Technical Area: Soil and Water Resources
Technical Lead: Mike Conway

WORKSHOP REQUEST

16. Please provide the following documents cited in the Revised AFC:

(a) Sierra Scientific Services, 2003. Determination of Aquifer Storage Capacity for the Rosedale -Rio Bravo Water Storage District, Bakersfield, California, January 20.

(b) Sierra Scientific Services, 2004. An Evaluation of Well Placements and Potential Impacts of the ID4/Kern Tulare/Rosedale - Rio Bravo Aquifer Storage and Recovery Project. July 20.

(c) Sierra Scientific Services, 2007a. A Water Quality Evaluation of the Strand Ranch Aquifer Storage and Recovery Project, Kern County, CA., in: Rosedale -Rio Bravo Water Storage District Strand Ranch Integrated Banking Project Environmental Impact Report, January, 2008, prepared by ESA, Los Angeles, CA. December 19.

(d) Sierra Scientific Services, 2007b. An Evaluation of Well Placements and Potential Impacts of the proposed Strand Ranch Well Field, Kern County, California, in: Rosedale - Rio Bravo Water Storage District Strand Ranch Integrated Banking Project Environmental Impact Report, January 2008, prepared by ESA, LA., CA. December 20.

(e) Sierra Scientific Services, 2009. An Evaluation of the Geology, Hydrology, Well Placements and Potential Impacts of the Buena Vista Water Storage District's proposed Brackish Groundwater Remediation Project.

(f) Kern County Water Agency, 1991: Study of the Regional Geologic Structure Related to Groundwater Aquifers in the Southern San Joaquin Valley Groundwater Basin, Kern County, California (September, 20, 1991).

RESPONSE

Documents (a), (b), (c), (d), and (f) have been provided as Attachment 16-1. Document (e) is under preparation and is not yet available.

ATTACHMENT 16A

Sierra Scientific Services, 2003. Determination of Aquifer Storage Capacity for the Rosedale -Rio Bravo Water Storage District, Bakersfield, California, January 20.

Sierra Scientific Services

Determination of Aquifer Storage Capacity for the Rosedale - Rio Bravo Water Storage district, Bakersfield, California.

20 January, 2003

prepared for:

Rosedale - Rio Bravo Water Storage District

P.O. Box 867

Bakersfield, Ca 93302-0867

Attn: Mr. Hal Crossley, General Manager

(661) 589-6045

prepared by:

Sierra Scientific Services

2609 Highland Ct.

Bakersfield, CA 93306-2370

Attn: Robert A. Crewdson, Ph.D.

(661) 872-4221

SIERRA SCIENTIFIC SERVICES

2609 Highland Ct. Bakersfield, Ca. 93306 (661) 872-4221

20 January, 2003

Mr. Hal Crossley, Manager
Rosedale - Rio Bravo Water Supply District
849 Allen Road
Bakersfield, California 93302

re: RRBWSD District Storage Capacity Determination

Dear Hal,

On behalf of Sierra Scientific Services, I am submitting the final report on the determination of District storage capacity for your review. The work program meets and exceeds industry standards and practices and includes professional certification of all petrophysical analyses by a registered civil engineer. If you have any questions or comments, please call at your convenience.

Sincerely yours,

R. A. Crewdson

Robert A. Crewdson, Ph.D.

SOILS ENGINEERING, INC.

December 6, 2002 File No. 02-100127

Sierra Scientific Services
2609 Highland Court
Bakersfield, CA 93306

Attention: Bob Crewdson

Subject: Laboratory Testing for the Rosedale-Rio Bravo (RRB) Soil Borings

Dear Bob:

Attached herewith are the results of laboratory tests performed on samples retrieved from borings for the above referenced project. The following tests are included:

- Forty-eight (48) In-place Density & Moisture Determinations using ASTM test method D2216;
- Eighteen (18) Sieve Analyses, ASTM Test Method D422;
- Seventeen (17) Constant Head Permeabilities determined using ASTM test method D2434;
- Five (5) Specific Gravity Determinations performed by ASTM test method D854.

We hope this provides the information you require. If you have any questions or need further assistance, please contact our office.

Respectfully submitted,
SOILS ENGINEERING, INC.

REGISTERED PROFESSIONAL ENGINEER
TONY M. FRANGIE
No. 39549
Exp. 12-31-05
CIVIL
STATE OF CALIFORNIA

Tony Frangie, P.E.

TF:ch

Attachments (13)

Table of Contents

Determination of Aquifer Storage Capacity
for the Rosedale - Rio Bravo Water Storage district,
Bakersfield, California.

1. Summary

The purpose of determining the storage capacity under the District is to demonstrate project viability to interested parties and to aid in calculating the District water balance.

The objective of this work program is to quantify the aquifer storage capacity under the Rosedale - Rio Bravo Water Storage District. Under this work program, Sierra Scientific Services (SSS) evaluated 71 available E-logs and net sand analyses from local water wells, collected 98 core samples from three stratigraphic test- borings, analyzed samples for relevant physical properties, and developed a numerical relationship for the relevant aquifer volumetrics from analytic representations of the undulating water table surface within the District.

We performed the work program according to the specifications and limitations contained in our Scope of Work proposal of 14 October, 2002, which was based on fundamental hydrogeological principles and industry standards and practices.

Total Storage Capacity. The total storage capacity of the District may be defined as that hypothetical volume of water which could be stored in the entire aquifer within the boundaries of the District if it were completely filled from the base of the aquifer to within twenty feet of the ground surface. Based on SSS's findings, the total storage capacity (SC_T) of the District is 6,510,000 acre-ft of water, assuming the base of the aquifer is defined as occurring at a depth of 720 ft. If the base of the aquifer is deeper than assumed, then the total storage capacity is larger than reported.

Current Storage. The current storage is defined as the actual volume of water currently stored in the aquifer below the water table within the boundaries of the District. The volume of water currently in storage is 5,580,000 acre-ft, based on a District- wide average depth to

water of 120 ft. For comparison purposes, the average annual ground water extraction for in-District consumption is 7,000 af/yr[1] . The average annual pumpage is within the safe- yield allocation and represents 0.13% (13 hundredths of one per cent) of the ground water currently in storage.

Available Storage Capacity. The available storage capacity is defined as the volume of water that could be stored in the unsaturated zone above the water table within the boundaries of the District up to within twenty feet of the ground surface. Based on SSS's findings and on a District- wide average depth to water of 120 ft, the available storage capacity (SC_A) of the District is 930,000 acre-ft of water.

For a changing water table, the available storage capacity increases or decreases by approximately 9,300 acre-ft for every one-foot of District-wide increase or decrease in the depth to water, respectively. In general, however, the water table surface changes in depth, shape, and/or orientation differentially rather than uniformly under the District, and there is no general formula which can be used to determine the changes in storage capacity. The determination of available storage capacity requires the correct determination of the bulk aquifer volume between the ground surface and the irregular water table surface under the entire District for each and every configuration of the water table, which we discuss below.

Calculation of Bulk Aquifer Volume. In our opinion, this is the most difficult part of the entire storage capacity determination. There is no explicit formula for the calculation of the aquifer volume under the District. The general formula must be evaluated numerically for each and every configuration of the water table using small partitioned subareas comprising the entire area of the District. Since the depth to water is not measured everywhere within the District, we interpolated into every partition by analytic substitution from the known measurements and then calculated the sum of products. We developed the specific algebra within this work product and tabulated some usable coefficients for this particular District.

Average Depth to Water. The water table surface under the District is an undulating, irregular, non-planar, non- horizontal surface in space and time. This undulating surface is the

[1]The average annual District consumptive use is 84,000 af and the average adjusted annual water supply is 77,000 af. See Boyle Engineering Corporation, July, 2001, Final MEIR, RRBWSD, Table 5, columns 2 & 15, 23-year averages (1978 - 2000).

physical boundary which separates the unsaturated zone from the ground water and thus separates available storage volume from actual water-filled aquifer volume. There is no explicit formula for calculating the average depth-to-water under the District and there is no shortcut for its determination apart from full numerical evaluation over the entire area for a specified configuration of the water table.

We can easily demonstrate that the simple average of the depth to water in the District wells *does not* give the correct result and generally results in a significant error. In our opinion, formulas which purport to calculate the value of the average depth to water under the District are most likely using an incorrect formulation (or at least a sloppy approximation) unless it can be shown that it is equivalent to an area-weighted integration over the entire area of interest. The correct average depth to water may be calculated by dividing the independently- determined total bulk volume of the unsaturated zone by the total District area.

Aquifer Materials. The aquifer under the District is composed of sandy, silty, and clayey sediments. Based on SSS's findings, the amount of clay layering is negligible with respect to its contribution to the storage capacity and the relative abundance of the sands and silts may, therefore, be described with just two parameters, the total aquifer thickness (H) and the net-sand fraction (F_{sand}). Under conditions and assumptions which are applicable to the District, the formula for equivalent specific yield may be approximated by the summation: $Sy_{eq} = \{Sy_{sand} \cdot F_{sand} + Sy_{silt} \cdot (1-F_{sand})\}$, where Sy is the specific yield of a particular sediment and the entire {...} term is the "average" or equivalent specific yield of the aquifer. Based on SSS's findings, the parameter values within the District are summarized in Figure S1.

Physical Properties. The volumetric specific *storage capacity (SC)* of aquifer material, as previously defined, is the sum of two components; the fillable (and drainable) void space in a rock or sediment which is at residual saturation, and a much smaller component which is a result of the small elastic dilation of this void space when the water in a confined aquifer is under pressure. The first component is termed the *specific yield (Sy)* and the second component is termed the *specific storage (Ss)*. For non-hydrologists, the terms may appear to be synonymous and perhaps misleading, and both are different from a third, similar-sounding term known as *storativity (S)*. The definitions of each are clearly established and the differences are well- understood by most ground water hydrologists. We are interested in *storage capacity (SC)*.

For layered aquifers we must determine the "index properties" of each type of sediment within the aquifer. Based on the appropriate aquifer geometry, we then calculate an equivalent specific yield for all aquifer layers from the thicknesses and index properties of all layers.

We determined that the specific storage (Ss) is negligible ($0.0005 < Ss/Sy < 0.00005$) compared to the specific yield (Sy) so we do not consider it in the calculation of storage capacity for this work program. Based on our experience, it is also difficult and often inaccurate to measure Sy directly, so we determine our index values of Sy indirectly but more accurately based on conventional means from hydrogeological principles. We determine the specific yield from measurements of porosity (ϕ) and in-situ residual saturation (S_r) of each layer (of every type of sediment) within the aquifer.

Water Balance. The District currently calculates an annual water balance by accounting for all allocated inflows, consumption, and losses. The account *reconciliation* term, which is calculated as all gains minus all losses, is used to balance the account by arbitrarily, but improperly, defining it as the change in District ground water storage.

In our opinion, this method can be improved by accounting for the movement of actual physical water, for example, by measuring the true annual change in aquifer storage and then using the reconciliation term to evaluate other ground water components which affect the water balance but which are currently excluded from consideration.

2. Discussion

Section I - Work Program.

The technical elements of the work program are based on the practical evaluation of material properties and the cumulative total of those properties summed up over an aquifer volume of specified size, but irregular shape and thickness. The breakdown of the work program into specific tasks and the selection of particular computational formulas are based on our understanding of the structure (distribution and variation of properties) within the specific area of interest.

Section II - Field Crew.

Dr. Robert A. Crewdson is a Bakersfield, California consultant doing business as Sierra Scientific Services (SSS). SSS specializes in quantitative ground water hydrology and applied potential theory, including quantitative ground water flow analysis, water quality geochemistry, well testing and monitoring, contaminant transport modeling, and aquifer properties determinations. Dr. Crewdson is an adjunct professor at California State University Bakersfield where he teaches hydrology, contaminant transport, geochemistry and geophysics in upper division and graduate level courses.

For this work program, SSS supplied the program design, geotechnical field crew, sampling expertise, onsite supervision, and subcontracted the drilling and petrophysical analyses to Soils Engineering, Inc., of Bakersfield, under the responsible charge of registered civil engineer, Mr. Tony Frangie.

Section III - Methods.

The determination of storage capacity (SC) has three parts: the first is based on fundamental hydrogeological principles in which the fillable void space within a representative volume of each type of aquifer material is measured through standardized procedures; the second is to determine the relative abundances of each aquifer material through an evaluation of E-logs; and the third is based on analytic geometry in which the volumes of the aquifer above and below the water table surface (on a given date) are calculated from analytic approximations of layer-like shapes bounded by irregular top, bottom, and side-surfaces. The final result is an algebraic combination of all parts.

The standard engineering approach (which we did not use) is to drill a test boring to determine the storage capacity (or average specific yield) at that location, and then drill a sufficient number of additional test borings to determine the variability between locations until a representative average value has been obtained. This method, however, is susceptible to unnecessarily large uncertainties because it relies entirely on large numbers of borings fully penetrating the aquifer to reduce the variability in the data and does nothing to optimize the cost or technical effectiveness of the procedure.

Based on our experience, we chose to design the sampling program similar to procedures used in the mining industry which is noted for its statistically efficient, robust, and cost-effective sampling programs (for example, see Koch and Link). The statistical basis for determining the kinds and numbers of samples is based on partitioned- variance sampling methods and this program included both hierarchal sampling and randomized block analysis. We determined average property values for each type of sedimentary layer and then separately determined the relative abundances of these layers, decreasing the overall variability by separating it into parts. The determination requires that we collect and test a sufficient number of representative samples of all aquifer materials for indexing the physical properties including density, moisture content, porosity, and ambient saturation. We then determined the relative sediment abundances by using E-logs from many existing wells rather than drilling many stratigraphic test wells in our own sampling program (and rather than extrapolating such information from the few wells that we actually drilled).

For unconsolidated sediments as in this work program, we also determined certain important sediment properties, but especially the *effective* grain size (d10) and the coefficient of uniformity, Cu, (aka degree of sorting) from a sieve analysis of every tested sample. In our experience, the geologist's distinctions between sands and silts are less accurate for our purposes than those determined from d10 and Cu with respect to measured properties and how they correlate with lithologies determined from E-logs. It is also our opinion that the standard engineering use of the uniform soils classification system (USCS) for sample descriptions is useless for this type of program because it is based on an entirely different set of properties and intended uses.

Sampling Method. The sampling method consisted of collecting triplicate core samples every ten ft in three auger holes drilled in representative locations and as deep as necessary

(>100 ft) to determine the lithology, porosity and degree of saturation in the unsaturated zone above the water table. We prepared a lithologic log during drilling which was based on a continuous evaluation of drill cuttings (Appendix 1) and prepared chip trays of ditch cuttings at five-ft intervals for all three borings for future reference. We also prepared daily drilling reports as a record of onsite operations (Appendix 3).

We obtained the core samples in standard $2^3/_8$ x 6-inch brass sleeves using a modified California split-spoon sampler. After being pulled from the borehole, we inspected them for basic identification, recovery, uniformity and suitability for testing before capping, sealing, and storing them for transport to the lab under record of daily chain-of-custody documents (Appendix 2). In our opinion, this inspection is a very important, but often under-emphasized or missing, part of some sampling programs. This inspection process is usually the only quality control (QC) that the sample receives before it is handed over to a lab technician to be tested. We always use this opportunity for QC to carefully determine whether or not the sample is actually a sample of what we are trying to test and whether or not it is uniform-enough that the measured results can be considered representative of what we are trying to measure.

Each core sample was evaluated in the field for two basic parameters: 1. the field classification of the sample as either sand, silt, or clay, and 2. the uniformity of the sample from end-to-end for a determination of its suitability for testing. Since the purpose of the sampling program was to measure the index properties of key aquifer materials and not the determination of site-specific values, our primary field priority was to collect and evaluate samples for their homogeneity and appropriateness for testing.

Testing Methods. The laboratory performed the tests according to the appropriate ASTM standards, as follows:

ASTM D2216	moisture	ASTM D2435	consolidation
ASTM D2937	tube density	ASTM D2434	permeability
ASTM D422	sieve analyses	ASTM D854	specific gravity

We report the results of petrophysical tests in Appendix 4 and the results of sieve analyses in Appendix 5 and the Data Tables.

E-log Evaluation method. For our purposes, the determination of storage capacity requires that we know the relative abundances of sand, silt, and clay layers in the entire aquifer thickness. We evaluated 32 E-logs from wells in the District and surrounding area by measuring the cumulative thicknesses of sand, silt and clay layers in the aquifer. With permission, we also reviewed and evaluated the net sand analyses completed by Tom Haslebacher of the KCWA on another 41 wells in the Pioneer Project and selected other wells. We evaluated the sand thicknesses three times on each log, each based on a different numerical value of log response for sand: 1) bulk resistivity greater than 15 ohm-m, 2) greater than 30 ohm-m, and 3) greater than a moving clay-base resistivity plus 15 ohm-m. We tabulated and analyzed the E-log data for all 73 wells (see Data Tables).

Average depth-to-water determination method. During most years, the water table surface under the District is relatively well-behaved, meaning that in almost any season of any year it might *generally* be described by dividing the District into several subareas under each of which the water table surface is approximated by a plane surface of determinable depth, slope, and orientation under a west-sloping topographic surface. To determine the available storage capacity, we must determine the bulk volume contained between these two surfaces for each subarea. The calculation of this bulk volume is a fairly tedious, if not complex, problem of analytic geometry involving an integration between two trend surfaces. Fortunately for the District, we only have to do the derivation once and can re-calculate for different data relatively easily, because we foresee a significant future need to do this calculation carefully and completely for other water table conditions. Nevertheless, we recognize a serious and common pitfall in the calculation that deserves mention below.

In practice, there are two methods of calculation. The first volume calculation is accomplished by multiplying the total area of the District times the average depth to the water table. The average depth to water is determined by collecting a sufficient density of depth-to-water measurements throughout the area; plotting, contouring, and gridding the data on a map; summing up the depth-to-water in each and every cell and then dividing by the total number of cells to give the average depth-to-water under the District. The process can be done by computer and merely requires inputting all of the surface elevation and depth-to-water data into a program that does the gridding, contouring, and integration calculations, but there are otherwise no shortcuts.

The serious pitfall to this method is to be tempted to calculate the average depth to water by merely averaging the depths to water as measured in the wells. This will not give the correct result unless there are sufficient wells to delineate the trends in the water table surface *and* they are equally-spaced across the entire area of interest. A simple test of calculating the volume both ways will convince the user of the truth of this warning. If the reader is still not convinced, then another test would be to eliminate the data from three wells selected at random as if they had never been drilled and recalculate an average depth to water to see if you obtain the identical result, as you must if the method were correct.

The second method of volume calculation is to fit one analytical model to the ground surface and another analytical model to the water table surface and then do a piecewise continuous summation of the integrated volumes under pre-selected areas of fixed geometry. The initial algebra to set up the models is tedious but, once determined, the result is a straightforward formula, perhaps formulated in a spreadsheet, which would immediately calculate the total volume based on the input of the depth-to-water at specified reference wells, and as an incidental additional output also provide a value of average depth to water.

Section IV - Equipment.

The SSS work program equipment included the following items:

- CME 75 hollow-stem auger drilling rig;
- modified California split-spoon samplers;
- miscellaneous geological field equipment;
- proprietary computational software.

Section V - Field Operations.

We drilled one test boring at each of three locations including: SC-01 near the center of the Allen Rd recharge ponds, about a half-mile north of Stockdale Hwy and Allen Rd (35° 21.828' N, 119° 09.039' W); SC-02 near the southwest corner of Mayer Rd and Highway 58, which is near the geographic center of the District (35° 23.876' N, 119° 17.251' W); and SC-03 near the center of the new Paul Enns recharge ponds about 1.5 miles northwest of Stockdale Rd and Enos Ln (35° 21.931' N, 119° 16.422' W).

We drilled SC-01 on Wednesday, 30 October, 2002. The site was sunny with scattered overcast and a mild breeze all day with a relative humidity of 44% and a temperature of 61° F at 0820 local time. We drilled SC-02 on Thursday, 31 October, 2002. The site was sunny with scattered overcast and breezy until mid-afternoon with a relative humidity of 45% and a temperature of 54° F at 0805 local time. We drilled SC-03 on Friday, 01 November, 2002. The site was sunny with scattered overcast with a relative humidity of 37% and a temperature of 55° F at 0805 local time.

We drilled all three borings to a depth of 100 ft which we considered to be a sufficient interval for sampling the unsaturated zone. We chose these well-separated locations to be broadly representative of the important parts of the District. We also chose the specific locations in detail for their different surface-water interactions. We located SC-01 within the main recharge pond so that of any location, this one would have had the largest volume and most-recent surface water percolated through the unsaturated zone. We located SC-02 far away from any recharge facilities and in an uncultivated area at a distance from any irrigation or other source of surface water. We located SC-03 in the center of a newly-constructed recharge pond which had never received water prior to the time we collected our samples and had been fallow prior to construction.

We were very careful to look for and record any qualitative measures of soil moisture, since the best opportunity to investigate anomalous soil moistures is usually in the field. All three holes drilled dry but not dusty, except for a "wet" interval at the bottom of SC-01 where we expected to hit the water table, and another at 60 ft in SC-03, where we apparently hit (just a little) perched water.

Section VI - Findings.

We have provided a summary of the data in Table 1, we present the raw and processed data in the other Tables and Appendices, a location map and graphs of selected data in the Figures. We have included copies of the original field notes and field data recording sheets including borehole logs in Appendix 1, chain of custody documents in Appendix 2, daily drilling reports in Appendix 3, petrophysical data in Appendix 4, sieve analyses in Appendix 5, a list of reference wells and average depth-to-water coefficients in Appendix 6, a copy of the DWR specific yield data in Appendix 7, and a set of viewgraphs in Appendix 8.

Section VI.1 - Aquifer Geology.

Based on E-logs from many wells drilled through the aquifer and the lith-logs and samples from the unsaturated zone in the three test borings, the aquifer appears to be a stack of interbedded, unconsolidated sandy and silty layers in almost equal proportion. Based on borehole lithology, the so-called sandy layers are well-sorted fine to coarse-grained sands with an overall effective grain size of fine sand. The so-called silty layers include fair to poorly sorted silty sands, sandy silts, silts, and clayey silts with an overall effective gain size of medium to coarse silt. Evaluating the lateral continuity of these layers and the structure of the aquifer was outside the scope of this work program and is unnecessary for this evaluation.

Sierra Scientific uses standard geological classification based on the texture and composition to identify a sediment. For sediments, the two primary classification textures include the Wentworth grain size and the degree of sorting in which sands have grain diameters in the range ($.062 < d < 2$mm), silts have grain diameters in the range ($0.004 < d < 0.062$ mm), and sorting is described from very good to very poor by a coefficient of uniformity in the range ($1 < C_u < 10+$). For sediments, the primary composition is reported as the volumetric grain percentages for the common rock- forming minerals. The sands and silts in this area of interest are composed of sub-angular to sub-round, equidimensional, clastic grains consisting of 70-85% quartz, 10-15% K feldspar, 5-10% biotite, 1% magnetite, 1-3% other mafics, and 0-5% lithic fragments. The sands are well-sorted and the silts are fair - poorly sorted[2]. Both sediment types are predominantly the weathering products of Sierran granitic rocks and re-worked, previously- eroded deposits from the same original sources, then transported and deposited by the Kern River within the last million years or less.

Based on our observations, clay is present in some strata but it mostly occurs as a fine fraction (up to 20%) in poorly sorted, silty sediments, and only rarely as thin (few inches or less thick) layers of true clay (>50%). We estimate the presence of true clay layers at 2% or less.

KEY FINDING: The entire aquifer can be described as being composed of alternating layers of varying thickness of either well- sorted, fine-grained sand or poorly-sorted, medium-

[2]The degree of uniformity of grain sizes within a sediment is called *sorting* by geologists whereas this property is called *grading* by engineers. Geologists reserve the term *grading* to describe an orderly change in grain sizes in a progression of thin beds. We use geological terminology.

coarse-grained silt in which clay comprises a minor fraction in some poorly sorted sediments. The sequence of layering and the thicknesses of individual layers are unimportant for this evaluation, except that we must be able to determine the relative abundances of each fraction within the aquifer.

Section VI.2 - Petrophysics.

Sediment classification. Based on our observations of grain size distributions, the geologist's textural classification of the aquifer sediments includes sands, silty sands, and sandy silts. We encountered no samples of "silt" and only two occurrences of thin (about 1 inch thick) layers of clay, although some small percentage of both must exist somewhere within the stratigraphic column.

For our purposes, all of the sediments may be classified according to "effective grain size" which might be defined as the equivalent, well-sorted sediment that would have the same physical properties as the real sample. Based on our observations of grain size distributions, the samples may be described as either well-sorted, fine-grained sands or poorly-sorted, fine- to very coarse- grained silts. Hereafter we will generally refer to these two types of sediments as just "sands" or "silts" but, when we do, we specifically refer to the District sediments which we have just categorized as such by this analysis.

Porosity. Based on our observations, the porosity of the sands and the silts are statistically the same at an average 35% porosity. This has important implications for the E-log analysis which we discuss below.

The other petrophysical properties including permeability, water content, residual saturation, and specific yield are all bi-modally distributed; each property of the sandy sediments forms one population and the same respective property of the silty sediments forms a second, distinct population.

Permeability. Based on our observations, the sand is about 300 times more permeable than the silt, and the silt is about 80 time more permeable than the clay. The hydraulic conductivity of the sands is an average 18.0 ± 3.9 ft/d; that of the silts is an average 0.057 ± 0.051 ft/d; and that of two clay samples is an average 0.00076 ± 0.00035 ft/d. These values are based on 1-D, vertical permeabilities measured on the tube samples and we have not evaluated how these values correlate with the in-situ properties. We also note that, while vertical conductivities are particularly useful in the unsaturated zone where most flow is vertical, the vertical permeability is commonly less than the horizontal permeability of the same material by perhaps an order of magnitude at a macroscopic scale.

Specific yield and Water Content. Based on our observations, the specific yield of the sands is an average 33.6 ± 2.5 %; that of the silts is an average 8.6 ± 6.3 %; and that of the clay is unmeasurably small. We actually measured gravimetric water content of the samples and then converted them to values of ambient saturation. The ambient saturation of the sands is an average 11.0 ± 3.6 %; that of the silts is an average 68 ± 27 %; and that of two clay samples is an average 98%. From these data we directly calculated the equivalent specific yield of these materials assuming that the ambient saturations represented the residual saturations of these sediments under the sampling conditions.

The calculation assumes that the ambient water content under the observed conditions is approximately at residual saturation. We have assumed that these three locations, one of which has been subjected to an unknown but possibly significant history of recent surface- water infiltration, have all had sufficient time to drain down to specific retention. To the extent that these sediments are not fully drained, we have actually underestimated the storage capacity of these sediments.

As previously mentioned, we paid special attention in the field to identify anomalous water contents during drilling, especially for the purpose of identifying samples which might not be a residual saturation, including samples from strata containing perched-water. We identified two such zones and eliminated those samples from consideration.

On the other hand, we also recognize that shallow sediments from areas which are chronically devoid of infiltration may become dessicated by soil-air circulation resulting in a water content lower than that which can be achieved naturally by gravity drainage alone. Therefore, we generally avoid using samples from within 20 ft of the ground surface, or even deeper in arid situations where the data indicate deeper effects.

Based on published data, the time required for a soil to drain down to residual saturation may be measured in weeks, months, or years, depending on the effective grain size of the sediments. For our purposes, we are more concerned with how much water can be effectively drained from the aquifer during realizable time periods under realistic operations, than with the theoretical maximum amount of water which might be drained from the aquifer if it were de-watered for a very long time period. Specifically, we define the storage capacity of interest as the so-called "effective" storage capacity which provides a measure of how much water is normally yielded by the aquifer for a drop in water table in a normal annual cycle of recharge and recovery, even if some additional water might be yielded if the aquifer were hypothetically drained for an infinite time period. As such, the physical property that we are measuring in this work program is the "effective" specific yield.

There is no recognized, single measurement that can determine the true state of drainage of a sediment when measuring the water content of an unsaturated sample. The appropriate method of evaluation in suspicious ground is to make repeated measurements over time and while monitoring the wetting history of the area of investigation. But it remains the responsibility of the investigator to make a judgment or to determine the representativeness of the data. In our opinion, these water content data represent adequate estimates of the residual saturation of these particular sediments.

<u>DWR specific yield data.</u> For comparison purposes, we reviewed the specific yield data which the California Department of Water Resources used into their Modflow (tm) computer model of the local ground water basin, including nodes 107 - 109 & 124 - 128 which cover the RRB District area of interest (see Appendix 7; Swartz, 1995 & DWR Kern Fan Element Input Data, 5/16/90). The DWR model uses a single value of 6% for the specific yield for 2 types of sand, 3 types of silt, and 4 types of clay. The DWR model uses a single value of 17% for silty sand and 5 types of gravel; uses 20% for fine sand; and 30% for all grain sizes from medium sand through fine gravel, except for 27% for a mixture of gravelly- sand. Based on their data, we would have used 6% Sy for the silt and 20% Sy for the sand, compared to our measured values of 8.6% and 34%, respectively. These DWR values significantly underestimate the storage capacity of the aquifer and may be significantly different than the true values on a cell-by-cell basis throughout their model. We also note, based on our evaluation of their parameter calibrations, that their computer model uses synthetic values of T, S, and K which were derived directly from their values of Sy within each cell. We recommend to Rosedale that the District

not use the DWR values of Sy, T, S, K, or the results of the DWR computer simulations, because we consider the DWR parameter data to be uncorroborated and suspicious based on comparisons with actual measurements and on theoretical considerations.

KEY FINDING: Based on our observations, the effective specific yield of the sandy sediments, as defined herein, is an average 33.6 ± 2.5 %; that of the silty sediments is an average 8.6 ± 6.3 %; and that of clay is unmeasurably small.

Section VI.3 - E-log Analysis.

The purpose of the electric log (E-log) evaluation was to determine the relative abundances of the significant types of sedimentary layers within the aquifer. An electric log is recorded by a tool which has been lowered down an uncased drillhole and results in a continuous plot of the measured value of electrical resistivity versus depth. E-logs are commonly but not always measured after a well has been drilled but before casing has been installed. The unit of resistivity is the ohm-meter, abbreviated (Ω·m).

Correlation. The interpretation of E-logs in water-saturated sediments is based on a correlation between the measured resistivity and two properties of the sediments themselves, i.e., the porosity and the resistivity of the water within the porosity. From experience, we generally find that the resistivity of sandy sediments is higher than the resistivity of clayey sediments, and the resistivity of silty sediments ranges widely between the other two. If we ignore the various interpretive complications which are known to result from what might be called "spurious tool responses", then we can make a simple interpretation of the E-log by dividing it into intervals of high, medium, and low resistivity and assume that these intervals contain sand, silt, and clay, respectively. The main interpretive issue, then, is what boundary values of resistivity do we use to define the dividing line between intervals of high, medium, and low resistivity.

Based on our observations, there isn't any significant clay layering in the aquifer, so we were only concerned with the relative abundances of sand and silt, as defined herein. Therefore, we only needed to select a value of resistivity which divided the E-logs into intervals of higher and lower resistivity, and then assume that these represented sands and silts, respectively. In our opinion, this assumption must be justified for each and every E-log analysis because it is not always true and must be evaluated for each area of investigation.

We evaluated most of our E-logs using three different criteria, all of which have been previously used by other workers in the Kern County area of interest. The first criterion was to define sands or silts as having resistivities more than- or less than- 30 Ω·m; the second criterion was to define sands or silts as having resistivities more than- or less than- 15 Ω·m; and the third criterion was to define sands or silts as having resistivities more than- or less than- the minimum "resistivity-base-value" found in each interval on the log plus15 Ω·m. Clearly, the use of the 30 Ω·m value results in a smaller sand fraction and the 15 Ω·m value results in a higher sand fraction.

The discrepancies in the relative fractions which are determined from using the first and second criteria are mostly the inevitable shortcomings from using "rules-of-thumb" to overcome spurious tool responses rather than hiring a log analyst to do the proper job. We chose to use the third criterion to minimize the arbitrariness of the other two numbers because it more-consistently divides the log into two groups with higher or lower values without requiring either to fall within specific ranges of absolute resistivities. It is a conservative criterion in that it is very difficult for a silt to be mis-interpreted as a sand, but this is at the expense of an unknown amount of sand being mis-interpreted as silt. The result is that the net-sand fraction that we report is near the lower limit of the locally accepted range of interpretations of the net sand fraction.

Clay factor. This interpretive technique is also based on the presumption that sands and silts have widely different E-log resistivities which, unlike sands and clays, may or may not be true and at least remains to be substantiated. The consequence of misinterpreting the E-logs on such a false presumption would be to conclude that low-resistivity sediments were silts when in fact they were clays and, as a result, overestimate the storage capacity for that fraction of the aquifer. So we have done some additional interpretive analysis to try to substantiate the correlation between high and low E-log resistivities with the presence of sands and silts, rather than the presence of sands and clays.

As previously mentioned, the measured resistivity is a function of both the porosity and the resistivity of the water in a sediment. But we have determined that the porosity of the sands and silts within the area of investigation are statistically identical, so we cannot attribute changes in resistivity to changes in porosity within these two types of sediment. Based on a review of available water quality data, we can also conclude that there are no observed variations in aquifer salinity that could explain the variation in resistivity, so why do we see any character at all in the E-logs?

The normal explanation would be that the E-logs are, in fact, responding to clay which we are trying to mis-interpret as silt. But we have access to other data which provides for a more-applicable explanation, in our opinion. Sierra Scientific Services has completed three major soil- resistivity surveys for clients within the immediate area in the last two years. While the data remain proprietary at this time, one of the clear and reportable results of this work was to identify a significant ion-exchange capacity of silty sediments which does lower the bulk resistivity of the sediment, but does not lower the resistivity of formation water which has been extracted for general mineral analysis, especially for low-salinity formation water as occurs in the District. This behavior is well- recognized in the literature (see Keller and Frischknecht, 1970; see also Schlumberger, 1972) and is a disproportionately large effect for a relatively small amount of clay particles within the silty sediments. Based on our data, there is sufficient clay content within these poorly-sorted silts to explain the reduced resistivity of the silty intervals. We conclude, then, that we have a logical basis for interpreting the E-log resistivities to determine the fractions of sand and silt in the aquifer within the District and we report the sand and silt fractions from 71 E-log analyses in the data tables.

E-log calibration. The tool-response issues which are most relevant to our interpretation are those which cause sand layers to be mis-interpreted as silts, i.e., the E-log response through a true sand interval fails to register a high-enough resistivity to meet our resistivity criterion for sand. The result is that true sand intervals are incorrectly counted as silt intervals and the size of the error increases as the resistivity criterion increases.

The significance of the issue is most apparent by looking at the differences in net sand fraction which result from the three different correlation criteria that we have used. If we assume that sands have E-log resistivities greater than 30 Ω·m, then the aquifer is 40% sand. If we assume that sands have E-log resistivities greater than 15 Ω·m, then the aquifer is 73% sand. This difference in interpretation places the properties of a 230- ft thickness of the aquifer in dispute, and is mathematically equivalent to underestimating the total storage capacity of the District by a maximum 2,650,000 af.

Although we are aware of these issues and know how to evaluate them, it is outside the scope of this work program to refine the interpretation. Nevertheless, if and when storage capacity measurements are used in the calculation of a ground water balance, then we recommend that such a work program be completed to determine the correct interpretive correlation between E-log response and properties of interest. We recommend that such a program include logging, sampling, and interpreting the same interval in the same stratigraphic test well and then producing an interpretive report which can be broadly applied throughout the Kern Fan area.

KEY FINDING. Based on the third criterion discussed above and on supplementary proprietary data, we have determined that the District-wide average sand fraction is 50%, and the District-wide average silt and clay fractions are 48% and 2%, respectively.

Section VI.4 - Calculation of Aquifer Volumes.

In our opinion, this is the most difficult part of the entire storage capacity determination when it involves calculating volumes which are bounded by the water table surface. Such a calculation may occur twice, once to calculate the available storage capacity above the water table and once to calculate the actual volume of water in the aquifer below the water table. There is no explicit formula for the calculation of the aquifer volume under the District, mainly because of the irregular shape of the water table surface and the irregular perimeter to the District. The general formula for irregular volumes must be evaluated numerically for each and every configuration of the water table using Riemann sums of the products of centroidal depth-to-water times small partitioned subareas comprising the entire area of the District. Since the depth to water is not measured everywhere within the District, we must also interpolate into every partition by analytic substitution from the known measurements and then calculate the sum of products. We developed the specific algebra within this work product and tabulated some usable coefficients for this particular District.

Definitions. We define the top of the fillable aquifer to be twenty (20) ft below ground level and we define the bottom of the aquifer to be 720 ft below ground level. Since the ground surface across the District slopes westerly at about 6 ft per mile, then the top and bottom surfaces of the aquifer, as defined, have similar slopes and orientations. The total aquifer volume for this aquifer geometry can be calculated as the total area times the (constant) net thickness. The correct datum for volumetric calculations that involve the water table is the sloping ground surface, not sea level, so the appropriate mensuration of the water table surface should be based on depths below ground level and not on elevations.

Derivation. We have derived (see Tables) the appropriate expression for the volumetric storage capacity from the integrated analytic approximations for twenty five cells grouped into four subareas within the District. We have also derived an equivalent expression that provides for the direct calculation of the average depth-to-water which will yield the correct aquifer volume when multiplied by the total area of the District. We can also provide the same valuations for each of the four subareas and the twenty five individual District partitions.

The resulting numerical formula to calculate the average depth to water within the District for any specified date and for rising, falling, or static water level conditions uses the depth-to-water measurements from twelve reference wells: $d_{AVG} = K_1 \cdot Z_1 + K_2 \cdot Z_2 + K_3 \cdot Z_3 + K_4 \cdot Z_4 + K_5 \cdot Z_5 + K_6 \cdot Z_6 + K_7 \cdot Z_7 + K_8 \cdot Z_8 + K_9 \cdot Z_9 + K_{10} \cdot Z_{10} + K_{11} \cdot Z_{11} + K_{12} \cdot Z_{12}$, where the Z values are the water depths in the twelve respective reference wells {1 ... 12} and the coefficients $\{K_1 \ldots K_{12}\}$ are empirical constants which have been derived from the analytic summations. We list the reference wells and the respective coefficients in Appendix 6. In general, if a reference well is replaced with a different well in a different location, then some or all of the coefficents will also change, i.e., they must be re-calculated and re-tabulated prior to calculating an average depth to water.

For January, 2001, the date we used for our determinations, the calculated average depth to water was 142 ft. For comparison purposes, the calculated average of the depths to water from the RRB District monitoring wells was 124 ft, an underestimate of 14.5% . The true depth to water at the geographic center of the District during this period was 139 ft and, a half-mile away, the measured depth to water in the McCaslin well (22-T29s/R25e) was 142 ft. Recalling that the top of the fillable part of the aquifer is considered to be 20 ft below ground level, the net fillable aquifer thickness for the purpose of calculating the available storage capacity on this date was 122 ft. Knowing that the depth to water has been and will continue to be more or less than this particular value over time, and for purposes of convenience and illustrative simplification only, we have actually assumed for the purpose of computing storage capacity that the average depth to water under the District was exactly 120 ft so that the fillable volume above the water table was exactly 100 ft. Of course, average depths to water deeper than this, as actually occurred in January, 2001, created larger available storage capacities.

Depth to water issues. In our opinion, it is useful to understand certain facts about the calculated average depth to water. The location of the ground water contour at the average-depth-to-water moves and changes shape as the water table surface changes. The computed average depth is not the true depth to water at the geographic center of the District, and there is no fixed location where the true depth at that location always equals or approximates the average depth with consistency or certainty. The calculated average depth is different than the average of the depths to water in the District wells and may be more or less, depending on the ground water conditions at the time. There is no simple correlation between the correct average depth and the water depths in one or a few wells, so there is no such thing as a well which "tracks" the average depth with sufficient accuracy in all or even most conditions. We cannot calculate the average water table elevation from the average depth to water unless we first determine the true average ground level elevation for the full area of the District.

Reference well issues. In our opinion, it is also useful to understand certain facts about the reference wells. For the analytic geometry to work correctly, we assume that the depth to water which we measure in a reference well responds quickly to-, and accurately represents-, the natural water table behavior under the region surrounding the well location. From among the available wells, we selected groups of reference wells within the same flow regimes and which are located as far away as possible from pumping wells and/or unresponsive locations. For wells in which we see recognizable drawdown, we can apply Cooper- Jacob corrections to recover an un-impacted water level. From theoretical considerations, the preferred depth-to-water measurement is that from the top, unconfined zone of the Kern Fan aquifer rather than piezometric depths from deeper zones, and the preferred time to get the best results is late in the calendar year when the aquifer has had time to recover from seasonal pumping and before seasonal recharge has begun.

The specific storage capacity is defined as an intrinsic property of a unit- volume of material. To obtain the total storage capacity (SC) of the entire District, we integrate (sum up) the unit-values for the total volume of the aquifer under the District. The volumetric integral is: $SC = \int^A\int\phi(1- S_r)dAdh$. and can be approximated by a numerical summation which looks like: $SC = \Sigma(Sy_{eq}\Sigma A_i h_i)$. It is a common practice to further simplify this summation and the resulting "reduced" formula is often more-conventionally written as: $SC = A \cdot H \cdot Sy_{eq}$, i.e., SC is equal to the product of total District area times the "average" aquifer thickness times the "average" or equivalent specific yield. This "reduced" formula is mathematically correct but it hides the fact that the computational difficulties have only been shifted into the computational formulas for the average values and have not been eliminated. We have fully evaluated those computational difficulties in our derivation of the average depth to water formula.

Based on the calculated average depth to water (d_{AVG}) and the measured equivalent specific yield (Sy_{eq}), we have used the reduced formula to calculate the District-wide storage capacity (SC).

KEY FINDING. We used a computational method for integrating the components of storage capacity over the appropriate aquifer volumes by a method which is necessary and sufficient for the scope and purpose of this work program.

Section VI.5 - Data Quality.

Based on conventional measures, the lithological and petrophysical data are very consistent between boreholes and within boreholes. The calculated coefficients of variation on all parameters are consistent with expected measures of natural variability. We conclude that we have determined the relevant physical properties with acceptable confidence and that we do not need more precise estimates or additional data for the scope and purpose of this work program at this time.

The deliberate computational shortcut involved in using geometric approximations in the calculation of aquifer volumes above and below an irregular water table surface results in a computational error which can be avoided by using better approximations. Once the deliberate computational error has been acceptably minimized, then further accuracies in volumetrics can be achieved by increasing the amount of useful depth-to-water data. In our opinion, we carefully evaluated the volumes which we used here and consider them necessary and sufficient for the scope and purpose of this work program, but we recognize that more accurate volumetrics are entirely possible and can be implemented for purposes of evaluating the aquifer water balance.

In our opinion, the E-log interpretation contains more uncertainty than the petrophysical results, the volumetric analysis, or any other part of the work program. We recommend that, if and when storage capacity measurements are used in the calculation of a ground water balance, then a work program be completed to determine the correct interpretive correlation between E-log response and properties of interest. We recommend that such a program include logging, sampling, and interpreting the same interval in the same stratigraphic test well and then producing an interpretive report which can be broadly applied throughout the Kern Fan area.

Section VI.6 - Summary of Findings.

The aquifer consists of 50% sand, 48% silt, and 2% clay fractions. The effective specific yields of these fractions are 33.6 ± 2.5 %; 8.6 ± 6.3 %; and 0 %, respectively. The equivalent specific storage capacity of the aquifer is 9300 af/ft under the total District area of approximately 44,150 ac. Assuming a total aquifer thickness of 700 ft, the total available storage capacity of 6,510,000 af. For a District-wide average depth to water of 120 ft, the available storage capacity is 930,000 af and the volume of water in storage is 5,580,000 af.

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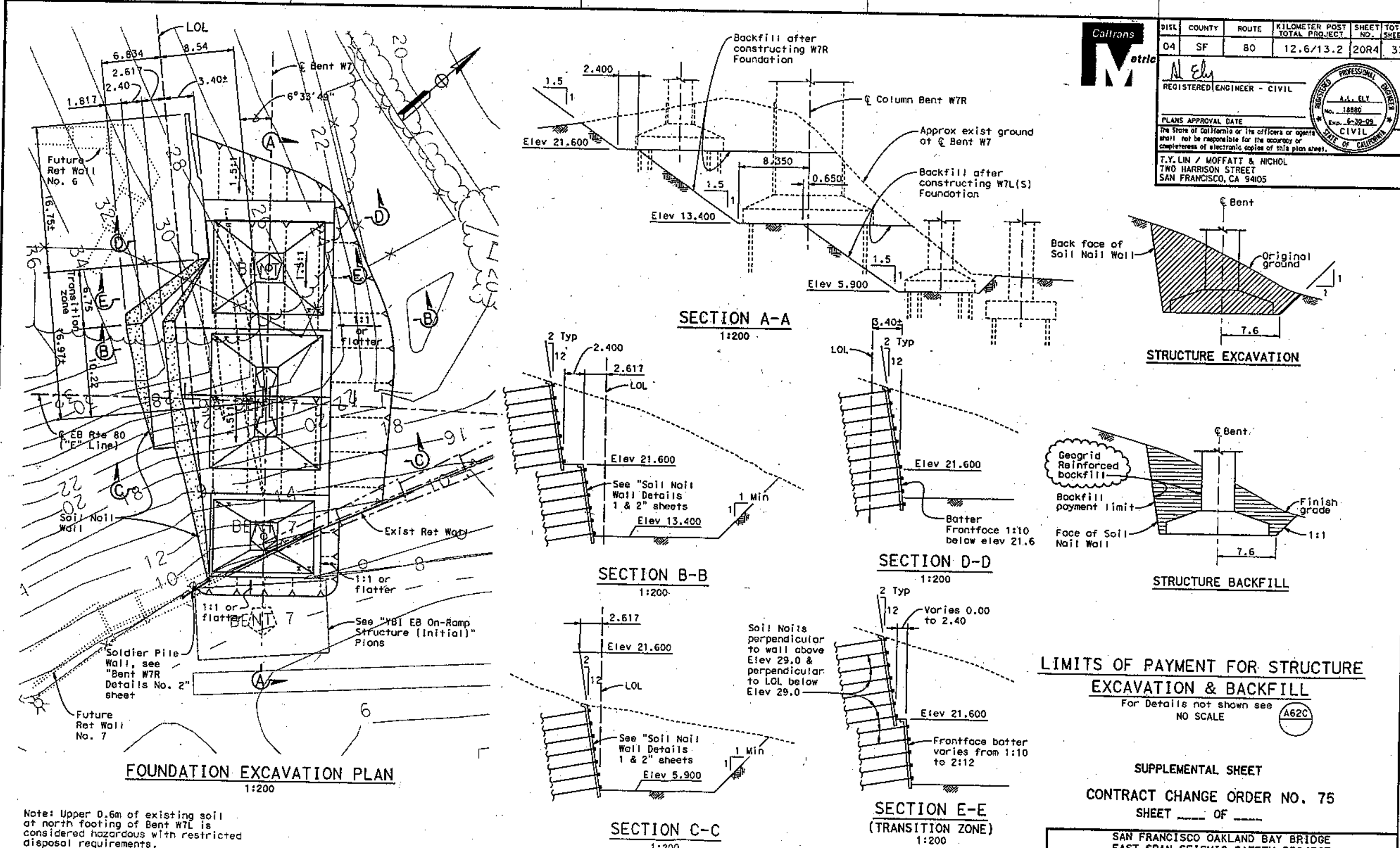

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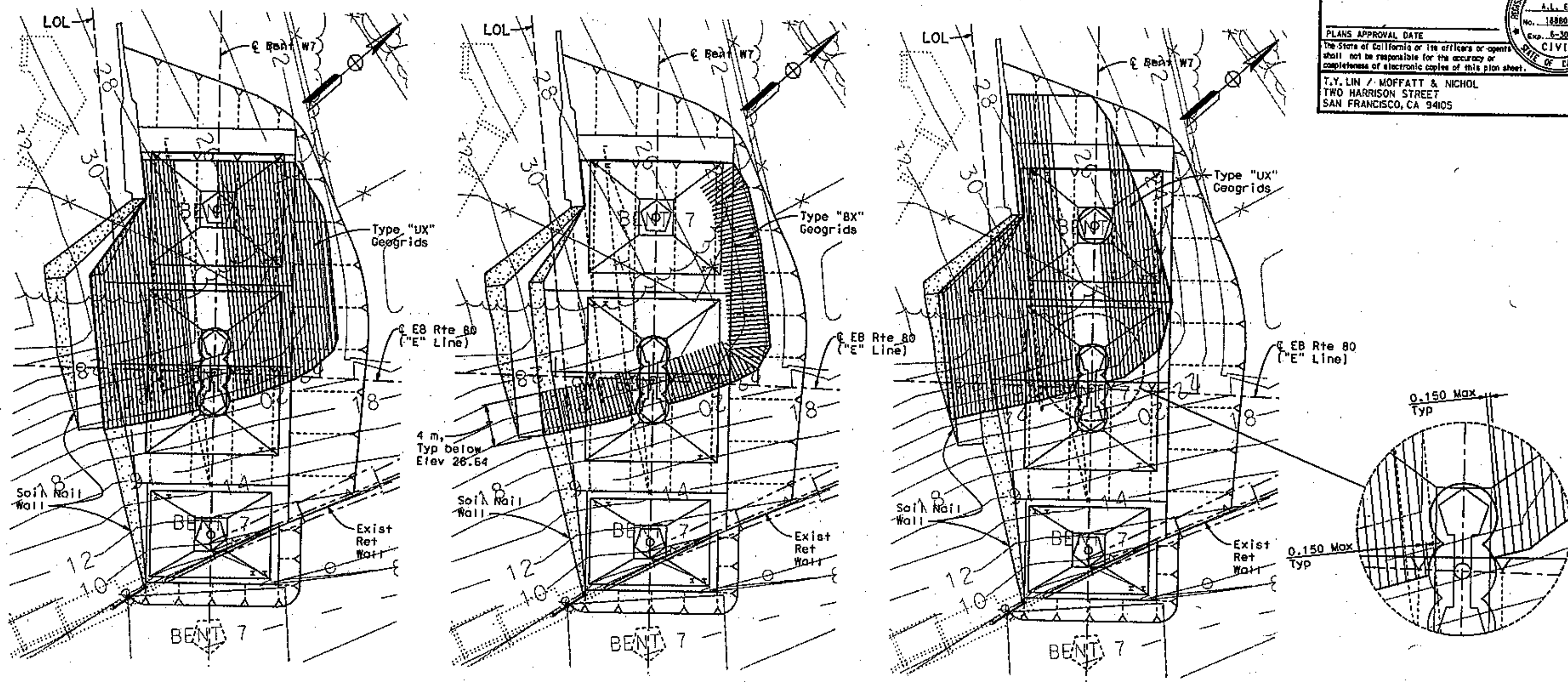

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DESIGN OVERSIGHT
JUAN F. CARPIO
SIGN OFF DATE
Rev. Date: 5-8-98

DESIGN	BY Kapuskar	CHECKED Lee
DETAILS	BY Samson	CHECKED Ely
QUANTITIES	BY	CHECKED

PREPARED FOR THE STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

Jal Birdy
PROJECT ENGINEER

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CONSTRUCTION REQUIREMENTS FOR GEOGRID SYSTEM

1.0 MATERIALS

1.1 Backfill

1.1.1 Reinforced backfill shall be free of excess moisture, roots, muck, sod, snow, frozen lumps, organic matter or other deleterious materials. All rock particles and hard earth clods shall be less than 4 inches in the longest dimension. Backfill which does not meet these criteria shall be considered unsuitable and shall be removed.

1.1.2 Reinforced backfill shall be on-site or import soils that meet the strength requirements defined in section 3.0 and the gradation limits listed below. The portion of the reinforced backfill passing the no. 40 sieeve shall have a liquid limit less than 20 and plasticity index less than 10. Reinforced backfill shall be classified per the unified soil classification system as low or non-plastic soils with: sand equivalent 20 min., % passing #200 50%, max particle size 32 mm, plasticity index 10 max, pH 4.5 to 9.

1.2 Soil reinforcement
Geogrid reinforcement shall be tensor uniaxial and biaxial geogrids or approved equivalent.

2.0 DESIGN RESPONSIBILITY

		Factor of Safety Static	Seismic
2.1	Internal Stability		
	Geogrid tensile strength, minimum	1.5	1.1
	Geogrid pullout capacity, minimum	1.5	1.1
	Geogrid connection strength, minimum	1.5	1.1
	Sliding at lowest geogrid, minimum	1.5	1.1
2.1.1	External stability		
	Sliding at MSE base, minimum	1.5	1.1
	Overturning, minimum	2	1.5

2.2 Responsibility of others:
The site characteristics listed below affect the performance of the reinforced backfill system. Caltrans is responsible for ensuring that the following site characteristics are properly addressed by a qualified Engineer and Geologist.

2.2.1 Geogrid design depends upon the physical and strength requirements of the backfill. State shall verify backfill specifications and appropriate backfill testing methods and frequency.

2.2.2 Hydrostatic Conditions

2.2.3 The reinforced backfill should remain free of water and all unbalanced hydrostatic forces.
A surface water drainage system is required.

3.0 DESIGN PARAMETERS

3.1 The following parameters control the design:

3.2 Backfill soil

Soil zone	Moist unit weight (pcf)	Effective friction (degrees)	Effective cohesion (psf)
Reinforced zone	125	34	150

3.3 Geogrid

Geogrid tensile properties and reduction factors are reported in the Geogrid design report date to be determined.

3.4 Design life = 75 years (BX), 120 years (UX)

3.5 Loadings = 240 psf

4.0 CONSTRUCTION

4.1 A complete set of approved construction drawings and contract specifications shall be on site at all times during construction of the backfill system.

4.2 Foundation preparation:
Prior to construction of the backfill system, the Contractor shall clear and grub the reinforced backfill footprint, removing top soil, brush, sod or other organic or deleterious material. Any unsuitable soils shall be over-excavated, replaced with compacted backfill material to project specifications or as otherwise directed by a qualified Geotechnical Engineer. The foundation shall be proof roll inspected using a loaded truck with 18 kip axle loads or per project specifications. A qualified Geotechnical Engineer and Engineering Geologist confirm that the site has been properly prepared and meets the design parameters stated in Section 3.0.

4.4 Geogrid replacement

4.4.1 Geogrids shall be installed at the lengths, elevations, and locations shown on the drawings herein. Changes to Geogrid layout are not permissible without the approval of State.

4.4.2 Geogrid reinforcement shall be continuous throughout their embedment length. Geogrid to Geogrid connection is not allowed.

4.4.3 Tracked construction equipment shall not be operated directly on the Geogrid reinforcement. A minimum backfill thickness of 150 mm is required for operation of tracked vehicles over the Geogrid reinforcement. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and/or Geogrid reinforcement. Rubber-tired vehicles may pass over the Geogrid reinforcement at speeds less than 10 mph. Sudden braking and sharp turning shall be avoided.

4.4.5 A minimum of 75 mm of reinforced backfill shall be placed between overlapping layers of Geogrid reinforcement.

4.5 Backfill placement

4.5.1 Backfill shall be placed in alternating lifts. The Geogrid shall be tensioned by hand to eliminate slack and anchored by pinning or placing soil on the Geogrid at the back of the reinforced zone. Backfill shall be placed in horizontal layers not exceeding 250 mm or 150 mm in uncompacted thickness for heavy or lightweight compaction equipment respectively.

4.5.2 Backfill shall be placed from the slope face towards the ends of the Geogrid to promote proper tensioning.

4.5.3 Backfill shall be placed at a moisture content no greater than two percent wet and no less than one percent dry of optimum moisture content and compacted to a minimum of 90% R.C. Overbuilding of slope may be required to achieve proper compaction at finished slope face.

4.5.4 At the end of each workday, backfill surface shall be graded away from the slope face a minimum of two percent slope. The backfill surface shall be compacted with a smooth drum roller to minimize ponding of water and saturation of the backfill. A temporary soil berm shall be constructed near the crest to prevent surface water runoff from overtopping.

5.0 SPECIAL PROVISIONS

5.1 The design presented herein is only valid for the Geogrid or equivalent system. The design is based on soil parameters, foundation conditions, groundwater conditions, and loadings stated in section 3.0. Geotechnical Engineer assumes no liability for interpretation or verification of subsurface conditions, for suitability of soil design parameters or for interpretation of subsurface groundwater conditions. State shall verify that actual site conditions, parameters, and geometries are as described herein prior to and during construction. Proceeding with construction without first verifying conditions and parameters discussed above shall absolve Geotechnical Engineers from all liability for the design and construction of this structure and the Contractor shall indemnify and hold harmless Caltrans and its representatives from all resulting claims, damages, losses and expenses.

5.0 SPECIAL PROVISIONS (CONTD.)

5.2 State shall provide Quality Assurance and Quality Control Programs that ensure construction of the reinforced backfill is performed in accordance with the contract plans and specifications.

5.3 Any changes in subsurface conditions or design shall be immediately reported to the State Geotechnical Engineer prior to proceeding with construction.

SUPPLEMENTAL SHEET

CONTRACT CHANGE ORDER NO. 75

SHEET ____ OF ____

ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SHOWN

DESIGN OVERSIGHT: JUAN F. CARPIO
SIGN OFF DATE
Rev. Date: 5-18-98

	BY	CHECKED
DESIGN	Kopuskar	Lee
DETAILS	Samson	Ely
QUANTITIES		

PREPARED FOR THE STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

Jai Birdy
PROJECT ENGINEER

BRIDGE NO. 34-0006 L/R
KILOMETER POST 12.8

CU 04251
EA 0120S1

ORIGINAL SCALE IN MILLIMETERS FOR REDUCED PLANS 0 10 20 30 40 50 60 70 80 90 100

SAN FRANCISCO OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

YBI TRANSITION STRUCTURES

ADVANCE CONST PACKAGE NO. 2RO

REINFORCED BACKFILL DETAILS NO.5

SHEET 4E OF 17

FILE => p:\4141-06\CADD\TS\Final Const 3\Adv Const Pkg 2RO\Revision 022709\edexc0-4E.dgn

USERNAME => fsamson DATE PLOTTED => 2/27/2009 TIME PLOTTED => 3:47:28 PM

February 27, 2009

Notes:

1a. Type UX geogrids shall be "Tensar" geogrid UX-1600HS or equal.

1b. Type UX geogrids shall be 1.33m wide rolls, rolled out parallel to the Soil Nail Wall LOL and shall extend from the face of the finished backfill slope to the excavation slope limits. Above Elev 21.60 the length of any type "UX" roll strip need not be longer than 21.3 m.

2a. Type BX geogrids shall be "Tensar" geogrid BX-1100.

2b. Type BX geogrids shall be oriented perpendicular to the face of the finished backfill slope. Below Elev 26.6 Type "BX" geogrids shall extend a minimum of 4 m behind the finished backfill slope; above Elev 26.64 Type "BX" geogrids shall extend a minimum of 6.1 m behind the finished backfill slope.

3. Adjacent geogrid roll strips shall be overlapped a minimum of 0.91 m with a 75 mm vertical separation.

DIST	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	SF	80	12.6/13.2	20A	33

Caltrans Metric

REGISTERED ENGINEER - CIVIL

PLANS APPROVAL DATE

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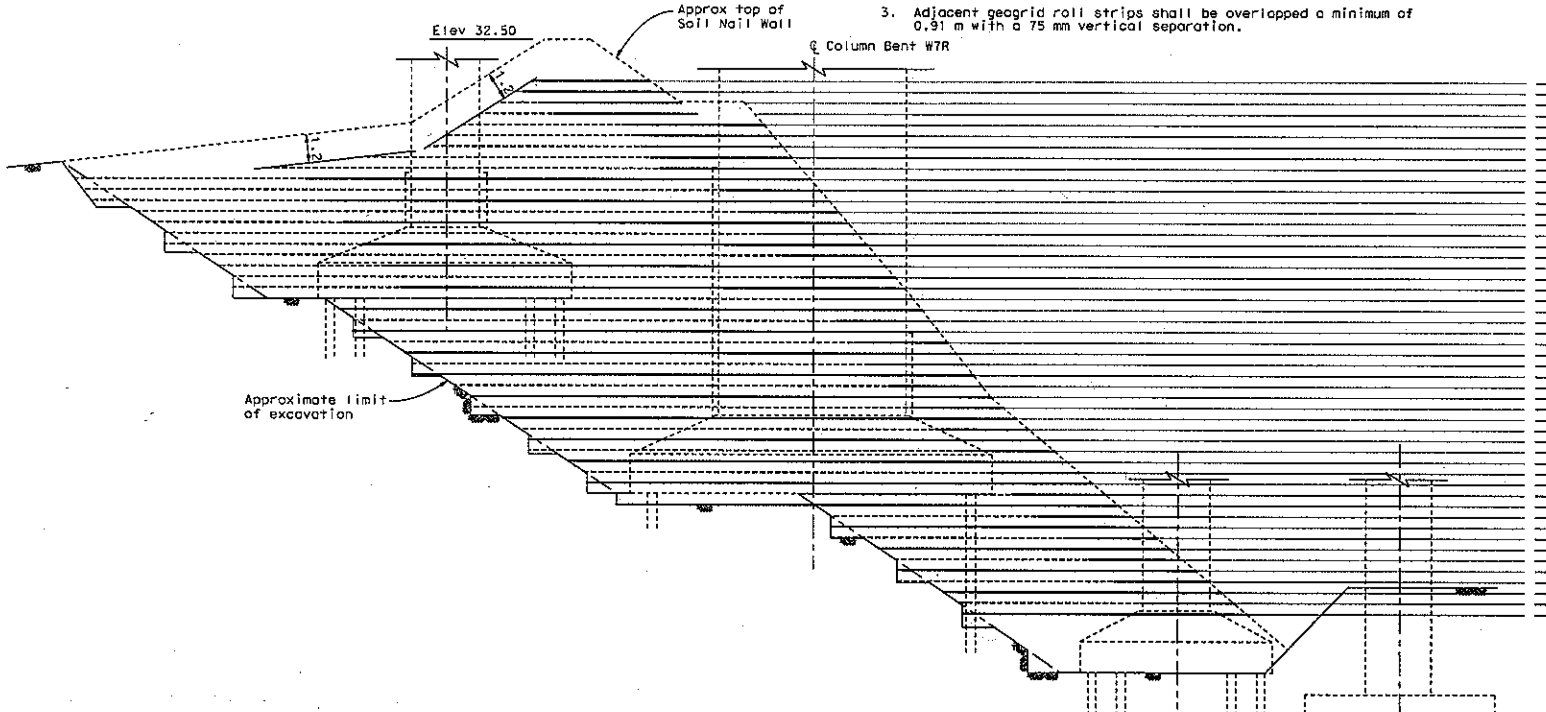
REGISTERED PROFESSIONAL ENGINEER A.L. ELY No. 18880 Exp. 6-30-09 CIVIL STATE OF CALIFORNIA

T.Y. LIN / MOFFATT & NICHOL
TWO HARRISON STREET
SAN FRANCISCO, CA 94105



Grid Number	Elevation	Grid Type
50	30.75	BX
49	30.30	BX
48	29.84	BX
47	29.38	BX
46	28.92	BX
45	28.47	BX
44	28.01	BX
43	27.55	BX
42	27.10	BX
41	26.64	UX
40	26.18	BX
39	25.72	UX
38	25.27	BX
37	24.81	UX
36	24.35	BX
35	23.89	UX
34	23.44	BX
33	22.98	UX
32	22.52	BX
31	22.07	UX
30	21.61	BX
29	21.15	UX
28	20.69	BX
27	20.24	UX
26	19.78	BX
25	19.32	UX
24	18.87	BX
23	18.41	UX
22	17.95	BX
21	17.49	UX
20	17.04	BX
19	16.58	UX
18	16.12	BX
17	15.67	UX
16	15.21	BX
15	14.75	UX
14	14.29	BX
13	13.84	UX
12	13.38	BX
11	12.92	UX
10	12.46	BX
9	12.01	UX
8	11.55	BX
7	11.09	UX
6	10.64	BX
5	10.18	UX
4	9.72	BX
3	9.26	UX
2	8.81	BX
1	8.35	UX

SECTIONAL VIEW ELEVATION PARALLEL TO ℄ BENT W7

1:100

Datum Elev 0.0

SUPPLEMENTAL SHEET

CONTRACT CHANGE ORDER NO. 75

SHEET ____ OF ____

ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SHOWN

SAN FRANCISCO OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

YBI TRANSITION STRUCTURES

ADVANCE CONST PACKAGE NO. 2R0

REINFORCED BACKFILL DETAILS NO.1

DESIGN OVERSIGHT JUAN F. CARPIO
SIGN OFF DATE
Rev. Date: 5-18-98

DESIGN	BY Kapuskar	CHECKED	Lee
DETAILS	BY Samson	CHECKED	Ely
QUANTITIES	BY	CHECKED	

PREPARED FOR THE STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

Jai Biroy
PROJECT ENGINEER

BRIDGE NO. 34-0006 L/R
KILOMETER POST 12.8

CU 04251
EA 012051

ORIGINAL SCALE IN MILLIMETERS FOR REDUCED PLANS 0 10 20 30 40 50 60 70 80 90 100

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES (PRELIMINARY STAGE ONLY)

SHEET 4A OF 17

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USERNAME => fsamson DATE PLOTTED => 2/27/2009 TIME PLOTTED => 3:46:40 PM

February 27, 2009

DIST	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	SF	80	12.6/13.2	208	33

REGISTERED ENGINEER - CIVIL

PLANS APPROVAL DATE

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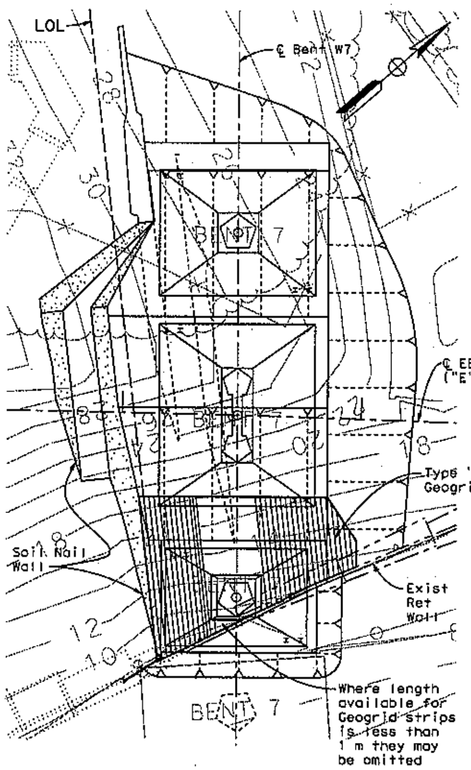
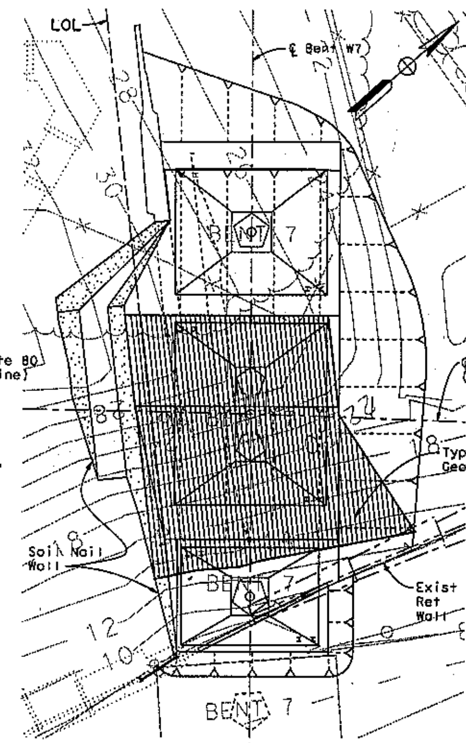
T.Y. LIN / MOFFATT & NICHOL
TWO HARRISON STREET
SAN FRANCISCO, CA 94105

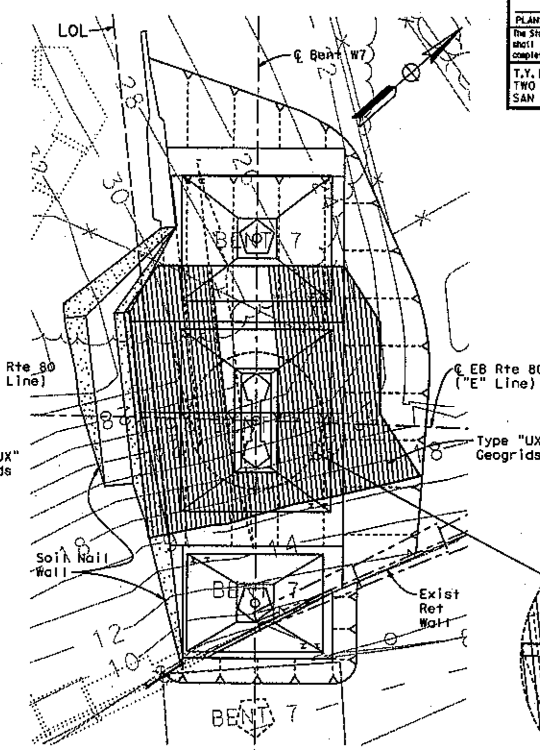
REGISTERED PROFESSIONAL ENGINEER A.L. ELY No. 18880 Exp. 6-30-09 CIVIL STATE OF CALIFORNIA



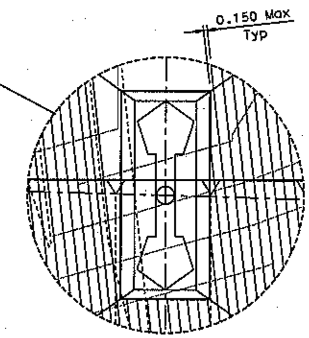
GEOGRID PLAN AT ELEVATION 8.35
1:200



GEOGRID PLAN AT ELEVATION 12.92
1:200



GEOGRID PLAN AT ELEVATION 16.58
1:200



SUPPLEMENTAL SHEET

CONTRACT CHANGE ORDER NO. 75

SHEET ____ OF ____

ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SHOWN

SAN FRANCISCO OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

YBI TRANSITION STRUCTURES

ADVANCE CONST PACKAGE NO. 2RO

REINFORCED BACKFILL DETAILS NO.2

DESIGN OVERSIGHT
JUAN F. CARPIO
SIGN OFF DATE
Rev. Date: 5-18-98

	BY	CHECKED
DESIGN	Kapuskar	Lee
DETAILS	Samson	Ely
QUANTITIES		

PREPARED FOR THE
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

Jol Birdy
PROJECT ENGINEER

BRIDGE NO. 34-0006 L/R
KILOMETER POST 12.8

ORIGINAL SCALE IN MILLIMETERS FOR REDUCED PLANS 0 10 20 30 40 50 60 70 80 90 100

CU 04251
EA 012051

DISREGARD PRINTS BEARING EARLIER REVISION DATES

REVISION DATES (PRELIMINARY STAGE ONLY) 2/27/09

SHEET 4B OF 17

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Figures

Rosedale - Rio Bravo Water Storage District.

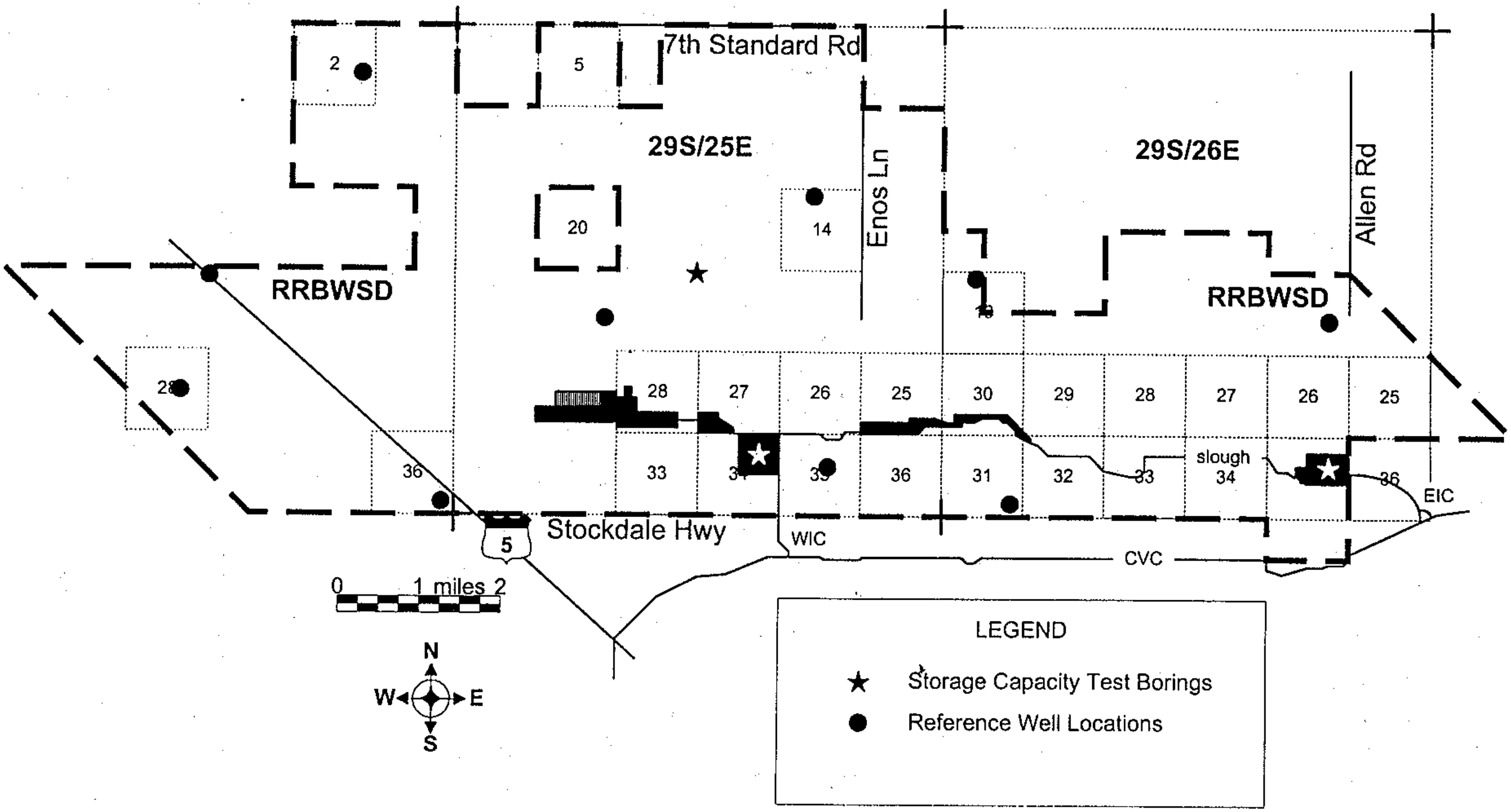
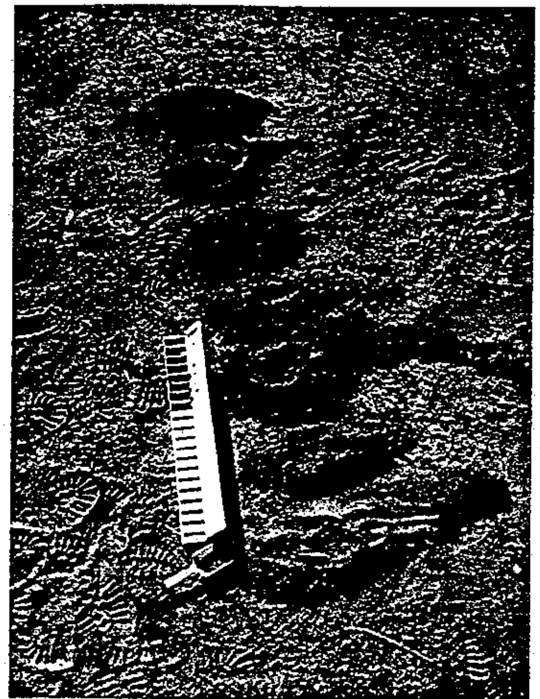
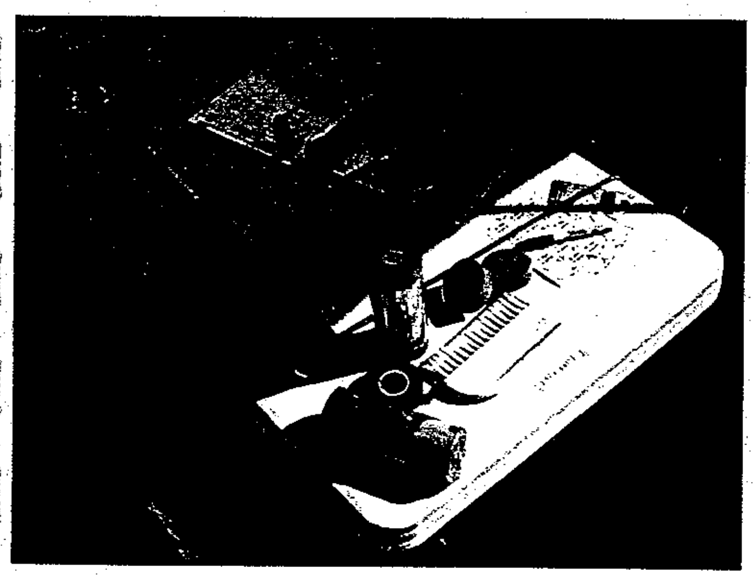


Figure 1.
Location Map.

