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Hydrology and Administration of Domestic Wells in New Mexico

ABSTRACT

Domestic wells in New Mexico are the subject of proposed policy on permitting and water planning. Using hydrologic models, this article examines the impact on water resources due to alternative policies. The authors orient the hydrological discussion by outlining the operation of domestic wells because problems with domestic well-water service are often related to well construction. A properly-constructed well has allowance for future changes in aquifer water levels. A standard protocol for showing domestic well-water availability is not yet established; however, such a standard would involve testing, recovery observation, and computation. Domestic wells in general do not interfere with one another regardless of whether the aquifer is of poor or good productivity because in the former, the area of influence is small, and in the latter, the magnitude of influence is small. Model calculations can quantify the foreseeable hydrologic results of several proposed policy interventions aimed at limiting or curtailing growth of domestic wells. We conclude that no area of New Mexico appears to have a systematic problem with resource depletion from domestic wells. Among the policy alternatives, requiring properly-constructed wells when drilled or sold would best reduce problems with water-service to residents of households who rely on domestic wells.

INTRODUCTION

Since year 2000, the legislature in New Mexico has seen repeated introduction of bills to add new administrative controls to domestic wells. However, domestic wells have remained largely exempt from administrative controls through year 2005. The hydrologic effect of various proposed policies is amenable to hydrologic modeling, which is the subject of this article. A quantitative understanding of the hydrologic

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effects can aid water planners in formulating a policy with foreseeable resource impacts.

Domestic wells are those permitted as such in New Mexico for up to three acre-feet per year (AFY) or defined by the U.S. Census as an "individual well" for five or fewer housing units. Household purposes include drinking, cooking, bathing, washing, flushing, and watering. In New Mexico, the permit for domestic wells may include water used for lawn and garden (up to one acre), livestock watering, drinking and sanitation at commercial operations, mining, or public works. Domestic well impacts are gaining increasing attention in New Mexico from individual users, neighbors, subdivisions, counties, regional basins, and statewide planners. This article begins by noting domestic well legislation proposed in New Mexico since year 2000. The proposed policy interventions illustrate the range of management options in addressing the various concerns.

Domestic wells are a component of a large suite of water uses such as agricultural, municipal, industrial, ecological, obligatory, unmanaged, and other uses, all of which draw on the stored and flowing water, affecting resource depletion and sustainability for other uses. Hydrologic understanding has advanced such that the functional relationships affected by domestic wells, and other uses, can be stated explicitly in mathematical models of basins in New Mexico. The models also isolate the categories of use for separate study. For example, methods established generations ago in New Mexico by Theis[1] readily analyze the performance and impact of a single well, whereas existing administrative models simulate the impacts from thousands of domestic wells.

This article is organized to examine the problem with domestic wells as reflected in legislative and agency statements of concern and then to review how domestic wells work, or sometimes fail. We discuss the characteristic levels of household-water use, which is near one-tenth the New Mexico permittable level of three AFY, and the net household depletion, which often is substantially less water. The availability of water from domestic wells for a planning horizon of 40 to 100 years is of interest to households and to subdivision planners. We outline some methods for projecting future performance of individual wells and groups of wells. We then describe the collective hydrologic effects of domestic wells on various scales (local, basin-wide, statewide). We map the domestic well density and isolate for study the projected growth of

1. Charles V. Theis, *The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage*, 16 AM. GEOPHYSICAL UNION 519 (1935).

wells that are subject to policy control. To arrive at a description of impacts from alternative courses of domestic well management, this article quantifies the location, number, growth rate, and typical construction of domestic wells in New Mexico. The New Mexico Office of the State Engineer (NMOSE) has developed administrative models to quantify larger-scale hydrologic effects of domestic wells. Similarly, the authors have developed models applicable to sites throughout the state.[2] Finally, policy approaches to managing domestic wells are evaluated as to quantitative hydrologic impacts in a statewide model prepared for the purpose of this study. The quantitative impacts suggest that the perception of a system-wide problem from domestic well use may be overdrawn, but that well construction and performance standards should be upgraded for the benefit of users.

PROBLEM STATEMENT

The management of domestic well effects has come forward in the New Mexico legislature, in public and scientific media,[3] and in other states and nations.[4] Legislation introduced in New Mexico since year 2000 is presented below.

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2. The statewide model program and higher-resolution color versions of this report's figures may be downloaded at http:///www.balleau.com/materials/Dom_Wellmodel.zip or http:///www.balleau.com/materials/Dom_WellFigs.pdf.

3. *See* ALLETTA BELIN ET AL., TAKING CHARGE OF OUR WATER DESTINY: A WATER MANAGEMENT POLICY GUIDE FOR NEW MEXICO IN THE 21ST CENTURY (2002); *see also* STATE OF N.M. GOVERNOR'S BLUE RIBBON TASK FORCE ON WATER, STEWARDSHIP OF NEW MEXICO'S WATER: ENSURING A SUSTAINABLE WATER SUPPLY FOR NEW MEXICO 2 (2004) [hereinafter N.M. TASK FORCE ON WATER]; State of N.M. Water & Natural Resources Comm., Report File No. 205.176-02, 31–32 (2002); N.M. Off. of the State Eng'r, *Impact of Domestic Wells Reported to Legislative Committee*, WATERLINE, Winter 2001; N.M. CHAPTER OF THE AM. PLANNING ASS'N, POLICY GUIDE ON WATER PLANNING (1998); Ted Montuori, *New Mexico Struggles with Water Well Dilemma*, WATERTECHONLINE, Feb. 18, 2002, *at* http://www.sharedwater.org (click on "water news" then "all news"); Anna Crook, *Water, Water Everywhere*? NEW MEXICO J. Oct. 2000, *at* http://www.wordpros.com (click on "The New Mexico Journal" then "October 2000" then "click here to read full story" under Anna Crook's name); WILLIAM COYNE & JEANNE BASSETT, WATER FUELS SPRAWL, AN ANALYSIS OF WATER TRANSFERS AND INEFFICIENT GROWTH IN NEW MEXICO (2002); Carlos Cisneros & Luciano Varela, Commentary, *Dry Holes, State Engineer Needs More Authority on Domestic Wells. If That Doesn't Happen, The Water Crisis Will Only Deepen*, ALBUQUERQUE TRIB., Feb. 17, 2004, *available at* http://web.abqtrib.com/ (monthly opinions archive); 1 DANIEL B. STEPHENS & ASSOCS., INC., JEMEZ Y SANGRE REGIONAL WATER PLAN ES-10 (2003).

4. *See* ENVTL. PROT. AGENCY, EPA 816-K-02-003, DRINKING WATER FROM HOUSEHOLD WELLS (2002); *see also* U.N. WORLD WATER ASSESSMENT PROGRAMME, WATER FOR PEOPLE—WATER FOR LIFE: THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT (MAR. 22, 2003), *available at* http://www.un.org (click "Welcome" then "Department of Social and Economic Affairs" then "World Water Assessment Program"); *Water for Health Declared a*

NEW MEXICO LEGISLATIVE INTRODUCTIONS

Year	Bill	Purpose
Year 2000	Senate Bill 99 and House Bill 482	• Place a ban on domestic wells in municipal service areas
Year 2002	House Bill 307	• Restrict domestic wells where there is no unappropriated water or where Interstate Compacts may be affected
Year 2003	House Bill 307 and Senate Bill 565	• Subject domestic wells to municipal ordinances • Define critical management area (CMA) of "heightened protection because water resources may be inadequate to sustain well production as evidenced by excessive drawdown rates or reduced aquifer thickness" • Authorize NMOSE to declare CMA "to prevent impairment of existing water rights" or if "likely to affect the state's obligations pursuant to an interstate compact." • Deny or limit domestic permits in CMAs • Bar new appropriation for domestic use in CMAs, but allow transfers • Limit transfer without public notice to one AFY for domestic wells • Require that new domestic wells be supported by existing rights to a density of 0.5 AF per unit Note: The State Engineer stated he supported the Bill because it allows "denial of a domestic well permit if it impairs rivers, streams or groundwater in high water use areas"
Year 2003	Senate Bill 484	• Define "household" and "shared household" wells • Subject domestic wells to municipal ordinances • Limit household wells to one AFY (shared three AFY) with metering and reporting • Verify usage and fine $1,000/AF overage
Year 2004	Senate Bill 89	• Provides for CMA where water resources are inadequate to sustain well production as evidenced by water level decline rates and available aquifer thickness • Provides heightened protection where depletions "affect Interstate Compact delivery requirements" • Limit domestic wells to 0.5 AFY in a CMA unless rights are transferred or discontinued in the CMA

Human Right, ENV'T NEWS SERV., Dec. 4, 2002, *at* http://www.ens-newswire.com/ens/dec2002/2002-12-04-01.asp.

Through the 2000 to 2005 legislative sessions, the New Mexico legislature has not passed the above domestic well bills. The legislative issues include the sustainability of well production and the associated impairment of existing rights or Interstate Compact deliveries. The administrative agency focuses on "threatened aquifers and surface water supplies…."[5] The proposed policy interventions would involve reducing presently permitted levels of new use or denying increases of permitted use in critical areas. Proposals include metering and imposing fines for water use exceeding the proposed new limits. Although legislators and agency officials have proposed designating critical management areas (CMAs), the agencies have not yet demonstrated quantitatively that any specific areas of the state need heightened controls in terms of aquifer resource depletion due to domestic wells.

This article addresses the above issues from a hydrological perspective. The authors use hydrologic models to quantify the current hydrologic effect of domestic wells and to contrast the future growth of effects both with and without the proposed water-policy interventions. Further, the article focuses on the issues of sustainability of well production and on Interstate Compact deliveries. Additionally, any associated reduction in consumer utility is noted as the price for new controls on household water use.

The published material indicates a variety of concerns with domestic wells that is less in the hydrological sphere than in that of rights or policy. The United Nations declared, "Water is fundamental for life and health. The human right to water is indispensable for leading a healthy life in human dignity. It is a prerequisite to the realization of all other human rights."[6] A similar rationale may explain the New Mexico practice since 1953 of granting domestic well permits without an impairment analysis.[7] In New Mexico, commentators have raised issues regarding subdivision land use, shared drought discipline, escape from administrative review, competition with other rights, "free" domestic

5. Press Release, John D'Antonio, State Engineer, *New Domestic Well Permits Need Clear Definition to Protect Senior Water Rights and Secure Compact Deliveries* (Jan. 11, 2005), *available at* www.ose.state.nm.us/hot-topics/press/pr-2005-01-11-DomesticWellPermits.pdf. Mr. D'Antonio is the current New Mexico State Engineer, the New Mexico state agency official empowered to administer water-use permits in general and to make findings on impairment, resource conservation, and public welfare in processing all water-use applications, except specifically domestic wells, which are permitted without such processing.

6. ENV'T NEWS SERV., *supra* note 4, at 1 (quoting The United Nations Committee on Economic, Cultural and Social Rights).

7. *See* NMSA 1978 § 72-12-1 (1997 Repl.) ("Meaning of This Act: The references to 'this act' properly refer to Laws 1953…, which added all of the section following the first sentence.").

water, water-borne disease, well-service lifetime, aquifer contamination in unsewered areas, and issues of "weak" or "strong" sustainability.[8]

To the degree that issues along these broader lines are related to water resource impacts, the projections outlined below, using models based on quantitative specifications of the physical relationships, may aid in assessing the related policy matters.

DOMESTIC WELL OPERATIONS

Proper Construction

We begin the hydrogeologic discussion with some background on how domestic wells work, the hydrology of proper construction of the as-built well, and the general question of sustainability of an apparently depletable stored resource. Domestic wells operate with a necessary submergence of the well pump setting at a depth below the pumping water level in the well. Serviceability, lifetime, and impairment questions depend on the good relationship of two factors: pumping water level and pump setting.

The role of the well driller is critical to a properly-constructed domestic well. The driller's role may include overcoming the site-owner's preference for least-cost well construction. A minimum yield and short-lifetime well construction may cost thousands of dollars less than a properly-constructed well providing full domestic service. However, a minimum performance may suffice in cases where a temporary service is intended before hooking up to community supply expected to become available or, less optimally, where property re-sale is involved and the long-term user has no voice in the initial well construction. Nevertheless, proper well construction and performance standards with necessary associated costs can ensure good service and lifetime from domestic wells under essentially all field conditions.

Figure 1 illustrates the yield components of a domestic well. The well is drilled below the level of the prevailing water table, below which is the zone of saturation of the natural soil and rock materials in the

8. *See* Werner Hediger, *Reconciling "Weak" and "Strong" Sustainability*, 26 INT'L J. SOC. ECON. 1120, 1126 (1999). Strong or "hard" sustainability maintains the stock of ecological capital intact. *Id*. at 1125. Weak or "soft" sustainability is defined by a non-decreasing value of aggregate economic activity and ecosystem capital. *Id*. at 1126; *see also* BELIN ET AL., *supra* note 3, at 27, 31; N.M. TASK FORCE ON WATER, *supra* note 3; N.M. CHAPTER OF THE AM. PLANNING ASS'N, *supra* note 3, at 2 n.1; COYNE & BASSETT, *supra* note 3, at 23 ; *see also* Cisneros & Varela, *supra* note 3; U.N. WORLD WATER ASSESSMENT PROGRAMME, *supra* note 4.

earth's crust. Multiple water-table zones of saturation may be present but those affect few well constructions.

