the aquifer is available for both the deep Monitor Well (obtained in a 6-hour constant rate pumping test; Morrison Knudsen, 1988) and for the Project Well (obtained during a 7-day development test; Waste Engineering, 1992). These data show that the Project Well's drawdown stabilized very early after commencement of pumping and remained steady for at least 7 days (at 530 gpm discharge). This response can be interpreted in two very different ways: (1) the aquifer is either an unconfined or a leaky confined system and the steady drawdown is a result of vertical drainage or leakage, respectively; or (2) the aquifer confined and is strongly influenced by a nearby hydrologic recharge boundary which stabilizes drawdowns.

TABLE 1 - Summary of specific capacity (Q/s) information for wells in the immediate study area

Well	Data Source	Q/s*	gpm/ft of drawdown	Comments
Gold Mine Well	Waste Engineering, 1992	60/14	4.3	max yield could be much larger, since >50 ft of available drawdown could yet be exploited (Morrison Knutsen, 198
Black Pine #1 Well	Development / well log	100/110	0.9	no information available
Johnson Well	Development / well log	372/80	4.7	no location given for well
Project Well	Waste Engineering, 1992	530/10.5	50.5	7-day development test
Monitor Well	Morrison Knutsen, 1988	10/4	2.5	air-lift, constant discharge
Monitor Well	Waste Engineering, 1992	10/5	2.0	discharge unknown, probably about 10 gpm

* Q = pumping rate, in gpm

Neither possibility can be discounted without detailed drawdown data for early time (i.e., the first 100-200 minutes). However, the length of time necessary to detect recharge to the Project Well from a nearby recharge boundary can be used as a criterion to decide between alternatives (1) and (2), above. For example, since the attainment of steady drawdown in the Project Well occurred very quickly (about 3.5 hours after commencement of pumping), the theoretically predicted time required to detect this boundary for one of the above aquifer scenarios should be more consistent with the observed time than that for the alternative scenario.

The minimum time required to clearly define a boundary effect in the pumping well's drawdown response can be estimated by

$$t_m = 0.5(d^2S/T) \qquad \text{(Ferris and others, 1962),}$$

where d/2 = distance between a boundary and the pumping well, T = aquifer transmissivity, and S = aquifer storativity or specific yield. For the Project Well, d/2 = 1000 ft (305 m), T = 13600 ft^2/day (170 ft/day x 80 ft) and S could range from 10^{-6} to 0.3 (for conditions ranging from confined to unconfined, respectively). Therefore, for t_m of the order of 3 hours, S would have to be of the order of 10^{-3} to 10^{-4}. On this basis, it can be inferred that the aquifer must be effectively confined so as to be responsive to the boundary over such a short time frame. If the aquifer were leaky or unconfined, the boundary could not have been observed within the time frame of the tests that have been conducted to date.

In contrast to the Project Well's pumping response, the 1988 test data from the Monitor Well showed an increased rate of drawdown shortly after the commencement of pumping and was interpreted as evidence for the existence of a possible nearby hydrologic *barrier* boundary (Morrison Knudsen, 1988). Further adding to the ambiguity of the data on record, a discharge test of the Monitor Well conducted at the same time as the Project Well's 7-day test (Verti-Line Pumps, written comm., 1989; Waste Engineering, 1992), showed a steady 5 feet of drawdown after 7 days of pumping (discharge rate unknown, but assumed to be similar to the 1988 Morrison Knudsen test, or approximately 10 gpm). The 1988 data would suggest that the Monitor Well's hydraulic behavior was very dissimilar to the Project Well's (i.e., influenced by a nearby recharge boundary), whereas the 1992 test data would make it very similar to the Project Well's response. However, no details of the latter test are available to assess its accuracy or reliability.