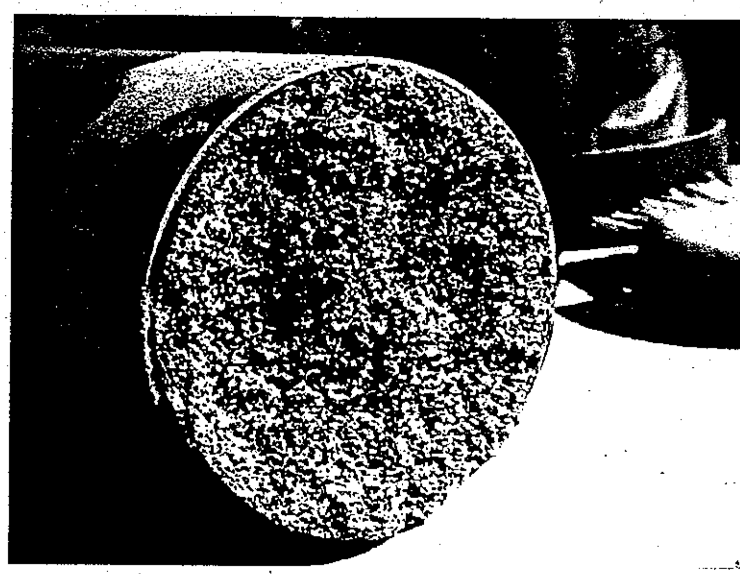
Hollw-Stem Auger Rig



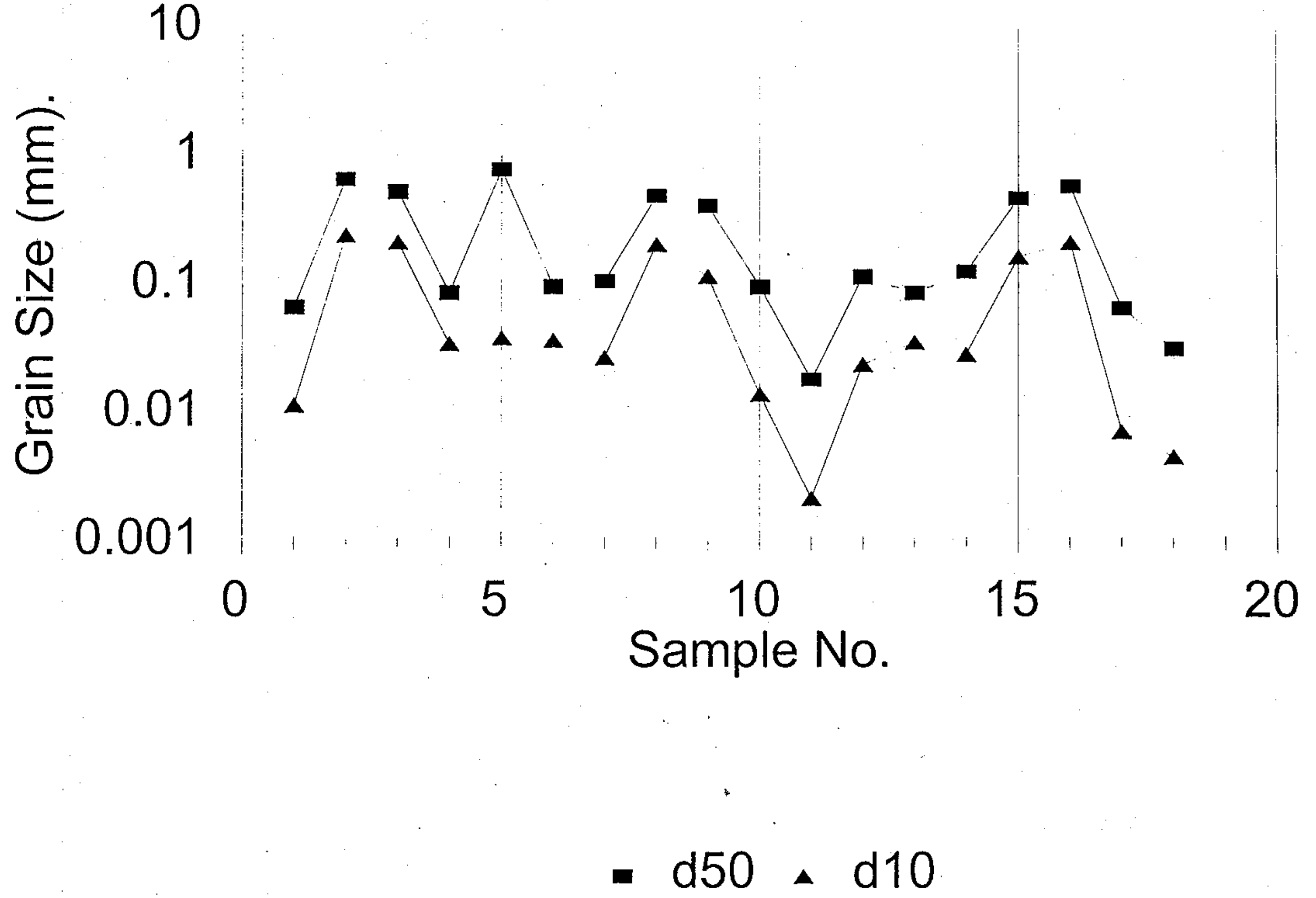
Cuttings Samples

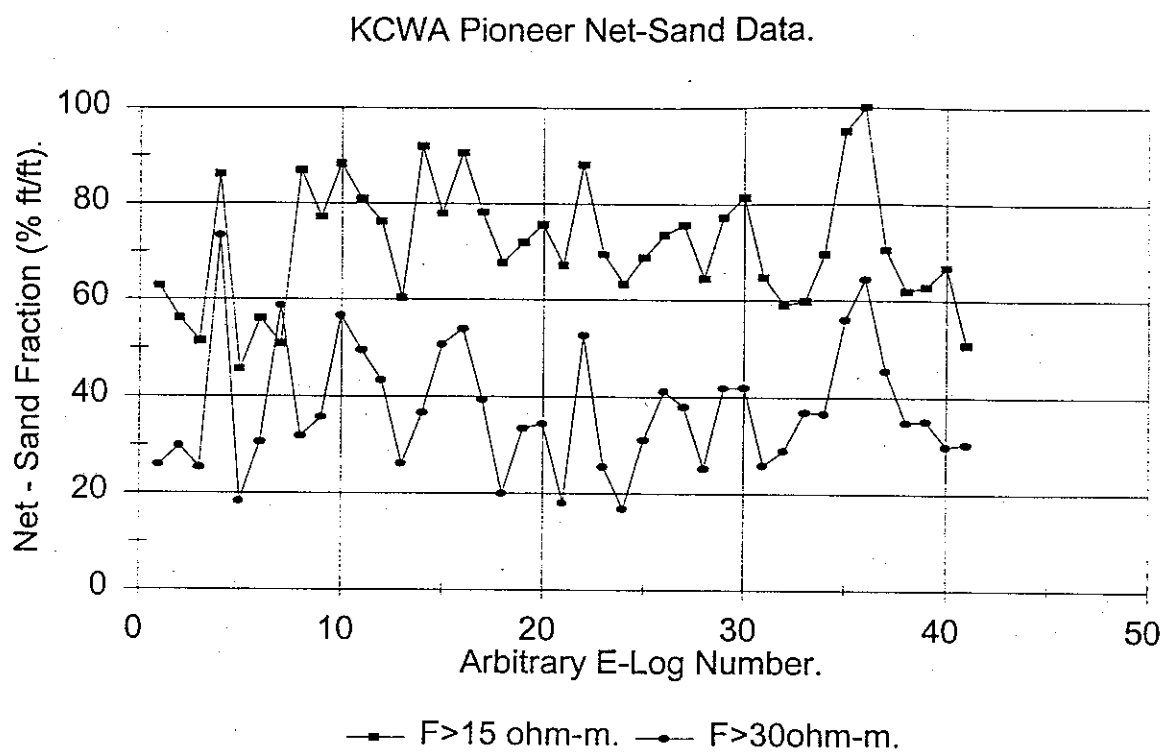


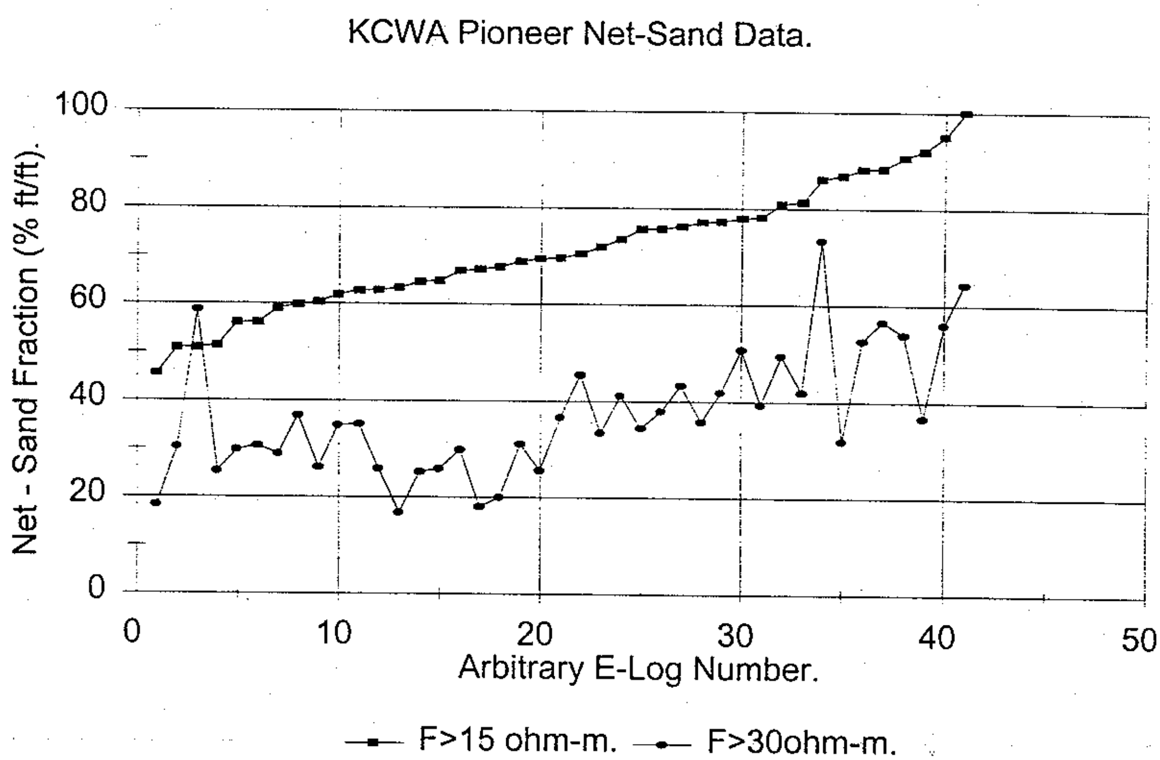
Sampler _Core Splits

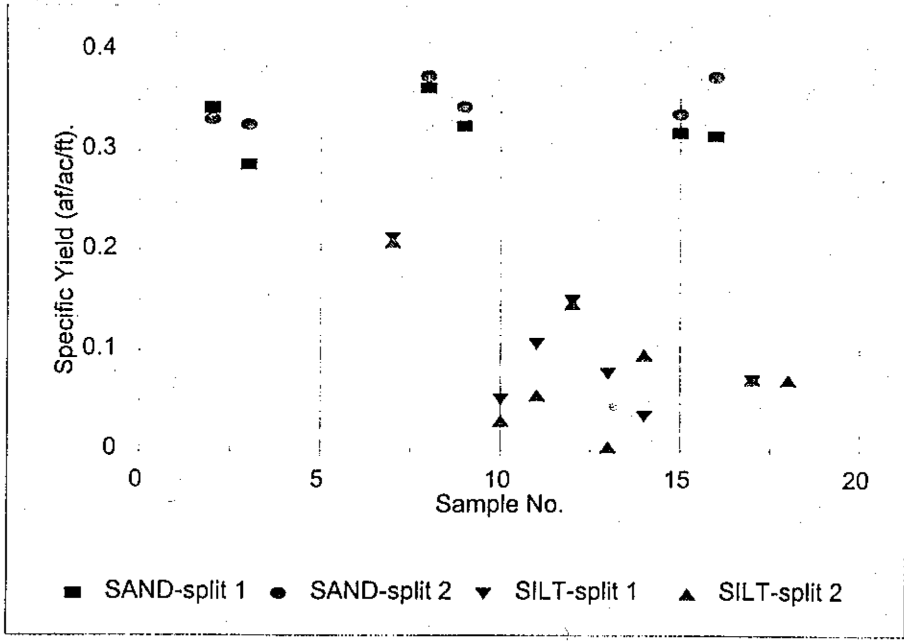


Sample 01-60B

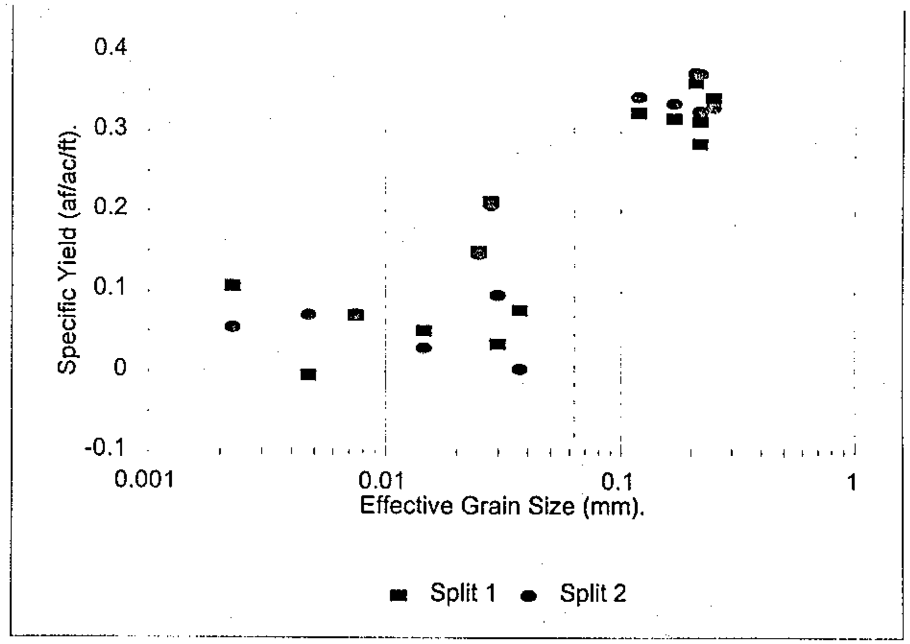

10
1
0.1
0.01
0.001
Grain Size (mm).
0
5
10
15
20
Sample No.
d50
d10


KCWA Pioneer Net-Sand Data.
Net - Sand Fraction (% ft/ft).
100
80
60
40
20
0
0
10
20
30
40
50
Arbitrary E-Log Number.
F>15 ohm-m.
F>30ohm-m.

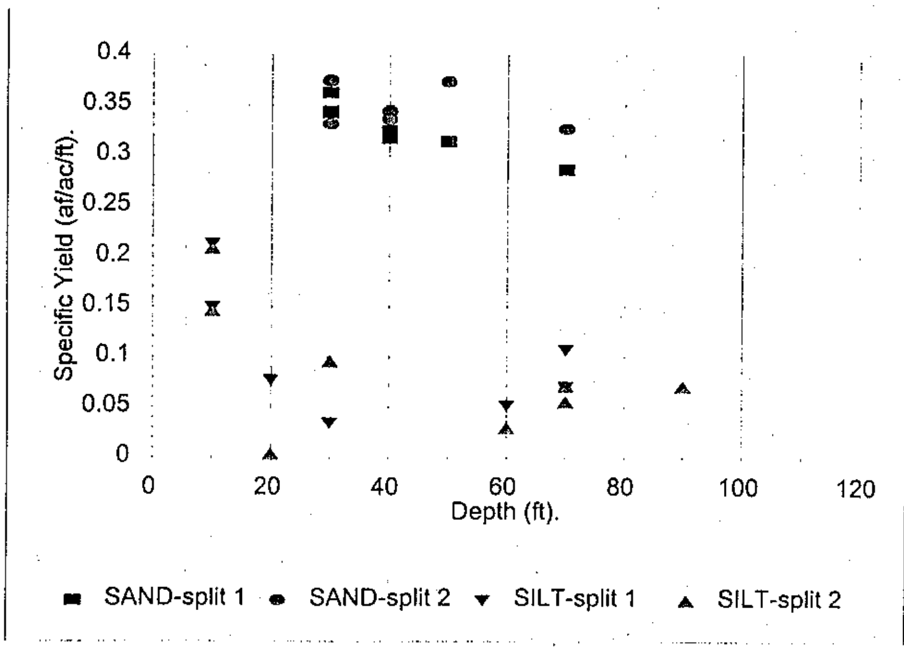

KCWA Pioneer Net-Sand Data.
Net - Sand Fraction (% ft/ft).
100
80
60
40
20
0
0
10
20
30
40
50
Arbitrary E-Log Number.
F>15 ohm-m.
F>30ohm-m.



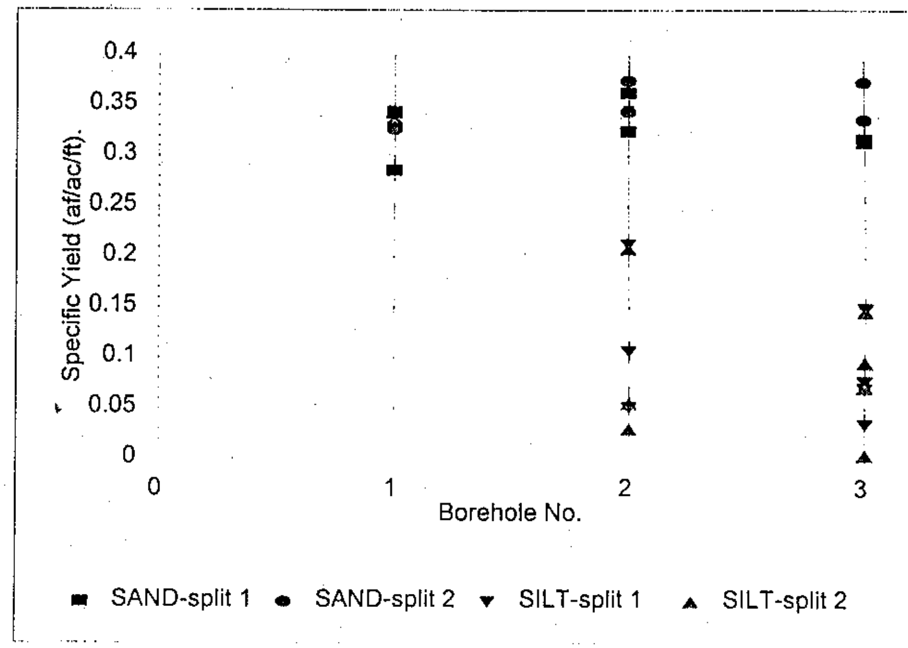
Specific Yield (af/ac/ft).
0.4
0.3
0.2
0.1
0
0
5
10
15
20
Sample No.
SAND-split 1
SAND-split 2
SILT-split 1
SILT-split 2



Specific Yield (af/ac/ft).
0.4
0.3
0.2
0.1
0
-0.1
0.001
0.01
0.1
1
Effective Grain Size (mm).
Split 1
Split 2



Specific Yield (af/ac/ft).
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
Depth (ft).
SAND-split 1
SAND-split 2
SILT-split 1
SILT-split 2



Specific Yield (af/ac/ft).
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
Borehole No.
SAND-split 1
SAND-split 2
SILT-split 1
SILT-split 2

Tables

Rosedale Rio Bravo Water Storage District.

DISTRICT LAYER PROPERTY SUMMARY

District Summary		
Area	44150	ac
Aquifer Thickness	700	ft
avg depth to water	120	ft
specific Storage Capacity	9300	af/ft
equiv. specific yield	21.1%	
Total SC	6510000	af
Avail. SC	930000	af
Current water in storage	5580000	af

Layer Property	SAND	SILT	CLAY
Aquifer Fraction:	0.50	0.48	0.02
Average Grain Size:	c sand	f sand	clay
Effective Grain Size:	f sand	c silt	clay
Degree of Sorting:	Good	Poor	na
Porosity:	37%	34%	45%
Residual Saturation:	11%	68%	98%
eff. Specific Yield:	34%	8.6%	0%
H. Conductivity (ft/d):	18	0.038	1E-08

PETROPHYSICAL RESULTS:

	Sand d50 (mm)	Sand d10 (mm)	Sand Coef.Unif. (-)	Sand Gr.Dens (g/cc)	Sand Porosity (%)	Sand Resid.Sat (%)	Sand Sp.Yield (%)	Sand HC (ft/d)
Num	6	6	6	2	6	6	12	6
Avg	0.54	0.2	2.58	2.58	0.37	0.11	0.336	18.0
Std	0.085	0.042	0.36	0.060	0.016	0.036	0.025	3.54
cv	0.16	0.21	0.14	0.02	0.04	0.33	0.07	0.20

	Silt d50 (mm)	Silt d10 (mm)	Silt Cu (-)	Silt Gr.Dens (g/cc)	Silt Porosity (%)	Silt Resid.Sat (%)	Silt Sp.Yield (%)	Silt HC* (ft/d)
Num	12	12	12	2	12	9	16	12
Avg	0.14	0.023	7.86	2.63	0.34	0.68	0.086	0.038
Std	0.200	0.013	3.45	0.030	0.059	0.27	0.063	0.047
cv	1.43	0.57	0.44	0.01	0.17	0.40	0.73	1.24

ELECTRIC LOG NET-SAND RESULTS:

	Pioneer ALL F15	Pioneer ALL F30	Pioneer 30/26 F15	Pioneer 30/26 F30	KCWA BK#1-6 F15	KCWA BK#1-6 F30
num	41	41	33	33	6	6
avg	0.71	0.37	0.75	0.38	0.81	0.48
std	0.13	0.13	0.11	0.11	0.05	0.07
cv	0.18	0.35	0.14	0.30	0.058	0.14

	RRBWSD ALL F15	RRBWSD ALL F30	RRBWSD 29/25 F15	RRBWSD 29/25 F30	RRBWSD 29/26 F15	RRBWSD 29/26 F30	RRBWSD KCWA4-11 F15	RRBWSD KCWA4-11 F30	RRBWSD ID4-3,8-12 F15	RRBWSD ID4-3,8-12 F30
num	30	32	6	6	6	8	8	8	6	6
avg	0.75	0.45	0.74	0.47	0.73	0.43	0.76	0.41	0.79	0.52
std	0.17	0.13	0.23	0.10	0.12	0.13	0.14	0.14	0.07	0.05
cv	0.22	0.30	0.32	0.21	0.17	0.30	0.18	0.33	0.089	0.094

	RRBWSD ALL Fc+15	RRBWSD 29/25 Fc+15	RRBWSD 29/26 Fc+15	RRBWSD KCWA4-11 Fc+15	RRBWSD ID4-3,8-12 Fc+15
num	23	4	5	8	6
avg	0.50	0.51	0.56	0.42	0.53
std	0.10	0.07	0.10	0.08	0.05
cv	0.21	0.13	0.17	0.20	0.085

Rosedale - Rio Bravo Water Storage District.

No.	Sample Nu Hole	Depth (ft)	Field Description	Textural Classif.	d50 (mm)	avg Gr.Size	Effective Classif.	d10 (mm)	eff. Gr.Size	per cent Sd/Slt/Cl (%)	Sorting	Coef. Uniform	H.C. (ft/d)
1	1	20	f-m SAND, silty	Silty Sand	0.07	vf sand	Silt	0.012	m silt	52 / 48 / na	Poor	7.38	0.068
2	1	30	m-vc SAND	Sand	0.68	c sand	Sand	0.250	f sand	98 / 2 / na	Good	2.76	17.01
3	1	70	f-c SAND	Sand	0.55	c sand	Sand	0.220	f sand	97 / 3 / na	Good	2.22	22.68
4	1	80	f-c SAND, silty	Sand	0.09	vf sand	Silt	0.036	vc silt	80 / 20 / na	Good	3.23	0.024
5	1	100	m-vc SAND, pebbly	Sand	0.8	c sand	Silt	0.040	vc silt	86 / 14 / na	Poor	10.35	0.037
6	1	110	vf-f SAND	Silty Sand	0.1	vf sand	Silt	0.038	vc silt	67 / 33 / na	Fair	5.74	0.013
7	2	10	v-f SAND, silty	Silty Sand	0.11	vf sand	Silt *	0.028	c silt	66 / 34 / na	Fair	5.15	0.153
8	2	30	f-m SAND	Sand	0.5	m sand	Sand	0.210	f sand	97 / 4 / na	Good	2.02	17.01
9	2	40	m-c SAND	Sand	0.42	m sand	Sand	0.120	vf sand	94 / 6 / na	Good	2.66	19.84
10	2	60	m SAND, silty	Silty Sand	0.1	vf sand	Silt *	0.015	m silt	60 / 28 / 12	Poor	10.06	0.001
11	2	70	f-c SAND, silty	Clayey Silt	0.02	c silt	Silt *	0.002	ilt/c clay	26 / 54 / 20	Poor	12.80	0.000
12	3	10	f-m SAND, silty	Silty Sand	0.12	vf sand	Silt *	0.025	c silt	73 / 27 / na	Poor	6.59	0.113
13	3	20	f-m SAND, silty	Silty Sand	0.09	vf sand	Silt *	0.037	vc silt	50 / 50 / na	Good	2.90	0.021
14	3	30	SILT	Silty Sand	0.13	f sand	Silt *	0.030	c silt	67 / 33 / na	Fair	5.83	0.027
15	3	40	m-vc SAND	Sand	0.48	m sand	Sand	0.170	f sand	98 / 3 / na	Good	2.74	11.34
16	3	50	m SAND	Sand	0.6	c sand	Sand	0.220	f sand	98 / 2 / na	Good	3.08	19.84
17	3	70	f SAND, silty	Silty Sand	0.07	vf sand	Silt *	0.007	f silt	52 / 38 / 10	Poor	14.03	0.001
18	3	90	CLAY & vf-m SAND	Sandy Silt	0.03	vc silt	Silt *	0.005	f silt	37 / 45 / 18	Poor	10.22	0.000

* = calc'd effective grain sizes; d10 not measured.

Project: Rosedale - Rio Bravo Water Storage District.

Grain Analyses.

No.	Sample Number Hole	Depth (ft)	Split	Field Description	Gr. dens. (g/cc)	Gr.Diam d(84) (mm)	Gr.Diam d(60) (mm)	Gr.Diam d(50) (mm)	Gr.Diam d(16) (mm)	Gr.Diam d(10) (mm)	Wt % -230 fines (%)	Wt % clay (%)	k (cm/s)
1	1	20	C	f-m SAND, silty		0.23	0.1	0.07	0.017	0.012	48	na	2.40E-05
2	1	30	C	m-vc SAND		1.2	0.83	0.68	0.32	0.25	2	na	6.00E-03
3	1	70	C	f-c SAND		0.85	0.63	0.55	0.3	0.22	3	na	8.00E-03
4	1	80	C	f-c SAND, silty		0.23	0.1	0.09	0.05	0.036	20	na	8.50E-06
5	1	100	C	m-vc SAND, pebbly		2.1	1.1	0.8	0.1	0.04	14	na	1.30E-05
6	1	110	C	vf-f SAND		0.39	0.11	0.1	0.04	0.038	33	na	4.50E-06
7	2	10	C	v-f SAND, silty	2.66	0.32	0.15	0.11	na	na	34	na	5.40E-05
8	2	30	C	f-m SAND		0.7	0.53	0.5	0.28	0.21	3.5	na	6.00E-03
9	2	40	C	m-c SAND		0.68	0.5	0.42	0.19	0.12	6	na	7.00E-03
10	2	60	C	m SAND, silty		0.45	0.15	0.1	na	na	40	12	1.80E-07
11	2	70	C	f-c SAND, silty		0.1	0.03	0.019	na	na	74	20	1.00E-08
12	3	10	C	f-m SAND, silty		0.41	0.21	0.12	na	na	27	na	4.00E-05
13	3	20	C	f-m SAND, silty		0.18	0.088	0.09	na	na	50	na	7.30E-06
14	3	30	C	SILT	2.60	0.41	0.2	0.13	na	na	33	na	9.40E-06
15	3	40	C	m-vc SAND	2.64	0.78	0.53	0.48	0.21	0.17	2.5	na	4.00E-03
16	3	50	C	m SAND	2.52	1.3	0.82	0.6	0.3	0.22	2	na	7.00E-03
17	3	70	C	f SAND, silty		0.4	0.11	0.068	na	na	48	10	3.80E-07
18	3	90	C	CLAY & vf-m SAND		0.2	0.05	0.033	na	na	63	18	1.00E-08

Rosedale - Rio Bravo Water Storage District.

Petrophysical Analyses.

Wtr.Dens: 1.00 g/cc
Gr.Dens: 2.61 g/cc

No.	Sample: Hole	Depth (ft)	Split	reported dry dens (p/cf)	adjusted dry dens 0.04 (p/cf)	62.43 dry bulk Density (Mb/Vb) (g/cc)	Grav. Wtr.Cont. (Mw/Mb) T (%)	T/(1+T)	Vol.Water Content (Vw/Vb) (%)	Porosity (Vv/Vb) (%)	Ambient Saturation (Vw/Vv) (%)	Specific Yield (Vw/Vb) (%)
		SPLIT # 1										
1	1	20	B	102.9	98.9	1.58	2.1%	2.1%	3.3%	39%	8.5%	35.9%
2	1	30	B	104.5	100.5	1.61	2.5%	2.4%	4.0%	38%	10.5%	34.3%
3	1	70	B	111.4	107.1	1.72	3.3%	3.2%	5.7%	34%	16.5%	28.6%
4	1	80	B wet	122.2	117.5	1.88	14.2%	12.4%	26.7%	28%	95.8%	na
5	1	100	B wet	130.8	125.8	2.01	12.2%	10.9%	24.6%	23%	107.7%	na
6	1	110	B wet	110.8	106.5	1.71	23.9%	19.3%	40.8%	35%	117.8%	na
7	2	10	B	111.9	107.6	1.72	7.4%	6.9%	12.8%	34%	37.5%	21.2%
8	2	30	B	104.2	100.2	1.60	1.4%	1.4%	2.2%	39%	5.8%	36.3%
9	2	40	B	107.2	103.1	1.65	2.6%	2.5%	4.3%	37%	11.7%	32.4%
10	2	60	B	123.4	118.7	1.90	11.6%	10.4%	22.0%	27%	81.1%	5.1%
11	2	70	B	98.8	95.0	1.52	20.4%	16.9%	31.0%	42%	74.4%	10.7%
12	3	10	B	110.2	106.0	1.70	11.8%	10.6%	20.0%	35%	57.3%	14.9%
13	3	20	B	115.9	111.4	1.79	13.4%	11.8%	23.9%	32%	75.7%	7.7%
14	3	30	B	100.6	96.7	1.55	24.0%	19.4%	37.2%	41%	91.5%	3.4%
15	3	40	B	110.8	106.5	1.71	1.7%	1.7%	2.9%	35%	8.4%	31.7%
16	3	50	A	107.3	103.2	1.65	3.2%	3.1%	5.3%	37%	14.4%	31.4%
17	3	70	B	107.4	103.3	1.65	17.9%	15.2%	29.6%	37%	80.9%	7.0%
18	3	90	A	97.9	94.1	1.51	28.3%	22.1%	42.7%	42%	101.1%	-0.4%
19												
20												
	1	avg		113.8	109.4	1.75	9.7%	8.4%	17.5%	32.9%	59.5%	16.5%
	1	cv		0.09	0.09	0.09	0.82	0.76	0.81	0.18	0.81	1.01
	2	avg		109.1	104.9	1.68	8.7%	7.6%	14.5%	35.6%	42.1%	21.1%
	2	cv		0.08	0.08	0.08	0.79	0.74	0.75	0.14	0.74	0.57
	3	avg		107.2	103.0	1.65	14.3%	12.0%	23.1%	36.8%	61.3%	13.7%
	3	cv		0.05	0.05	0.05	0.64	0.59	0.60	0.09	0.55	0.88
	ALL	avg		109.9	105.7	1.69	11.2%	9.6%	18.8%	35.1%	55.4%	16.7%
	ALL	cv		0.08	0.08	0.08	0.76	0.71	0.73	0.14	0.71	0.84

Rosedale - Rio Bravo Water Storage District.

Petrophysical Analyses.

Wtr.Dens: 1.00 g/cc
Gr.Dens: 2.61 g/cc

No.	Sample: Hole	Depth (ft)	Split		measure dry dens (p/cf)	adjusted dry dens 0.04 (p/cf)	62.43 dry bulk Density (Mb/Vb) (g/cc)	Grav. Wtr.Cont. (Mw/Mb) T (%)	T/(1+T)	Vol.Water Content (Vw/Vb) (%)	Porosity (Vv/Vb) (%)	Ambient Saturation (Vw/Vv) (%)	Specific Yield (Vw/Vb) (%)
	SPLIT # 2												
1	1	20	C		110.9	106.6	1.71	2.5%	2.4%	4.3%	35%	12.4%	30.3%
2	1	30	C		106.9	102.8	1.65	2.3%	2.2%	3.8%	37%	10.3%	33.1%
3	1	70	C		103.6	99.6	1.60	3.9%	3.8%	6.2%	39%	16.0%	32.6%
4	1	80	C	wet	127.8	122.9	1.97	12.3%	11.0%	24.2%	25%	98.5%	na
5	1	100	C	wet	126.2	121.3	1.94	13.8%	12.1%	26.8%	26%	105.1%	na
6	1	110	C	wet	115.1	110.7	1.77	16.9%	14.5%	30.0%	32%	93.4%	na
7	2	10	C		117.1	112.6	1.80	5.6%	5.3%	10.1%	31%	32.7%	20.8%
8	2	30	C		103.0	99.0	1.59	1.1%	1.1%	1.7%	39%	4.4%	37.5%
9	2	40	C		104.9	100.9	1.62	2.3%	2.2%	3.7%	38%	9.8%	34.4%
10	2	60	C		117.3	112.8	1.81	15.4%	13.3%	27.8%	31%	90.4%	3.0%
11	2	70	C		101.2	97.3	1.56	22.3%	18.2%	34.8%	40%	86.3%	5.5%
12	3	10	C		109.5	105.3	1.69	12.3%	11.0%	20.7%	35%	58.6%	14.6%
13	3	20	C		117.6	113.1	1.81	16.7%	14.3%	30.2%	31%	98.8%	0.4%
14	3	30	C		99.7	95.9	1.54	20.6%	17.1%	31.6%	41%	76.8%	9.5%
15	3	40	C		105.6	101.5	1.63	2.5%	2.4%	4.1%	38%	10.8%	33.6%
16	3	50	B		98.7	94.9	1.52	2.9%	2.8%	4.4%	42%	10.6%	37.3%
17	3	70	C		124.3	119.5	1.91	10.2%	9.3%	19.5%	27%	73.3%	7.1%
18	3	90	B		100.4	96.5	1.55	21.8%	17.9%	33.7%	41%	82.7%	7.0%
19													
20													
	1 avg				116.1	111.7	1.79	9.1%	8.1%	16.9%	31.5%	59.3%	14.4%
	1 cv				0.08	0.08	0.08	0.60	0.56	0.62	0.17	0.68	1.04
	2 avg				107.2	103.1	1.65	10.7%	9.2%	17.8%	36.8%	49.9%	19.0%
	2 cv				0.05	0.05	0.05	0.75	0.72	0.74	0.09	0.73	0.76
	3 avg				107.7	103.6	1.66	12.5%	10.6%	20.6%	36.4%	58.8%	15.8%
	3 cv				0.09	0.09	0.09	0.63	0.59	0.60	0.16	0.59	0.90
	ALL avg				110.5	106.3	1.70	10.8%	9.3%	18.4%	34.8%	56.4%	16.3%
	ALL cv				0.09	0.09	0.09	0.68	0.64	0.65	0.16	0.67	0.90

Rosedale - Rio Bravo Water Storage District.

Petrophysical Analyses.

Wtr.Dens: 1.00 g/cc
Gr.Dens: 2.61 g/cc

No.	Sample: Hole	Depth (ft)	Split	measure dry dens (p/cf)	adjusted dry dens 0.04 (p/cf)	62.43 dry bulk Density (Mb/Vb) (g/cc)	Grav. Wtr.Cont. (Mw/Mb) T (%)	T/(1+T)	Vol.Water Content (Vw/Vb) (%)	Porosity (Vv/Vb) (%)	Ambient Saturation (Vw/Vv) (%)	Specific Yield (Vw/Vb) (%)
	EXTRA 3rd-split ANALYSES											
	1	100	A wet	122.3	117.6	1.88	9.2%	8.4%	17.3%	28%	62.3%	na
	1	110	A wet	105	101.0	1.62	20.9%	17.3%	33.8%	38%	88.9%	na
	2	40	-	110.6	106.3	1.70	3.3%	3.2%	5.6%	35%	16.2%	29.1%
	3	10	A	107.6	103.5	1.66	10.6%	9.6%	17.6%	37%	48.1%	18.9%
	EXTRA paired ANALYSES											
	2	20	B	90.5	87.0	1.39	30.3%	23.3%	42.2%	47%	90.6%	4.4%
	2	20	C	98.1	94.3	1.51	21.4%	17.6%	32.3%	42%	76.8%	9.8%
	2	50	B	102.1	98.2	1.57	2.0%	2.0%	3.1%	40%	7.9%	36.6%
	2	50	C	101.2	97.3	1.56	2.3%	2.2%	3.6%	40%	8.9%	36.7%
	2	90	B	103.0	99.0	1.59	2.9%	2.8%	4.6%	39%	11.7%	34.6%
	2	90	C	114.9	110.5	1.77	1.0%	1.0%	1.8%	32%	5.5%	30.4%
	3	60	B wet	100.5	96.6	1.55	11.0%	9.9%	17.0%	41%	41.8%	na
	3	60	C wet	116.6	112.1	1.80	14.8%	12.9%	26.6%	31%	85.2%	na
	ALL avg			106.0	102.0	1.63	10.8%	9.2%	17.1%	37.4%	45.3%	25.1%
	ALL cv			0.08	0.08	0.08	0.84	0.77	0.78	0.13	0.73	0.47

	Porosity	resid.Sat	ALL Sy	sorted Sand Sy	unsorted Sand Sy	Silt Sy	edited Silt Sy
ALLnum	36	30	28	12		16	12
ALLavg	35.0%	45.0%	19.3%	33.6%		8.6%	5.5%
ALLcv	0.00	0.78	0.69	0.07		0.73	0.59
SPLIT 1	35.1%	45.0%	18.9%	32.5%		8.7%	5.6%
BH1avg	32.9%	11.8%	31.5%	31.5%		0.0%	0.0%
BH2avg	35.6%	42.1%	21.1%	34.4%		12.3%	7.9%
BH3avg	36.8%	61.3%	13.7%	31.6%		6.5%	4.4%
SPLIT 2	34.8%	44.9%	19.8%	34.8%		8.5%	5.4%
BH1avg	32.1%	12.9%	32.9%	32.9%		0.0%	0.0%
BH2avg	35.9%	44.7%	20.2%	35.9%		9.8%	4.2%
BH3avg	36.3%	58.8%	15.7%	35.5%		7.7%	6.0%

Rosedale - Rio Bravo Water Storage District.

Specific Yield.

No.	BH	Depth (ft)	Effective Classif.	d-eff (mm)	Sorting (Cu)	Porosity (Vv/Vb) (%)	est'd max. resid.Sat (Vw/Vv) (%)	0.062 ALL Sy (Vw/Vb) (%)	sorted Sand Sy (Vw/Vb) (%)	unsorted Sand Sy (Vw/Vb) (%)	Silt Sy (Vw/Vb) (%)	edited Silt Sy (Vw/Vb) (%)	
		SPLIT #1											
1	1	20	m silt	0.012	Poor	39.3%	8.5%	->			->	->	mxd smpl
2	1	30	f sand	0.250	Good	38.3%	10.5%	34.3%	34.3%				
3	1	70	f sand	0.220	Good	34.3%	16.5%	28.6%	28.6%				
4	1	80	vc silt	0.036	Good	27.9%	na	na			na	na	
5	1	100	vc silt	0.040	Poor	22.8%	na	na			na	na	
6	1	110	vc silt	0.038	Fair	34.6%	na	na			na	na	
7	2	10	c silt	0.028	Fair	34.0%	37.5%	21.2%			21.2%	->	dessicated
8	2	30	f sand	0.210	Good	38.5%	5.8%	36.3%	36.3%				
9	2	40	vf sand	0.120	Good	36.7%	11.7%	32.4%	32.4%				
10	2	60	m silt	0.015	Poor	27.2%	81.1%	5.1%			5.1%	5.1%	
11	2	70	vf silt/c clay	0.002	Poor	41.7%	74.4%	10.7%			10.7%	10.7%	
12	3	10	c silt	0.025	Poor	35.0%	57.3%	14.9%			14.9%	->	dessicated
13	3	20	vc silt	0.037	Good	31.6%	75.7%	7.7%			7.7%	7.7%	
14	3	30	c silt	0.030	Fair	40.6%	91.5%	3.4%			3.4%	3.4%	
15	3	40	f sand	0.170	Good	34.6%	8.4%	31.7%	31.7%				
16	3	50	f sand	0.220	Good	36.7%	14.4%	31.4%	31.4%				
17	3	70	f silt	0.007	Poor	36.6%	80.9%	7.0%			7.0%	7.0%	
18	3	90	f silt	0.005	Poor	42.2%	101.1%	-0.4%			-0.4%	-0.4%	
		SPLIT #2											
1	1	20	m silt	0.012	Poor	34.6%	12.4%	->			->	->	mxd smpl
2	1	30	f sand	0.250	Good	36.9%	10.3%	33.1%	33.1%				
3	1	70	f sand	0.220	Good	38.9%	16.0%	32.6%	32.6%				
4	1	80	vc silt	0.036	Good	24.6%	na	na			na	na	
5	1	100	vc silt	0.040	Poor	25.5%	na	na			na	na	
6	1	110	vc silt	0.038	Fair	32.1%	na	na			na	na	
7	2	10	c silt	0.028	Fair	30.9%	32.7%	20.8%			20.8%		dessicated
8	2	30	f sand	0.210	Good	39.2%	4.4%	37.5%	37.5%				
9	2	40	vf sand	0.120	Good	38.1%	9.8%	34.4%	34.4%				
10	2	60	m silt	0.015	Poor	30.8%	90.4%	3.0%			3.0%	3.0%	
11	2	70	vf silt/c clay	0.002	Poor	40.3%	86.3%	5.5%			5.5%	5.5%	
12	3	10	c silt	0.025	Poor	35.4%	58.6%	14.6%			14.6%		dessicated
13	3	20	vc silt	0.037	Good	30.6%	98.8%	0.4%			0.4%	0.4%	
14	3	30	c silt	0.030	Fair	41.2%	76.8%	9.5%			9.5%	9.5%	
15	3	40	f sand	0.170	Good	37.7%	10.8%	33.6%	33.6%				
16	3	50	f sand	0.220	Good	41.8%	10.6%	37.3%	37.3%				
17	3	70	f silt	0.007	Poor	26.6%	73.3%	7.1%			7.1%	7.1%	
18	3	90	f silt	0.005	Poor	40.8%	82.7%	7.0%			7.0%	7.0%	

Comparison of DWR Tabulated Specific Yield and RRB Measured Specific Yield for 18 samples based on their correct textural classification.

Sam. No.	Textural Classif.	DWR Sy	Split #1 Meas'd Sy	Split #2 Meas'd Sy
1	sandy silt	6%	35.9%	30.3%
2	sand	27%	34.3%	33.1%
3	sand	27%	28.6%	32.6%
4	silty sand	6%	na	na
5	sand	27%	na	na
6	sandy silt	6%	na	na
7	silty sand	6%	21.2%	20.8%
8	sand	27%	36.3%	37.5%
9	sand	27%	32.4%	34.4%
10	silty sand	6%	5.1%	3.0%
11	sandy silt	6%	10.7%	5.5%
12	silty sand	6%	14.9%	14.6%
13	silty sand	6%	7.7%	0.4%
14	silty sand	6%	3.4%	9.5%
15	sand	27%	31.7%	33.6%
16	sand	27%	31.4%	37.3%
17	silty sand	6%	7.0%	7.1%
18	sandy silt	6%	-0.4%	7.0%

Appendices

Appendix 2.
Chain-of-Custody Documents.

Sierra Scientific Services. **(661) 872 - 4221.**

Project Name: ROSEDALE - RIO BRAVO WSD

Today's Date: 30 OCT 02

Chain of Custody Document.

PAGE : 1 of 1

	Sample #	Description	Analyses	
1	01-010 B	SAND - DRY	TO BE DETERMINED	
2	" C			
3	01-020 B			
4	" C			
5	01-030 B			
6	" C			
7	01-040 B			
8	" C			
9	01-050 B			
10	" C			
11	01-060 B			
12	" C			
13	01-070 B			
14	" C			
15	01-080 B			
16	" C			
17	01-090 B			
18	" C	SAND - DRY		
19	01-100 B	SAND - WET		
20	" C	" - WET		
21	01-110 B	" - WET		
22	" C	" - WET		
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				

	Relinquished by (name & Co.):	Date/time	Received by (name & Co.):	Date/time
1	R. [illegible] - SSS	10/30/02 1422	[illegible]	10/30/02 2:30 PM
2				
3				

Sierra Scientific Services. **(661) 872 - 4221.**

Project Name: Rosedale-Rio Bravo WSD

Today's Date: 31 OCT 02

Chain of Custody Document.

PAGE : 1 of 1 .

	Sample #	Description	Analyses	
1	02-010 B	SAND - DRY	TO BE DETERMINED	
2	C	↓		
3	02-020 B			
4	C			
5	02-030 B			
6	C			
7	02-040 B			
8	C			
9	02-050 B			
10	C			
11	02-060 B			
12	C	↓		
13	02-070 B	SILT - DRY		
14	C	″		
15	02-080 B	SILT/SAND		
16	C	SAND		
17	02-090 B	PEBBLY SAND		
18	C	PEBBLY SAND		
19	02-100 B	SILT		
20	C	SAND		
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				

	Relinquished by (name & Co.):	Date/time	Received by (name & Co.):	Date/time
1	R. Crewdson (SSS)	10/31/02		
2				
3				

Sierra Scientific Services. (661) 872 - 4221.

Project Name: RRB WSD SCAP

Today's Date: 01 NOV 02

Chain of Custody Document.

PAGE : 1 of 2 .

	Sample #	Description	Analyses	
1	03-005 A	SAND & SILT	TO BE DETERMINED	
2	B			
3	C			
4	03-010 A			
5	B			
6	C			
7	03-020 B			
8	C			
9	03-030 A			
10	B			
11	C			
12	03-040 A			
13	B			
14	C			
15	03-050 A			
16	B			
17	C			
18	03-060 A	WET		
19	B	WET		
20	C	WET		
21	03-070 A			
22	B			
23	C			
24	03-080 B			
25	C			
26	03-090 A			
27	B			
28	C			
29	03-100 B			
(30)	C			
31				
32				
33				
34				

30 TOTAL

	Relinquished by (name & Co.):	Date/time	Received by (name & Co.):	Date/time
1	R Chandler (SSS)	11/01 1725	[signature]	11/1/02
2				
3				

Sierra Scientific Services. (661) 872 - 4221.

Project Name: RRB WSD SCAP

Today's Date: 01 NOV 02

Chain of Custody Document.

	Sample #	Description	Analyses	
1	01-010 A	SANDS & SILTS	STORAGE ONLY	
2	01-020 A			
3	01-030 A			
4	01-040 A			
5	01-050 A			
6	01-060 A			
7	01-070 A			
8	01-080 A			
9	01-090 A			
10	01-100 A	WET		
11	01-110 A	WET		
12				
13				
14				
15				
16				
17				
18				
19				
20				
21	02-010 A	SANDS & SILTS	STORAGE ONLY	
22	02-020 A			
23	02-030 A			
24	02-040 A			
25	02-050 A			
26	02-060 A			
27	02-070 A			
28	02-080 A			
29				
30				
31				
32				
33				
34				

19 TOTAL

	Relinquished by (name & Co.):	Date/time	Received by (name & Co.):	Date/time
1	R. Cerda (SSS)	11/01 1725	[illegible signature]	11/1/02
2				
3				

Sierra Scientific Services. (661) 872 - 4221.

Soil TEST List. 01 November, 2002.

shading means "no analysis".

	Sample number		splits	Moisture content	Porosity	Perm.	Sieve analysis	4-point compaction	Spec. gravity	
	SCAP-01	010	B & C							
vf-m	SCAP-01	020	B & C	YES	YES	YES	YES			
m-vcs	SCAP-01	030	B & C	YES	YES	YES	YES			
	SCAP-01	040	B & C							
	SCAP-01	050	B & C							
	SCAP-01	060	B & C							
f-cs	SCAP-01	070	B & C	YES	YES	YES	YES			
silt	SCAP-01	080	B & C	YES	YES	YES	YES			
	SCAP-01	090	B & C							
vcs	SCAP-01	100	B & C	YES	YES	YES	YES			
vf	SCAP-01	110	B & C	YES	YES	YES	YES			
	SCAP-01	120	B & C							
vf	SCAP-02	010	B & C	YES	YES	YES	YES			
clay	SCAP-02	020	B & C					YES- "B" split		
f-m	SCAP-02	030	B & C	YES	YES	YES	YES			
m-cs	SCAP-02	040	B & C	YES	YES	YES	YES			
m-cs	SCAP-02	050	B & C					YES either		
slt-sd	SCAP-02	060	B & C	YES	YES	YES	YES			<-hydrometer
sd/slt:cl-slt	SCAP-02	070	B & C	YES	YES	YES	YES			<-hydrometer
	SCAP-02	080	B & C							
cl-peb-sand	SCAP-02	090	B & C					YES either		
	SCAP-02	100	B & C							
	SCAP-03	005	B & C							
	SCAP-03	010	A, B & C	YES	YES	YES	YES	YES either		
	SCAP-03	020	B & C	YES	YES	YES	YES			
	SCAP-03	030	B & C	YES-B	YES-B	YES-C	YES-B		YES B-split	
	SCAP-03	040	B & C	YES	YES	YES	YES		YES either	
	SCAP-03	050	A & B	YES	YES	YES	YES		YES either	
	SCAP-03	060	B & C							
	SCAP-03	070	B & C	YES	YES	YES-C	YES			<-hydrometer
	SCAP-03	080	B & C							
	SCAP-03	090	A & B	YES	YES	YES	YES			<-hydrometer
	SCAP-03	100	B & C							

Appendix 3.
Daily Drilling Reports.

Sierra Scientific Services. End-of-Day Drilling Report.

Project Name: RRB WSD – SCAP

SSS Drilling Supervisor: R. CREWDSON

Well No.: SCAP-01
Today's Date: 30 OCT 02
Start Time: 0833
End Time: 1430
PAGE 1 of 1.

Drilling	
Contractor:	SEI
Driller:	LEO
Rig Type:	CME-75
Bit Type:	8" HSA
RPM:	
WOB:	
Mud Type:	N/A
HELPER:	BOBBY

Completion Record	Diam (in)	Dept Top	Dept Btm	Length (ft)
Conductor				
Blank				
Slotted				na
Blank				
Btm Plug			none	
TD Drld:			110	
1st Water Entry:		100		
Static Water Level:		96		

Daily Summary		
Well No.:	SCAP-01	
Day No.:	01	
Spud Date:	30 OCT 02	
Start Depth:	0	ft.
End Depth:	110	ft.
Footage Drilled:	140	ft.
Rotating time:	4.11	hr.
Drlg Rate:	34	fph.
Comp Date:	30 OCT 02	
Tot. Depth:	BACKFILLED.	

Elevations:	
Ground Level:	360 ±
Casing Lip:	

Materials Used	
Gel:	
Polymer:	
Foam:	
Barite:	
Bentonite:	
Sand:	
Cement:	
	NONE

Tubulars Used	
Conductor:	
Blank Csg:	
Slot'd Csg:	
Plug:	
Cap:	
	NONE

Materials Used	
Sam. tubes used	33
# sent to Lab	22
end caps used	66

Hourly Operations — PAGE 1 of 1.

Time	Depth	Operations	Ft Drld	Hr Drlg
0658		ONSITE		
0833		RIG ONSITE – SAFETY MTG – R/U		
0900	0	SPUD		
0930	30	LU Sampler in hole @ 30 Ft – Fish	30	1.0
0948		try overdrilling & PO AUGERS		
1000	0	OOH. MOVE RIG WEST 6'. SPUD NEW Hole	0	
1016	30	AUGER TO 30 FT. Collect Sample	30	0.25
1030		Tony F onsite		
1055	60		30	0.66
1230	100	AUGER DROPPED 4-5in. Possible WATER.	40	1.6
		SED. on BIT PLUG "WET"		
1255	110	PROBLEM? POH – WORKING AUGERS SLOWLY	10	0.6
		TO ELIMINATE POSSIBLE RUNNING SAND		
1340		Sample OOH. POH. OOH @ 1415		
1415		BACKFILL. NO BOTTOM PLUG		
~~1415~~ 1430		DONE. LEAVE SITE.		
		— EOD —		
		Total	140	4.11

Sierra Scientific Services. End-of-Day Drilling Report.

Project Name: RRB WSD SCAP

SSS Drilling Supervisor: R. CREWDSON

Well No.: SCAP-02
Today's Date: 31 OCT 02
Start Time: 0755
End Time: 1500
PAGE 1 of 1.

Drilling

Contractor:	SEI
Driller:	LEO
Rig Type:	CME 75
Bit Type:	8" HS AUGER
RPM:	60-180
WOB:	
Mud Type:	

HELPER: BOBBY

Completion Record

	Diam (in)	Dept Top	Dept Btm	Length (ft)
Conductor				
Blank				
Slotted				na
Blank				
Btm Plug			none	
TD Drld:			100	
1st Water Entry:		—		
Static Water Level:		—		

Daily Summary

Well No.:	SCAP-02	
Day No.:	01	
Spud Date:	31 OCT 02	
Start Depth:	0	ft.
End Depth:	100	ft.
Footage Drilled:	100	ft.
Rotating time:	4.50	hr.
Drlg Rate:	22	fph.
Comp Date:	31 OCT 02	
Tot. Depth:	BACKFILLED	

Elevations:

Ground Level:	320±
Casing Lip:	

Materials Used

Gel:	
Polymer:	
Foam:	
Barite:	
Bentonite:	
Sand:	
Cement:	

Tubulars Used

Conductor:	
Blank Csg:	
Slot'd Csg:	
Plug:	
Cap:	

Materials Used

Sam. tubes used	3x10-2=28
# sent to Lab	20
SSS	8
CAPS used	56

Hourly Operations PAGE 1 of 1.

Time	Depth	Operations	Ft Drld	Hr Drlg
0728		ONSITE		
0740		RIG ARRIVES – R/U		
0755		PIPE TRUCK ARRIVES		
0812	0	SPUD		
0847	30	SAMPLING	30	0.60
0925	50	R/W for Sample: STOP FOR Hammer repair	20	0.65
0935	50	Resume – pull sample		
1000	60	STOP FOR HYDRAULIC REPAIR –	10	0.40
		Driller & helper leave site to get FLUID.		
1100		Crew Returns – work on hydraulics		
1110	60	Resume Drilling		
1118	65			
1135	70	SAMPLING @ 70	10	0.40
1220	80	Sampling @ 80	10	0.75
1320	90	Sampling @ 90	10	1.00
1340		Conditioned Hole – Resume Drilling		
1403	100	Sampling @ 100 – Last Sample	10	0.70
1410	100	POH		
1445		AUGERS OUT OF HOLE		
1500		DEMOB OFF SITE		
		— EOD —		
		Total	100	4.50

Sierra Scientific Services. End-of-Day Drilling Report.

Project Name: RRB WSD SCAP

SSS Drilling Supervisor: R. CREWDSON

Well No.: SCAP-03
Today's Date: 01 NOV 02
Start Time: 0755
End Time: 1730

Drilling

Contractor:	SEI
Driller:	LEO
Rig Type:	CME 75
Bit Type:	8" HS AUGER
RPM:	
WOB:	
Mud Type:	

HELPER: BOBBY

Completion Record

	Diam (in)	Dept Top	Dept Btm	Length (ft)
Conductor				
Blank				
Slotted				
Blank				na
Btm Plug			none	
TD Drld:			100	
1st Water Entry:		—		
Static Water Level:		—		

Daily Summary

Well No.:	SCAP-03	
Day No.:	01	
Spud Date:	01 NOV 02	
Start Depth:	0	ft.
End Depth:	100	ft.
Footage Drilled:	100	ft.
Rotating time:	4.25	hr.
Drlg Rate:	24	fph.
Comp Date:	01 NOV 02	
Tot. Depth:	BACKFILLED	

Elevations:

Ground Level: 320±
Casing Lip:

Materials Used

Gel:
Polymer:
Foam:
Barite:
Bentonite:
Sand:
Cement:

Tubulars Used

Conductor:
Blank Csg:
Slot'd Csg:
Plug:
Cap:

Materials Used

Sam. tubes used: 30
sent to Lab: 30 today
" " ": 17 From 10/30-31

CAPS used TODAY: 60

Hourly Operations PAGE 1 of 2.

Time	Depth	Operations	Ft Drld	Hr Drlg
0735		ONSITE.		
0755		RIG & PIPE TRUCK ONSITE – need to		
		repair/adjust hammer hydraulics during		
		operations to GET "full pull"		
0813	0	SPUD – AUGER TO 5 Ft.		
0815		begin repairs		
0835		continuing repairs		
0905		" " – RC surface sampling		
0920		drilling @ 20 Ft;		
0930	25	sampling @ 25 Ft; hose breaks & FLUID	25	1.30
		SPRAYS on Ground		
0940		will TRY TO Sample with Pull-down cable		
		NO luck – blowing Fluid – Driller calls		
		IT QUITS for offsite REPAIRS		
0950		RIG & CREW Demob offsite – Leave		
		25 Ft Augers in-hole & contam soil		
		to be cleaned up.		
1000		R. Coffee onsite.		
1100		RC LV SITE – GO TO RRB ofc		
1220		LEO calls from Shop – READY TO Resume		
1240		RC onsite		
1248		RIG ONSITE		
1300		clean up fluid spill – 1 Full BBL		
1325		RIG UP; PREP TO DRILL		
1340	25	AUGERS @ 25 Ft in CLAY – check footage – OK		
		Driller SAYS 25' Sampler From AM WAS 20'.		
1345	30	Sampling @ 30 Ft	5	0.10
1430		Call SEI – talk to Tom B For 10 min		
1455	70	Sampling @ 70 Ft	40	1.15
		next page		
		Total	70	2.55

Sierra Scientific Services. End-of-Day Drilling Report.

Project Name: RRB WSD SCAP

SSS Drilling Supervisor: R. CREWDSON

Well No.: SCAP-03

Today's Date: 01 NOV 02

Start Time:

End Time:

Drilling	
Contractor:	
Driller:	
Rig Type:	
Bit Type:	
RPM:	
WOB:	
Mud Type:	

Completion Record

	Diam (in)	Dept Top	Dept Btm	Length (ft)
Conductor				
Blank				
Slotted				
Blank				
Btm Plug				
TD Drld:				
1st Water Entry:				
Static Water Level:				

Daily Summary		
Well No.:		
Day No.:		
Spud Date:		
Start Depth:		ft.
End Depth:		ft.
Footage Drilled:		ft.
Rotating time:		hr.
Drlg Rate:		fph.
Comp Date:		
Tot. Depth:		

Elevations:	
Ground Level:	
Casing Lip:	

Materials Used	
Gel:	
Polymer:	
Foam:	
Barite:	
Bentonite:	
Sand:	
Cement:	

Tubulars Used	
Conductor:	
Blank Csg:	
Slot'd Csg:	
Plug:	
Cap:	

Materials Used	
Sam. tubes used	30
# sent to Lab	30 TODAY
" "	17 From other two holes
Caps used	60

Hourly Operations PAGE 2 of 2.

Time	Depth	Operations	Ft Drld	Hr Drlg
1455	70	Sampling @ 70 CUM	70	2.55
1522	80	Sampling @ 80	10	0.45
1555	90	Sampling @ 90	10	0.55
1637	100	Sampling @ 100	10	0.70
1646		OOH w/ 100' Sample - RIG DOWN		
1717		OOH w/ AUGERS. RIG OFF.		
1730		DEMOB OFF SITE.		
		— EOD —		
		Total	100	4.25

SOILS ENGINEERING, INC.
4400 Yeager Way
Bakersfield, CA 93313
Ph. (661) 831-5100
Fax (661) 831-2111

TIME LEFT SHOP : ____
TIME ON SITE : ____
TIME LEFT SITE : ____
TIME IN SHOP : ____

DAILY DRILLING REPORT

DATE 10-30-02
CLIENT [illegible]
ENGINEER ____

PROJECT: [illegible]
JOB NO. 10,127

BORING & DEPTH
#1 110' #4 ____
#2 ____ #5 ____
#3 ____ #6 ____

DRILL RIG: [illegible]
TYPE OF DRILLING: [illegible]
OTHER VEHICLE: [illegible]
MILEAGE: ____

EQUIPMENT USED:

STEAM CLEANER	☐ YES	☐ NO
CONCRETE MIXER	☐ YES	☐ NO
GENERATOR	☑ YES	☐ NO
JACK HAMMER	☐ YES	☐ NO
OTHERS	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO

NO.	MATERIALS USED	QUANTITY
	PVC SCREEN Th. END	
	PVC BLANK Th. END	
	END PLUGS	
	SLIP CAPS	
	BAGS MONTEREY SAND #3	
	BUCKETS OF BENTONITE PELLET	
	BAGS OF READY MIX CONCRETE	
	CHRISTY BOXES	
	WATER PROOF BOXES	
	MONUMENT CASINGS . . . . FT	
	PADLOCKS	
	(55g) DRUMS	
	BRASS RINGS	11
	PLASTIC CAPS	[illegible]
	BAGS OF ASPHALT PATCH	
	BAGS OF QUICK-GEL	
	OTHERS	

REMARKS: [illegible]

DRILLING TIME : ____
TRAVEL TIME : ____
STAND-BY TIME : ____
DOWN TIME : ____
MOB/DEMOB. : ____
OTHERS : ____

DRILLER : [illegible]
HELPER : [illegible]
OTHERS : ____

TOTAL HOURS : [illegible]

APPROVED BY CLIENT: ____

SIGNATURE: X ____

DRILLER'S SIGNATURE:
X [illegible]

SOILS ENGINEERING, INC.
4400 Yeager Way
Bakersfield, CA 93313
Ph. (661) 831-5100
Fax (661) 831-2111

TIME LEFT SHOP : 7:00
TIME ON SITE : 7:00
TIME LEFT SITE : 2:00
TIME IN SHOP : 3:00

DAILY DRILLING REPORT

DATE 10-31-02
CLIENT Sierra Scientific Services
ENGINEER

PROJECT: [illegible]
JOB NO. # 10,127

BORING & DEPTH

#1	105'	#4	
#2		#5	
#3		#6	

DRILL RIG: CME 75 HT?
TYPE OF DRILLING: [illegible]
OTHER VEHICLE:
MILEAGE:

EQUIPMENT USED:

STEAM CLEANER	☐ YES	☐ NO
CONCRETE MIXER	☐ YES	☐ NO
GENERATOR	☐ YES	☐ NO
JACK HAMMER	☐ YES	☐ NO
OTHERS	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO

NO.	MATERIALS USED	QUANTITY
	PVC SCREEN Th. END	
	PVC BLANK Th. END	
	END PLUGS	
	SLIP CAPS	
	BAGS MONTEREY SAND #3	
	BUCKETS OF BENTONITE PELLET	
	BAGS OF READY MIX CONCRETE	
	CHRISTY BOXES	
	WATER PROOF BOXES	
	MONUMENT CASINGS . . . . FT	
	PADLOCKS	
	(55g) DRUMS	
	BRASS RINGS	
	PLASTIC CAPS	
	BAGS OF ASPHALT PATCH	
	BAGS OF QUICK-GEL	
	OTHERS	

REMARKS:

DRILLING TIME : 5 1/2 Hr
TRAVEL TIME : 2 Hr
STAND-BY TIME :
DOWN TIME :
MOB/DEMOB. :
OTHERS :

TOTAL HOURS : 7 1/2

DRILLER : [illegible]
HELPER : [illegible]
OTHERS :

APPROVED BY CLIENT:
SIGNATURE: X [signature]

DRILLER'S SIGNATURE:
X [signature]

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Bakersfield, CA 93313
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Fax (661) 831-2111

TIME LEFT SHOP :
TIME ON SITE :
TIME LEFT SITE :
TIME IN SHOP :

DAILY DRILLING REPORT

DATE
CLIENT
ENGINEER

DRILL RIG:
TYPE OF DRILLING:
OTHER VEHICLE:
MILEAGE:

PROJECT:
JOB NO.

BORING & DEPTH

#1		#4	
#2		#5	
#3		#6	

EQUIPMENT USED:

STEAM CLEANER	☐ YES	☐ NO
CONCRETE MIXER	☐ YES	☐ NO
GENERATOR	☐ YES	☐ NO
JACK HAMMER	☐ YES	☐ NO
OTHERS	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO
	☐ YES	☐ NO

NO.	MATERIALS USED	QUANTITY
	PVC SCREEN Th. END	
	PVC BLANK Th. END	
	END PLUGS	
	SLIP CAPS	
	BAGS MONTEREY SAND #3	
	BUCKETS OF BENTONITE PELLET	
	BAGS OF READY MIX CONCRETE	
	CHRISTY BOXES	
	WATER PROOF BOXES	
	MONUMENT CASINGS . . . . FT	
	PADLOCKS	
	(55g) DRUMS	
	BRASS RINGS	
	PLASTIC CAPS	
	BAGS OF ASPHALT PATCH	
	BAGS OF QUICK-GEL	
	OTHERS	

REMARKS:

DRILLING TIME :
TRAVEL TIME :
STAND-BY TIME :
DOWN TIME :
MOB/DEMOB. :
OTHERS :

TOTAL HOURS :

DRILLER :
HELPER :
OTHERS :

APPROVED BY CLIENT:

SIGNATURE: X

DRILLER'S SIGNATURE:

X

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Appendix 4.
Petrophysical Data.

DENSITY DATA 2 3/8" I. O. TUBES

Thin Wall / Split Spn.						
Location	**B-1**	**B-1**	**B-1**	**B-1**	**B-1**	**B-1**
Depth	**20' B**	**20' C**	**30' B**	**30' C**	**70' B**	**70' C**
Sample + Tare	994.6	1027.3	1008.2	998.7	1018.9	1009.7
Tare	261	261	261	261	261	261
Wet Wt. Sample	733.6	766.3	747.2	737.7	757.9	748.7
Length (in.) "L"	6	5.8	6	5.8	6	6
Wet Density, p.c.f.	105.1	113.6	107.1	109.4	108.6	107.3
% Moisture (avg.)	2.1	1.3	2.5	2.3	3.3	3.9
Dry Wt., p.c.f.	103.0	112.2	104.5	106.9	105.1	103.3
Moisture Can #	**22F**	**16**	**D**	**6**	**103**	**13**
Wet Sample + Tare	109	102	107.8	145.6	143.7	132.3
Dry Sample + Tare	107.3	101	105.8	142.9	140.1	128.3
Moisture loss	1.7	1	2	2.7	3.6	4
Tare	25.1	24.7	26.2	24.9	31.5	24.6
Dry sample	82.2	76.3	79.6	118	108.6	103.7
% Moisture	2.1	1.3	2.5	2.3	3.3	3.9

Thin Wall / Split Spn.						
Location	**B-1**	**B-1**	**B-1**	**B-1**	**B-1**	**B-1**
Depth	**80' B**	**80' C**	**100' A**	**100' B**	**100' C**	**110' A**
Sample + Tare	1202.2	1245.2	1191.2	1250.9	1267.8	1132.1
Tare	261	261	260.1	260.1	261	261
Wet Wt. Sample	941.2	984.2	931.1	990.8	1006.8	871.1
Length (in.) "L"	5.8	5.9	6	5.8	6	5.9
Wet Density, p.c.f.	139.6	143.5	133.5	146.9	144.3	127.0
% Moisture (avg.)	14.2	12.2	9.2	12.2	13.8	20.9
Dry Wt., p.c.f.	122.2	127.9	122.2	131.0	126.9	105.0
Moisture Can #	**006**	**11**	**T2**	**10A**	**B17**	**21**
Wet Sample + Tare	145.7	149	175.9	178	174.1	173.1
Dry Sample + Tare	130.8	135.8	163.3	161.5	156.3	147.8
Moisture loss	14.9	13.2	12.6	16.5	17.8	25.3
Tare	25.6	27.6	26	25.7	26.9	27
Dry sample	105.2	108.2	137.3	135.8	129.4	120.8
% Moisture	14.2	12.2	9.2	12.2	13.8	20.9

Thin Wall / Split Spn.						
Location	**B-1**	**B-1**	**B-2**	**B-2**	**B-2**	**B-2**
Depth	**110' B**	**110' C**	**10' B**	**10' C**	**20' B**	**20' C**
Sample + Tare	1184	1199.4	1071.6	1095.2	993.4	991.7
Tare	261	261	261	261	211.9	202.4
Wet Wt. Sample	923	938.4	810.6	834.2	781.5	789.3
Length (in.) "L"	6	6	5.8	5.8	5.7	5.7
Wet Density, p.c.f.	132.3	134.5	120.2	123.7	117.9	119.1
% Moisture (avg.)	23.9	16.9	7.4	5.6	30.3	21.4
Dry Wt., p.c.f.	106.8	115.1	111.9	117.1	90.5	98.1
Moisture Can #	**A47**	**7**	**6**	**11**	**10A**	**21**
Wet Sample + Tare	120.8	123.8	99.9	112	75.2	89.6
Dry Sample + Tare	102.1	109.7	94.7	107.5	63.7	78.6
Moisture loss	18.7	14.1	5.2	4.5	11.5	11
Tare	23.9	26.2	24.9	27.6	25.7	27.1
Dry sample	78.2	83.5	69.8	79.9	38	51.5
% Moisture	23.9	16.9	7.4	5.6	30.3	21.4

Project No.: 10127 **DENSITY DATA 2 3/8" I. O. TUBES**

Thin Wall | Split Spn.						
Location	**B-2**	**B-2**	**B-2**	**B-2**	**B-2**	**B-2**
Depth	**30' B**	**30' C**	**40' A**	**40' B**	**40' C**	**50' B**
Sample + Tare	949.6	849	1018.4	1027.3	983.6	974.1
Tare	212.3	207.5	261	260	260	260
Wet Wt. Sample	737.3	641.5	757.4	767.3	723.6	714.1
Length (in.) "L"	6	5.3	5.7	6	5.8	5.9
Wet Density, p.c.f.	105.7	104.1	114.3	110.0	107.3	104.1
% Moisture (avg.)	1.4	1.1	3.3	2.6	2.3	2.0
Dry Wt., p.c.f.	104.2	103.0	110.7	107.2	104.9	102.1
Moisture Can #	**22F**	**103**	**7**	**4**	**A47**	**T2**
Wet Sample + Tare	132.8	132.7	102.1	119.4	105.4	109.4
Dry Sample + Tare	131.3	131.6	99.7	117.3	103.6	107.8
Moisture loss	1.5	1.1	2.4	2.1	1.8	1.6
Tare	25.1	31.4	26	36.2	23.8	26
Dry sample	106.2	100.2	73.7	81.1	79.8	81.8
% Moisture	1.4	1.1	3.3	2.6	2.3	2.0

Thin Wall | Split Spn.						Disturbed
Location	**B-2**	**B-2**	**B-2**	**B-2**	**B-2**	**B-2**
Depth	**50' C**	**60' B**	**60' C**	**70' B**	**70' C**	**90' B**
Sample + Tare	934	1188.4	1204.8	1062.8	1284.4	988.4
Tare	260	260	260	260	420.9	261
Wet Wt. Sample	674	928.4	944.8	802.8	863.5	727.4
Length (in.) "L"	5.6	5.8	6	5.8	6	5.9
Wet Density, p.c.f.	103.5	137.7	135.4	119.0	123.8	106.0
% Moisture (avg.)	2.3	11.6	15.4	20.4	22.3	2.9
Dry Wt., p.c.f.	101.2	123.3	117.4	98.8	101.2	103.1
Moisture Can #	**D**	**D2**	**13**	**B17**	**16**	**006**
Wet Sample + Tare	115.3	96.2	97.3	100	100.4	108.1
Dry Sample + Tare	113.3	88.9	87.6	87.6	86.6	105.8
Moisture loss	2	7.3	9.7	12.4	13.8	2.3
Tare	26.3	26.2	24.6	26.9	24.8	25.6
Dry sample	87	62.7	63	60.7	61.8	80.2
% Moisture	2.3	11.6	15.4	20.4	22.3	2.9

Thin Wall | Split Spn.	Disturbed					
Location	**B-2**	**B-3**	**B-3**	**B-3**	**B-3**	**B-3**
Depth	**90' C**	**10' A**	**10' B**	**10' C**	**20' B**	**20' C**
Sample + Tare	1029.6	937.6	1119.8	1046.5	1176.8	1218.2
Tare	261	261	261	261	261	261
Wet Wt. Sample	768.6	676.6	858.8	785.5	915.8	957.2
Length (in.) "L"	5.7	4.9	6	5.5	6	6
Wet Density, p.c.f.	116.0	118.8	123.1	122.8	131.3	137.2
% Moisture (avg.)	0.8	10.6	11.8	12.3	13.4	16.7
Dry Wt., p.c.f.	115.1	107.4	110.1	109.4	115.8	117.6
Moisture Can #	**9A**	**7**	**006**	**11**	**D2**	**6**
Wet Sample + Tare	102.6	89.6	88	95.2	94.5	87.2
Dry Sample + Tare	101.9	83.5	81.4	87.8	86.4	78.3
Moisture loss	0.7	6.1	6.6	7.4	8.1	8.9
Tare	13	25.7	25.4	27.6	25.9	25
Dry sample	88.9	57.8	56	60.2	60.5	53.3
% Moisture	0.8	10.6	11.8	12.3	13.4	16.7

Project No.: 10127 **DENSITY DATA 2 3/8" I. O. TUBES**

Thin Wall / Split Spn.						
Location	**B-3**	**B-3**	**B-3**	**B-3**	**B-3**	**B-3**
Depth	**30' B**	**30' C**	**40' B**	**40' C**	**50' A**	**50' B**
Sample + Tare	1116.4	1071.7	1047.2	990.5	1007.3	946.2
Tare	261	261	261	261	261	261
Wet Wt. Sample	855.4	810.7	786.2	729.5	746.3	685.2
Length (in.) "L"	5.9	5.8	6	5.8	5.8	5.8
Wet Density, p.c.f.	124.7	120.2	112.7	108.2	110.7	101.6
% Moisture (avg.)	24.0	20.6	1.7	2.5	3.2	2.9
Dry Wt., p.c.f.	100.5	99.7	110.8	105.5	107.3	98.7
Moisture Can #	**T2**	**10A**	**A**	**9A**	**103**	**A47**
Wet Sample + Tare	94.5	78.3	120.2	107	115.8	105.4
Dry Sample + Tare	81.2	69.3	118.8	104.7	113.2	103.1
Moisture loss	13.3	9	1.4	2.3	2.6	2.3
Tare	25.8	25.6	35.9	12.6	31.2	23.5
Dry sample	55.4	43.7	82.9	92.1	82	79.6
% Moisture	24.0	20.6	1.7	2.5	3.2	2.9

Thin Wall / Split Spn.						
Location	**B-3**	**B-3**	**B-3**	**B-3**	**B-3**	**B-3**
Depth	**60' B**	**60' C**	**70' B**	**70' C**	**90' A**	**90' B**
Sample + Tare	1026.1	1163.6	1114.6	1201.1	1108.2	1114.2
Tare	261	261	261	261	261	261
Wet Wt. Sample	765.1	902.6	853.6	940.1	847.2	853.2
Length (in.) "L"	5.9	5.8	5.8	5.9	5.8	6
Wet Density, p.c.f.	111.5	133.8	126.6	137.0	125.6	122.3
% Moisture (avg.)	11.0	14.8	17.9	10.2	28.3	21.8
Dry Wt., p.c.f.	100.4	116.5	107.4	124.4	97.9	100.4
Moisture Can #	**10**	**X**	**16**	**D**	**21**	**22F**
Wet Sample + Tare	112.1	108.5	109	89.2	79.2	111
Dry Sample + Tare	103.6	97.8	96.2	83.4	67.7	95.6
Moisture loss	8.5	10.7	12.8	5.8	11.5	15.4
Tare	26.5	25.7	24.6	26.4	27.1	25.1
Dry sample	77.1	72.1	71.6	57	40.6	70.5
% Moisture	11.0	14.8	17.9	10.2	28.3	21.8

Thin Wall / Split Spn.						
Location						
Depth						
Sample + Tare						
Tare						
Wet Wt. Sample						
Length (in.) "L"						
Wet Density, p.c.f.						
% Moisture (avg.)						
Dry Wt., p.c.f.						
Moisture Can #						
Wet Sample + Tare						
Dry Sample + Tare						
Moisture loss						
Tare						
Dry sample						
% Moisture						

LABORATORY TESTING
Rosedale-Rio Bravo
Sierra Scientific Services

File No. 02-10127
December 2, 2002

TABLE 1

CONSTANT HEAD PERMEABILITY TEST RESULTS (ASTM D2434)

TEST LOCATION	SOIL DESCRIPTION	PERMEABILITY cm/sec
B-1 @ 20c	Inorganic Silts & Clays (ML-CL)	2.447×10^{-5}
B-1 @ 30c	Poorly-Graded Sand (SP)	.006
B-1 @ 70c	Poorly-Graded Sand (SP)	.008
B-1 @ 80c	Silty Sand (SM)	8.54×10^{-6}
B-1 @ 100c	Silty Sand (SM)	1.293×10^{-5}
B-1 @ 110c	Silty Sand (SM)	4.460×10^{-6}

LABORATORY TESTING
Rosedale-Rio Bravo
Sierra Scientific Services

File No. 02-10127
December 3, 2002

TABLE 2
CONSTANT HEAD PERMEABILITY TEST RESULTS
(ASTM D2434)

TEST LOCATION	SOIL DESCRIPTION	PERMEABILITY cm/sec
B-2C @ 10'	Silty Sand (SM)	5.403×10^{-5}
B-2C @ 30'	Poorly-Graded Sand (SP)	.006
B-2C @ 40'	Poorly-Graded Sand (SP)	.007
B-2C @ 60'	Silty Sand (SM)	1.805×10^{-7}
B-2C @ 70'	Clay	No Flow

TABLE 3
CONSTANT HEAD PERMEABILITY TEST RESULTS
(ASTM D2434)

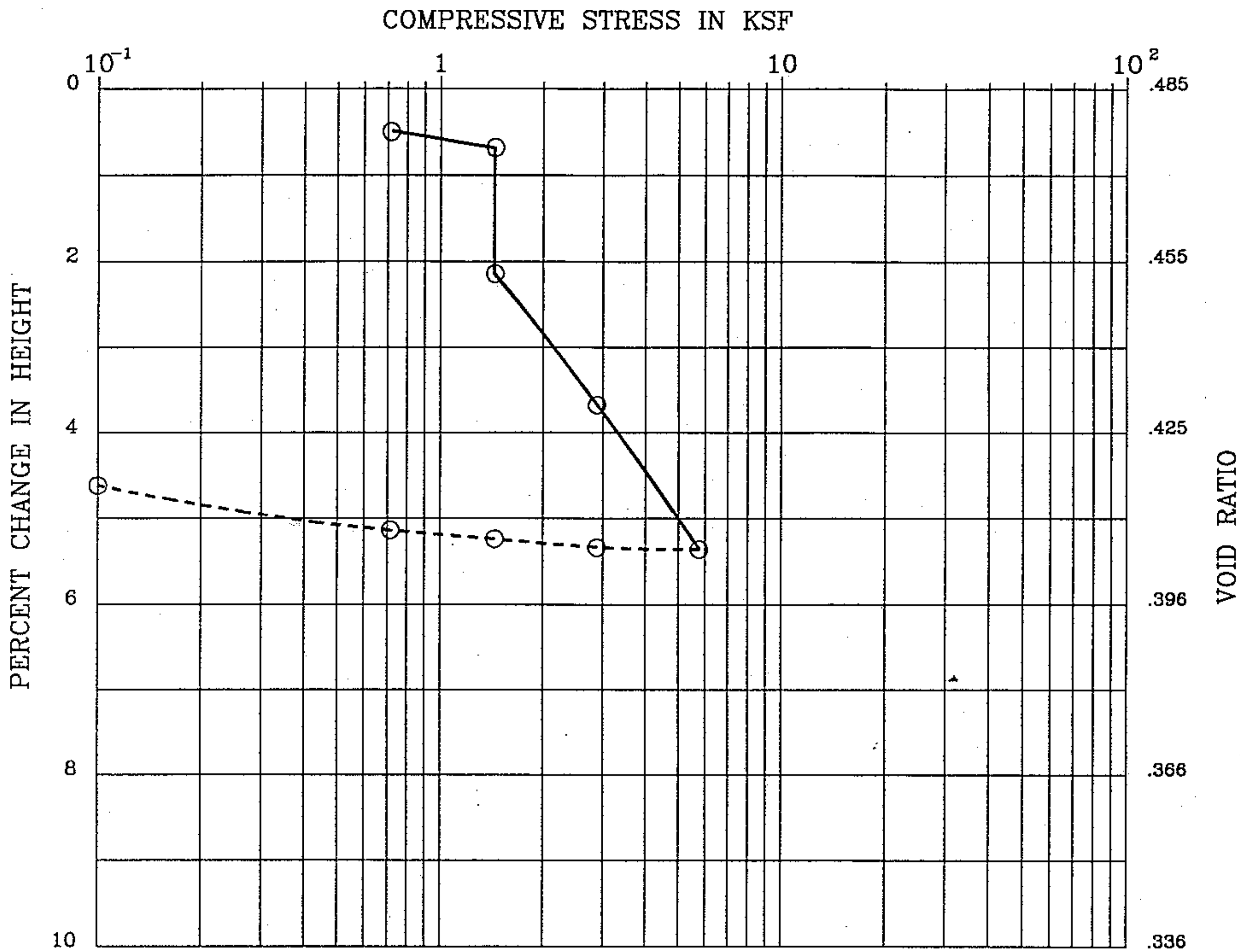
TEST LOCATION	SOIL DESCRIPTION	PERMEABILITY cm/sec
B-3C @ 10'	Silty Sand (SM)	$4.021 X 10^{-5}$
B-3C @ 20'	Inorganic Silts & Clays (ML-CL)	$7.262 x 10^{-6}$
B-3C @ 30'	Silty Sand (SM)	$9.379 x 10^{-6}$
B-3C @ 40'	Poorly-Graded Sand (SP)	.004
B-3C @ 50'	Poorly-Graded Sand (SP)	.007
B-3C @ 70'	Clay	$3.797 x 10^{-7}$

LABORATORY TESTING
Rosedale-Rio Bravo
Sierra Scientific Services

File No. 20-10127
December 4, 2002

SPECIFIC GRAVITY
(ASTM D-854)

Sample No.	Depth	Specific Gravity
B-2	10' (c)	2.660
B-3	30' (c)	2.604
B-3	40' (c)	2.641
B-3	50' (c)	2.520