A successful well requires the driller to find suitably productive stratae at reasonable depth. The depth of saturation, however, is practically unlimited. The deepest hole on record (7.6 miles at Kola, Russia, in Baltic Shield granite) was saturated with water in the interval three to six miles deep.[9] Without going to such extremes, domestic well drillers can generally obtain adequate domestic supplies by drilling as deep as necessary, installing lengthy well screens or perforations to access the formation water, and, where water quality is poor, providing suitable on-site or point-of-use treatment.

In practice, the driller identifies a suitable stratum (the Principal Water-Bearing Stratum on New Mexico's well record) and installs the casing and screen or perforations to draw water from that stratum. The driller's selected stratum is rarely the exclusive producing interval, and additional yields generally could be obtained at other levels.

Next, the pump is placed below the non-pumping, or static, water level at a position that allows drawdown to a pumping water level without dewatering the pump. A minimum net positive suction head of a few feet over the pump intake is required. The driller matches the specific properties of the pump with the well performance characteristics. The self-induced drawdown from pump operation may be a few feet or hundreds of feet depending on productivity of the screened zone. A 5-to-20 gallon per minute (gpm) household pump that suits the as-built well may be installed depending on the driller's judgment of the owner's requirements, available drawdown, and the remaining submergence of the pump. A drill hole that does not support a minimum yield near five gpm at the planned depth may be reported a "dry hole" and redrilled elsewhere on the owner's property. It is often preferable to drill deeper within the capabilities of the drilling equipment rather than drill two shallow holes. Deepening a completed (cased and screened) domestic well is seldom practical.

The driller's considerations in building a properly constructed well include an allowance in the water column above the pump for future changes in water level conditions. Drought causes a lower natural water table position, which is commonly ten feet lower during drought in the basin areas and up to 30 feet lower in the mountain areas. Mountain areas are more sensitive to drought because steeper water-table gradients drain water more rapidly in areas of steep topography. An allowance for regional trends of interference from other wells is set at

9. Richard A. Kerr, *Deep Holes Yielding Geoscience Surprises*, 245 SCIENCE 468 (1989).

2.5 feet per year by NMOSE guidelines,[10] *i.e.*, 40 to 100 feet in a well-service lifetime of 40 years. Positive operating head over the pump should be about ten feet. Accordingly, the water column reserved for safe allowances other than self-induced pump drawdown is about 60 feet. Pump-induced drawdown, sometimes termed "dynamic drawdown," is found by observation of a short pumping test at the time of construction. A few feet to hundreds of feet may be required. With all necessary allowance, a properly-constructed domestic well may be expected to require 60 feet of pumping water column (submergence) above the pump at the time of construction, which is reserved for regional trends and droughts over the life of the well. Accordingly, exceptionally poor wells may need hundreds of feet of non-pumping submergence in order to retain a 60-foot allowance for trends and drought. The available well record data for New Mexico shows that most wells built by licensed drillers in New Mexico meet professional standards and are not expected to have any problem sustaining decades of service. Nevertheless, some domestic wells fail to deliver a full service life for lack of sound provisions at the time of initial construction. One commentator noted that, "[f]or most of New Mexico, perhaps the only practical change needed is a strengthening of the well-construction and well-record requirements.…"[11] We conclude that one reasonable policy intervention may be to require documentation of proper well construction and performance at the time of permitting.

Sustainability of Well Service

Where regional trends have dewatered a significant depth of the local water table, drillers must construct future wells deeper and with longer screens or perforations to accommodate the declining water-table conditions. The authors are not aware of any site where the water table in New Mexico has been dewatered to the point that there is no potential for new domestic wells to be constructed (or for old wells to be replaced) by accessing deeper stratae. The planned service life of domestic wells is 25 to 40 years,[12] after which time they can be redrilled as new

10. TOM C. TURNEY, N.M. OFFICE. OF THE STATE ENG'R, MIDDLE RIO GRANDE ADMINISTRATIVE AREA GUIDELINES FOR REVIEW OF WATER RIGHT APPLICATIONS (2000); N.M. OFFICE OF THE STATE ENG'R, TULAROSA UNDERGROUND WATER BASIN ADMINISTRATIVE CRITERIA FOR THE ALAMOGORDO-TULAROSA AREA (1997).

11. John. Shomaker, *Domestic Well Depletions in the Rio Grande Basin*, N.M. 44TH ANNUAL N.M. WATER CONFERENCE PROCEEDINGS (N.M. WATER RESOURCES RESEARCH INSTITUTE) 4 (2000), *at* http://wrri.nmsu.edu/publish/watcon/proc44/contents.html.

12. T.A. McMahon, *Hydrologic Design for Water Use*, *in* HANDBOOK OF HYDROLOGY T.27.2.4 (David R. Maidment ed., 1993); HYDROLOGY BUREAU, N. M. OFFICE OF THE STATE

replacement wells. The other option is for households to be connected to expanded public supply systems. In terms of individual household service, domestic wells are sustainable in the "soft" sense[13] of a persistent non-decreasing aggregate economic activity such that the social utility of water service never is lost. Regarding sustainability of the household source of water, we conclude that replacement wells or conversion to public-supply sources will sustain the household water service long after the initial well 40-year service life has expired.

Domestic Water Requirement

To proceed with assessing the impact of domestic wells individually and collectively, we need a characteristic value for the amount of water used. Domestic wells in New Mexico are permitted at up to three AFY. However, the NMOSE guidance relied upon by counties for subdivision water use from domestic wells or from public supply recommends that planned use be provided at 0.5 to 0.6 AFY.[14] Further, the NMOSE fact sheet on domestic wells presents 0.3 AFY (less than 100,000 gallons per year) as the common level of use.[15] Nationally, self-supplied houses use a mean of 79 gallons per day (gpd) per capita with a standard deviation of 21 gpd per capita,[16] which is equivalent to 0.27 AF at three persons per household. That statistic implies a normal distribution with a mean usage of 0.27 AFY, but with small fractions of the total number of households using higher rates estimated as 13 percent of households using over 0.30 AFY, three percent using over 0.50 AFY, and a fraction of a percent using over 1.0 AFY. Although it is unlikely that many domestic well permittees use three AFY for strictly household purposes, some (as provided for in New Mexico) merit the larger amount by irrigating up to one acre.

Few public records of metered domestic well usage exceed the permitted three AFY, but indications from remote sensing and aerial

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ENG'R, DOMESTIC WELLS IN NEW MEXICO: THE IMPACT OF, AND PROBLEMS ASSOCIATED WITH DOMESTIC WATER WELLS IN NEW MEXICO 10 (2000) [hereinafter HYDROLOGY BUREAU].

13. Hediger, *supra* note 8, n.18.

14. INTERSTATE STREAM COMM'N, N.M. OFFICE. OF THE STATE ENG'R, STATE ENGINEER'S GUIDELINES FOR COUNTY SUBDIVISION REGULATIONS GOVERNING WATER SUPPLY REQUIREMENTS 3 n.6 (1996) [hereinafter INTERSTATE STREAM COMM'N].

15. N.M. OFF. OF THE STATE. ENG'R, FACT SHEET: CAN YOU TELL ME ABOUT DOMESTIC WELLS IN NEW MEXICO 2 (undated), *available at* http://www.ose.state.nm.us/water-info/NMWaterPlanning/fact-sheets/domesticwells.pdf (last visited Jan. 23, 2006).

16. Wayne B. Solley et al., *Estimated Use of Water in the United States in 1990*, *in* U.S. GEOLOGICAL SURVEY 26 (1993), *available at* http://water.usgs.gov/watuse/wucircular2.html; NATIONAL HANDBOOK OF RECOMMENDED METHODS FOR WATER DATA ACQUISITION 11.D.3.C., *available at* http://pubs.usgs.gov/chapter11/.

imagery suggest that some tracts of land with domestic wells support more than one acre of healthy vegetation. Such sites imply that there are instances of over-use relative to the three AFY limitation. Where reporting of any category of well use is required in New Mexico, the National Academy of Sciences cites the NMOSE for the information that "approximately 40 percent of water right holders are non compliant about reporting their usage."[17] The reliability of self-reported metering data appears to be weak.

Long-term average rates of water use may be substantially less than instantaneous peak rates. Both rates are pertinent to the question of local well interference. The nominal 0.3 AF annual volume of domestic water use does not represent adequately the instantaneous schedule of household demand and associated pump operations. The typical annual 0.3 AFY usage is equivalent to much less than one gpm of constant flow. Household demand, however, is intense for short periods when fixtures and appliances are in use at rates of 5 to 15 gpm. Accordingly, a household well pump normally operates at full rate only an hour or less per day, including time for filling storage tanks. The schedule of pump operation is important in providing for individual well performance that must meet the instantaneous household demands at peak rates. In contrast, the average volume per annum (0.3 AFY or 0.2 gpm) applies to the accumulated multi-year impacts on the aquifer and the interrelated surface water system.

Return flow from domestic wells is routed to drain fields in shallow soil or to sewerage systems where those are available for hook-up. Soil moisture accounting shows that the low flow rate discharged to arid soils by a household septic tank may be entirely absorbed then returned to the atmosphere by moist soil evaporation.[18] However, if the water table is less than 30 feet in depth, such as in the riparian zone of perennial streams, the already moist soil may afford a net gain of water recharged to the water table due to the drain-field return flow. For that

17. NAT'L ACAD. OF SCI., ESTIMATING WATER USE IN THE UNITED STATES, A NEW PARADIGM FOR THE NATIONAL WATER-USE INFORMATION PROGRAM 167 app. A (2002).

18. WILLIAM PETER BALLEAU, AM. WATER RESEARCH ASSOC., NET RECHARGE AND DISCHARGE IN SOILS OF SANTA FE COUNTY, ANNUAL MEETING AND FIELD TRIP—SANTA FE AREA WATER RESOURCE ISSUES: BRINGING THE REGULATORS AND PRIVATE SECTOR TOGETHER 28 (1995); SCOTT K. ANDERHOLM, U.S. GEOLOGICAL SURVEY, WATER INVESTIGATIONS REPORT 94-4078, GROUND-WATER RECHARGE NEAR SANTA FE, NORTH-CENTRAL NEW MEXICO 21–22 (1994); Christopher J. Duffy, *Semi-Discrete Dynamical Model for Mountain-Front Recharge and Water Balance Estimation, Rio Grande of Southern Colorado and New Mexico*, *in* 9 GROUNDWATER RECHARGE IN A DESERT ENVIRONMENT: THE SOUTHWESTERN UNITED STATES, AMERICAN GEOPHYSICAL UNION WATER SCIENCE APPLICATION 255, 257, fig. 6 (James F. Hogan et al. eds., 2004).

reason, household drain-field return flow to useful water of the state is not expected to be seen in areas of deep water table but may be credited as reusable water in areas of shallow water table. The appropriate depth-to-water threshold of a few tens of feet is reasonable for categorizing the impact of drain-field return flow. For example, the NMOSE applied 50 feet to the threshold of return-flow effectiveness in his year 2000 report on domestic well impacts on interstate streams.[19]

The household water balance for withdrawals of 0.35 AFY is illustrated schematically for the two cases of depth to water table near a stream in Figure 2. Stream depletion is expected to be a small fraction, near 25 percent, of well withdrawals in a shallow water table setting, but a large fraction, near 80 percent, in a deep water table setting in a river-connected basin. Close to half of the domestic wells in the state are located in each type of deep or shallow water table setting. Subsequent analysis applies 0.30 AFY as a nominal statewide average domestic well withdrawal rate, which is then adjusted to 0.1 AFY of net depletion for the shallow water-table setting.

Cost

The cost of a properly-constructed domestic well depends primarily on depth and may range from $2,000 to $20,000.[20] The energy cost to raise water into the pressurized household system, depending on pump lift, is in the range of a few dollars to tens of dollars per year. Nationally, wells for domestic water in 1998 averaged $2,460 and replacement wells make up 40 percent of the wells drilled.[21] At that average cost, the investment in New Mexico domestic wells may be near $300 million to support water service to 136,000 existing households with permits. The U.S. Environmental Protection Agency (EPA) estimates that community water systems are more costly than domestic wells.[22] Domestic well costs may range from about $250 to $1,000 annually or $20 to $80 per month, which is generally comparable to the range of public water supply billing costs.[23] The benefits to the consumer from the two sources are also comparable, except that the homeowner reliant on

19. HYDROLOGY BUREAU, *supra* note 12, at 14.

20. R.S. MEANS, BUILDING CONSTRUCTION 61 (62nd ed. 2003).

21. RICHARD C. CARLSON, TRENDS IN THE UNITED STATES MARKETPLACE FOR INDIVIDUAL OWNED PRIVATE WATER WELLS, at iii (1999).

22. OFFICE OF WATER, ENVTL. PROT. AGENCY, EPA 816-R-01-004, DRINKING WATER INFRASTRUCTURE NEEDS SURVEY: SECOND REPORT TO CONGRESS 41 (2001), *available at* http://www.epa.gov/safewater/needs/99fullreport.pdf.