Given the close proximity of the two wells, a large difference in drawdown behavior would not be expected. Because the 1988 Monitor Well test is known to have been conducted with air-lift pumping and for only a short duration, the accuracy of those test data (discharge and drawdown measurements) are suspect. Furthermore, since that testing was performed immediately after Monitor Well construction, it is possible that the test results were affected by inadequate well development. For these reasons, the Project Well's pumping test data are considered more representative of the aquifer's long-term safe yield and local aquifer permeability, at least in the immediate vicinity of these wells. However, it is cautioned that neither set of available well test data is sufficient to form a reliable conclusion. On the basis of the preceding discussion, a confined aquifer with a nearby recharge boundary is more defensible than a leaky or unconfined aquifer model, and therefore will be considered the preferred scenario.

CONCEPTUAL HYDROGEOLOGIC MODEL

In order to predict well response under different production well scenarios and to develop recommendations for siting additional production wells, a conceptual hydrogeologic model was formulated that is based on the premise of a confined aquifer in proximity to a local recharge boundary.

The model assumes that ground-water recharge occurs to the west of the Project Well site and that aquifer storage and eastward ground-water flow along local faults are adequate during years of normal and above-normal precipitation (as well as during short periods of below-normal precipitation) to maintain water levels in the Project Well (cf. Figure 6). A similar situation may exist in the vicinity of the Gold Mine Well, where the low amplitude of its historic water level variations (Figure 4) may be due to the proximity of a fault-controlled recharge boundary (Figure 1). A southerly hydraulic gradient of 3.3 % in the vicinity of the Project Well (Figure 1) suggests that localized subsurface recharge exists, possibly sustained by a fault just north of the Project Well. The interpretation of development data from the Project Well suggests that this fault may represent a nearby hydrologic recharge boundary.

Specific capacity data gleaned from area wells (Table 1) indicate that the hydraulic conductivity of local water-bearing sediments is of the order of 10-20 feet/day (3-6 meters/day), but the results of a 7-day development test on the Project Well indicate that this estimate may be increased by an order of magnitude in the vicinity of the Project/Monitor Wells to about 170 feet/day (52 meters/day).

HYDRAULIC EFFECTS OF ADDITIONAL WELLS

On the basis of this conceptual hydrogeologic model, a simple two-dimensional analytical aquifer model was constructed and used to estimate the effects of hypothetical additional pumping wells located in the vicinity of the Project Well. All simulations are based on the premise that: the geology and hydraulic characteristics of the aquifer are known only in the immediate vicinity of the Project Well; the siting of additional production wells is only to be considered within this limited area; and well interference due to the operation of multiple wells within this area is the primary criterion for siting new wells.

The aquifer was assumed to be confined, 100 feet (30 meters) thick, with a hydraulic conductivity of 170 feet/day (52 meters/day). Production wells were assumed to be 8 inches (0.2 meter) in diameter and fully penetrating. An east-west-trending recharge (fault) boundary located 1,000 feet (305 meters) north of the Project Well was assumed to maintain a constant hydraulic head along the northern edge of the sumulated aquifer. All simulations were run for the "worst-case" scenario: continuous, long-term pumping at

500 gpm (i.e., steady-state hydraulic head distributions) of both production wells.