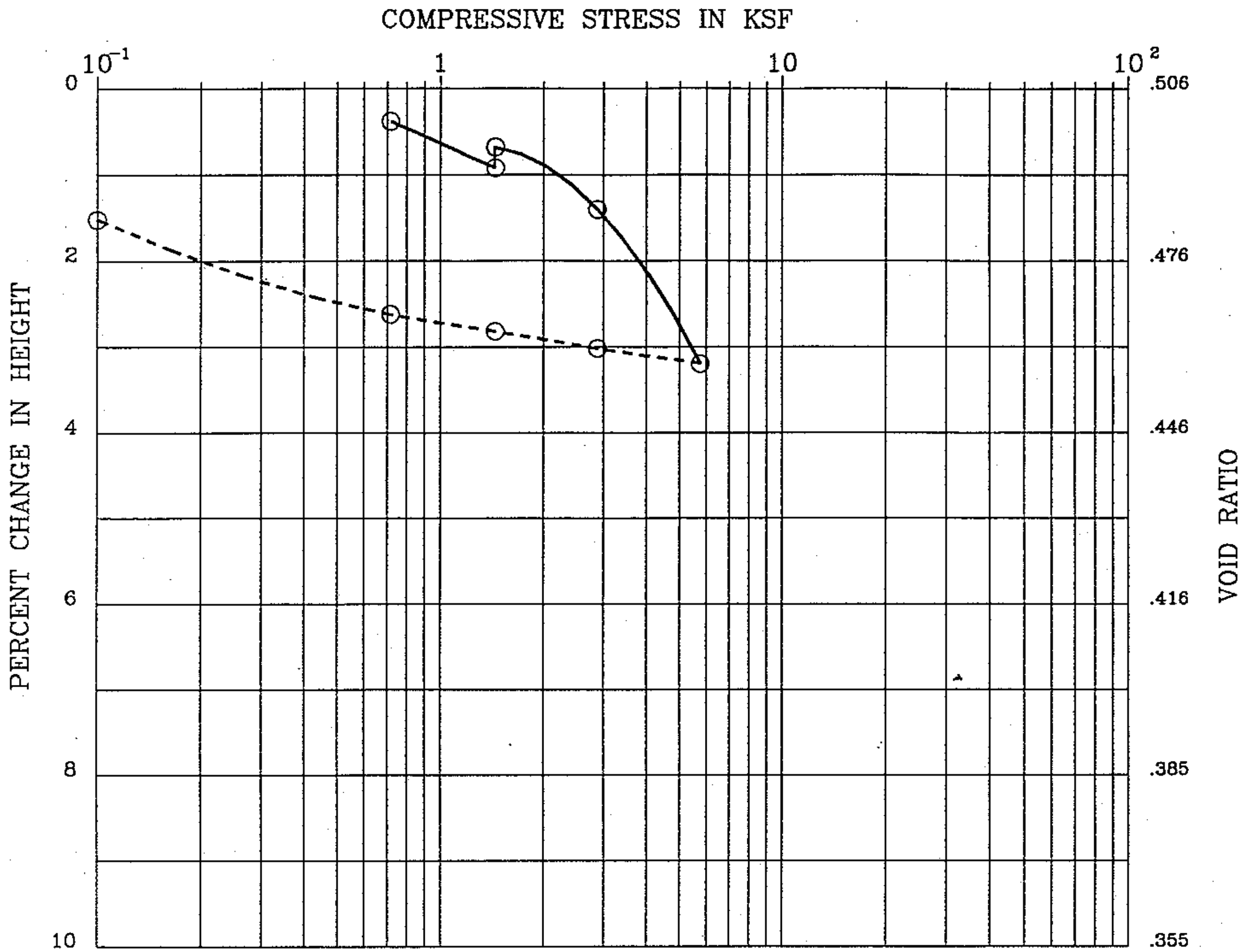
BORING : B-2
DEPTH (ft) : 90'(B)
SPEC. GRAVITY : 2.65

DESCRIPTION : SANDY CLAY (CL)
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	7.2	111.5	40	.485
FINAL	13.5	117.9	89	.404

Remark : SIERRA SCIENTIFIC SERVICES

FILE No. 02-10127	LABORATORY TESTING
Soils Engineering Inc	CONSOLIDATION TEST — Plate No. B-4



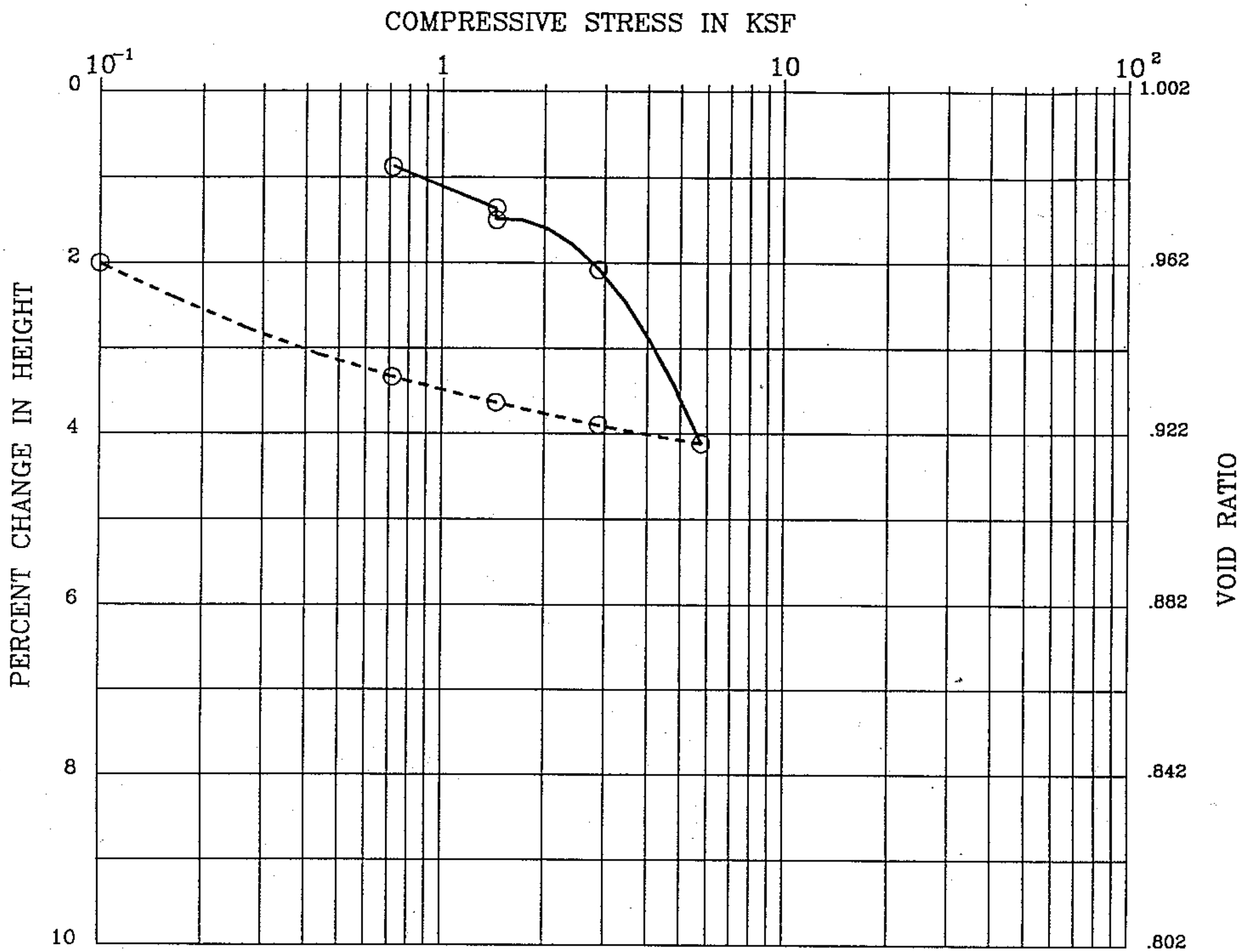
BORING : B-2
DEPTH (ft) : 10'(B)
SPEC. GRAVITY : 2.65

DESCRIPTION : SILTY SAND (SM)
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	16.3	109.9	86	.506
FINAL	17.0	111.5	93	.485

Remark : SIERRA SCIENTIFIC SERVICES

FILE No. 02-10127	LABORATORY TESTING
Soils Engineering Inc	CONSOLIDATION TEST Plate No. B-1



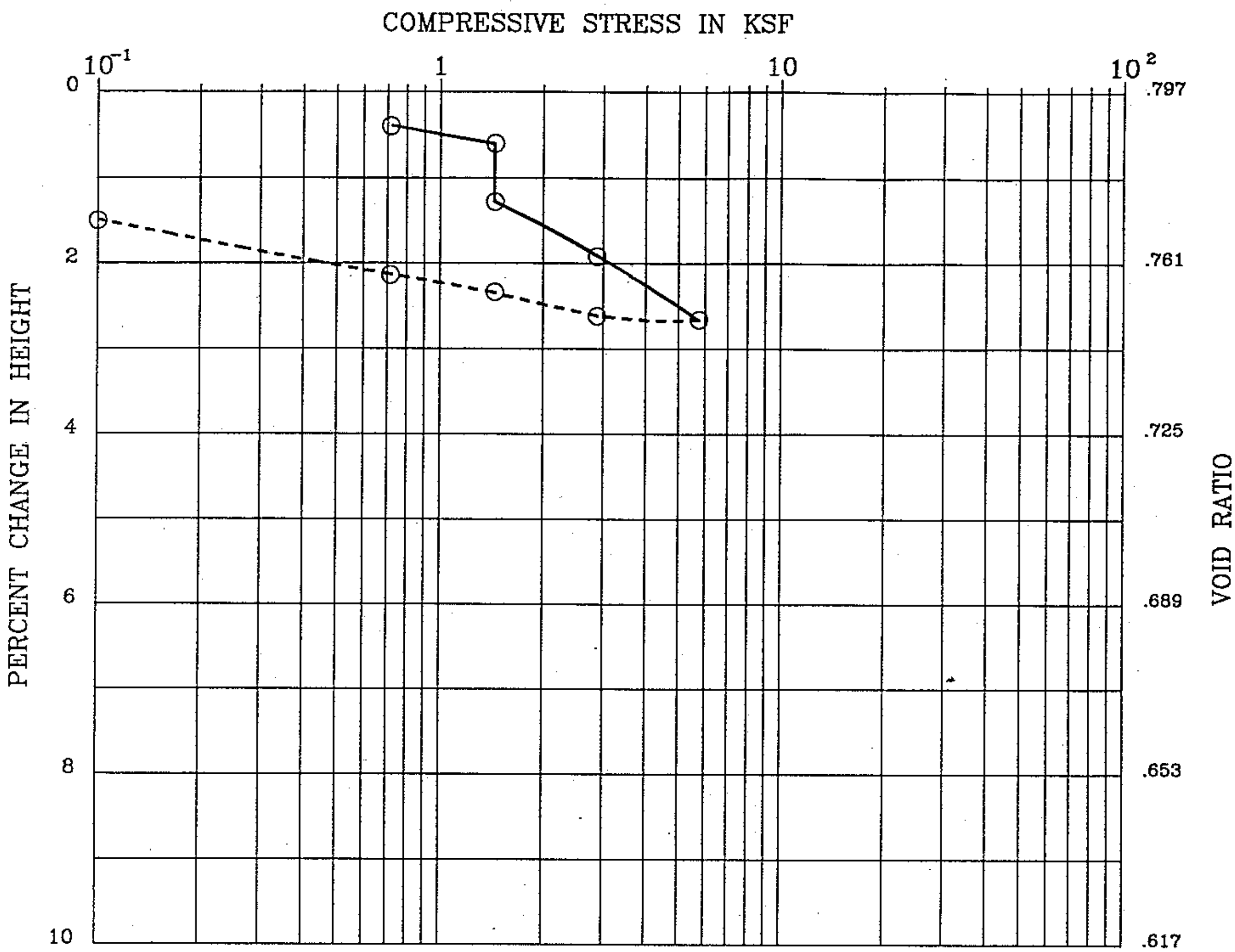
BORING : B-2
DEPTH (ft) : 20'(B)
SPEC. GRAVITY : 2.65

DESCRIPTION : SILTY SAND (SM)
LIQUID LIMIT :
PLASTIC LIMIT :

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	35.7	82.7	95	1.002
FINAL	38.1	84.3	105	.964

Remark : SIERRA SCIENTIFIC SERVICES

FILE No. 02-10127	LABORATORY TESTING
Soils Engineering Inc	CONSOLIDATION TEST Plate No. B-2



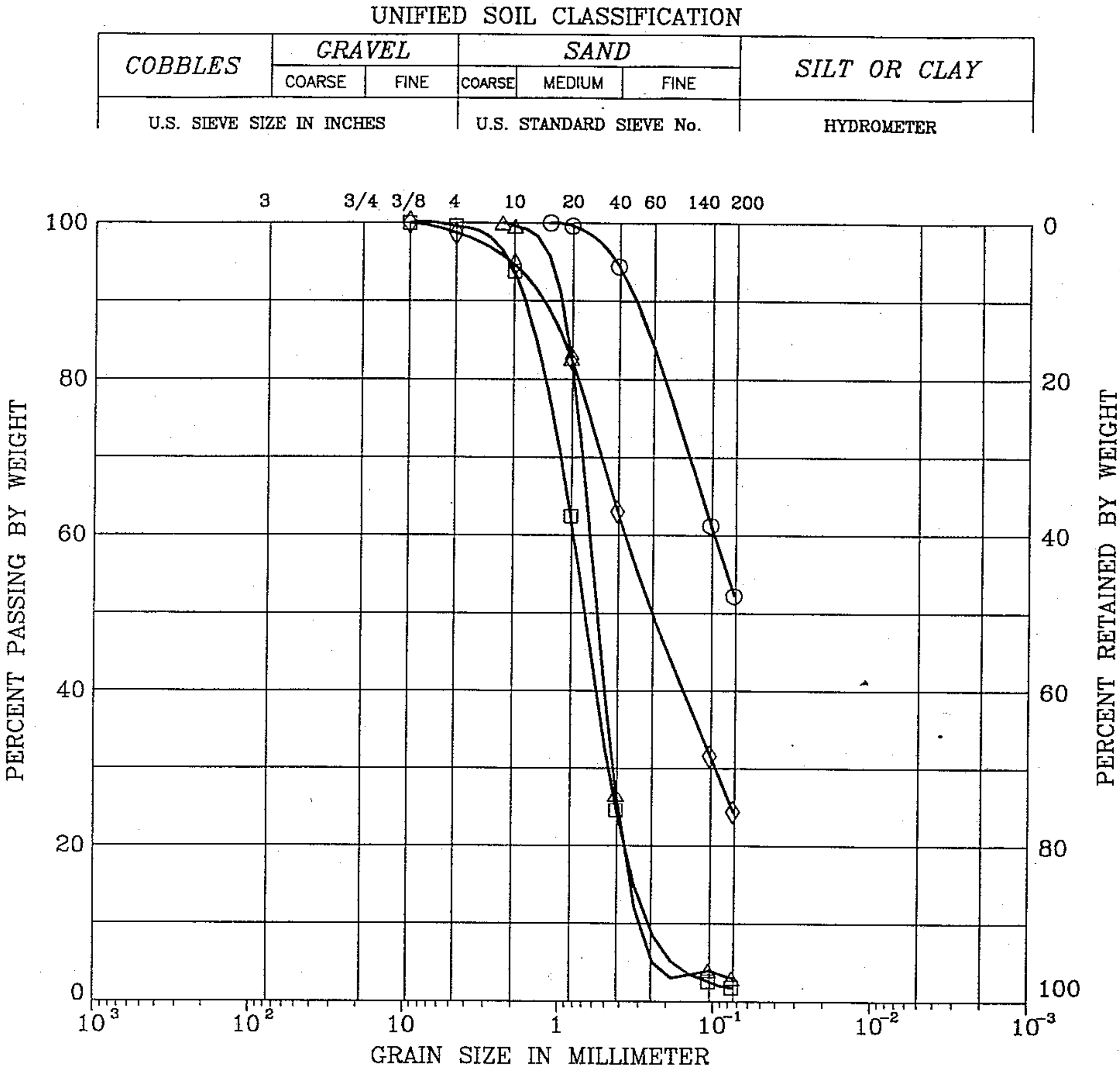
BORING	:	B-2	DESCRIPTION :	POORLY-GRADED SAND
DEPTH (ft)	:	50'(B)	LIQUID LIMIT :	
SPEC. GRAVITY	:	2.65	PLASTIC LIMIT :	

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	11.9	92.1	40	.797
FINAL	25.6	94.3	90	.757

Remark : SIERRA SCIENTIFIC SERVICES

FILE No. 02-10127	LABORATORY TESTING
Soils Engineering Inc	CONSOLIDATION TEST Plate No. B-3

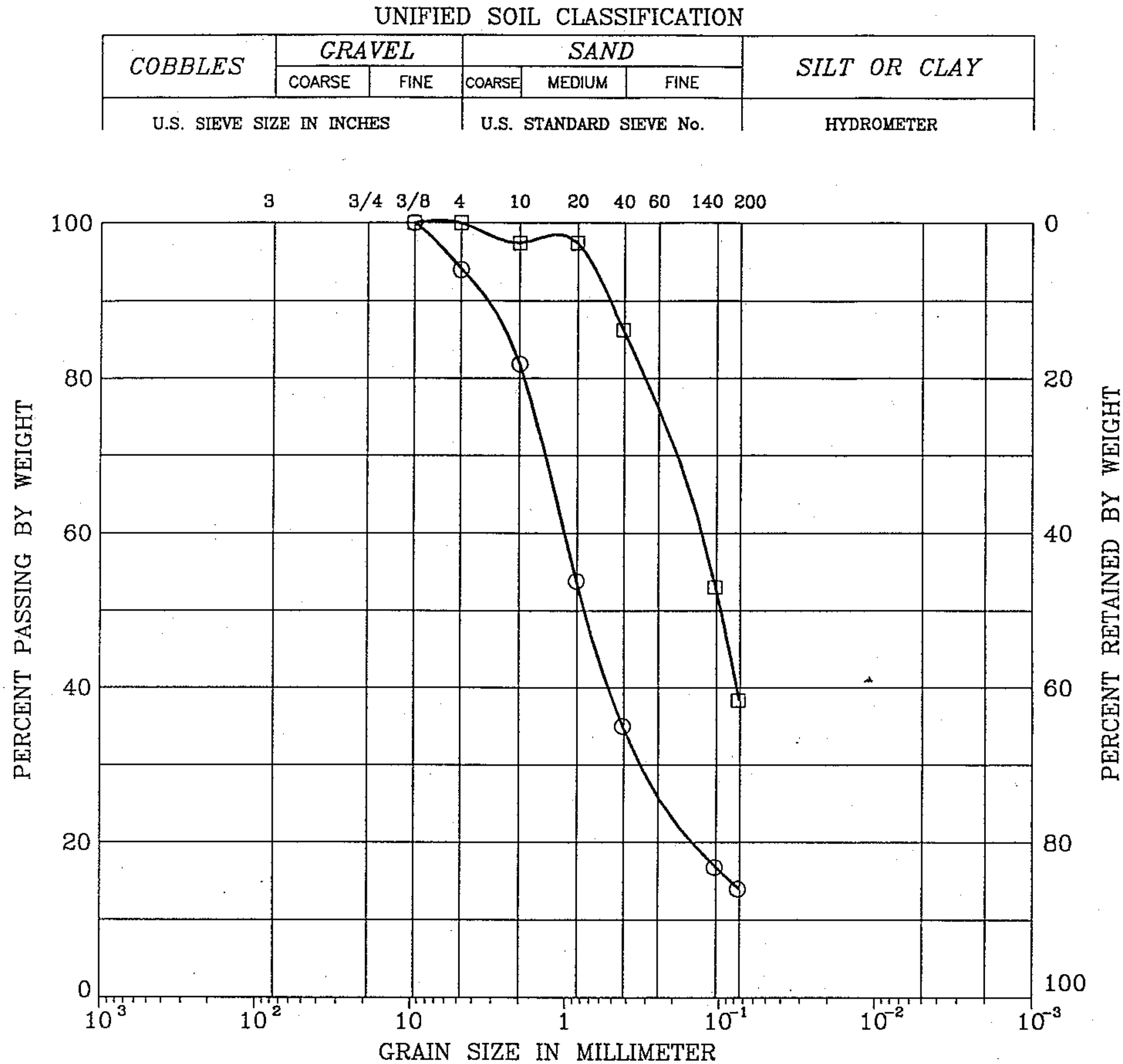
Appendix 5.
Grain Size Analyses.



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	B-1	20c			INORGANIC SILTS AND CLAYS (ML-CL)
□	B-1	30c			POORLY-GRADED SAND (SP)
△	B-1	70c			POORLY-GRADED SAND (SP)
◇	B-1	80c			SILTY SAND (SM)

Remark : SIERRA SCIENTIFIC SERVICES

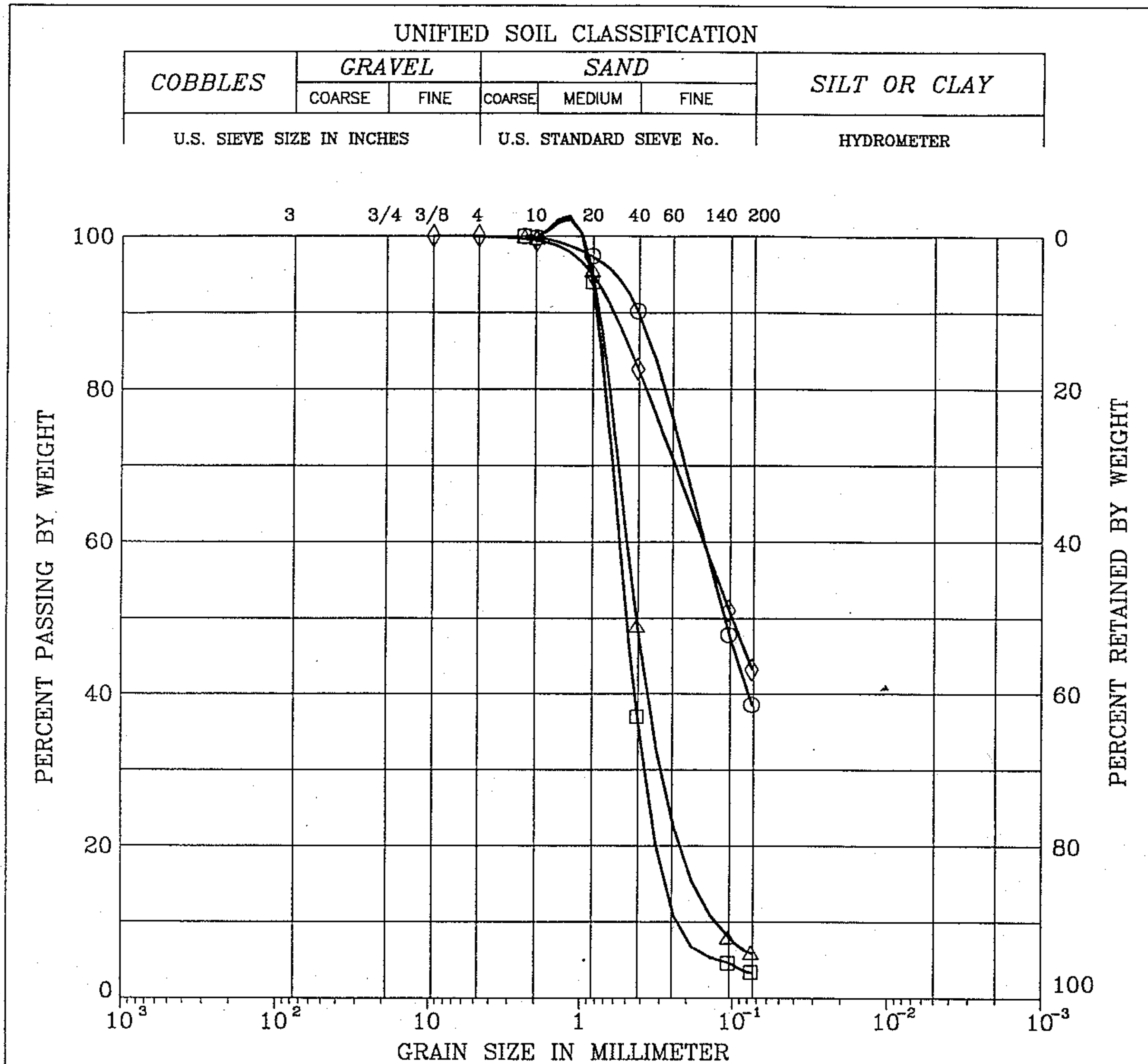
FILE NO. 02-10127	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION PLATE NO. A-1



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	B-1	100c			SILTY SAND (SM)
□	B-1	110c			SILTY SAND (SM)

Remark : SIERRA SCIENTIFIC SERVICES

FILE NO. 02-10127	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION PLATE NO. A-2



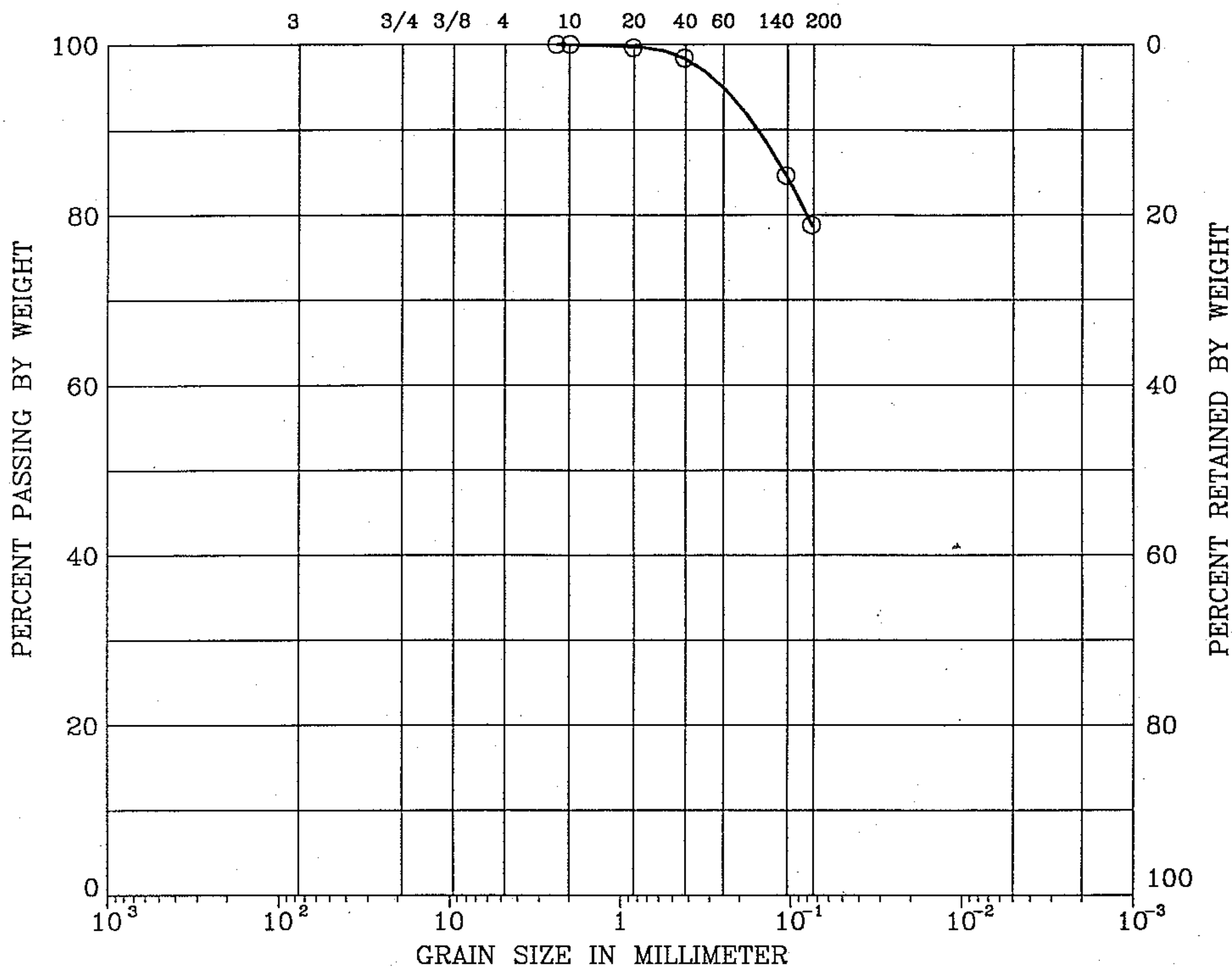
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	B-2C	10'			SILTY SAND (SM)
□	B-2C	30'			POORLY-GRADED SAND (SP)
△	B-2C	40'			POORLY-GRADED SAND (SP)
◇	B-2C	60'			SILTY SAND (SM)

Remark : SIERRA SCIENTIFIC SERVICES

FILE NO. 02-10127	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION PLATE NO. A-3

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



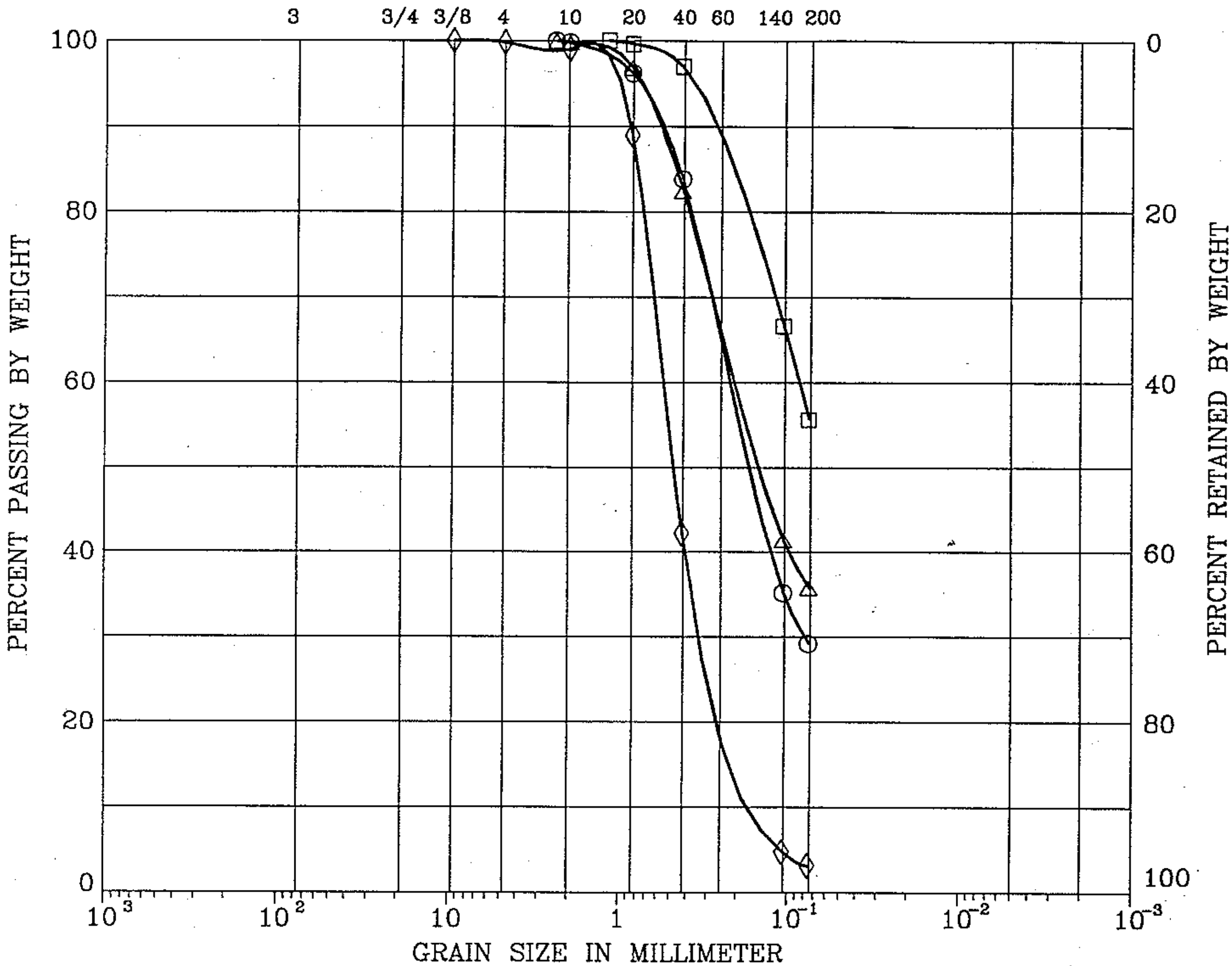
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	B-2C	70'			INORGANIC SILTS AND CLAYS (ML-CL)

Remark : SIERRA SCIENTIFIC SERVICES

FILE NO. 02-10127	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION PLATE NO. A-4

UNIFIED SOIL CLASSIFICATION

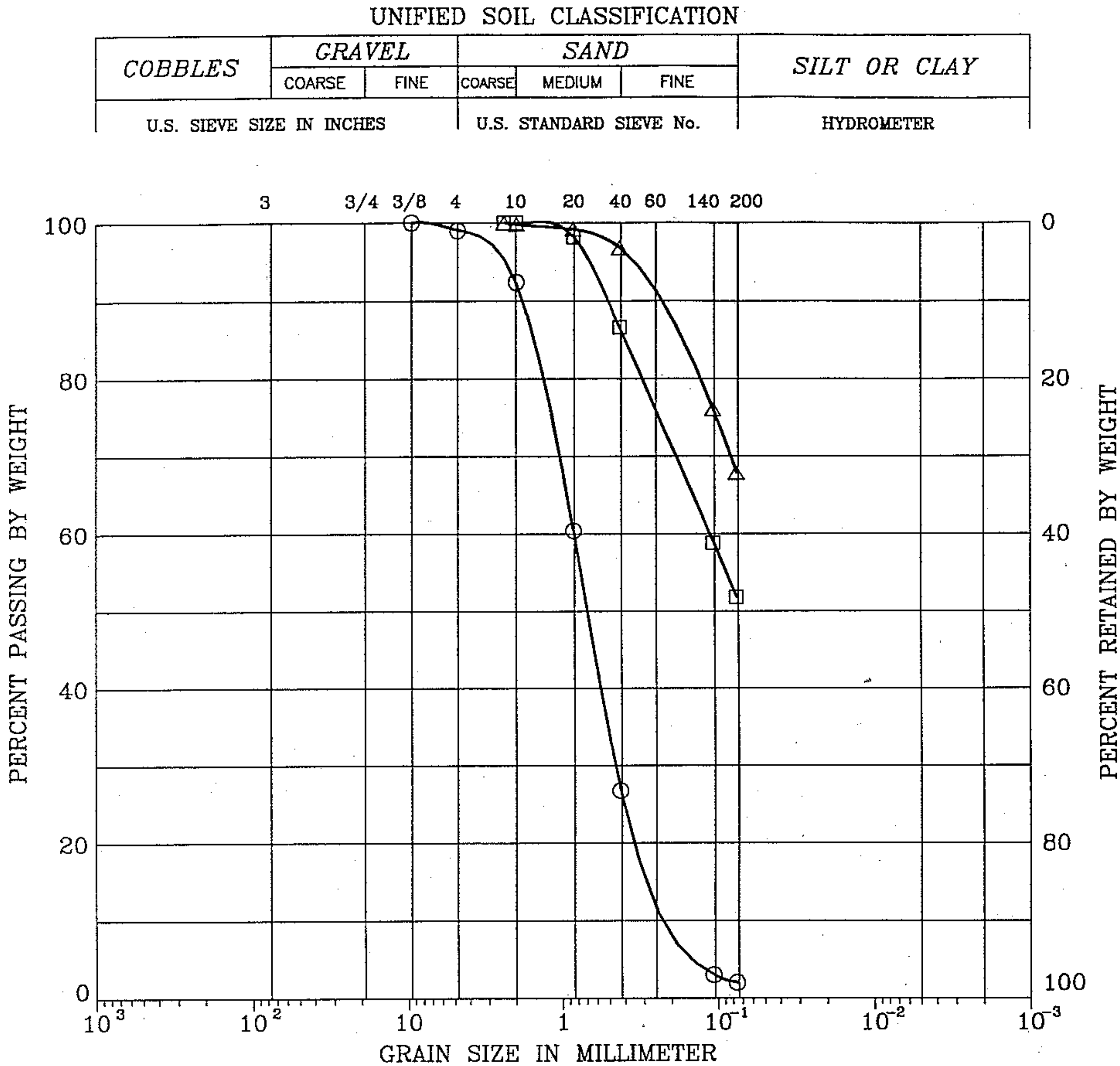
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	B-3C	10'			SILTY SAND (SM)
□	B-3C	20'			INORGANIC SILTS AND CLAYS (ML-CL)
△	B-3C	30'			SILTY SAND (SM)
◇	B-3C	40'			POORLY-GRADED SAND (SP)

Remark : SIERRA SCIENTIFIC SERVICES

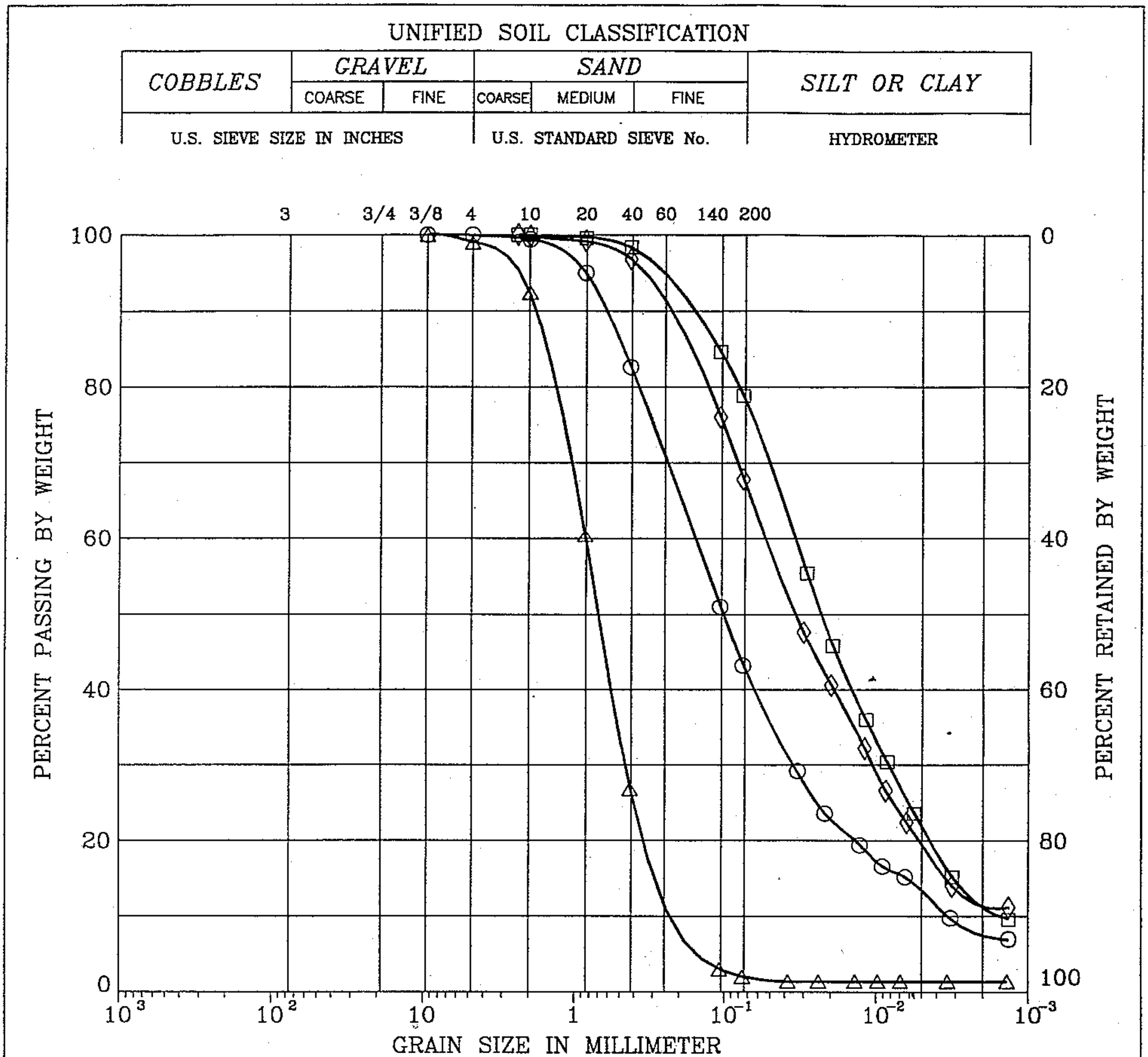
FILE NO. 02-10127	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION PLATE NO. A-5



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	B–3C	50'			POORLY–GRADED SAND (SP)
□	B–3C	70'			INORGANIC SILTS AND CLAYS (ML–CL)
△	B–3C	90'			INORGANIC SILTS AND CLAYS (ML–CL)

Remark : SIERRA SCIENTIFIC SERVICES

FILE NO. 02–10127	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION PLATE NO. A–6



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	B-2	60'(C)			SILTY SAND (SM)
□	B-2	70'(C)			INORGANIC SILTS AND CLAYS (ML-CL)
△	B-3	50'(C)			POORLY-GRADED SAND (SP)
◇	B-3	90'(C)			INORGANIC SILTS AND CLAYS (ML-CL)

Remark : ROSEDALE-RIO BRAVO, SIERRA SCIENTIFIC

File No. 02-1027	LABORATORY TESTING
Soils Engineering Inc	GRAIN SIZE DISTRIBUTION Figure No. H-1

Appendix 6.
Reference Wells and Coefficients.

Reference Wells and dtw Coefficients.

										incorporating do -->			
								using do	using do		Cj		
				Jan, 2001				K^i =		C*i	C*iAj/At	Ki =K^iCi	
Vertex	Wellset D	x	y	Zi	Ki*	Aj	At	Ki*Aj/At	K^iZi	do coefs		Ki	KiZi
do				63.71	1	32.50	67.72	0.48	30.58				
1	P. Enns	-1.6	3.9	177	0.25	32.50	67.72	0.12	21.08	0.120	0.057761	0.177	31.3
2	Frito Lay	-4.1	2.4	146	1.10	32.50	67.72	0.53	76.81	-0.554	-0.26587	0.260	38.0
3	Nikkel	-1.45	0.6	86	-1.34	32.50	67.72	-0.65	-55.49	1.434	0.688036	0.043	3.7
do				122.39	1.00	19.22	67.72	0.28	34.73				
4	Gardiner	0.375	2.875	161	-0.04	19.22	67.72	-0.01	-2.05	0.104	0.029547	0.017	2.7
5	Romanini	0.9	0.2	116	-0.73	19.22	67.72	-0.21	-23.91	1.109	0.31461	0.108	12.6
6	Reed	4.875	2.45	108	0.77	19.22	67.72	0.22	23.64	-0.213	-0.06035	0.159	17.1
do				77.59	1.00	10.50	67.72	0.16	12.03				
7	Bushnell	-7.1	5.5	199	-0.83	10.50	67.72	-0.13	-25.57	1.280	0.198433	0.070	13.9
8	Cauzza	-9.1	2.95	181	2.60	10.50	67.72	0.40	72.90	-2.460	-0.38142	0.021	3.9
9	WI5	-6.1	0.1	123	-1.77	10.50	67.72	-0.27	-33.74	2.180	0.338039	0.064	7.8
do				263.72	1.00	5.50	67.72	0.08	21.42				
10	Parsons	-9.4	1.5	108	3.90	5.50	67.72	0.32	34.22	-3.282	-0.26659	0.050	5.4
11	Cauzza	-9.1	2.95	181	-1.24	5.50	67.72	-0.10	-18.21	1.577	0.128108	0.027	5.0
12	WI5	-6.1	0.1	123	-2.66	5.50	67.72	-0.22	-26.60	2.705	0.219703	0.003	0.4
					3.00	67.72		1.00	141.85	OK		1.000	141.85 OK

do = depth to water at the origin of each subarea, determined separately for each subarea from the well data.
Zi = current depth to water in each reference well (Jan, 2001).
K^i = the weighting coefficient for each Zi.
District average depth to water is the sum of all 16 K^iZi terms (12 well depths plus four origin depths).
District average depth to water is the sum of all 12 KiZi terms (12 well depths incorporating do calc'n).

Appendix 7.
DWR Specific Yield Data.

DWR Specific Yield Data.

Terminology is that of the DWR sources.
Data are qualitatively re-arranged by SSS based on decreasing grain size.

Sediment type	Source 1 Sy	Source 2 Sy
boulders	17%	
gravel & boulders	17%	
cobbles & gravel	17%	
large gravel	17%	
coarse gravel	17%	
medium gravel	27%	
fine gravel	30%	
gravelly sand	27%	27%
coarse sand	30%	30%
medium sand	30%	27%
sand	27%	
fine sand	20%	20%
silty sand	17%	17%
silty sand	6%	
clayey sand	6%	
sandy silt	6%	
silt	6%	
clayey silt	6%	
gravelly clay	6%	
sandy clay	6%	6%
silty clay	6%	
clay	3%	3%

Misc other sediment types reported in Source 1:

	Sy	Sy
tight boulders	12%	
cemented boulders	12%	
water gravel	27%	
dry gravel	27%	
heavy gavel	17%	
heaving gravel	17%	
hard gravel	12%	
dead gravel	12%	
cemented gravel	12%	
heavy rocks	12%	
broken rocks	17%	
rocks	17%	
tight coarse gravel	12%	
tight medium gravel	17%	
dirty pack sand	12%	
hard sand	12%	
heaving sand	20%	
tight sand	20%	
quicksand	20%	
sediment	6%	
soil	6%	
loam	6%	
silty loam	6%	
silty clay loam	3%	
clayey loam	3%	
hard clay	3%	
cemented clay	3%	
adobe	3%	
muck	3%	

Misc other sediment types reported in Source 2:

medium sand with gravel	20%
coarse sand with clay	12%
fine to medium sand	20%
sand with streaks of clay	12%
clay with streaks of sand	6%

Source 1: DWR Kern Fan Input Data, 1/16/90.
Source 2: Swartz, Robert, J., 1995, Development and Calibration of the Kern Fan Ground Water Model, DWR San Joaquin District Office Report, Table C-1, p.114.

Comparison of DWR Tabulated Specific Yield and RRB Measured Specific Yield for 18 samples based on their correct textural classification.

Sam. No.	Textural Classif.	DWR Sy	Split #1 Meas'd Sy	Split #2 Meas'd Sy
1	sandy silt	6%	35.9%	30.3%
2	sand	27%	34.3%	33.1%
3	sand	27%	28.6%	32.6%
4	silty sand	6%	na	na
5	sand	27%	na	na
6	sandy silt	6%	na	na
7	silty sand	6%	21.2%	20.8%
8	sand	27%	36.3%	37.5%
9	sand	27%	32.4%	34.4%
10	silty sand	6%	5.1%	3.0%
11	sandy silt	6%	10.7%	5.5%
12	silty sand	6%	14.9%	14.6%
13	silty sand	6%	7.7%	0.4%
14	silty sand	6%	3.4%	9.5%
15	sand	27%	31.7%	33.6%
16	sand	27%	31.4%	37.3%
17	silty sand	6%	7.0%	7.1%
18	sandy silt	6%	-0.4%	7.0%

Appendix 8.
Presentation Viewgraphs.

Sierra Scientific Services

Storage Capacity Determination
Rosedale - Rio Bravo Water Storage District

December, 2002

This DRAFT presentation is prepared by Sierra Scientific Services and is intended only for the interim use of RRBWSD until a final report has been completed

This presentation is not intended for distribution to any party outside the RRBWSD Board of Directors

Sierra Scientific Services

Purpose of this Work Program

- Determine the storage capacity of the District.

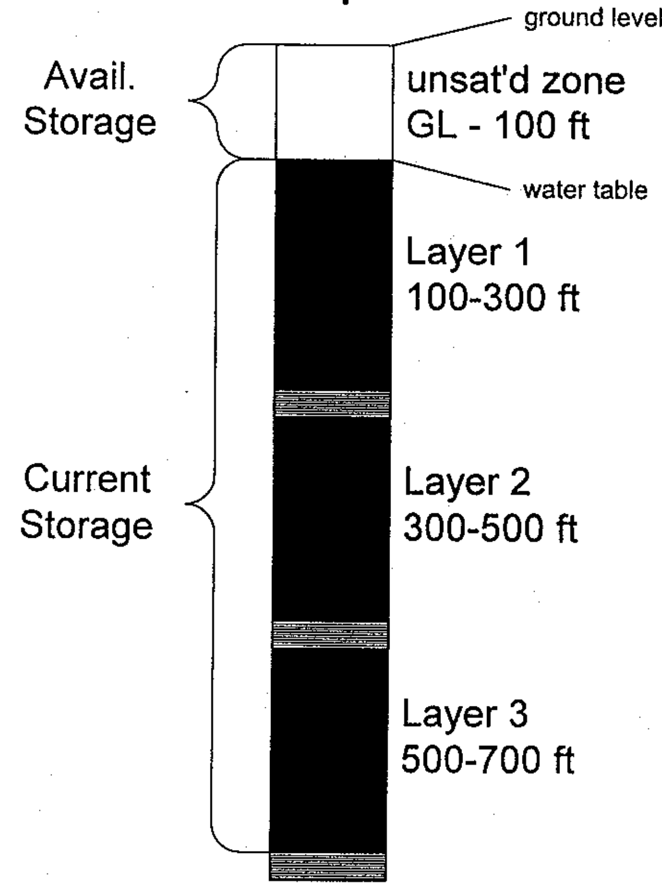
Purpose of knowing the Storage Capacity

- Demonstrate project viability to KCWA.

Definitions

- **Current Storage** is the actual volume of water currently stored in the aquifer below the water table within the boundaries of the District.
- **Available Capacity** is the volume of water which could be stored in the unsaturated zone above the water table within the boundaries of the District.
- **Total Storage Capacity** is the total volume of water which could be stored in the entire aquifer within the boundaries of the District if it were full.

Vertical Depth Profile



Summary of Findings

- District Dimensions
  - District Area (A) = 44,150 acres
  - Aquifer Thickness (T) = 700 ft; (20 ft to 720 ft below ground surface)
  - Water table Depth (D) = 100 ft (average depth below top of aquifer)
- **Storage Capacity (SC)**
  - Total Storage Capacity = 6,510,000 af (a constant)
    - Current Storage = 5,580,000 af
    - **Available Capacity = 930,000 af**

The Storage Capacity Formula

- Purpose: to determine the available storage capacity for any depth-to-water (D').

- Total SC $= A \cdot T \cdot (F_{sd} \cdot Sy_{sd} + F_{st} \cdot Sy_{st} + F_c \cdot Sy_c)$
- Available SC $= Total \cdot D/T$

- **Available SC (af)** $= 9300 \cdot (D' - 20)$

- Note 1:
  - **depth-to-water (D') = weighted average of true dtw in 8 specified District wells.**

- Methodology
  - F_i from E-logs
  - Sy_i from petrophysical measurements including:
    - $S_y = \phi \cdot (1 - S_r)$; $\phi = 1 - D_{dry}/D_{gr}$; $S_r = \theta_g \cdot D_{dry}/D_{wtr/}\, \phi$; $\theta_g = (M_{wet} - M_{dry})/M_{dry}$
    - by ASTM Standards D2216; D422; D2434; D854; D2435.

What we did to evaluate Storage Capacity

- Evaluated available, previous work from other sources
  - DWR KGWM specific yield data as used by KCWA and local engineers
- Designed program based on partitioned- variance sampling methods
  - hierarchal sampling & randomized- block analyses
  - the most efficient (& cost-effective) method available
- Measured the physical properties of the actual layers
  - Collected 98 samples from 3 drill holes
  - Analyzed 48 samples in duplicate splits for variable properties (Dw, Dd, Vb, θg, Sr)
  - Analyzed 18 samples for fixed properties (Dg, ϕ, β, k)
- Measured the distribution and thicknesses of the layers
  - Evaluated 32 E-logs for geo- parameters (Fsd, Fst, Fc) and formation factors (a, m)
  - Incorporated 41 net-sand analyses by Tom Haslebacher @ KCWA (Fsd, Fst, Fc)
- Evaluated volumetric changes under rising and falling water table conditions
  - considered the effect of topographic slope
  - considered the effect of water table slope and flow lines

Findings

- District is underlain by multiple layers of sand, silt, or clay
  - the order and frequency of layering is unimportant
  - the correct correlation between E-log units and geological layer classifications must be based on d_{eff} & C_u and not on standard geological classification

	d_{eff} & C_u Fraction	Compare to Geol-Fraction	Porosity	Sr	Sy	Compare to Sy (KGWM)
• Sand	50%	80%	38%	11%	34%	20 - 30%
• Silt	48%	15%	36%	76%	8.6%	6%
• Clay	2%	5%	45%	99%	<1%	3%

- In our opinion, the KGWM data are not representative of the District and are based on a theoretical correlation between geology and Sy which does not apply to the Kern Fan Area.
- These methods, but not necessarily these findings, may be applicable to other districts.
- We are still working to finalize a couple of relevant data correlations before final report.

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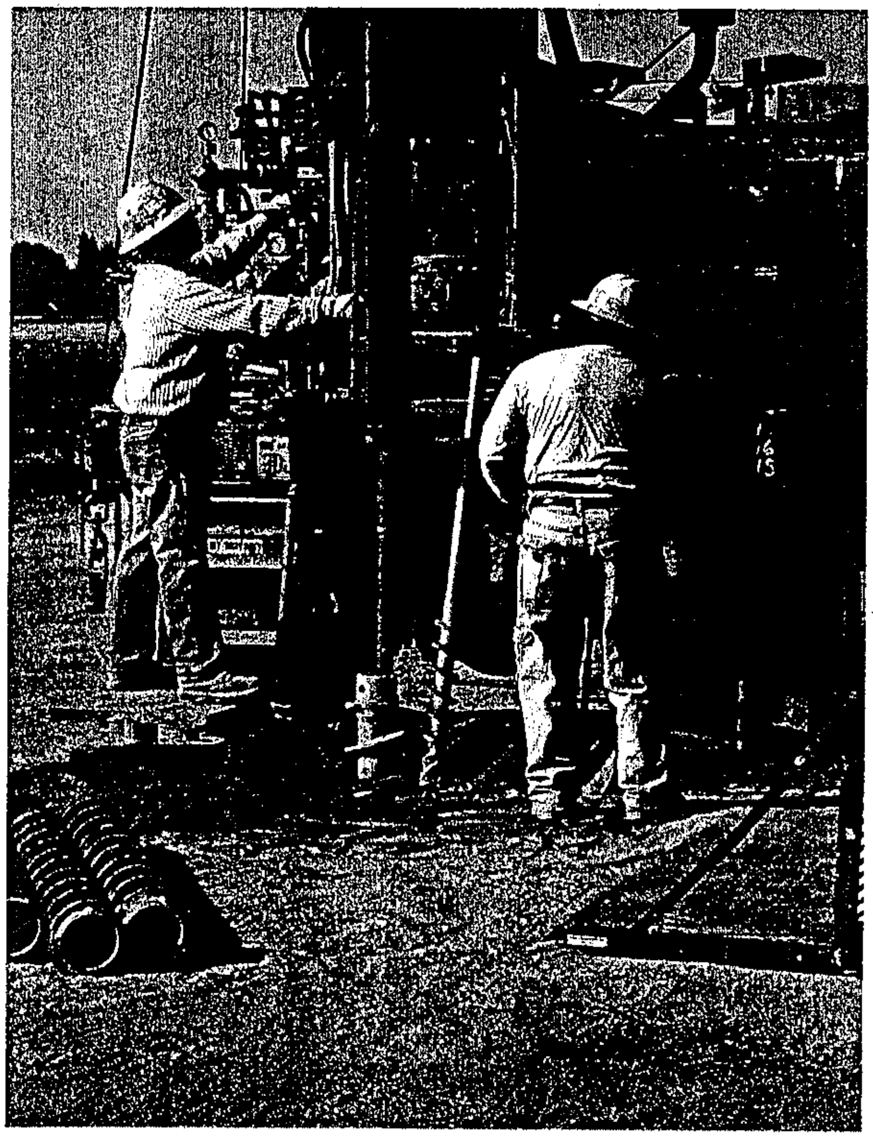

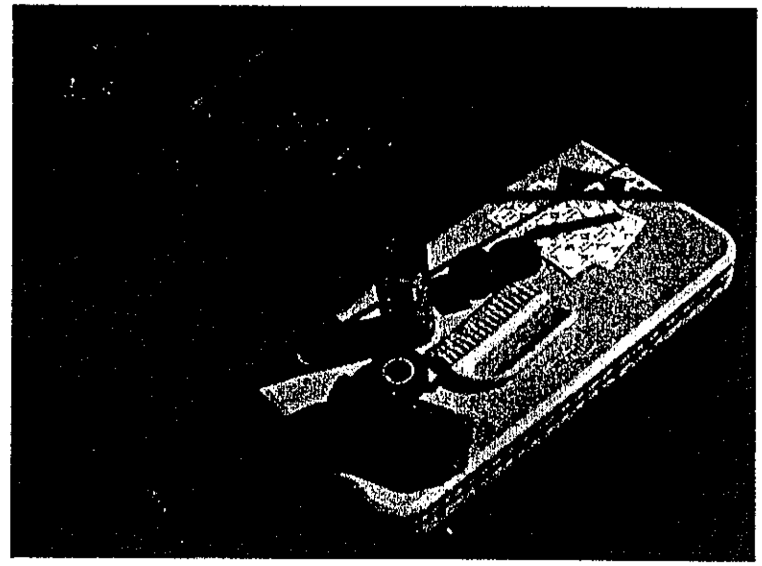

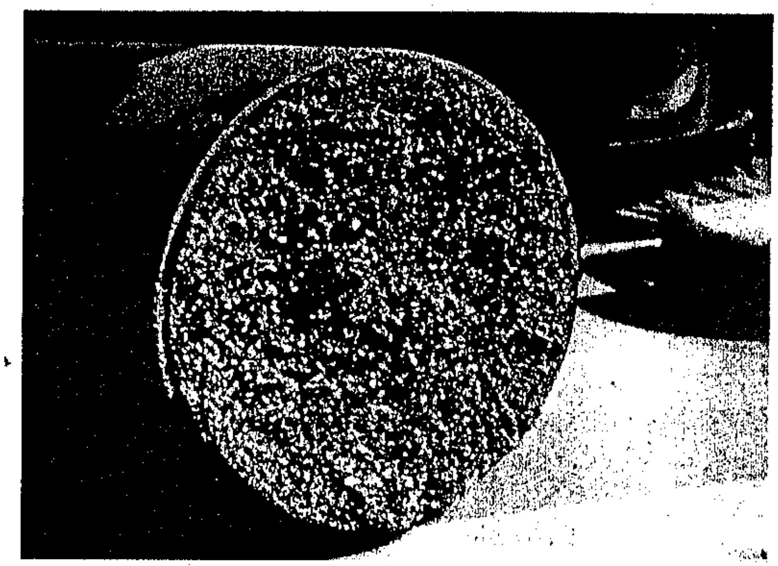

ATTACHMENT 16B

Sierra Scientific Services, 2004. An Evaluation of Well Placements and Potential Impacts of the ID4/Kern Tulare/Rosedale - Rio Bravo Aquifer Storage and Recovery Project. July 20.

Sierra Scientific Services

An Evaluation of Well Placements and Potential Impacts of the ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project, Bakersfield, California.

20 July, 2004

prepared for:

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Table of Contents

List of Appendices.

1. Aquifer Geology and Hydrology.
2. Mathematical Aquifer Models.
3. Aquifer Parameter Values.
4. SSS Cooper - Jacob re-analysis of the ID4 December, 2002 Well Test.
5. KCWA report on the ID4 pump test of December, 2002.
6. Catalog of Drawdown Analyses for non- Base Case Conditions.
7. Limitations of the Analyses.

Sierra Scientific Services

An Evaluation of Well Placements and Potential Impacts of the
ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project.

1. Conclusions and Recommendations

The purpose of this Report is to present the findings of an impact evaluation for a well field of seven proposed wells which are a part of the ID4/KT/RRB aquifer storage and recovery (ASR) project. The projected recovery capacity of the well field is 90af/d (45 cfs) and the base case operating scenario is continuous pumping for 300 days per year in approximately three of every ten years years to produce 27,000 af/yr. The project wells are designed to be 1,000 ft or more away from the nearest non- project wells and 1,200 ft or more away from each other.

We conclude that the proposed well field minimizes drawdown impacts by putting the maximum available distances between wells. We conclude that for this project to operate as predicted and desired, the total recharge to this area must start out and remain in long term balance with total recovery in this area. We conclude that there is currently no recognized threat to water quality within the capture zone but it is very important to monitor the good water quality within well field capture zone for any contamination entering the flow paths leading to the wells.

This project represents only 25% of the total installed recovery capacity in the general area. We also observe, based on historical data, that the basinwide water level response to the climatic wet/dry cycle alone can be as large or larger than pumping drawdowns and may dominate the water level fluctuations in some years, independent of the project operations. Since project impacts may well occur at the same time as impacts from other causes, the combined year- to- year water level declines due to both climate and non- project pumping may be significantly greater than we have predicted due to project pumping alone.

For the base case scenario under leaky aquifer conditions, the predicted drawdowns within the aquifer during pumping will decline quickly and then stabilize at steady- state values of 16 - 24 ft at a distance of 1000 ft from the wells and 3 - 5 ft at a distance of 5000 ft from the wells. These drawdowns are as little as one- third of what would have been predicted under confined- aquifer conditions, as the aquifer has been modeled in the past by previous workers.

The project has considerable flexibility in delivering less than the full base case recovery volume of 27,000 af/yr. The project may meet reduced delivery obligations by choosing to pump for less time, and/or at lower pumping rates, and/or using fewer wells. Each of these possible alternatives provides different drawdowns and benefits, as we discuss in this Report.

Multi- year continuous pumping will not increase the drawdown as long as the project maintains its recharge commitment and the immediate area also continues to receive sufficient total recharge to re-supply all non-project wells in the area. The key to moderating the aquifer behavior is to keep the local area adequately recharged over time. If recharge does not match recovery, then the predicted drawdowns within the aquifer after 300 days of pumping will be as much as 60 - 70 ft at a distance of 1000 ft from the wells and 40 - 50 ft at a distance of 5000 ft from the wells.

For 300 days of pumping, the capture perimeter surrounding the entire well field extends only 500 - 1200 ft outward from the individual wells for this pumping period. For a hypothetical 30 years of continuous pumping, the capture zone would extend about 3,400 ft downgradient to the northwest and would extend a few thousand feet upgradient to the recharge boundary associated with the Kern river channel to the south and southeast.

Based on available literature, there are no known plumes or sources of contamination within the theoretical capture zone limit, but there are plumes of concern farther to the east. It is possible that, over time, these known contaminant plumes and any other unknown plumes in this area could be transported westerly by foreseeable aquifer dynamics to the point where they fall inside the capture limit of the well field. One important mitigation against the potential encroachment of contaminant plumes from the east is through the deliberate and sustained placement of local recharge to maintain the local ground water gradients at favorable levels and gradients.

We caution that the quantitative results of this entire study are based on a limited understanding of the aquifer and on a very small data set of existing, available, and verifiable parameter values which we have obtained from other sources. This ASR project presents an opportunity for the groundwater community to greatly benefit from the results of testing, monitoring, aquifer model calibration, and parameter verification that could be incorporated into this project. In our opinion, early and continued monitoring and verification will provide an important and useful baseline database in case the project has to defend itself against claims for impact damages. In some respects, this impact study is the first of its kind in this area, and the project operator has every opportunity to set the standard for good basin management within the program.

We recommend that the project test each new water well individually with a testing program which will provide for aquifer parameter measurement as well as pump parameter measurement. We recommend that the project partners consider contracting with SSS to help design, observe, and interpret the well tests.

We recommend that the project impacts be carefully monitored from startup so that we can calibrate and verify the results of this work program and then make refinements in our model of the aquifer behavior for future use.

We recommend installing monitoring wells to satisfy four different purposes, including well testing, model calibration and verification, long- term operational water level monitoring, and contaminant- detection monitoring. We recommend as many monitoring well installations as are necessary to cover all of these functions at all important locations. It may be necessary to install some monitoring wells which are useful for only one of these functions, since a single well placement may not be effective for all purposes. We recommend that the project consider designing the completion depth interval of each monitoring well depending on the intended purpose for the well. We also recommend that the project be willing to use multiple monitoring wells which are completed in different depth intervals where potentially effective or necessary.

We recommend that the project consider using the drawdown maps from this study to locate the placement of monitoring wells for water level monitoring especially in and around the recharge/recovery zones. We recommend that the project consider using the particle trajectory and capture zone maps from this study to locate the placement of monitoring wells for contaminant detection monitoring, especially to the east of the well field. We again recommend that the project consider restricting the completion depth interval of each monitoring well depending on the intended purpose for the well.

Crewdson, Robert, A., 20 July, 2004, An Evaluation of Well Placements and Potential Impacts of the ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project., Sierra Scientific Services, Bakersfield, CA.

An Evaluation of Well Placements and Potential Impacts of the
ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project.

2. Summary of Findings

The purpose of this Report is to present the findings of a water well impact evaluation for a cluster of seven proposed wells which are a part of an aquifer storage and recovery (ASR) project. The technical elements of the work program included reviews of previous work, E-log evaluations, aquifer parameter determinations, computer modeling of water level drawdowns and aquifer flow trajectories, and interpretations. The figures which we reference in *this* section are at the back of this section.

Project Operations.

The proposed aquifer storage and recovery (ASR) project consists of conveyance facilities, recharge ponds, and seven proposed recovery wells (Location Maps, Figures A1 & A2). The proposed well field contains seven wells in an array which looks like a diamond-shaped kite with 4 wells at the corners and 3 wells in the tail. From tip to tail this array is about 5,500 ft long and is oriented west to east. The individual wells are about 1,200 - 1,500 ft apart. The base case operating scenario is to pump all seven wells for 300 days per year at a total flow capacity of 90 af/d (45 cfs) for an estimated 3 out of every 10 years. The most aggressive proposed scenario is to pump all wells at the full flow rate for 300 d/yr for 3 consecutive years. Less aggressive alternate operating scenarios include operating for fewer days, or at lower flow rates, or using fewer wells within a single operating year. Within this scope of work, we have analyzed the cases in which the project delivers only 50% and 25% of the full annual delivery of 27,000 af/yr.

The surrounding area is already being used by other entities for aquifer recharge, particularly along the Kern River channel, and for groundwater extraction by private domestic water supply wells and by municipal water supply wells. When completed, this proposed project will represent only 25% of the total groundwater extraction capacity in the immediate area, so the predicted impacts from this project represent only a fraction of the total possible local impact to the aquifer. The predicted impacts in this report refer only to the hypothetical impacts of operating this project.

Summary.

Based on our analysis, the actual aquifer behavior after pumping begins will depend significantly on the actual, but unpredictable, schedule and volume of the local recharge over the project life. If total local recharge remains in approximate balance with recovery (the balanced scenario), then the drawdown will decline quickly but stabilize at a shallow steady-state value. If local recharge fails to keep up with recovery (the unbalanced scenario), then the drawdown will decline in steps but will decline continuously as cumulative recovery dewaters the successive aquifer layers from top down.

In the balanced scenario, the capture zone will expand and water levels will decline for only 10 - 20 days before stabilizing at a predicted 16 - 24 ft drawdown at a distance of about 1,000 ft from the well field and about 3 - 5 ft drawdown or less at distances of 5,000 ft or more from the well field (Drawdown Maps, Figures A3 & A4). The steady- state condition of little or no water level decline may last for weeks or months and will continue as long as the extraction rate from the aquifer is fully supplied by leakage recharge from the overlying layers. This decline- and- stabilize behavior is characteristic of semi-confined, i.e., "leaky" aquifers. The predicted drawdowns which we calculated are based on leaky aquifer modeling.

In this scenario, the deeper, semi-confined aquifer will exhibit drawdown that is perhaps as little as one- third of what would be expected under confined conditions, as the aquifer has been modeled in the past. The price for this limited drawdown is that the shallow unconfined aquifer will be dewatered as it supplies recharge water to the underlying aquifer. The key to moderating this aquifer behavior is to keep the local area adequately recharged over time. If this happens, then the cyclic rise and fall of the water levels will remain within predicted ranges.

In the unbalanced scenario, the capture zone will expand and water levels will decline continuously, albeit at declining rates, but without ever stabilizing. This condition of declining water level will continue as long as pumping continues. This decline behavior is characteristic of unconfined aquifers which exhibit temporary flattening of the decline rate as delayed yield from overlying layers temporarily supplies some recharge to the extraction rate before continuing to dewater from the top down. The predicted drawdowns which we present for the alternate conditions described in this Report are based on unconfined aquifer modeling.

These predicted drawdowns are from this project alone under maximum recovery rates and do not include the potential impacts from other nearby pumping wells or the impacts due to basinwide water level changes due to the climatic wet/dry cycle.

Well placement.

The wells are optimally placed for minimum impact by spreading the well field over the largest available area and by placing the wells no closer than about 1,000 ft from nearby non-project wells. The nearest non- project wells (Well Location Map, Figure A2) are about 1,000 ft away and include 5 domestic wells, 3 City of Bakersfield wells, and 2 other municipal water supply wells. There are another 6 non- project wells out to 3,000 ft and another 13 non-project wells out to 5,000 ft away. Of these 29 wells within about a mile of the project perimeter, there are thirteen shallow domestic wells, seven deep City of Bakersfield wells, 4 deep municipal water supply wells, and five deep non- project ID4 wells. The predicted drawdowns at any of these locations may be read directly off the drawdown map (Figure A3).

Aquifer model.

The local aquifer beneath a depth of approximately 200+ ft is a semi-confined (leaky) aquifer separated from a shallow unconfined aquifer by a complex and heterogeneous aquitard which causes irregular vertical flux (Aquifer Cross Section, Figure A4). Based on E-logs, geologic cross sections, well test results and hydrograph behavior, we conclude that the sandy sedimentary layers below depths of 200 - 300 ft behave as a semi-confined aquifer which is separated from the overlying shallow, unconfined aquifer by an aquitard of interbedded silty and sandy sediments. For wells which are completed in the zones below the aquitard, the drawdown response to pumping is what hydrologist's refer to as "leaky" aquifer behavior, because recharge in response to pumping comes from the overlying layers as well as from aquifer storage within the zones of completion. SSS used the mathematics for leaky aquifer behavior to predict the drawdowns which we present in this Report. The leaky aquifer model is different than the confined aquifer model used by previous workers in other impact analyses on nearby projects.

Historical water level data shows that the natural ground water gradient changes over time. During wet years of the climatic wet/dry cycle, the gradient tends to point northwesterly in the project area under the influence of recharge in the nearby Kern River channel just south and east of the well field. During dry years of the climatic wet/dry cycle, the gradient tends to point due westerly in the project area under the influence of recharge and other dominating influences farther to the east. These gradient trends dominate the direction of the upgradient projection of the well field capture zone, as discussed in this Report.

Aquifer parameters.

Based on a review of published sample measurements and well test results, we have compiled a set of single values for each of the required parameters for our quantitative analysis. In our opinion, much of the available data are inconsistent and poorly documented, so that we are unable to corroborate or place measures of reliability on our parameter choices. The intrinsic parameter values we have used in our analysis are documented in this Report and include: Kh_{sand} = 80 ft/d, H_{sand} = 250 ft, Kv'_{silt} = 0.08 ft/d, H'_{silt} = 40 ft, S_s = 0.000041 ft^{-1}, S_y = 0.21, L' = 0.002 d^{-1}. We have also used values of T = 20,000 ft^2/d and S = 0.00056 which we re-calculated from the ID4 December, 2002 well test data. These parameter values are significantly different than the broad range of values reported by other workers in other impact analyses on nearby projects.

Base Case Drawdown.

For the balanced scenario under leaky aquifer conditions, the predicted drawdowns within the aquifer after 300 days of pumping would be 16 - 24 ft at a distance of 1000 ft from the wells and 3 - 5 ft at a distance of 5000 ft from the wells (Table of Drawdowns, Figure A6). The actual operating drawdowns will be similar to these calculated drawdowns if our selected parameter values are representative and if the true aquifer conditions at the time of startup reflect the assumptions of the balanced scenario.

For the unbalanced scenario under unconfined aquifer conditions, the predicted drawdowns within the aquifer after 300 days of pumping would be as much as 60 - 70 ft at a distance of 1000 ft from the wells and 40 - 50 ft at a distance of 5000 ft from the wells (Table of Drawdowns, Figure A5). The actual operating drawdowns will be similar to these calculated drawdowns if our selected parameter values are representative and if the true aquifer conditions at the time of startup reflect the assumptions of the unbalanced scenario, i.e., a lack of shallow recharge.

Alternate Case Drawdown.

For multi- year pumping under the balanced scenario, the leaky- aquifer model predicts that the steady- state final drawdown which is achieved after 10 - 20 days of pumping will remain steady indefinitely, even for 2 - 3 years, as long as the shallow aquifer layer is recharged and remains full of water. Without forecasting a specific future recharge schedule, it is impossible to determine if or when leakage will cease and the water table will continue to decline.

For multi- year pumping under the unbalanced scenario, the drawdowns are much bigger than the steady- state conditions, and the unconfined aquifer model predicts that the drawdown at any location after three years of pumping is only about 10% bigger than the unconfined drawdown after the first year of pumping. Thus, the gradual decline in the second and third years of pumping is relatively negligible compared to the majority of drawdown which occurs over the first year.

For ground water recovery of less than the full base case volume, the project has the following options in meeting the delivery obligation. These options provide choices which provide trade- offs between minimizing impacts and minimizing costs depending on future conditions and the potential relative impacts on the project and adjacent entities.

Option 1. To deliver 50% or 25% of the base case volume, the project may choose to pump all wells at the full rate for only 50% or 25% of base case the time, i.e., for 150 or 75 days instead of a full 300 days. The project would deliver 13,500 af and 6,750 af, respectively. The predicted drawdowns are the same as the full base case since both pumping durations exceed the 10 - 20 day period required to reach static decline. However, these water level drawdowns last only a half or a quarter as long.

Option 2. To deliver 50% or 25% of the base case volume, the project may choose to pump all wells for the full 300 days but at only 50% or 25% of the full design flow rate, i.e., at 45 or 22.5 af/d instead of the full 90 af/d . The project would deliver 13,500 af and 6,750 af, respectively. It is significant to note that the predicted drawdowns are only 50% and 25% as big, respectively, as the base case drawdowns, but they last the full 300 days. Of all the scenarios, reducing the total flow rate always makes the biggest reduction in the size of the drawdowns, all else being equal. Although pump efficiency is worse when pumps are not operated at their design flow rate, the value of secondary factors such as lifting cost should be carefully evaluated against the benefits of reduced drawdown impacts on the project and neighboring entities before this scenario is dismissed from consideration.

Option 3. To deliver about 50% of the base case volume, the project may choose to pump fewer wells. The project could operate just the five wells on the RRB property for the full 300 days at their full design flow rate of about 50 af/d. The project would deliver 15,000 af which is actually 56% of the base case delivery. The predicted drawdowns are slightly less than the base case and the capture zone covers a smaller area which is centered in the west half of the project area.

Alternately, the project may choose to pump just the two wells on the ID4 property for the full 300 days at their full design flow rate of about 40 af/d. The project would deliver 12,000 af which is actually 44% of the base case delivery. The predicted drawdowns are slightly less than the base case but slightly more than the RRB case, and the capture zone covers a similar area which is centered in the east half of the project area.

Option 4. To deliver about 25% of the base case volume, the project may choose to pump fewer wells at full rates and full durations or any combination of wells, rates, and durations which satisfy the delivery obligation. If the project operates just the two wells at opposite ends of the well field at full rates for the full duration of 300 days, then the drawdown would be spread over the largest possible area. The project would deliver 9,000 af which is actually 33% of the base case delivery. The predicted drawdowns are somewhat less than the base case but cover a comparable area. The expediency of this and other alternatives have not been evaluated or optimized within this scope of work with respect to secondary criteria.

Capture zone.

For 300 days of pumping, the capture zone of each well is small enough to be influenced by- but have only a little contact with- the capture zones of the adjacent project wells. The capture perimeter surrounding the well field extends only 500 - 1200 ft outward from the individual wells for this pumping period (300-day Capture Zone Map, Figure A7).

For a hypothetical 30-years of continuous pumping under a representative northwesterly groundwater gradient in an ideal aquifer, the capture zone would extend about 3,500 ft downgradient, extend about 9,900 ft upgradient, and cover an oval area of about 5100 ac (7.9 mi^2). In actuality, the hypothetical capture zone is smaller and the upgradient capture perimeter is actually much closer to the well field since the Kern River channel forms an upgradient recharge boundary only 3,000 - 6,000 ft away from the southern flank of the well field. The hypothetical capture perimeter for infinite pumping represents the theoretical capture zone limit for this well field, and the actual capture zones for shorter pumping periods will be smaller than, nested inside of, and conformal to this hypothetical capture limit (30-year Capture Zone Map, Figure A8).

Contaminant capture.

Contaminant transport is more complicated than groundwater flow because of the effects of dispersion, retardation, and attenuation along the flowpath. For this scope of work we assumed that a hypothetical molecule of contamination moves the same way as a molecule of water, so that any slug or plume of contamination within the capture zone limit will sooner or later reach the well field. And any contamination or potential source of contamination outside the capture zone limit will never reach the well field, except for one recognized case under the possible influence of changing conditions.

Based on the available literature, there are no known plumes or sources of contamination within the theoretical capture zone limit. To the north, the EDB and DBCP plumes which consultant Ken Schmidt identified near to- and north of- Rosedale highway, which is about 1.5 miles north of the well field, are outside the theoretical capture limit and therefore pose no threat to this well field. To the west, the capture zone does not extend very far downgradient to the west and northwest and there are no recognized sources of contamination in those directions. To the south, there are no known sources of contamination between the well field and the Kern River channel recharge boundary. To the east, there is no recognized contamination within the capture zone, but there are plumes of concern farther to the east which must be considered contaminants of concern.

Consultant Ken Schmidt identified several fuel- constituent plumes in the shallow aquifer near the oil refineries on either side of Coffee Rd, about 3 miles east of the well field. During wet years the potential migration pathway of these contaminants is to the northwest and along a trajectory which misses the capture zone of the project well field. The issue of concern is that during dry years when the gradient swings westerly, the potential migration pathway of these contaminants is directly toward the well field. Furthermore, based on KCWA groundwater maps for the area, the potential recharge of water in the Kern River channel just east of these plumes causes steep localized gradients which may accelerate the rate of movement of these plumes. In addition to the recharge gradients, non-project water wells to the east of the project well field will have capture zones of their own which may also create westerly gradients which draw these plumes toward those wells and, hence, also closer to this project's capture zone. It is possible that, over time, these known contaminant plumes and any other unknown plumes in this area could be transported westerly to the point where they fall inside the capture limit of the well field.

Key issues.

The number one key issue is that for this project to operate as predicted and desired, the total recharge to this area must start out and remain in long term balance with total recovery in this area. If the area remains balanced, then drawdown and contaminant capture impacts will remain within the predicted limits, subject to the identified uncertainties of this analysis. If the area becomes unbalanced, then drawdowns will worsen and contaminant capture dynamics may change significantly. The project itself is based on a program which is required to operate in balance but this project is only 25% of the identified recovery capacity in the area and the predicted recharge/recovery impacts, operating criteria, and water supply forecasts for these other wells are unknown.

The second key issue is that it is very important to protect the good water quality within the well field capture zone against any contamination entering the flow paths leading to the wells. There may be sources of contamination within the 30-year capture zone that we have no knowledge of. There are no operational safeguards that we know of to prevent contaminant capture if this is the case other than not pumping. The detection and delineation of unknown contaminant plumes doesn't lessen the seriousness of their eventual impacts unless the knowledge leads to mitigation or remediation. Such detection monitoring is beyond the scope of almost any affordable monitoring program unless there are abundant wells of opportunity upgradient of the well field that may be monitored in conjunction with dedicated monitoring wells which are installed in critical flowpaths (Individual- Well Capture Zones, Figure A9). One important mitigation against the potential encroachment of contaminant plumes from the east is through the deliberate and sustained placement of local recharge to maintain the local ground water gradients at favorable levels and gradients.

The third key issue is that this project represents only 25% of the total installed recovery capacity in the general area, which means that at any given time, some or all of an observed drawdown at some location could be caused by non-project pumping. Since project impacts may well occur at the same time as impacts from other sources, the combined drawdowns from project and non- project wells may be significantly greater than we have predicted due to project pumping alone. During climatic dry cycles, every well in the area may be pumping, and surrounding domestic wells may be significantly impacted. The cause- and- effect relationship between project and non- project wells and their proportionate share of the total impact cannot be easily resolved by direct observation alone. In our opinion, early and continued verification of the project impact model through well testing and drawdown monitoring will provide an important and useful baseline database in case the project has to defend itself against claims for impact damages.

The fourth key issue is that the dominant cause of water level fluctuations may be the basinwide response to the climatic wet/dry cycle. The rise and fall of the local water table due to the climate cycle is completely independent of- and may well be bigger in magnitude than- the combined impacts of local recharge and local pumping. For example, in the 20 years from 1984 - 2004 the water level in the project area has varied by more than 100 ft due to the impact of the climatic wet/dry cycle on the basin. In the decade from 1992 - 2002, the annual water level change due to non- pumping climatic factors was in the range of 20 - 30 ft in five different years. The project impacts and other local non- project impacts are superimposed on top of this broader, large- scale climatic trend. The generic cause and effect relationship between pumping and drawdown cannot be used to explain all future drawdowns without also considering the independent effects of basinwide behavior on the local area.

The fifth key issue is that the quantitative results of this entire study are based on a limited understanding of the aquifer and on a very small data set of existing, available, and verifiable parameter values. In our opinion, the uncertainty in the calculated drawdowns is not just due to the natural variability of the aquifer itself, but in the complete lack of verifiable replicate data apart from the single reported values which we used, which prevents us from even determining the range of actual values let alone estimating the uncertainty in these parameters.

In our opinion, the existence of this project and the likelihood of many more to come, point out the need to improve the quantitative understanding of the Kern Fan aquifer hydrology beyond the current rudimentary state of knowledge. This project presents an opportunity for the groundwater community to greatly benefit from the results of testing and monitoring that could be incorporated into this project. In some respects, this impact study is the first of its kind in this area, and the project operator has every opportunity to set the standard for good basin management within the program.