23. CARLSON, *supra* note 21, at 10–12.

public water supply is relieved of maintenance and management duties by hooking-up to community water systems.

WELL WATER AVAILABILITY

The legislative introductions and the administration concerns relate to resource depletion and well sustainability. Other commentators have cited land subdivision and development growth as an issue for domestic well control. In this section, we introduce the hydrologic evaluation of water availability for domestic wells. Water availability to domestic wells incorporates the idea of physical capacity to produce the yield at an instantaneous rate and at an associated annual volume through the service-life for which the well was designed. Water availability is a joint function of a properly constructed well and the prevailing aquifer condition. Problems with water availability more often involve well design than aquifer functions.

The permitting and well-record process for the State of New Mexico does not require that domestic wells show water availability. Individual homeowners may construct and use a well with any level of yield and service life. However, some problems in water service arise from cost cutting in well construction. In contrast, state statute and county regulation require that subdivision proposals for county approval show that water is available, whether from public supply or private domestic well sources. Various counties call for service periods of 40 to 100 years.

Although a demonstration of water availability for subdivisions is required by regulations, well water availability for future decades cannot be tested and observed today but must be projected from short-period tests, calculations, or models. The aquifer system applicable to the question must be characterized as part of the showing of available subdivision water. Hydrologic practice has not standardized any hydrologic procedure for demonstrating single or multiple domestic water availability for a service life of many decades. The standards for agency review and for subdivider demonstration are in the process of development. Technical procedures in county regulations following NMOSE guidance[24] have proved intractable at producing a result uniformly acceptable to the community at interest.

The authors have found the following procedure suited to the subdivision domestic-well demonstration. There are three elements to the demonstration: (1) tested pumping performance of the well, (2)

24. INTERSTATE STREAM COMM'N, *supra* note 14.

observed recovery performance of the well, and (3) computed long-term regional performance of the aquifer system. The steps are as follows:

1. Drill and install a properly-constructed domestic well on the subdivision site
2. Pump the well under controlled conditions at a rate of 5 to 20 gpm for 24 hours
3. Collect water-level recovery data for three days after the end of pumping
4. Calculate the radius of influence of the test and check if additional wells and tests are needed to get a representative sample of the subdivided area
5. Drill and test as many wells as needed to cover the subdivision with four-day radii of influence. An example in Figure 3 shows multiple wells with radii of influence covering the subdivision area of interest.

The pump test data resolve two aspects but not the entire question of water availability. First, the operational performance of the well to deliver initially a certain gpm with a suitable remaining water column (60 feet or more) above the pump will be apparent. Second, one can then interpret the recovery data to show the four-day trend (one pumping and three of recovery) of transmissivity[25]-dependent specific drawdown (feet per gpm/log cycle of time). We project that trend beyond the test and recovery observation period to indicate average aquifer properties and boundary character for the period to full recovery. The average trend to recovery serves as a best estimate of the expected future, although the projected trend may not be the specific path of the future data.

To illustrate the interpretive method, Figure 4 is a conventional Theis recovery plot[26] showing that most of the drawdown observed at one day is expected to be recovered by the fourth day of a test period. The nature of the Theis recovery plot can indicate whether the aquifer in the expanding cone of depression through the recovery period is more or less transmissive than seen during the one-day test.

25. Transmissivity: The rate at which water is transmitted through a unit width of a groundwater system under a unit hydraulic gradient [L^2T^{-1}]. It is the measure of the ease with which aquifers transmit water to discharge at wells, larger values indicating greater transmissive capacity. GLOSSARY OF HYDROLOGY (William E. Wilson & John E. Moore eds., 1998).

26. Theis, *supra* note 1.

The interpretive principles for recovery data follow the methods of Daungkaew and others who found that "the use of (recovery) data can clearly provide more information than the preceding drawdown."[27] Klusman recently published similar findings about domestic well recovery data.[28] It is reasonable to apply the late-time recovery trends to the extended future that represents the remaining period to full recovery. Insofar as the ultimate recovery is to the origin (at t/t′ = 1, residual drawdown = 0), the nature of the long-term well performance can be projected. A flatter projection from the end of recovery value to the origin indicates better aquifer performance at the end than at the beginning of the four-day period; whereas a steeper projection from the end of recovery value to the origin indicates the expectation of continued lesser aquifer performance. Figure 5 uses three projections to illustrate a recommended method for interpreting projections of well performance according to recovery trends. Well recovery comes to full recovery only after infinite time. That aspect provides a theoretical basis for projecting the remaining trend of recovery from incompletely recovered four-day observations.

After observing drawdown and recovery and then projecting trends to characterize the individual wells, as a final step the individual well tests must be superimposed on a regional model of the water-level trends that are generated by baseline wells and expected growth for the subdivision area. Recognizing that individual domestic well performance can be tested and projected reasonably, the remaining question about water availability involves the cumulative effect of numbers of wells in combination and in relation to other water features such as streams, springs, and wetlands. Even though a single well appears serviceable for the planned lifetime, is the aquifer system capable of sustaining many such single wells? Projecting the long-term response through simulation in models such as those established for basin administration by the NMOSE can best answer that question.

The model projection of water level decline under current and expected growth for the county planning period can be provided for in the subdivision well design. Properly designed and constructed wells with allowance for regional decline trends and with pump-induced peak rate allowances in the water column can be shown to have water reasonably available for subdivision purposes. The 60-foot allowance for

27. S. Daungkaew et al., Society of Petroleum Eng'rs, Inc., SPE 63077, Frequently Asked Questions in Well Test Analysis 3 (paper presented at the SPE Annual Technical Conference and Exhibition, Dallas, Tex., 1–4 Oct. 2000).

28. Kate Klusman, *A Procedure for Automated Analysis of Brief Pumping Tests of Domestic Wells*, 42 GROUND WATER 945, 945–48 (2004).

regional trends is safe except near major municipal and other well fields, or near mine dewatering sites.

It is not practical to predict well failures due to mechanical or electrical problems, screen-clogging, casing breaks, etc., but it is practical to predict long-term aquifer resource conditions related to available water.

DOMESTIC WELL EFFECTS

Well Data

Having reviewed how domestic wells work and the patterns of use, this section proceeds to the basic data on well location, growth, and depth used in calculating the core questions of the local, basin-wide, and statewide impacts on the aquifer resource and on the interstate streams.

An NMOSE report in year 2000 described the impact of domestic wells in New Mexico and concluded that 136,816 domestic well files were recorded as of August 2000, affecting streamflow statewide by 5,400 AFY.[29] However, the water-level drawdown associated with domestic wells was not reported. That remaining gap in information is one reason for on-going interest in domestic well policy. The legislative introductions since year 2000 have focused on sustainable well production "as evidenced by excessive drawdown rates or reduced aquifer thickness," as well as interstate obligations. The cumulative drawdown rates may be judged "excessive" where they markedly influence well-service life or aquifer thickness and resource availability.

The NMOSE has established administrative models (Figure 6) that simulate domestic wells in 17 areas of the state. Figure 7 displays the location of 68,665 domestic wells as of June 2002 in the Water Administration Technical Engineering Resources System (WATERS) database.[30] The administrative agency can simulate the effects of most wells, insofar as they lie inside NMOSE model areas. Additionally, major aquifers and other basin-fill aquifers as classified by U.S. Geological Survey (USGS)[31] are shown on Figure 7. Areas not classified as major aquifers contain minor aquifers that are capable of supporting domestic or stock wells. Concentrations of domestic wells are found in all classes

29. HYDROLOGY BUREAU, *supra* note 12, conclusions 1 & 3, at 23, 24.

30. N.M. Office of the State Eng'r, *GIS Data*, *at* http://www.ose.state.nm.us/water-info/gis-data/index.html. WATERS is the NMOSE web-based facility for delivering digital water rights records to the public.

31. U.S. Geological Survey, *Principal Aquifers of the 48 Contiguous United States*, *at* http://gcmd.nasa.gov/records/GCMD_USGS_aquifers_us.html (last updated Jan. 2006).

of aquifer, as well as in stream-connected and isolated aquifers. The chart below summarizes the year 2002 domestic well count in each aquifer category.

2002 DOMESTIC WELL COUNT FOR NEW MEXICO

	Domestic Wells	**% of Total**
In Major aquifers	47,329	69
In Minor aquifers	21,336	31
In Shallow water table (<50 ft)	32,878	48
In Deep water table (>50 ft)	35,878	52
Wells located in WATERS	68,665	100

The ratio of locatable well permits to total wells in the WATERS data file can be used to index wells in each category upward to the total.

Figure 8 is a statewide water table map used to identify areas with a shallow water table. Also illustrated is the area of the state where depth to water is less than 50 feet, implying that return flow from domestic use may affect the water table.

In addition to having the number of existing wells, we must determine the growth trend of well permits to project the number of wells that would be subject to any new domestic well policy. Figure 9 charts the growth of domestic well permits in WATERS alongside the growth of state population.[32] Domestic wells entered in the WATERS database are growing substantially faster than the population. One water policy issue involves limiting or interdicting that growth. For ease of analysis, we examine the extreme case of curtailing all future domestic well permits. Any policy to constrain permits to a lesser degree would have a smaller hydrologic impact than portrayed in this article. We assume that the high historical permitting rate will not persist over the next 40 years. Instead, we apply the Bureau of Business and Economic Research's (BBER) growth estimates for county population.[33]

The wells that the NMOSE permits in the next 40 years will likely be constructed similarly to existing wells unless construction standards are upgraded. Figure 10 charts the recorded distribution of well water columns, total depth and screen length. The majority, about 64 percent, of domestic wells have more than a 60-foot water column and are reasonably expected to provide water reliably. Shallower and lesser water columns may be the result of shallow initial construction due to

32. Bureau of Bus. & Econ. Research, Univ. of N.M., *Revised Population Projections for New Mexico and Counties* (released Aug. 2002, revised Apr. 2004), *at* http://www.unm.edu/~bber/demo/table1.htm (last updated May 3, 2004).

33. *Id*.

factors such as cost. Many such wells are unreliable for a full service lifetime regardless of the effects of other adjacent or regional well operations. Upgraded construction standards could help the situation for future households.

Adjacent Well Interference

Can individual domestic wells dry-up their neighbors? The concept of a physical limit on maximum interference between wells is described by Robinson and Skibitzke, who found that "the maximum effects of proposed or predicted pumping in a region" can be used to analyze the significance of well interference.[34] Figures 11 and 12 illustrate their principle. The method is useful because it describes the physical limit on drawdown without the need to characterize the sites of interest. Drawdown cannot be more than the Robinson and Skibitzke curve regardless of aquifer transmissivity. Theis curves, copied in Figure 11, show that domestic wells in low transmissivity systems affect a smaller radius of influence than do wells in moderate or higher transmissivity systems. Further, domestic wells produce at relatively low average pumping rates. Figure 12 illustrates the limits on domestic well drawdown at 0.3 AFY for any transmissivity. Considering that properly constructed wells provide tens of feet of water column to accommodate water level trends, there is no prospect of systematic interference between properly constructed domestic wells that are spaced at more than two-to-five-acre lots (300 to 500 feet spacing). In poor aquifers, the individual well effects do not reach adjacent wells, and in good aquifers the individual effects are small.

Regional Well Interference

Can thousands of domestic wells collectively dry up the aquifers in a regional groundwater basin? Available models can project such information. The proposed legislation discussed above focuses on limiting domestic wells where they are associated with "excessive drawdown or reduced aquifer thickness." The magnitude of drawdown caused by the collective effects of domestic wells in high well-density areas of the state is pertinent to that concern. In various groundwater basins of the state that have high well density, the NMOSE has designated certain groundwater flow models as tools for guiding

34. G.M. Robinson & H.E. Skibitzke, U.S. Geological Survey Water-Supply Paper 1536-F, *A Formula for Computing Transmissibility Causing Maximum Possible Drawdown Due to Pumping*, *in* GROUND-WATER HYDRAULICS 179 (1962).

administrative decisions about drawdown effects. The Middle Rio Grande Basin (MRG), Estancia closed basin, and 15 other basins have NMOSE-designated administrative MODFLOW[35] models. Domestic well specifications are commonly included in the baseline model scenarios. The NMOSE routinely determines the effects of an application, in terms of a hydrologic change from a future baseline, by examining all existing permits in exercise, including existing domestic well permits. The authors have prepared a model of problematic areas near Placitas where the NMOSE has not designated a model.

