A HYDROLOGIST'S PERSPECTIVE ON DEEP SALINE WATER EXPLORATION

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Introduction

Deep, non-potable water is defined in New Mexico as: "*an aquifer, the top of which aquifer is at a depth of twenty-five hundred feet or more below the ground surface at any location at which a well is drilled and which aquifer contains nonpotable water. 'Nonpotable water,' means water containing not less than one thousand parts per million of dissolved solids.*" Such water lies outside (actually below) the boundaries of basins declared to be subject to administration for permitting new appropriations.

Few water users have attempted to develop the deep resource below the administrative basins until recently. Improvements in desalination technology and the rising cost of water transfers have made deep-water appropriation economically more attractive. We are aware of three projects involving five wells constructed or deepened under notices of intent (NOI) to appropriate deep non-potable water. None of the wells has yet produced water put to beneficial use, other than for aquifer testing.

This paper presents a summary from a hydrologist's perspective of applicant requirements for deep non-potable water appropriation in New Mexico, an illustrative assessment of the saline resource potential in the San Andres/Glorieta (SAG) aquifer, a history of deep saline exploration, an overview of feasibility of developing the resource, and approaches for assessing the effects of development.

Applicant Requirements

One wishing to appropriate deep non-potable water must file NOI with New Mexico Office of the State Engineer (OSE) on a form prescribed by OSE and publish notice in a local newspaper indicating location and depth of proposed wells, the amount of water sought and the intended purpose of use. Pertinent data, metering and quarterly reports may be required by OSE. The notice does not necessarily require further administrative hearing or approval.

OSE has a form for appropriating deep non-potable water[1], which prescribes the content of the NOI, specifies that the well be drilled by a New Mexico licensed driller, and requires wells to be constructed to artesian specifications. A plan of operations is requested by OSE demonstrating artesian construction, including casing and cementing to 2500 feet or below. Data requested by OSE include a well record, quarterly reports of quantity and quality of water and "*any other pertinent data*". Recent applicants have obtained OSE exploratory drilling permits, although New Mexico Oil Conservation Division permitted wells can be converted to appropriation.

As part of planning for deep-saline appropriation, hydrologists and engineers should be aware that other water users may file suit in district court against a deep non-potable appropriator for damages or injunctive relief if they find that such appropriation has caused impairment of existing rights. The court can order OSE to provide his information on the situation. Thus, appropriators should anticipate the effect of the proposed withdrawal by testing and characterizing the source aquifer and projecting effects. A numeric groundwater model is appropriate for the purpose.

[1] "Appropriation of Nonpotable Water at a Depth of Twenty-Five Hundred Feet or More – Notice of Intention:" Handout from Doug Rhappuhn, OSE, September 18, 2007.

Resource Potential – San Andres/Glorieta Aquifer Example

Any qualifying geologic formation thought to lie 2500 or more feet below ground may be targeted. For example, the SAG aquifer is known to yield hundreds to thousands of gallons per minute (gpm) to agricultural and municipal wells in the Roswell, Estancia, Bluewater, Sandia and other basins. The SAG is buried below 2500 feet at many locations throughout New Mexico. Figure 1 shows the locations of selected wells completed below 2500 feet and the extent of SAG below 2500 feet in New Mexico. The wide extent at depth and the potential for good yields make the SAG an attractive target for deep non-potable appropriation. Four of five wells recently drilled or deepened under NOI's have been completed in the SAG (Rio West and Hideout project wells).

History of Deep Non-Potable Appropriation

Motor Speedway

The first NOI we have found for deep non-potable appropriation was filed in 1997 for a proposed motor speedway in Bernalillo County (Figure 1). The well was drilled under exploratory permit RG-67055-Expl to about 2800 feet and completed in the Cretaceous Gallup Formation. Site geology consists of Mesozoic bedrock with little overlying alluvium, bisected by Rio Grande rift-related normal faults. The published NOI indicated produced water contains about 11,000 parts per million (ppm) total dissolved solids (TDS) and indicated intent to appropriate up to 400 acre feet per year (AFY) for various purposes. The well was tested at 12.5 gpm for four days with 50 feet of drawdown. OSE reviewed[2] the well logs and published regional geology to "*address the impairment issue*" and concluded that "*effects to stream systems or other water rights in the basin would be de minimus*". OSE agreed[3] that the top of the producing formation is below 2500 feet, and acknowledged that the applicant properly filed and published the NOI.