Crewdson, Robert, A., 20 July, 2004, An Evaluation of Well Placements and Potential Impacts of the ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project., Sierra Scientific Services, Bakersfield, CA.

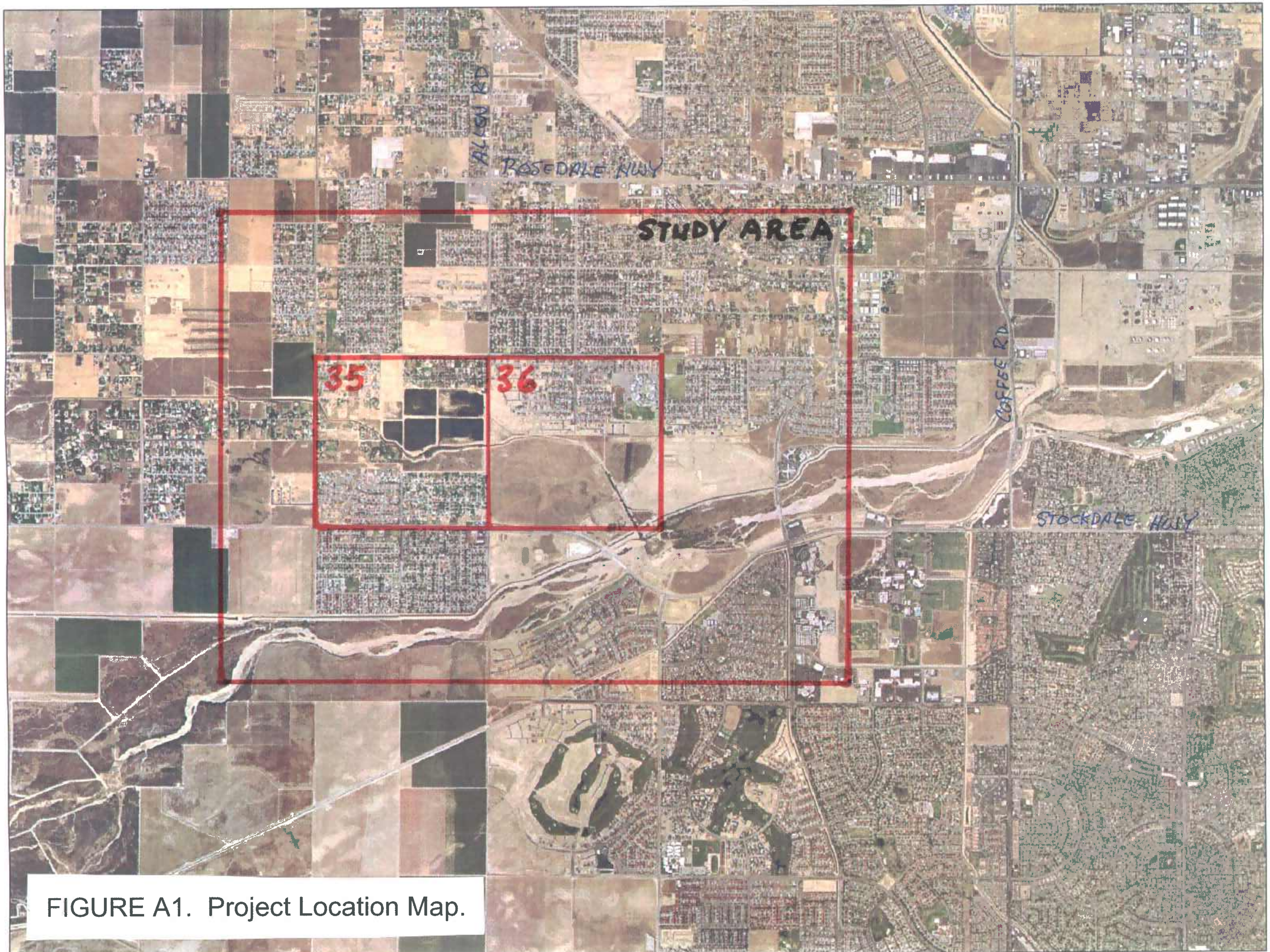

FIGURE A1. Project Location Map.

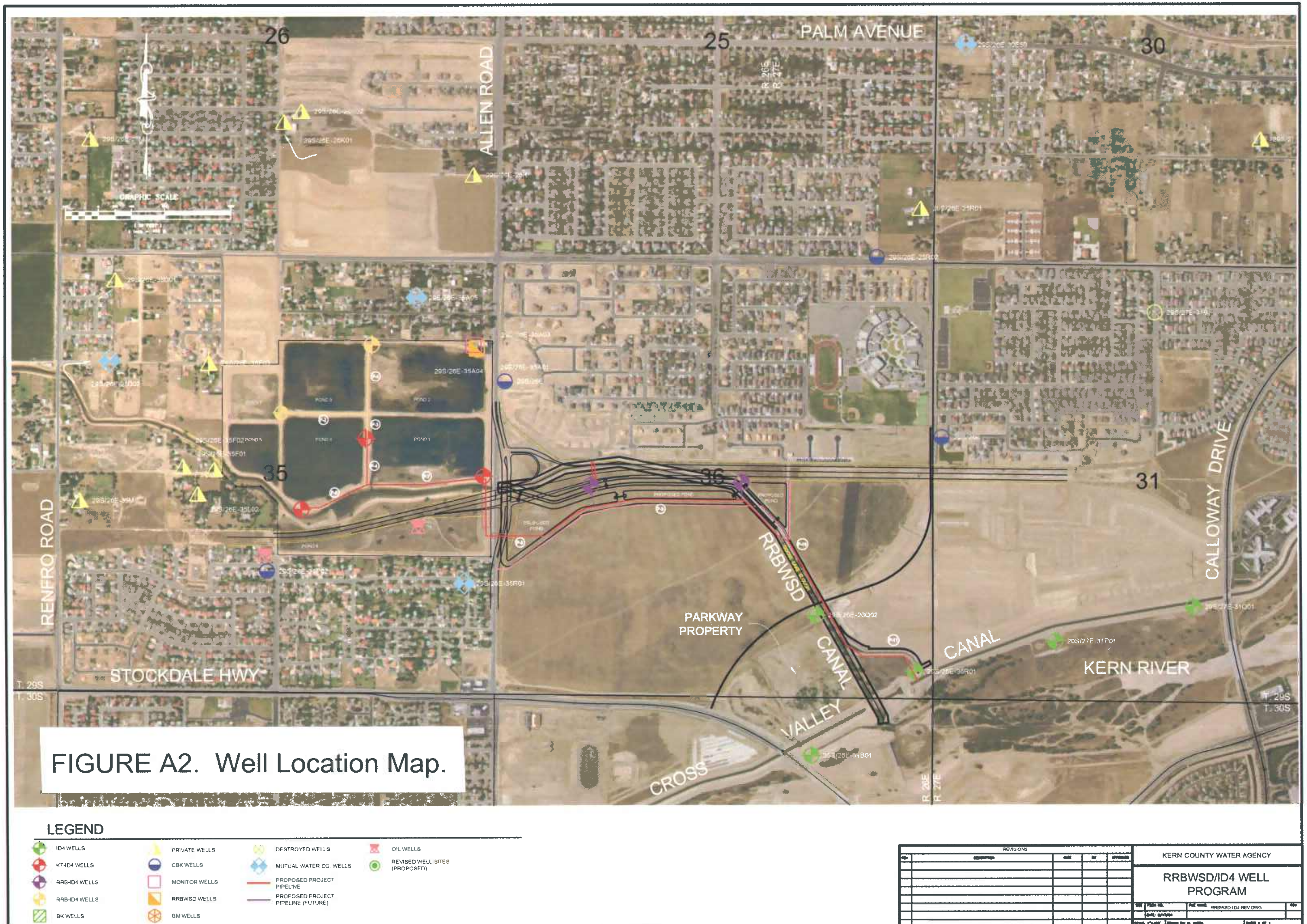

FIGURE A2. Well Location Map.

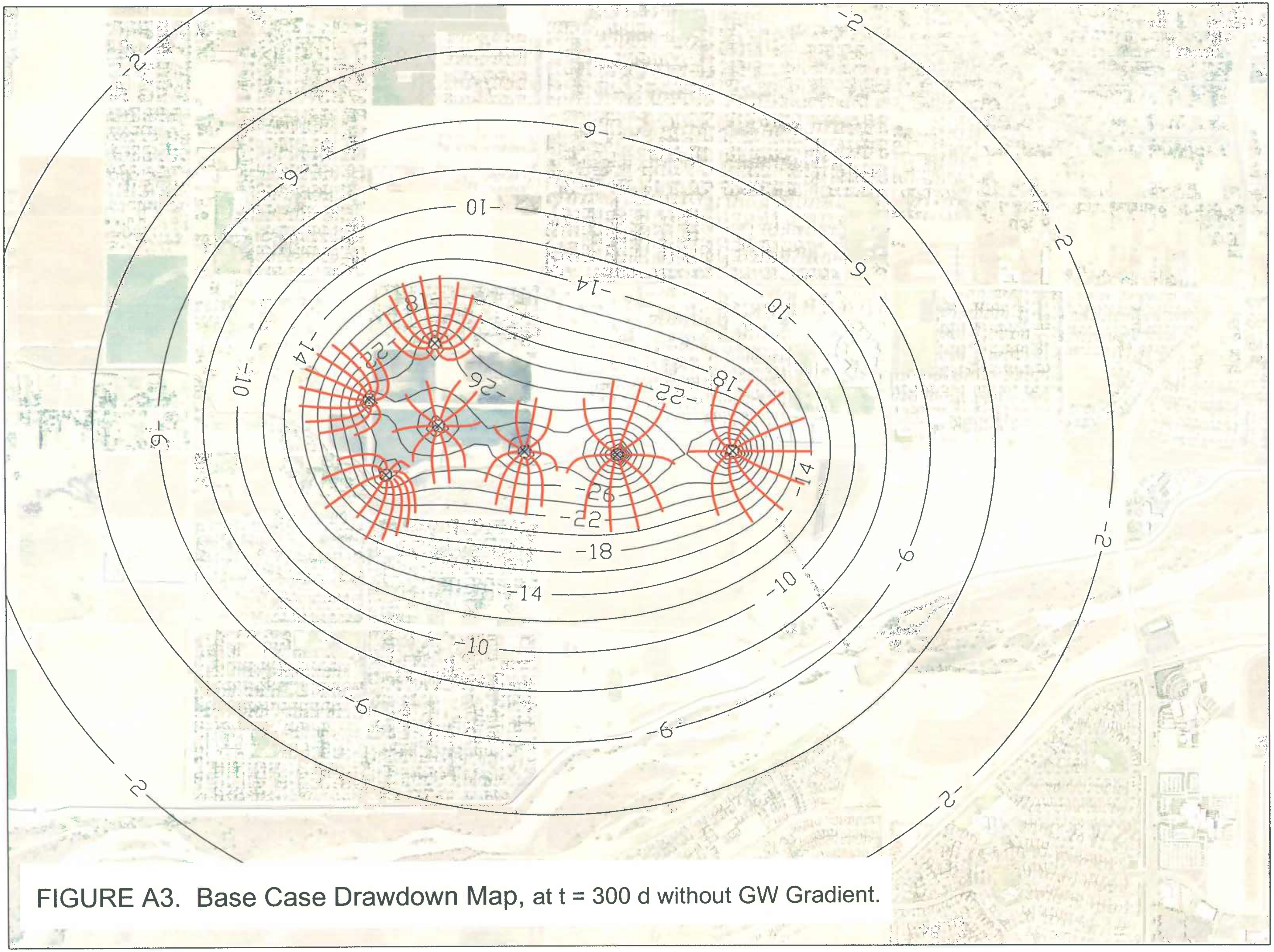

FIGURE A3. Base Case Drawdown Map, at t = 300 d without GW Gradient.

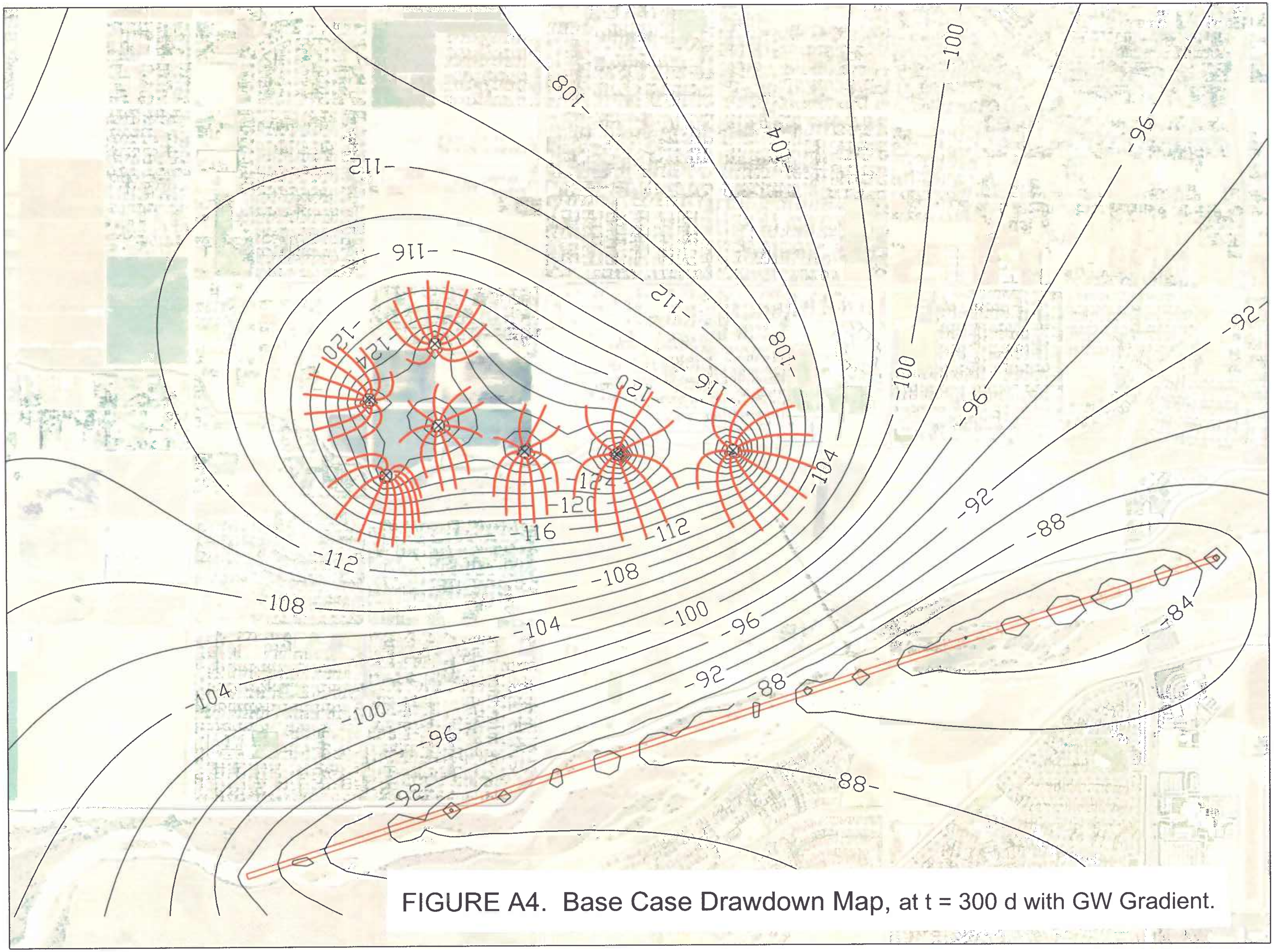

FIGURE A4. Base Case Drawdown Map, at t = 300 d with GW Gradient.

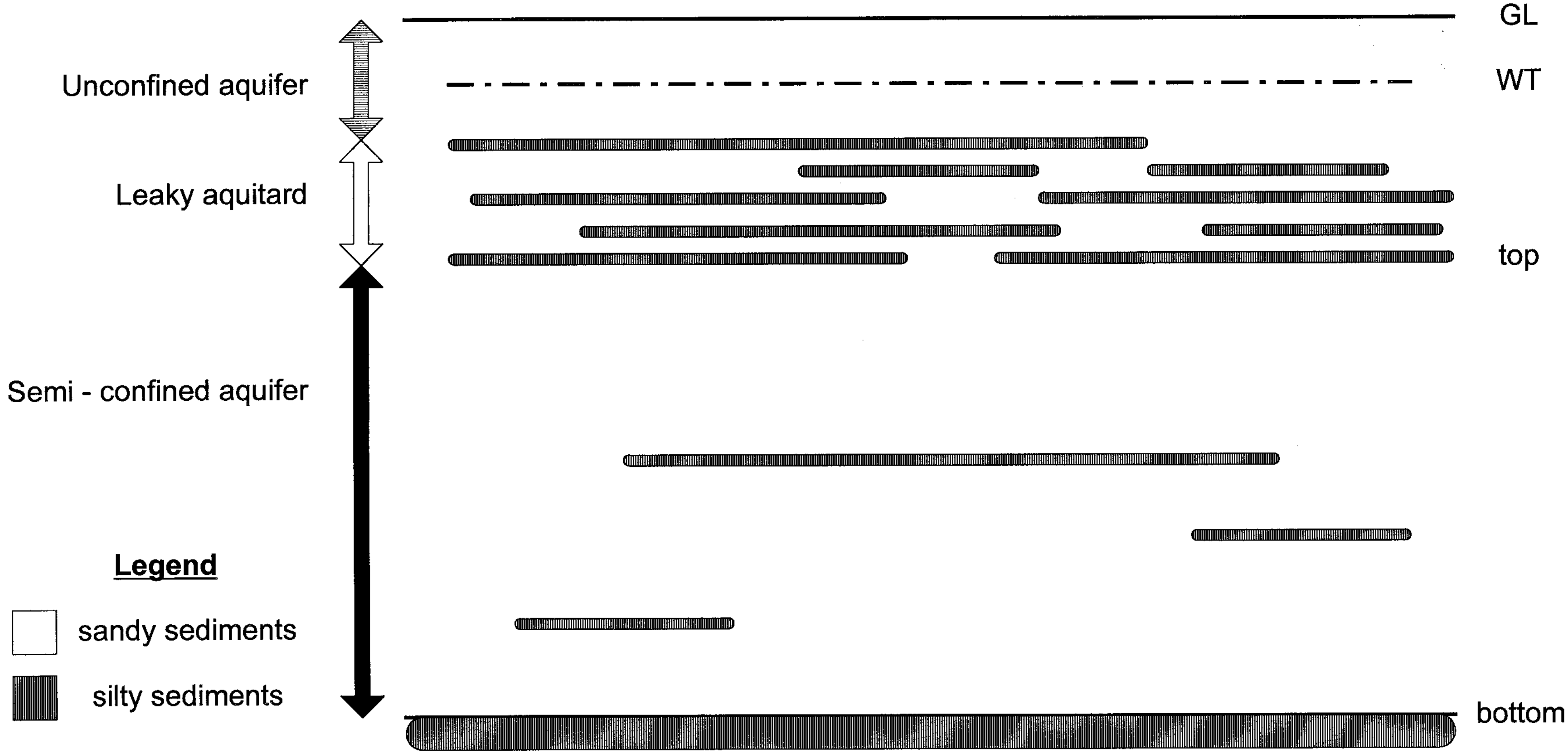

FIGURE A5. Schematic Geological Cross Section of a Semi- confined Aquifer.

ID4 / KT / RRB Well Field Predicted Drawdown Summary.

Aquifer Model		pumping time (d)	Predicted drawdown at 1000 ft (ft)	3000 ft (ft)	5000 ft (ft)
300 days pumping					
semi-confined, B = 2600		300 d	12 - 20	4 - 7	1 - 3
semi-confined, B = 3200	*	300 d	16 - 24	6 - 10	3 - 5
semi-confined, B = 6000		300 d	28 - 38	16 - 23	10 - 14
semi-confined, B = 10000		300 d	42 - 52	28 - 36	20 - 26
unconfined, low		300 d	22 - 30	13 - 19	9 - 14
unconfined, high		300 d	71 - 78	62 - 69	56 - 62
confined		300 d	120 - 132	103 - 115	98 - 103
3-years pumping					
semi-confined, B = 3200	*	3 yr	16 - 24	6 - 10	3 - 5
unconfined, high		3 yr	79 - 86	70 - 77	65 - 70
confined		3 yr	134 - 146	118 - 130	105 - 117

* = base case

FIGURE A6. Table of Calculated Drawdowns.

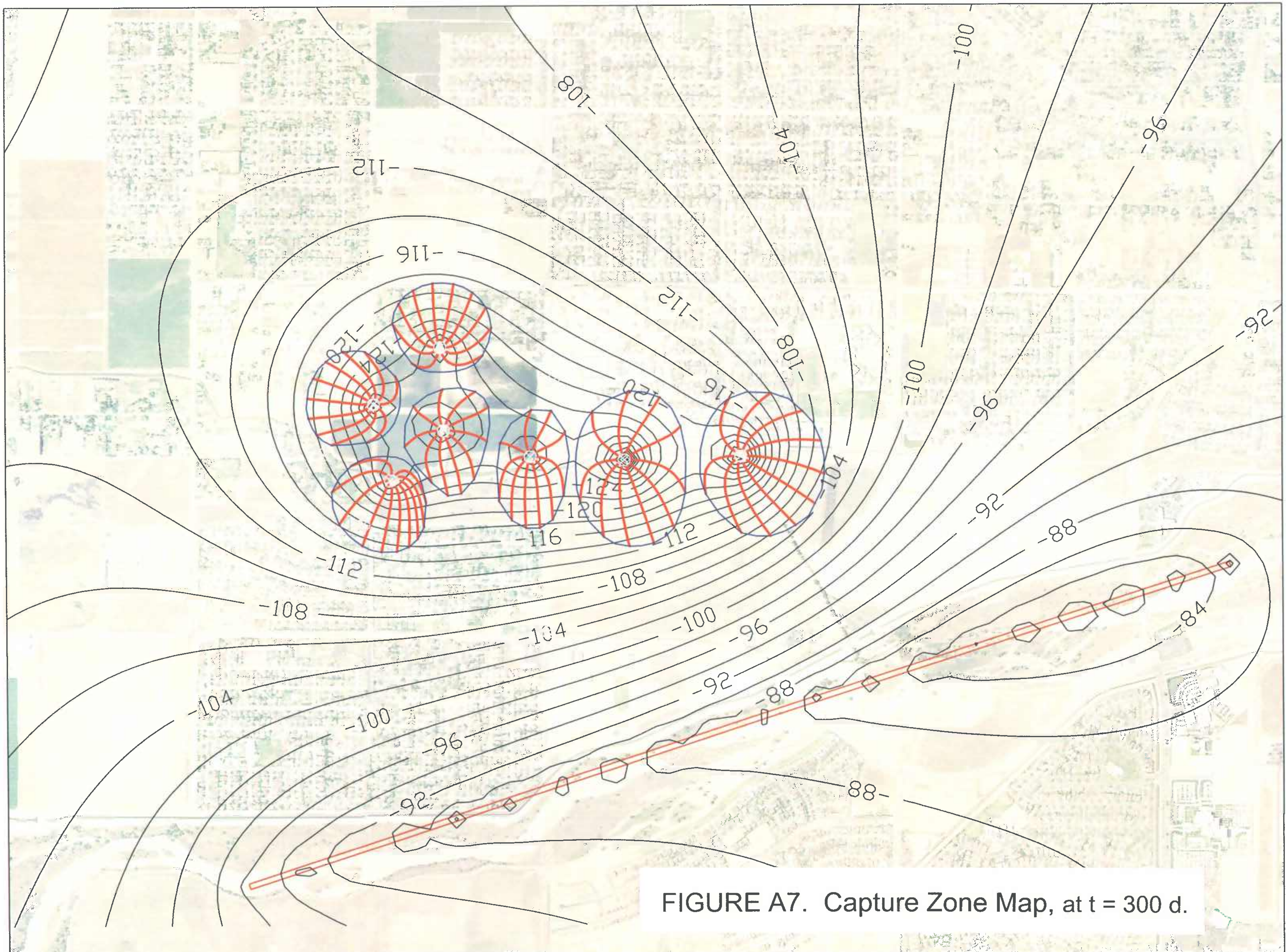

FIGURE A7. Capture Zone Map, at t = 300 d.

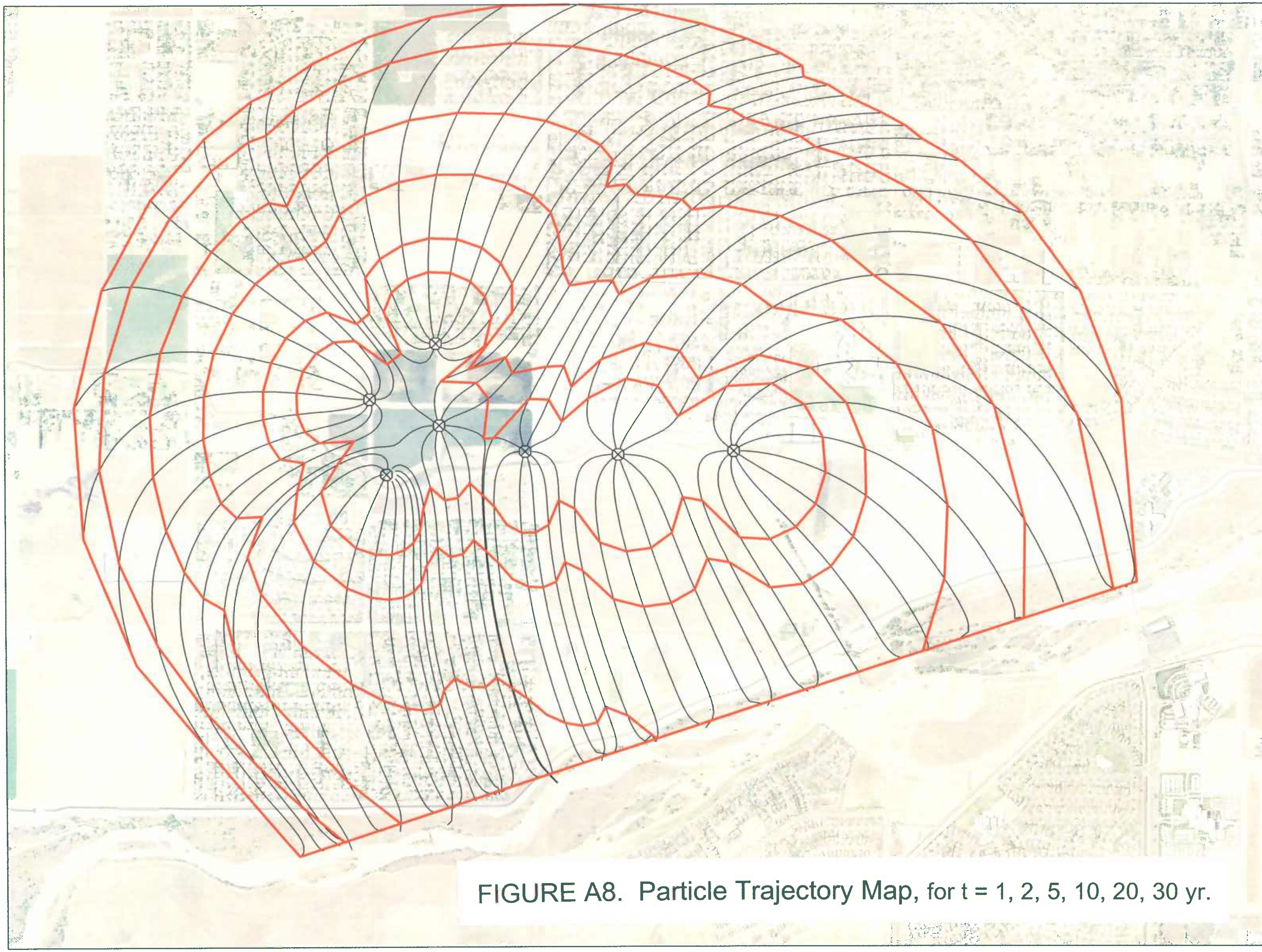

FIGURE A8. Particle Trajectory Map, for t = 1, 2, 5, 10, 20, 30 yr.

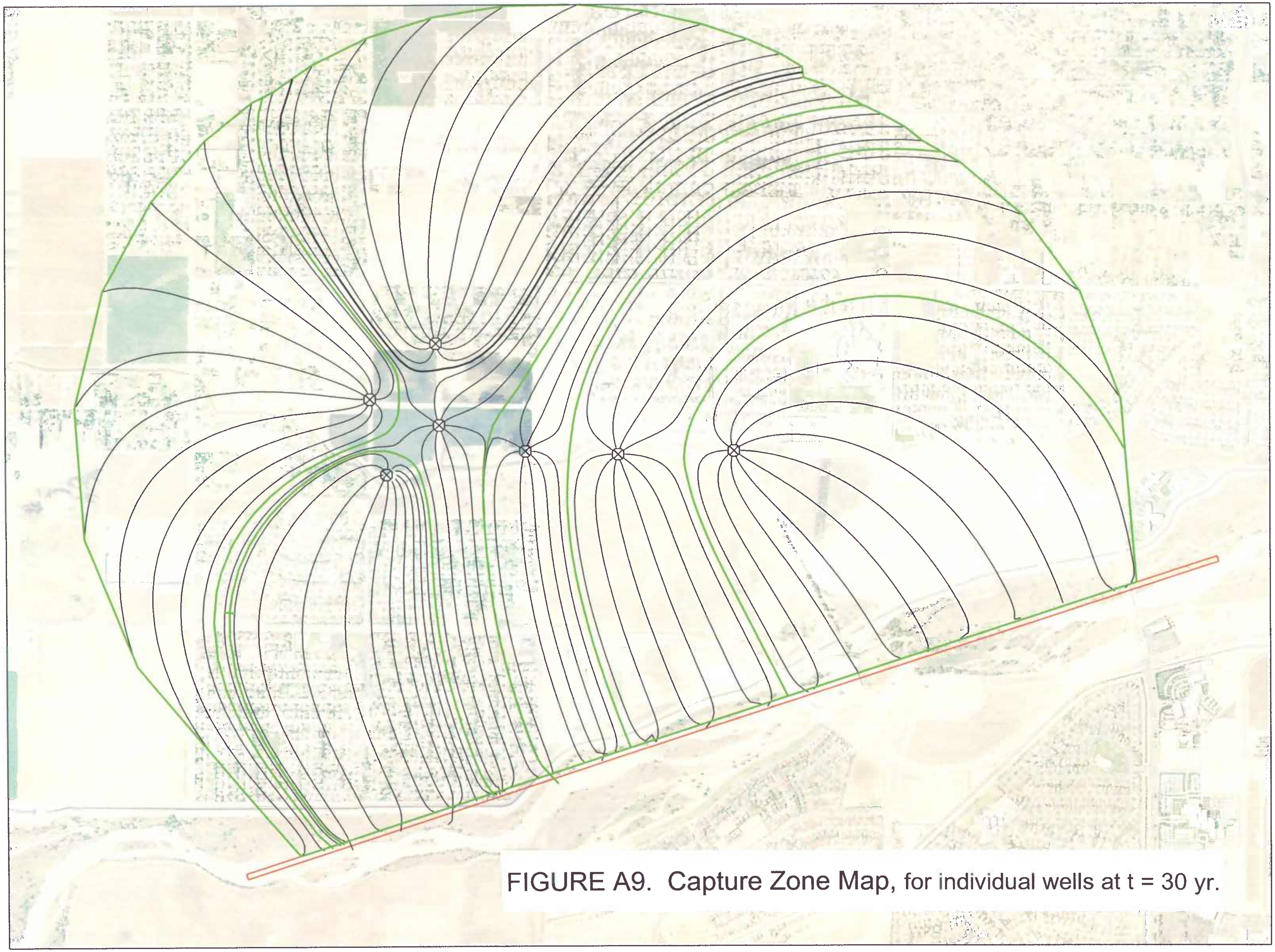

FIGURE A9. Capture Zone Map, for individual wells at t = 30 yr.

An Evaluation of Well Placements and Potential Impacts of the
ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project.

3. Introduction

Section I - Work Program.

The focus of this work program is an array of seven proposed wells which are a part of the ID4/KT/RRB aquifer storage and recovery (ASR) project. The proposed scope of work includes a well placement and impact analysis including a review of surrounding wells, a geological review, an aquifer parameter selection, a pumping drawdown impact analysis for designated scenarios, a review of potential water quality impacts, and preparation of report.

The purpose of evaluating the well placements and impacts of the ASR Project is to demonstrate project viability within the proposed operating parameters to interested parties. The technical elements of the work program include E-log evaluations, aquifer parameter determinations, and computer modeling of water level drawdowns and aquifer flow trajectories.

Section II - Personnel.

Dr. Robert A. Crewdson is a Bakersfield, California consultant doing business as Sierra Scientific Services (SSS). SSS specializes in quantitative ground water hydrology, applied potential theory and time series analysis, quantitative ground water flow analysis, water quality geochemistry, well testing and monitoring, contaminant transport modeling, and aquifer properties testing. Dr. Crewdson is a research associate and adjunct professor at California State University Bakersfield where he teaches hydrology, contaminant transport, geochemistry and geophysics in upper division and graduate level courses.

Section III - Methods.

This Report presents the findings of several types of analyses and evaluations which we summarize here. The well log and geological analysis includes a review of the completion intervals in surrounding wells and a review of E-logs primarily for stratigraphy and net- sand analysis. The aquifer parameter analysis includes a review of published data, a review and re-calculation of T & S values from the December, 2002 ID4 well tests for nearby ID4 wells, and a review of published infiltration rate data for nearby recharge ponds and test ponds. The drawdown impact analysis includes Cooper- Jacob calculations for a range of transient conditions and parameters, and analytical computer modeling and mapping of multi-well drawdowns and particle trajectories. We used SSS proprietary software for the Cooper- Jacob calculations and WinFlow (tm) software by Environmental Simulations, Inc. for the drawdown modeling and mapping.

This impact analysis is the fourth such study that we know of in the general area of interest. The previous three impact analyses include reports on the Kern Water Bank (Schmidt, 1997), the Pioneer Project (Schmidt, 1998), and the ID4 Kern Parkway Project (Schmidt, 2003a & 2003b).

Section IV - Acknowledgments.

Thank you very much Tom Haslebacher, KCWA hydrogeologist, for providing the ID4 project location maps and for preparing and printing selected SSS data overlays on the KCWA air photo base map for inclusion in this Report.

4. Discussion

Section I - Project Description.

The ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project is a uniquely collaborative effort between three local water districts to operate and optimize an aquifer storage and recovery (ASR) project. The site of the Project is located about ½- mile north of the intersection of Allen Rd and Stockdale Hwy in southwest Bakersfield, Kern County, California (Figures 1 & 2).

The Kern Tulare Water District (KT) is the banking partner who will provide a wet-year water supply to the project and who will receive a dry- year water supply in return. The Rosedale - Rio Bravo Water Storage District (RRB) is the storage partner who will provide existing recharge ponds and aquifer storage. The Kern County Water Agency Improvement District No. 4 (ID4) is the operating partner who will engineer and operate the wells and pipeline facilities related to project operation. Kern Tulare WD and ID4 are funding the installation of five new water wells and a new pipeline gathering system.

Kern Tulare WD will store and recover an estimated net 243,000 acre-feet (af) of water over the initial 30 year project life. KT surface water will be delivered to the Project through turnouts or headworks that connect the RRB conveyance canal to both the nearby Cross Valley Canal (CVC) and the nearby Kern River channel. Well water will be returned to the CVC by the proposed pipeline gathering system. The forecast dry- year return of water is projected to occur in three years out of ten, and the well field operation is projected to be 90 af/d for 300 days in a return year.

The proposed project recovery design capacity is 90 af/d (approx. 45cfs) which includes three wells at 5 cfs and two wells at 10 cfs which will be installed in 2004 and another two proposed wells at 5 cfs which may be installed in the next 2 - 3 years. The full proposed well field straddles the boundary between RRB and ID4 with a 5-well array located on RRB property and a 2-well array located on ID4 property. The surrounding area contains private domestic water wells and municipal water wells of various depths which belong to private parties and other entities. Two of ID4's engineering design objectives are to 1. estimate the drawdown and water quality impacts of the proposed well field for a range of operating scenarios, and 2. minimize the drawdown impacts of the well field on surrounding wells by optimizing the well- location placements.

The proposed project ground water extraction capacity of 45 cfs is only 25% of the total estimated recovery capacity of 180 cfs for all of the wells in the local area. The City of Bakersfield owns 7 wells with an estimated pumping capacity of 45 cfs, there are 4 other recognized municipal water supply wells with an estimated capacity of 20 cfs, and 7 other ID4 wells with an estimated capacity of 70 cfs. It is reasonable to assume that during some dry periods when the demand for water is the highest, that all of these wells may be pumping at the same time. Our scope of work is limited to evaluating the potential impacts of this project operating as if it were operating alone.

Apart from selecting the proposed well locations, the drawdown impact analysis is the main objective of this evaluation. This analysis assumes that the wells are drilled, completed, and developed properly so that they are efficient and productive water wells, limited only by the delivery capacity of the aquifer. The drawdown impact analysis requires several types of essential information including operating parameters, well parameters, aquifer model and aquifer parameters. We describe each of these parameter sets below.

Section II - Project Operating Parameters.

For the purpose of impact analysis, the base case annual operating scenario is to operate all seven wells at specified flow rates for a combined design capacity of 90 af/d for 300 days, which produces 27,000 af of ground water over the period. The hypothetical long term project operation is based on the historical wet/dry climatic cycle which is predicted to require base case pumping in three years out of ten. The "worst-case" design scenario therefore is base case operation in three consecutive years. Other impact design scenarios of interest include one-year operations at 25% and 50% of base case.

There are, of course, many other possible operating scenarios and even multiple options in achieving the one- year operations at 25% and 50% of base case. These multiple options may include different pumping rates and/or different pumping durations for some wells or perhaps not using all of the available wells to meet the production target. It is outside the current scope of work to evaluate all of these possible operating scenarios, nor is it really necessary to do so. We have sensitivity analyses which cover the range of likely operating conditions.

There are other design variables which affect, and could perhaps even dominate, the impact analysis which are difficult to forecast in advance. The primary natural factors include the depth to the water table at project startup, the magnitude and direction of the ground water gradient, and the large basinwide water level fluctuation due to the climatic wet/dry cycle. The primary manmade variables include non-project impacts caused by other recharge or pumping operations in the surrounding area. The evaluation of these design variables is outside the scope of work.

Section III - Well Placement Analysis.

Several constraints and operating criteria limit the selection of the seven proposed project well locations. The two wells intended to be located on ID4 property needed to be placed along the proposed pipeline right of way and the five wells intended to be located on RRB property needed to be placed on the network of levees which provide access to the RRB recharge ponds. ID4 established the two locations on their property according to their own criteria so that the balance of the well placement analysis referred to the cluster of five wells on the RRB property.

The three main criteria for the five RRB well placements are to: 1. minimize well interference, 2. distribute the drawdown impacts as uniformly as possible across the largest possible area, and 3. minimize the drawdown impacts to any wells in the surrounding area. The first two criteria are best met by placing the wells on the nodes of a uniform rhombic grid at the largest possible spacing and operating all five wells simultaneously at the same flow rate. The third is best met by orienting and sizing the grid so that every possible well node is no closer to the nearest surrounding well of concern than a minimum specified standoff distance.

Five possible 5- well arrays (Figures 3A - 3F) fit the criteria for well placement and each array has a node spacing of 1200 ft between project wells and a minimum standoff distance of 1000 ft from surrounding wells. Each of the five possible well arrays has its advantages with respect to secondary criteria such as total gathering system pipeline length, lengths of larger and smaller diameter pipes, proximity to future road alignments, capital and operating costs, and other factors. Sierra Scientific used well array "A" for the calculation of hypothetical drawdowns (Figure 3A) and, for reference purposes, located each well on a coordinate system with respect to a local origin (0,0) at the intersection of Allen Rd and Stockdale Hwy.

Section IV - Aquifer Model and Parameter Selection.

There are many computation methods for predicting drawdown from a pumping well in space and time and every method requires that the user select the equations which are most appropriate for the user's preferred model of the aquifer. In essence, the user must try to select the set of mathematical expressions which best represent the user's physical model of the aquifer. The calculated results, if done correctly, always represent the mathematical model but only represent the real aquifer behavior to the extent that the parameters, simplifications and assumptions of the mathematical model reflect the true workings of nature. The selection of the mathematical model and the equations, the accuracy of the parameter values, and the representativeness of the calculated output all reflect the correctness of- and uncertainty in- the judgments of the user. These judgments cannot be made by the computer and the two main judgments include the choice of mathematical model and the choice of aquifer parameters.

The Real Aquifer. Based on our analysis of the E-log stratigraphy and hydrogeology, the local aquifer is a semi-confined (leaky) aquifer which is recharged from the sides and from the overlying layers. The aquifer consists of a sequence of nearly- horizontal, laterally discontinuous, interbedded, unconsolidated, sandy and silty sediments. Horizontal ground water flow occurs almost entirely within the sandy units. The shallow sands behave as an unconfined aquifer, but deeper sands show increasing amounts of delayed yield and confinement, according to KCWA hydrographs.

Because the interbedded silts have some permeability of their own, and because pumping in the deeper zones causes significant downward vertical gradients, the deeper sands obtain a significant fraction of their recharge from the overlying layers. This "leakage recharge" through the permeable silts is augmented by higher- speed, vertical flow at the lateral margins of the silty layers through the more permeable sand facies between layers.

This type of aquifer behavior is complex and difficult to model at the observed scale of variability unless we have much more data than is currently available. However, this aquifer can easily be modeled as a semi-confined (leaky) aquifer with a few simplifications and assumptions. The mathematical theory is available for us to model the project impacts under leaky aquifer conditions, and we consider this to be an acceptable approximation and the best choice among the available alternatives.

Aquifer Model. For this scope of work, there are three mathematical aquifer models from which we are free to choose, i.e., a confined aquifer, an unconfined aquifer, or a leaky aquifer. We must choose one of these three models based on our interpretation of the local geology and hydrology.

The SSS interpretation of the local geology, based on available well logs, consists of complexly- interbedded sandy and silty sediments with reported localized confining layers about 150 ft below ground level and a more extensive confining layer about 550 - 700 ft deep. The cluster- well hydrographs (Figures 6A, 6B, 7A, 7B) which are prepared and presented by the Kern County Water Agency on a monthly basis corroborate the widespread and persistent presence of downward vertical gradients between successively deeper depth intervals which are indicative of leaky aquifers.

We interpret the hydrology and stratigraphy with significant vertical gradients, lateral facies changes, and widespread absence of shallow clay layers to be an aquifer which behaves neither as a confined nor an unconfined aquifer but as a non-ideal leaky aquifer. The combined effects of many thin, laterally discontinuous silty layers contribute to aquifer and well behaviors with delayed yield and both horizontal and vertical flow gradients. Our interpretation differs from the models proposed by Schmidt in 2003 and by the Department of Water Resources (DWR) in 1995, which we summarize for reference in Appendix 1.

Aquifer Parameters. For the leaky aquifer model, we must specify the aquifer dimensions, regional gradient, aquifer storage properties, and aquifer flow properties in both the horizontal and vertical directions. There is a scarcity of reliable parameter data in the Kern Fan area. We have reviewed all of the available data and have found just enough data to make a single estimate of every required parameter. Because of the lack of replicate data, there is an unknown amount of uncertainty in the representativeness of these single parameter values, which is in addition to the uncertainty in the accuracy of these measurements themselves.

We have reviewed the available published sources of parameter values (Appendix 3) and we consider the ID4 well test of December, 2002 to be the best source of a verifiable T & S value for the area of interest. SSS re-analyzed the reported time- drawdown data for one observation well (Appendix 4) and determined the local value of transmissivity to be T = 20,000 ft^2/d and the value of storativity to be S = 0.00056 for the slotted intervals of the tested wells . These values of T & S differ from those published in the original analysis (Schmidt, 2003b) and from other published values in the area. This value of S = 0.00056 from the pump test, disagrees with our calculated value of S which is based on bulk compressibility measurements on sediment samples from the project area of interest. Based on our measurements, we expected a well- test to provide a storativity (S) in the range of $0.003 \leq S \leq 0.015$. Lacking any corroborating data to resolve the discrepancy, we chose to use the measured value of S = 0.00056 from the ID4 December, 2002 well test for this work program.

Based on E-logs, we estimate that the test wells were completed across an estimated 250 ft net sand interval in the local area of the well test, so that the hydraulic conductivity of the sandy strata must be about K_{sd} = 80 ft/d. Based on published RRB data, we have used a value for specific yield of S_y = 0.21 and an average porosity of p = 0.30 for the aquifer sands.

The Hantush leakage factor (B) is a function of the aquifer transmissivity and the vertical flow properties of the aquitard(s) overlying the aquifer. In the project area, the high-permeability zones of the aquifer are sandy sediments and the low-permeability zones are silty sediments. These silty sediments are the aquitards which retard the vertical flow of water between the sandy layers of the aquifer. The vertical flow parameters of interest include the thicknesses and vertical hydraulic conductivities of the silty layers but neither the horizontal nor the vertical hydraulic conductivity can be determined from the local wells or well tests. Based on our measurements and estimates of the relevant properties (Appendix 3), we estimate that the value of B varies in the range of about $1800 \leq B \leq 6000$ and we have used a value of B = 3200 as our base case value.

Both Swartz (1995) and Schmidt (1997) quote generic values for vertical hydraulic conductivity (K_v)for the Kern Water Bank area (see Appendix 1) ranging from .0004 - .0027 ft/d which are within the two orders of magnitude of typical textbook values for silty sediments. Swartz (1995, p.116) indicated that the selected DWR values were guessed at and did not work very well in their computer models and had to be changed to other, unreported values. Schmidt reported (1997, p.7) that their values were determined from long- term well tests performed in the KWB area in 1990 - 1991 but we do not know how this might have been done and Schmidt did not present either the well locations, test methods, test data, or calculations so we cannot independently verify the reported values or their relevance to the ID4 / KT / RRB project area. Except that these reported values fall within the range of expected textbook values for silty sediments, we place no particular credibility in the representativeness of these particular values of K_v. We do not know of any other reported pump test data which provide a determination of the vertical hydraulic conductivity of the local sediments.

There are several reported measured values of vertical hydraulic conductivity Kv_{sand} for both sand and silt samples collected in the area of interest. RRB (Crewdson, 2003) and the City of Bakersfield (COB, 2000) separately reported independent sediment permeability data which are based on laboratory core analyses of shallow unconsolidated sediments which have been retrieved from boreholes down to 120 ft deep. The RRB sand samples had a $Kv_{sand} = 18$ ft/d and the COB sand samples had a $Kv_{sand} = 112$ ft/d. The RRB silt samples had a $Kv_{silt} =$ 0.038 ft/d and the COB silt samples had bimodally distributed values of $Kv_{silt} = 0.3$ and $Kv_{silt} =$ 0.03 ft/d. Based on these core- sample data, we observe that the local silty sediments are about 500 - 1000 times less permeable than the local sandy sediments.

Based on the Kv/Kh ratio for these sediment analyses and the well-test value of $K_{Hsand} =$ 80 ft/d, we estimate that the range of vertical hydraulic conductivity of the silty intervals is about $0.04 < K_{Vsilt} < 0.16$ ft/d with an average estimated value of $K_{Vsilt} = 0.08$ ft/d . Finally, we have estimated the aquitard thickness (b′) based on E-logs and dimensional considerations to be 50 - 100 ft thick and have calculated a range of values of leakance (L′) and Hantush leakage factor (B) accordingly. We have selected an average value of B = 3200 ft for base case drawdown calculations and a range of about $1800 \leq B \leq 6000$ for sensitivity analyses.

For the calculation of drawdown impacts, we have initially assumed that the regional gradient in the test area is zero so that all model impacts are superimposed on an initially flat water table. We set our reference elevation to be zero at the initial water table rather than at ground level or at mean sea level so that all calculated drawdowns are relative to the initial water table. This device allows us to easily observe just the predicted pumping- induced drawdown at any location without the complicating effects of the natural gradient.

However, in order to perform particle trajectory and capture zone analyses, we must superimpose the calculated pumping- induced drawdowns on a realistic approximation of the natural water table gradient. We have based our approximations on observed historical water table behavior.

The Ken Schmidt, 2003a, report presents two different groundwater conditions in their impact analysis of the project area. One condition represents a *northwesterly* water table gradient and a second condition represents a *westerly* water table gradient. Based on our review of KCWA groundwater elevation maps for the area, we have observed an overall change in the groundwater gradient as the climate swings from wet to dry conditions. During a wet cycle, the recharge in the three- mile stretch of the Kern River channel from Allen Rd east to Coffee Rd tends to create a northwesterly component to the overall gradient on the north flank of the river recharge axis such as for the years 1996 - 1998 (Figure 8). During a dry cycle, the absence of recharge in this stretch of river causes a westerly gradient to dominate due to the effects of aquifer dynamics farther to the east such as in years 1991 - 1993 (Figure 9).

This shift may cause contaminant plumes located outside of, but close to, the long term capture zone limit to move into the capture zone. The reverse is not really possible, i.e., contaminant plumes leaving the capture zone, because even though particle trajectories say it is possible, actual contaminant migration invariably leaves in situ residues behind in its pathway which linger as continuing in situ sources of low- grade contamination for many years thereafter. We have included the uncertainty in ground water gradient in our analysis by using a long- term background average ground water gradient behavior within the computational model, based on the observed trends from the KCWA historical ground water elevation maps.

In other model runs we have assumed that the regional water table gradient is 0.002, i.e., about 10 ft per mile either to the west (α = -180 degrees, left azimuth from east), which is typical of dry cycle conditions, or to the northwest (α = -135), which is typical of wet cycle conditions. In these cases, we have set our reference elevation such that the water table approximates the true depth of the water table in the area of interest, which we assumed to be 100 ft deep at the intersection of Stockdale Hwy and Allen Rd for this evaluation.

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Section V - Drawdown Analysis.

The basic output from a single drawdown analysis is a contour map of the predicted drawdowns in and around the area of the well field. Each map shows the well locations, the contours representing the drawdown for a specified set of pumping parameters, and flowpath particle trajectories for a specified duration of pumping. The maps cover an area of approximately ten square miles centered on the middle of the well field. Using local (east, north) coordinates in units of feet, the local origin (0,0) is at the intersection of Stockdale Hwy and Allen Rd, the southwest map corner is located at (-8400, -4600), and the northeast corner (+11600, +10600).

The predicted drawdowns from this work program are significantly different than the predicted drawdowns from three other recent impact analyses by other workers in five respects. First, SSS modeled the aquifer as a leaky aquifer rather than as a confined aquifer. Second, SSS used the superposition method versus the so-called centroid method used in the other studies. Third, SSS's parameter values are different than those of the other studies, and incidentally are different in such a way as to increase the calculated drawdowns, all else being equal. Fourth, the leaky aquifer model which SSS used predicts that the water levels will decline and then stabilize at a static, steady- state drawdown at least for a while, compared to the other forecasts which predict that water levels will continue to decline as long as pumping is continued. Fifth, for SSS's choices of aquifer model and aquifer parameters, the predicted drawdowns are significantly less than the predicted drawdowns from these other studies.

<u>Expected results.</u> We expect at any moment after pumping has begun that a cone of depression will form around each well and that the cone of depression will deepen and expand outward with time, subject to certain limits. We expect at any moment, that the drawdowns will be larger close to the wells and smaller farther away from the wells. We expect at any location that drawdown increases as the duration of pumping increases. We also expect for any specified time and location, that the drawdown will be larger for higher pumping rates and

smaller for lower pumping rates. We also expect that for any location that is within the radii of influence of more than one pumping well, that the observed drawdown will be the sum of the individual drawdowns caused by every pumping well superimposed at that location.

What is not as intuitive is the expected drawdown behavior depending on the choice of aquifer model. If the aquifer is fully confined or fully unconfined, the drawdowns will continue to decline indefinitely. If the aquifer is semi-confined with leakage recharge from the overlying layers, the observed qualitative behavior will be more complicated. For a short period of time, the aquifer will behave as a confined aquifer, meaning that the observed drawdowns near each of the wells will decline quickly and with the same time - distance relationship as is predicted for a confined aquifer with the same values of T & S. Thereafter, the water table will decline at a decreasingly slower rate than predicted by the confined-aquifer model until the water table stops falling altogether.

After an undetermined time period of leaky behavior during which there is little or no observed drawdown despite continued pumping, we expect that the water table will once again start to decline at a rate which is consistent with the de-watering of an unconfined aquifer with the assumed values of T & S_y. The durations of each of these behavioral phases may be estimated but the calculated times of transition are not particularly precise because of the inability to predict future recharge. This project can be in leaky steady state for a very long time if the shallow aquifer is consistently recharged. Once this program has begun, a properly designed well- testing and monitoring program will provide a wealth of new understanding of the aquifer, well beyond what we are able to model with the small parameter set which is available at this time.

ID4 observed decline- and- stabilize behavior in the December, 2002 well test after only 6 days of pumping, which they attributed to the onset of ground water recharge in the nearby Kern River channel. Perhaps. But the observed stabilization of the water table more likely represents the leaky aquifer condition in which all pumped water was being supplied by downward leakage from the overlying layer and the well pumpage had achieved balance with the rate of vertical recharge.

For the ID4 December, 2002, well test, the drawdowns reportedly stopped declining in some wells after only six days of pumping, which was attributed to ongoing recharge in the

Kern River channel. But the math doesn't really support this logical sounding explanation. The combined recovery rate of the six pumping wells was about 95 af/d but the river was recharging only about 20 af/d. The river recharge could only have supplied about 20% of the total recovery rate even if there had been no delay whatsoever in moving recharge water from the river to the producing intervals of these six wells. If the river had really been supplying the pumped water, the river would have dried up! Most of the recharge that caused the drawdowns to stop declining must have come from a "real- time" source other than the Kern River channel.

In our opinion, the available data suggest that the more likely explanation of the drawdown behavior which was observed during the ID4 December, 2002 well test is that the aquifer was behaving like a leaky aquifer and the drawdowns stabilized as soon as the zone of depression had spread sufficiently to capture enough recharge leakage to balance the recovery rate of the test wells. In this model, the river recharge is essential to keep the shallow water table aquifer replenished over the long term against the loss from this zone due to leakage, but based on theoretical and practical grounds we would not say that the river was the direct cause of the observed stabilization of drawdowns during the December, 2002, well test. However, subject to confirmation during future project operation, this previously- observed behavior suggests that the leaky aquifer model is an appropriate approximation to the aquifer under the project area.

Computed results. The base case operating scenario is to pump all seven wells at a combined flow rate of 90 af/d for 300 days to recover 27,000 af from aquifer storage. The base case aquifer model is a leaky aquifer with T = 20,000 ft^2/d, S = 0.00056, ϕ = 0.30, and B = 3200 ft. The base case water table model is a horizontal water table for impact analysis, and two cases of sloping water table; a planar gradient of pointing either in the direction N45°W or N90°W with or without river recharge, for zone of capture and particle trajectory analyses. We present the calculated drawdowns for the base case and for other cases representing a broad range of parameter values in the figures and appendices. The calculated drawdown at any specific location for any specified set of conditions may be read directly off the respective drawdown contour map.

Base Case. If the local aquifer is a *leaky aquifer* as we have modeled it under the base case conditions, then after 300 days of pumping, the induced steady state drawdowns at distances of 1000, 3000, and 5000 ft from the well field perimeter are predicted to be 16 - 24 ft, 8 - 12 ft, and 3 - 5 ft, respectively (Figures 10 & 14). The model predicts that the entire drawdown will take place in the first 10 - 20 days and then remain steady or nearly so thereafter. These maximum, steady-state drawdowns will remain unchanged even for multiple consecutive years of well operation as long as the shallow zones continue to be recharged and are not dewatered. The actual operating drawdowns will be similar to these calculated drawdowns if our selected parameter values are representative of the aquifer when the project actually begins.

This steady- state drawdown condition does not come for free, i.e., the water must come from somewhere. The real- time recharge to the aquifer comes at the expense of the shallow zone which will experience a decline in water table of 30 ft near the well field for the duration of pumping or more if this layer is not recharged.

There are five domestic water supply wells and four municipal water supply wells within approximately 1,000 - 1,200 ft of any one of the project wells (Figure A2). There are another nine wells 1,200 - 3,000 ft away, and another 9+ wells within 3,000 - 5,000 ft. These wells include six City of Bakersfield wells, at least four other municipal water supply wells, and five non-project ID4 wells within this zone of influence. None of these other entities except ID4 has performed or published a well placement analysis or impact analysis on their wells, to our knowledge.

The potential impacts of these nearby wells on this ID4/KT/RRB project is currently outside our scope of work, but the bigger wells will certainly have drawdown impacts and particle trajectory - capture zone impacts in the project area which we have not incorporated into this study.

The ASR project is designed to put a wet- year water supply into the ground and then recover it in some future dry year, so there is little likelihood of recharge and recovery happening simultaneously. However, as long as the project puts as much water in the ground as they take out, the net basin impacts of recovery will be exactly compensated for by the mounding impacts of recharge, so there will be no net long term effect on the basin no matter how far apart recharge and recovery are separated in time. The purpose of this study is to determine the magnitude of the potential drawdowns over a single season of pumping, and whether or not these short- term temporary impacts are large enough to exceed project impact criteria.

Base Case Specific Capacity of the Pumped Wells. The specific capacity (SC) is defined as the ratio of discharge rate to drawdown within a pumping well and is used by local engineers as a measure of well performance from which other parameters are calculated. Unfortunately SC is not a constant and varies with pumping time, length of completion interval, hole diameter, and well efficiency, so it is not an effective measure of anything without making the corrections for each of these factors. We can calculate the theoretical specific capacity (SC) of the project wells for the steady- state leaky aquifer condition from the selected base case parameters for purposes of preliminary pump parameter selection. Normally for pump design purposes, we would recommend using actual drawdown data from nearby pumping wells as the best predictor of well performance, but we can calculate a value as well.

For an aquifer transmissivity of 20,000 ft/d which is based on a re-calculation of the ID4 December, 2002, well test and a Hantush leakage factor of $2600 \leq B \leq 3200$, we estimate the expected *steady- state* project- well specific capacity to be around $0.15 \leq SC \leq 0.25$ cfs/ft. For all pumping times less than required to reach steady- state, the observed SC will appear to be larger, perhaps much larger than this predicted final value. For example, the reported time-drawdown data from a 12-hour ID4 pump test of nearby ID4 well #12 (29s/26e- 36Q02) gives uncorrected SC values in a range equivalent to $0.46 \leq SC \leq 0.60$ cfs/ft. Previous workers have used such non-stabilized values of SC to report calculated, but undocumented, values of aquifer transmissivity as high as 40,000 - 60,000+ ft^2/d in this immediate area. Until more documented and verifiable data are available in the project area, we will remain skeptical of these values.

Modified Base Case. Because of the uncertainties in the actual aquifer conditions, the actual operating drawdowns may be different than the calculated base case values. We have already acknowledged that there is considerable uncertainty in the few data available to us. Since the accuracy of the impact calculations depends primarily on the values of T, S, and B, we have varied the base case parameters within the credible ranges of possible values and have re-calculated the drawdowns for these other parameter values.

In general terms, we have selected base case values of T, S, and B based on actual measurements but which are at the lower end of their respective ranges of possible values. If the true aquifer transmissivity (T) is higher than our value, then the drawdowns will be less than predicted, but the zone of impact will extend farther out than predicted. If the true aquifer storativity (S) is higher than our value, then the drawdowns will propagate outward more slowly but the final drawdowns will not change in the long run. If the actual leakage factor (B) is higher than our value, then the actual leakage from the shallow zone into the underlying aquifer will be less than we've assumed, the aquifer will behave more like a confined aquifer than expected, and the drawdowns will be larger than predicted. These qualitative trends can be evaluated by modifying the base case parameters through a range of values and observing the changes in calculated drawdowns.

We have assembled a catalog of calculated drawdown maps (Appendix 6) for modified base case parameters and have summarized some of the interesting results in Appendix 6.

Limiting Cases. In general terms, the limiting cases for any impact analysis occur when pumping continues for a very long time, i.e., approaching the condition of steady - state. If the aquifer extends uniformly outward for a very long distance away from the area of operations (i.e. what we call infinite extent) and the aquifer is either confined or unconfined, then the drawdown will never actually achieve steady state but will, instead, continue declining forever at a very slow rate. This rarely occurs in real life because either pumping stops, or the drawdown extends outward until a recharge boundary is reached and then the drawdown stabilizes, or pumping wells nearly drain the aquifer dry and the theory falls apart. Other things which can happen along the way are outside the scope of this discussion.

In these two hypothetical steady state cases, drawdown is greater and propagates farther in the confined aquifer than in the unconfined aquifer. In the ID4 area of interest, the aquifer behavior in either case would achieve about 90% of steady state behavior by the time the wells have been pumped for 300 days. One implication of this is that once the aquifer behavior has achieved steady state, no further (significant) drawdown will occur even if pumping is continued for a long period of time. And this is true of the ID4 project. The calculated drawdown due to three consecutive years of base case pumping is only a few feet deeper than the drawdowns at the end of the first year.

For comparison purposes, the hypothetical steady state drawdowns for fully confined and fully unconfined conditions are as follows. If the local aquifer were *fully confined*, then after 300 days of pumping the drawdowns within the aquifer would be greater than 100 ft at a distance of 1000 ft from the wells and 74 - 82 ft at a distance of 5000 ft from the wells (Figure 11). If the local aquifer were *unconfined*, then after 300 days of pumping the drawdowns within the aquifer would be as much as 60 - 70 ft at a distance of 1000 ft from the wells and 44 - 50 ft at a distance of 5000 ft from the wells (Figure 12).

Section VI - Flow Trajectory and Capture Analysis.

Particle trajectories. A particle trajectory represents the hypothetical flowpath of a water molecule under ideal flow behavior, i.e., ignoring the effects of dispersion, flowpath tortuosity, heterogeneity, etc. We can calculate particle trajectories in downgradient or upgradient directions, which we refer to as forward or reverse particle tracking, respectively. In our computational models we assume that the aquifer is horizontally isotropic so that particle trajectories are always perpendicular to water level contours. For this project we used reverse particle trajectories to determine the shapes and extents of the capture zones for each of the pumping wells in the well field for different pumping durations.

The flowpath behavior in the project area under pumping conditions represents non-Darcy flow in which the particle trajectories of adjacent water molecules are not parallel and do not travel at constant velocity. We can easily calculate the water flow velocity at any point at any time but it is not particularly useful to do so. The best generalization we can make is that groundwater flows the slowest at the perimeter of the capture zone, the fastest as it approaches a well, and at intermediate velocities in between because it varies with the gradient which varies with the distance and position relative to the well field.

It is much more useful to be able to map the flowpaths that aquifer water takes as it flows toward a well because any potential constituents of concern in the groundwater will follow the same flowpaths. One important use of particle trajectory mapping is for designing contaminant- detection monitoring programs so that the operator can place the monitoring wells in the likely flowpaths from known or suspected contaminant sources.

Capture zones. A capture zone is the enclosing perimeter of the actual bulk volume of the aquifer from which a pumping well extracts water over a specified time period. For a confined or semi- confined aquifer, the capture zone is a vertical cylinder centered on the well and bounded by the confining layers at the top and bottom of the aquifer. The radius of the capture zone increases as the pumping rate and/or duration increase. The shape of the capture zone will be distorted by the presence of other wells and/or recharge boundaries but it will always have a fully enclosing perimeter. The method of reverse particle tracking will always provide a means to map the shape and extent of the capture zone for a specified pumping duration.

The capture zone (CZ) is the cylindrical volume of the aquifer centered on the well field from which ground water is actually removed by pumping over a specified time. The CZ is not the same volume or the same shape as the cone of depression which merely shows the distribution of head within the aquifer. The importance of mapping the capture zone is for purposes of evaluating water quality, particularly the potential for contaminant capture. We have mapped (Figure 13) and tabulated (Figure 15) the approximate locations of the expanding capture zone for continuous pumping for pumping times from 1 - 30 years for an aquifer with a northwesterly water table gradient (Figure A9).

A slug or plume of contamination which is inside the capture zone will arrive at the well field within the specified pumping time if the contaminant moves at the same speed as the groundwater. For many contaminant constituents, this assumption is false, since the processes of dispersion, retardation, and attenuation affect the flow velocity of contaminants in ground water. There are no rules of thumb in this regard without specifying the contaminant of concern, but the capture zones which are based on the flow velocity of the ground water form the base case of any contaminant capture analysis. Sierra Scientific Services has performed contaminant transport modeling for other clients, but it is outside this scope of work, particularly since no zones of contamination have been reported in the immediate project area.

Based on the base case operating scenario, the following table gives the approximate dimensions of the well field capture zone for various hypothetical periods of continuous pumping. The distances are measured from the nearest edge of the well field and not the center.

Capture Zone Perimeter Distances, measured from well field perimeter.

Pumping Time (yr)	Downgradient Distance (ft)	Upgradient Distance (ft)	Rate of outward Expansion (ft/yr)
1	1000	1400	1400
2	1500	2100	700
5	2300	3500	560
10	3000	5200	340
20	3500	5800	80
30	3500		
∞	3500		

Based on these data, the well field will never capture water (or contamination) from plumes or sources which are farther downgradient (to the northwest) than about 3500 ft regardless of the duration of pumping. In real life, a capture zone only continues to expand upgradient until it reaches a recharge boundary. For this well field, the upgradient is actually quite close to the south and southeast because the Kern River channel is only about 3,000 - 6,000 ft upgradient. Under the natural gradient alone, with a homogeneous groundwater flow velocity of about 0.5 ft/d, it would take a water molecule of river recharge about 30 - 40 yr to reach the wells and under continuous pumping it would still take 10 - 20 yr. If there are no sources of contamination exist between the well field and the Kern River channel, then the ground water arriving from this direction will always have the same general water quality as Kern River water.

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Figures

1. Project Location Map.
2. Project Well Location Map.
3. Well Placement Arrays.
4. Recovery Well Operating Scenarios.
5. Impact Analysis Parameters.
6. KCWA Hydrograph for cluster well 29/26-35H (RRB short & long term).
7. KCWA Hydrograph for cluster well 30/26-04J (Pioneer short & long term).
8. KCWA 1998 Groundwater Elevation Map.
9. KCWA 1993 Groundwater Elevation Map.
10. Base Case Drawdown Map, leaky aquifer at t = 300d.
11. Base Case Drawdown Map, confined aquifer at t = 300d.
12. Base Case Drawdown Map, unconfined aquifer at t = 300d.
13. Capture Zone Map, leaky aquifer with GW gradient for t = 1, 2, 5, 10, 20, 30 yr.
14. Table of Drawdowns versus Distance.
15. Table of Capture Zone Perimeter Distance versus Time.

Figures

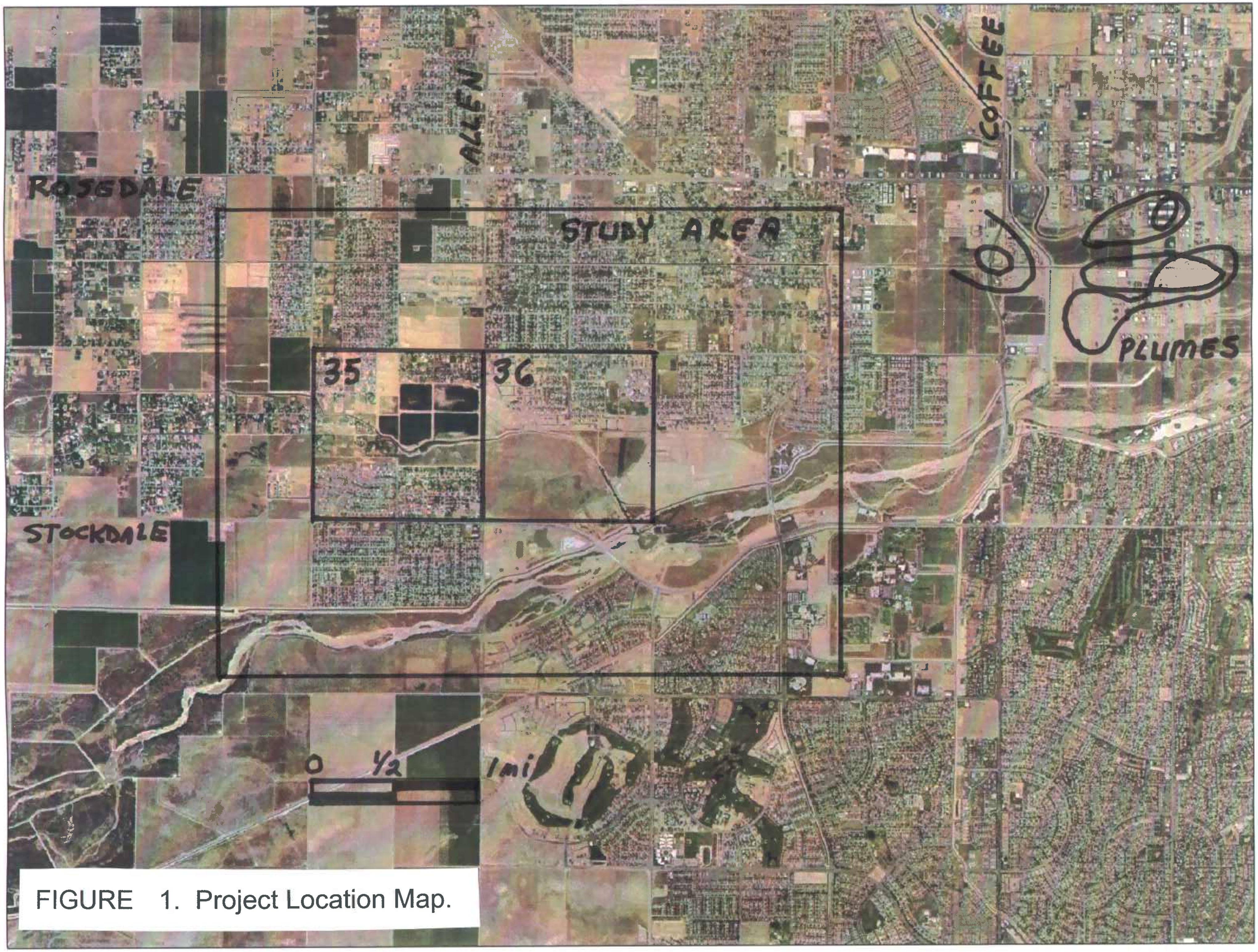

FIGURE 1. Project Location Map.

FIGURE 2. Project Well Location Map.

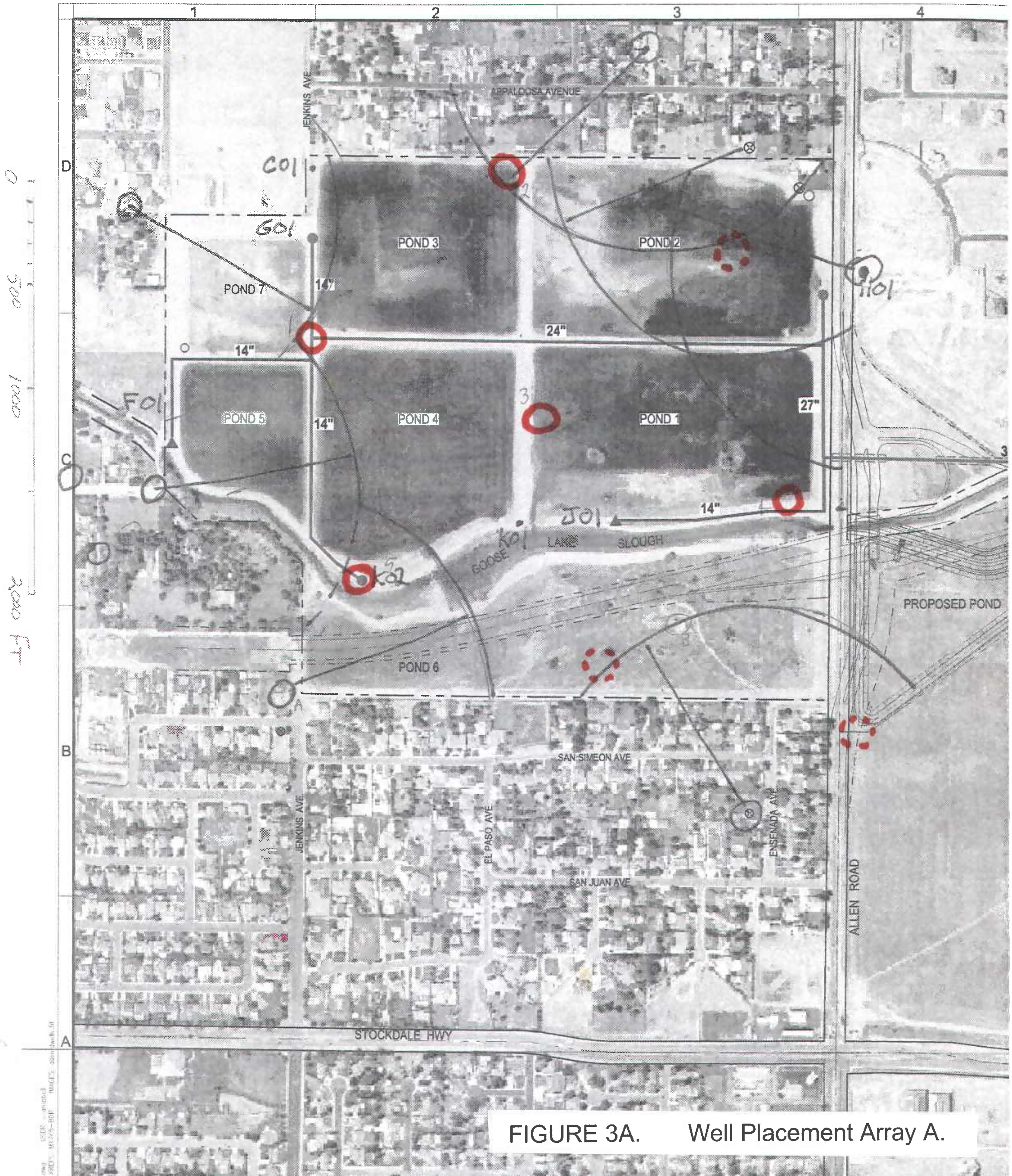

FIGURE 3A. Well Placement Array A.

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				IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY	CHECKED BY	PROJECT NUMBER: BK-R01-002-04	
					DATE: MAY 2004	CADD STANDARDS	

FIGURE 3B. Well Placement Array B.

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DESIGNED BY MYR
DRAWN BY VENE
CHECKED BY
DATE MAY 2004

PROJECT ENGINEER
RCE NUMBER EXP. DATE
PROJECT NUMBER BK-R01-002-04
CADD DRAWINGS

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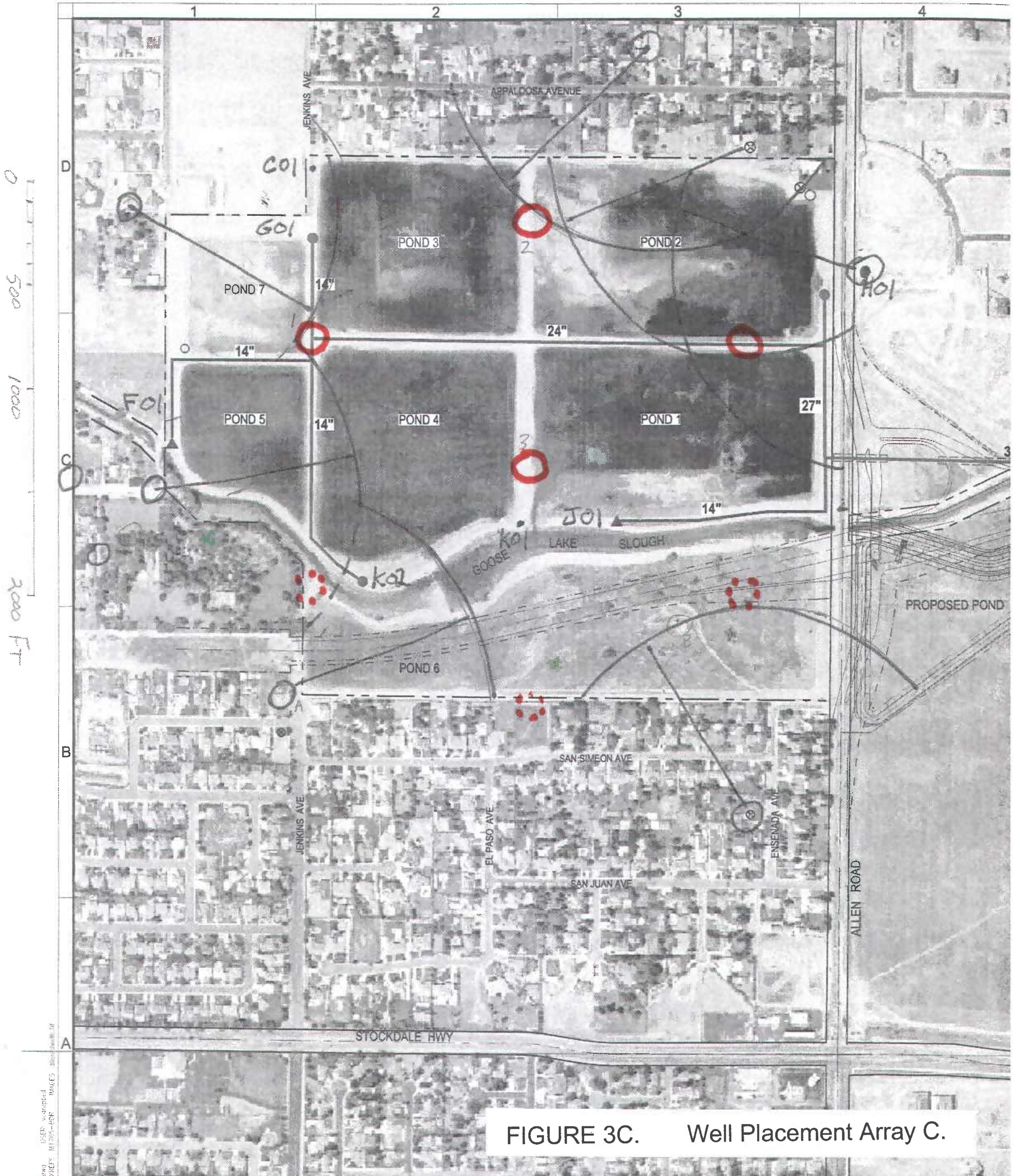

FIGURE 3C. Well Placement Array C.

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CHECKED BY:
DATE: MAY 2004

PROJECT ENGINEER
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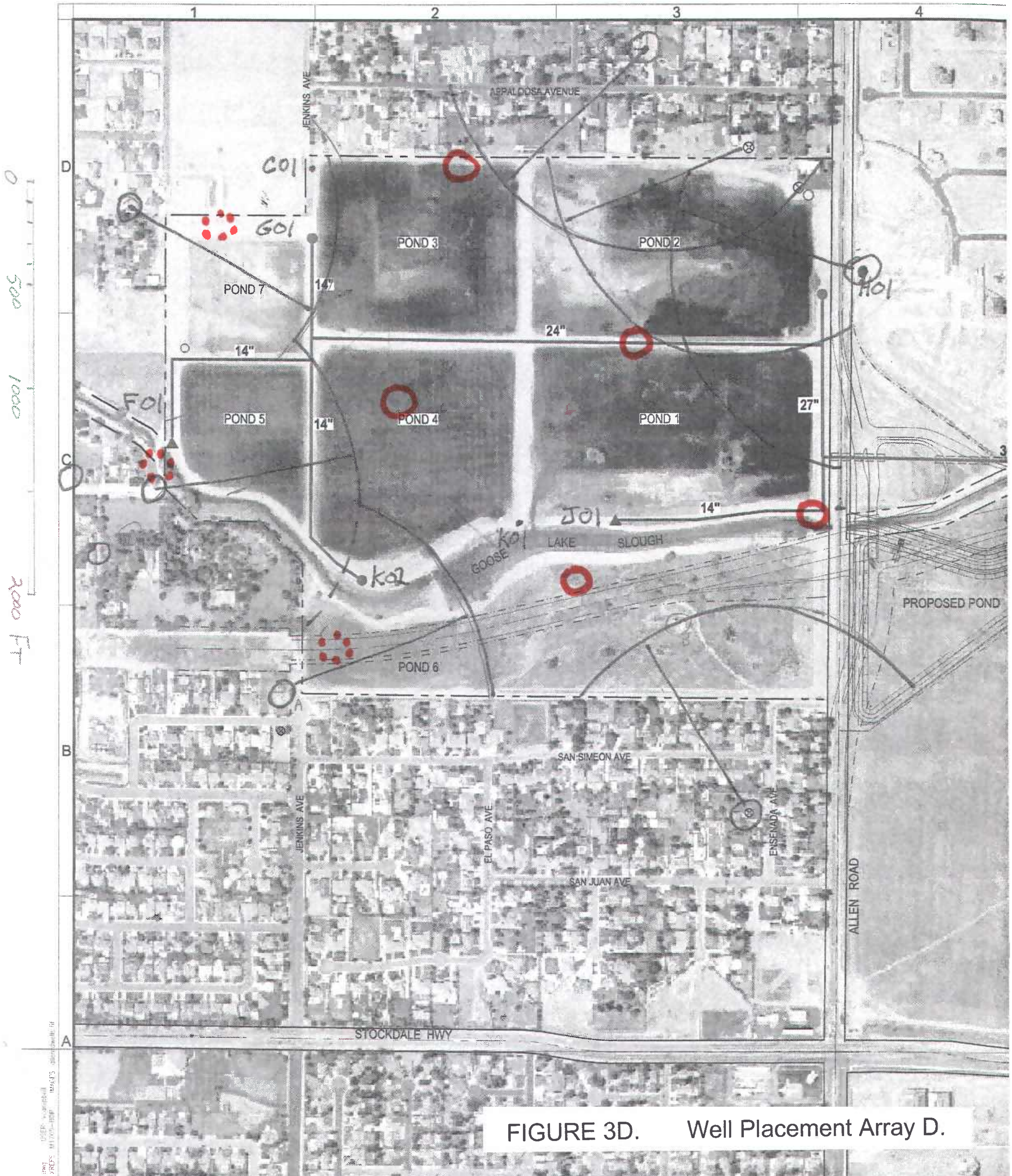

FIGURE 3D. Well Placement Array D.