To illustrate the scale of domestic well impacts in highly developed basins in New Mexico, Figure 13 shows the NMOSE-designated model results for 40 years of impact from the withdrawal by domestic wells at areas near Albuquerque and Estancia, alongside the authors' results for Placitas. Generally, impact in the NMOSE models does not exceed five feet in the 40-year nominal lifetime of a properly constructed well. That amount of water-table decline will not affect water service from a properly constructed well. Conditions for domestic wells in other parts of the state covered by NMOSE models are not expected to be appreciably different from conditions projected in the Albuquerque and Estancia areas.

Although the administrative models cover many parts of the state, the MODFLOW program is amenable to simulations of the entire state (Figure 14). A statewide picture is pertinent to the statewide policy questions. In this study, simplified specifications are applied to represent general properties of perennial streams as well as major and minor aquifers, which are delineated statewide by the USGS.

The authors develop a model for the purpose of displaying statewide well impacts on aquifers and streams. A one-square-mile grid of domestic well density statewide is calculated and located in a corresponding MODFLOW model grid for the state (Figure 14). Thus, information is resolved for each square-mile section (397 nodes x 363 miles) of the State of New Mexico. The authors assign major and minor aquifers characteristic properties based on their regional understanding consistent with the plausible range used in the NMOSE report[36] on domestic well streamflow effects. The authors simulate minor aquifers

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35. ARLEN W. HARBAUGH & MICHAEL G. MCDONALD, U.S. GEOLOGICAL SURVEY, Open-File Rep. 96-485, USER'S DOCUMENTATION FOR MODFLOW-96, AN UPDATE TO THE U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL (1996). MODFLOW is a computer program for calculating aquifer water-level change and flow induced by specified stresses such as well pumping. The MODFLOW program is applied to particular aquifers by specifying the properties of the particular aquifer to the generic program.

36. *See generally* HYDROLOGY BUREAU, *supra* note 12.

with hydraulic conductivity[37] of 0.2 feet per day (ft/d), major aquifers in basin fill with hydraulic conductivity of 2 ft/d, and major limestone aquifers with hydraulic conductivity of 20 ft/d. Domestic wells withdraw from the 500-foot thick top layer of the model. A second 500-foot thick layer makes a 1000-foot thick flow system simulation. Specific yield[38] is simulated as 15 percent of aquifer space in basin fill, and as two percent of aquifer space in other material. The authors consider the simplified specifications to be suitable to the purpose of informing policy decisions.

Although about half of recorded domestic wells cannot be readily located using WATERS database information, we can index the locations upward to the full count. To account for wells without location information, domestic well withdrawals were simulated at sites containing locatable wells (68,000) and were distributed by county using NMOSE water use data[39] to an equivalent 136,000 wells. Accordingly, the statewide model stress grows from 14,000 domestic wells in 1950, to 136,000 in year 2000, and then to 203,000 in year 2040. County population projections in BBER[40] guide the proportional distribution of the future growth of domestic wells. We modify the proportionality such that square-mile model cells, which would have an equivalent well density greater than one well per five acres (128 wells per square mile) in year 2040, have density curtailed at year 2000. We assume that county land use standards prevent a density greater than one per five acres. In that case, we distribute growth of withdrawals onto adjacent square-mile cells with fewer domestic wells.

We have simulated future domestic wells for the 40-year period (year 2000 to year 2040) assuming cases with both a BBER growth rate and an alternative no growth rate. Figure 15 is a statewide projection of 40-year effects of domestic well growth by each of the wells in Figure 14 based on 0.3 AFY withdrawals, or a net 0.1 AFY in areas of shallow water table. Figure 15 represents the impact on water levels of domestic

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37. Hydraulic Conductivity: A coefficient of proportionality describing the rate at which water moves through a unit cross sectional area of permeable medium under a unit hydraulic gradient. Also called permeability. Closely related to transmissivity by the relationship hydraulic conductivity x aquifer thickness = transmissivity. GLOSSARY OF HYDROLOGY, *supra* note 25.

38. Specific Yield: A ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is stated as a percentage. It represents the fraction of the earth's crust that contains produceable water. *Id*.

39. *See generally* BRIAN C. WILSON, P.E. ET AL., N.M. OFFICE OF THE STATE ENG'R, TECHNICAL REPORT 51: WATER USE BY CATEGORIES IN NEW MEXICO COUNTIES AND RIVER BASINS, AND IRRIGATED ACREAGE IN 2000 (2003).

40. Bureau of Bus. & Econ. Research, *supra* note 32.

well growth for the 40-year period to year 2040 and is the core result of this article's conclusion regarding aquifer depletion and sustainability.

Assuming that policy intervenes to curtail all growth of domestic well service, Figure 15 shows the difference in future drawdown due to such policy. Curtailment of growth depletes the aquifers 0 to 13.4 feet less than does continued growth of domestic well use.

No area of the state appears to qualify as a "critical management area" requiring that domestic wells be limited "because water resources may be inadequate to sustain well production as evidenced by excessive drawdown rates or reduced aquifer thickness." The largest area of projected domestic well impact is in the east slopes of the Manzano Mountains, in the Estancia Basin, which does not reach the stated threshold of critical concern, even though it is already protected by administrative area guidelines controlling domestic wells.

A greater drawdown than displayed on Figure 13 is foreseeable due to the additional impact of non-domestic (irrigation, municipal, industrial) wells. However, the sustainability of well production is not affected anywhere because of domestic well effects. In the NMOSE models and in this statewide model, domestic well effects are to be viewed as superimposed on the larger effects of irrigation or municipal/industrial wells.

Surface Water Depletion

Next, we expand the Figure 15 result regarding aquifer sustainability to derive a picture of impacts on interstate streams and compact deliveries. The NMOSE reported his estimates of year 2000 stream depletion on domestic wells in five interstate streams, each with Interstate Compact delivery requirements.[41] The two tables below compare the NMOSE estimates for year 2000 and the statewide results from this article for years 2000 and 2040.

Interstate River	**NMOSE Estimate of Year 2000 Domestic Well Stream Impact (AFY)**
Rio Grande (2 basins)	2740–7930
Pecos (4 basins)	616–1760
San Juan	593–1695
Gila-San Francisco	520–1485
Canadian (partial)	288–822
Total	4757 AFY

41. *See generally* HYDROLOGY BUREAU, *supra* note 12, at 24; *id.* at 2, 18–19 (the range calculated impacts are reasonable).

Also, the NMOSE adds wells on other rivers to conclude that "[e]xisting domestic wells may currently affect perennial stream flow statewide by 5,400 AFY."[42]

The statewide model described above displays an independent estimate of domestic well impacts on interstate streams that are subject to Interstate Compact obligations. For comparison to the NMOSE-published year 2000 estimate of stream depletion, the statewide model prepared for this article simulates a year 2000 estimate, as well as year 2040 estimates—one with continued growth of domestic wells and one without growth of domestic wells. The difference between the two estimates for year 2040 shows the effect of a policy curtailing domestic wells. The table below summarizes simulated difference in streamflow due to curtailing growth.

STREAM DEPLETION (AFY)

River Basin	Year 2000 = 136,800 Existing Domestic Wells Producing 41,000 AFY	Year 2040 Existing + Growth = 203,000 Wells Producing 60,900 AFY	Year 2040 w/o Growth = 136,800 Wells Producing 41,000 AFY	Salvaged Streamflow by Curtailing Growth of 66,200 Wells Producing 19,700 AFY
Rio Grande	8030	14580	10150	4430
Pecos	1290	1980	1780	200
San Juan	1010	1520	1270	250
Gila–San Francisco	780	1250	1090	160
Canadian	480	700	580	120
Other	190	280	300	-20
Total	11780	20310	15170	5140

The statewide model prepared for this study shows more river depletion for year 2000 (11,780 AF) than was estimated earlier by the NMOSE using simpler analytical calculations (5400 AFY). The statewide model locates half of all WATERS wells in the same square mile cells that represent adjacent perennial rivers and tends to emphasize stream depletion impacts. In our future projection, some streams are in counties projected to lose population through year 2040.

One might expect the policy of intervening in growth of future domestic well permitting to save about 5,140 AFY by curtailing service from 66,200 domestic wells in the next 40 years. However, those 66,200 households would likely be hooked-up to community public water

42. *Id.*

systems thereby consuming an equivalent or greater amount of water as compared to the alternative case.

We may expect that continued growth of wells in the next 40 years will add about 5,000 AFY to the statewide stream depletion total. We assume public water supplies would cause similar impacts as an alternative source for the population served by domestic wells. In no basin but the Rio Grande does growth in impact exceed 250 AFY in 40 years. Therefore, in view of the one million AFY average yield in the Rio Grande and 0.7 million AFY average yield in the Pecos River, it is pertinent to consider whether or not a CMA curtailing domestic well growth is a reasonable requirement to effect protection of "the states obligations pursuant to an Interstate Compact." One may expect the future households to deplete the basins similarly whether the water comes from a domestic well or from a public source drawing on the same aquifers.

A further aspect of domestic well impact on minor tributaries of the mainstem rivers appears to be hydrologically important, even though it is not the stated concern of the legislative bills or of the administrative agencies. Minor tributaries are more susceptible to sensible depletion than are the mainstem Interstate Compact rivers. If hundreds of AFY of well depletion are found to be concentrated on minor tributaries that flow only thousands of AFY, then a reasonable basis for control may become apparent. Control of impacts in tributaries might be made effective by priority enforcement rather than by curtailing new permits, particularly where new domestic well permits could compensate vulnerable senior rights or ecological impacts by an economic transaction or by physical replacement.

ADMINISTRATIVE INTERVENTIONS

Legislators and agency officials have proposed several interventions in domestic well administration in New Mexico. The statewide model results presented above allow a means to quantify the foreseeable consequences of the interventions, which are sometimes described in New Mexico as part of "active river management." Among the eight actions examined, one involving upgraded construction standards appears to be beneficial to water users. The state's interstate obligations and resource sustainability are insensitive to any of the actions.

Impairment Analysis

The NMOSE grants domestic well permits without consideration of impairment and perhaps domestic wells need not be protected against impairment. From the point of view of promoting economic development of the state's water resource, it might be appropriate to exempt domestic wells consistently from impairment analysis both at the time of permitting household use and at the time of permitting other economic uses. In addition, excluding domestic wells from administration protection might be reasonable because properly constructed domestic wells are not impaired when economic development adheres to the 40 to 100 foot general decline rate that the NMOSE administers in basins around the state.

Critical Management Area

Designating CMAs appears to have no functional role because no part of the state would be found to qualify for the designation with respect to domestic well impacts. For example, the Placitas, Manzano, and Silver City areas have relatively poor aquifers but remain sustainable with 40-year domestic well stresses in the statewide model. The uniformity of model results, as evidenced by drawdown rates and aquifer thickness, suggest that no area of the state would likely qualify as a CMA. We anticipate that the 17 NMOSE-designated models will be compatible with our statewide results. The NMOSE models represent a means to quantify domestic well effects in specific areas of interest in the state, such as proposed CMAs.

Deny Domestic Well Permits

Denying domestic well permits would have two hydrologic results. First, a small fraction of households might leave, or not move to, the state, thereby reducing water demand. Second, other households would hook up to a public water supply, thereby renewing their demand. Public water supplies derive well water from the same regional aquifer sources as most domestic wells within reach of piped service. Public water supply users have higher per capita demand according to agency reports. The foreseeable result of domestic well curtailment is equivalent, if not greater, drawdown and stream depletion.

Water Rights Inflation

Domestic well rights at three AFY have caused a concern that the basin water rights accounts are inflated. The MRG basin, with 64,000 domestic wells, may appear to have 180,000 (64,000 x 3) AFY excess domestic well rights. The NMOSE baseline model of the basin shows 155,000 AFY of total well rights, including domestic wells, in exercise and 237,000 total well rights to ground water, including 82,000 AFY not in exercise. The NMOSE model has 7,063 AFY of domestic well rights in exercise representing about 64,000 wells consuming 0.11 AFY per well. Apparently, the domestic well rights are less significant to the NMOSE account of MRG basin water-rights than are the excess 82,000 AFY well rights approved with a full administrative analysis. The 19,700 AFY projected growth in statewide household demand to year 2040, identified in the table above, may be served by domestic wells, or alternatively by public supply systems. With a policy to prevent water rights inflation, the new domestic wells would acquire rights from other categories of use. We foresee no hydrologic offset to match the paper water rights acquired from unexercised excess rights in the basins. Ultimately, adjudication deals with the issue of inflated rights. Adjudication of water rights serves the function of validating the amount of water behind any inflated permits or claims. Adjudication may better test domestic wells and the claims of other uses than would a new administrative policy.