Rio West

In 2006, Recorp New Mexico filed NOI for 14 deep wells in the Rio West development of Sandoval County for appropriating 16,000 AFY of non-potable water. Recorp and Sandoval County jointly drilled two wells (Expl-5 and Expl-6, OSE File No. RG-88934) in the Rio Puerco Valley in 2007 (Figure 1). Prospective target formations included Cretaceous Dakota Sandstone, Sandstone members of the Jurassic Morrison Formation, basal Triassic Sandstone, Permian SAG and Pennsylvanian Madera Limestone. The geologic setting is similar to the motor speedway site, with little alluvium overlying rift-faulted Cretaceous and older bedrock.

The exploratory wells, about one-mile apart, were drilled to 3840 feet to reach the SAG (Expl-6) and to 6460 feet through SAG and underlying beds into Precambrian basement rock (Expl-5). Upon drilling, the wells flow at the surface at 1000 and 30 gpm, respectively, with shut-in pressures 150 and 200 psi. Expl-5 was hydraulically fractured to improve yield to about 150 gpm. Yield to the wells appears to be mostly from the SAG. Both wells produce water at 140°F with TDS around 12,000 ppm and CO_2 gas that evolves as water rises to the surface. Testing indicates Expl-6 is completed in a highly transmissive fracture connected to a less permeable regional system with a leakage boundary. Well Expl-5 a mile away responds to flow at Expl-6 in several hours, confirming they are completed in the same aquifer. Expl-5 apparently lacks the high-yield fracture penetrated by Expl-6.

[2] Logan, L.M., 1997, Memorandum: RG-67055-exp exclusion from declared basin permitting requirements based on §72-12-25 through §72-12-28 NMSA, 1978.

[3] Letter from Paul Saavedra, OSE, to William Turner, Westwater Resources, September 23, 1997, RG-67055-EXLOR.

We use the tested properties at the Rio West site in an analytical calculation to estimate the potential yield of a wellfield completed in the SAG. Recognizing bounding faults as a barrier to the west and a slight leakage boundary to the east, and limiting practical drawdown to 500 feet, the aquifer can support several hundred to a thousand AFY for a few decades. However, yield is projected to decline throughout the 100-year Sandoval County planning period. Long-term testing is needed to confirm the nature of the system boundaries, with subsequent numerical modeling that incorporates the three-dimensional structure of the site to project wellfield yield and effects. Long-term impacts on the Rio Grande Compact remain to be studied, but the potential need for surface water offsets of a small fraction of the Rio West project appropriation has been acknowledged.

Hideout of Lincoln County

In 2007, the Hideout of Lincoln County filed and published NOI to drill one well (H-4043) and deepen another (H-3923) for deep non-potable appropriation of 1000 AFY (recently readvertised at 300 AFY). The wells are located in Lincoln County in the Rio Bonito drainage (Figure 1). The wells are completed in limestone and dolomite interpreted as SAG at drilled depths 3100 to 3500 feet. One well (H-4043) was tested for four days. We understand the test results prompted the change in the appropriation amount. The second well has not yet been tested.

The impairment issues are of interest at the Hideout site. The San Andres is thousands of feet below ground at the Hideout well sites, but rises to the surface several miles east, where the formation provides baseflow to springs and streams tributary to the Hondo River. The local geology and flow conditions imply that the regional streams are vulnerable to impacts. Numeric modeling is needed to quantify those effects.

Discussion – Feasibility and Issues

Projects seeking appropriation of deep non-potable water often are driven to do so because of the scarcity and expense of purchasing offset rights, the uncertain outcome of OSE administrative action on a transfer application, and in some cases, lack of productive shallow freshwater aquifers. Before pursuing the deep resource, appropriators should evaluate the feasibility of deep exploration and development in terms of costs and uncertainties relative to developing the freshwater resource.

As an example, the cost of purchasing water rights in the Middle Rio Grande is reported to be in excess of $10,000 per AF, in which case buying 100 AF would cost $1 million. Drilling and constructing a shallow well to divert the newly-acquired water may cost a few hundred thousand dollars. Transferring water to the well through the OSE administrative process may cost another few hundred thousand, particularly if a protest is involved. Assuming a successful outcome (which is not guaranteed), total cost to begin pumping the example 100 AF is about $1.5 million, or near $15,000 per AF, before an operating water distribution, storage treatment, or sewerage system is budgeted. Thus, the source water for a new community may be annualized at $870 per AF.[4] Albuquerque and Santa Fe water is sold to customers at basic rates of $1,000 and $2,000 per AF. Therefore, source water cost is a big fraction of delivered water costs.