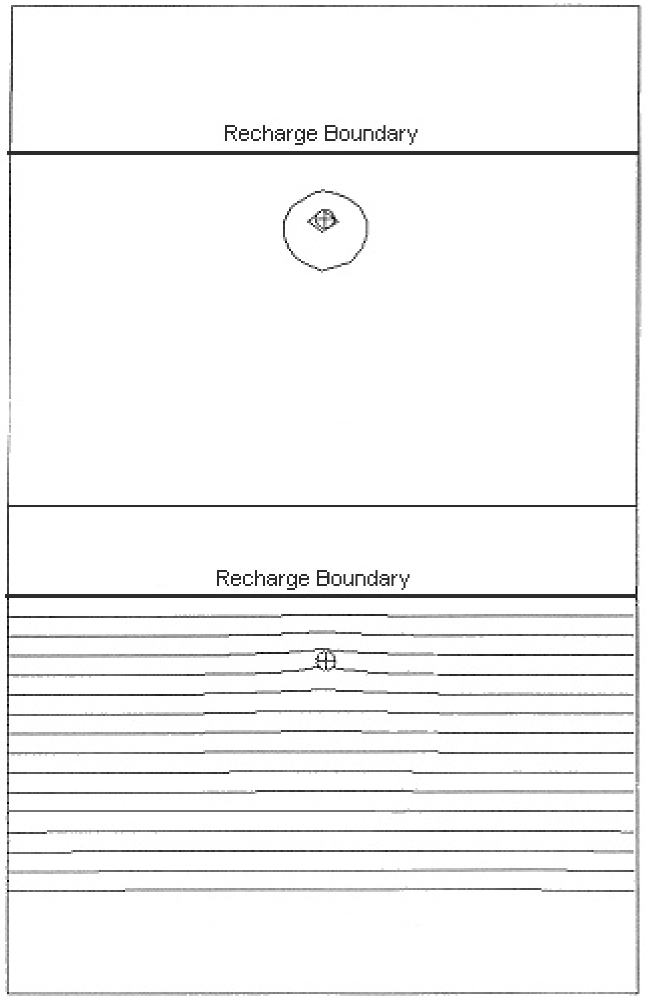
The Project Well was pumped at a constant rate of 500 gpm (0.03 cubic meter/sec) to establish a steady drawdown distribution around the well, with and without the presence of a regional gradient. The hydraulic conductivity was adjusted downward slightly to 100 feet/day (30 meters/day) so that predicted drawdown in the Project Well equaled the 10 feet of drawdown observed during the 7-day development test. Contour maps of predicted drawdowns for the base case (only the Project Well pumping) are shown in Figure 7. Under these conditions, the drawdown observed in the Project Well was found to be independent of the presence or absence of a regional hydraulic gradient.

Water level data from the Monitor Well are not available to check the validity of the model's drawdown predictions. However, the predicted drawdown in the Monitor Well, due to continuous pumping of the Project Well, is 2.9 feet (0.88 meters). Measurements of actual drawdown in the Monitor Well could be made to verify the model predictions, and would help in establishing confidence in the model.

A hypothetical second well, also pumping continuously at 500 gpm (0.03 cubic meter/sec), was placed in the model at three alternative locations: (1) north of the Project Well, half-way between it and the recharge boundary; (2) an equivalent distance south of the Project Well; and (3) at varying distances from the Project Well at the same distance south of the recharge boundary as the Project Well. The predicted steady-state drawdown distributions for these scenarios are shown in Figures 8 and 9; only the no-gradient case is shown because computed drawdown in the presence of a gradient was very similar.

As shown in Figure 10, for the case where a second well is situated on a line parallel with the inferred recharge fault boundary (scenario 3, above), the total drawdown in either well (due to the mutual interference of drawdown between wells) is only a function of inter-well separation distance. Although total drawdown is a function of separation distance in scenario (1) and (2) as well, it is also sensitive to the position of wells relative to the recharge boundary.