Reduced Amount of Domestic Well Permits

Many of the legislative introductions have sought a 0.5 to 1.0 AFY limit on the present 3.0 AFY domestic use. However, domestic wells permitted at up to three AFY are exercised typically at more nearly one tenth of that amount and, as reflected in the administrative models, consumptive use is even less. Reducing the permitted amount to a cap of 1.0 or 0.5 AFY would only constrain the upper end of the distribution of users and the hydrologic effect would be modest. Assuming that the state distribution of well use is in similar proportion to national data,[43] the amount of water use in year 2040 that might be reduced by capping permits at various levels is estimated from the fraction of growth described above (66,200 future wells) that would become constrained to a lower level of use:

43. *See generally* Wayne B. Solley et al., *supra* note 15.

Permit Limit	Year 2040 Affected Households	Year 2040 Curtailed Well Use With Permit Limit
1.0 AFY	Nil	Nil
0.50 AFY	<1%	17 AFY
0.40 AFY	3.5%	80 AFY
0.30 AFY	34%	1000 AFY

At the more restrictive levels, connection to public supplies would likely replace some curtailed household use. The foreseeable result from reducing the acre-foot amount of domestic well permits for the next 40 years will be a few tens or hundreds of AFY of future stream depletion as well as negligible drawdown. However, the national data used for this estimate does not include the New Mexico category of up to one acre of lawn or garden use. Additionally, some of the New Mexico households using higher than average rates under their three AFY permit are in remote ranch areas or are watering gardens for consumption and are not reflected in the national statistic for household use. Ultimately, the few households that presently benefit from the domestic well permit provision for up to one acre of lawn or garden would be the households most affected by a loss of utility from lowering the permitted cap.

A question arises as to why equivalent household use limits would not similarly cap public water supply users. The per capita rate of 165 gpd is equivalent to 0.5 AFY per household at 2.7 persons. It is likely that the consumer benefit to the few households who use more than 0.5 to 1.0 AFY, but less than three AFY, may justify the higher level of use for both domestic well and public supply consumers.

Indoor Use Only

Indoor use is about 50 percent of total household water use.[44] Limiting new domestic wells statewide to indoor use only for the next 40 years would save a few thousand AFY of stream depletion and one or two feet of drawdown based on growth projections. Some of the households so constrained would be expected to hook-up to public water supplies and to revert to the higher capita use rates with renewed

44. *See generally Urban Water Use in California*, CAL. DEP'T OF WATER RESOURCES BULL. 166-3, 1983, at 9 (statewide residential water use comprises about 61% of total urban use, exceeding all other urban uses combined); HYDROLOGY BUREAU, *supra* note 12, at 11 (Of the total water produced from domestic wells, a portion is consumed within the household (the consumptive use) and a larger fraction is returned to the ground as septic tank effluent.).

depletion and drawdown. Although the legislative bills introduced in recent years have not proposed constraining public supplies to indoor use only, such a policy would add five times more saved water than a policy constraining solely domestic wells in that way. After some domestic well conversion to public supply sources, net water savings may be less than 1000 AFY after 40 years statewide from an indoor use policy for domestic wells. However, the loss of consumer utility would be a net economic negative.

Metering

Metering and reporting of domestic well use would have no effect in reducing use among those not over-using their permitted amount. Additionally, the recent rate of 6,000 new permitted wells each year, estimated at $700 each, would entail about $4 million annually for metering and reporting. No benefit to the metered water-using household is apparent. Furthermore, the administrative cost of policing water readings and database management for enforcement would likely exceed the value of water saved. The current 40 percent non-compliance rate reported to the National Academy of Science by the NMOSE devalues any management use of metering data. Homes in southeastern Arizona are using dataloggers coupled to water meters to quantify domestic-well use and have found that self-reported usage is costly, unreliable, and biased.[45] This is partly due to the fact that those houses aware of being metered perform differently from others.

Properly Constructed Wells

Properly constructed wells, as described above, would produce a change in water use to the benefit of households that have inadequate present well service. Costs would increase, but the primary effect would be to reduce problems with water service to such households. The new well water users would be the beneficiaries of the added cost.

CONCLUSIONS

The recurring proposals dealing with domestic well permitting and management in New Mexico primarily involve issues concerning

45. Gary Woodward, *Gaining Insights on Domestic Water Demand Through Remote Sensing: Applications of Low-Cost Loggers*, *in* SAHRA, CENTER FOR SUSTAINABILITY OF SEMI-ARID HYDROLOGY & RIPARIAN AREAS 6, 12–13, http://www.sahra.arizona.edu/research/TA5/loggers_web.pdf (last visited Nov. 19, 2005).

water resource sustainability and state obligations to deliver water to downstream states. The hydrological aspects of domestic well issues are amenable to specific quantification. Other issues involving administrative duties, legal standing, private rights, government supervision, and compact obligations may be aided by the specific hydrologic information.

Groundwater modeling of the local, regional, and statewide aquifer systems illustrates individual well performance, adjacent well impacts, and collective regional domestic well impacts. The models imply that water supply services are fully sustainable in properly constructed domestic wells. Modeled drawdown in the range of tens of feet is acceptable because the yield of properly-constructed wells is not affected. CMAs requiring heightened protection due to domestic wells cannot be identified by model results in any part of the state whether in stream-related aquifers, closed basins, or in major or minor aquifers. Improper well construction, rather than domestic well interference, explains the exceptions to the characteristically sustainable well pattern. Due to the physical limits on hydrologic performance of aquifers, domestic well interference cannot be extensive in minor aquifers and cannot be of significant magnitude in major aquifers. Among the major categories of water use, domestic well use is the smallest category and the most sustainable of water uses with the least impact on the water resource and the interrelated streams. The New Mexico practice of granting domestic water without administrative review is compatible with the view that domestic water is a universal human right. Domestic wells support a persistent economic activity by households that is, as a rule, highly-valued, safe, and harmless to other water users.

Domestic wells serve more than 136,000 households in New Mexico, about 20 percent of total households in the state, and are growing toward 200,000 by year 2040. Most domestic wells are properly constructed for an economic life of 40 years with an expectation of full service from the well. Nonetheless, about a third of existing wells do not have adequate water column upon initial construction to expect a full service life from the well.

The typical domestic well utilizes ten percent of its three AFY permitted right and consumes less. Use of the full three AFY is not expected unless households utilize the New Mexico irrigation allowance. Administrative inspection and enforcement could constrain any over-use of the irrigation provision.

The cost and benefit of domestic-well water service is comparable to that from public water systems except in remote areas where domestic wells are less costly. Curtailing homeowner access to domestic wells would convert the self-served household use into consequent increased public system demand with greater resource impacts. Population growth is necessarily served with household water from one source or another. Domestic well sources and alternative public water supply sources affect the resource base, service life, and interstate obligations in much the same way. One distinction is in the management level of the household well operator versus the certified public water system operator. Nevertheless, management failures of quantity or quality of water affect more households when connected to public supply.

The set of management actions proposed to intervene in the growth of domestic well permits is, for the most part, counterproductive or of little foreseeable benefit to the objectives. Limiting permit amounts would alter the behavior of few households. Mandating indoor use would save about half of household water at the cost of a large loss of consumer utility. Metering adds millions of dollars of cost annually with little foreseeable saving of water.

One apparent beneficial intervention is to mandate proper construction, testing, and certification of domestic wells when drilled or sold. Sub-standard sanitation, reliability, and service life in the case of domestic wells can be addressed by construction standards and adequate water column, rather than by limiting access to the opportunity for self-service.

FIGURE 1
YIELD COMPONENTS OF PROPERLY-CONSTRUCTED DOMESTIC WELL

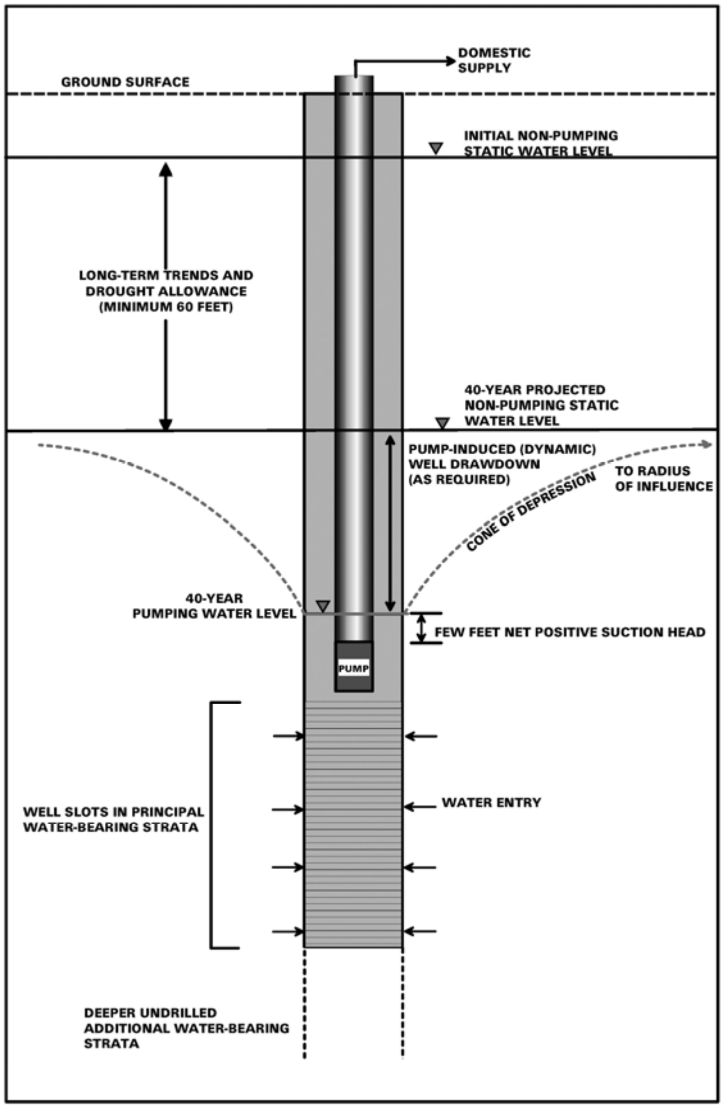
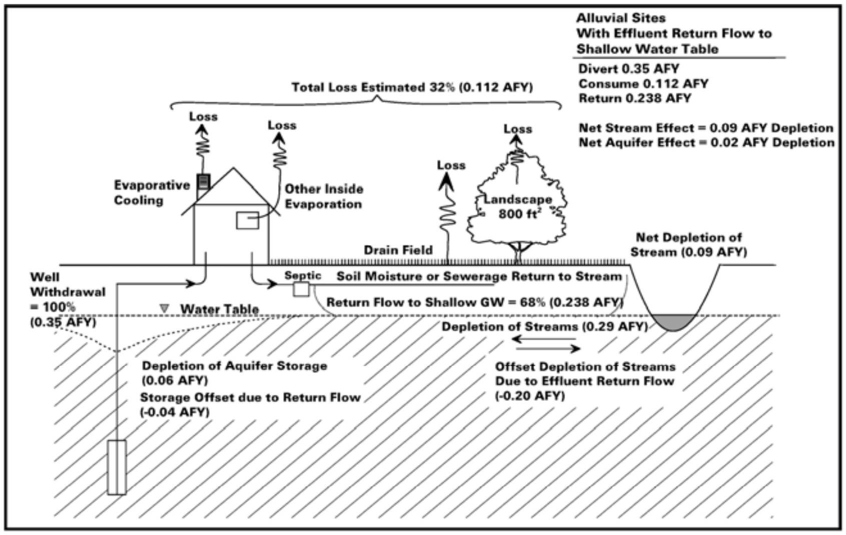
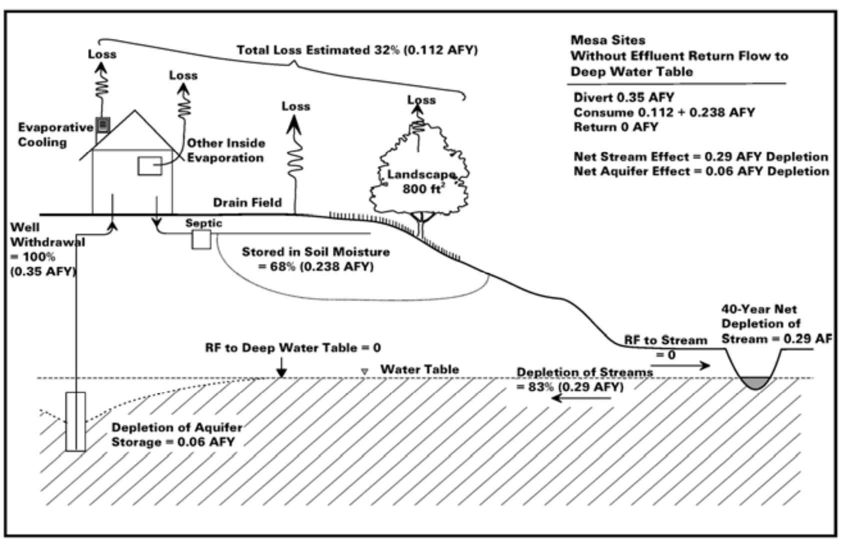