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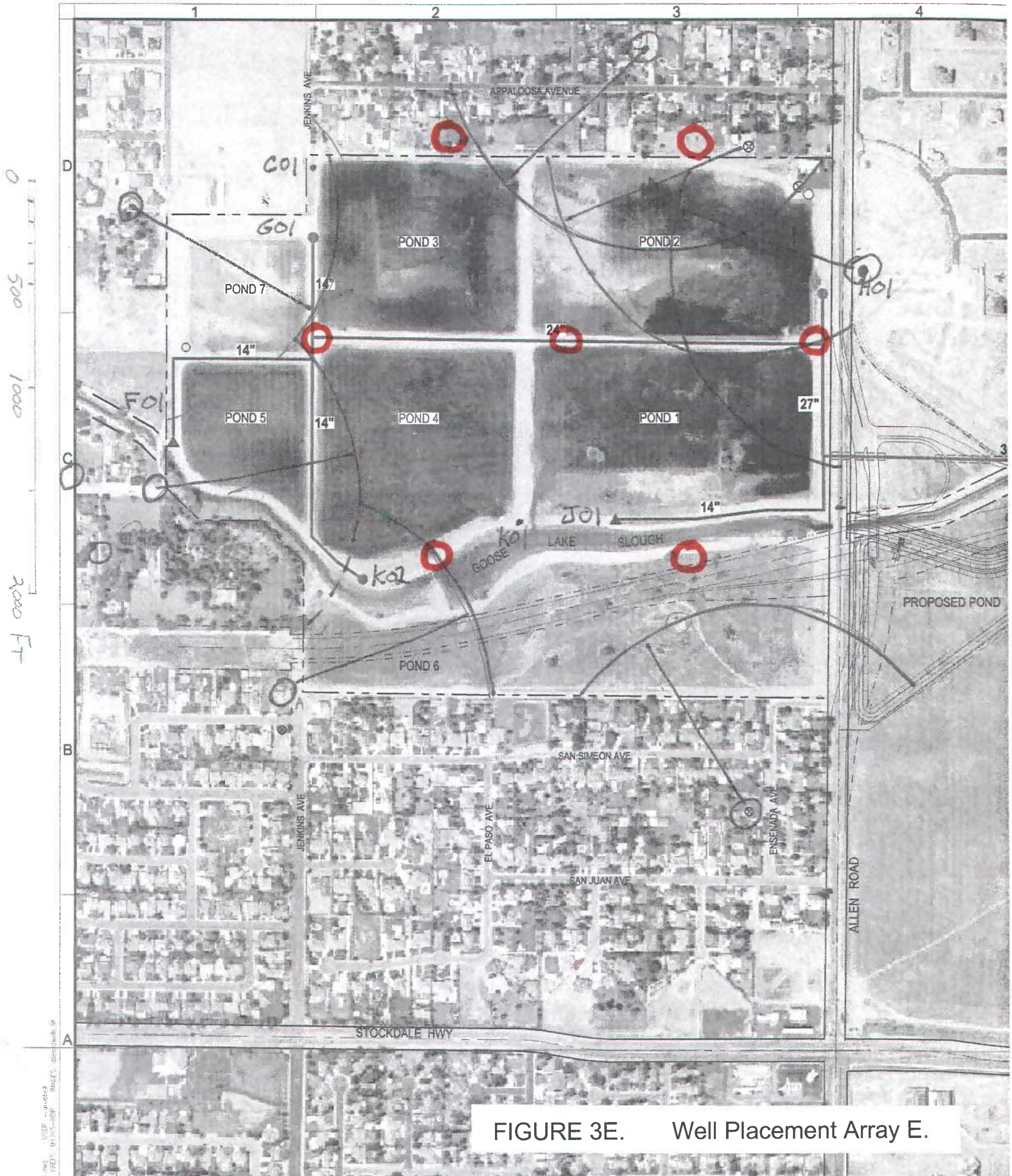

FIGURE 3E. Well Placement Array E.

REV	DATE	DESCRIPTION	APPR

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DATE	MAY 2004
PROJECT ENGINEER	
RCE NUMBER	EXP DATE
PROJECT NUMBER	BK-R01-002-04
CADD STANDARDS	

E

ID4 / KT / RRB Project Operating Scenarios.

	Wells	Rate (af/d)	Duration (yr)	Duration (d/yr)	Recovery (af/yr)	Recovery (% full)
base case (100%)	7	90	1	300	27000	100%
3-yr base case	7	90	3	300	27000	100%
Half base case 1 (t = 1/2)	7	90	1	150	13500	50%
Half base case 3 (Q = 1/2)	7	45	1	300	13500	50%
Half base case 3 (RRB wells)	5	50	1	300	15000	56%
Half base case 4 (ID4 wells)	2	40	1	300	12000	44%
Quarter base case 2 (t = 1/4)	7	90	1	75	6750	25%
Quarter base case 3 (Q = 1/4)	2	22.5	1	300	6750	25%
Quarter base case 1 (1 well each)	2	30	1	300	9000	33%

FIGURE 4. Recovery Well Operating Scenarios.

ID4 / KT / RRB Impact Analysis Parameters.

Property	Sym.	Value	Units
Aquifer Hy. Conductivity (Hor)	K(h)	80	ft/d
Aquifer Hy. Conductivity (Vert)	K(v)	8	ft/d
Aquifer Thickness	H	250	ft
Aquifer Transmissivity	T	20000	ft^2/d
Aquifer Specific Yield	Sy	0.21	v/v
Aquifer Specific Storage	Ss	4.1E-05	ft^-1
Aquifer Storativity	S	0.00056	v/v
Aquifer Porosity	phi	0.3	v/v
Aquitard Hy. Conductivity (Vert)	Kv'	0.08	ft/d
Aquitard Thickness	H'	40	ft
Aquitard Leakance	L'	0.002	d^-1
Hamtush Factor	B	3200	ft
GW gradient 1	G	0.002	@ ra = 270
GW gradient 2	G	0.002	@ ra = 315
GW gradient 2 w/rvr rchg	G	0.001	@ ra = 300
river recharge	qrvr	210	ft^2/d
pond recharge	qpond	1	ft/d

FIGURE 5. Impact Analysis Parameters.

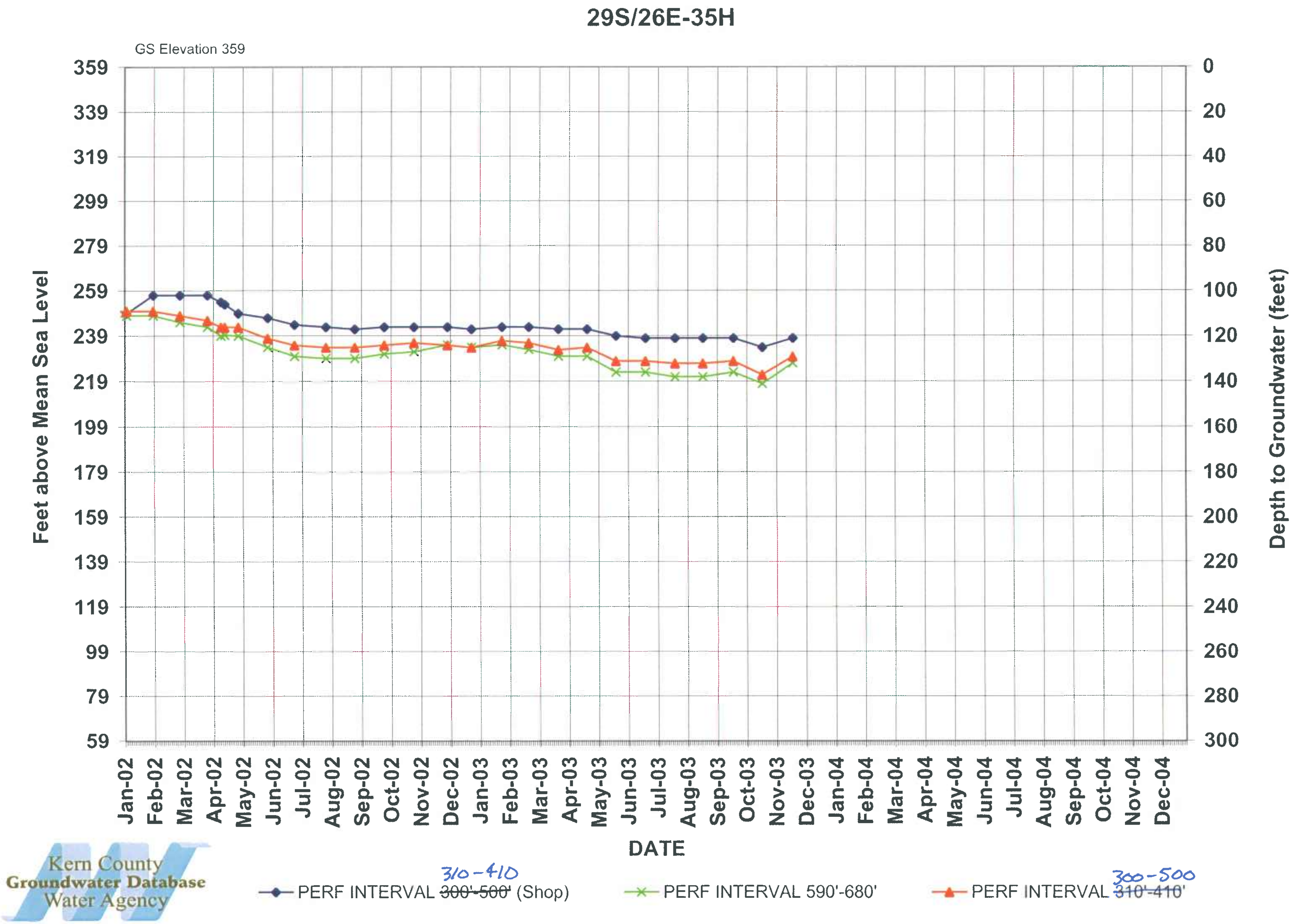


FIGURE 6a. KCWA Hydrograph for cluster well 29/26-35H (RRB short term).

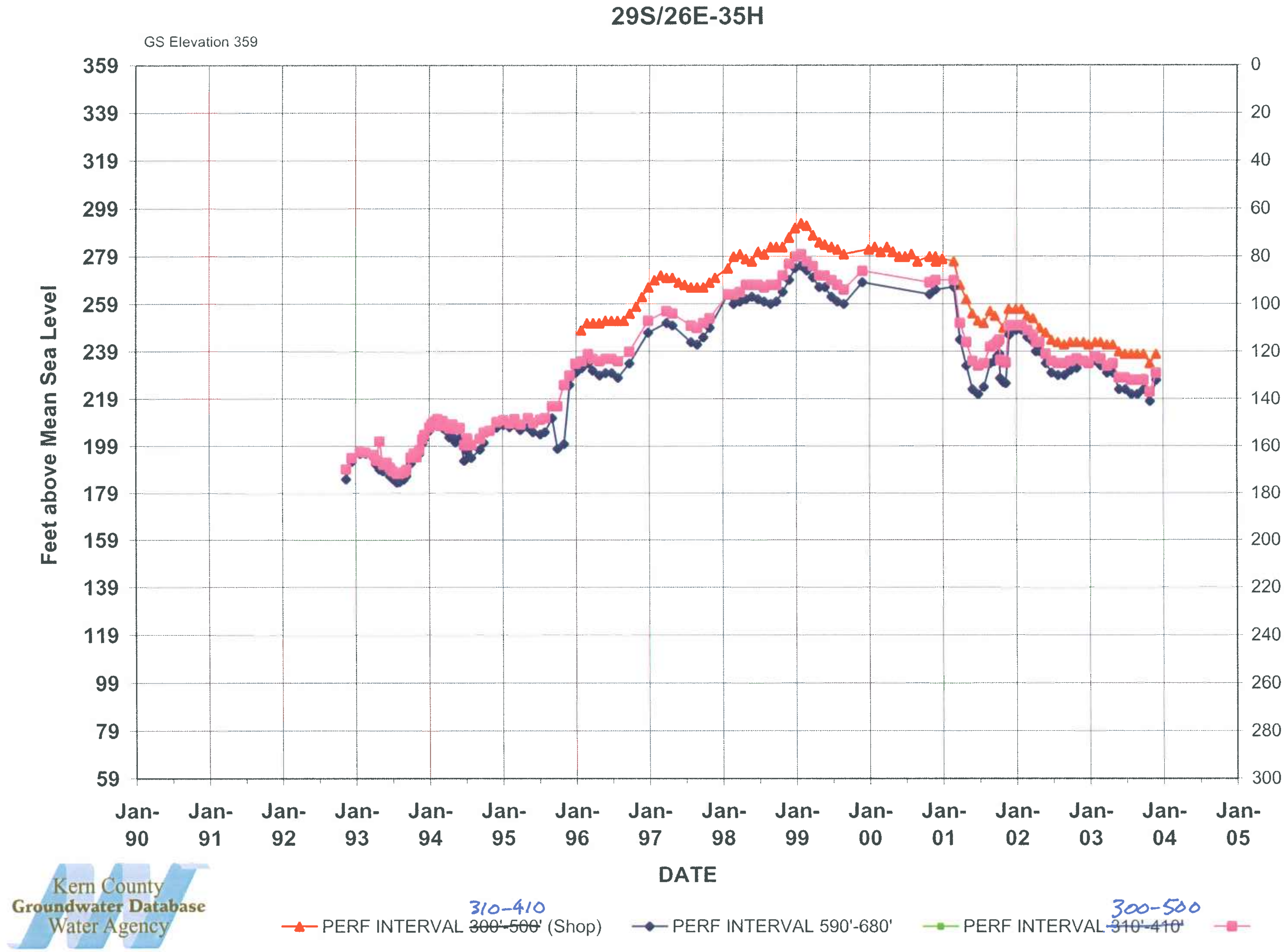


FIGURE 6b. KCWA Hydrograph for cluster well 29/26-35H (RRB long term).

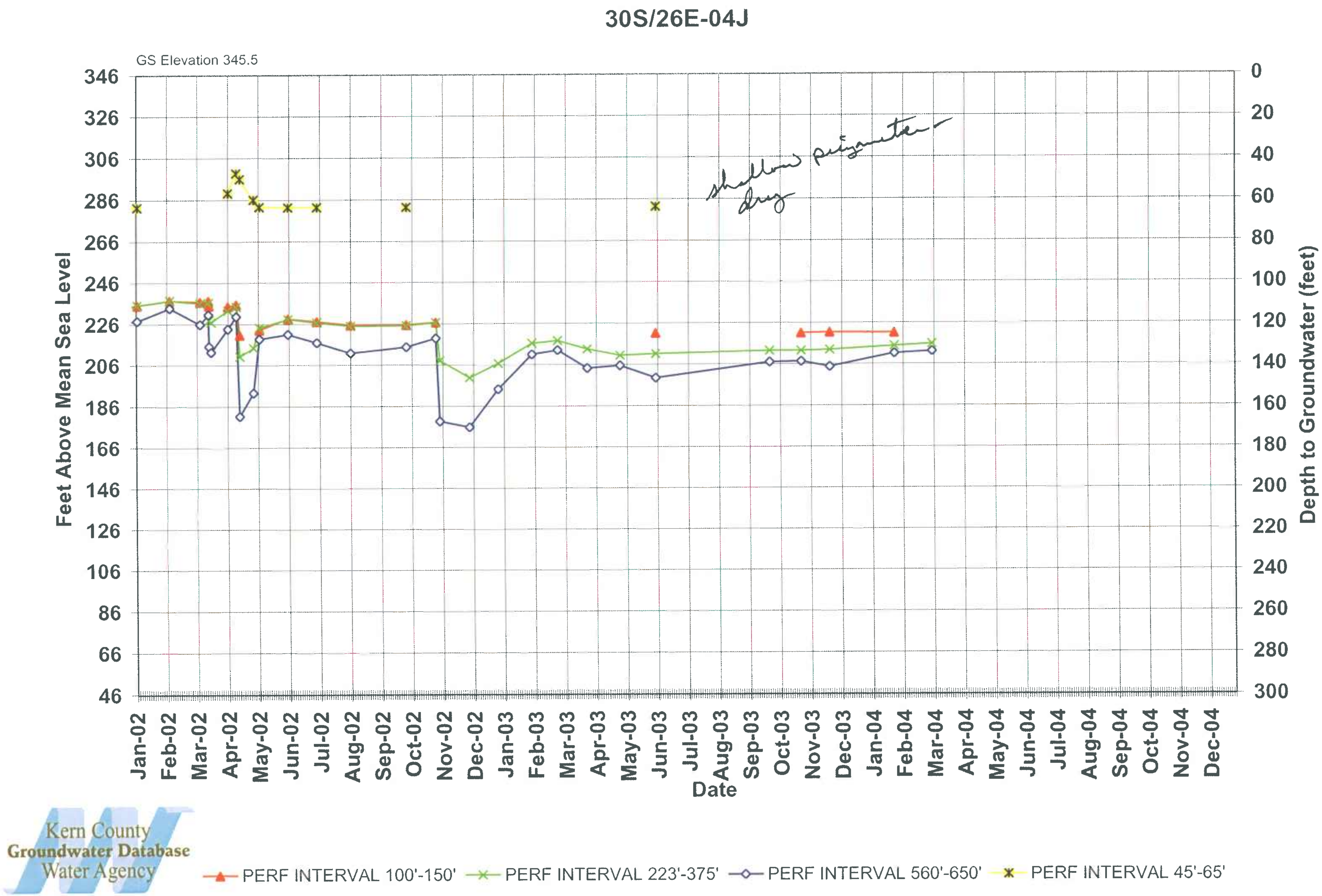


FIGURE 7a. KCWA Hydrograph for cluster well 30/26-04J (Pioneer short term).

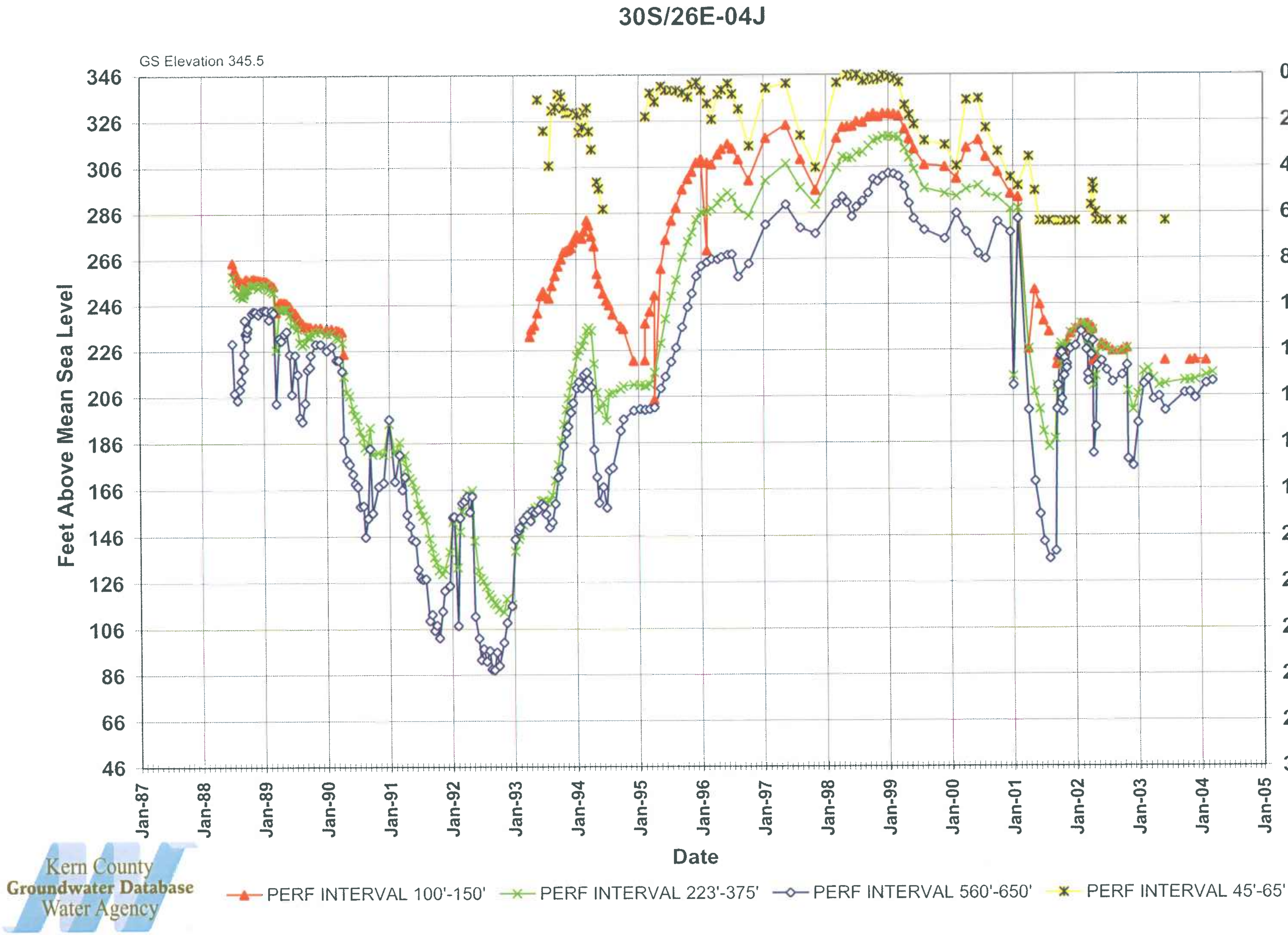
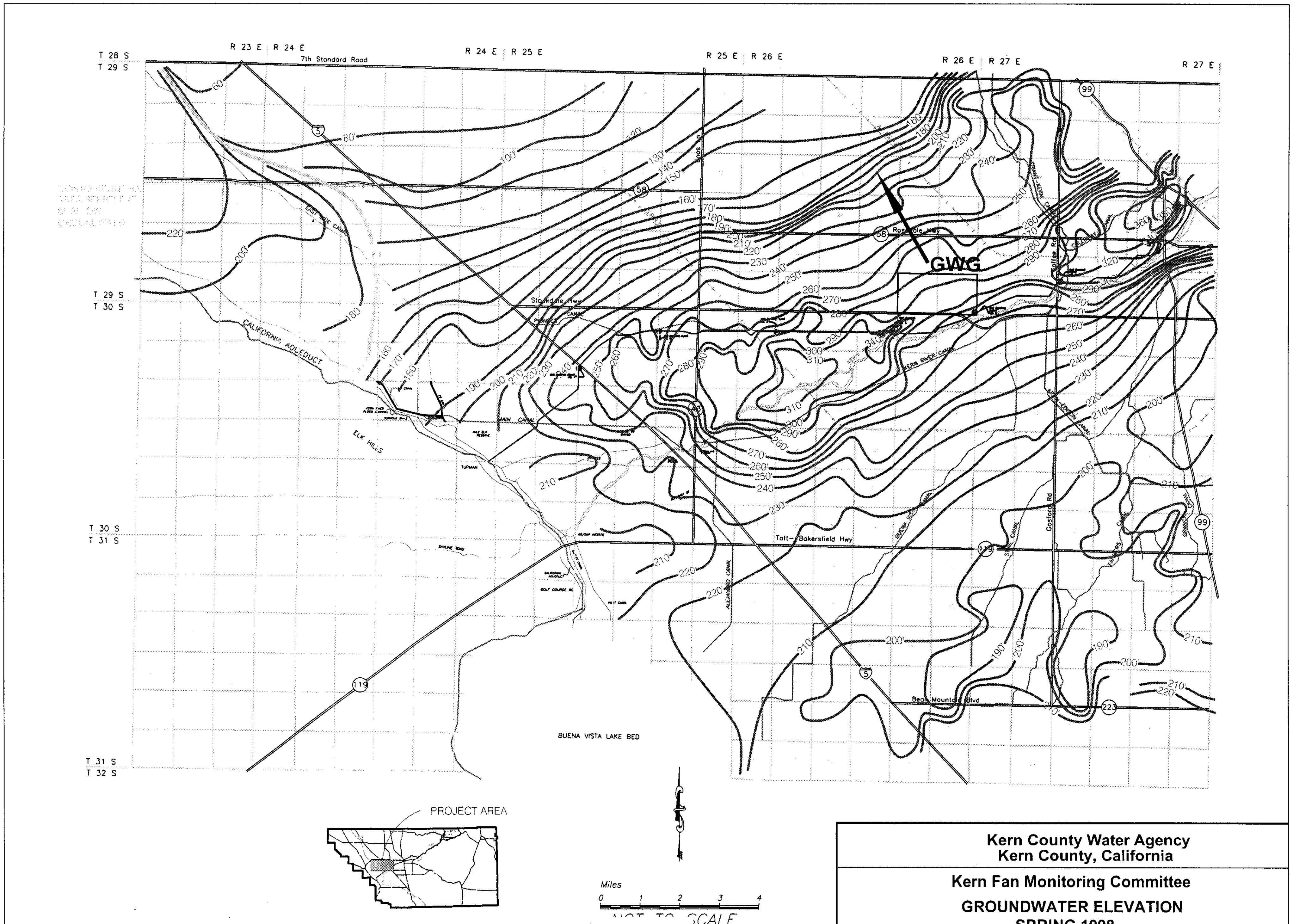


FIGURE 7b. KCWA Hydrograph for cluster well 30/26-04J (Pioneer long term).



Kern County Water Agency
Kern County, California

Kern Fan Monitoring Committee

GROUNDWATER ELEVATION
SPRING 1998

JULY, 1998

FIGURE 8. KCWA 1998 Groundwater Elevation Map (wet- year gradient).

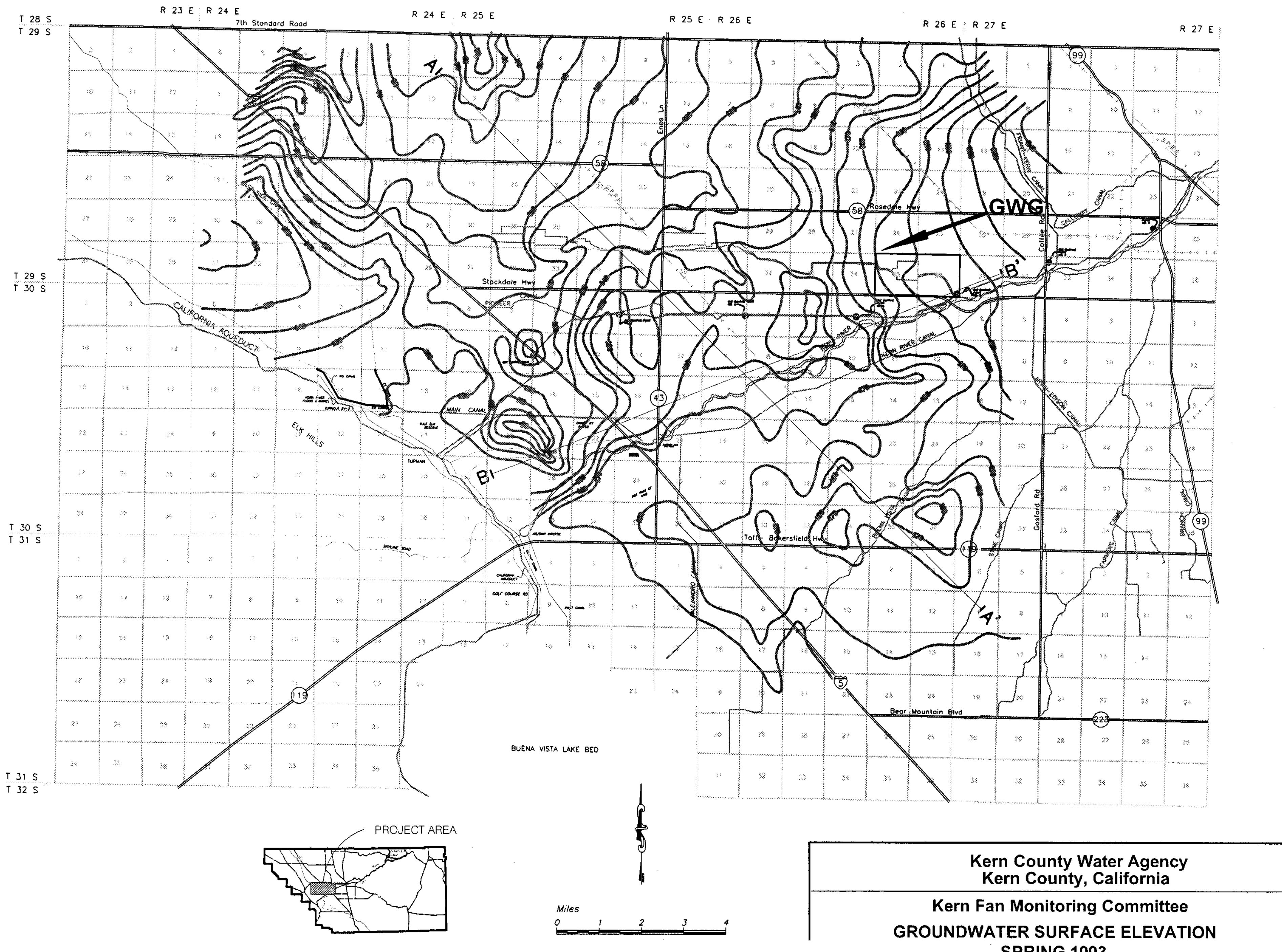


FIGURE 9. KCWA 1993 Groundwater Elevation Map (dry- year gradient).

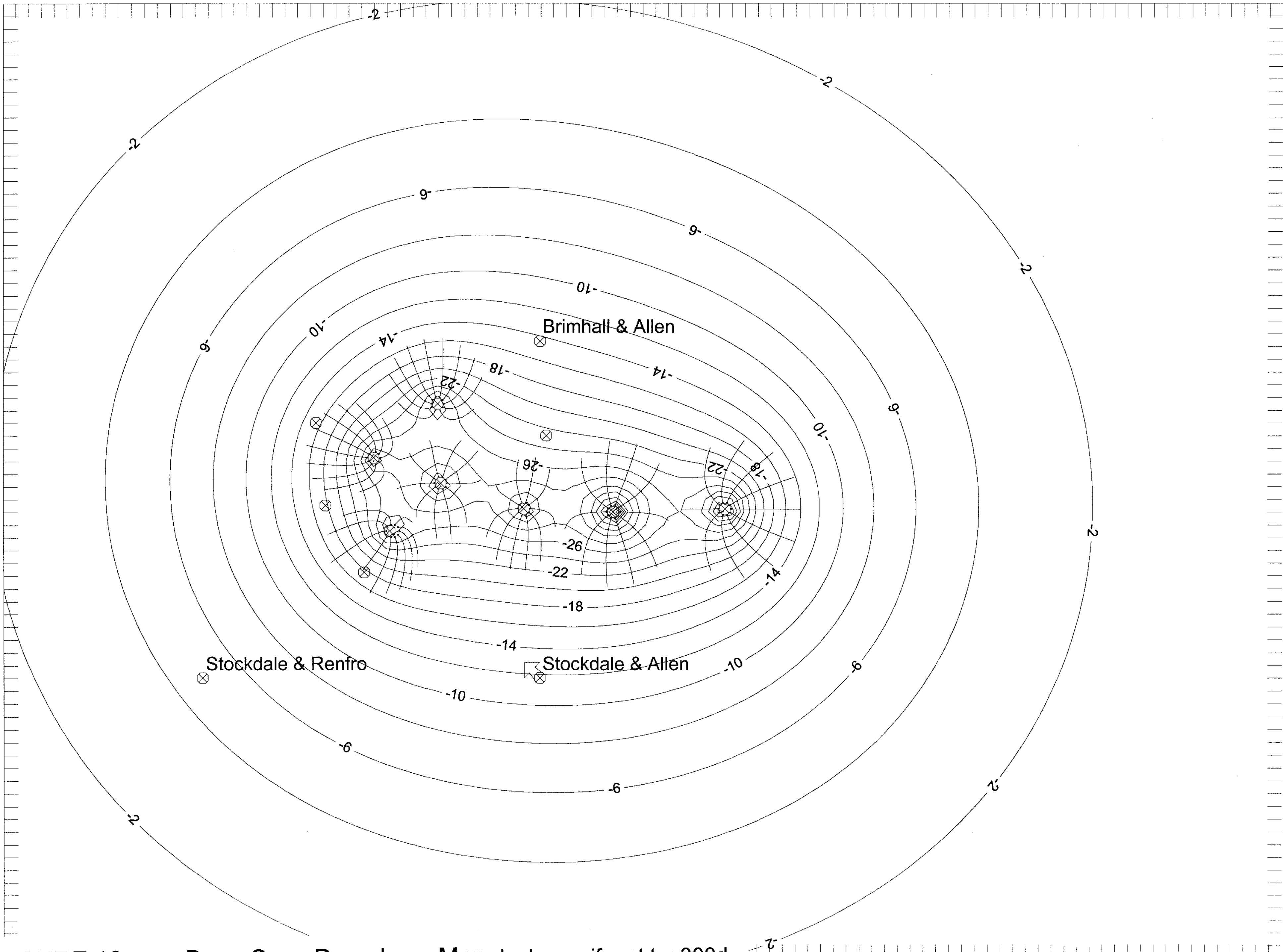


FIGURE 10. Base Case Drawdown Map, leaky aquifer at t = 300d.

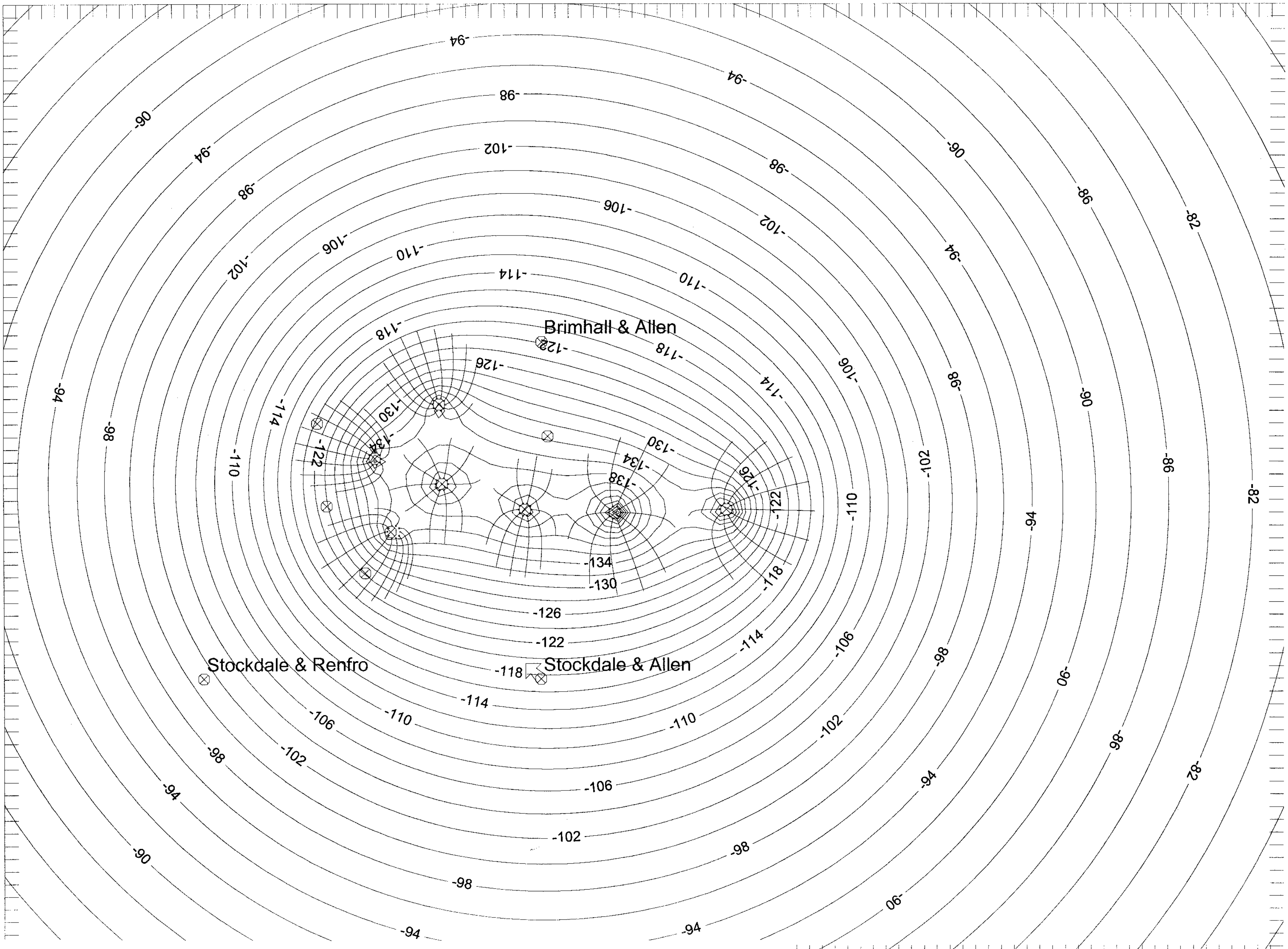


FIGURE 11. Base Case Drawdown Map, confined aquifer at t = 300d.

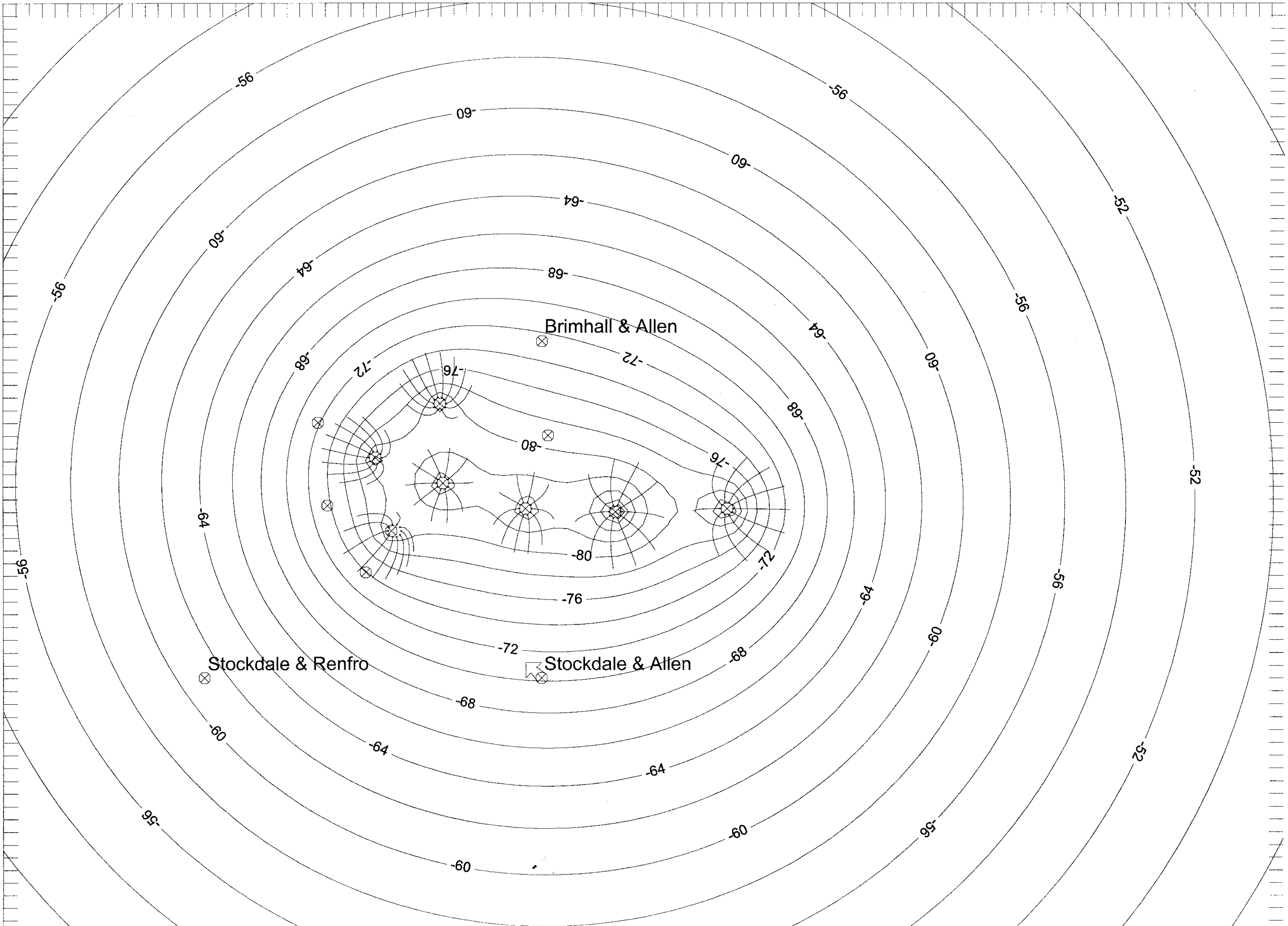


FIGURE 12. Base Case Drawdown Map, unconfined aquifer at t = 300d.

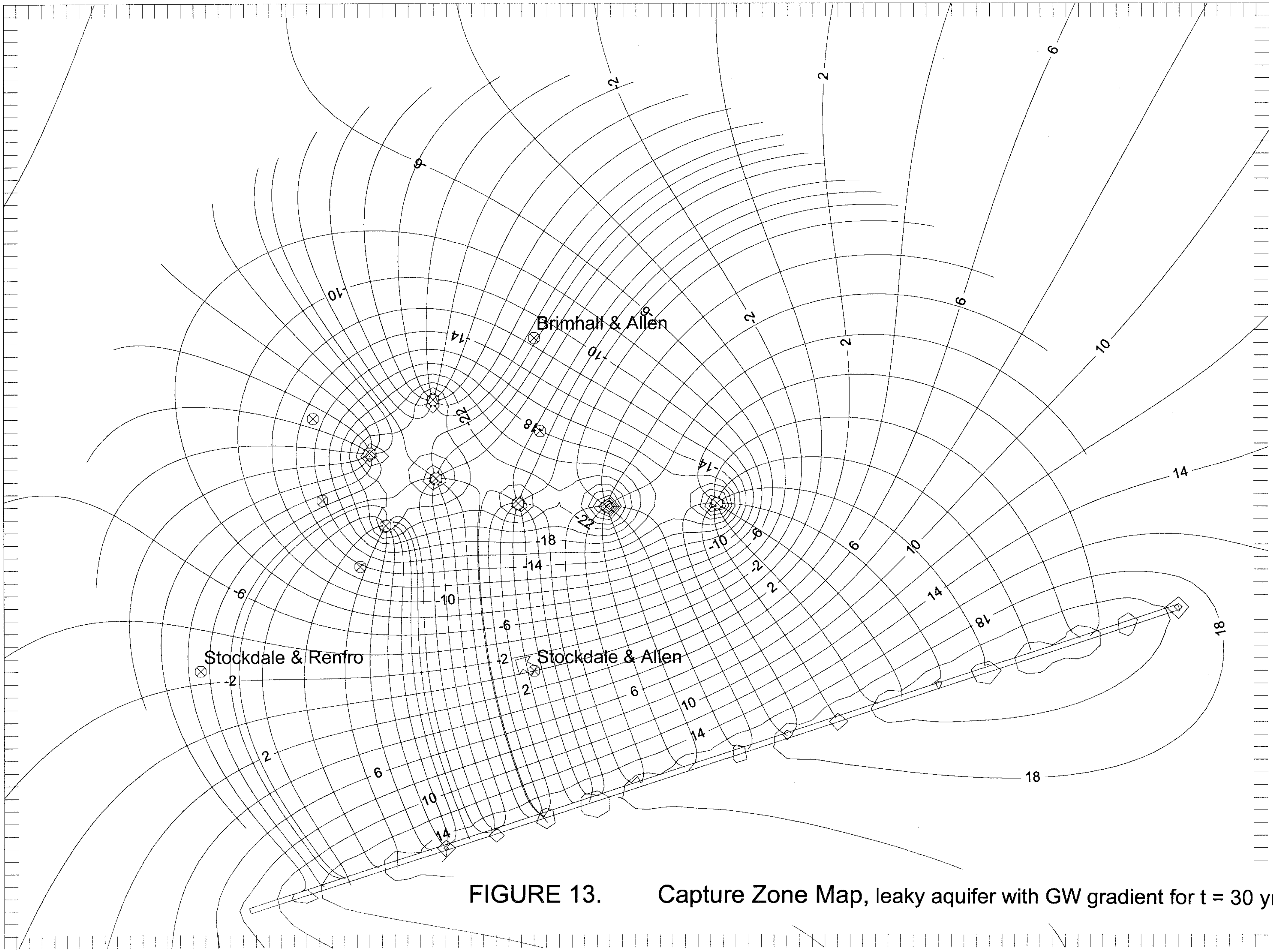


FIGURE 13. Capture Zone Map, leaky aquifer with GW gradient for t = 30 yr.

ID4 / KT / RRB Well Field Predicted Drawdown Summary.					
		pumping	Predicted drawdown at		
		time	1000 ft	3000 ft	5000 ft
Aquifer Model		(d)	(ft)	(ft)	(ft)
300 days pumping					
semi-confined, B = 2600		300 d	12 - 20	4 - 7	1 - 3
semi-confined, B = 3200	*	300 d	16 - 24	6 - 10	3 - 5
semi-confined, B = 6000		300 d	28 - 38	16 - 23	10 - 14
semi-confined, B = 10000		300 d	42 - 52	28 - 36	20 - 26
unconfined, low		300 d	22 - 30	13 - 19	9 - 14
unconfined, high		300 d	71 - 78	62 - 69	56 - 62
confined		300 d	120 - 132	103 - 115	98 - 103
3-years pumping					
semi-confined, B = 3200	*	3 yr	16 - 24	6 - 10	3 - 5
unconfined, high		3 yr	79 - 86	70 - 77	65 - 70
confined		3 yr	134 - 146	118 - 130	105 - 117

* = base case

FIGURE 14. Table of Drawdowns versus Distanc

ID4 / KT / RRB Well Field Predicted Capture Zone Summary.

Aquifer Model	Distance* Downgradient (ft)	Distance* due North (ft)	Distance* due East (ft)	Distance* due South**	Distance* due West (ft)
Pumping Duration (yr).					
1	1100	2300	1600	1500	1300
2	1800	2900	2300	2200	1800
5	2800	4000	3600	4100	2900
10	3700	5000	4800	4000 - 4600	3800
20	4600	6200	6100	4000 - 6200	4600
30	5100	6800	6800	4000 - 6200	5100

* Distance measured from nearest well in well field.
** South-ward limit is at Kern River recharge boundary.

FIGURE 15. Table of Capture Zone Perimeter Distance versus Time.

Appendices

Appendix 1.
Aquifer Geology and Models.

Excerpts from the
KDSA, 2003, Report regarding the
ID4 Kern Parkway Project Impact Analysis,

and

Excerpts from the
DWR 1995 Report regarding the
DWR Kern Fan aquifer model.

GROUNDWATER CONDITIONS AND POTENTIAL IMPACTS OF PUMPING FOR THE ID-4 KERN PARKWAY AND ROSEDALE-RIO BRAVO WSD PROJECTS

prepared for
Improvement District No. 4
Kern County Water Agency
Bakersfield, California

by
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January 2003

SUBSURFACE GEOLOGIC CONDITIONS

The project site is on the upper part of the Kern River fan, where coarse-grained deposits are predominant above a depth of about 700 feet. As part of this evaluation, drillers reports and electric logs were obtained for wells and test holes in the vicinity. Two subsurface geologic cross sections were then developed. Figure 1 shows the locations of the River Parkway and proposed RRBWSD wells, the cross sections, and locations of other selected wells referenced in this report. Cross Section A-A′ extends generally along the Kern River, from near Heath Road on the southwest, through a number of ID-4 and City of Bakersfield wells, to near the Atchison, Topeka, and Santa Fe Railroad tracks on the northeast. Cross Section B-B′ extends from near Palm Avenue north of Brimhall Road on the northwest to the southeast through several KCWA wells, to near Calloway Drive, north of Fraser Road.

Cross Section A-A′ (Figure 2) is oriented parallel to the inferred dip of the alluvial deposits. Coarse-grained deposits extend to a depth of at least about 750 feet along much of the section. Stream channel deposits (coarser than sand) are indicated to be present along most of the section. These deposits generally extend to greater depths as one progresses farther southwest. Fine-grained strata that could act as significant confining beds are of limited extent along the section, except below a depth of about 450 to 500 feet. A fairly continuous confining bed (primarily clay) appears to be present below this depth and above a depth of about 750 feet along most of this section. A localized shallow potential confining bed appears to be present primarily west of Calloway Drive, along this section. The top of this layer is about 150 feet deep. The layer appears to be discontinuous, the deposits are not primarily clay, and the bed is indicated to be much less effective than the deeper more extensive confining bed.

Cross Section B-B′ (Figure 3) generally extends perpendicular to the inferred dip of the alluvial deposits. Coarse-grained deposits are also predominant along this section, and are overwhelmingly present in the area north of the Kern River. Stream channel deposits (coarser than sand) are present along this section only in the areas east of Allen Road, and most of these are near or south of the Kern River. A localized, possibly significant shallow confining bed (primarily clay) is present along this section south of the Kern River. The top of this bed is about 150 feet deep. A more extensive deeper confining bed is present below a depth of about 500 feet along the section. This bed is thicker to the southeast, and thinner to the northwest.

Additional subsurface geologic cross sections have been prepared by Environmental Resources Management (2000) for the area east of the Friant-Kern Canal and south of the Calloway Canal.

These sections extend to a depth of about 250 feet and provide more information in the area of volatile aromatic and MTBE-contaminated groundwater, which is discussed in a subsequent section of this report.

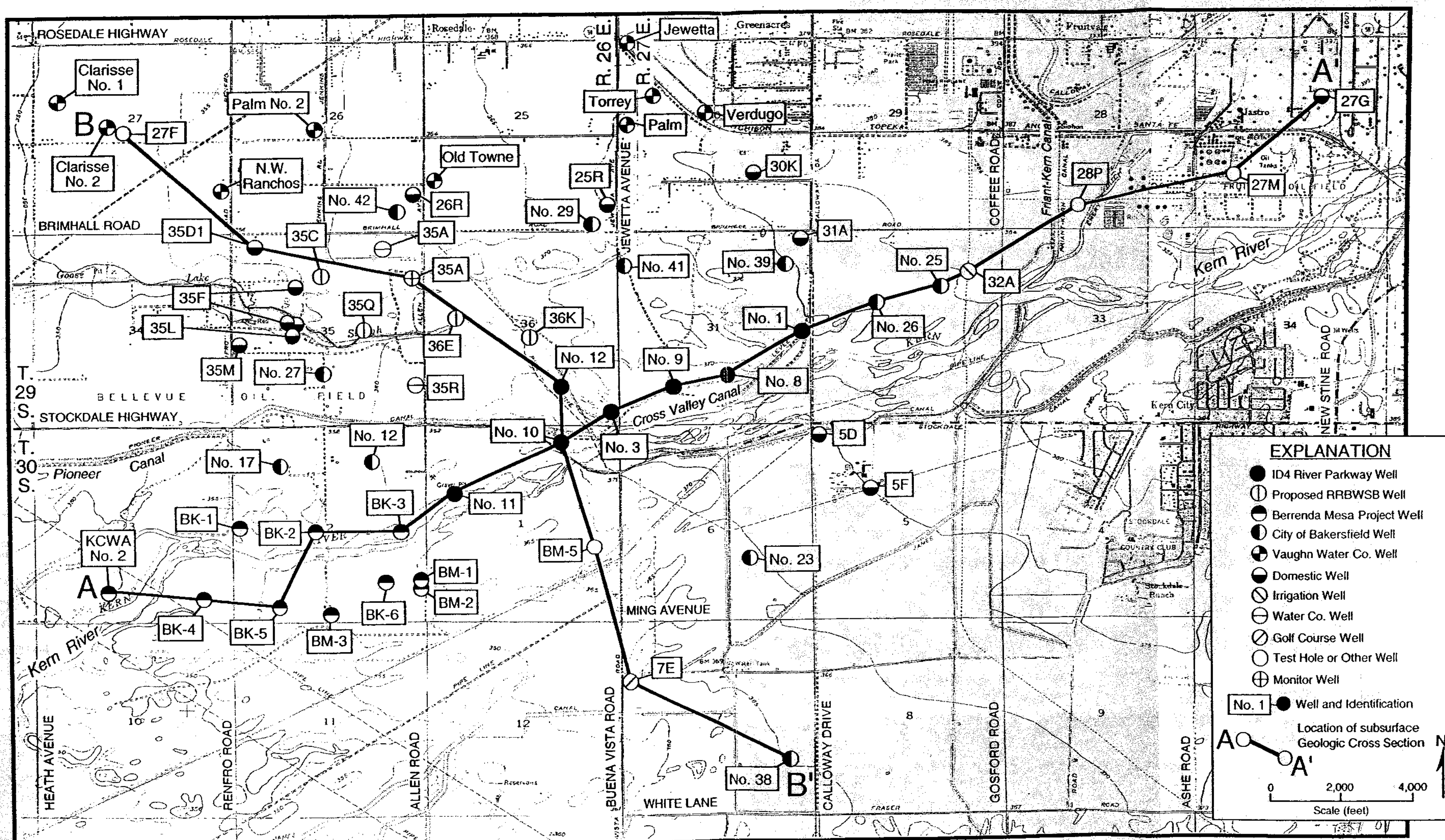

FIGURE 1 - LOCATION OF SELECTED WELLS AND SUBSURFACE GEOLOGIC CROSS SECTIONS

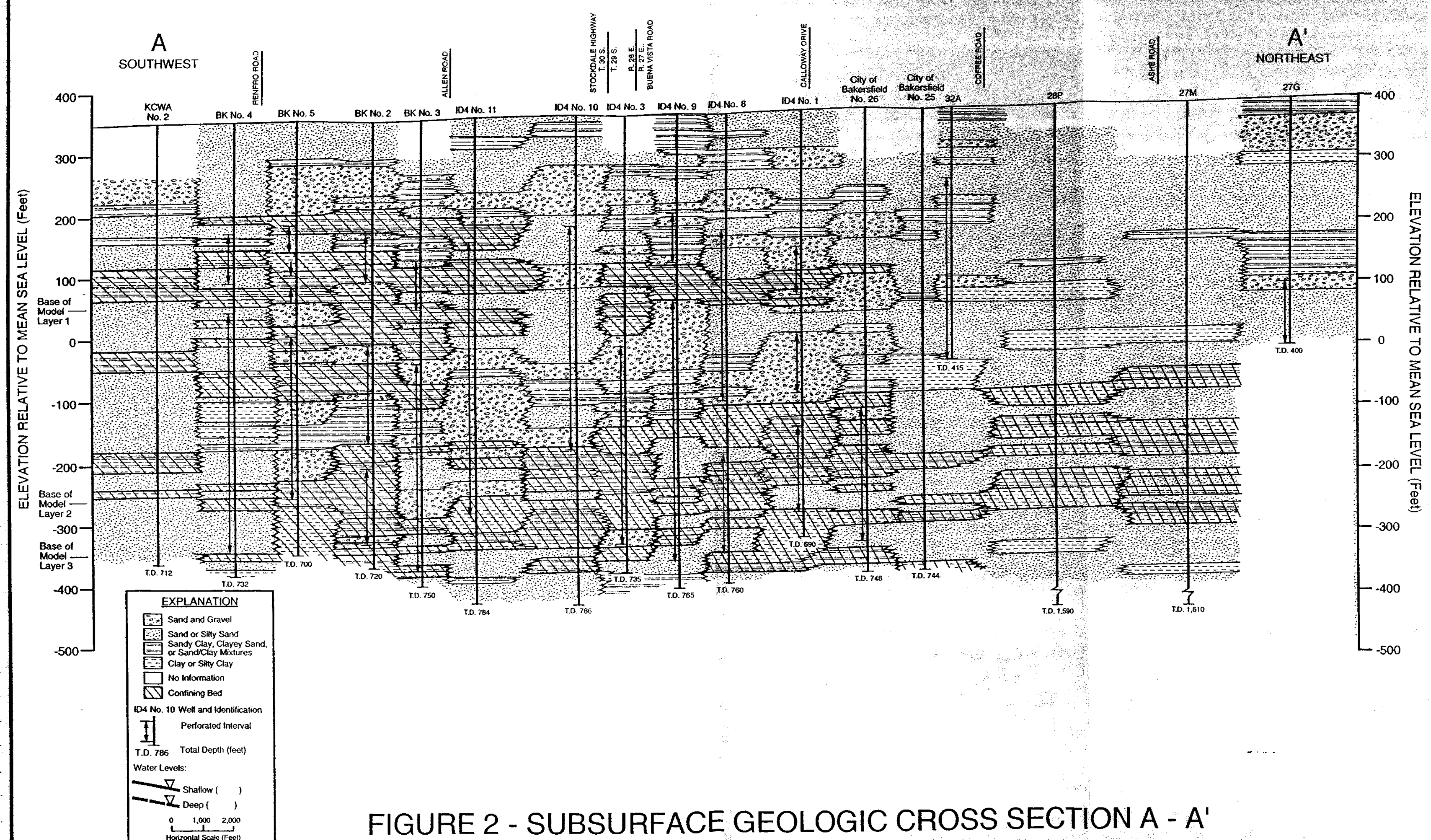

FIGURE 2 - SUBSURFACE GEOLOGIC CROSS SECTION A - A'

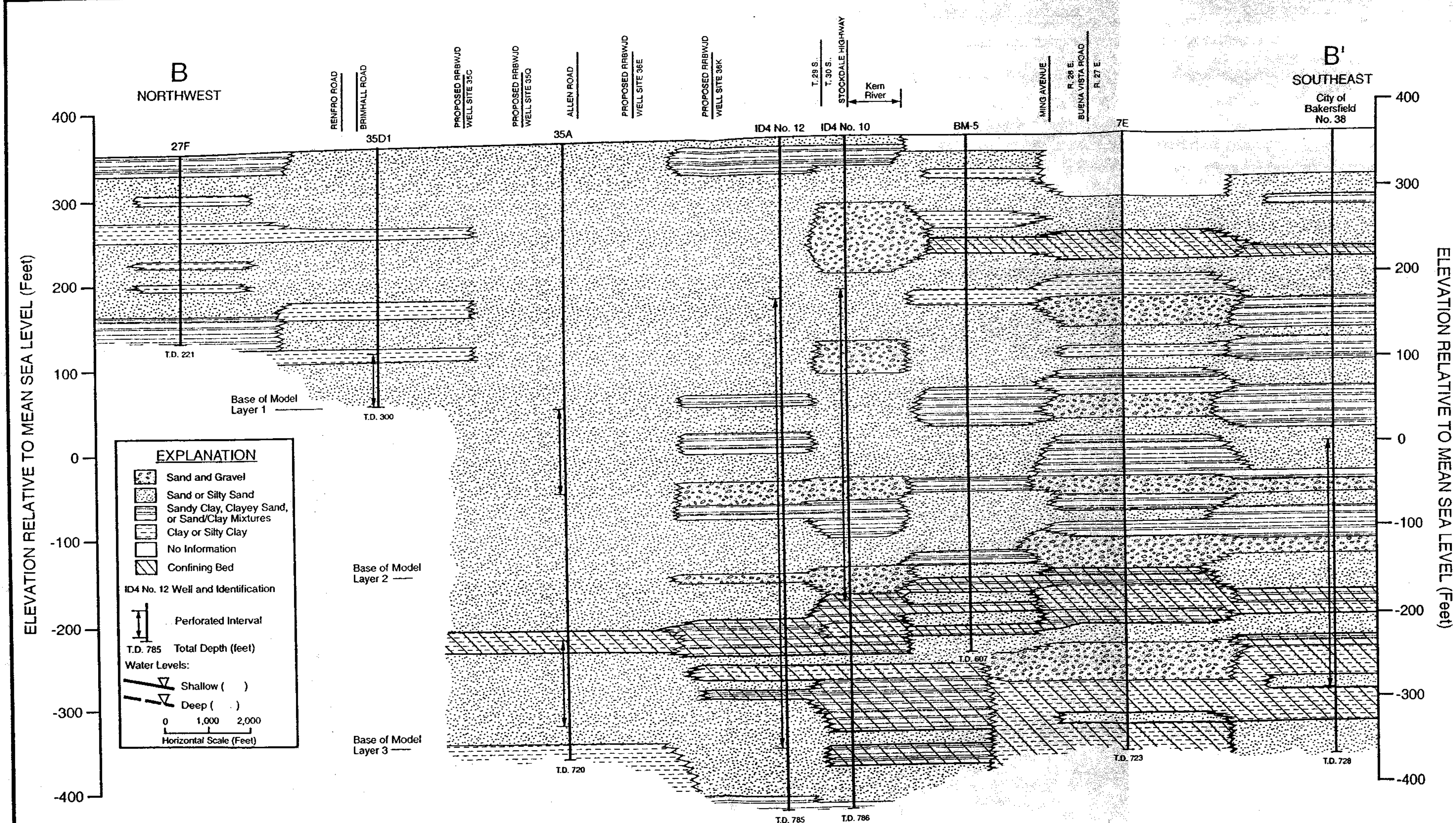

FIGURE 3 - SUBSURFACE GEOLOGIC CROSS SECTION B - B'

AQUIFER CHARACTERISTICS

Aquifer characteristics have previously been determined from the Pioneer and Berrenda Mesa water-banking projects (Kenneth D. Schmidt and Associates, 1998). These, along with the east part of the City of Bakersfield 2,800-acre area, are the closest previously evaluated water banking project areas to the proposed project wells.

The California Department of Water Resources (DWR) divided the alluvial deposits in the Kern Fan area into three layers for groundwater modeling. Layer 1 extends from the land surface to a depth of 300 feet, Layer 2 extends from 300 to 500 feet in depth, and Layer 3 extends from 500 to 700 feet in depth. The DWR provided values of transmissivity for the lower two layers and hydraulic conductivity for the upper layer. However, these values weren't based on aquifer tests and evaluations of some recovery well pumping, nor recharge mound evaluations for the local area following large-scale recharge. Substantial aquifer test data are now available for dozens of water bank project recovery wells, including five of the ID-4 wells. In addition, more information on the upper layer aquifer characteristics is available for 1) aquifer tests when the water level was relatively shallow, and 2) evaluations of water-level rises associated with recharge activities for the water-banking projects.

For the Pioneer and Berrenda Mesa projects, values of aquifer characteristics from the DWR Kern Fan Model for areas close to the proposed project were provided by KDSA (1998, Appendix A). Appendix B of that report contained transmissivity values for Layer 1 and the combined values for all three layers when water levels are shallow. Transmissivity values are normally expected to be higher when water levels are shallower and the saturated thickness of the alluvial deposits is greater. DWR model values were modified to incorporate the results of aquifer tests and mounding evaluations. A significantly higher transmissivity (247,000 gpd per foot) was indicated for the part of the Pioneer area north of the Kern River, compared to the model values. This assumes a starting water level of only 10 feet in depth (the shallow water level condition).

In the Pioneer Project drawdown evaluation, drawdowns were calculated both for a shallow and intermediate starting depth to water. Based on available information, such as specific capacity values for wells covering different time periods, the transmissivity values for the drawdown calculations starting at the intermediate water level (120 feet deep) were reduced only about fifteen percent from those for the shallow water-level conditions (10 feet deep).

Table 4 shows the results of aquifer tests for five ID-4 wells, based on Summer 2001 tests. Pumping rates for these 72-hour constant discharge tests ranged from about 4,500 to 5,055 gpm. Specific capacities ranged from 163 to 232 gpm per foot of drawdown, which are some of the highest observed for such wells in the Kern Fan. The static water levels at the time of these tests averaged about 116 feet deep, or near the "intermediate" level, as previously defined. Transmissivity values for the drawdown measurements were higher than corrected recovery values. Drawdown values for these tests are indicated to be more meaningful, because the duration of measurements was 72 hours, compared to only from

TABLE 4 - RESULTS OF AQUIFER TESTS ON PROJECT SUPPLY WELLS

Well No.	Date	Static Level (ft)	Pumping Rate (gpm)	Pumping Level (ft)	Drawdown (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd per ft)	
							Drawdown	Recovery
8	6/01	116.6	5,055	144.1	27.5	184	381,000	267,000
9	7/01	116.5	4,980	144.6	28.1	177	346,000	-
10	6/01	114.5	5,000	139.1	24.6	203	440,000	377,000
11	5/01	118.1	4,980	148.6	30.5	163	438,000	227,000
12	8/01	116.4	4,500	135.8	19.4	232	440,000	410,000

Drawdown values are for 72 hours of pumping. Recovery values are for only 3 to 6 hours of recovery. The drawdown values are indicated to be more representative.

three to six hours for the recovery measurements. Previous evaluations have indicated that these wells are highly efficient, thus making the use of drawdown measurements more meaningful. Transmissivities ranged from 346,000 to 440,000 gpd per foot, and averaged 409,000 gpd per foot. Although these values are relatively large compared to those elsewhere in the Kern Fan, they are consistent with the high specific capacities for the ID-4 wells. The average transmissivity value for the tested wells was used for drawdown calculations provided later in this report.

The storage coefficient can't be readily determined from the available pump tests, mainly because the tests could not be run for long enough periods in the absence of interference with other wells. Results of short-term tests on wells tapping layered deposits often provide low values for the storage coefficient, which aren't representative of long-term conditions. The average specific yield of Layer 1 is estimated to be about 17 percent, based on the DWR groundwater modeling. Specific yields for Layers 2 and 3 weren't provided in the modeling reports, because it was assumed that groundwater in these layers is confined (ie. specific yields would not be applicable). The measured water-level declines in KCWA recovery wells during the 1991 recovery pumpage provide the best long-term storage coefficients in the area. The best specific yield value that can be used along with the previously developed values for transmissivity to explain the observed water-level declines due to the 1991 recovery pumpage is 0.10. This is thus considered an appropriate value to use to estimate future water-level declines due to recovery pumpage for the proposed projects.

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
San Joaquin District

DEVELOPMENT AND CALIBRATION OF THE KERN FAN GROUND WATER MODEL

by

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<u>Office Report</u>

July 1995

CONCEPTUAL MODEL OF THE KERN FAN GROUND WATER MODEL

The following section describes the physical environment and conceptualized model layout of the study area. Included in this description are discussions of the general geology and movement of ground water in the study area. Additionally, the physical framework and processes which impact the modeled system are discussed.

Physical Setting

Understanding the physical setting is an important first step in model development. Included in the physical setting discussion of KFGWM are the general geology and ground water.

Geology

The KFE is located in the southern San Joaquin Valley, a large northwest-trending, asymmetrical trough. Overlying the crystalline basement of the Valley are more than 15,000 feet of shales, siltstones, and sandstones deposited in a variety of marine environments. The upper 3,000 to 4,000 feet of these sediments were deposited primarily in alluvial fan, lacustrine, or deltaic environments (Wilson, 1993).

The upper several hundred feet of these deposits are dominated by unconsolidated sediments comprising the upper portion of the Kern River Alluvial Fan (Kern Fan) as described by Dale et al. (1966) (Figure 1). The Kern Fan comprises some 800 square miles of surface area and contains the principal water-bearing sediments of the aquifer. Sedimentary deposits in the fan are highly heterogeneous, with a predominance of sand and gravel deposited in channels and finer-grained overbank deposits. Sediments of the Kern Fan are derived from weathered granodiorite of the Sierra Nevada Range which is transported into the southern Valley by the Kern River.

The KFE, the core of the study area encompassed by the KFGWM, is located on the distal portion of the Kern Fan and straddles the Kern River channel (Figures 1 and 2). The distal portion of the fan also contains lower energy deposits, such as clays in the Buena Vista lacustrine basin to the south, and several laterally discontinuous clay/silt layers.

The Elk Hills, located at the western limit of the Kern Fan (Figure 1), are composed of three major doubly-plunging anticlines (Reid, 1990). The consolidated sedimentary rocks of this structure act as a physical barrier to ground water movement to the west of the study area.

Ground Water

Many sources contribute to ground water recharge. Historically, the Kern River has been the primary source of direct recharge to the aquifer. Infiltration of excess irrigation water is also a significant component of recharge. Precipitation is a negligible source of recharge because the region gets fewer than 6 inches of annual rainfall.

While the Elk Hills act as a barrier to ground water flow to the west, there are no significant faults or barriers to lateral movement of water within the study area. One minor permeability barrier exists along the western margin of the KFGWM. This area trends parallel to the Elk Hills and causes elevated heads in a small area on the western KFGWM boundary.

Laterally discontinuous clay/silt bodies in the study area act as aquitards to vertical flow. A network of multiple-completion monitoring wells on the KFE indicates that these aquitards cause semi-confined conditions in the deeper portions of the aquifer, while the upper few hundred feet of the aquifer is predominantly unconfined. This fact is demonstrated in a hydrograph from a typical study area monitoring well (Figure 3). During the summer months, the two deeper zones tend to diverge from the shallow zone and quickly recover during periods of reduced pumping in winter months.

?

Ground water elevation contours from spring 1993 indicate that the principal direction of ground water flow is from east to west along the Kern River channel. Near the western extent of the study area, flow is naturally diverted by the Elk Hills toward the northwest and, to a lesser degree, toward the south. Historical records indicate this flow pattern has been consistent since at least the beginning of this century.

Conceptual Model Layout

Model conceptualization is a key step in the development of the ground water model. Components of the hydrogeologic setting are transformed into the model's physical framework during the conceptualization process; e.g., the physical structure of the Elk Hills is considered as a no-flow boundary to the southwest of the model. A grid is devised to represent the study area. The size of the rows and columns is based upon the required level of detail for the modeling effort. Also considered in the conceptualization process is the assignment of factors (system stresses) that influence the modeled system.

Physical Framework

Although the depositional system is highly heterogeneous, ground water flow in the aquifer is considered to be isotropic (similar in all directions). A pattern of increasing confinement with

?

depth also exists in the model area. To represent increasing confinement, the KFGWM is composed of three discrete model layers: Layer 1 (ground surface to sea level)[1], Layer 2 (sea level to -200 feet), and Layer 3 (-200 to -400 feet). Layer 1 represents the unconfined portion of the aquifer; Layers 2 and 3 represent semi-confined portions (Figure 4). In general, these layers correspond to perforated intervals of the monitoring well network.

The KFGWM grid is presented in Figure 5. The KFGWM grid is composed of 58 columns and 41 rows, and consists of 2,051 active cells per layer (6,153 total cells). The cells range in size from 160 acres in the northwestern, northeastern, and southeastern corners, to 40 acres in the model's core area. The irregular boundary in the southwest area represents the base of the Elk Hills. Since the KFGWM was developed to simulate the effects of ground water banking activities within the KFE, the remaining boundaries were set approximately 3 to 5 miles away from the KFE's perimeter.

System Stresses

Major internal stresses within the KFGWM include pumpage of ground water for agricultural usage and minor municipal and industrial uses, and ground water recharge resulting from intentional recharge or deep percolation of applied water to crops. Calculation of pumpage and recharge for the KFGWM is an important step prior to running the ground water model.

Model boundaries represent a source of external stresses to the model area. Use of a constant head boundary allows water to flow in and out of the modeled area. When ground water levels in perimeter cells are higher than the constant boundary heads, water flows out of the model. When the heads in perimeter cells dip below the constant boundary heads, water flows into the model area.

Each KFGWM cell represents a potential source of pumpage or recharge depending on the activities at or near the location represented by the cell. To simplify the assignment of internal system stresses, cells were grouped into hydrologic zones of similar characteristics of water use and supply. The result is an array in which each active cell is represented by a number corresponding to an identified hydrologic zone (see Appendix A for an example of a pumpage/recharge array). Within each zone, land use data provide individual crop acreages from which water demand is derived.

[1]The KFGWM was originally developed as a four-layer model; however, initial attempts at calibration using MODFLOW's original Block-Centered Flow package resulted in the "drying out" of upper layer cells which rendered them inactive. This problem was eliminated by combining the two uppermost layers into Layer 1.

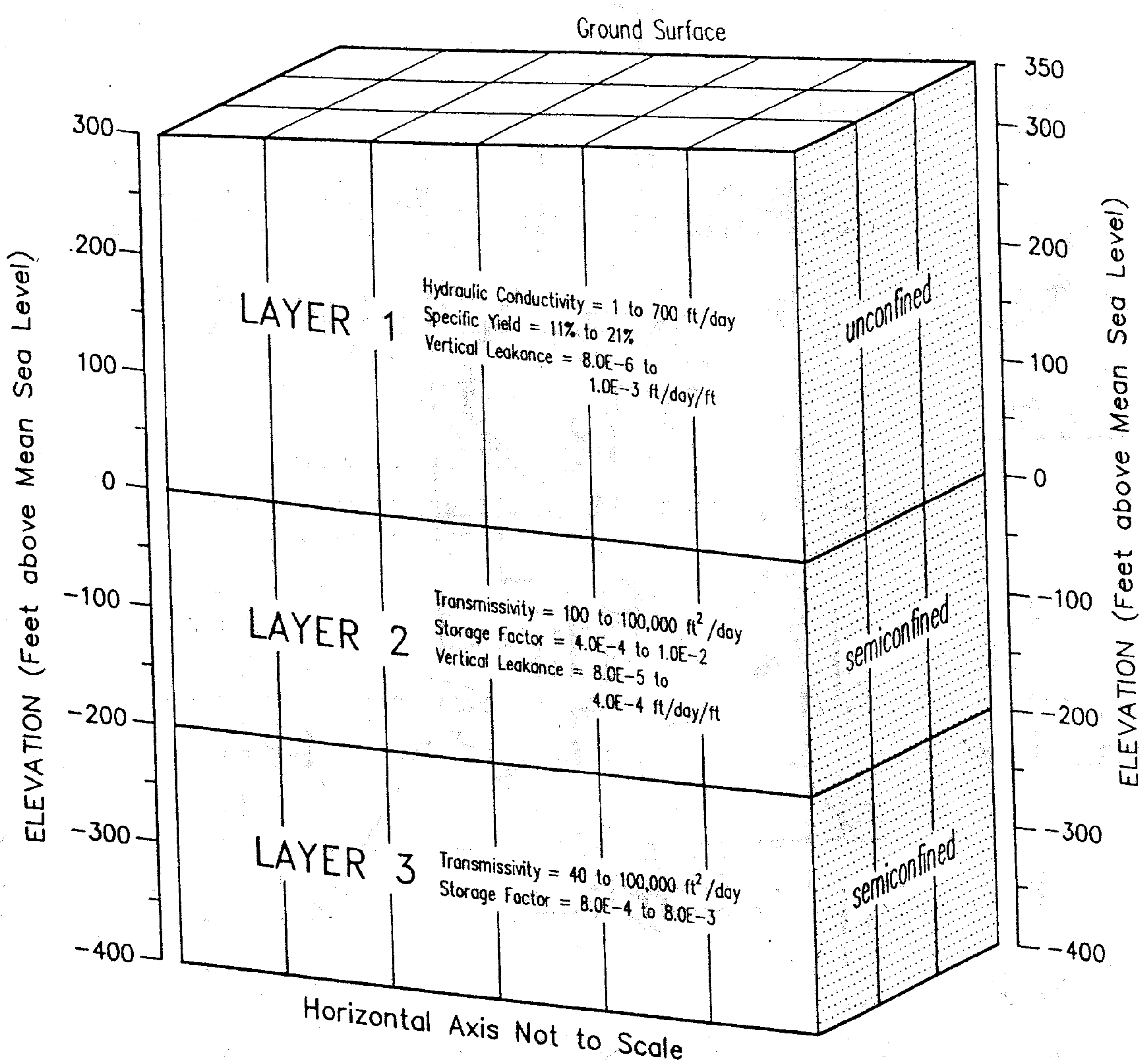

Figure 4. Conceptualized Layers and Ranges of Hydrogeologic Parameters in KFGWM

Referenced from page 16.

DEVELOPMENT OF HYDROGEOLOGICAL PARAMETERS

Over 1,000 lithologic and electric logs from wells and borings drilled within the project area were collected and evaluated for reliability and detail of information. Each log was assigned a category from A through F. The A-log category was assigned to geologist logs with detailed lithologic descriptions. The B-logs are driller logs with detailed descriptions. C-logs are driller logs with some detail, and D-logs are driller logs with little detail. E-logs are electric logs. Every available E-log was used in the analysis. F-logs are driller logs which are too generalized to adequately represent the subsurface environment and were not used in the analysis.

Each evaluated log was plotted spatially on a KFGWM map, then two to three logs per section (1 square mile) were chosen to represent the geology of that section. The decision of which logs to accept was primarily based on obtaining proper well density, followed by the category assigned to each log. Two lists of wells were compiled for further analysis: (1) wells representing shallow depths (ground surface to sea level), and (2) wells representing deep units (sea level to 400 feet below sea level). The logs were then utilized to develop estimates of aquifer hydrogeological parameters.

A guess based on E-log/grain size

But it doesn't mean it's accurate.

Specific Yield

Specific yield (Sy) is a unitless number representing the ratio of the volume of water which gravity drains from a porous material to the total volume of that porous material (Fetter, 1988). Each lithologic interval from the well logs was assigned a value of Sy based on the sediment type in that interval (Table C-1). The basis for use of this method is well documented (DWR, 1961; Johnson, 1967; Walton, 1970). The lithologic interval and corresponding Sy value for each well were entered into a data file (kfespyd.god) for processing by a DWR FORTRAN program SPYD, which computes a weighted average of Sy for 100-foot intervals in each well. Each 100-foot interval was subsequently averaged into intervals (utilizing a spreadsheet) representing the KFGWM layers. The upper layer (Layer 1) utilized an average of the uppermost three 100-foot intervals. KFGWM Layer 2 was represented by the fourth and fifth 100-foot intervals, and KFGWM Layer 3 was represented by the sixth and seventh 100-foot intervals.

Mostly $15 \leq S_y \leq 19\%$ for Kern Fan Area.