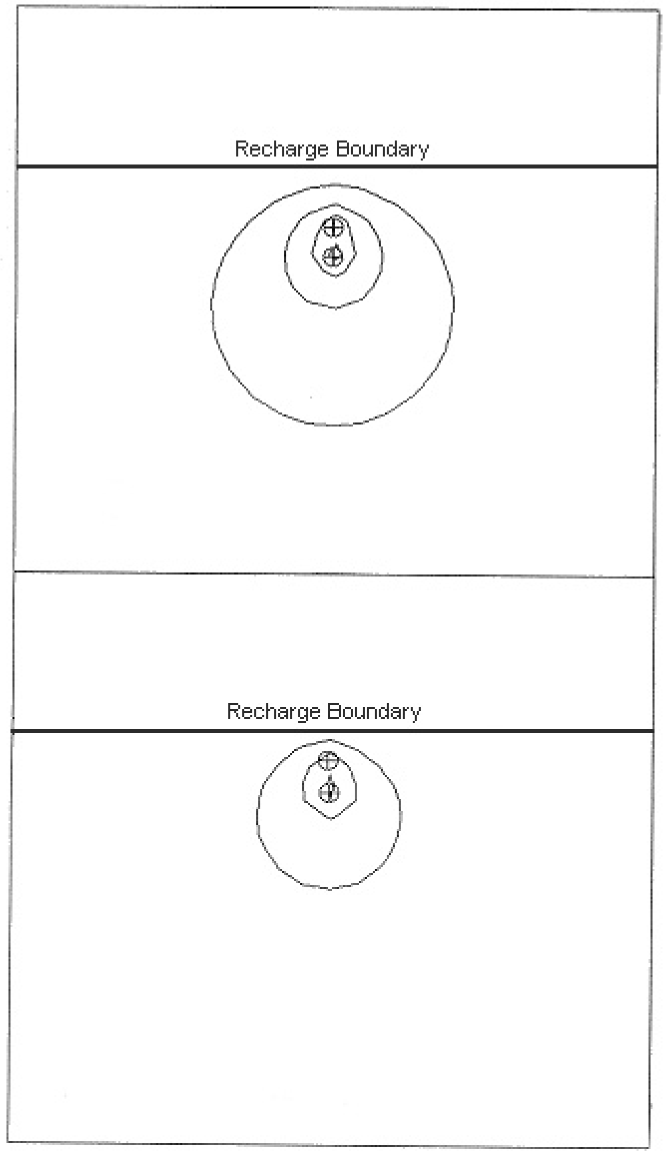
To test the sensitivity of the model drawdown predictions to the choice of an aquifer model (i.e., recharge-bounded vs. unbounded aquifer), the model was modified and run without a recharge boundary in both unconfined and leaky confined modes. Aside from a minor hydraulic conductivity adjustment to the base case and larger areal extents of the predicted drawdown cones, the total drawdowns for two-well pumping scenarios did not change substantially. Thus, the choice of aquifer model and the conclusions summarized in the following section will be essentially the same for either a recharge-bounded or an unbounded aquifer.



A. Base case without gradient, with 10 feet of drawdown in production well while pumping at 500 gpm. Contour interval is 2 feet.

B. Base case with gradient, with 10 feet of drawdown in production well while pumping at 500 gpm. Contour interval is 10 feet.

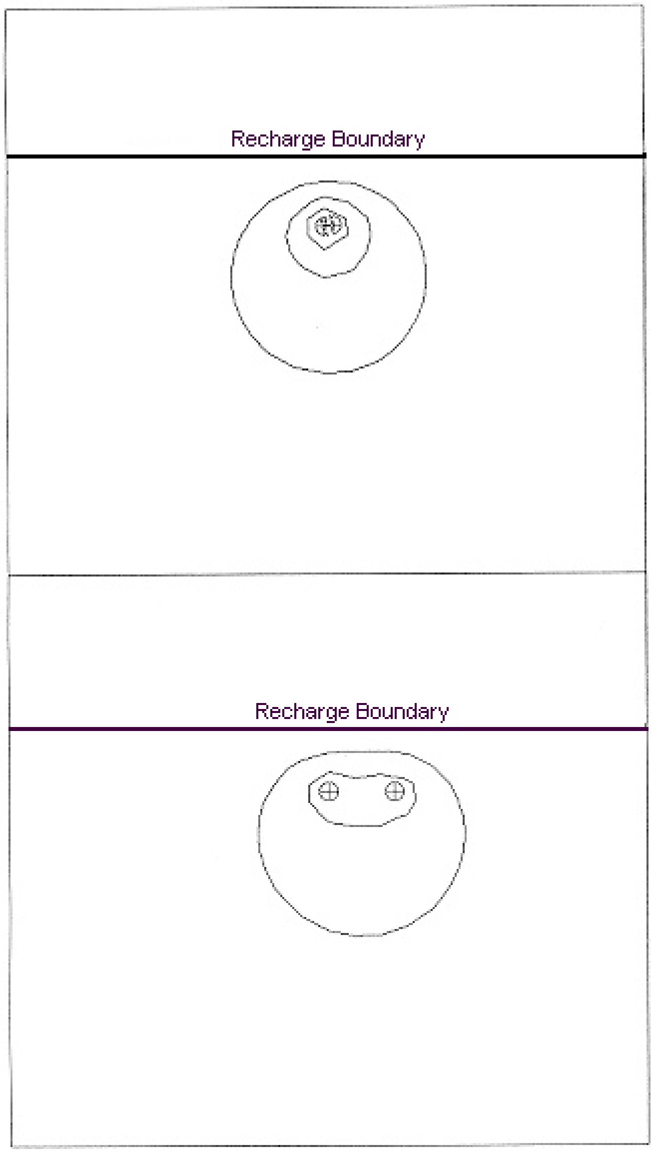
Figure 7. Base modeling case for comparison of predicted water level elevations (shown as feet above an arbitrary datum). Confined aquifer assumed, bounded on the north by a fault-controlled recharge boundary. (A) No regional hydraulic gradient, aquifer hydraulically adjusted to match observed 7-day observed well drawdown. (B) Regional hydraulic gradient of 3.3% superimposed on (A), with same hydraulic parameters. Note that for wells located the same distance from the recharge boundary, the presence of a regional hydraulic gradient does not appreciably affect the predicted drawdowns.