FIGURE 2
HOUSEHOLD WATER BALANCE AT SHALLOW AND DEEP WATER TABLE NEAR A STREAM



COMPONENTS OF DOMESTIC WATER ROUTING AT ALLUVIAL SITE (YEAR 2040)



COMPONENTS OF DOMESTIC WATER ROUTING AT MESA SITE (YEAR 2040)

FIGURE 3
RADII OF INFLUENCE OF TEST WELLS FOR WATER AVAILABILITY IN PLACITAS AREA

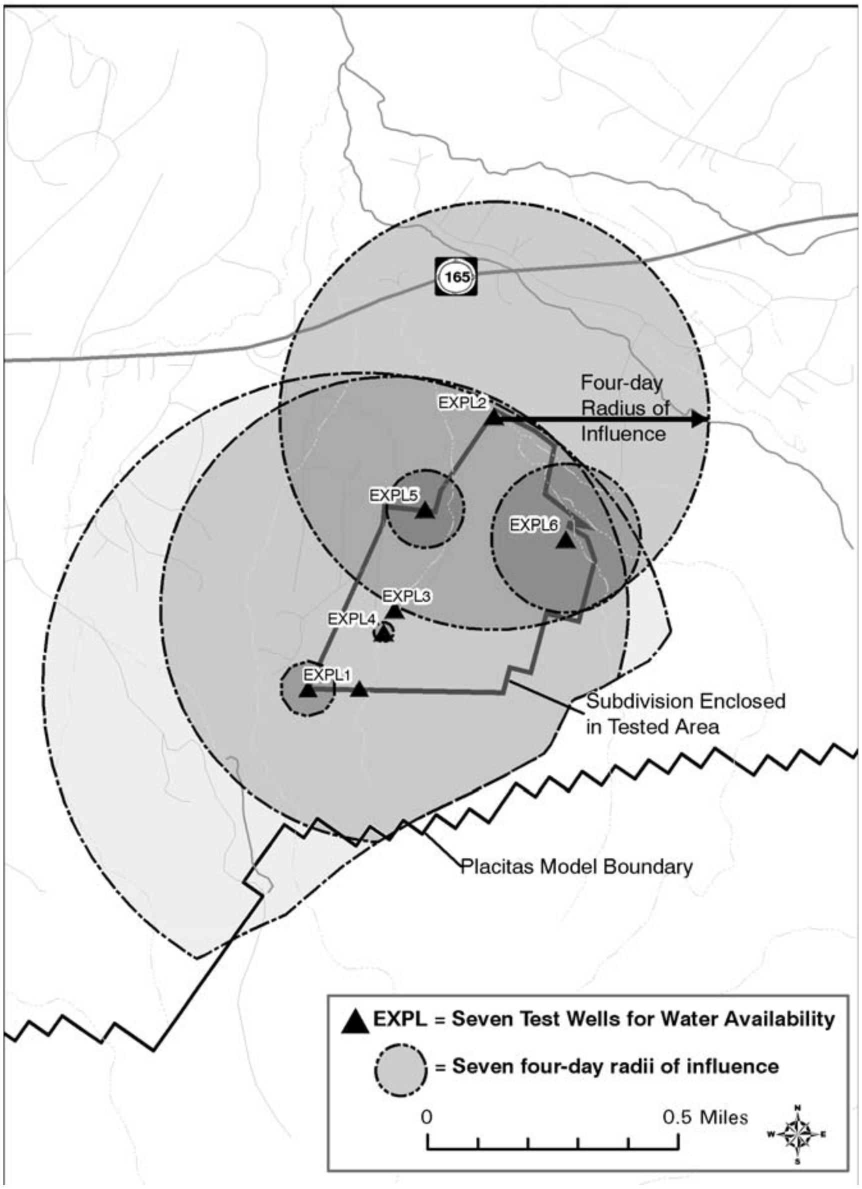
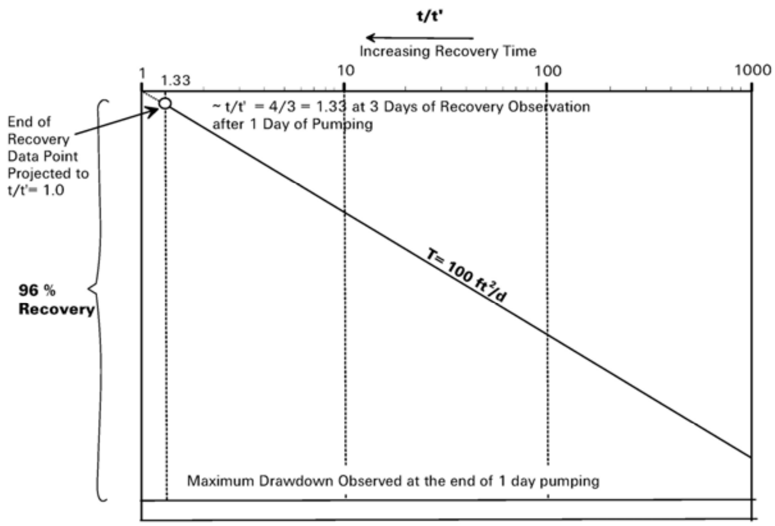
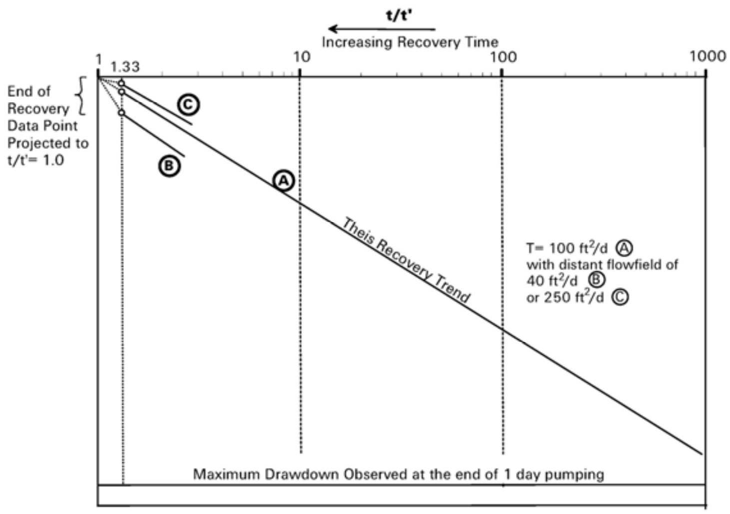


FIGURE 4
RECOVERY TREND IN GROUNDWATER SYSTEM WITHOUT BOUNDARIES IN THE AREA OF INFLUENCE



t = Time since pumping started (1 day + 3 days = 4 days)
t' = Time since pumping stopped (3 days)

FIGURE 5
RECOVERY TRENDS IN GROUNDWATER SYSTEM WITH BOUNDARIES IN AREA OF INFLUENCE

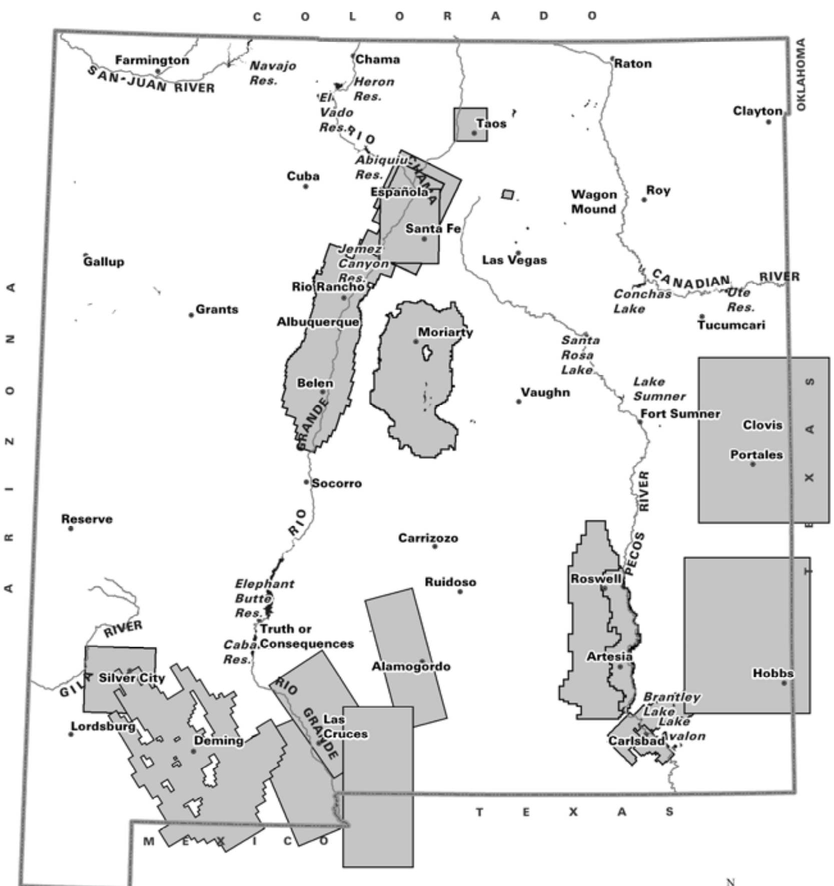


Trend A is the Theis recovery trend indicating standard projection to t/t' = 1.0

Trend B has the 3-day recovery measurement at a lesser water level indicating steeper slope and smaller transmissivity in projection to t/t' = 1.0

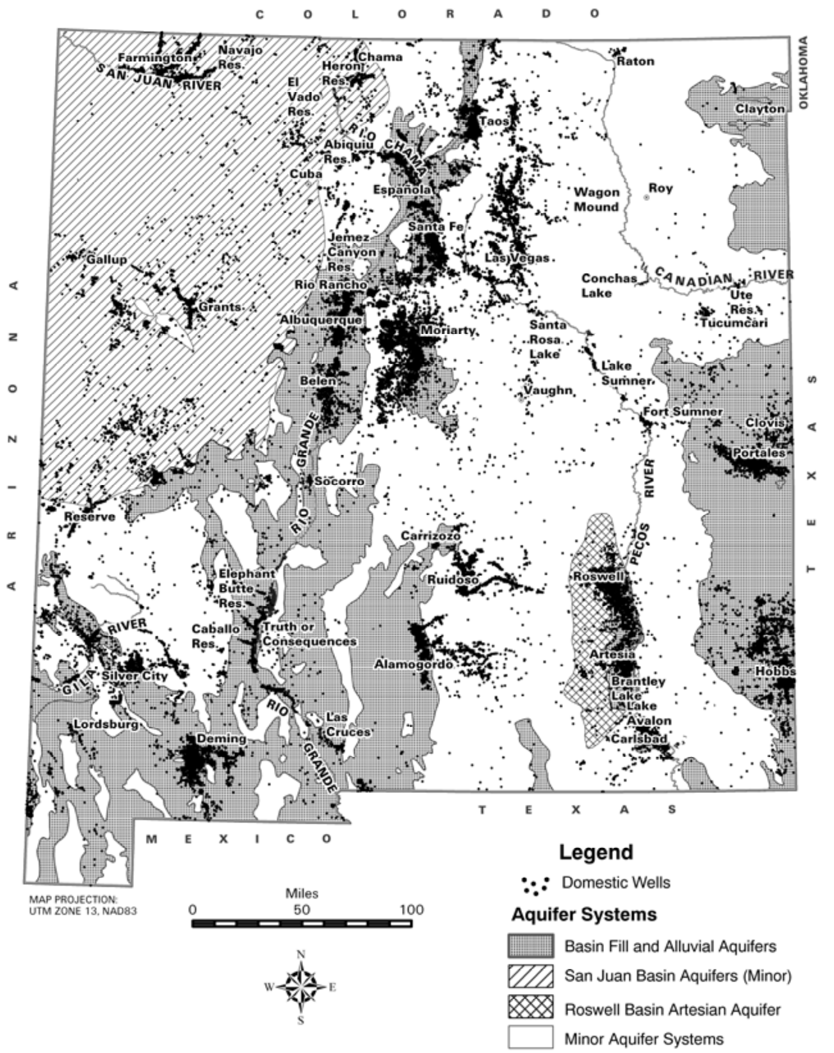
Trend C indicates a flatter slope and larger transmissivity in projection to t/t' = 1.0

FIGURE 6
NEW MEXICO OFFICE OF THE STATE ENGINEER
ADMINISTRATIVE MODELS FOR 17 AREAS



Note: Surface water models also are established for the Rio Grande, Pecos and San Juan Rivers.

FIGURE 7
DOMESTIC WELLS AND AQUIFERS IN NEW MEXICO



Aquifer Systems Adapted from U.S.Geological Survey, Principal Aquifers of the United States, Puerto Rico and U.S. Virgin Islands, ArcView Shapefile (http://www-atlas.usgs.gov/aquifersm.html).