TABLE C-1

ASSIGNED Sy VALUES TO
AQUIFER SEDIMENT TYPES

Soil Type	Sy Percent
Clay	3
Sandy clay	6
Clay with streaks of sand	6
Sand with streaks of clay	12
Fine sand	20
Medium sand	27
Coarse sand	30
Medium sand with gravel	20
Coarse sand with clay	12
Gravel	30
Medium to coarse sand	27
Medium sand with streaks of fine sand	17
Coarse sand and gravel	27
Sand (fine to medium)	20
Silty sand	17

Hydraulic Conductivity

Hydraulic conductivity (K) represents the rate at which water moves through a porous medium (expressed in KFGWM as feet/day). Values for K based on soil type were obtained from published correlation charts (Driscoll, 1986). Although a range of values is given for each soil type in the Driscoll chart, a typical K value was selected based on first-hand knowledge of the soils within the southern San Joaquin Valley. These estimated values of K (for various soil types) were then plotted against the calculated values of Sy (Figure C-1). The points on the graph represent corresponding values of Sy and K based on soil type; Line 1 is a visually fit line of these points and was subsequently used to estimate all values for K based on the calculated values of Sy for each well. However, the estimates of K yielded modeled heads below the observed heads within the aquifer

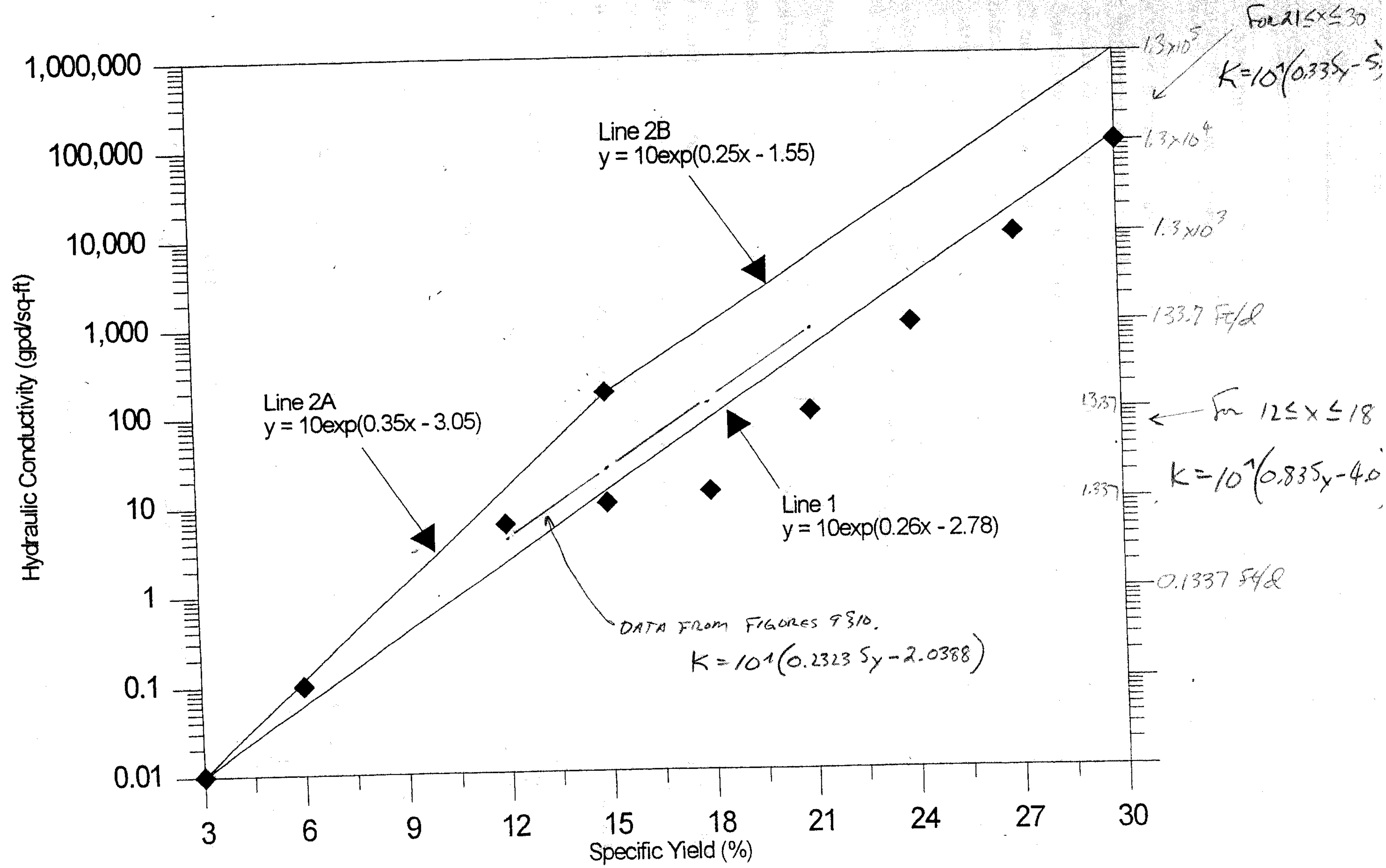

Figure C-1. Graph for Estimating Hydraulic Conductivity from Specific Yield.

during an initial model demonstration run. Values of K were raised in order to compensate for the low head values.

A second linear relationship between Sy and K (Lines 2A and 2B) was developed based on the premise that the maximum value of K used previously was not high enough to represent the coarse sediments within the basin; a higher K value is further supported by the lack of significant, laterally-continuous clay layers within the project area. The "kink" point on the line at which the slope changes is an estimated value of K based on limited pump recovery test data from the City of Bakersfield's 2,800-Acre Recharge Site (Wilson, 1989). Equations to fit this line were calculated and used in model calibration. The result was a good comparison between modeled piezometric surface and observed piezometric surface for the calibration years from 1988-1991.

Storativity

Storativity (S) is a dimensionless coefficient defined as the volume of water stored or expelled per unit area of an aquifer per unit change in head (Fetter, 1988). Values for S were also estimated using a graphical method developed by plotting Sy versus S (Figure C-2); the initial values of S were obtained from published data (Driscoll, 1986) and estimated degree of confinement (Table C-2). Line 1 represents the first estimated set of values for S. However, these values did not fit well into the initial model calibration. The maximum S value was increased for Line 2 because the aquifer appears to be lacking truly confined zones. Line 2 was successfully used to estimate values of S in subsequent model calibration runs. The S value obtained from the graph is for a semi-confined aquifer; values of S for a confined aquifer were estimated by decreasing the value obtained for S from the graph by a factor of 10.

Vertical Hydraulic Conductivity

Vertical hydraulic conductivity (Vcont), as defined in MODFLOW, is vertical K divided by the distance from the center of one layer to the center of the layer below it. This parameter was difficult to estimate using the average Sy values, because a thin clay layer could potentially represent the most restrictive unit to vertical flow; this would not present a significant restriction to flow in the horizontal direction. Values for Vcont were initially estimated as approximately 0.0004 feet/day. This parameter was then modified as necessary during the calibration process.

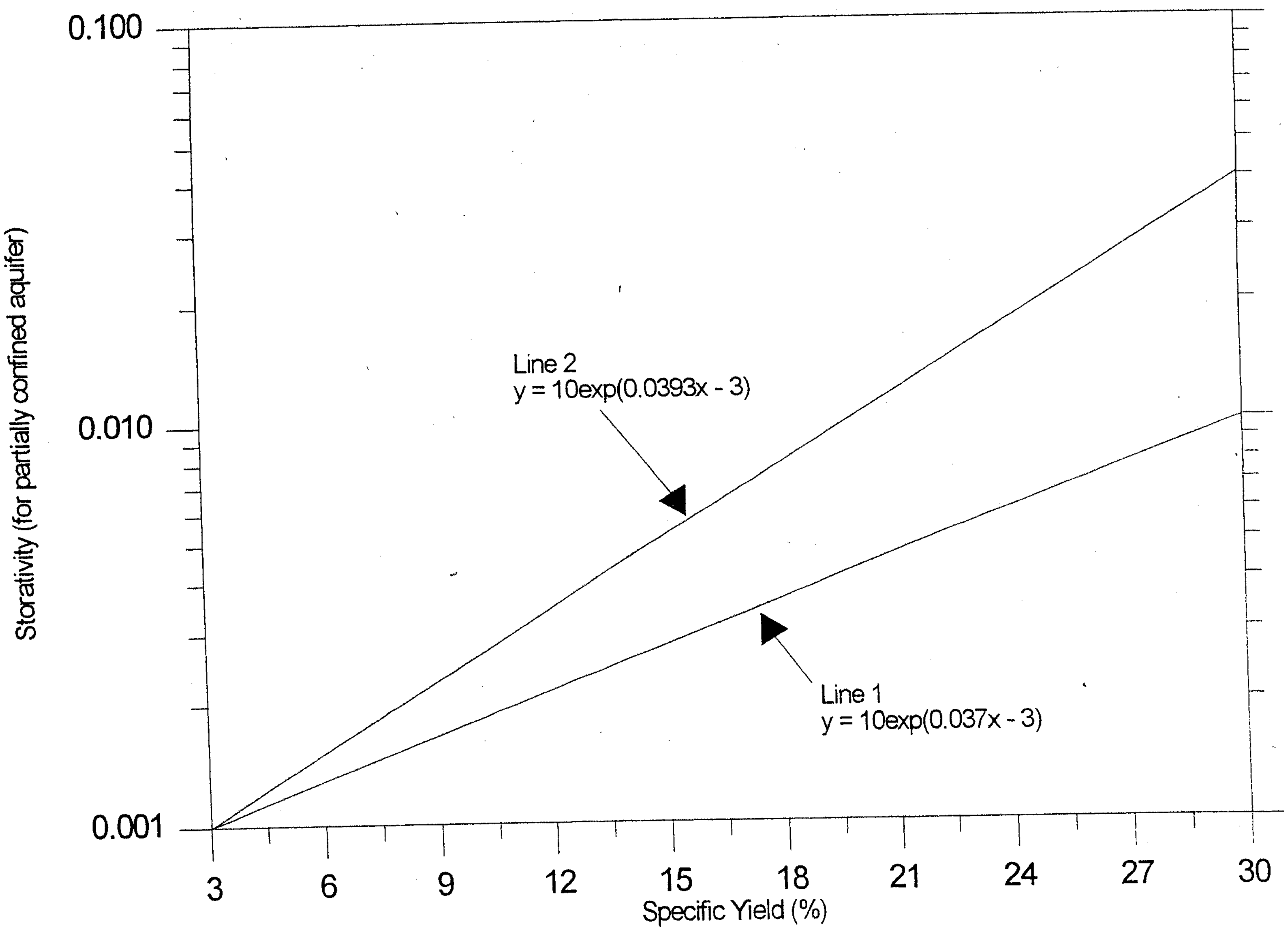

Figure C-2. Graph for Estimating Storativity from Specific Yield.

TABLE C-2

RANGE OF STORATIVITY (S) BASED ON SOIL TYPE AND DEGREE OF CONFINEMENT

Layer	Clay	Sand
1	0.03	0.30
2	0.0001	0.004
3	0.0001	0.004

Appendix 2.

Mathematical Aquifer Models.

Appendix 2.
Mathematical Aquifer Models.

Aquifer behavior. An aquifer is a porous medium consisting of one or more layers of rock or sediment which can store and transmit water in useful quantities. In the simplest terms, ground water aquifers function in two ways: aquifers function as a reservoir to store water and aquifers function as a pathway for ground water flow. All changes in aquifer storage or aquifer flow are caused by either gains or losses of water from the aquifer due to any of several natural or manmade actions.

In the case of aquifer storage, hydrologists evaluate ground water storage with a map of the water level elevation which basically represents how "full" the aquifer is at any particular location and time. If a hydrologist wants to determine the hypothetical impacts of gaining or losing water from the aquifer due to, for example, recharge ponds or pumping wells, then the impacts would be represented by changes in the configuration of the water table as presented in one or more maps or cross sections. All estimates of the change in aquifer storage use the area-weighted vertical changes in this surface to calculate the volumetric change in storage.

In the case of aquifer flow, hydrologists evaluate ground water flow in the aquifer by determining the flow paths (which we call particle trajectories) and flow rates (particle velocities) that describe the movement of water molecules in the aquifer. If a hydrologist wants to determine the hypothetical impacts of changing the aquifer dynamics due to, for example, recharge ponds or pumping wells, then the impacts would be represented by changes in the lengths and directions of the flow paths as presented in one or more maps or cross sections.

Impact analysis. Hydrologists use mathematical aquifer models (sets of equations including sets of conditions and parameters) to calculate the hypothetical water table elevation maps and the ground water flow path maps which are predicted to result from the changes in aquifer dynamics due to recharge ponds, pumping wells, and/or any other natural or manmade action of interest. Let us consider the potential water table drawdown and inward radial flow of ground water due to installing and then pumping a new water well. Let us refer to our evaluation as an impact analysis. Our desired output is a map which shows the hypothetical water table drawdown and ground water flow paths within the capture zone surrounding the new well.

There are many computation methods for predicting drawdown from a pumping well in space and time and every method requires that the user select the equations which are most appropriate for the user's preferred model of the aquifer. In essence, the user must try to select the set of mathematical expressions which best represents the user's physical model of the aquifer. The hydrologist's physical model of the aquifer includes knowledge of the geology and hydrology including the layering, structure, depths, dimensions and physical properties of the aquifer as well as the locations and flow rates of all sources of inflow and outflow to the aquifer such as wells, streams, ponds, etc.

The calculated result, if done correctly, always represents the workings of the mathematical equations but only represents the behavior of the real aquifer to the extent that the parameters, simplifications and assumptions of the mathematical model reflect the true workings of nature. The selection of the mathematical model, the equations, the accuracy of the parameter values, and the representativeness of the calculated output all reflect the experience, expertise, correctness of- and uncertainty in- the judgments of the hydrologist. These judgments cannot be made by the computer and the two main judgments include the choice of mathematical model and the choice of aquifer parameters. There is no such thing as a simple calculation. A good impact analysis rests at least as much on a hydrologist's competence in understanding equations, validity tests, boundary conditions, and model parameterization as it does on the determination of aquifer properties. In our opinion, many hydrologists and engineers who use mathematical models to compute aquifer impacts would benefit from a better background and understanding of the proper use and pitfalls of such models.

Analytical Models. For any scope of work, there are two basic choices of mathematical model. The first choice is to select a "canned" analytical model which best approximates the interpreted aquifer conditions and then supply the user's best estimates of the required aquifer parameter values. The great advantage to this alternative is that the models are fast, convergent, easy to customize and operate, and the models result in a *unique* set of solutions because the degrees of freedom in the model are the same as the number of available parameters. The disadvantage is that the mathematical model may not represent all of the known or suspected complexities of the real aquifer and the user must evaluate the relevance and magnitude of the possible errors in the results due to the simplifications in the mathematical model. The analytical models which are frequently used today include the familiar equations attributed to Theis, Cooper - Jacob, Hantush, Hantush - Jacob, Neuman, Strack, etc., for all of the useful recharge and recovery interactions (wells, ponds, rivers, surface recharge, etc) for transient and steady- state conditions in unconfined, confined, and leaky aquifers. SSS selected this option for the ID4 project scope of work.

Numerical Models. The second choice, which SSS did not choose, is to design and program a numerical computer model which best approximates the interpreted aquifer conditions in all its 3-D detail and then supply the user's best estimates of the required aquifer parameter values. The only advantage to this alternative is that the model may be designed to any degree of complexity in order to approximate the true aquifer structure. The disadvantages are numerous and punishing. The models are tedious and difficult to build; the models require an impossibly vast knowledge of the aquifer properties because the user must define the value of every aquifer parameter at every depth at every location; the hundreds or thousands of degrees of freedom always outnumbers the amount of real data which causes non-uniqueness[1] and equivalence[2] in the model outputs; and there is a significant likelihood that numerical complexity does nothing to improve the quality or accuracy of the output of the calculation while giving a false sense of precision in the effort. One of the most popular numerical models is actually a number of programs which are all referred to by the name *Modflow* (a trademark of the United States Geological Survey), which are based on a publicly- available computer code developed by the U.S.G.S. and commercialized in several proprietary forms by different scientific software companies. Sierra Scientific Services owns a complete set of Modflow simulators for groundwater flow, contaminant transport modeling, and parameter estimation but SSS favored the analytic model to be better suited to the ID4 project scope of work.

[1]Uniqueness is a property of a model solution which refers to the condition that a given set of inputs can result in only a single, fully determined output. Non-uniqueness may refer to a condition in which a given set of inputs may result in more than one fully- determined possible output.

[2] Equivalence is a property of a model solution which refers to the condition that two or more different set of inputs can result in exactly the same, fully determined output.

Appendix 3.

Aquifer Parameters and Parameter Values.

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Aquifer Parameters and Parameter Values.

The aquifer parameters of interest for mathematical modeling include those *intrinsic* physical properties of the porous media which determine the volume- specific storage and unit flow properties of the aquifer. These intrinsic properties are then combined with the physical dimensions (depths, thicknesses, and gradients) of the aquifer media to determine the full-aquifer behavior. The storage properties include the specific storage (S_s)and specific yield (S_y) of each of the porous media. The required flow properties include the hydraulic conductivity (K), porosity (ϕ), and dispersivity (α) of each of the porous media. The hydraulic conductivity is required for volumetric flux and flow rate in directions of interest (K_h for horizontal flow and K_v for vertical flow), the porosity is required for particle tracking, and dispersivity (both longitudinal α_L and transverse α_T) is required for contaminant transport.

These properties are normally determined either by physical properties measurements on actual rock or sediment samples or by special types of pumping tests on water wells which have been completed across the thickness of the aquifer. Some of these properties vary by several orders of magnitude for common aquifer rock- and sediment- types, so for aquifer materials which have not been measured or tested, there is little likelihood that a best- guess "textbook" value which is based on rock type or another index property will be very close to the actual value. We recommend that the careful determination of the relevant physical properties be an essential and early part of any groundwater program.

It is important to emphasize that the values of these physical properties are all constants for each of the respective aquifer media and that they do not vary with changes in either the water table, or in the pump rate or completion interval of a well, or with any other observed variable, apart from the natural variability of the property within the porous medium itself. It is good practice to measure these properties as many times as possible to determine the average value and range of natural variability for each. And since hydrologists recognize that the natural variability of these parameters may be large, it is best to obtain measured values which are representative of the aquifer under the entire area of interest for which impact analyses are desired, and measured in ways which minimize the unassociated variance in the determination. It is also important to emphasize that few of these properties can be determined directly from well tests and must instead be derived indirectly from well test data by also using other information. The ability to do this is governed by cost, access to wells, and the expertise of the hydrologist to perform the right test and to make the necessary corrections for factors and interferences which otherwise cause errors in the values.

Storage properties.

Water is stored in an aquifer by occupying the intergranular void spaces of the porous aquifer material. The physical amount of water which can be stored in and recovered from a porous medium is the sum of two components; the fillable void space remaining in a rock or sediment which is at residual saturation, and a very much smaller component which is a result of the minute elastic dilation of this void space when the water in the aquifer is under pressure combined with the slight compression of the water itself.

When water is released or recovered from an aquifer, the first water recovered is always that which is released due to the elastic rebound of the pore space and the water. The last water recovered is always that which drains from the pore space and dewaters the aquifer. When water is stored in the aquifer, the reverse actions occur, i.e., water first fills the void spaces and then dilates the void space as the pressure increases.

<u>Specific yield.</u> The first component is termed the *specific yield* (S_y) and is the amount of water produced by "de-watering" the aquifer void space as the water table falls within the aquifer. This term effectively determines the amount of water which is gained or lost under the district or some specific area due to the rising or falling water table. The values for well sorted sandy sediments[3], such as in the area of interest may range from $0.10 \leq S_y \leq 0.35$. The formula for calculating the volume of water released by dewatering is $V_w = A \cdot S_y \cdot \Delta h$ for a drop in water table of Δh. The aquifer thickness is not a term in this calculation.

<u>Specific storage and Storativity.</u> The second component is termed the *specific storage* (S_s) and is the much smaller amount of water produced by contraction of the dilated pore space and expansion of the water as the pressure drops within the aquifer. The values for loose- to well-packed silty or sandy sediments[4], such as in the area of interest may range from $0.00017 \leq S_s \leq$

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[3]Fetter, C. W., 1994, Applied Hydrogeology, 3rd ed., Prentice - Hall, Inc., Table 4.4, p.91.

[4]Domenico, P.A. and Schwatrz, F.W., 1990, Physical and Chemical Hydrogeology, John Wiley, Inc, Table 4.1, p.111.

0.0032 ft^{-1}. This property is related to the in situ bulk compressibility of the aquifer media and the water itself. The compressibility of water is known and we can measure the compressibility of sediment samples, as SSS has done for RRBWSD on another project.

The formula for calculating the volume of water released from the aquifer by depressuring is $V_w = A \cdot H \cdot S_s \cdot \Delta h$ for a drop in head of Δh in an aquifer of thickness H. The product of aquifer thickness and specific storage in this equation is defined as *storativity*, $S = H \cdot S_s$, and it is obvious that if the thickness of an aquifer changes, then the value of S will change, even though the intrinsic property of the porous medium, i.e., the specific storage, remains constant. It should also be noted that if only a portion of the full thickness of an aquifer is relevant to a particular problem, then the appropriate value of S to be used in any calculation is the value for the interval of interest.

The specific storage term is also an essential term in the flow equations which describe transient, i.e. non steady- state, aquifer flow. The ratio of hydraulic conductivity to specific storage is defined as the hydraulic diffusivity and this ratio explicitly occurs in all non steady-state equations of flow. Therefore, while it is tempting to dismiss the need for an accurate value of S_s because it is negligible for the calculation of aquifer storage, it is important to obtain as good a value as is possible because it occurs directly in the flow equations along with conductivity. For example, the 20-fold difference between low and high values of S_s will make only a negligible difference in the calculated storage capacity of the aquifer, but will significantly alter the calculated results of the flow equations.

Available storage capacity (SC). The available storage capacity, which is not relevant to this particular scope of work, is defined as the volume of water that could be stored in the unsaturated zone above the water table within the boundaries of the District up to within a few feet of the ground surface. This working definition is usually used to calculate a change in aquifer storage due to a rise or fall of the water table over some time period, and is not an important or even relevant part of many types of aquifer modeling. In practice, the specific storage (S_s) is negligible compared to the specific yield (S_y) ($0.0005 < S_s/S_y < 0.00005$) so, unless an aquifer is very thick, we do not consider the specific storage in the calculation of storage capacity and just use the specific yield formula.

Layered- aquifer storage properties. For aquifers which are either heterogeneous or layered, we must determine the storage properties of each type of sediment within the aquifer and the proportions of each, and perhaps even the sequence in which they are successively filled and/or dewatered. For a layered aquifer, the volumetric storage capacity under an area (A) is defined as being equal to the volumetric integral: $SC = \int^A \int \phi(1- S_r)dAdh$, which simplifies to a summation which looks like: $SC = A\Sigma(h_i \cdot Sy_i)$, that is, the total District area times the sum of products of the individual layer thicknesses and specific yields which, finally, is often more-conventionally written as: $SC = A \cdot H \cdot Sy_{eq}$, the product of total District area times total aquifer thickness times the "average" or equivalent specific yield. We must always remember that the correct values for determining an actual change in storage must be those values of $h_i \cdot Sy_i$ which represent the actual interval being filled or dewatered, and not the "full-aquifer" average value. Any modeling effort which simplifies the aquifer stratigraphy by reducing the number of layers must address the issue of determining the equivalent parameters of each layer model relative to the actual parameters of the actual stratigraphy.

The same additive property is true of storativity (S) for a sequence of layers in an aquifer. The value of storativity is a summation which looks like: $S = \Sigma(h_i \cdot Ss_i) = \Sigma(S_i)$, that is, the storativity of any depth interval is the sum of the individual- layer storativities for all layers within the interval. This additive property is important to consider when interpreting well tests which are not completed across the full layered- aquifer thickness.

Flow properties.

Water flows down-gradient in an aquifer from higher to lower potential. Groundwater flow may be horizontal or vertical or have components of both. The externally applied forces which cause water to move come primarily from gravity and secondarily from manmade actions. In other words, left to itself, the groundwater in aquifers and in basins "seeks its own level" and always prefers the path of least resistance. Water will stop moving when there is no change in potential along the pathway, otherwise water is moving in one of two type of conditions, either steady- state flow or transient flow. In steady state flow, water passing any location continues to flow in the same direction at the same flow rate and at the same head without any change over time. In transient flow, water passing any location will not be steady in direction, flow rate, or head because of dis-equilibrium somewhere in the system. Transient flow is non-Darcy flow and this is the condition of the aquifer in the project area most of the time.

The persistent re-equilibration of a groundwater system toward a no-flow condition takes time and often the cycle of recharge to- and recovery of- water from the system is faster than the ability of the groundwater system to either re-balance or even achieve a steady- state. As in most cases, the groundwater system is always dynamic and in a transient state, even if it appears to respond slowly and steadily by human perception.

The groundwater flow behaviors of interest include flow direction and flow rate. Flow direction may be visualized as an arrow pointing in the down- direction of the potential gradient, since water moves in the direction of the applied force. Flow direction may also be visualized as a hypothetical flowline that a single water molecule would follow under steady-state. A contour map of the water table or piezometric surface is a map of the groundwater potential in the aquifer, and the direction of flow at any location will be perpendicular to the contours and pointing in the direction of lower potential.

Flow rate can be described as the average flow speed of a water molecule at a specified place and time or as the "instantaneous" volumetric flux of a volume of water through a specified cross sectional area (W·H) of the aquifer over a short period of time. Apart from the externally applied driving forces and the physical dimensions of the aquifer, these measures of ground water flow depend only on the hydraulic conductivity and porosity of the porous medium.

Hydraulic conductivity. The *hydraulic conductivity (K)* is a measure of the ease with which water flows through a porous medium and is not quite a fundamental property. The fluid flow through a porous medium also depends on the density and viscosity of the fluid as well as what we call the *permeability (k)* of the porous medium. But for convenience hydrologists have combined the standard values for the properties of water with the measure of permeability and have defined this property as the hydraulic conductivity.

This term effectively determines the flow rate or volumetric flux of water through the aquifer under whatever potential gradient exists at the time and place of interest. The values for silty and sandy sediments, such as occur in the area of interest may range from $0.001 \leq K \leq$

300 ft/d, a range covering more than five orders of magnitude. The formula for calculating the steady- state volumetric flux of water (Q_w) in an aquifer is $Q_w = W \cdot H \cdot K \cdot G$ for a groundwater potential gradient $G = \Delta h/\Delta x$, through an aquifer cross sectional area of width W and thickness H. If the aquifer is not in steady- state, then the calculation represents only the "instantaneous" flow at that moment at that location under those conditions and the full equation of flow must instead be used to describe the transient flow behavior over time.

The steady- state flux equation applies to both horizontal and vertical groundwater flow with the condition that the values of K and G are the values of hydraulic conductivity and gradient in the direction of flow. Most aquifer materials, whether unconsolidated sediments or sedimentary rocks, are anisotropic and are commonly 5 - 20 times more permeable in flow directions parallel to the bedding planes than in flow directions perpendicular to the bedding planes. Thus, in order to quantify or model aquifer flow with both horizontal and vertical components, it is necessary to specify both the horizontal and vertical hydraulic conductivities of relevant aquifer materials.

Leakance. The *leakance (L')* is a property which determines the rate of downward vertical flow of water from a water table aquifer, through a permeable aquitard, and into an underlying semi-confined aquifer due to head differences across the aquitard. The value of L' is determined as the ratio of vertical hydraulic conductivity to the thickness of the aquitard, $L' = K_v'/h'$. (The prime (′) in the abbreviations symbolize that these are properties of the *aquitard* and not of the underlying aquifer). We refer to aquifers which show this type of recharge behavior as leaky aquifers and one flow equation which describes this type of flow behavior is the Hantush - Jacob equation, named after its authors.

The mathematics of leakage occurs in the flow equation in the form of what is referred to as the Hantush leakage factor (B) and B is related to known parameter values according to the formula $B = (T/L')^{1/2}$. In the project area, the high- permeability zones of the aquifer are sandy sediments and the low-permeability zones are silty sediments. These silty sediments are the aquitards which retard the vertical flow of water between the sandy layers of the aquifer. Based on our measurements and estimates of the relevant properties, we estimate that the value of B varies in the range of about $1800 \leq B \leq 6000$ and we have used a value of B = 3200 as our base case value.

Porosity. The *porosity* (ϕ) is the dimensionless ratio of the volume of void space in a unit volume of a porous medium. As a flow property, it determines the amount of intergranular flowpath within the porous medium that is available to the water. The formula for calculating the steady- state flow velocity of water (v_w) in an aquifer is $v_w = K \cdot G/\phi$. If the aquifer is not in steady- state, then the calculation represents only the "instantaneous" flow speed at that moment at that location under those conditions and the full equation of flow must instead be used to describe the transient flow behavior over time. For our modeling we have used an average porosity of 30%.

Layered- aquifer flow properties. For aquifers which are either heterogeneous or layered, we must determine the hydraulic conductivity and porosity of each type of sediment within the aquifer and the proportions of each. For a layered aquifer, the total average horizontal hydraulic conductivity of the full saturated aquifer thickness is defined as being equal to a summation which looks like: $K_{avg} = \Sigma(h_i \cdot K_i)/H$, that is, the sum of products of the individual layer thicknesses and hydraulic conductivities divided by the total aquifer thickness. Since the product of thickness and conductivity in this equation is defined as transmissivity (T), this is often more-conventionally written as: $T_{eq} = H \cdot K_{avg} = \Sigma(h_i \cdot K_i) = \Sigma(T_i)$, i.e., the equivalent aquifer transmissivity is the sum of the individual layer transmissivities.

The average conductivity and equivalent aquifer transmissivity refer to a hypothetical, homogenous aquifer which would deliver the same total volumetric flux as the specified layered aquifer. However, it must be remembered that the true flow behavior and volumetric fluxes are different in the individual layers of the actual aquifer than in the hypothetical equivalent- layer model and that the average or equivalent properties represent a mathematical fiction which is usable only in certain specific ways.

Transport properties.

Transport in this context refers to the motion of constituents which are dissolved and/or suspended in ground water, especially the movement of unregulated contaminant releases which propagate as slugs or plumes within the aquifer. The important transport processes are advection, dispersion, retardation, and attenuation which might be defined as follows. Advection is the physical transport of a constituent by the flow of water within a porous medium. Retardation includes all processes which cause a plume or constituents to move slower than the ground water. Dispersion includes all processes which re-distribute constituents away from the center of mass of a plume. Attenuation includes all processes which permanently remove constituent mass from a ground water plume.

These processes affect contaminant transport and plume behavior in specific ways. Mathematically, they may all be represented by terms in the transport equation which describes the location, speed, amount and distribution of contamination within the plume in space and time. Advection refers to groundwater flow which we have already discussed. Both retardation and attenuation may be thought of as properties related to the type of constituent rather than as properties of the aquifer. Dispersion is related to dispersivity which is strictly an aquifer property which can be measured with special types of well test or estimated from theoretical considerations. Since the treatment of transport is outside this project scope of work, we omit the discussion of these processes from this report. However, it is important to note that most contaminants travel at different flow speeds and different particle trajectories than the ground water and must be modeled in different ways.

Sources of data.

Sierra Scientific Services (SSS) used four sources of information for the aquifer properties within the area of interest (AOI) including:

1. SSS physical property data (S_y, S_s, ϕ, K, H, F_{sd}) measured on samples & logs from the AOI,
2. ID4 well test data (T & S) from wells in the AOI,
3. C.o.B. infiltration test data (Kv) for test ponds in the AOI,
4. KCWA water table elevation maps covering the AOI.

SSS carefully reviewed and chose not to use the data from two other sources including:

5. DWR aquifer model data (Sy, S, K & T) for the Kern Fan area,
6. KWBA and Pioneer Project pump test data from various reports (T & S).

SSS did not use the data from these two sources for several reasons, chief among them is that we obtained a minimum but sufficient amount of well- documented, actual measurements for all of the necessary parameters of interest from the first four sources. However, with all due respect, we also consider the data from both of these other two sources to be questionable and we recommend that ID4 carefully evaluate the data from these sources against their own technical and theoretical criteria before they use them in their own analyses. We offer some of our observations regarding the data from these two sources below, for purposes of clarification since we consider the selection (or rejection) of parameter values to be an important, documentable, exercise of judgment in a modeling program.

The DWR parameter data. In 1988, the California Department of Water Resources (DWR) purchased approximately 20,000 acres of land in Kern County for an aquifer storage and recovery (ASR) program. The area is now known as the Kern Water Bank. In the early 1990's, the DWR attempted to develop a computer model to simulate the aquifer behavior and evaluate various aspects of their project. The modeling effort concluded in early 1996 with the publication of a DWR memorandum which summarized the work. The memorandum included a discussion and summary of all the aquifer parameter values that the DWR used, and these parameter values have been referenced and used by some workers in the local water community.

In the process of parameterizing their computer model of the Kern Fan area, the DWR never actually measured a single value of any parameter in preparation for what became a massive modeling effort. The DWR assigned "textbook" values of specific yield obtained from the general literature (but not specific to the study area) to each of 55 different types of sediment. Then, after blundering through a simplistic and erroneous application of trend analysis in which all other parameter values were numerically correlated to the assigned values of specific yield, they proceeded to put these values into their computer model.

Apart from the parameter values, the DWR approach to developing the basic model appears to be sound and many of their model simplifications which were required in order to approximate the true physical aquifer behaviors within the constraints of the model show careful thought if not always the best choice. However, in our opinion, their treatment of aquifer parameters shows poor judgment perhaps stemming from an insufficient understanding of the physical properties and property interrelationships of porous media and geological materials.

DWR reported that the model results were unsatisfactory based on the initial values so they changed the parameter values around their control points to improve the outcome. Unfortunately, the DWR computer model never provided good results, which we attribute to incorrect parameter values, poor assumptions and poor choices of free parameters in the "calibration" tests. Since the initial parameter values were questionable on petrophysical and theoretical grounds and since the model results were unsatisfactory, we conclude that there is very little credibility in the representativeness of any of the DWR parameter values except to the extent that they fall within the ranges of published values for similar geological materials.

KWBA and Pioneer Project well test data. The operators of these two sites have conducted a number of pump tests on wells in these areas over the years, and the test data have been interpreted by other workers to provide estimates of the aquifer parameters T & S. With respect to the available literature, part of the issue with these well tests as a source of aquifer parameters is that the test operations and test data are only poorly documented in the available reference literature. But based on our review of the scant information in the literature, we can make the following observations.

The pump tests appear to have been designed and operated by engineers in order to determine well- function parameter values rather than aquifer parameter values. Many of these tests had multiple wells pumping simultaneously and most tests lasted for only a short duration, both of which make it difficult to determine aquifer properties. The available interpretations of aquifer transmissivity (T) appear to use the specific capacity (SC) approximation method rather than the standard Theis or Cooper - Jacob methods. Since the SC approximation method does not determine the aquifer storativity (S), the value of S must be guessed at in order to calculate the value of T. With possible values of S ranging over three orders of magnitude, this creates considerable uncertainty in the value of T, and none of the available reports discusses the specific value of S or the method of determination that was used.

If we speculate that the discharge/drawdown ratios (SC) are the only pump test data actually available from all of these tests, then the SC approximation method is all that is really available to anyone to estimate some T-values. However, we found that the determinations of more than two dozen values of T by the SC method were also poorly documented. Based on our review of the limited discussions, we conclude that there is evidence of a disregard for certain basic assumptions and limitations of the SC method which call the T-values into question. There was no discussion on the value of S which was assumed in the determinations of T nor any discussion of how the value was arrived at. There was no discussion on the value of well efficiency or whether or not it was included in the calculation, since the drawdown inside the pumping well must be corrected to fit the assumptions of the method. There was no discussion or mention of whether or not the T values were corrected for differences in pump test duration, effects of partial well penetration, length of completion interval, or differences in static head between wells.

When all of the T-values are looked at collectively, there is a surprisingly large variation within what is considered to be a "sweet spot" of aquifer geology. The reference reports attempt to explain this variation by citing differences in water table elevation at the different times of the tests. However, this explanation failed to explain why some wells had higher T-values when the water table was deep and lower T-values when the water table was shallow; failed to explain why none of the differences in T-values for different water table conditions were equal to the expected T-value of the dewatered interval, as it should be from theoretical considerations; and failed to consider the effects of different completion intervals in different test wells. Based on these observations and our questions regarding the undocumented and questionable use of the SC approximation method without the standard corrections, and further that the calculations are based on data from multi-well tests of short duration, we conclude that the more likely explanation for the difficulties with the T-values is that they are inaccurate and non- representative of the aquifer properties in the areas of the tests. We conclude that these data are of questionable value and have little credible use for aquifer modeling given the range of variability and the likelihood for a considerable range of error.

Parameter values.

Specific yield (S_y). Specific yield is a function of the porosity and grain surface area of porous media and is a property which varies over only a limited range of values for the few aquifer materials of interest. The source of specific yield values for this scope of work is the field work that SSS[5] completed for the Rosedale - Rio Bravo WSD and reported in 2003. RRB contracted SSS to drill coreholes, collect sediment samples and obtain laboratory analyses for specific yield and a set of other useful physical properties. One suite of samples which came from the RRB recharge pond area which is part of the ID4/ KT/ RRB project area.

Based on the RRB study, the average specific yield of the sandy and silty sediments in the area of interest are 33% and 8.6%, respectively. Based on the relative fractions of each in the upper aquifer, the average specific yield of the interval is about 21%.

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[5]Crewdson, Robert A., 20 January, 2003, Determination of Aquifer Storage Capacity for the Rosedale - Rio Bravo Water Storage district, Bakersfield, California., Sierra Scientific Services, Bakersfield, Ca.

Specific storage (S_s). Specific storage is a function of the porosity and bulk compressibility of porous media and is a property which varies over only a limited range of values for the packed, unconsolidated sandy and silty media of interest. The source of specific storage values for this scope of work are also from the 2003 field work that SSS completed for the Rosedale - Rio Bravo WSD. Based on compressive stress tests on samples of poorly sorted sand and silty sand, the bulk compressibilities of these samples range from 4.5 - 7.9 x 10^{-8} m^2/N from which we have derived the values for the dense, compacted equivalents of these sediments as 1 - 1.8 x 10^{-8} m^2/N which are in the expected range of compressibilities for dense sands. From these values we have calculated the corresponding values of S_s ranging from 0.000030 to 0.000053 ft^{-1} and averaging 0.000041 ft^{-1}. This range of S_s values is entirely consistent with the range of published values expected for dense sands and silts.

Porosity (ϕ). The source of porosity values for this scope of work are also from the 2003 field work that SSS completed for the Rosedale - Rio Bravo WSD. Based on those samples, the measured average porosity of well sorted sandy sediments is 37% and the measured average porosity of the silty sediments is 34% and give a weighted average porosity for the aquifer media of 30% for this project.

Transmissivity (T) and Storativity (S). The source of T and S values for this scope of work are based on the ID4 well test of December, 2002 which has been summarized in a 2003 KDSA impact report and a supplemental well test report[6] (see Appendix 5). Based on our review of the supplemental report, we disagreed with the interpretation of T & S values because of a failure to select values of Q and r which met the necessary Cooper - Jacob assumptions and validity conditions for the method. We also disagreed with the entire distance - drawdown interpretation presented in the same report because of an incorrect application of the Cooper - Jacob (single-well) method to a cluster of several pumping wells. As a result, we have chosen not to use the reported values of T & S, in favor of our own reinterpretation of the data.

Based on our re-analysis (Appendix 4) of the Cooper - Jacob time - drawdown data, the correctly determined value of transmissivity is T = 20,000 ft^2/d and the correctly determined

[6]Schmidt, Kenneth, D., January, 2003, Groundwater Conditions and Potential Impacts of Pumping for the ID-4 Kern Parkway and Rosedale - Rio Bravo WSD Projects, Kenneth D. Schmidt & Associates, Fresno, CA, and Supplement to the [January Report], by the same source, dated February 28, 2003.

value of storativity is $S = 0.00056$ for the slotted intervals of the tested wells. As we report in Appendix 4, we are unable to determine any other values of T or S from any of the other data from this multi- well, 20-day test. Apart from the correctness of the calculations, we cannot determine the accuracy or representativeness of these T & S values because of a lack of corroborating data and because of known factors associated with the operation of this test which may have affected the data.

The calculated value of T is reasonable in our opinion based on experience. But because there is a body of other data, even though of questionable value in our opinion, which reports a wide range of possible and particularly much higher values of T, we have treated T as one of our free parameters which we vary in our modeling.

In our opinion, the calculated value of S seems to be too low for an aquifer which is at least 500 ft thick and for test- well completion intervals which cover a significant fraction of the full aquifer thickness. We point out that $S = H \cdot S_s$, and for S_s in the range of 0.000041 and H in the range of 300 - 500 ft, the storativity should be in the range of $0.01 < S < 0.02$. The very small measured value of S from the well test would suggest that either the effective aquifer thickness is actually quite small or that the validity of the entire test should be questioned. However, since part of the scope of work includes an evaluation of long- term drawdown impacts and since the steady- state aquifer behavior does not depend on the value of S, we take some consolation against our concern for the value of this parameter. However, the value of S is a factor in transient aquifer behavior, particularly in the size and expansion of the capture zone about a well so, to the extent that the value of S may be in error, this part of the modeled transient behavior may be in error as well.

Hydraulic conductivity (K). For the following two assumptions that 1. the fraction of sand (F_{sd}) by thickness in the aquifer is at least 20%, and 2. the sand is at least 100 times more permeable that the silt, we can demonstrate that the horizontal hydraulic conductivity (K) of the aquifer equals $K = T/(H \cdot F_{sd})$ with an error of less than 5%. Based on the geological cross sections presented in the first KDSA report, we estimate that the test wells were completed across an estimated 250 ft net sand interval in the local area of the well test, so that the hydraulic conductivity of the sandy strata must be about $K_{sd} = 80$ ft/d. However, we note that if the effective net sand thickness is much smaller in the region of this well test, especially if the flowpath between the pumped well and the observation well is stratigraphically limited, then the value of K might be very much higher for this value of T.

<u>Aquitard leakage factor.</u> The mathematics of leakage occurs in the flow equation in the form of what is referred to as the Hantush leakage factor (B) and B is related to known parameter values according to the formula $B = (T/L')^{1/2}$. In the project area, the high-permeability zones of the aquifer are sandy sediments and the low-permeability zones are silty sediments. These silty sediments are the aquitards which retard the vertical flow of water between the sandy layers of the aquifer. Based on our measurements and estimates of the relevant properties, we estimate that the value of B varies in the range of about $1800 \leq B \leq 6000$ and we have used a value of B = 3200 as our base case value.

Based on the local geology as interpreted from available E-logs, the shallow water table aquifer is separated from the underlying semi- confined aquifer by a sequence of thin, laterally-discontinuous, localized silty facies rather than a single, laterally- continuous aquitard. Since the silty strata are interbedded with more permeable sandy strata, the downward vertical flow of recharge to the aquifer is a non-uniform flux of slower vertical flow through the retarding silty strata and faster vertical flow through the sandy strata. If the aquitard is to be viewed or treated as a single layer, then it might look like a slice of swiss cheese, i.e., what we might call a "leaky aquitard". The overall leakiness of the aquitard is neither that of the silts alone nor of the sands alone, but a composite intermediate value of both which cannot be determined from the limited E-log data in the project area.

Appendix 4.

Cooper - Jacob analysis of the ID4 December, 2002 Well Test.

Appendix 4.

Cooper - Jacob analysis of the ID4 December, 2002 Well Test.

The Kern County Water Agency conducted a pumping test of several of their wells in the ID4 area of interest (see Appendix 5) in December, 2002. Kenneth D. Schmidt & Associates interpreted the well test data and presented the results in a pair of reports dated in early 2003.

To summarize, ID4 owns seven wells, six of which (Nos. 11, 10, 3, 9, 8, & 1 from SW to NE) have been installed along a line bearing N65E, parallel to the Kern River channel over a distance of about 10,800 ft and centered just NE of the southeast corner of section 36, T29S/R26E. On December 10, 2002, ID4 turned on all of these wells and let them flow at constant rates for 20 days. The flow rates in the six wells ranged from 5.6 - 10 .0 cfs and ID4 extracted a total of 1890 af from the aquifer at an average rate of 94.5 af/d over the 20-day duration of the test. ID4 monitored the flow rates and drawdowns in each pumping well over time and monitored the drawdowns in selected other non-pumping wells in the immediate area.

Cooper - Jacob time - drawdown analysis. ID4 recorded the drawdown in observation well ID4-12 several times over the first two days of pumping. This observation well is approximately equidistant from the two closest pumping wells (3 & 10) and much more distant from the other pumping wells. The KDSA Supplemental Report (SR) presented these drawdown data for well ID4-12 on a log-linear Cooper - Jacob time - drawdown plot and calculated values of T & S from the data. The standard procedure is to calculate T from the slope of the straight line plot of the data, and then calculate S from the x-intercept and the value of T. Although the method and calculation are not presented in the SR, we assume that *the KDSA calculations* were approximately as follows for Q = 23,850 gpm, r = 2240 ft, slope = 13.2 ft/decade, and intercept = 0.03 day.

$$T = 2.3Q/(4\pi \text{slope}) = \text{for } Q = (2.3)\cdot(23{,}850\cdot 1440)/((12.56)\cdot(13.2)) \approx 476{,}200 \text{ gpd/ft}$$

and

$$S = 2.25T(\text{intercept})/r^2 = (2.25)\cdot(476{,}200)(0.03)/((7.48)\cdot(2240)^2) \approx 0.00086$$

In our opinion, the values of Q and r which were used in these calculations are incorrect. The value of Q = 23,850 gpm is the total combined pumping rate of all six wells. But based on Cooper - Jacob validity criteria, only wells 3 & 10 are close enough to the observation well to have caused measurable drawdowns after 2 days of pumping, and the other wells are too far away. Therefore, if the effects of pumping at wells 1, 8, 9, & 11 have not yet reached the observation well, then the flow rates of these wells should not be included in the calculation. The combined Q of wells 3 & 10 is about 7,500 gpm so we conclude that this is the appropriate value of Q for this test, subject to other validity criteria.

With respect to the value of "r", The value of r = 2,240 ft is the distance from the observation well to the centroid of all six pumping wells (SR Table 3). But based on Cooper - Jacob validity criteria, the Cooper - Jacob calculation method only applies to the observed drawdown caused by one of two cases, either 1. a single pumping well at a distance r from an observation well, or 2. multiple wells ALL of which must be at the same distance r from the observation well AND all of which must start pumping at the same time. This method does not apply to, i.e., does not give the correct results from, any other set of conditions and does not apply to the "centroid" of a multi-well cluster of pumping wells.

We note, however, that the placement of observation well 12 with respect to pumping wells 3 & 10, approximately meets the second of the two C-J validity conditions with a value of r = 1,540 ft to both wells as determined from the KDSA map (Schmidt, 2003b, Figure 1).

Therefore, based on our re-analysis using Q = 7,500 gpm (1,444,000 cf/d) and r = 1,540 ft, and the SR values of slope and intercept which we agree with, then we determined (after a units conversion) the local value of transmissivity to be T = 20,000 ft^2/d and the value of storativity to be S = 0.00056 for the slotted intervals of the tested wells, as follows:

$$T = 2.3Q/(4\pi \text{slope}) = (2.3)\cdot(1{,}444{,}000)/((12.56)\cdot(13.2)) = 20{,}000 \text{ ft}^2/\text{d},$$

and

$$S = 2.25T(\text{intercept})/r^2 = (2.25)\cdot(20{,}000)/(1540)^2 = 0.00056.$$

<u>Cooper - Jacob distance - drawdown analysis.</u> The SR presented a distance - drawdown plot of the drawdowns in non-pumping wells after a pumping duration of 10 days. In our opinion, the

observed scatter in the plotted data (Schmidt, 2003b, Figure 3) is in obvious contradiction to the expected Cooper - Jacob straight line, and is sufficient to cause us to question the data. It appears that the drawdowns from a number of non-pumping wells have been plotted against the radial distance from the geographic centroid of the six pumping wells. But based on Cooper - Jacob validity criteria, the Cooper - Jacob distance - drawdown calculation method only applies to the observed drawdowns at various distances at a single specified time caused by a single pumping well. This method does not apply to, i.e., does not give the correct results from, any other set of conditions and does not apply to the "centroid" of a multi-well cluster of pumping wells, as should be obvious from geometrical considerations alone. Therefore, we have rejected the results of that analysis based on incorrect methodology. Unfortunately, there is no method of interpretation for to determine T & S from a cluster of multiple pumping wells and no way to isolate the component of drawdown in an observation well that is due to just a single pumping well.

Appendix 5.

Excerpts from the KDSA, 2003b, Supplemental Report regarding the ID4, December, 2002, Pump Test.

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February 28, 2003

Mr. Martin Varga
District Engineer, ID-4
Kern County Water Agency
P. O. Box 58
Bakersfield, CA 93302-0058

Re: Allen Road Well Field
December 2002 Pump Test

Dear Martin:

Following are the results of my review of the December 2002 pump test on the six ID-4 Wells. Wells No. 1, 3, 8, 9, 10, and 11 were pumped for the test. Pumping of the wells began between 8:23 and 9:29 am on December 10, 2002. Pumping of Well No. 10 stopped at 7:20 pm on December 20, 2002, due to a pump malfunction. Pumping of the remaining wells continued until between 10:35 and 11:35 am on December 30, 2002. Figure 1 shows the locations of these wells and observation wells that were used for the test. A network was developed of both shallow and deep observation wells. There were a total of 13 deep observation wells and three "shallow" observation wells.

Pumpage

Total pumpage and average pumping rates were determined for the first day, next three days, first ten days (through December 20, 2002), and for the entire duration of pumping. Table 1 summarizes pumpage from each of the pumped wells for these periods, based on totalizer readings from the flowmeters on each well. A total of 34,716,000 gallons was pumped during the first day, 101,815,000 gallons during the next three days, 384,900,000 gallons during the first 10 days, and 615,943,000 gallons during the entire 20-day period. The average pumping rates were 24,110 gpm for the first day, 23,570 gpm for the next three days, 23,260 gpm for the first 10 days, and 21,390 gpm for the entire test. Because of the combined well decreased pumping rate after December 20, drawdowns in the pumped wells and observation wells were primarily examined during the first ten days of the pump test.

Drawdowns

Pumped Wells

Table 2 summarizes drawdowns in the pumped wells that were determined for the test. The centroid of pumping was located about midway between Wells No. 3 and 9. Static water levels in these wells ranged from 127.8 to 131.9 feet, and were deepest to the northeast. Drawdowns in these wells after 10 days of pumping ranged from 31.7 to 55.7 feet. The largest drawdowns were in Wells No. 1 and 3, even though these wells had the lowest pumping rates. Drawdowns after 20 days of pumping ranged for 31.5 to 53.3 feet.

Observation Wells

The primary observation well for the test was ID4 Well No. 12, which is in the vicinity of the pumped wells, and was not pumped during the test. Table 3 shows drawdowns in the deep and shallow observation wells that were measured during the test. The distances of these wells from the centroid of pumping are also shown.

Although three observation wells were initially chacterized as "shallow", only one of these (2-inch galvanized) is believed to tap only the shallowest deposits (Layer 1). The water-level in this well rose during most of the pumping period, and was directly influenced by recharge from streamflow in the Kern River. Well 35A4, located near the RRBWSD office, is perforated from 310 to 410 feet in depth and is actually an intermediate zone (Layer 2) well. The water level in the shallow nearby well (Shop Well) couldn't feasibly be measured during the test. The depth of the Hay Barn Well is not known, but the depth to water in this well is also indicative of an intermediate zone well. Two other shallow monitor wells were planned to be measured during the test, but they were dry. Because of these factors, the pump test did not provide useful information on the influence of pumping the ID4 Allen Road wells on shallow groundwater in the vicinity. However, substantial information was obtained on aquifer characteristics for the composite pumped interval.

Figure 2 is a drawdown plot for Well No. 12. The measurements for the first two days of pumping indicated a transmissivity of 476,000 ppd per foot and storage coefficient of 0.0008. Water-level measurements in this well after six days of pumping the other wells indicated no further drawdown. This was due to recharge from streamflow in the Kern River, which began between December 12 and

16, 2002, and reached the ID4 Well No. 10 vicinity by December 19.

Drawdowns in deep wells (most are actually composite wells) ranged from 1.3 to 26.3 feet after ten days of pumping the ID4 wells. Figure 3 shows drawdowns in these wells after ten days of pumping plotted against the logarithm of distance from the centroid of pumping. The overall trend is excellent, and a transmissivity of 395,000 gpd per foot and storage coefficient of 0.01 were determined. This transmissivity value is in excellent agreement with the average value of 409,000 gpd per foot used in our January 2003 report. The increase in apparent storage coefficient (ten days versus two days) is as expected. Afer several months of pumping the ID4 Allen Road Wells, the storage coefficient is expected to be in the range of 0.05 to 0.10.

Recovery

Recovery measurements indicated almost full recovery within the first day after pumping stopped. Unfortunately, frequent water-level measurements were not made during the first day of recovery. Therefore, values for aquifer characteristics could not be determined from the recovery measurements.

Please call me if you have any questions.

Sincerely Yours,

Kenneth D. Schmidt

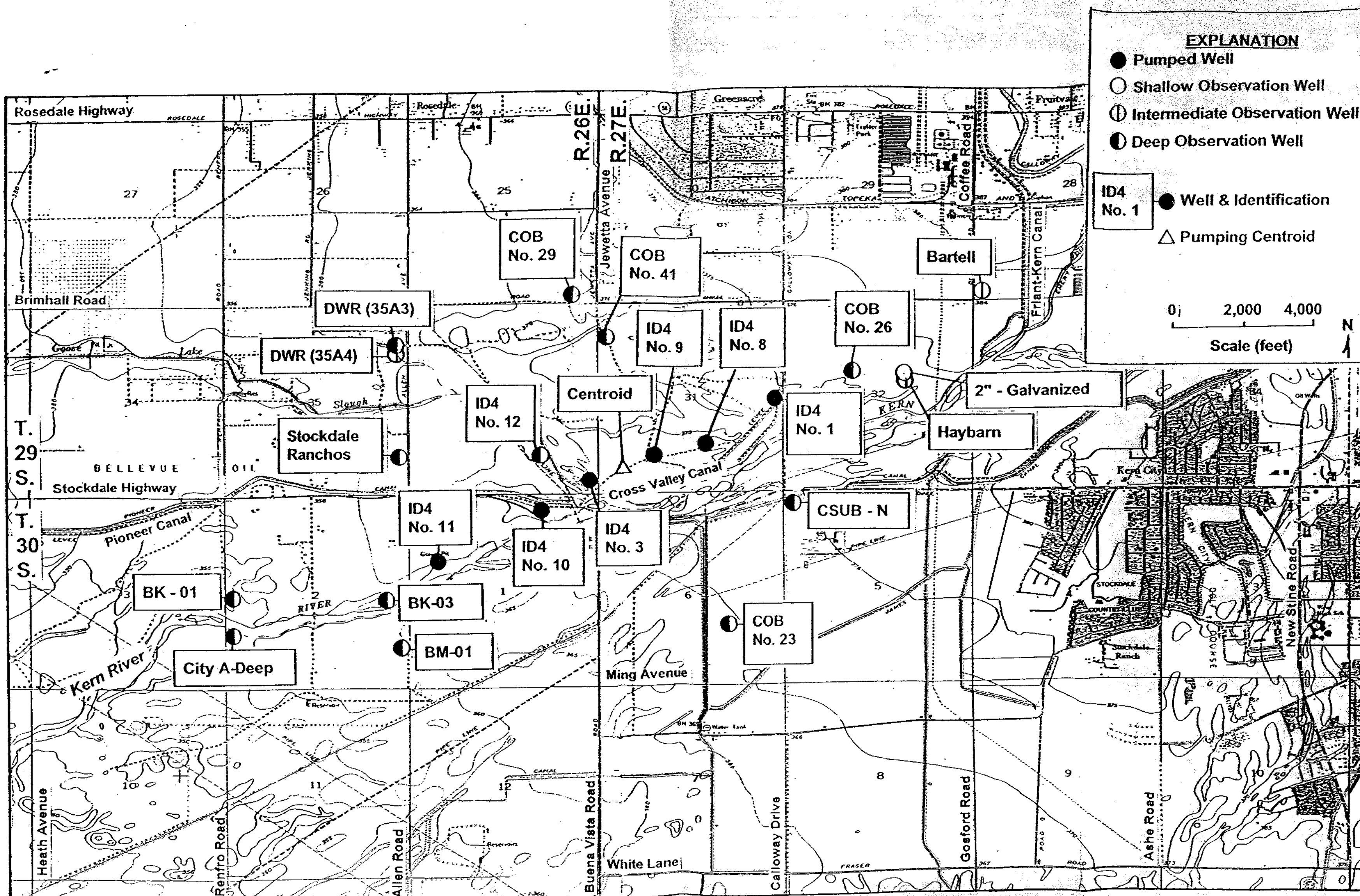


FIGURE 1 - LOCATION OF PUMPED WELLS AND OBSERVATION WELLS

TABLE 1 - PUMPAGE AND PUMPING RATES
FOR THE PUMP TEST

Well	First Day		Next Three Days		First Ten Days		Entire Test	
	1,000g	Ave gpm	1,000g	Ave gpm	1,000g	Ave gpm	1,000g	Ave gpm
1	3,991.7	2,770	11,743.7	2,730	39,209.6	2,730	79,031.9	2,730
3	4,359.9	3,020	12,760.3	2,940	41,969.6	2,920	86,627.5	2,990
8	6,578.9	4,570	19,319.7	4,470	63,407.4	4,410	127,749.9	4,410
9	6,585.5	4,600	19,182.9	4,440	62,863.2	4,370	126,863.6	4,390
10	6,578.9	4,550	19,287.1	4,490	63,446.5	4.410	66,216.2	2,300
11	6,621.3	4,610	19,521.7	4,510	64,003.7	4,450	129,454.1	4,480
Total	34,716.2	-	101,815.4	-	334,900.0	-	615,943.2	-

TABLE 2 - DRAWDOWNS IN PUMPED WELLS

Well No.	Static Level (ft)	December 20, 2002		December 30, 2002	
		Pumping Level (ft)	Drawdown (ft)	Pumping Level (ft)	Drawdown (ft)
01	131.6	187.3	55.7	184.9	53.3
03	125.8	180.8	55.0	176.7	50.9
08	132.1	179.2	47.1	177.7	45.6
09	131.9	163.6	31.7	163.4	31.5
10	129.1	178.0	48.9	Pump Off	-
11	127.8	179.1	51.3	174.2	46.4

TABLE 3 - DRAWDOWNS FOR OBSERVATION WELLS

Zone	Well No.	Distance to Centroid(ft)	Static Level(ft)	December 20, 2002		December 30, 2002	
				Depth to Water(ft)	Drawdown(ft)	Depth to Water(ft)	Drawdown(ft
Shallow	2" Galvanized	8,320	87.6	86.0	-1.6	84.2	-3.4
Intermediate	DWR-35A4	17,150	122.5	131.9	8.5	129.8	7.3
	Bartell	11,250	118.0	132.5	14.5	132.0	14.0
	Hay Barn	8,320	114.3	117.1	2.8	116.5	2.2
Deep	ID4-12	2,240	124.4	150.7	26.3	149.1	24.7*
	COB-23	5,330	145.1	159.2	14.1	156.1	11.0
	COB-26	6,990	134.2	154.1	19.9	153.3	19.1
	COB-29	4,960	139.1	150.0	10.9	148.6	9.5*
	BM-01	7,870	127.4	131.1	3.7	131.3	3.9
	BK-01	11,680	142.1	146.0	3.9	146.7	4.6
	BK-03	7,570	127.8	134.2	6.4	133.1	5.3
	CSUB-N	5,120	133.5	151.8	18.3	150.8	17.3*
	COB 41	3,680	136.7	145.8	9.1	143.1	6.4
	Stockdale Ranchos	6,190	125.0	130.5	5.5	130.0	5.0
	DWR-35A3	7,150	124.5	132.4	7.9	131.3	6.8
	City A-Deep	11,970	124.3	125.6	1.3	126.2	1.9

*Pumping levels and drawdowns were for December 27.

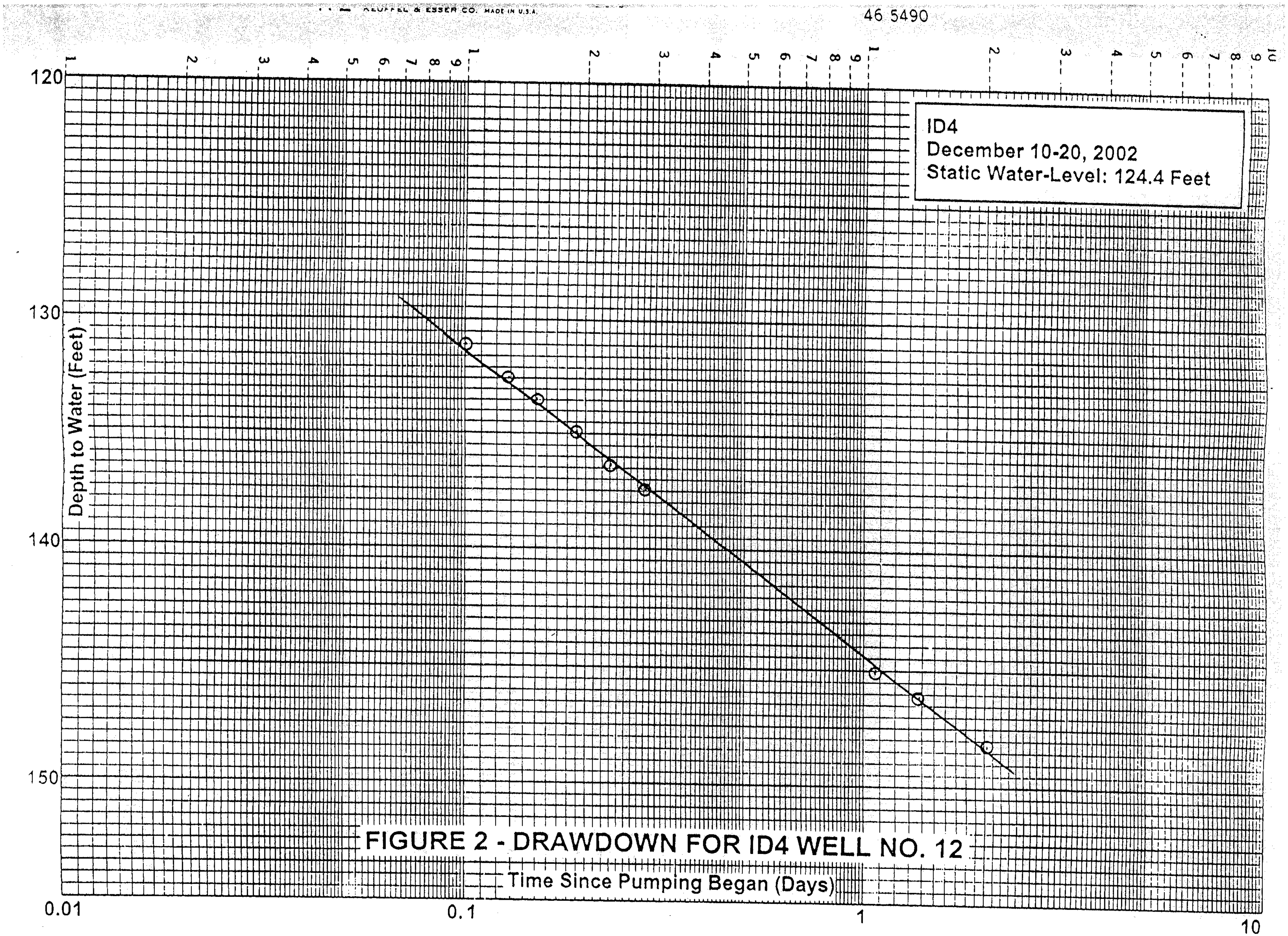


FIGURE 2 - DRAWDOWN FOR ID4 WELL NO. 12

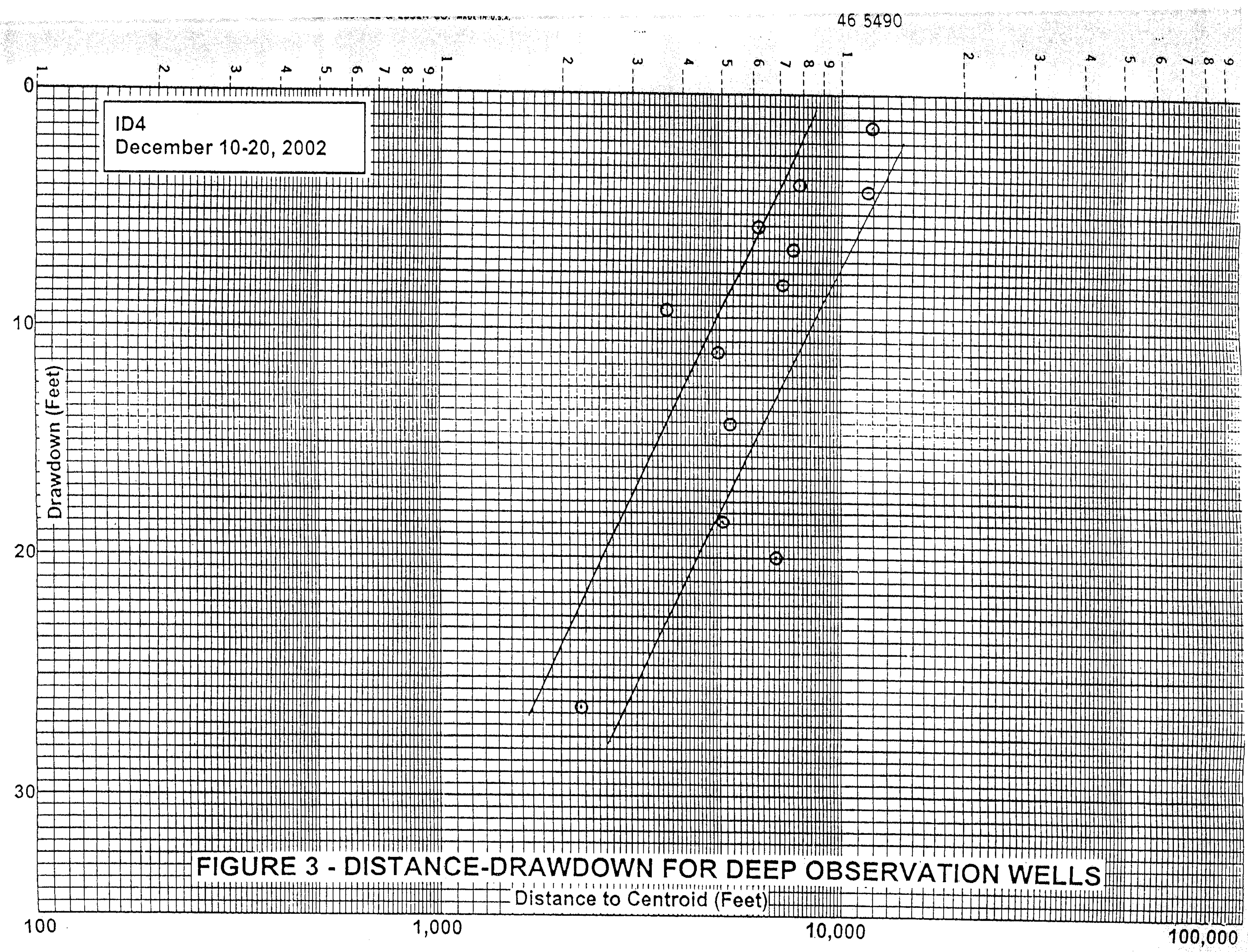


FIGURE 3 - DISTANCE-DRAWDOWN FOR DEEP OBSERVATION WELLS

Distance to Centroid (Feet)

Appendix 6.

Catalog of Drawdown Analyses for non- Base Case Conditions.

Appendix 6.

Catalog of Drawdown Analyses for non- Base Case Conditions.

SSS has evaluated several sets of non- base case conditions to illustrate the calculated drawdowns for purposes of comparison and evaluation. We have listed the sets of conditions below and have discussed each in subsequent sections. The best way to compare variations is to look at the maps to observe the changes in drawdown at locations of interest with respect to the changes in the free parameters and remember that the parameter changes are intended to reflect hypothetical changes in the real aquifer properties which affect the groundwater behavior.

We have compiled a set of introductory maps (Set 0) showing the well locations and the various groundwater gradient scenarios in the absence of project pumping. We have compiled the data sets into a group of drawdown analyses (Sets 1 - 6), a group of particle trajectory and capture analyses (Sets 7 - 8), and a group of other analyses (Sets 9-10). The difference is only in emphasis because the same basic map output is provided for every model calculation. From the drawdown analyses, we have tabulated the observed drawdowns at perimeter distances of 1000, 3000, and 5000 ft from the array of seven pumping wells which are presented in Figure 14. For the particle trajectory and capture analyses, we have tabulated (Figure 15) the capture reach (the equivalent of capture radius for a multi-well array) of the well array for pumping times of 1, 2, 5, 10, 20, and 30 years.

We present a list of the complete set of drawdown analyses in the catalog on the following page. We then present discussions of every set of maps in the remainder of this Appendix along with the catalog of maps.

List of Drawdown Analyses.

Set 1. Base case and limiting cases.

- Leaky aquifer, t = 300, 770 days (equiv. to 3 project years)
- Confined aquifer, t = 300, 770 days
- Unconfined aquifer, t = 300, 770 days

Set 2. Variation of base case drawdown with leakage rate (B) for constant t = 300d.

- B = 1800, 2200, 2600, 3200, 4600, 6000, 10000 ft

Set 3. Variation of base case drawdown during pumping at $Q = Q_{full}$.

- t = 10, 30, 100, 300, 770 days

Set 4. Modified base case by varying pump duration (t) at constant $Q = Q_{full}$.

- t/t_{max} = 100%, 50%, 25%   t = 300, 150, 75 days

Set 5. Modified base case by varying flow rate (Q) for constant pumping time t = 300d.

- Q/Q_{max} = 100%, 50%, 25%   Q = 90, 45, 22.5 cfs.

Set 6. Modified base case by pumping only selected wells for t = 300d.

- A1 - A5 only; ID4 1&2 only; A1 & ID4-2 only.

List of Particle Trajectory and Capture Analyses.

Set 7. Base case superimposed on a natural GW gradient (t = 300, 720d).

- G = -0.002; bearing 270° & 315° (rt azim. from North).

Set 8. Continuous pumping superimposed on a natural GW gradient (t = 1, 3, 5, 10, 20 yr).

- G = -0.002; bearing 270° & 315° (rt azim. from North).
- G = -0.001; bearing 300° and 0.7 ft/d recharge in Kern River channel.

List of Other Analyses.

Set 9. Base case by superposition method compared to centroid method.

Set 10. Three hypothetical pond infiltration scenarios.

Appendix 6.

Discussion

SET 00.

Summary of Introductory Maps; Set 0.

Set 0. Location Map and Ground water gradients.

This set of introductory maps includes five basic features. The first map is a location map showing several well locations and three reference- location markers positioned at local street intersections. The second and third maps show two hypothetical ground water gradient scenarios assuming an aquifer of infinite lateral extent. The two gradients are northwesterly at 0.002 and westerly at 0.002, respectively. These two ground water gradients are intended to represent the average gradients associated with the wet and dry periods, respectively, of the climatic wet/dry cycle. The fourth and fifth maps show a hypothetical west- northwesterly ground water gradient which includes the same upgradient recharge boundary at the Kern River channel, but have particle trajectories drawn on each for pumping periods of 3 years and ten years, respectively, for illustrative purposes without any pumping wells.

Appendix 6.

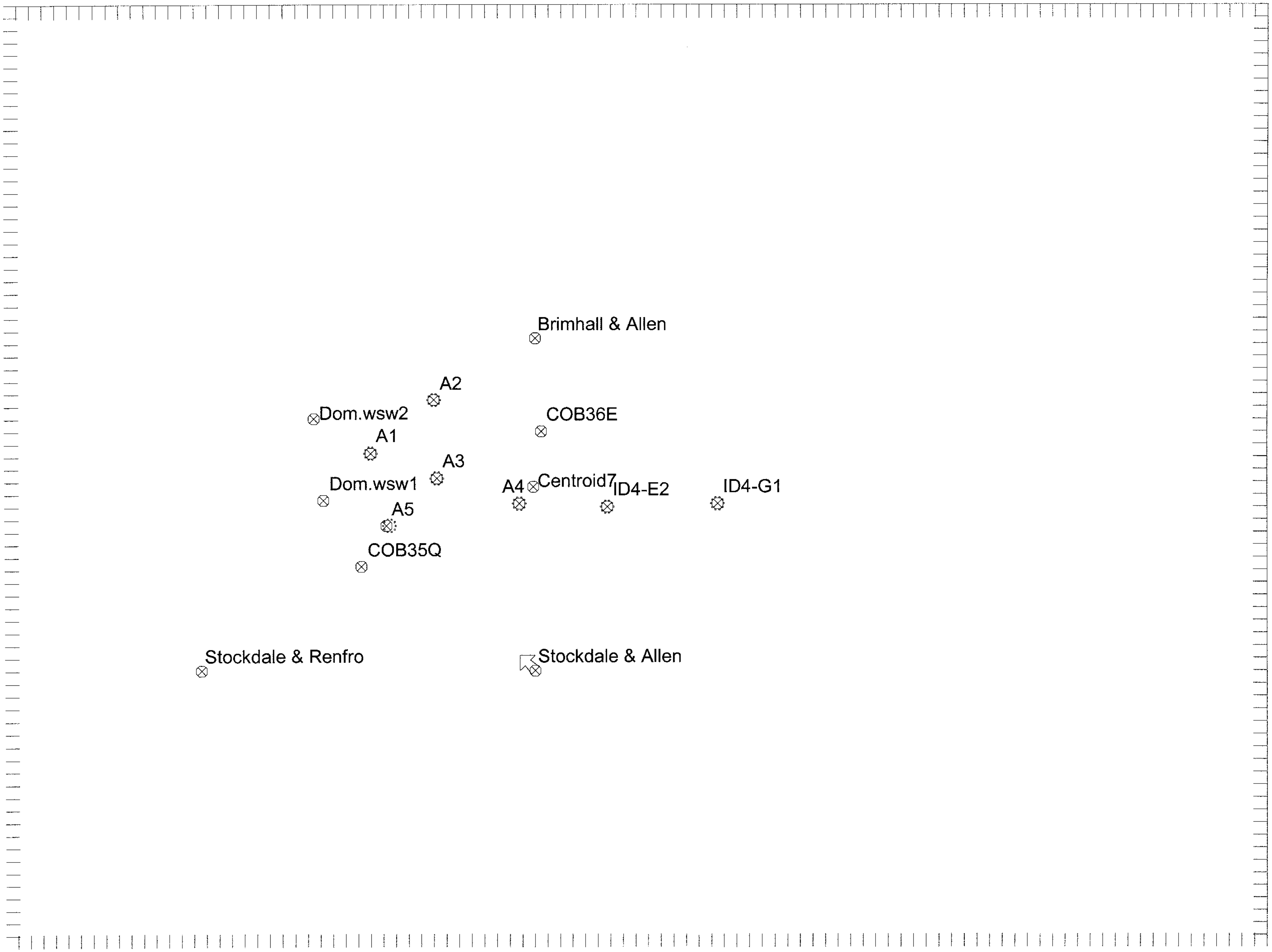
SET 00.

ID4 / KT / RRB Well Field Model Parameters.