A. Both wells pumping at 500 gpm, with 12-14 feet of drawdown in Project Well and in the new well. Contour interval is 2 feet.

B. Both wells pumping at 500 gpm, with 11-12 feet of drawdown in Project Well and in the new well. Contour interval is 2 feet.

Figure 8. Predicted drawdowns in the Project Well and a new well located 500 feet south (A) and north (B) of the Project Well, in response to a nearby recharge boundary and without the influence of a regional hydraulic gradient. Note that predicted drawdowns are sensitive to the position of the new well despite equal well separation distances in both scenarios. Well drawdown as modeled with the local hydraulic gradient is similar to those shown here.



A. Both wells pumping at 500 gpm, with 14.9 feet of drawdown in Project Well and in new well. Contour interval, 2 feet.

B. Both wells pumping at 500 gpm, with 11.4 feet of drawdown in Project Well and in new well. Contour interval, 2 feet.

Figure 9. Comparison of predicted drawdowns for the Project Well and a new well separated by (A) 100 feet and (B) 1000 feet a fixed distance from the recharge boundary. Note that in this scenario, total drawdown in either well is only a function of separation distance between wells. Well drawdown as modeled with the local hydraulic gradient is similar to those shown here.

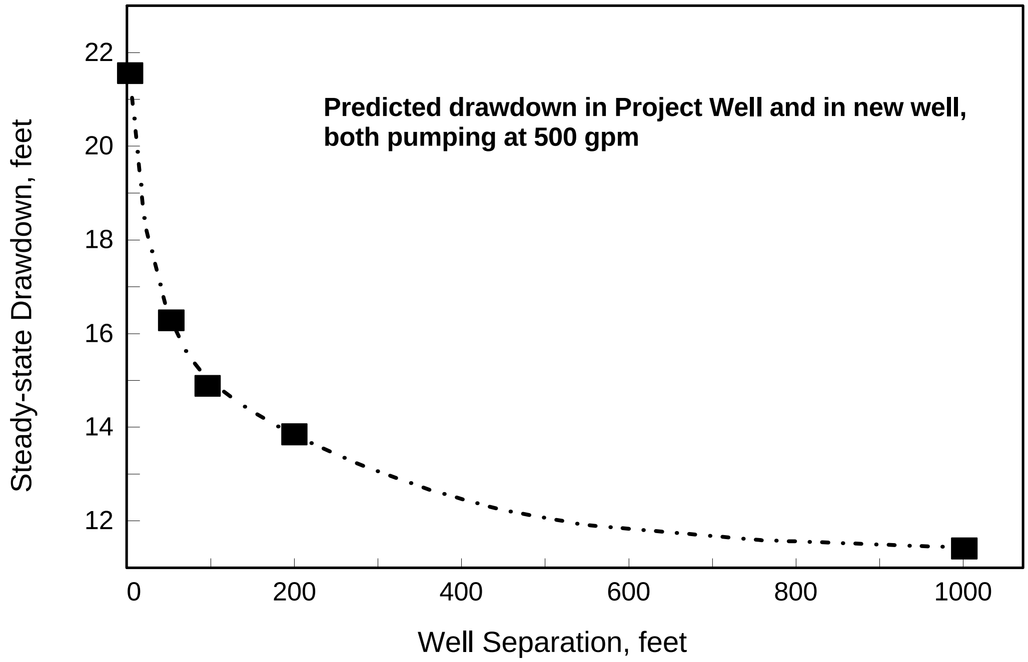


Figure 10 - Predicted dependence of total drawdown in both the Project Well and a new well, as a function of well separation, when the wells are both 1000 feet from recharge boundary.

In view of the paucity of data on subsurface geologic and hydrologic conditions, the above drawdown predictions are valid only in the immediate vicinity of the Project-Monitor Wells. Although inter-well drawdown interference decreases with increasing separation distance (cf. Figure 10), confidence in the uniformity of subsurface hydrogeologic conditions (and in the predicted drawdowns) also decreases with separation distance. Hence, it is recommended that a second production well not be located at a distance from the Project Well greater than the separation between the Project and Monitor Wells (i.e., about 400 feet or 122 meters).

CONCLUSIONS AND RECOMMENDATIONS

The principal conclusions arising from the modeling are:

A. Total drawdown in any production well is independent of hydraulic gradient when new wells are sited parallel to the recharge boundary (location scenario (3), above);

B. Total drawdown in wells aligned along the direction of the hydraulic gradient, or at different distances from the recharge boundary, varies depending on the location of the new well(s) and the presence/absence and magnitude of a regional hydraulic gradient;

C. Where wells are spaced at equal distances from the recharge boundary (location scenario (3), above) and are pumping at equal rates, the total drawdown in any well is a function only of inter-well separation distance. If well spacing is greater than about 100 feet (30 meters), the predicted increase in drawdown in the Project Well due to a second well is less than about 50% of its current drawdown.