FIGURE 8
WATER TABLE ELEVATION AND DEPTH IN NEW MEXICO

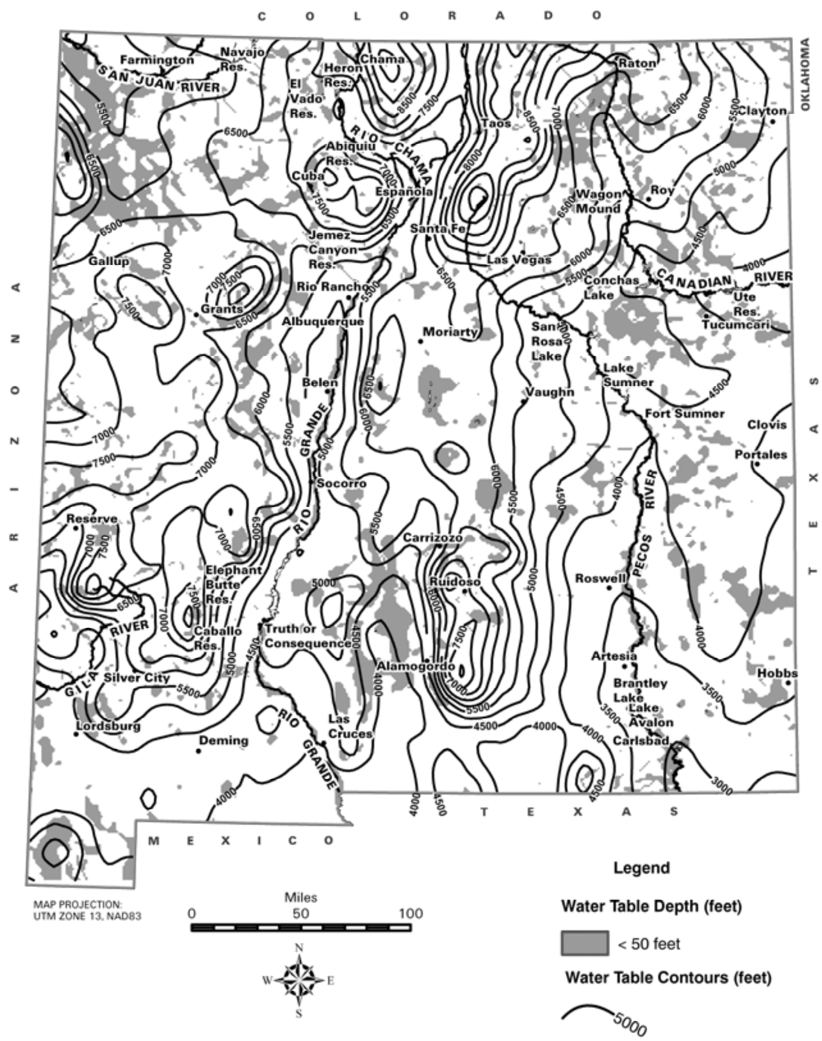


FIGURE 9
GROWTH OF DOMESTIC WELL PERMITS AND POPULATION IN NEW MEXICO

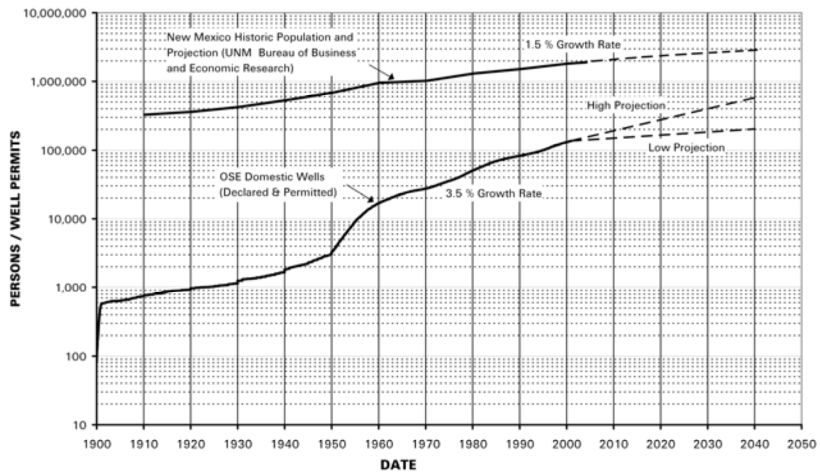


FIGURE 10
DISTRIBUTION OF PROPERLY-CONSTRUCTED WELLS IN NEW MEXICO

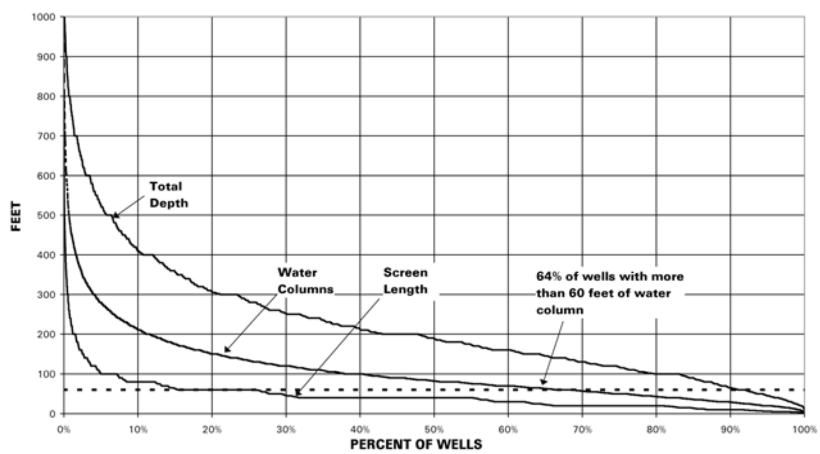


FIGURE 11
MAXIMUM POSSIBLE DRAWDOWN FROM PUMPING

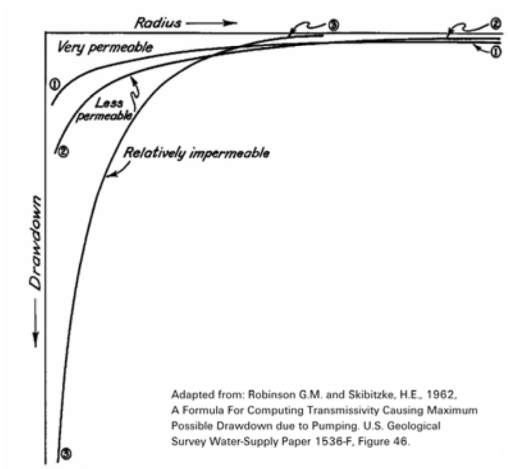


FIGURE 12
HYDROLOGIC LIMIT ON MAXIMUM INTERFERENCE BETWEEN DOMESTIC WELLS

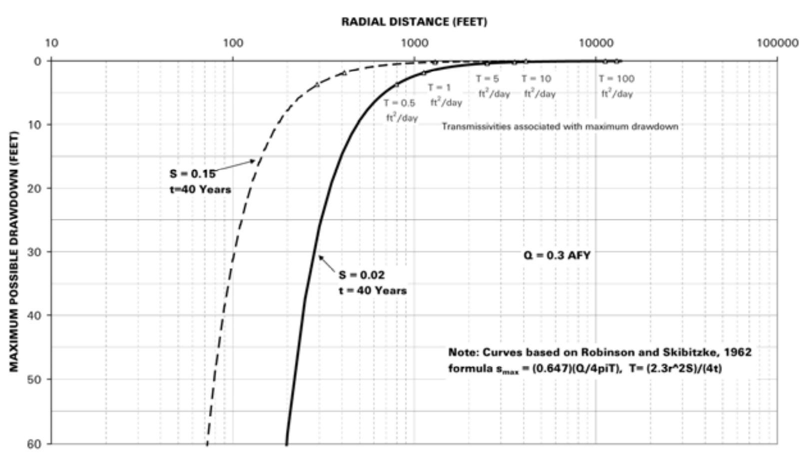


FIGURE 13
40-YEAR WATER TABLE DRAWDOWN IMPACT OF DOMESTIC WELLS IN THREE MODELED BASINS

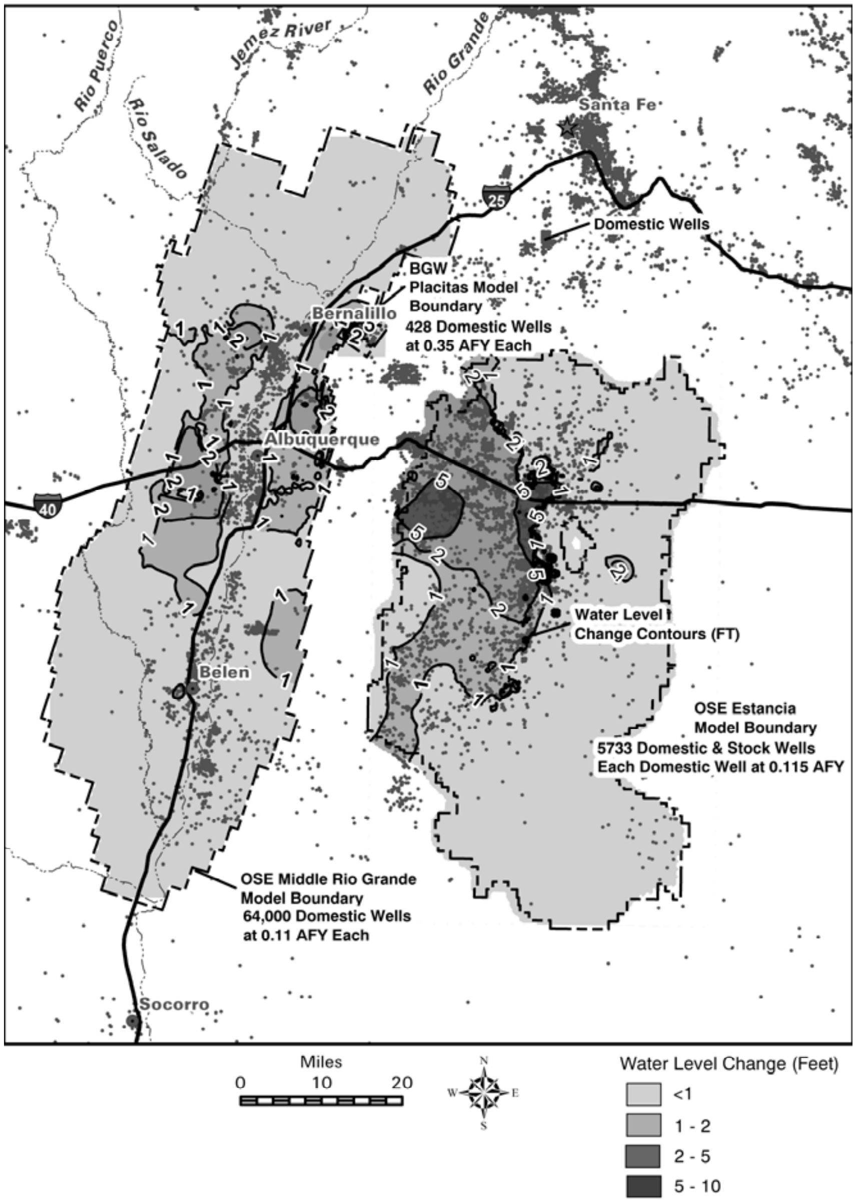


FIGURE 14
LAYOUT OF PERENNIAL STREAMS AND GROWTH OF DOMESTIC WELL DENSITY TO YEAR 2040 IN STATEWIDE MODFLOW MODEL

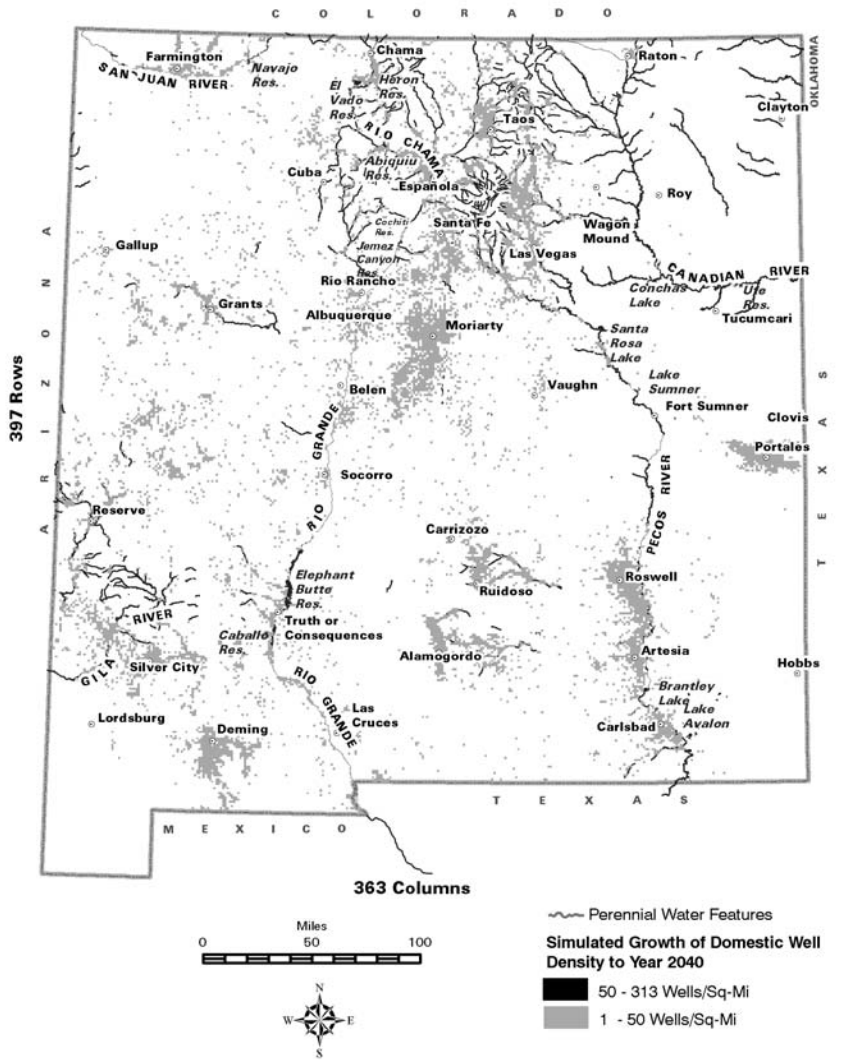
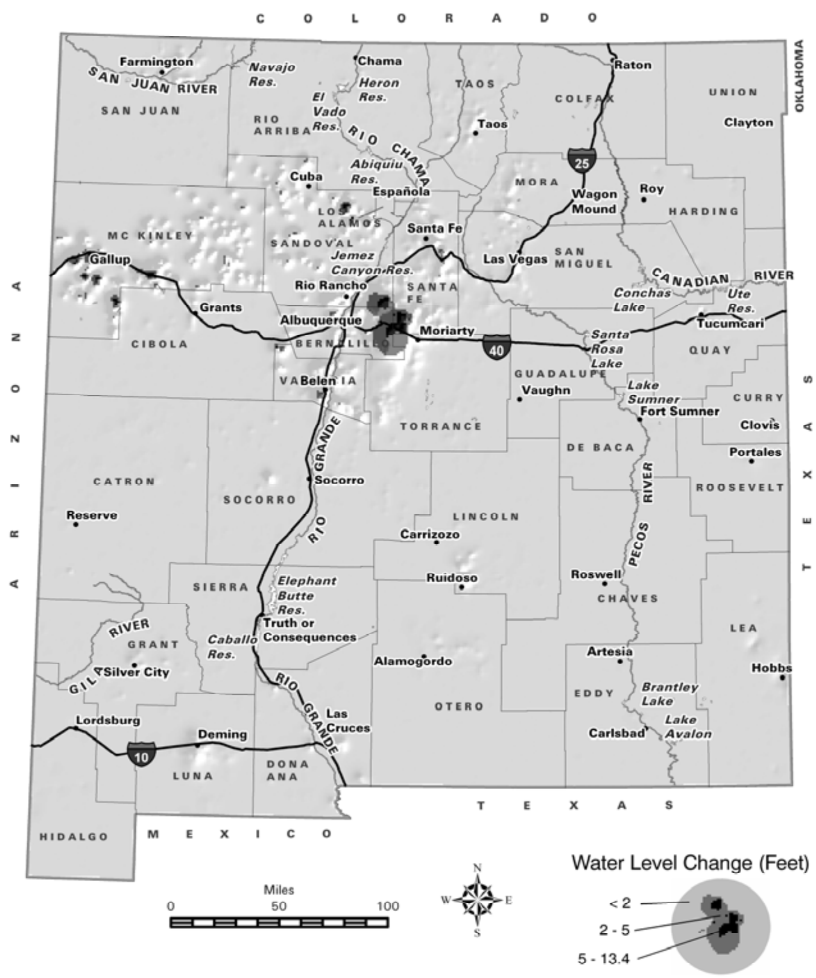


FIGURE 15
40-YEAR FUTURE DRAWDOWN IMPACT OF CURTAILING GROWTH OF WELLS IN NEW MEXICO



AUTHORS' RESPONSE[46]

"To overcome the isolation of scholars in various disciplines" is the *Natural Resources Journal* sentiment that prompted us to submit our hydrology article as background for legislative and administrative policy makers. Dr. Titus, both hydrologist and policy maker, is the epitome of our sought-after readers. He goes directly to the policy implications and concludes that the priority system should be supported as an influence for fairness and justice in negotiations over water. We concur on that point, but differ with his view that:

- Domestic wells have no valid rights but deplete water that comes from other people's valid water rights.
- Interstate stream commitments and CMA planned lifetimes are threatened by impacts of domestic well pumping and owners of valid rights must cover the shortages.
- Domestic wells must be brought into priority systems to protect and avoid "taking" pre-existing valid water rights and obtaining valid rights for domestic wells in CMA and in floodplain aquifers will correct the effects on valid right owners.

Titus is also concerned about double dipping on former irrigated land, annual permit renewal, well sanitary sealing, legislature approval for less than 3 AFY, and construction standards. He does not favor metering or absolute denial of domestic wells.

We favor the view that any intrusion of domestic wells into established priority may appear less offensive if domestic wells are found by the legislature and the courts to have valid and even preferred rights alongside others, and if the valuable social benefit to families outside public-supply service areas is appreciated. The valued water services come at relatively small hydrologic cost.

Our article quantifies the hydrologic effects of domestic wells subject to management on various interstate streams and CMAs:

Interstate Stream	Year 2000—2040 Impact Subject to Curtailment (AFY)	Average Flow (AFY)	Domestic Well Impact Ratio
Rio Grande	4430	1,083,000	0.0040
Pecos	200	134,000	0.0015
San Juan	250	1,598,000	0.0001
Gila	160	144,900	0.0011

46. This response is to Frank B. Titus, Ph.D., *On Regulating New Mexico's Domestic Wells*, 45 NAT. RESOURCES J. 853 (2005), which follows this article.

CMAs in the Albuquerque and Estancia Basins lose less than five feet of water level in the 40-year period, which is a similarly small percentage of the aquifers' resource base.

Domestic well impact at a few thousandths of the interstate streamflow is de minimus where, for example, the Rules and Regulations of the Rio Grande Compact Commission require their records to be accurate within ten percent.[47] The Middle Rio Grande water supply from Otowi and internal tributaries is half (650,000 AFY) delivered to Texas under the Compact, one-sixth (243,000 AFY) consumed by unmanaged riparian losses, and two-sixths (479,000 AFY) consumed by permitted uses.[48] The delivery to Texas exceeds New Mexico obligations by an average 19,000 AFY or more due to occasional spills from Elephant Butte. The spills exceed domestic well impacts. There is no historical example of Compact shortages being covered by valid rights in the Middle Rio Grande or in other interstate streams of New Mexico, because priority enforcement is unknown in the interstate streams of New Mexico. Domestic wells, therefore, are not penalizing other rights. Managing the large riparian depletion would yield a better payoff in terms of Compact deliveries.

CMA planned lifetimes are defined by the OSE in terms of "fully deployed" claims on file. Claims on file are four times existing pumping in the Estancia Basin. Less than one percent of the OSE defined CMA area would fail to meet the guideline criteria if actual pumping, rather than claims on file, were applied to the CMA-defining criteria. CMAs are administered by the OSE to protect empty claims that are not expected to survive adjudication due to non-use. That administrative practice may involve much more detriment to the use of valid rights than does the domestic well exemption.

As a practical matter, no water right owner has had to "cover shortages" caused by domestic wells because there is no administrative policy for such enforcement actions and no demonstrable damage to be covered.

Another hydrologic factor important to the problem of shortage is administration of the transferable amount in a change of place or purpose of use. For hydrologic balance, the transferable amount is the former net consumption (about 0.5 feet on floodplain irrigated acres) rather than the present practice of transferring consumptive irrigation requirement (2.1 feet). Throughout the floodplain areas, healthy

47. Commission accounts are published with 100 AFY implied accuracy, with the notation that they are based on "good" gaging records within ten percent of the true value.

48. S.S. PAPADOPULOS & ASSOCS., INC., DRAFT MIDDLE RIO GRANDE WATER SUPPLY STUDY (June 16, 2000).