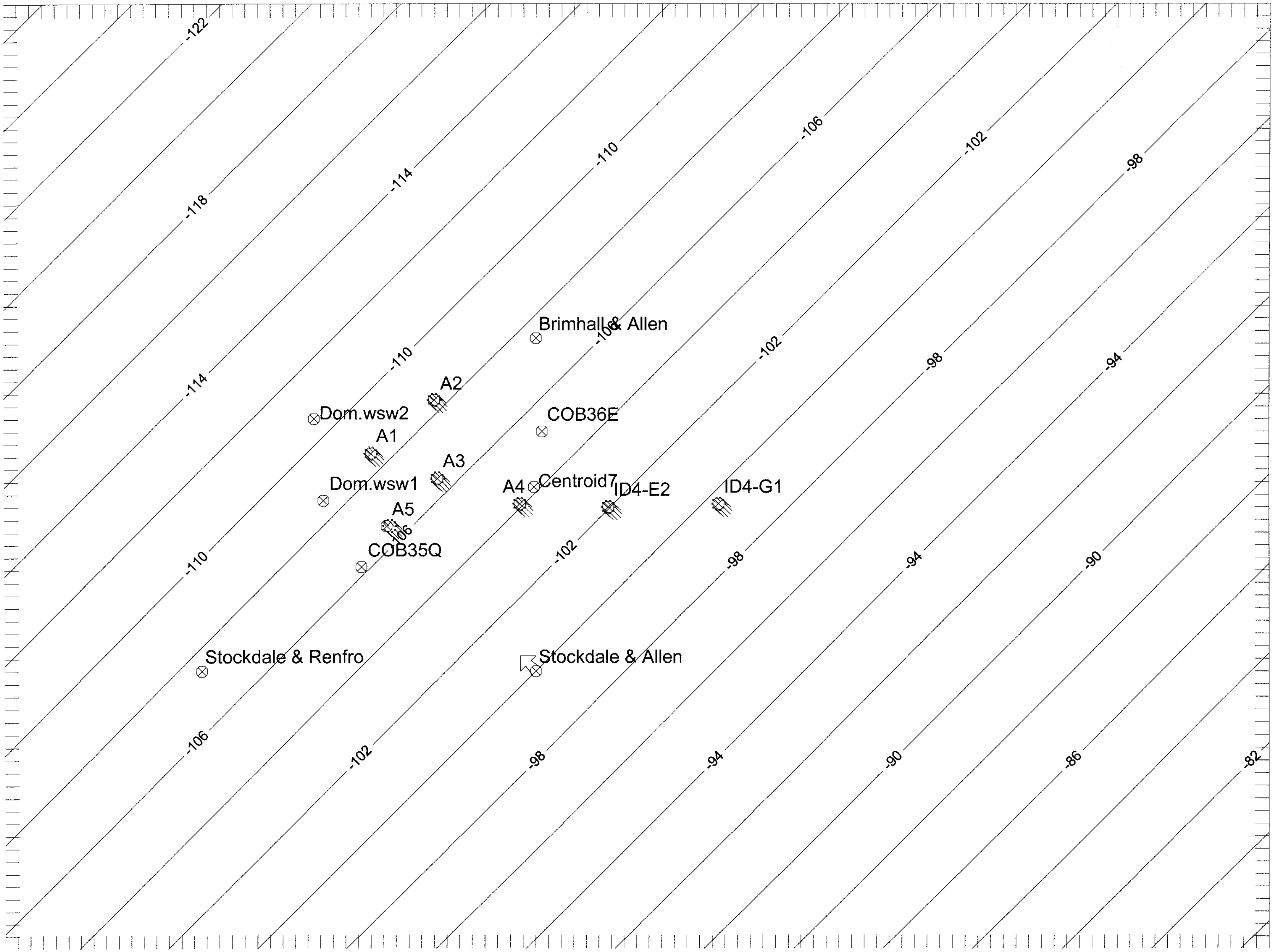
Set No. 0.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	loc.map	GW grad	GW grad	GW grad	GW grad							
calc		transient												
Run No.		ref.only	001	002	003	004	005							
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0		-100										
Grad	G	0												
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300	0											
Ref Hd	Ref	0		-100										
Grad	G	0		0.002		0.001								
Azim	A	135			180	150								
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300	0	300	770		3653							
Flow Rate	Q	full	0											
Wells	W	all	none											
River Rch	Q	0				-210								



Brimhall & Allen
A2
Dom.wsw2
COB36E
A1
A3
Dom.wsw1
A4
Centroid7
ID4-E2
ID4-G1
A5
COB35Q
Stockdale & Renfro
Stockdale & Allen



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Brimhall & Allen
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COB36E
A1
A3
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A4
Centroid7
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ID4-G1
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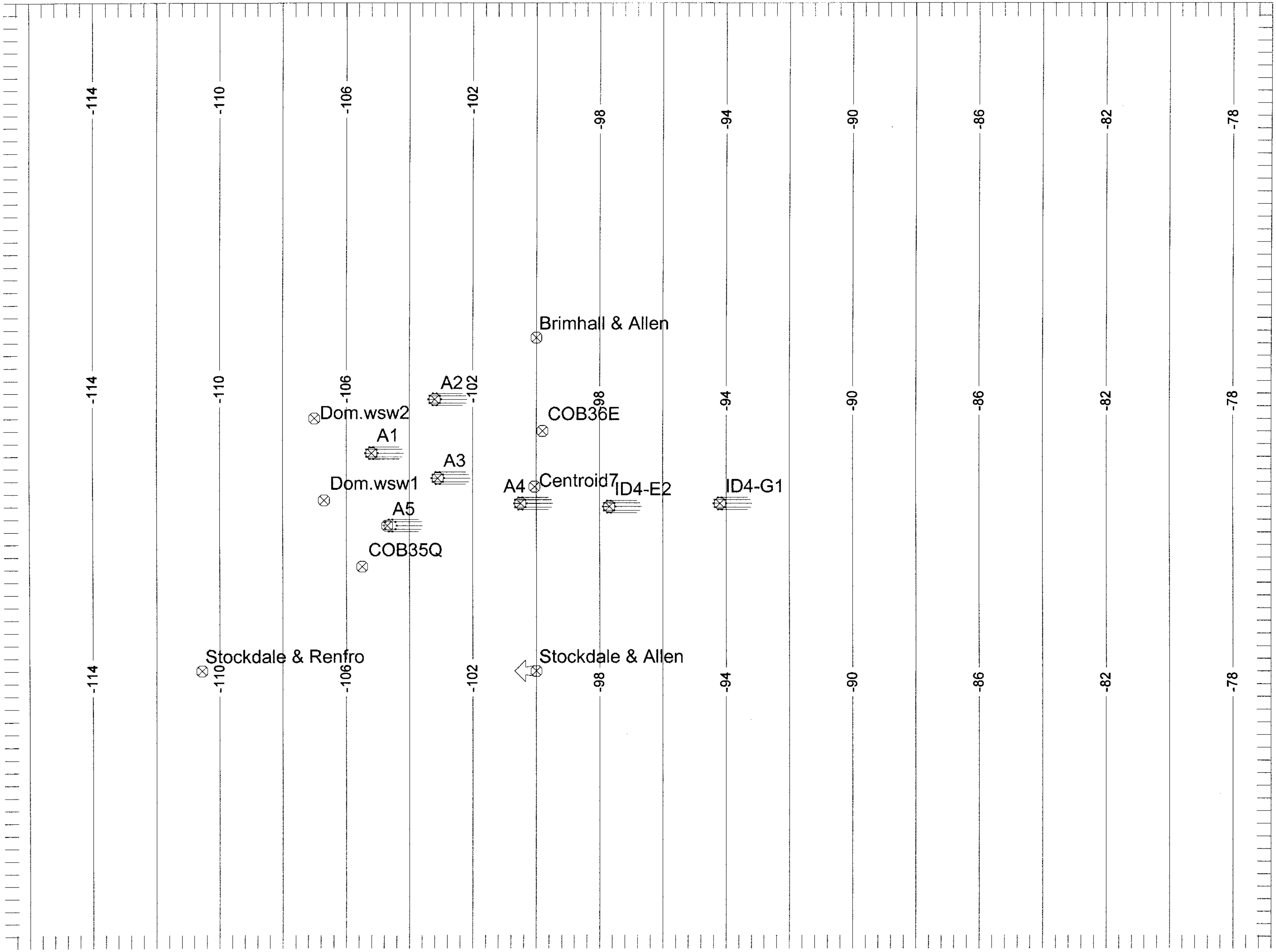
Stockdale & Renfro
Stockdale & Allen

002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A3
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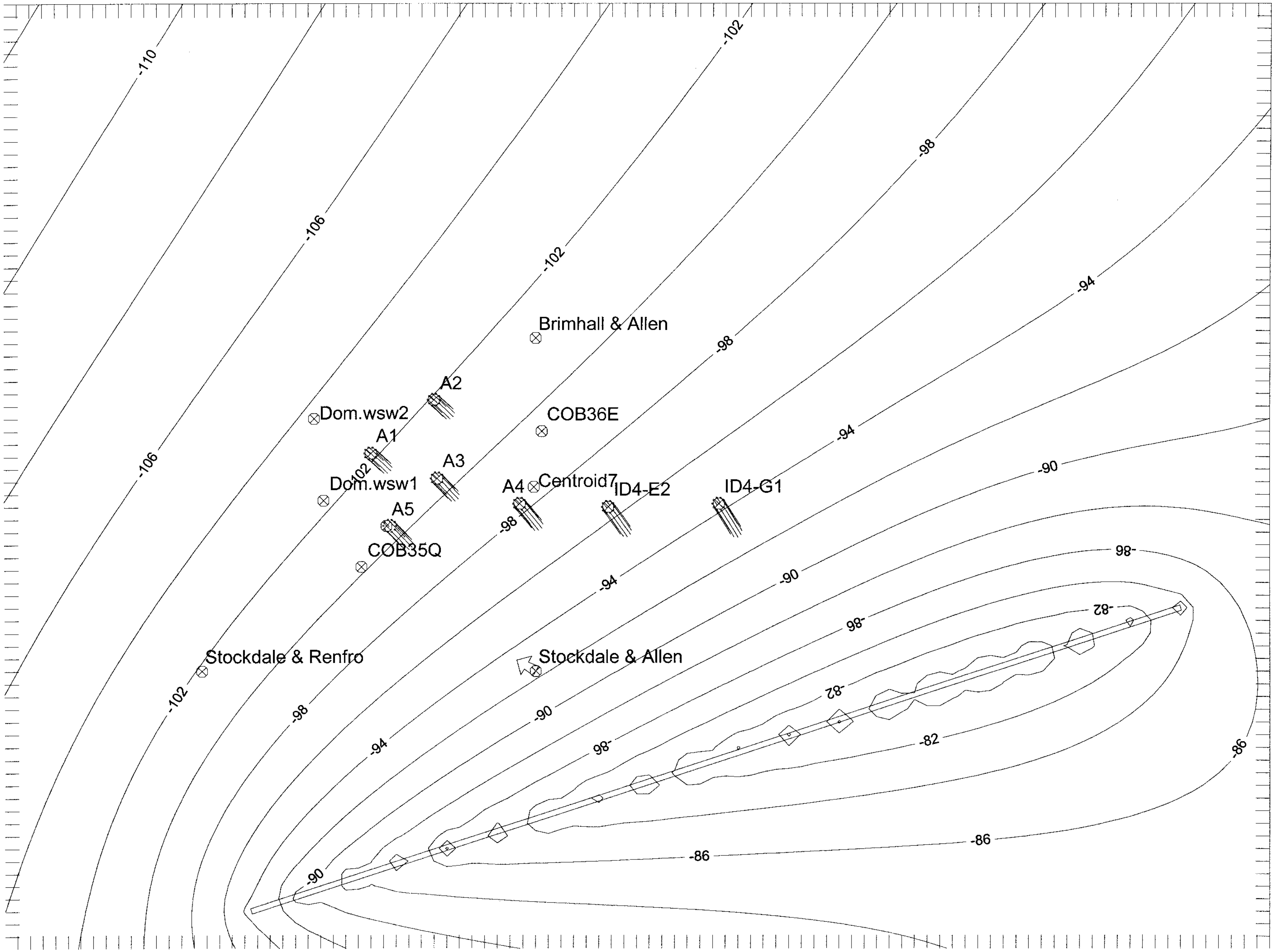
COB35Q
Stockdale & Renfro
Stockdale & Allen

003



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A3
Dom.wsw1
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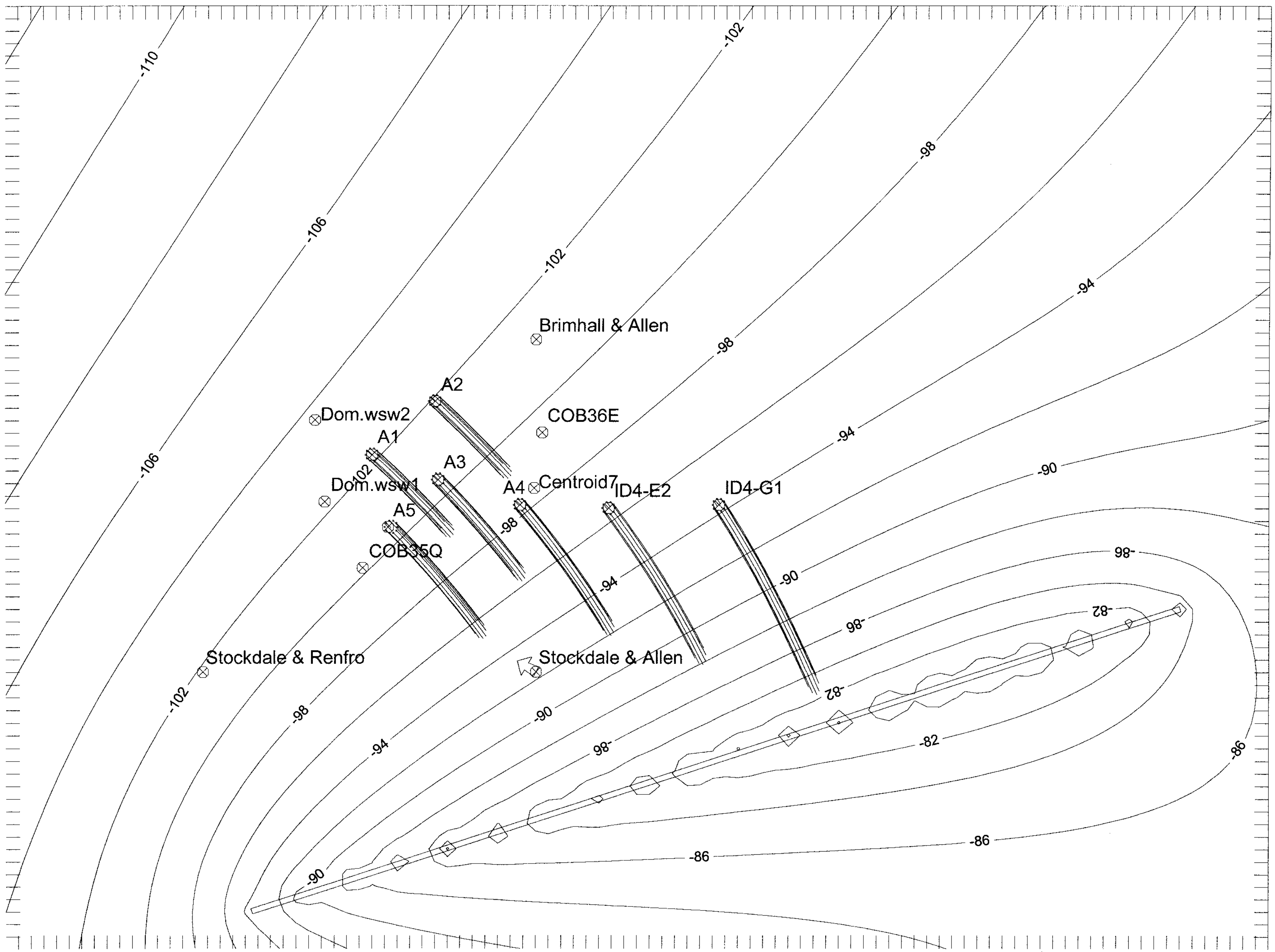
Centroid7
ID4-E2
ID4-G1
A5
COB35Q
Stockdale & Renfro
Stockdale & Allen

GO 4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Brimhall & Allen
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COB36E
A1
A3
Dom.wsw1
Centroid7
A4
ID4-E2
ID4-G1
A5
COB35Q
Stockdale & Renfro
Stockdale & Allen

005

Appendix 6.

Discussion

SETS 01 - 06.

Summary of Drawdown Analyses; Sets 1 - 6.

Set 1. Base case and limiting cases.

The aquifer in the area of interest is neither a fully confined aquifer nor a fully unconfined aquifer. The aquifer is a semi-confined aquifer, also referred to as a leaky aquifer, meaning that this aquifer is bounded on the top by a semi-permeable layer (an aquitard) rather than impermeable layer. Furthermore, this semi- confining layer is itself overlain by another water-bearing zone which is a source of recharge water to the aquifer. The aquifer gets recharged from above as well as from the sides, and this is how we have modeled the aquifer in the project area for the calculation of drawdowns.

We can also calculate hypothetical drawdowns as if the aquifer were either fully confined or fully unconfined, all else being equal, as well. It is useful to do so for illustrative purposes because the drawdowns are dramatically different and serves to remind the user of the pitfalls of underestimating the importance of careful model and parameter selection.

Leaky aquifer. In our opinion, this is the computational model that best represents the actual aquifer conditions in the project area. The base case drawdown is for seven wells pumping continuously for 300 days from a leaky aquifer with a parameter set which currently consists of the best available measured values for the required parameters. Under these conditions, the drawdown due to pumping is predicted to decline for only 10 - 20 days before leveling out and remaining steady for an indefinite period, perhaps years, depending on actual recharge.

This steady state condition will persist as long as the rate of aquifer extraction is re-supplied by the rate of downward recharge from the overlying water table, i.e., leakage into the aquifer. This steady state could continue for a long time and represents the limiting condition for a leaky aquifer, as long as recharge keeps up with extraction. It is possible that pumping may never continue long enough to exceed leaky steady state behavior.

If the project area does not receive sufficient recharge, then the shallow zone may be dewatered in which case shallow wells may go dry. If this happens, then leakage will be insufficient to re-supply the rate of extraction, at which time the pumping will continue to remove water from aquifer storage and the head will continue to decline. If the confined aquifer were laterally infinite, then the head would continue to decline forever. But the project area is relatively close to an upgradient recharge boundary so that even drawdown in the confined aquifer would ultimately stabilize at some lower head.

Confined aquifer. This computational model has been used by other workers in previous investigations but, in our opinion, it does not represent the observed historical - and expected future- behavior of the aquifer in the project area. This hypothetical case is for seven wells pumping continuously for 300 days from a fully confined aquifer with the same parameter set except that there is no leakage and all water comes from aquifer storage. Under these conditions, the drawdown due to pumping is predicted to decline forever in an infinite aquifer. The drawdown after a pumping duration of 300 days is about 90% of the total drawdown that would be observed after a pumping period of 3 years, so for any of the proposed operating scenarios this essentially represents the confined aquifer limiting case.

Unconfined aquifer. This computational model is not representative of the observed historical- or expected short- term- behavior of the aquifer in the project area under the project assumption of ongoing recharge but, in our opinion, may represent the long- term behavior of the aquifer if long- term total recharge does not keep up with total recovery in the greater project area. This hypothetical case is for seven wells pumping continuously for 300 days from a fully unconfined aquifer with the same parameter set except that there is no aquitard and all water comes from dewatering the aquifer. Under these conditions, the drawdown due to pumping is also predicted to decline forever in an infinite aquifer. Like the previous case, the drawdown after a pumping duration of 300 days is about 90% of the total drawdown that would be observed after a pumping period of 3 years, so for any of the proposed operating scenarios this essentially represents the unconfined aquifer limiting case.

The aquifer in the project area is not currently an unconfined aquifer but it could become one if the shallow aquifer is dewatered and/or insufficiently recharged. If the actual aquifer conditions start out in the leaky aquifer condition and then change to an unconfined condition, then the observed drawdowns will no longer remain at the leaky steady state static levels but will continue to decline in the project area until the predicted unconfined drawdowns have been achieved.

Set 2. Variation of base case drawdown with leakage rate (B) for t = 300d.

The rate of leakage through the aquitard determines the rate of aquifer recharge and this leakage rate is incorporated mathematically into the model through the Hantush leakage factor (B). Higher leakage rates (lower B values) cause the drawdown to stabilize at the steady state value more quickly and at a smaller final drawdown. Conversely, lower leakage rates (higher B values) cause the aquifer to behave more like a confined aquifer in which drawdown lasts longer and is larger when it finally stabilizes.

We have calculated the drawdowns for the other base case parameters and for the set of leakage values of B = 1800, 2200, 2600, 3200, 5000, 10000. For example, a leakage factor of B = 2,000 might represent a thin, more transmissive aquitard perhaps 20 ft thick aquitard with a Kv = 0.1 ft/d, while a leakage factor of B = 10,000 might represent a thicker, less transmissive aquitard perhaps 50 ft thick aquitard with a Kv = 0.05 ft/d.

As previously discussed, the overall aquitard leakiness of this particular project area is neither that of the silts alone nor of the interbedded sands alone, but a composite intermediate value of both which cannot be determined from the limited E-log data in the project area. The leakance of the aquitard is complicated by the unretarded vertical flow at the edges of a localized silt/clay layer. The bypass flow makes an aquitard look leakier than the measured parameters indicate, but this is very difficult to evaluate. The discontinuous nature of the aquitard contributes an unpredictable component of non-ideal behavior to the results which we cannot model, but some of the observed differences between predicted and actual drawdown behavior which we anticipate will be observed once the project has begun will likely be due to different rates of leakage recharge at different pumping wells based on the non-ideal particular properties of the overlying aquitard at those locations.

Set 3. Variation of base case drawdown with time (t).

Based on the base case parameter values, we calculate that drawdown will stabilize at the steady state maximum drawdown after 10 - 20 days. This means that as long as the shallow water table aquifer continues to supply the underlying semi-confined aquifer with recharge water, the aquifer drawdown *will remain constant*, even for three consecutive years of pumping. The accuracy of this hypothetical forecast depends mostly on whether or not sufficient water is recharged into the project area to sustain the recovery volumes over time. We have calculated the drawdowns for the base case parameters and for the set of pumping times of t = 10, 30, 100, 300, 720 days. The calculation for t = 720 d represents the 300 recovery days per year for 3- consecutive year operating scenario after being corrected for the effect of two months recovery time in between pumping periods.

Set 4. Variation of base case by varying pump duration (t) at $Q = Q_{full}$.

In any year for which the amount of groundwater to be recovered is less than the project design capacity of 27,000 af over a 300 day period, the operator has several options. The operator might pump all wells at the design pump rate but for a shorter time period. The operator might pump all wells for the full period but at a lower pump rate. The operator might also pump fewer wells at any combination of rates and durations which will supply the required recovery volume. The evaluation of the secondary factors which might govern such a decision are outside the scope of this analysis but they might include scheduling priorities or capacity availability in conveyance systems, differing well efficiencies and lifting costs, water quality issues, etc. For our scope of work, we have evaluated the drawdown scenarios for 50% and 25% of the 100% base case recovery volume of 27,000 af.

Before we present the results, we can state certain qualitative differences in the amount of drawdown associated with each of these choices based on applicable flow theory. For a given recovery volume where the choice is to either cut the pumping time in half or cut the flow rate in half, the drawdown is always significantly smaller by cutting the flow rate and increasing the time correspondingly. For a given recovery volume where the choice is to either use all wells or fewer wells, the drawdown is always somewhat smaller by using all wells because the extraction is distributed over a somewhat larger pumping area.

The first set of illustrative variations is to operate all wells at full design pump rates for pumping durations of t = 300, 150, & 75 days to recover 100%, 50%, and 25% respectively of the base case recovery volume of 27,000 af. As we have previously presented, the drawdowns for all three cases are exactly the same because all three of these pumping durations exceed the time required to achieve leaky steady state. Therefore, shortening the pumping time does not lessen the amount of drawdown. What is not illustrated in these scenarios is that since pumping lasts for a shorter time period, the drawdown also lasts for a shorter time period before the aquifer begins to recover. For anyone who might operate a domestic water supply well in the zone of impact, two months of extra lift is easier to bear than 5 or 10 months.

Set 5. Variation of base case by varying flow rate (Q) for t = 300d.

The second set of illustrative variations is to operate all wells for the full 300 day recovery period but at lower pumping rates of Q = 50% or 25% of Q_{full} to recover 50% or 25% respectively of the base case recovery volume. Although the pumps will run at lower efficiency, the payoff is big in terms of reduced drawdown impacts. If the wells are operated at x% of base case, then the drawdowns will be x% of the base case drawdowns! So, by operating at 50% of full Q, the drawdowns will be 50% of the base case drawdowns, although they will last for the same length of time. Therefore, reducing the pumping rate causes significant reductions in the amount of drawdown at all locations and for any pumping period.

Set 6. Variation of base case by pumping only selected wells (t = 300d).

The third set of illustrative variations is to operate some but not all wells for the full 300 day recovery period. We have selected just three of many possible cases for illustration. One case is to pump just the five RRB wells at full pump rate of 5 cfs for a 300 day recovery period which would supply about 56% of the full recovery capacity. A second case is to pump just the two ID4 wells at full pump rate of 10 cfs for a 300 day recovery period which would supply about 44% of the full recovery capacity. The third case is to pump one RRB well and one ID4 well at their respective design rates for a 300 day recovery period which would supply about 33% of the full recovery capacity. For this third case, we selected the two wells which are the farthest apart, i.e., at opposite ends of the east - west trending well field.

Because the first two cases add up to 100% of the full base case, these two cases represent the respective components of the total drawdown for the wells west of Allen Rd (case 1, RRB wells) and east of Allen Rd (case 2, ID4 wells). Divided in this way, either grouping can supply approximately 50% of the base case recovery volume and the drawdowns from each are centered on significantly different parts of the project area.

The third case illustrates the overlapping impacts of two pumping wells which are about 5,500 ft apart after 300 days of pumping. The westerly well pumps at 5 cfs while the easterly well pumps at 10 cfs. The differences in drawdowns are most pronounced in the vicinity of each well, where the drawdowns of the 10 cfs well are twice that of the 5 cfs well. The drawdowns become more nearly alike at the farther radial distances from each well as the drawdowns decrease logarithmically with distance out to the edge of the zone of influence. These two wells can supply about 33% of the base case recovery volume.

There are numerous other possible operating scenarios to recover any amount of water within the project design capacity, all of which involve a choice of wells, pumping rates, and pumping durations. An evaluation of other such scenarios is outside the scope of work, but can be completed, if desired, as an extension of this work program.

Appendix 6.

SET 01.

ID4 / KT / RRB Well Field Model Parameters.

Set No. 1.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

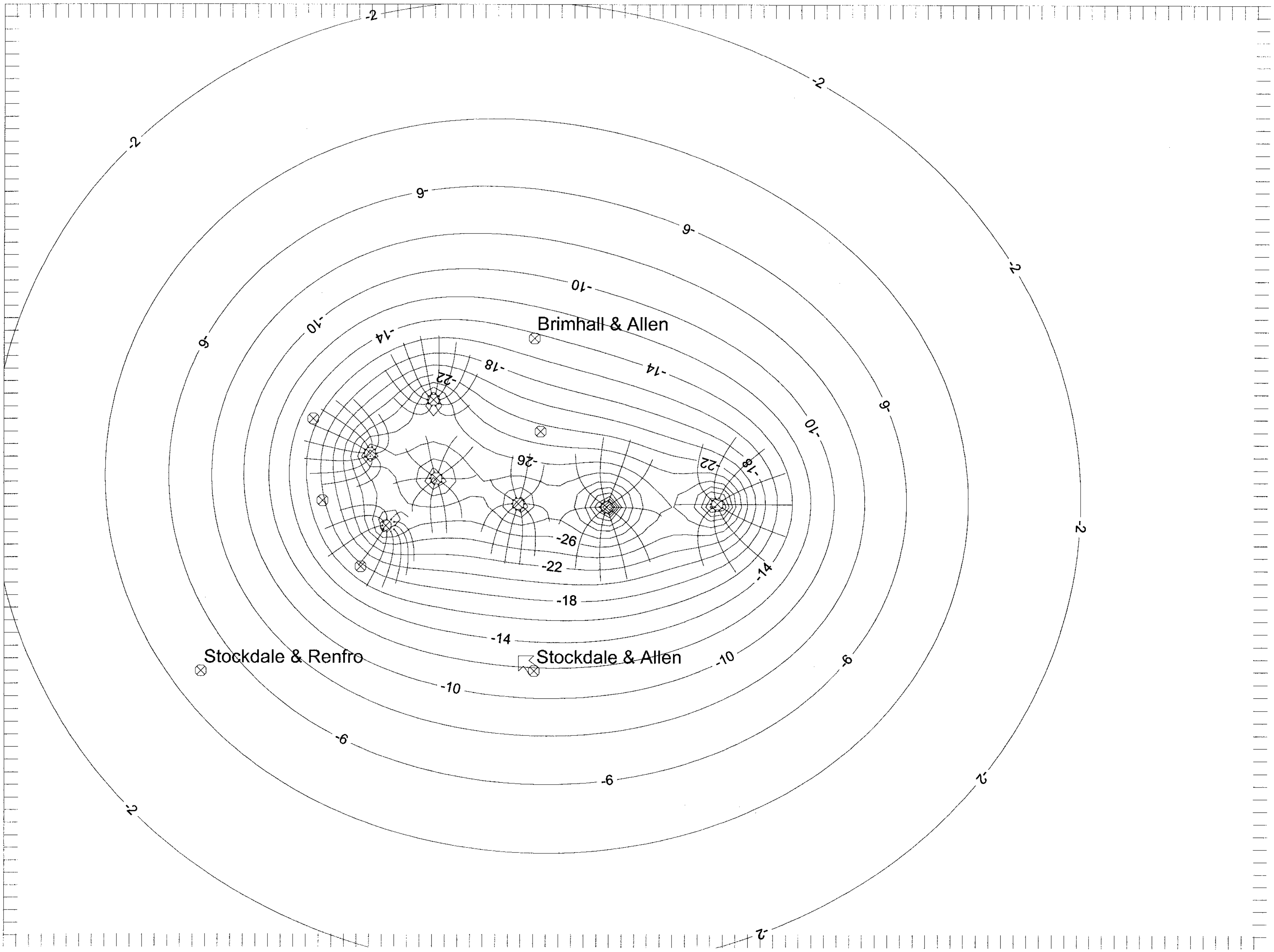
		base case												
model		leaky	confined	uncon	uncon	uncon	uncon	confined	leaky					
calc		transient	transient	transient	transient	transient	transient	transient	transient					
Run No.		101	102	103	104	105	106	107	108					

H.Cond.	K	80												
Btm	B	-450												
Top	T	-200		1				-200						
Ref Hd	R	0												
Grad	G	0												
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04			0.21		5.60E-04							
Lkg	L	3200	0						3200					
pump-t	t	300				770								

Ref Hd	Ref	0												
Grad	G	0												
Azim	A	135												
Ref-X	X	0												
Ref-Y	Y	0												

Const Hd	CH	no												
trace-t	tt	300												

Flow Rate	Q	full												
Wells	W	all				770								



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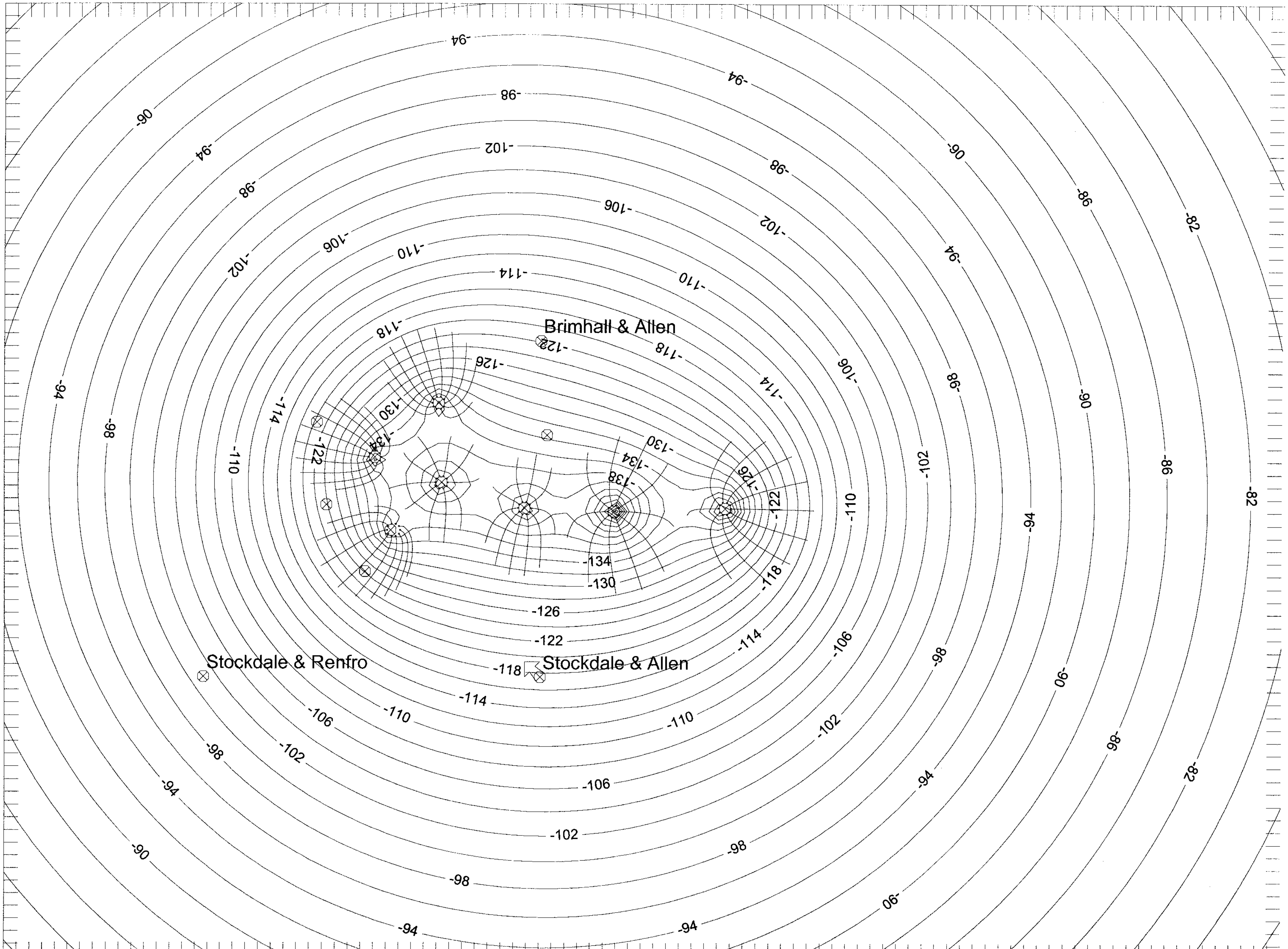
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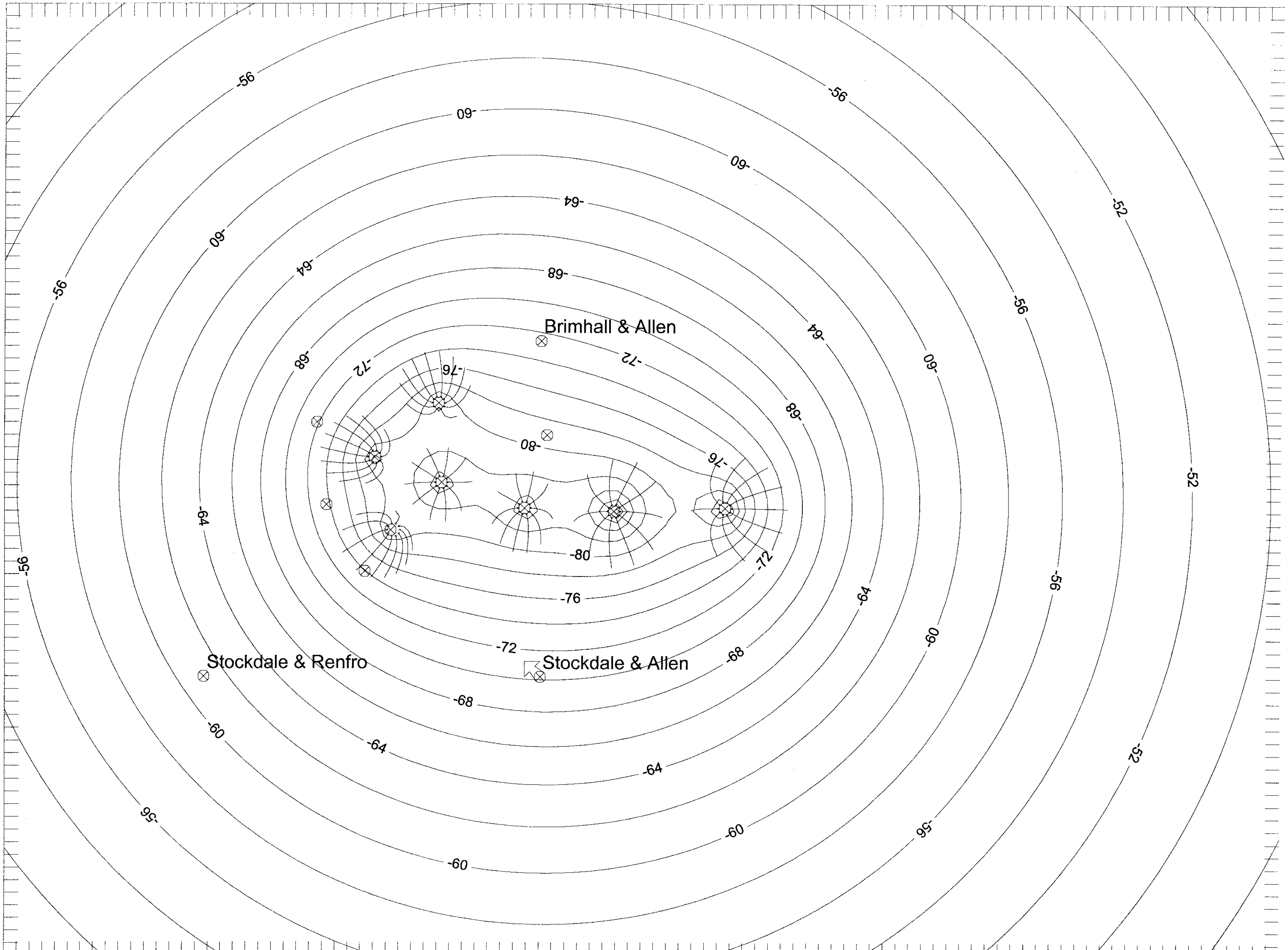
102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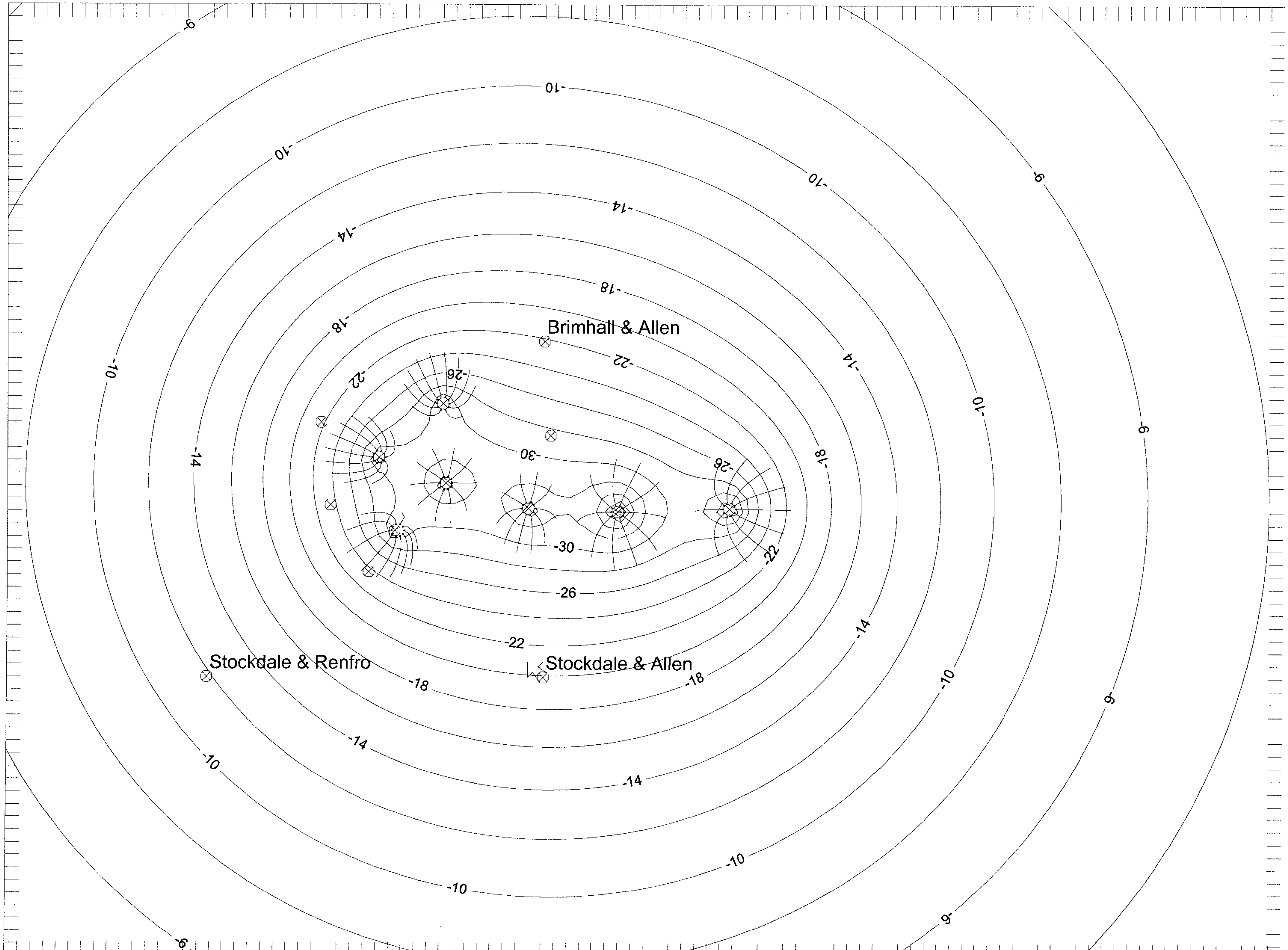
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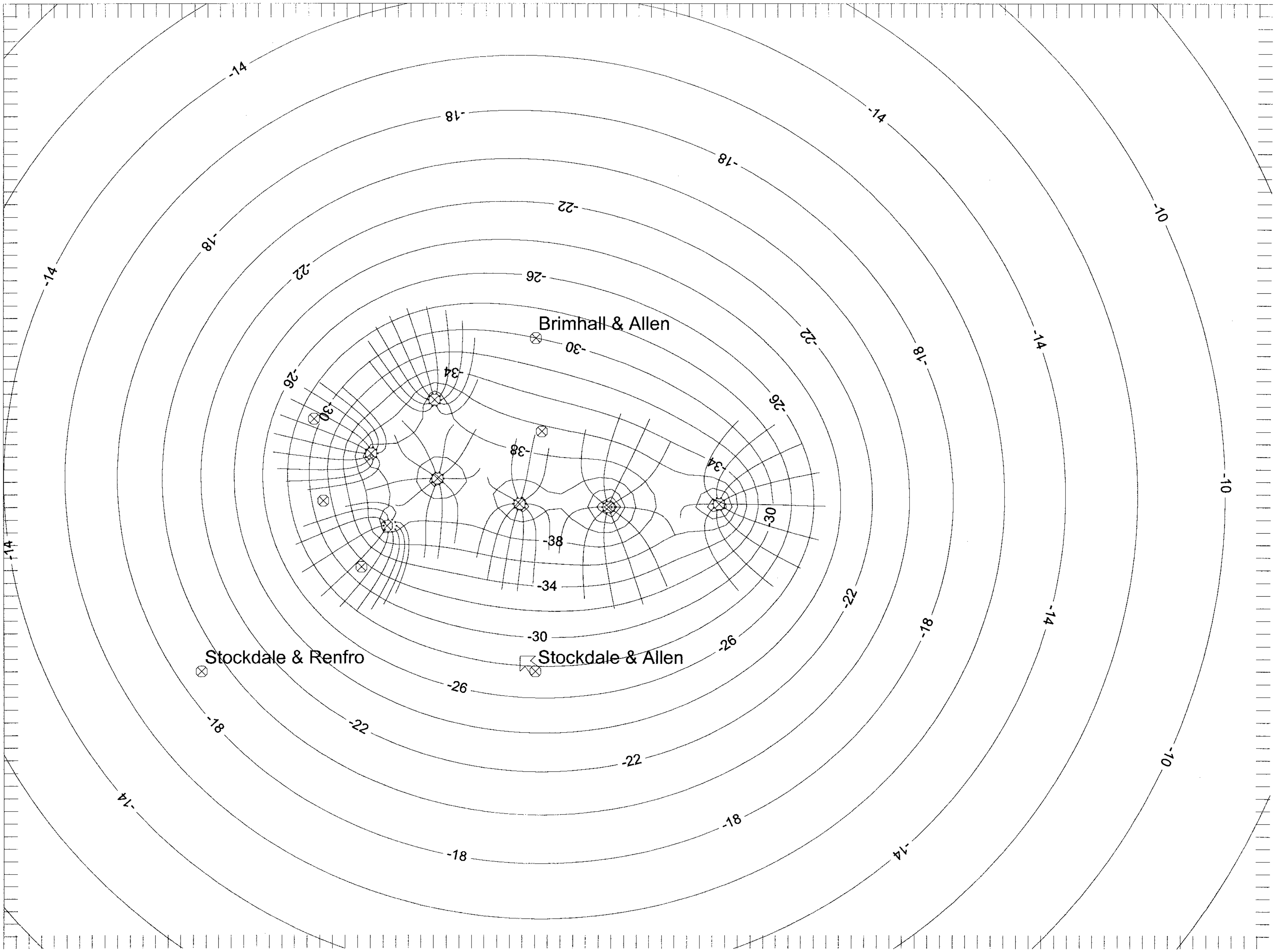
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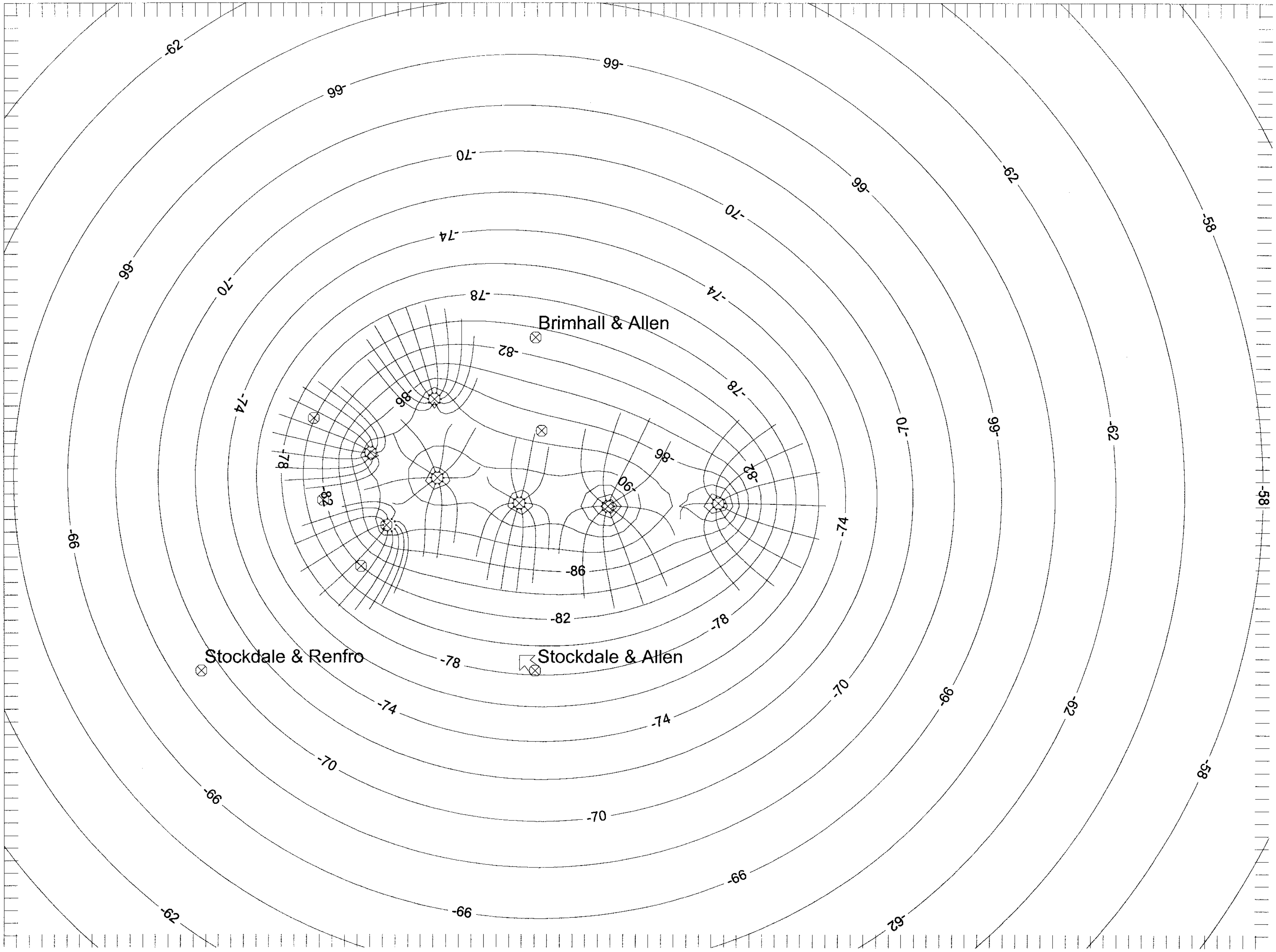
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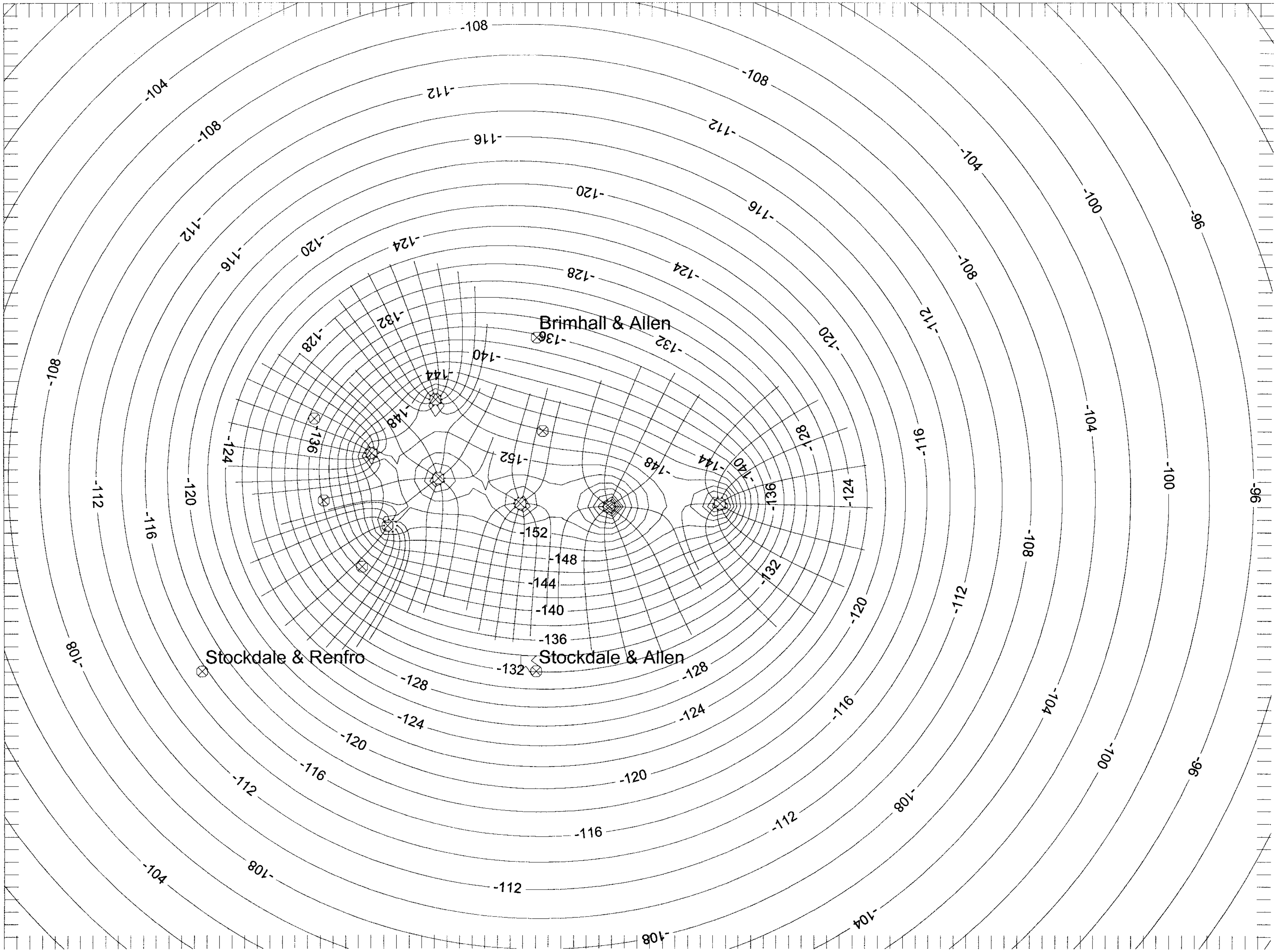
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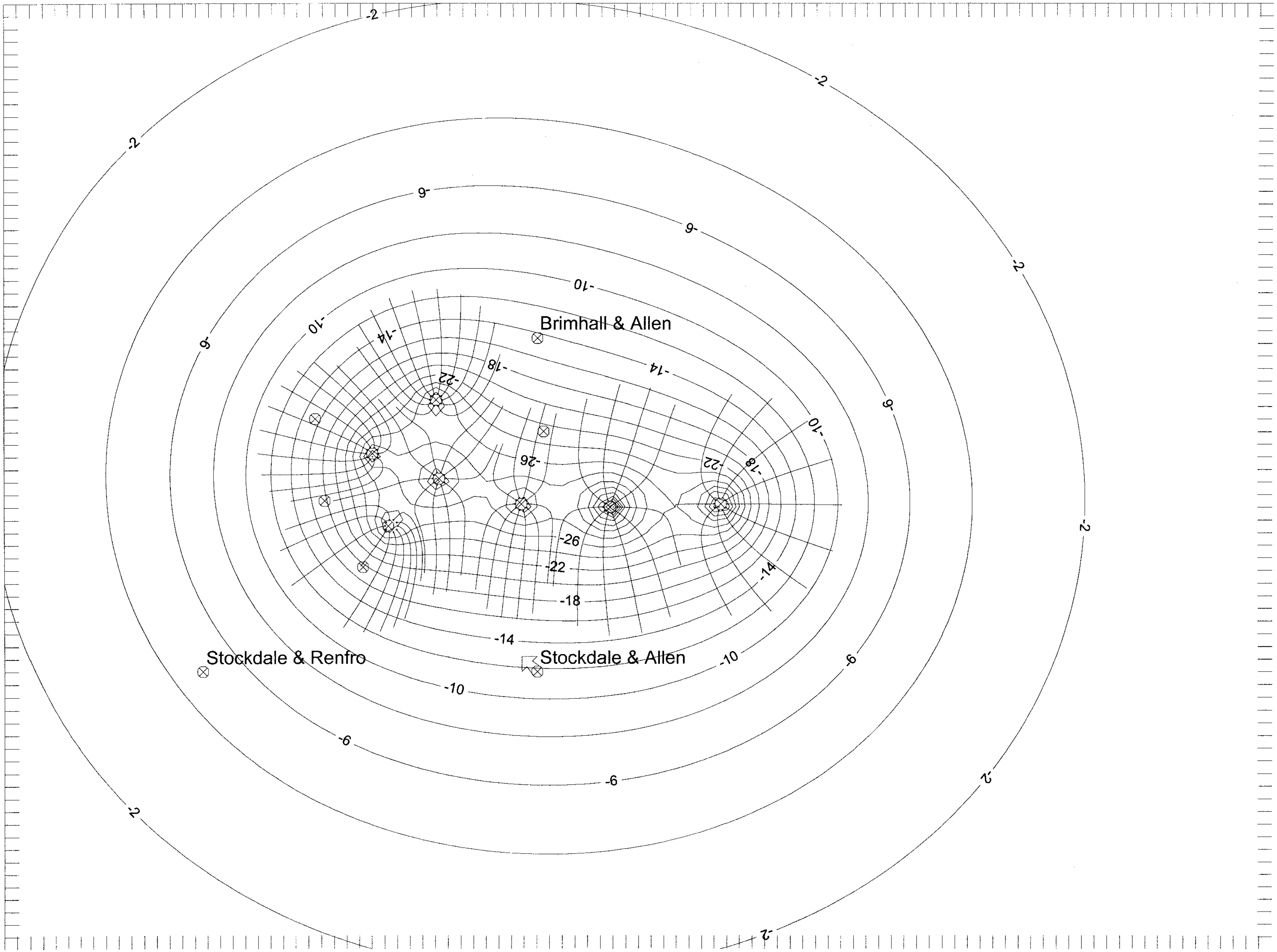
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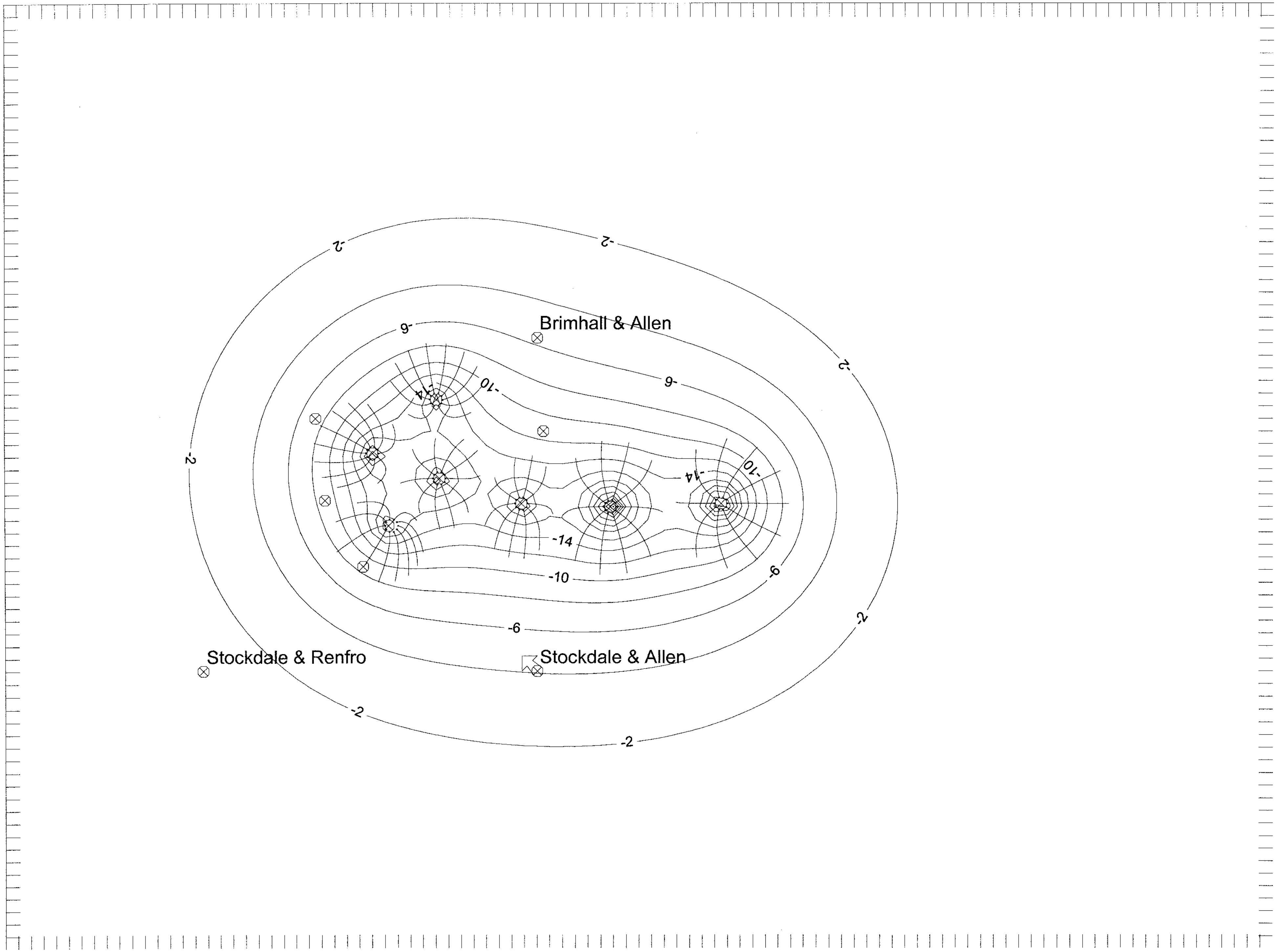
Appendix 6.

SET 02.

ID4 / KT / RRB Well Field Model Parameters.
Set No. 2.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky	leaky	leaky	leaky	leaky					
calc		transient	transient	transient	transient	transient	transient	transient	transient					
Run No.		ref.only	201	202	203	204	205	206	207					
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0												
Grad	G	0												
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200	1800	2200	2600	3200	4600	6000	10000					
pump-t	t	300												
Ref Hd	Ref	0												
Grad	G	0												
Azim	A	135												
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300												
Flow Rate	Q	full												
Wells	W	all												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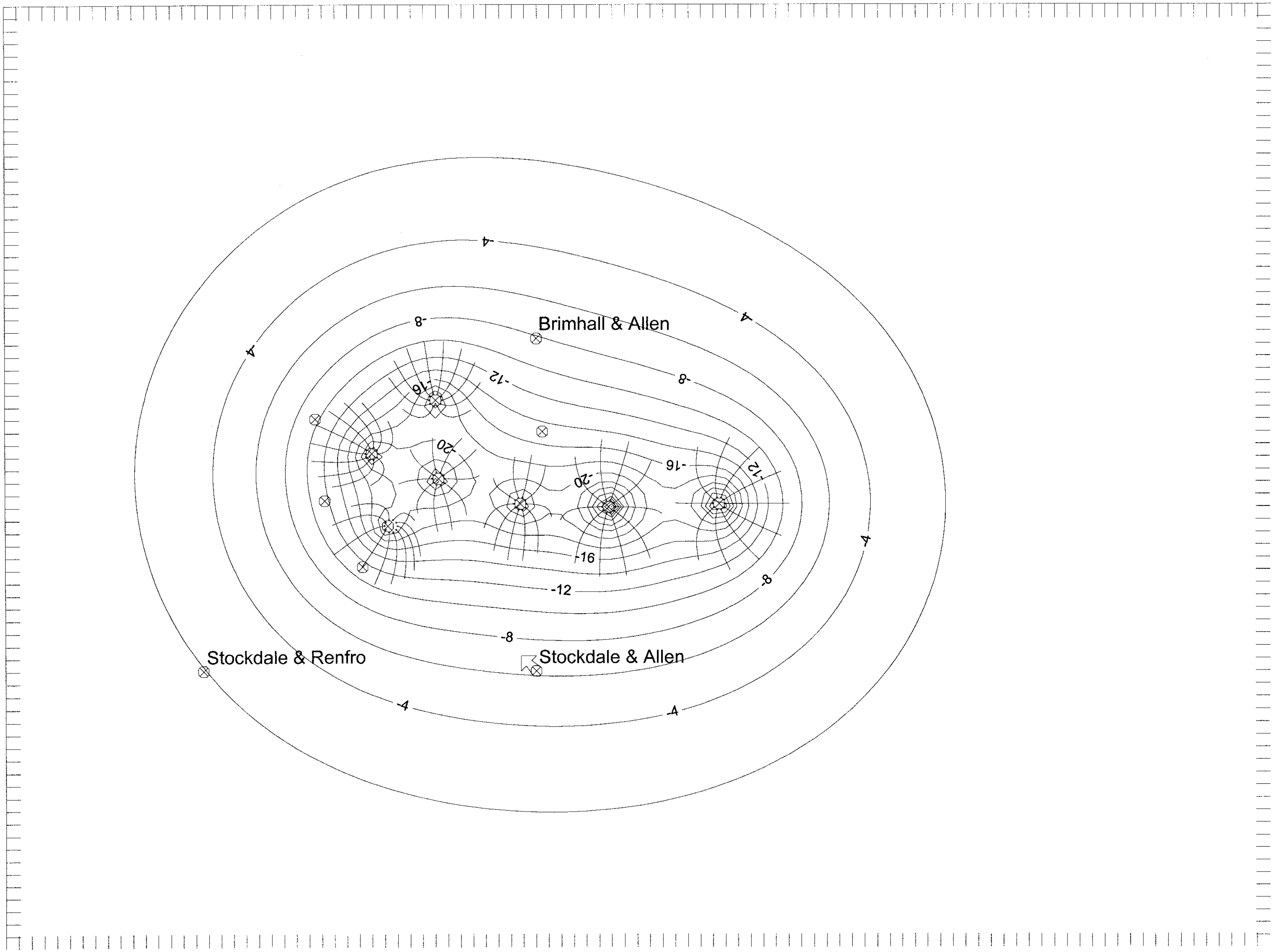
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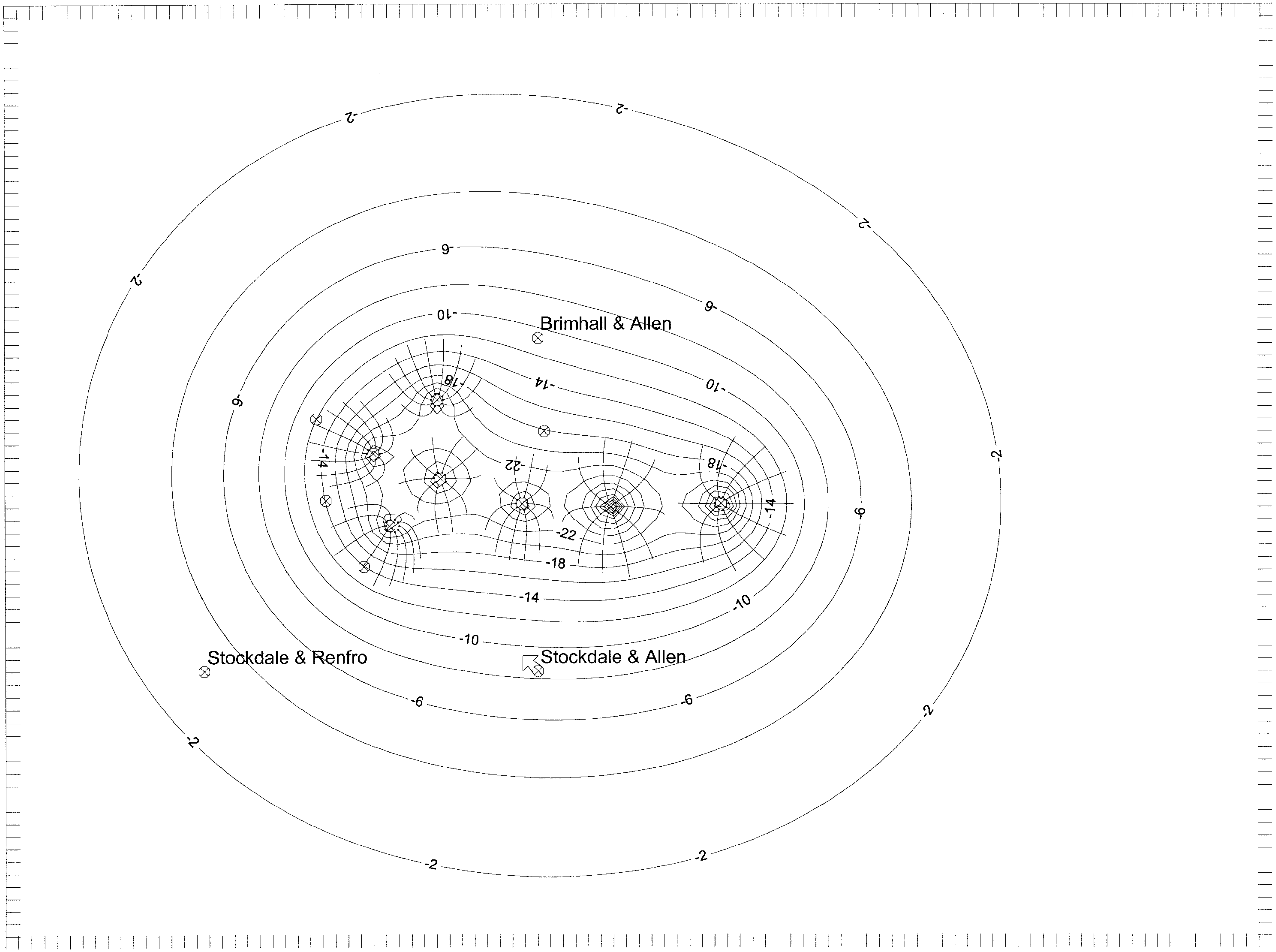
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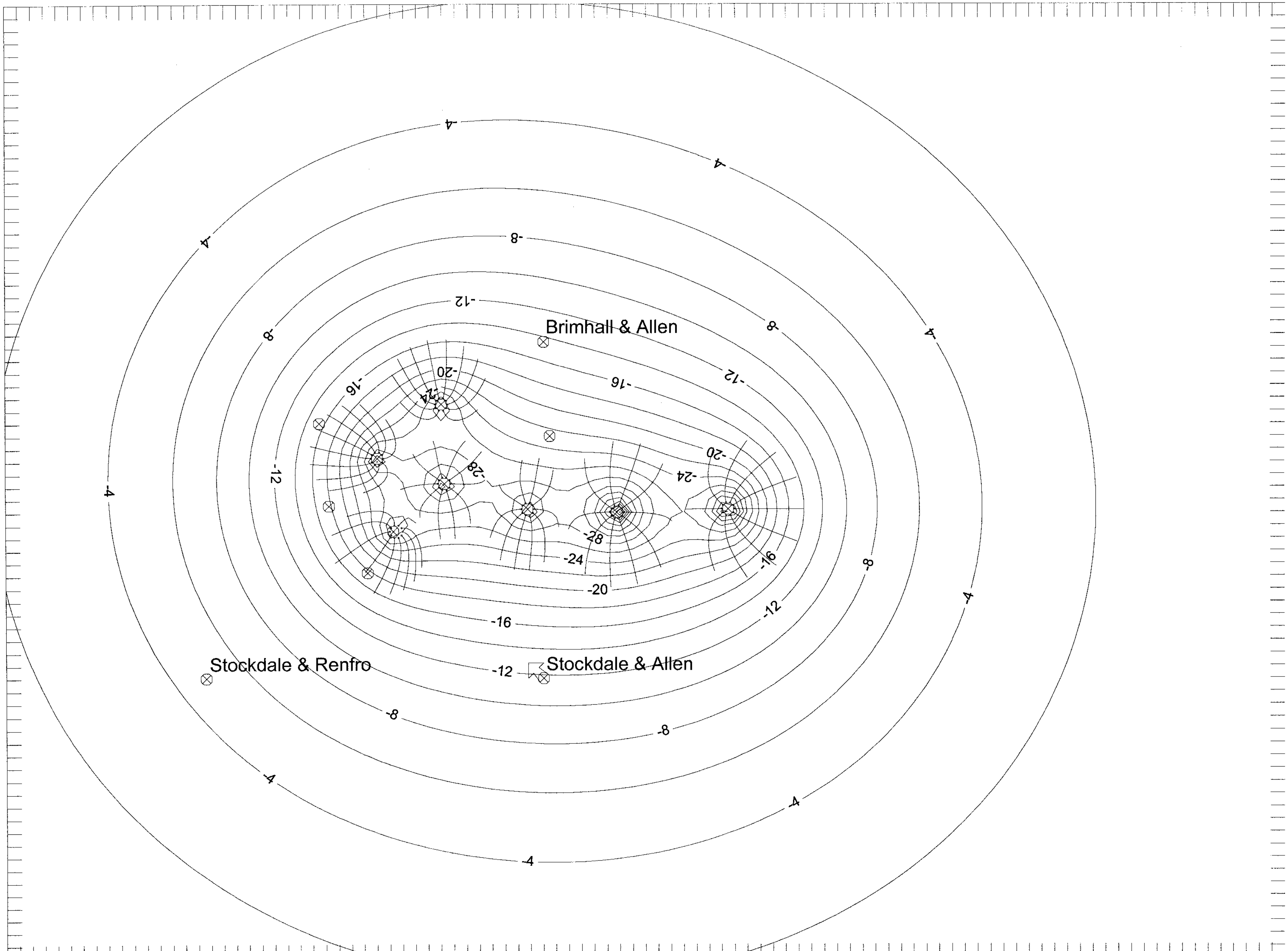
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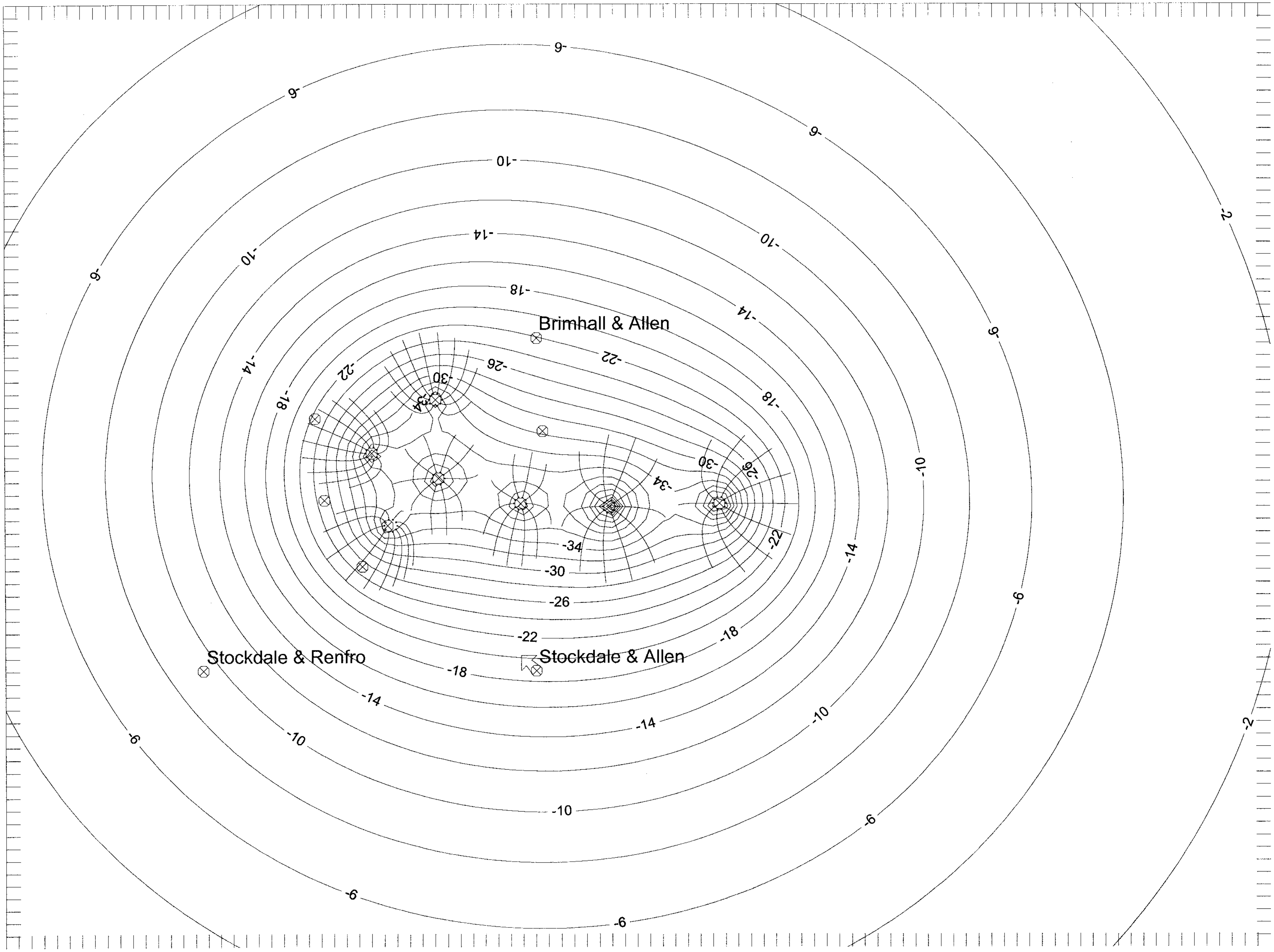

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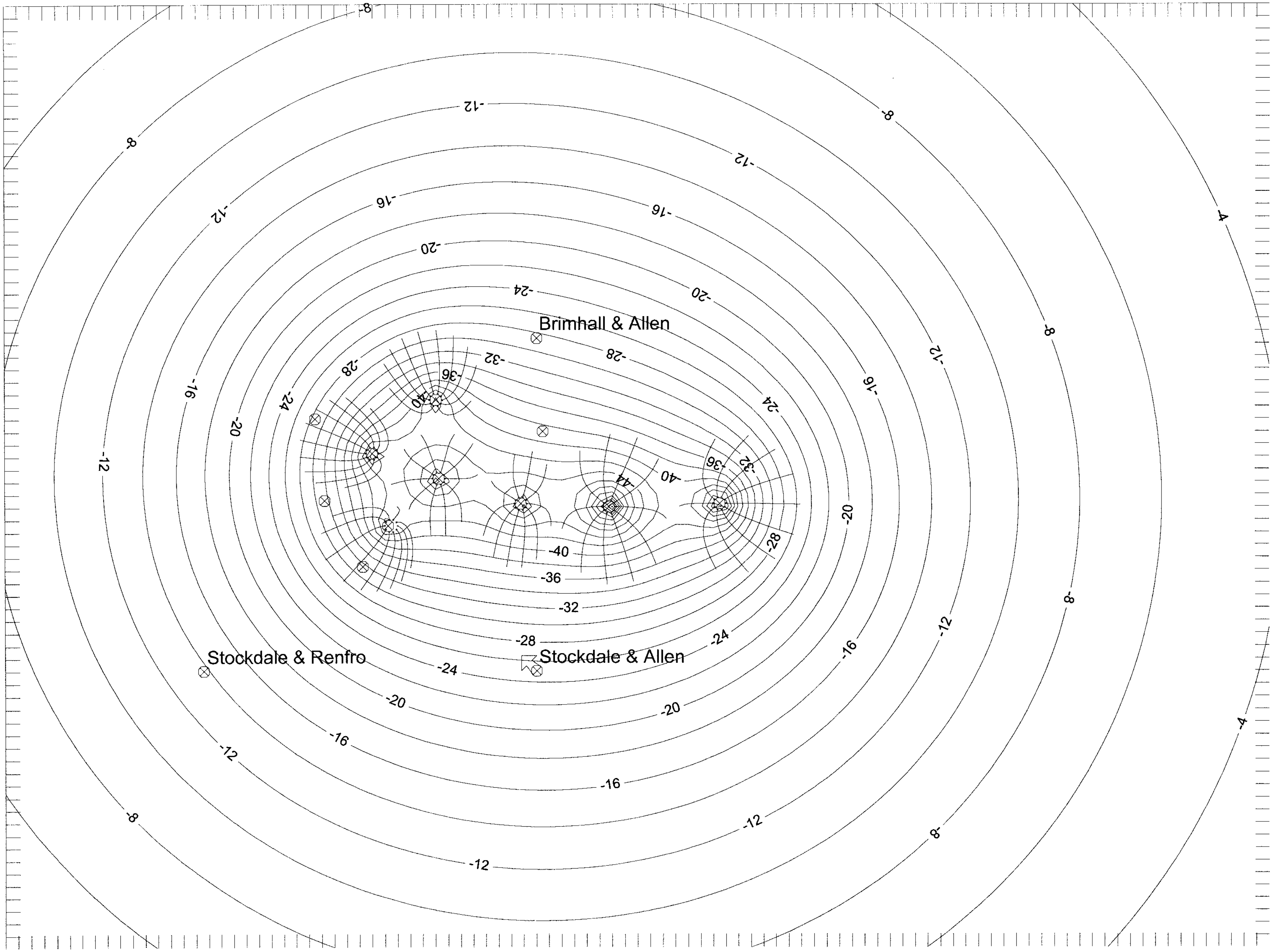
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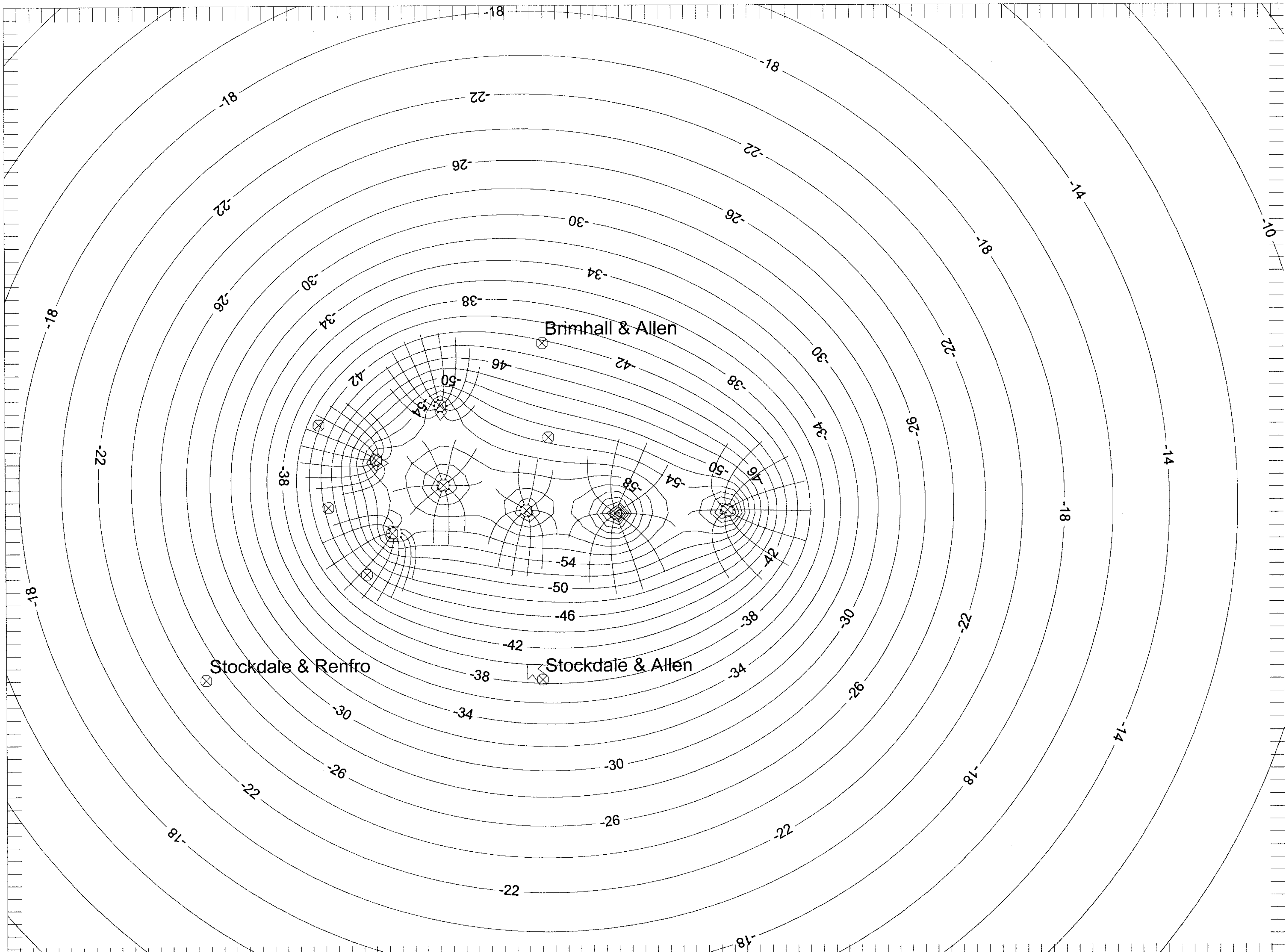

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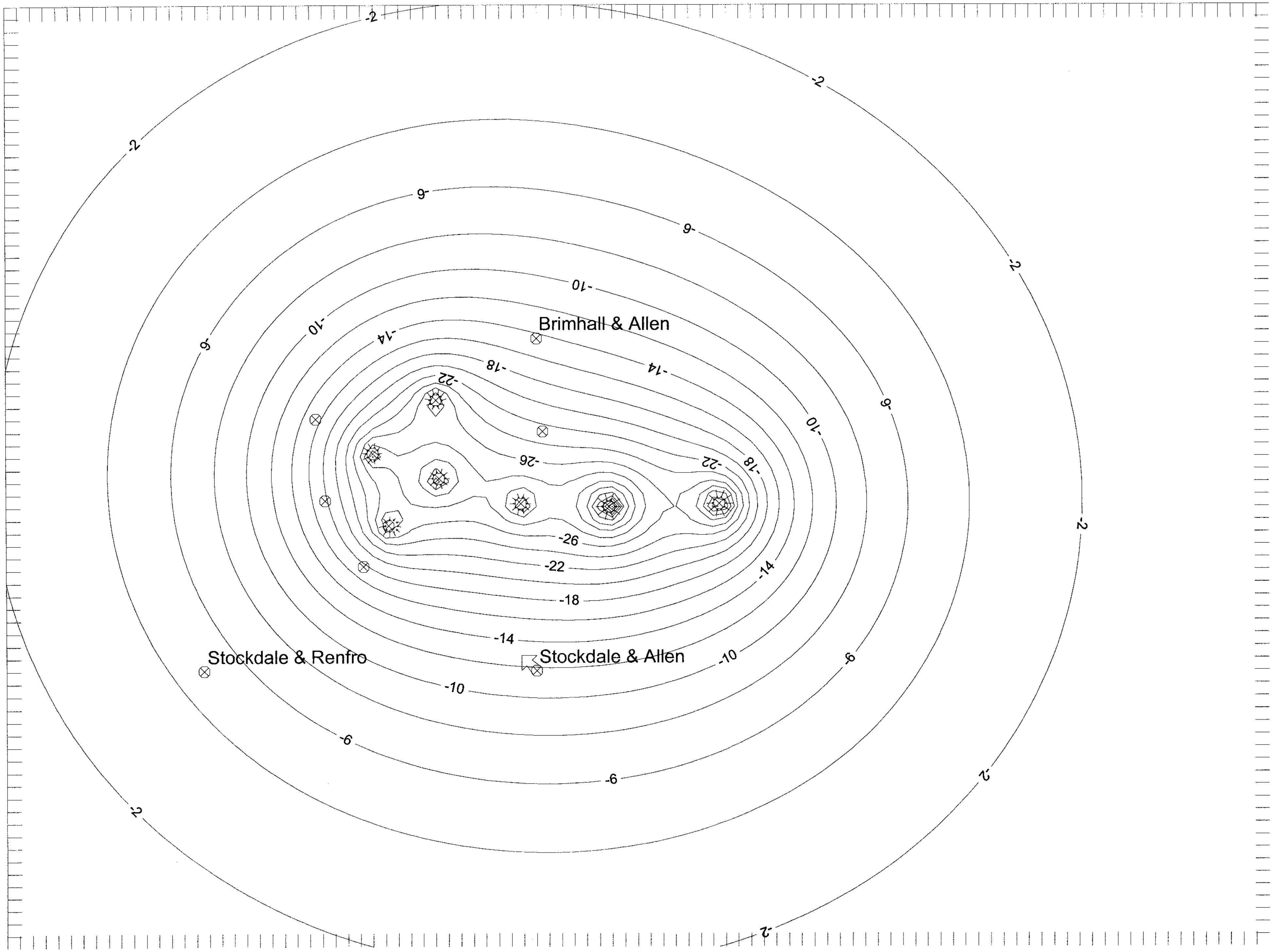
Appendix 6.

SET 03.