D. Because of the geologic complexity of the subsurface, the confidence in predicted well drawdown decreases with distance from the Project Well; hence, a second production well should not be spaced farther from the Project Well than about 400 feet (122 meters) or about the distance between the Project and Monitor Wells.

The most significant result is the prediction that drawdown in the Project Well will not substantially increase under a variety of different possible locations of a new well, except when wells are spaced closer than about 50 feet. Because the drawdown effect of additional production wells are cumulative and depend on well separation, Figure 10 also can be used to estimate the additional increase in drawdown for a third or fourth hypothetical well. Furthermore, production wells will seldom be pumped simultaneously for extended periods of time, so the steady-state drawdowns predicted herein represent worst-case situations. Thus, the actual drawdowns to be expected when production is cycled on and off, or rotated between wells, or shared among wells (so that individual wells are either pumping intermittently or at less than the 500 gpm assumed in the model) will be less than predicted here. This provides additional design flexibility in developing a well field with larger capacity.

Again, note that these conclusions are valid only for the immediate vicinity of the Project Well, and that additional well testing should be conducted to confirm the interpretations and assumptions on which this modeling is based (notably, the confined nature of the aquifer, the existence of a recharge boundary, and the effective thickness and hydraulic conductivity of the aquifer). As noted in a previous section, the available well drawdown data can be interpreted in different ways; the interpretations discussed herein need to be verified with a controlled, constant-discharge pumping test on the Project Well, ideally of several days duration, including measurements of concomitant drawdown in the Monitor Well. Alternatively, a short pumping test (12 hours) should be planned. Such a test would provide crucial information on aquifer response over a scale equivalent to the distance between the Project and Monitor Wells. These data are not currently available.

It cannot be over-emphasized that in the absence of a controlled pumping test, the drawdown predictions contained in this report can only be considered a general indication of the aquifer's response to increased exploitation. The conceptual hydrogeologic model of the aquifer and the specific hydraulic parameters controlling flow must be corroborated and better defined prior to the design and siting of additional production wells.

REFERENCES

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