For comparison, drilling a deep non-potable well may cost $1 to $2 million, depending on depth. Ostensibly, no transfer of water rights and no administrative permitting is required. For a deep well capable of producing a reasonable 100 AFY, the source-water cost per AF is similar to a freshwater transfer ($10,000 to $20,000 per AF or about $870 per AF annualized). A more productive deep non-

[4] Assuming P = $15,000, i = 5%, n = 40 years.

potable well becomes proportionally more economical, but there are no examples yet of much over 100 AFY sustainable yield. Thus the productivity of the well and aquifer is a major factor in feasibility of deep water appropriation, but is uncertain as demonstrated by variability in the historical exploratory wells.

Another cost the deep-water appropriator must bear is that of treatment and waste-stream disposal. For brackish water, these costs average $3 to $6 per 1000 gallons for coastal desalination plants, and two to three times more for inland systems, where salt disposal requires deep injection or evaporation[5,6]. Costs are projected to trend downward. By comparison, freshwater treatment may cost $1 or $2 per 1000 gallons. Furthermore, treating brackish water requires disposing 10 to 20 percent of the source water to carry off salts. Assuming the treatment cost difference is $5 per 1000 gallons, treating the example 100 AFY of non-potable water and disposing the waste stream would cost about $160,000 per year more than potable water, and yield about 85 AF of potable water, adding $1,900 per AF of potable water to source-water costs. With deep drilling annualized at $870 per AF, source water may reach nearly $2,800 per AF before regular operational costs of a community system are added. Water delivered at over $3,000 per AF would exceed the highest prevailing rates in New Mexico, although trends are favorable for a foreseeable crossover in costs.

A number of risks are involved in deep non-potable exploration. Aquifers that are reliably productive at shallow levels may or may not be productive at depth. Finding out requires a million dollar exploratory well. Deep-water salinity may fall below the statutory non-potable threshold, such as at some Bluewater Basin wells. For example, the Acoma well (Figure 1) penetrated a productive fracture in the SAG below 2500 feet that produces water with about 800 ppm TDS.[7] In general, groundwater tends to become saltier with depth, mostly because deeper water has been in the ground longer and has had more time to dissolve the host rock. But water that moves through fractured, highly transmissive rock picks up less salt (because of shorter residence time), even in deep aquifers. The paradox is that the deep fractured aquifers are the best target for high yield wells, but the water therein may be too fresh to qualify for the non-potable exemption.

Another risk is the possibility of encountering oil and gas, which can complicate treatment and disposal. Produced water is often hot, contains dissolved gas that evolves when depressurized, and may precipitate minerals. These characteristics complicate operations, treatment and maintenance, but can be mitigated with a properly engineered pumping, treatment and distribution system. The heat stored in deep water can be a resource, either to enhance treatment if flash distillation is used, or to heat buildings prior to treatment.

Demonstrating Non-Impairment

There is no reasonable expectation that deep-saline wells will have zero effect on the shallow hydrologic system. However, the timing and degree of the effects is pertinent to the question of "impairment". Appropriators of deep non-potable water should plan to calculate the effects of their proposed withdrawal on neighboring wells and surface water features. The method is the same as with other water appropriations, involving testing to characterize the aquifer and boundaries and comprehensive numeric modeling. The speedway and Hideout wells were tested for multiple days. Rio West wells have been

[5] Bureau of Reclamation, July 1997, Survey of U.S. Costs and Water Rates for Desalination and Membrane Softening Plants: Water Treatment Technology Program Report No. 24.

[6] Sandia National Laboratories, August 2002, Draft, Bureau of Reclamation Report to Congress: Development of Desalination Technology, Including Tularosa Basin Facility.

[7] Geoscience Consultants, Ltd., September 26, 1984, Final Report on Acoma #1 San Andres Formation Exploratory Well.

recommended for 30 days of testing to characterize boundaries. Where available, observation wells should be instrumented. Recovery following test shutdown should be monitored for months. Disposal of saline water produced during testing may require environmental permitting. Test data should be analyzed to account for the effects of evolving gas and thermal expansion/contraction of the water column.

The hydrogeologic setting of the target aquifer controls the timing and magnitude of effects. At Rio West and the motor speedway, the aquifers are laterally bounded by rift faults and overlain by thousands of feet of shale. These characteristics attenuate the propagation of pumping effects, but also limit long-term yield of the aquifers. In the Hondo Basin, the San Andres is a conduit for a regional flow system that conveys mountain-front recharge eastward to discharge at streams, springs and the Pecos River. Wells that penetrate the San Andres at any depth will capture some of that baseflow. Numeric models should be constructed to incorporate details of the regional system and local properties at the exploratory well site. Applicants that follow this process will have an understanding of the impact of their appropriation, and will be better prepared if a dispute arises.