vegetation is supported by moist soil from the shallow water table. After a transfer, that vegetation continues to use slightly less water than irrigated crops on the same land. The Compact stream depletion from permitted wellfield pumping in the Middle Rio Grande will grow another 44,000 AFY, ten times the projected domestic well effect, in the next 40 years according to the OSE administrative model. The slow historical creep in consumption and associated decline in Middle Rio Grande Basin Compact delivery is largely due to the practice of transferring 2.1 feet from thousands of agricultural acres to new M & I uses, rather than transferring the 0.5 feet per acre that is closer to the net project effect. Again, domestic wells are not the problem with Compact deliveries.

Under the heading "Water Rights Inflation," our article notes that the Middle Rio Grande permits that are recognized by the OSE as valid total 82,000 AFY more than the rights in exercise. The permits that go through administrative examination result in excess paper rights an order of magnitude greater than the unexamined domestic well permits. The unexercised empty rights are used to define CMAs. If those are the "valid rights" to be protected from taking by domestic wells, then they are protected for no apparent future use.

It is not obvious to us that obtaining rights for domestic wells from that body of empty rights would in any way correct the domestic well effects on other rights in exercise. Balancing the empty rights on file does not balance the water in the river. Administering empty paper rights (the ones largely available in the marketplace) is a more significant problem than any to do with domestic wells.

We are familiar as observers with some of the court decisions and governmental policies that lead us to a different understanding on the status of domestic well rights. The *Abousleman* court decreed domestic well rights priority, amount and transferability (312 pre-basin rights transferable and 164 non-transferable after 1973) and excused all domestic wells from priority enforcement.[49] Domestic wells seem to a hydrologist to have valid water rights on equal or superior footing with others in the decree.

49. Honorable Santiago Campos, Order Amending the Pretrial Order, June 22, 1987:

> The owners of minimal water rights…shall be exempt from any priority calls of other parties in the administration of the decrees entered hereafter in this cause. Minimal water rights are defined as: a) Domestic well uses…b) The use of groundwater for irrigation of not more than 1300 square-feet of land, c) The use of groundwater for livestock watering....

United States v. Abousleman, U.S. Dist. Ct. Civ. 83-1041-SC (D.N.M. 1983).

Nothing in the hydrologic situation has altered the supposed 1953 rationale for exempting domestic wells from an impairment analysis. The cost of policing domestic wells is minimized without harm. Our conclusion is that domestic well construction should be upgraded for the sake of the household users, not to protect other existing rights. Professional hydrogeologic oversight is not necessary to ensure a 60 to 100 foot margin of safety in the water column. Any driller can build a reliable well.

We concur with Dr. Titus's conclusion that the priority system needs support and we hope that Dr. Titus will join us in framing the relevant questions for consideration by the policy-making bodies. Some remaining questions that lie outside the hydrology sphere still deserve political answers from our citizen legislators:

1. Does household use of a domestic well create a secure water right?
2. Does 72-12-1 give legislative recognition to a de facto water right appurtenant to each household? Is that right derived from the domicile and household necessity, rather than from the OSE permit?
3. Is the human right to water in New Mexico indispensable, as declared by the United Nations?
4. Did the 1953 legislature recognize that domestic wells cannot dry one another up, and, therefore, they can be given a blanket approval without a particular impairment analysis? That is, after all, the approach being offered for water-bank impairment analysis today to reduce the cost of policing transfers during drought.
5. Should critical uses such as international treaties, interstate compacts, endangered species habitat, and basic levels of necessary household (domestic and public-supply) water have explicitly preferred standing during administration of priority?
6. Is it good policy to treat aquifers as an approved water-bank for families who need household wells?
7. If domestic wells were totally curtailed, can the OSE demonstrate that interstate shortages would be corrected?
8. Is a failure to deliver compact, treaty, habitat, or potable water obligations the responsibility of only certain categories of use: domestic wells? agriculture? big users? junior users (such as municipalities)? unmanaged riparian uses? state agencies?
9. Does mandatory water-right acquisition from other sources for new domestic wells accomplish any public-policy purpose?

10. Is the baseline of future consumptive use better protected by water-right transfer using the full CIR of the former use or by using the net hydrologic effect of the transfer?
11. Does double-dipping by domestic wells on retired water-right land have any different systematic impact than supplying the same household with water from off-site sources?
12. How would annual permit renewal affect administrative costs and consumer utility?
13. Is more command and control (active water resource management) needed from administrative agencies or more priority enforcement so water-right owners can manage their operations on a sound basis for themselves?
14. Would priority enforcement plus construction standards solve most issues between domestic well owners and other water users?
15. Are domestic wells among the most valuable, safest, and least harmful water uses in the state?