Conclusions

Deep non-potable groundwater appropriation offers an alternative water source where freshwater supplies are scarce or unavailable. The deep water resource apparently is outside OSE declared basins, but issues of impairment of existing water users still must be addressed. Five deep non-potable wells have been drilled in New Mexico under the exemption, but no water has yet been put to beneficial use. The cost of drilling a deep saline well can be similar to the cost of buying and transferring a freshwater right, but the treatment and disposal costs are higher. The extent below 2500 feet and the high yield of the San Andres/Glorieta aquifer make it an attractive target, but deep wells drilled and tested in the formation indicate high variability of yields from tens to thousands of gpm. Applicants for the deep resource should plan to characterize the target aquifer with extensive testing and numeric modeling to understand thoroughly the effects of the appropriation.

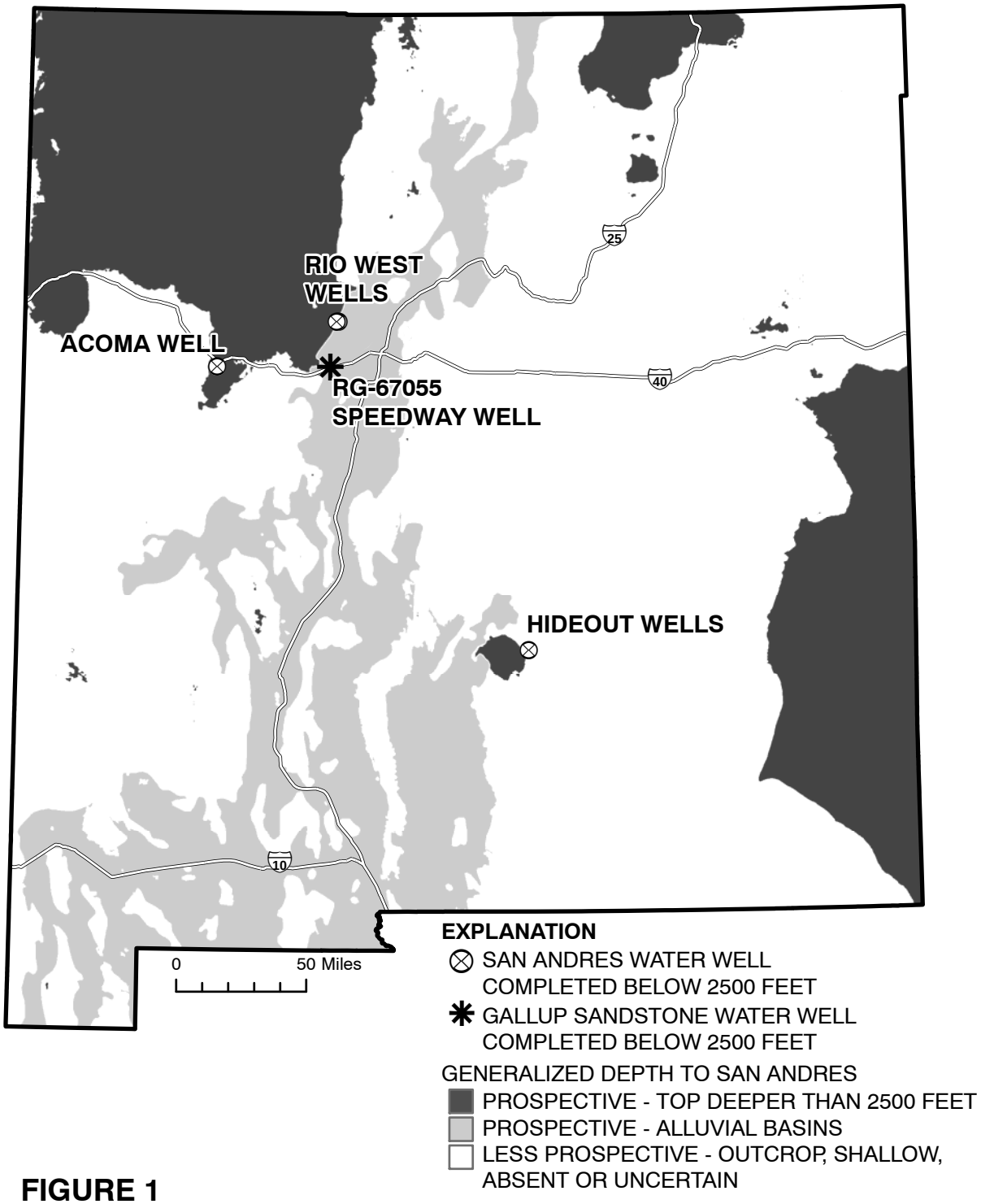

FIGURE 1
LOCATIONS OF WATER WELLS AND SAN ANDRES/GLORIETA FORMATION BELOW 2500 FEET