ID4 / KT / RRB Well Field Model Parameters.
Set No. 3.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky	leaky	leaky	leaky	leaky					
calc		transient	transient	transient	transient	transient	transient	transient	transient					
Run No.		ref.only	301	302	303	304	305							
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0												
Grad	G	0												
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300	10	30	100	300	770							
Ref Hd	Ref	0												
Grad	G	0												
Azim	A	135												
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300												
Flow Rate	Q	full												
Wells	W	all												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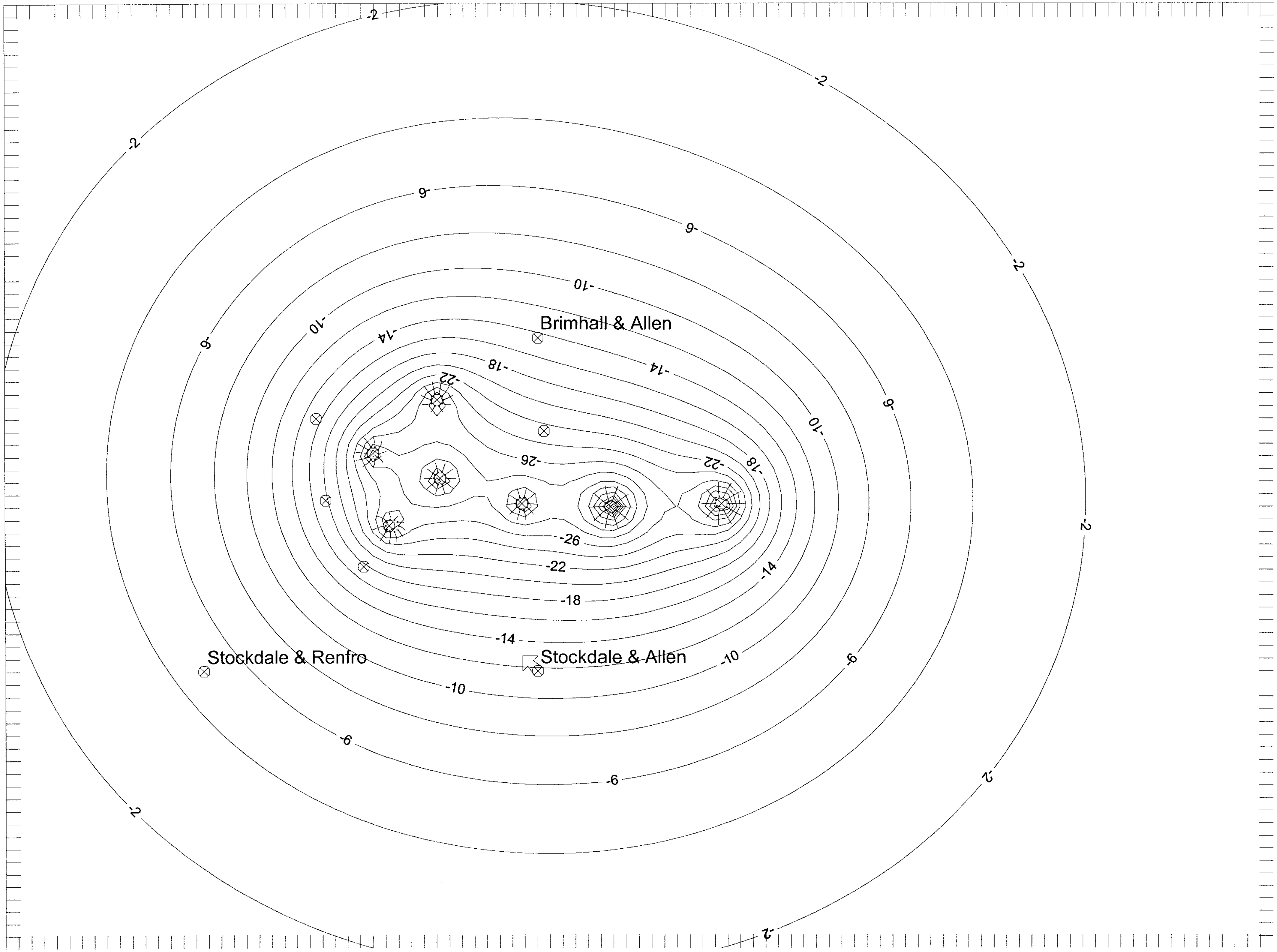
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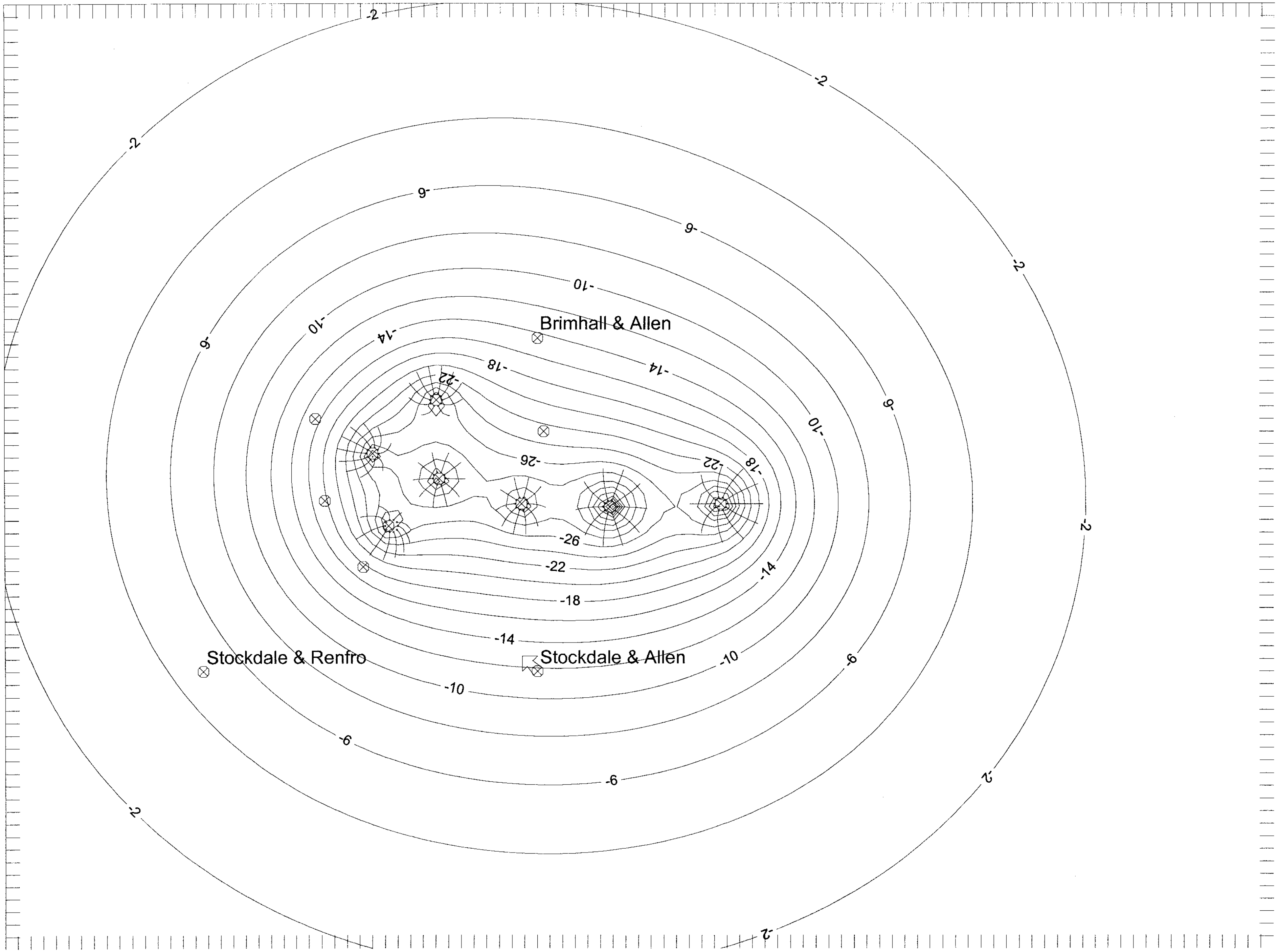
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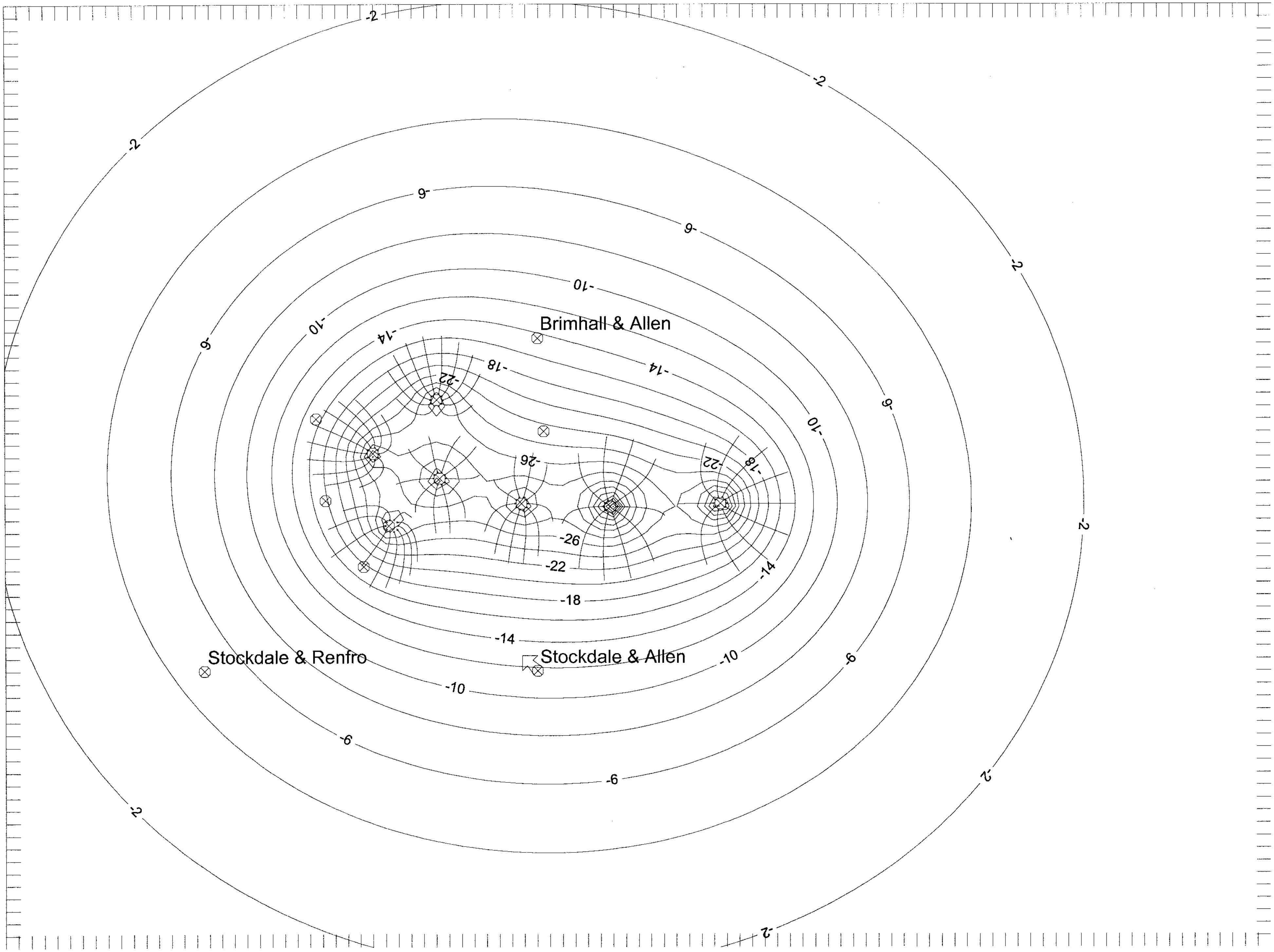
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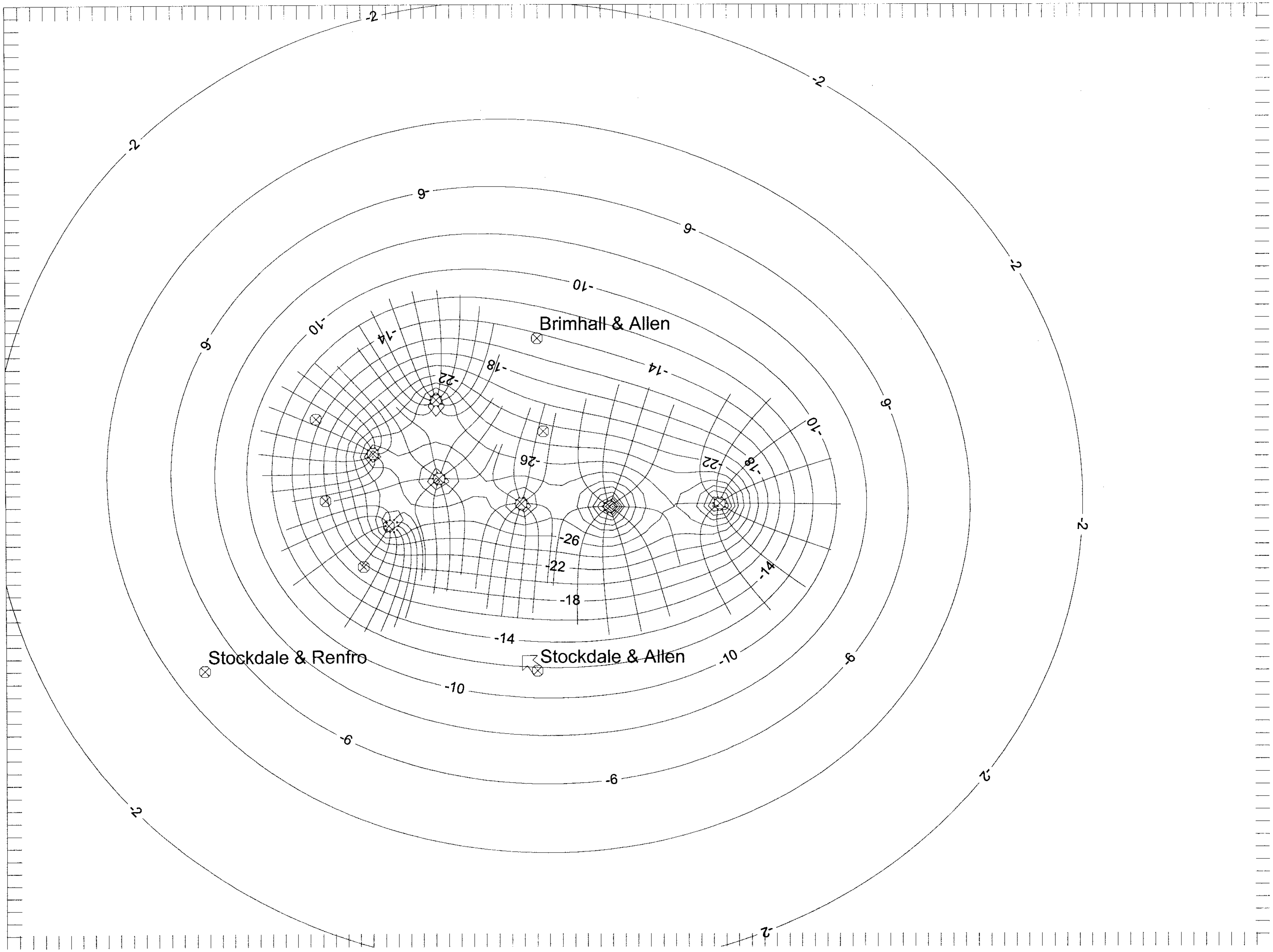
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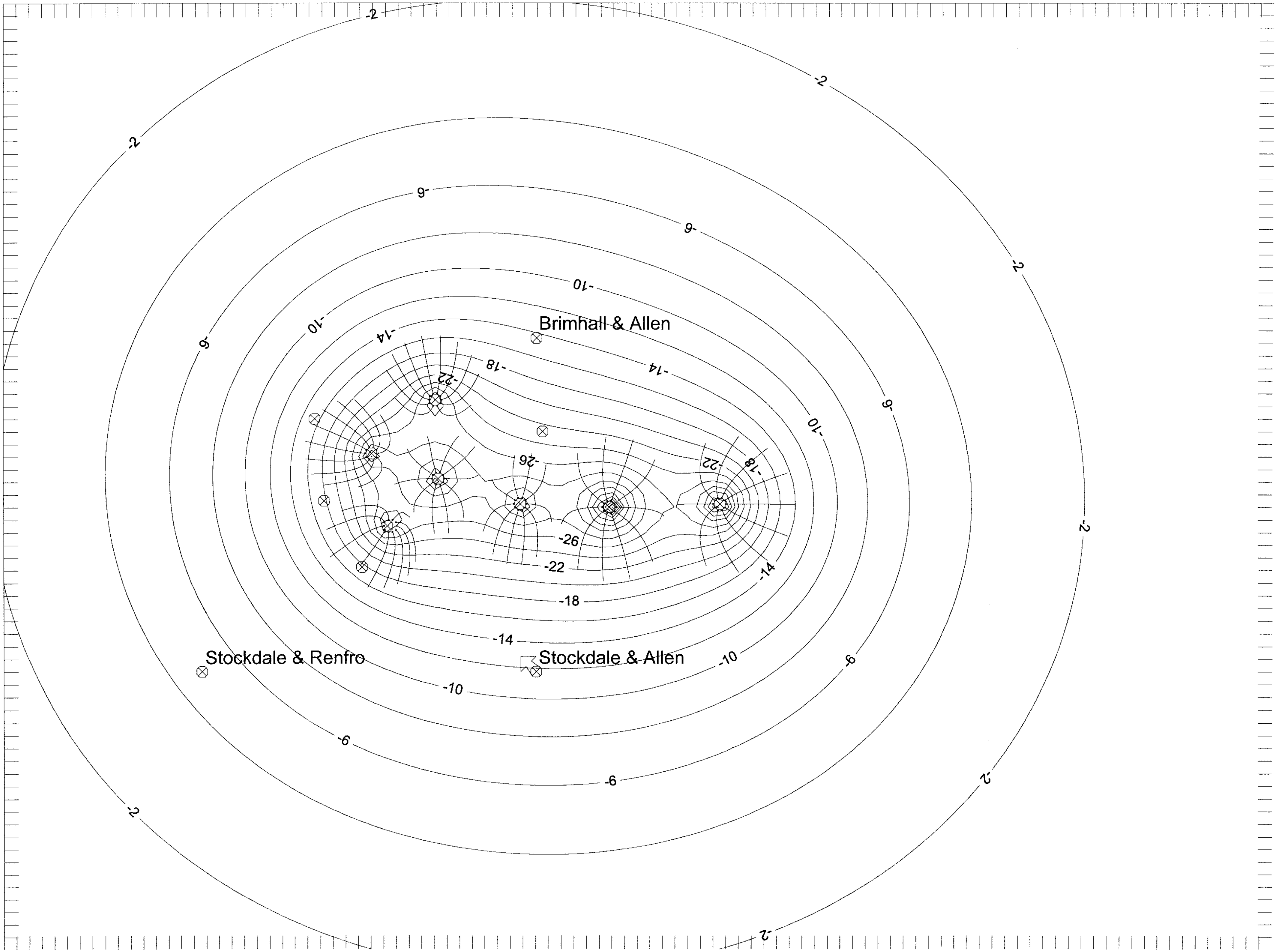
Appendix 6.

SET 04.

ID4 / KT / RRB Well Field Model Parameters.
Set No. 456.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky		leaky	leaky	leaky		leaky	leaky	leaky	leaky
calc		transient	transient	transient	transient		transient	transient	transient		transient	transient	transient	transient
Run No.		ref.only	401	402	403		501	502	503		601	602	603	604
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0												
Grad	G	0												
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300	300	150	75		300							
Ref Hd	Ref	0												
Grad	G	0												
Azim	A	135												
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300												
Flow Rate	Q	full					full	half	quarter		full			
Wells	W	all									all	A1-A5	ID4 1&2	A1 & ID4-2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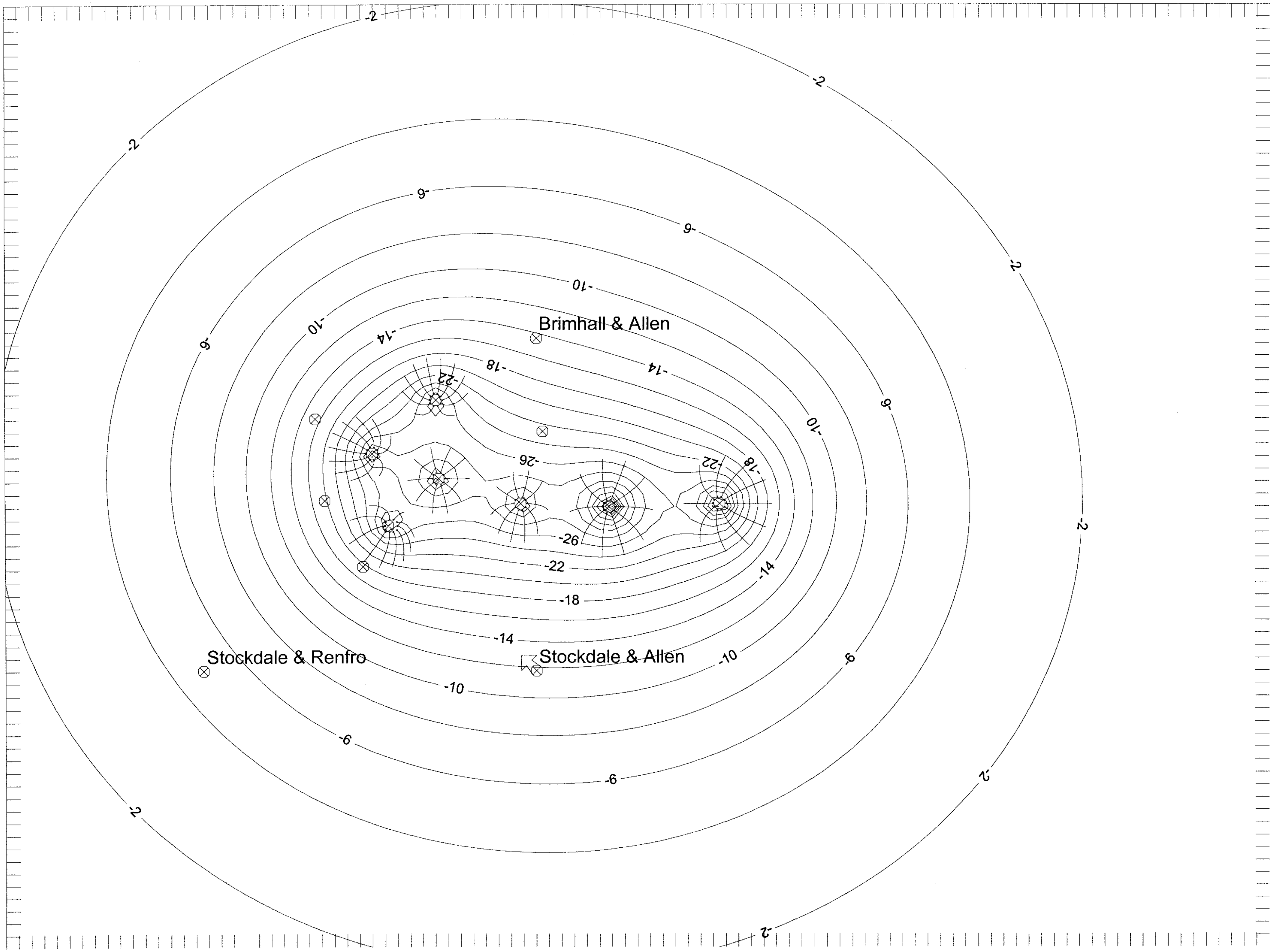
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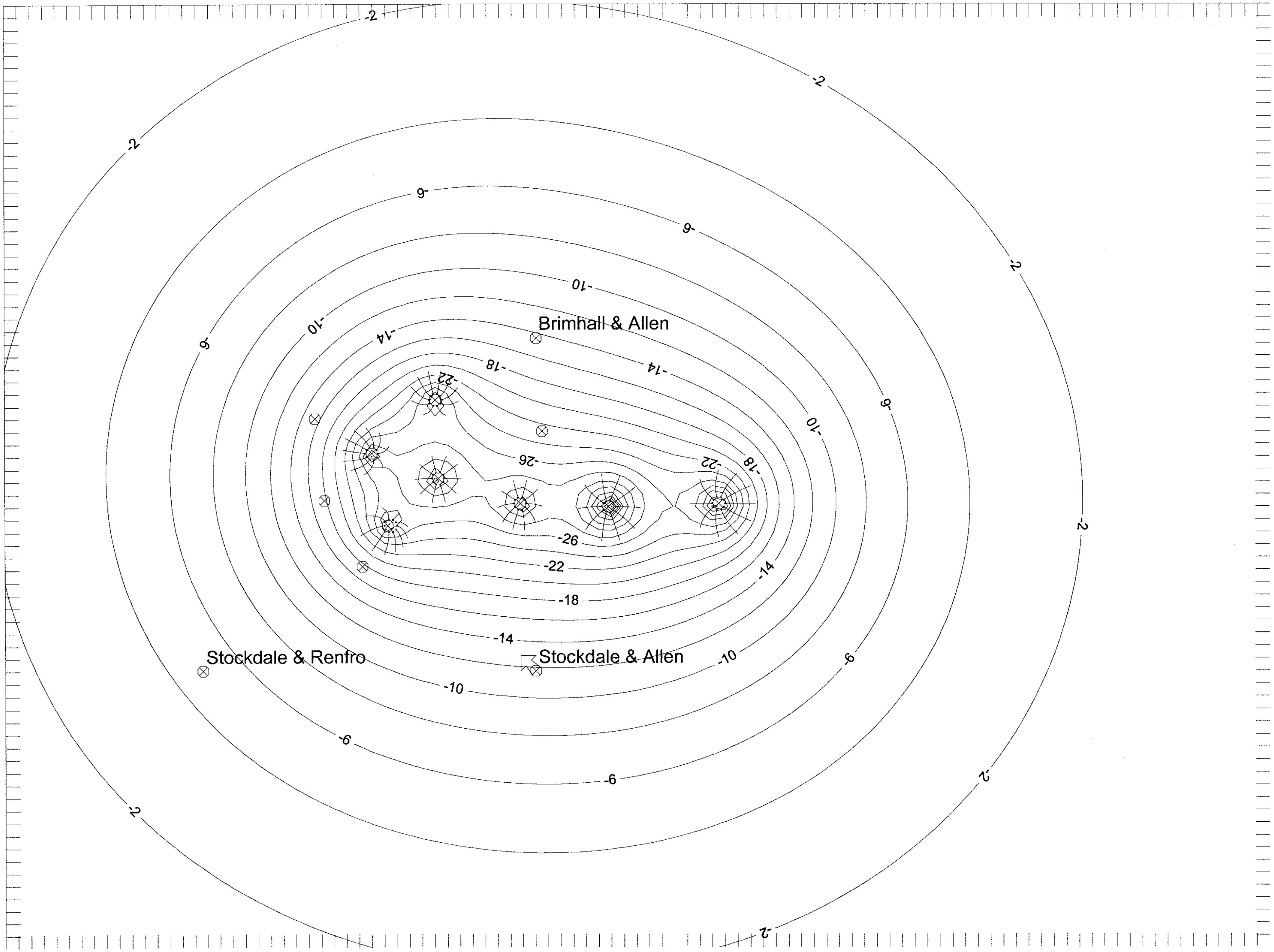
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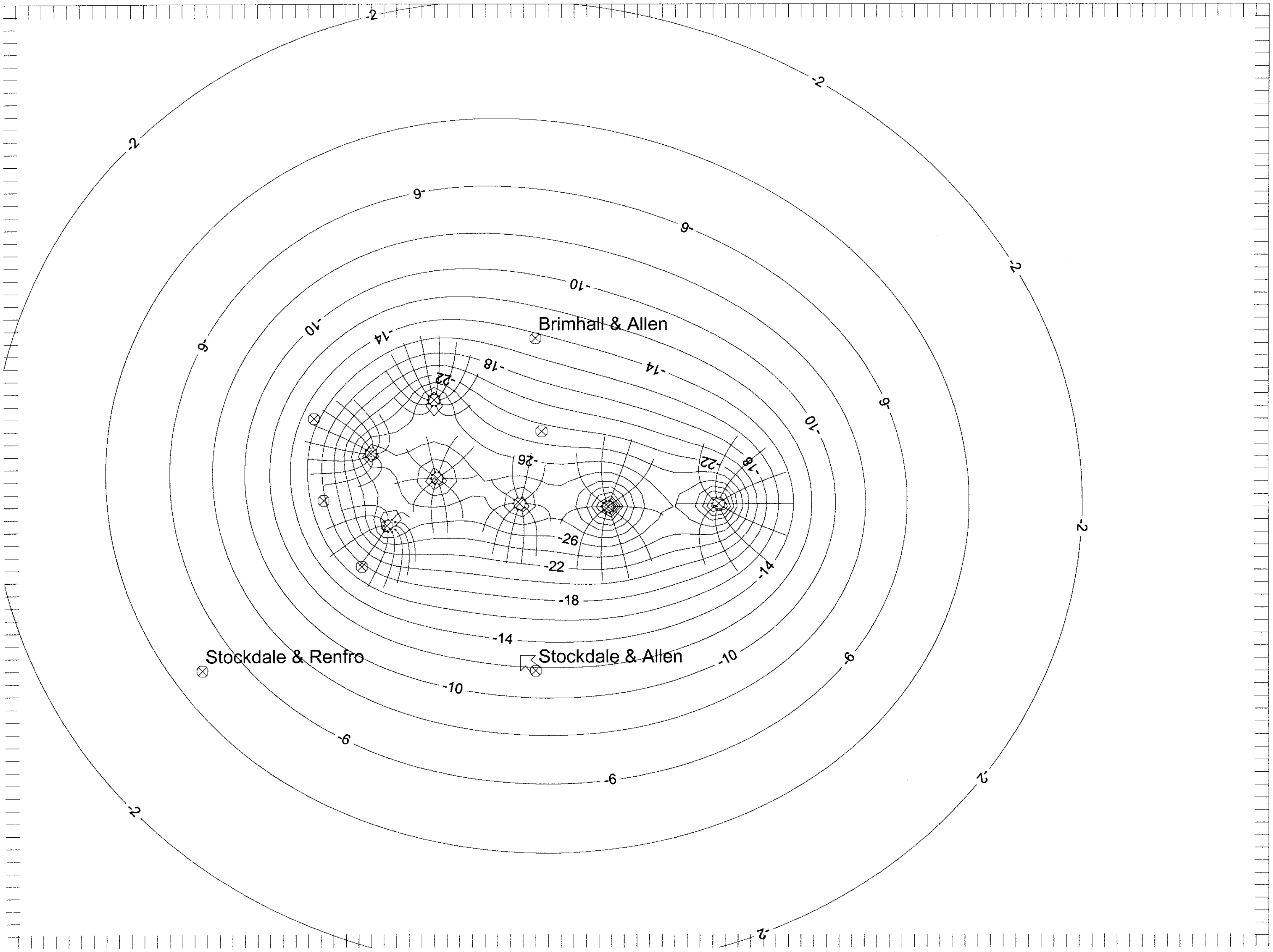
Appendix 6.

SET 05.



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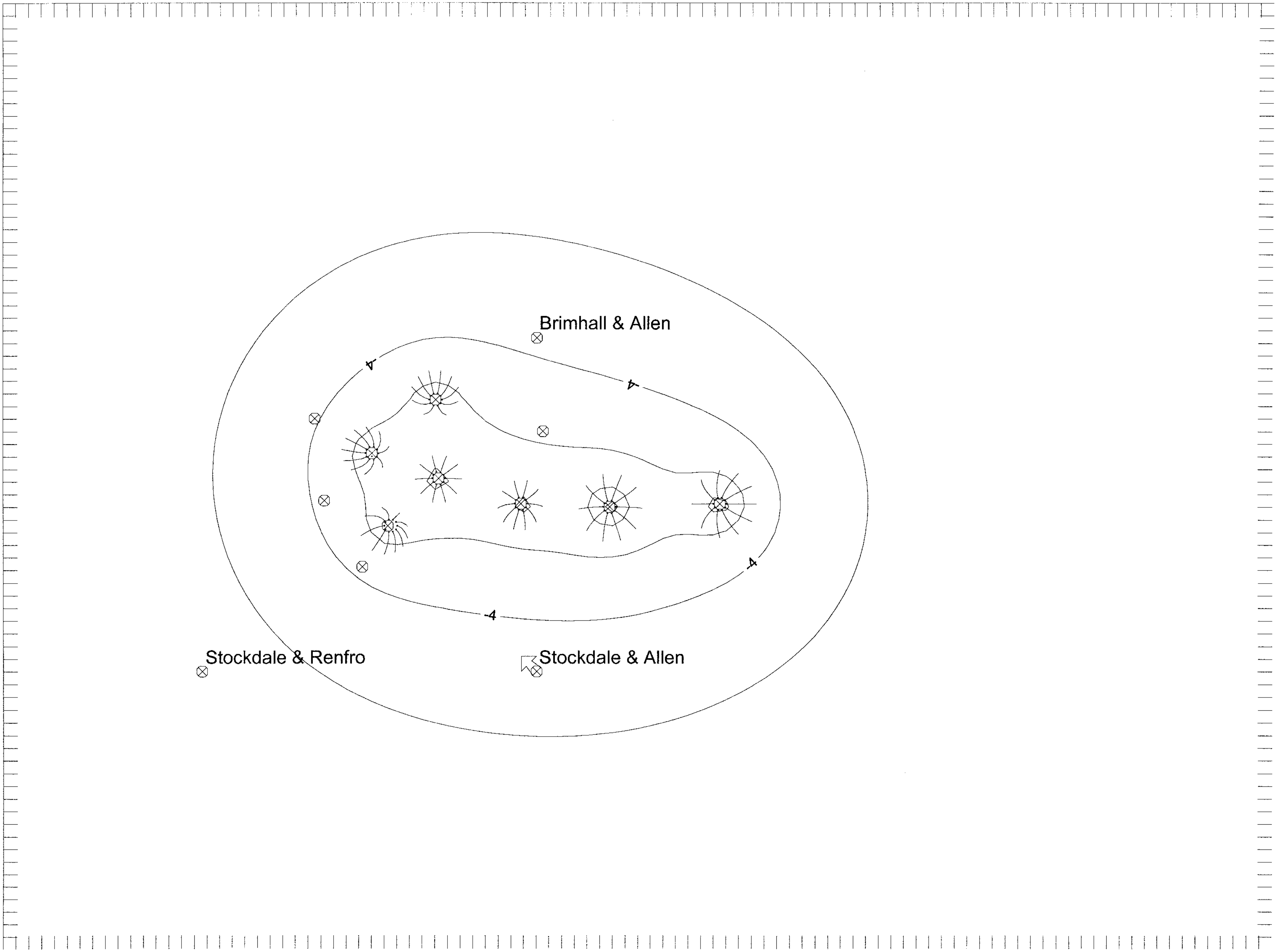
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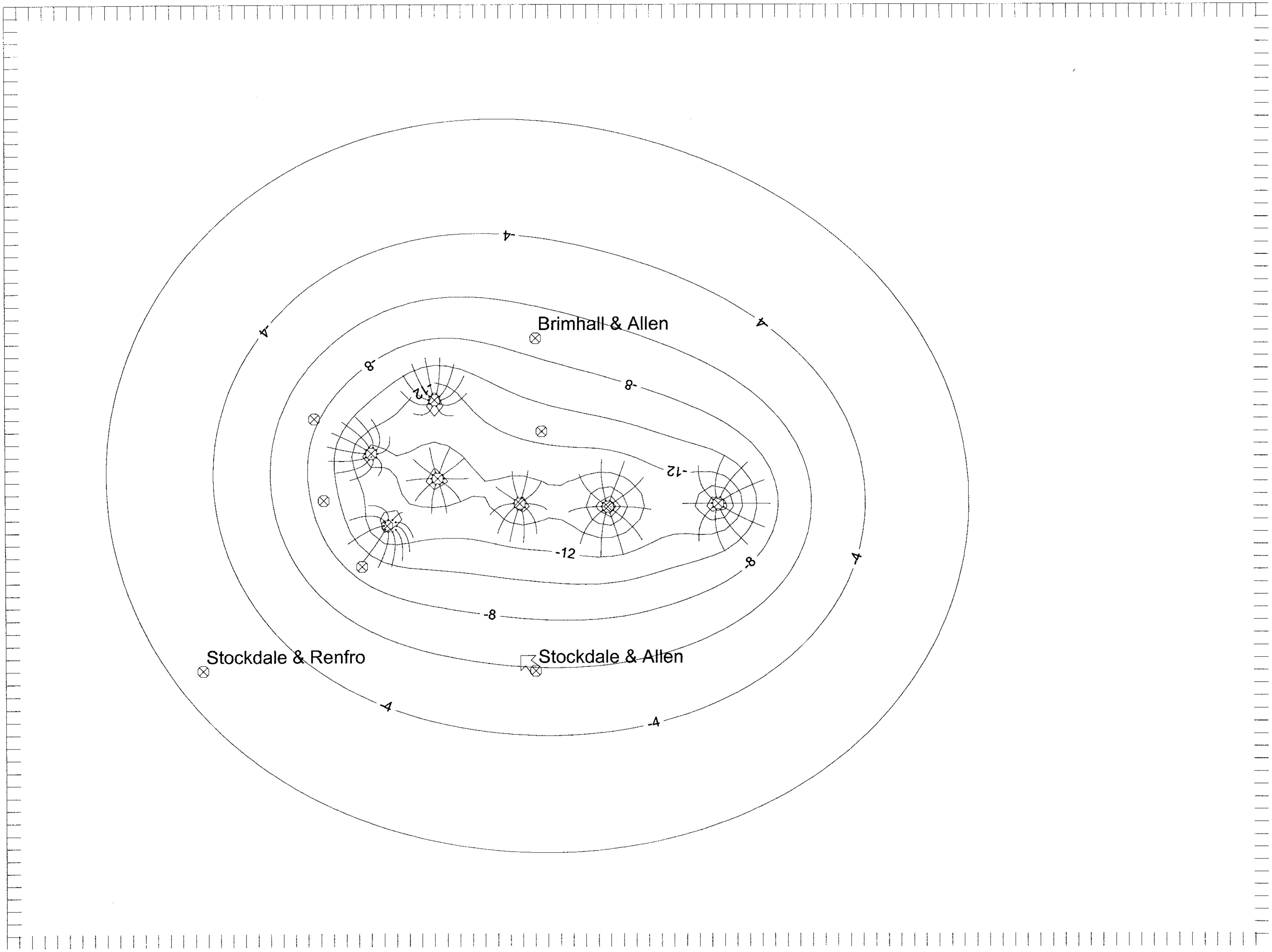
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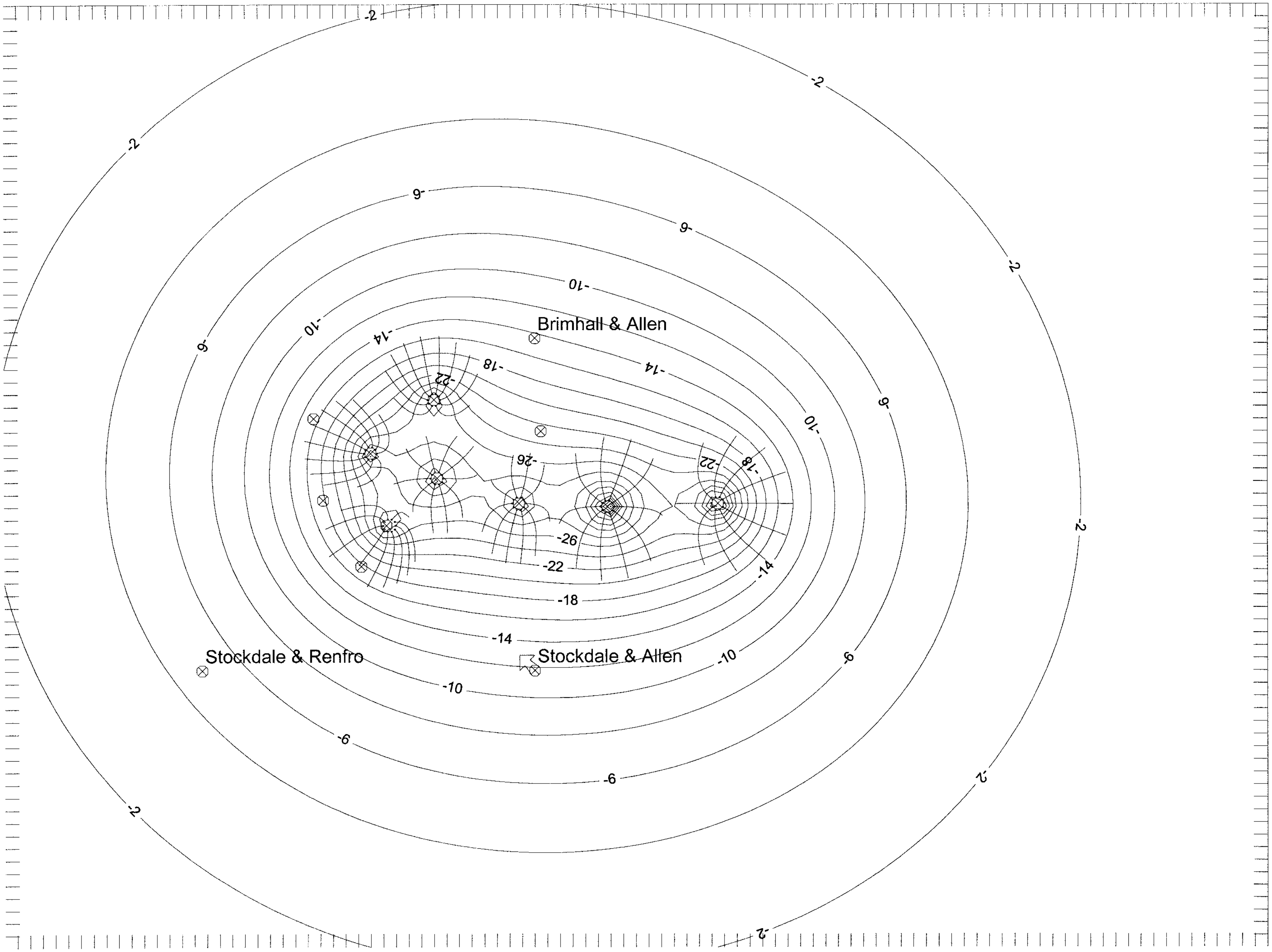
Appendix 6.

SET 06.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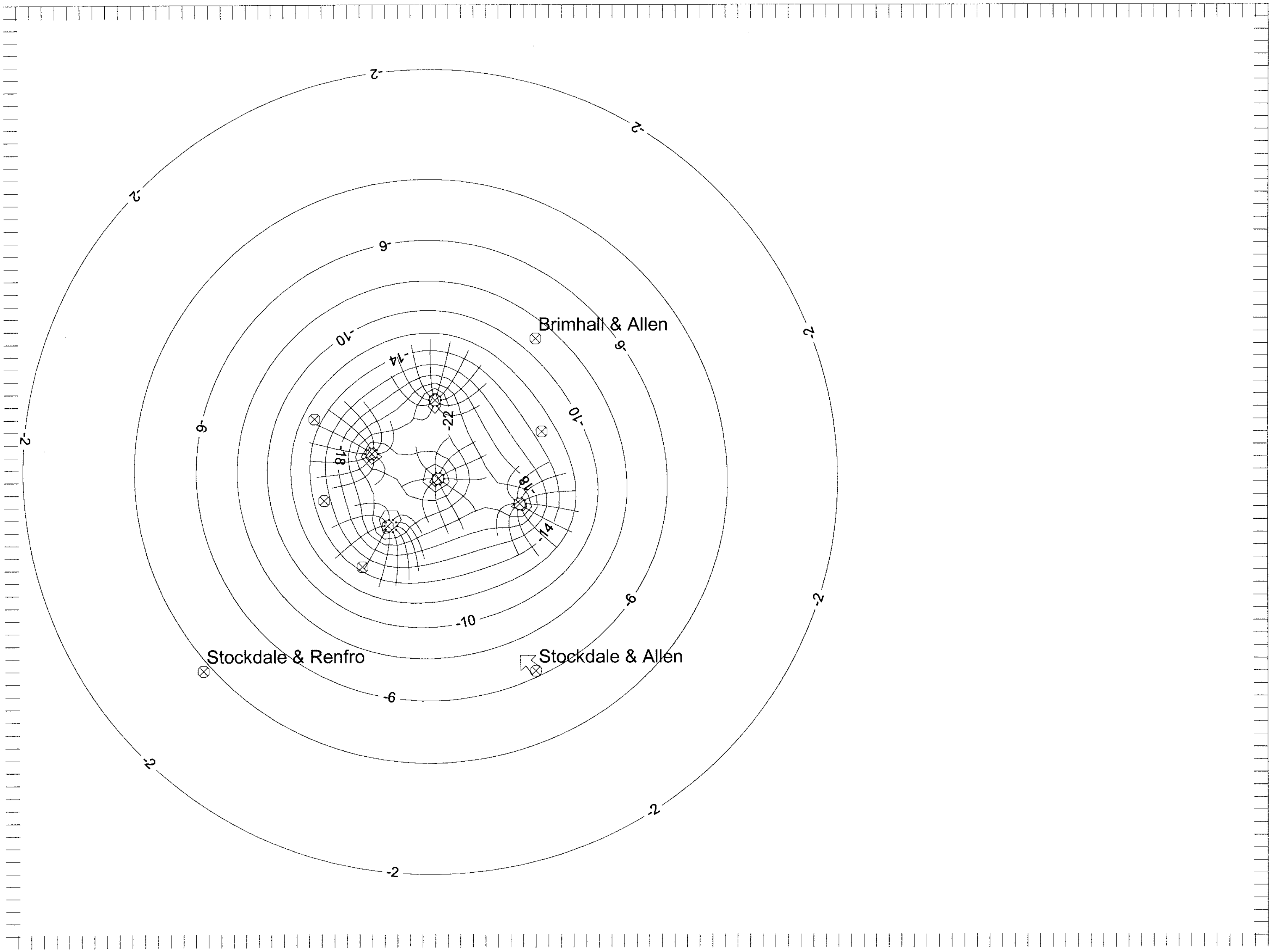
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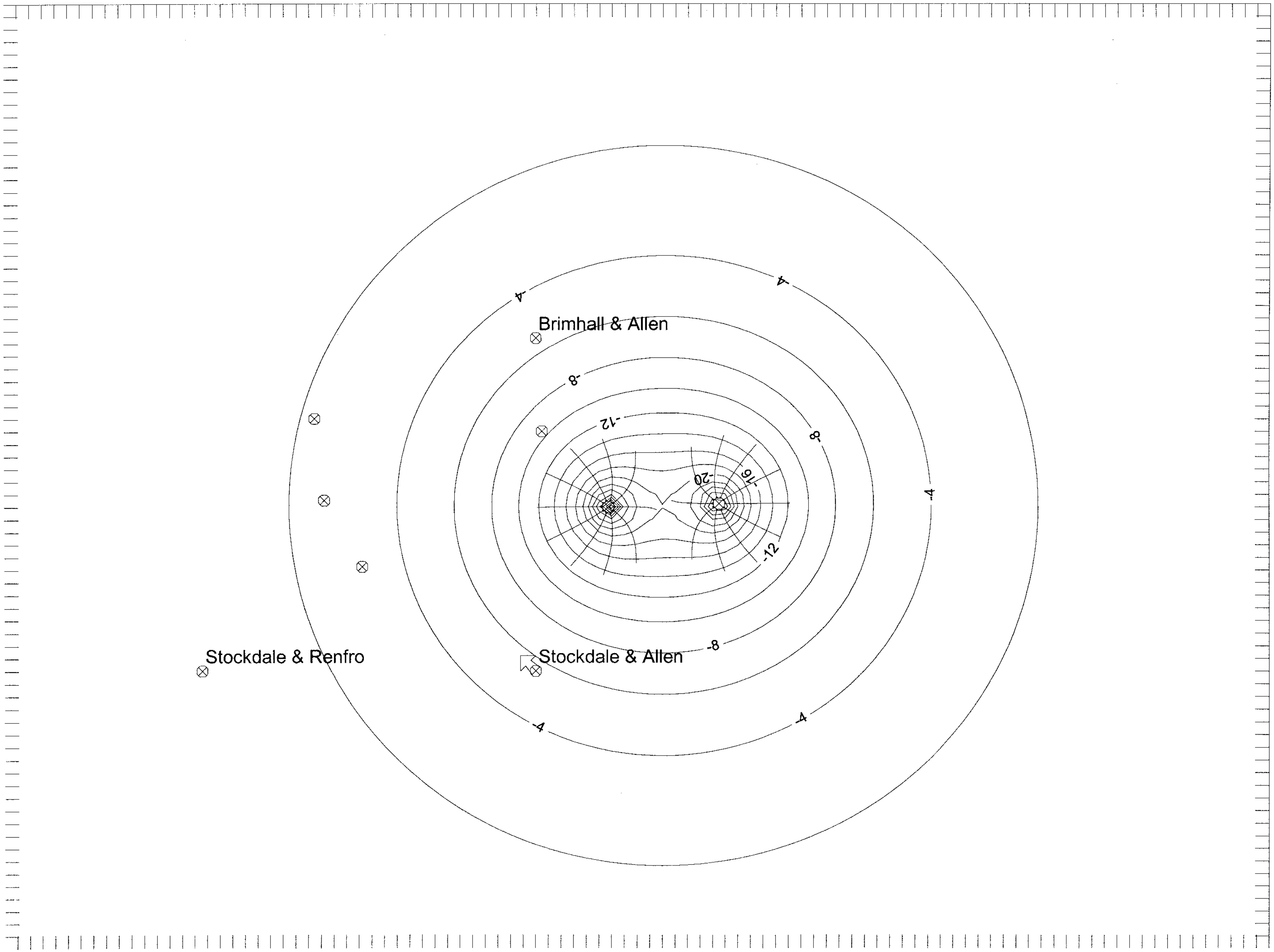
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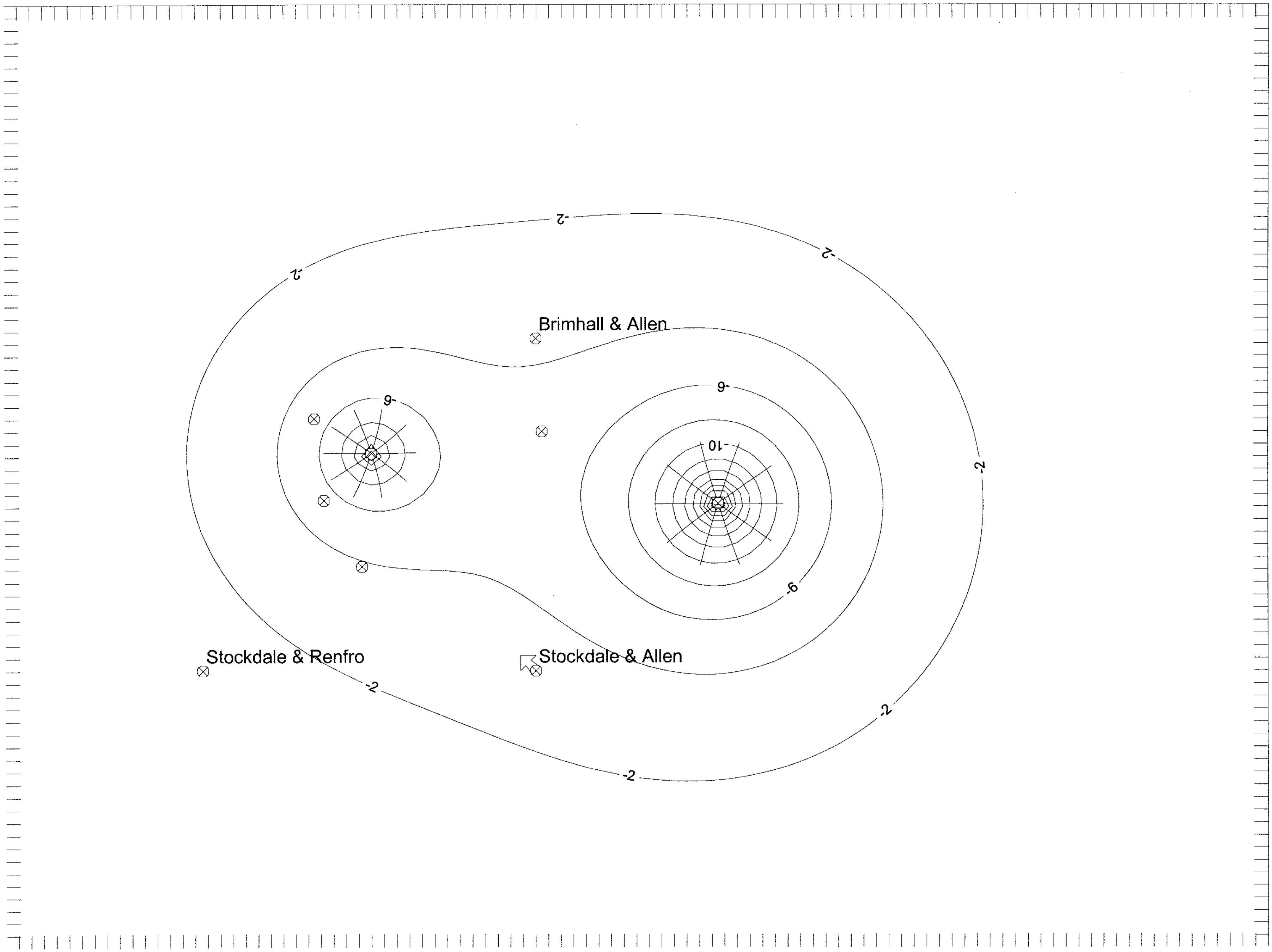

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Appendix 6.

Discussion

SETS 07 - 08.

Summary of Particle Trajectory and Capture Analyses, Sets 7 - 8.

The actual, physical volume of water which is captured by a single pumping well over any finite period of time does not come from the cone of depression surrounding the well but rather comes from the part of the aquifer enclosed by a vertical-sided circular cylinder centered on the well. The radius of this "capture" cylinder increases as the rate and duration of pumping increase and is easily determined arithmetically from the continuity equation. Except for the theoretical case of infinite pumping time in infinite aquifers, all capture zones have fully enclosing perimeters as seen on a map.

For a pair of pumping wells within each other's zone of influence, a drainage divide forms between them and either well can only drain water from its own side of the drainage divide. Therefore, the capture zones of these two wells do not overlap; they are ovals centered on each well and flattened against each other along the drainage divide. Theoretically, all water molecules on the divide are stagnant, not moving toward either well because they rest at a location of zero gradient where the opposing induced gradients exactly cancel each other out.

For a cluster of pumping wells, a system of drainage divides separates the capture zone of each well from that of every other well. The locations of the drainage divides depend on the relative pumping rates of the wells and the size and orientation of the natural gradient, all other things being equal. For base case pumping of all seven project wells, the drainage divide between the RRB and ID4 wells happens to nearly coincide with Allen Rd.

For a single well or cluster of wells in the presence of a groundwater gradient, the shape of this capture zone (CZ) is distorted into an oval which extends farther upgradient than downgradient. If a well or wells are pumped continuously, then this capture zone expands outward as the pumping time increases, but only out to a theoretical maximum limit in every direction. For a hypothetical infinite pumping time, the CZ is shaped like a parabola which is bounded on the downgradient end and transverse sides, and opens indefinitely in the upgradient direction. This particular, theoretical capture zone is the largest possible capture zone for a given set of parameters and we define this theoretical perimeter as the capture zone limit (CZL). For all *finite* pumping times, the actual capture zone is smaller than, inside of, and conformal to the CZL.

In reality, i.e., in the real aquifer and for real pumping operations in this project area, a real capture zone may approach the location of the CZL in downgradient and transverse locations in just a few years of pumping but will never extend farther upgradient than the location of the recharge boundary caused by the Kern River Channel. The real capture zone will stop expanding as soon as the total recovery rate is fully balanced by aquifer recharge at any or all of the aquifer boundaries.

Any water within the CZL has the potential to be ultimately recovered by the wells if pumping continues long enough. Any water outside of the CZL will never be captured by the wells as long as conditions remain the same. Our forecast of the location of the CZL is predicated on constant conditions and our choice of conditions is based on our guess of the long term average ground water gradient behavior in the project area. The most significant possible exception is based on the recognized swing in the direction of the prevailing northwesterly natural gradient to westerly when climatic conditions change from wet to dry.

On SSS's drawdown maps, the spider- like particle trajectories centered on each well extend outward to the most distant location from which water is captured in a user- specified period of time. The curved shapes and convergence of some trajectories represent the effect of the non-Darcy flow regime within the capture zone. The non- Darcy flow also causes water molecules to speed up as they follow a particle trajectory inward toward a well. Although we chose to not show velocities or interval transit times on the maps, the qualitative measure of speed increase is the rate of convergence of the particle trajectories as seen on the maps.

The inward radial gradient which develops within the cone of depression surrounding a pumping well is not the only driving force which moves water toward the well. The movement of groundwater along any particle trajectory is always due to the combined total influence of all sources, even the influences of other wells. Particle trajectories and capture zones have only limited relevance unless they are superimposed on a realistic approximation of the local ground water gradient for the project area, including any other predictable influences.

The natural groundwater gradient is of particular importance. In the presence *and* absence of pumping, upgradient water continues to move toward a well due to the presence of the natural groundwater gradient. Therefore, a plume or slug of groundwater contamination which is upgradient of a well will move toward the well due to the natural gradient whether the well is pumping or not. The primary lesson to be appreciated is that if and when contamination shows up in a well which had previously been contaminant- free, it should not be assumed that pumping caused the contamination to show up until it is shown that it wasn't headed there anyway under the natural gradient. The presumption of causality is a common pitfall which is difficult to avoid without a careful analysis of particle trajectory and capture analysis.

The 2003 KDSA report presents two different groundwater conditions in their impact analysis of the project area. One condition represents the *northwesterly* water table gradient which typifies wet years when Kern River recharge occurs and the orientation and close proximity of the recharge mound dominates the local hydrology. The second condition represents the *westerly* water table gradient which typifies dry years when river recharge does not occur and more distant features of the aquifer to the east dominate the local hydrology. We have not independently verified the persistence or representativeness of these two specific scenarios within this scope of work, but we have reviewed the KCWA ground water elevation maps for the years since 1990 and these two scenarios appear to be consistent with the observed overall trends.

For our scope of work, we have adopted three hypothetical groundwater gradient scenarios; one in which a NW gradient of -0.002 points northwesterly (135° left azimuth from east), a second in which a W gradient of -0.002 points westerly (180° left azimuth from east), and a third set in which we model active recharge in the Kern River Channel superimposed on a WNW gradient of -0.001 which points west-northwesterly (180°, 150°, and135° left azimuth from east). In all scenarios, we have assumed that the ground water at the beginning is 100 ft deep at the intersection of Stockdale Hwy and Allen Rd, which is approximately correct for Summer, 2004, and that the gradient defines the depth to water elsewhere relative to this reference point.

<u>Set 7. Base case superimposed on a natural GW gradient (t = 300, 770d).</u>

For the base case superimposed on the NW gradient, the 770- day capture zone extends a maximum of about 2,000 ft directly upgradient and a maximum of about 1,500 ft downgradient from the wells at opposite ends of the well array. Ignoring the fact that this is non-darcy, variable velocity flow, the average groundwater particle velocities moving from the capture perimeter to the wells during the 770 day capture period range from 2.1 - 2.7 ft/d; slower at first and faster just prior to capture. For comparison purposes, the calculated Darcy groundwater flow velocity under the uniform natural gradient alone is about 0.46 ft/d for base case parameters.

For the base case superimposed on the W gradient, the dimensions and flow velocities are essentially the same as the NW gradient case except that the orientation is slightly different.

For the base case superimposed on either gradient, the 300- day capture zone extends a maximum of about 1,300 ft directly upgradient and a maximum of about 1,000 ft downgradient from the wells at opposite ends of the well array. Ignoring the non-darcy flow factor, the average groundwater particle velocities moving from the capture perimeter to the wells during the 300 day capture period range from 3.3 - 4.3 ft/d. For comparison purposes, the calculated Darcy groundwater flow velocity under the uniform natural gradient alone is about 0.46 ft/d for base case parameters.

Set 8. Base case superimposed on a natural GW gradient (t = 1, 3, 5, 10, & 20 yr).

These cases are the same as the previous ones except that the hypothetical capture zones extend farther upgradient for much longer time pumping periods . This is not completely realistic since the assumption that the aquifer is laterally infinite does not actually apply to the project area, but it gives a general impression of what upgradient areas are- or are not- within the capture zone for the specified durations of continuous pumping. Since the groundwater flow velocities are less under the natural gradient than under pumping, these scenarios represent maximum capture zones for the given time periods, subject to the representativeness of the assumptions and parameters. For intermittent pumping over these time periods, the actual capture zone will be smaller than those presented in the following cases.

Based on these models, the farthest upgradient extents of the capture zone are 1,400, 2,100, 3,600, 5,200, and 5,900 ft for continuous pumping times of t = 1, 3, 5, 10, & 20 yr, respectively. These scenarios show which areas surrounding the project are inside and outside the capture zone for the specified pumping times. Groundwater which is outside these capture zones will not be captured by any scenario of less-than-continuous pumping, all else being equal, over these respective time durations.

If contamination shows up in one or more wells during actual project pumping, then this analysis limits the possible directions from which it may have come. The duration of pumping up to the onset of contamination can be used to determine how far away the contamination was before it showed up at the wells.

Conversely, if a source of contamination or an existing plume is known to be upgradient from the project wells, then the obvious question is, "How long will the contamination take to get here?". The upgradient limits of the capture zones for the specified times give ballpark estimates, but this oversimplified analysis ignores other issues of contaminant transport which bear on this determination. For example, longitudinal dispersion causes the leading edge of a plume to travel faster than the center of the plume so "breakthrough" arrives sooner than predicted. On the other hand, many contaminants have flow velocities which are slower than the groundwater flow velocity, so this retardation delays the arrival. SSS has performed such an analysis for several types of contaminant plumes, but a more detailed discussion here is outside the scope of work. The point is that other factors determine the motion of contaminants in groundwater and so it is not appropriate to assume that contaminants move at the same speed as the groundwater that they are dissolved in.

Appendix 6.

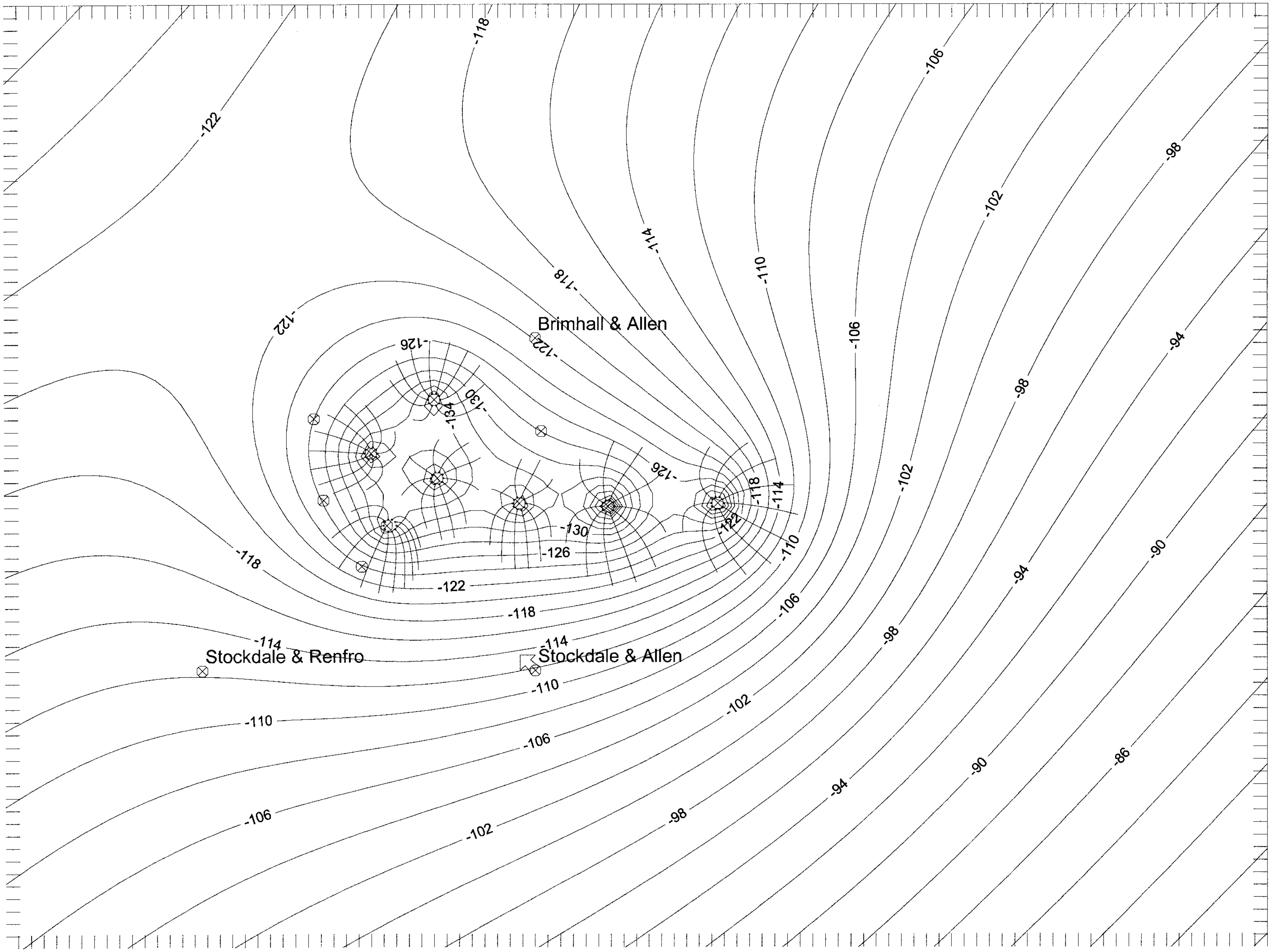
SET 07.

ID4 / KT / RRB Well Field Model Parameters.

Set No. 7.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky	leaky	leaky	leaky						
calc		transient	transient	transient	transient	transient	transient	transient						
Run No.		ref.only	701	702	703	704	705	706						
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0	-100											
Grad	G	0	0.002											
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300		7305	10958	300	7305	10958						
Ref Hd	Ref	0	-100											
Grad	G	0	0.002											
Azim	A	135				180								
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300		7305	10958	300	7305	10958						
Flow Rate	Q	full												
Wells	W	all												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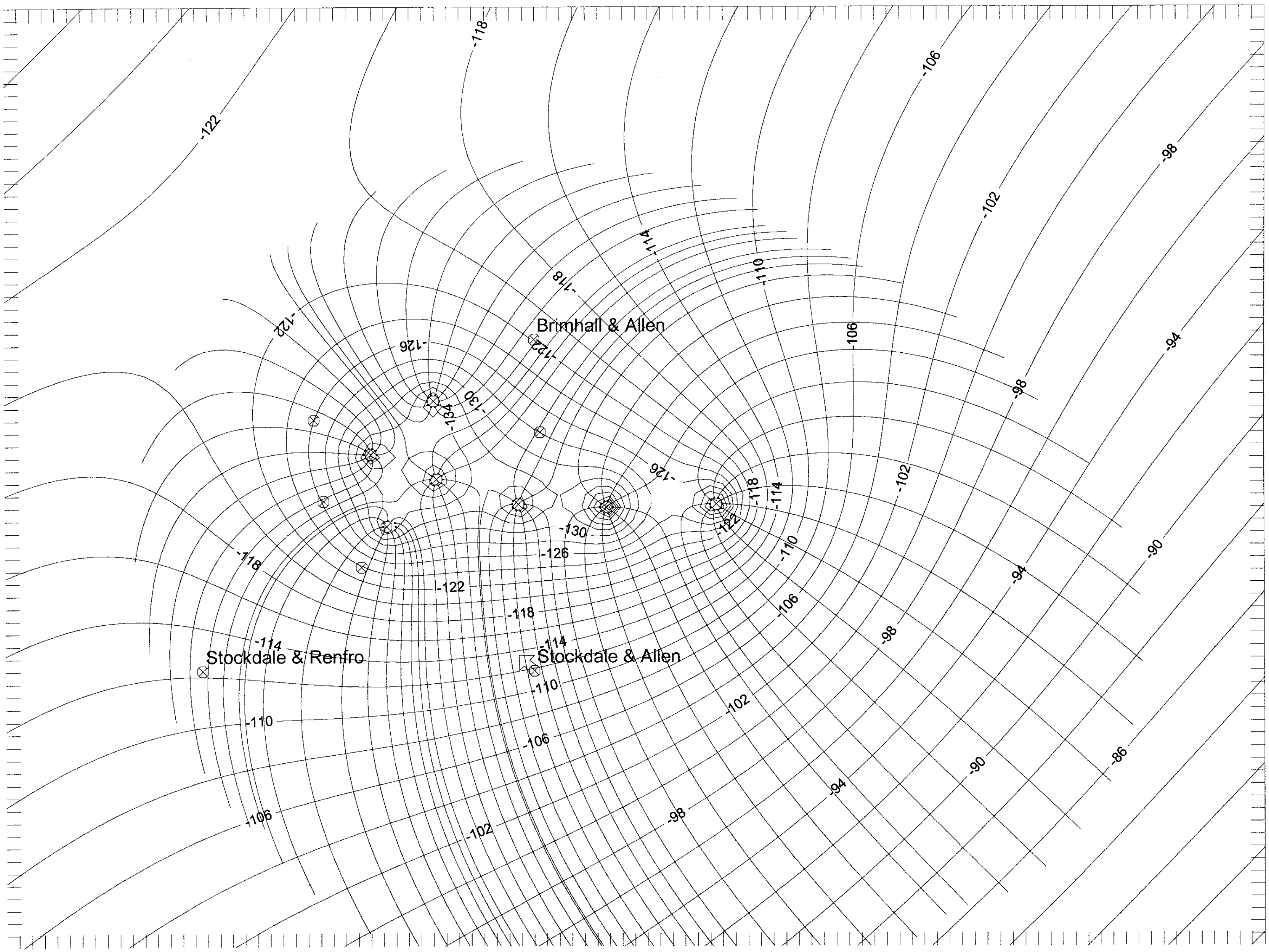
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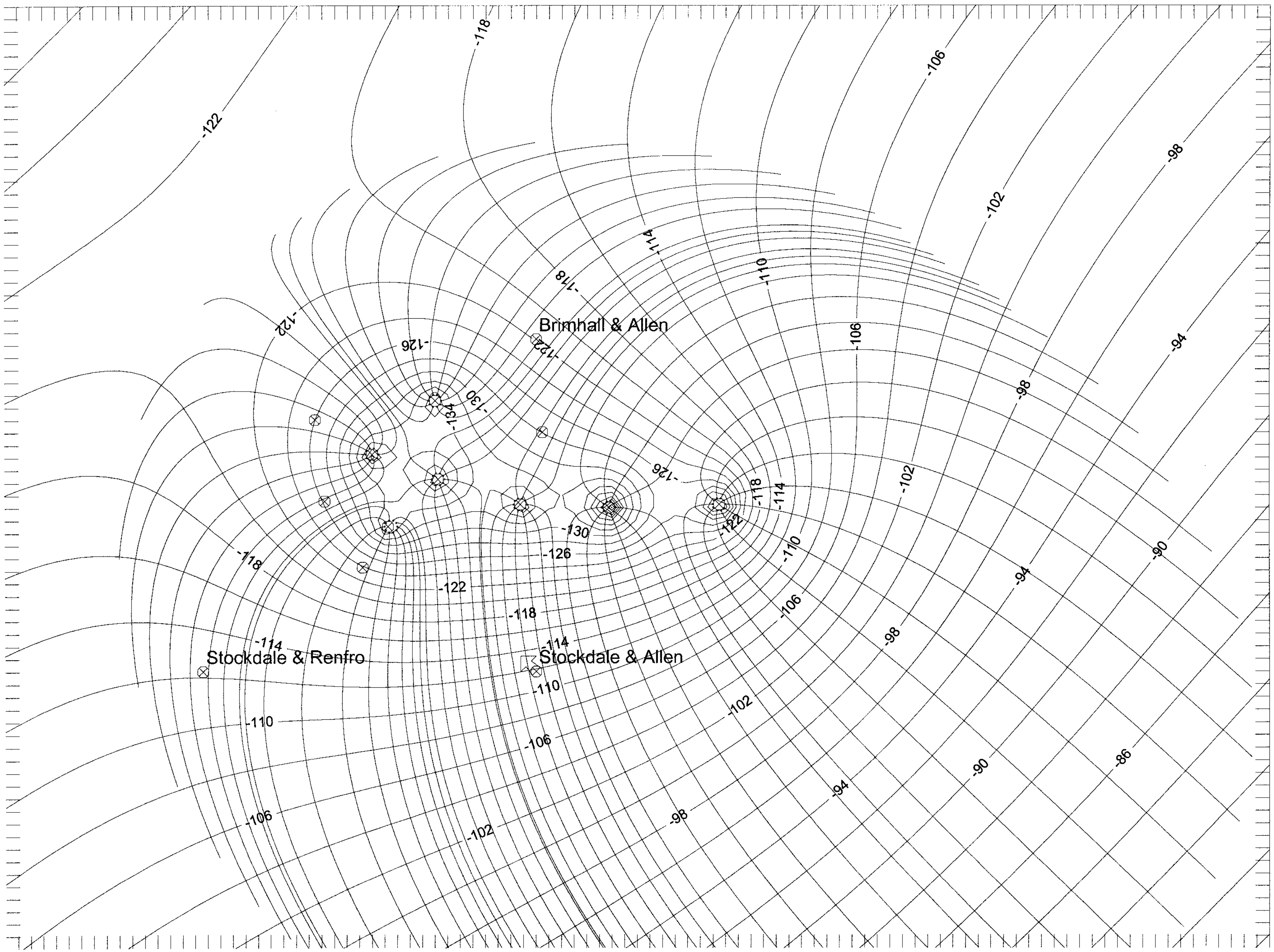
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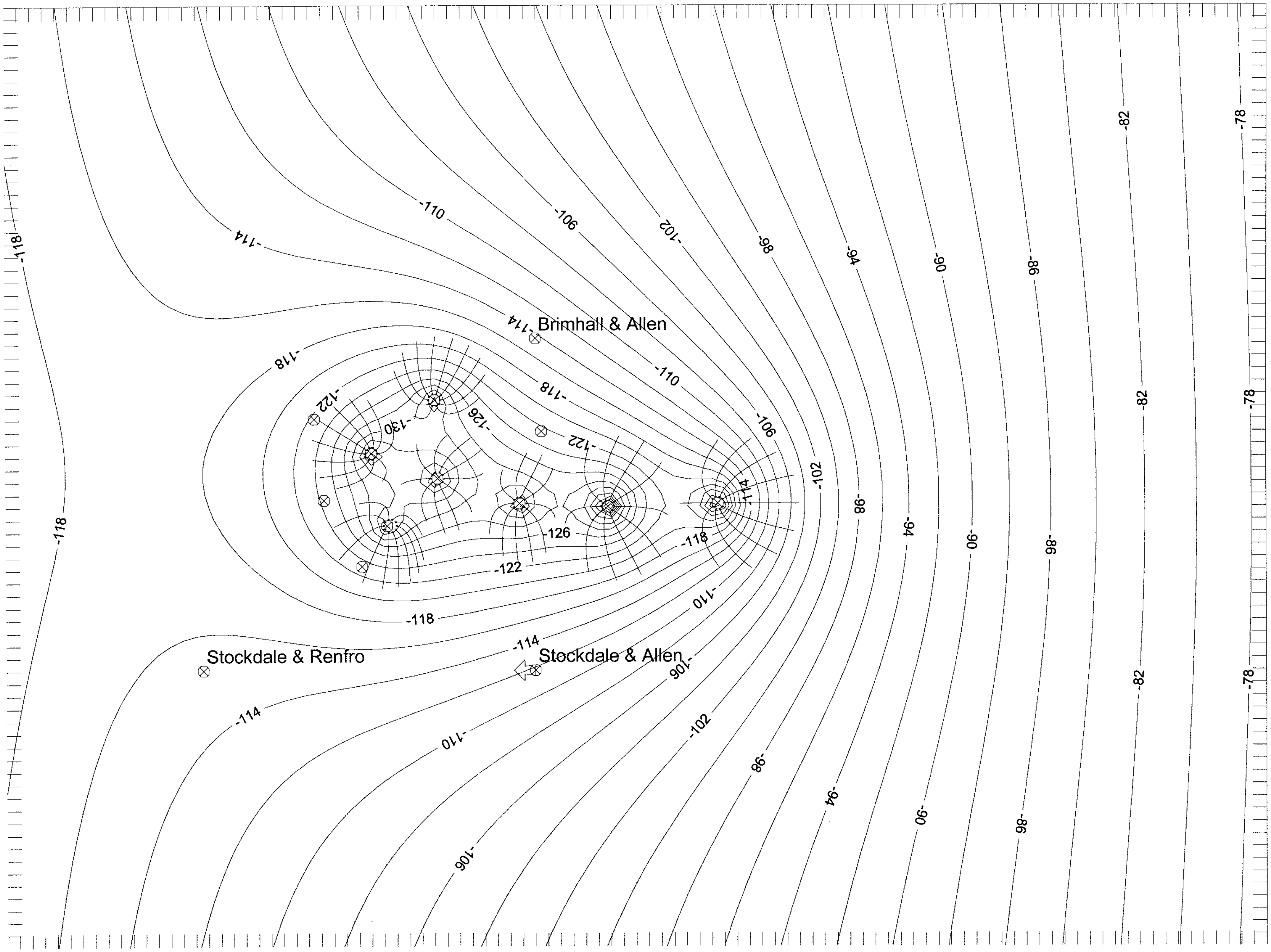
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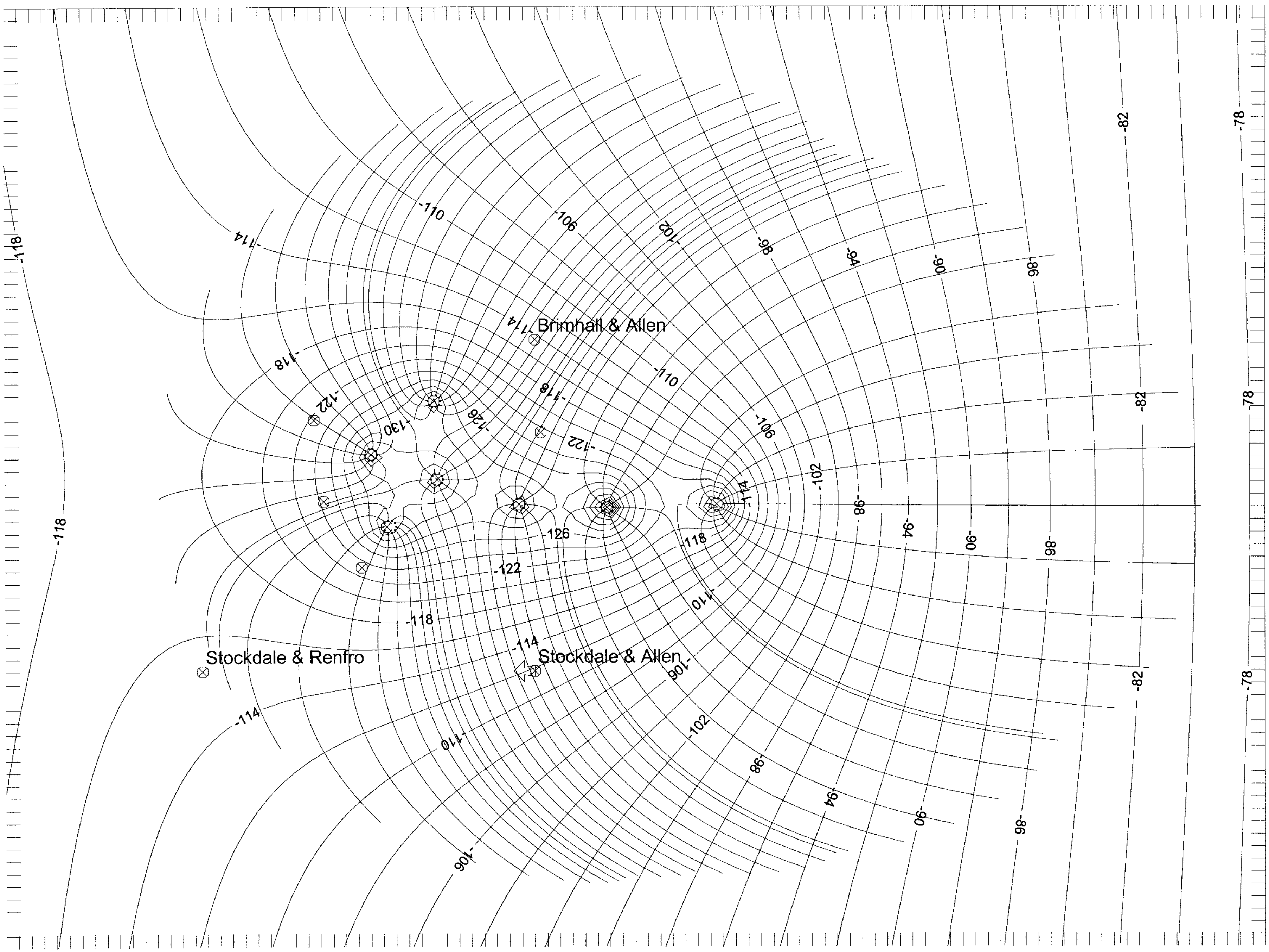
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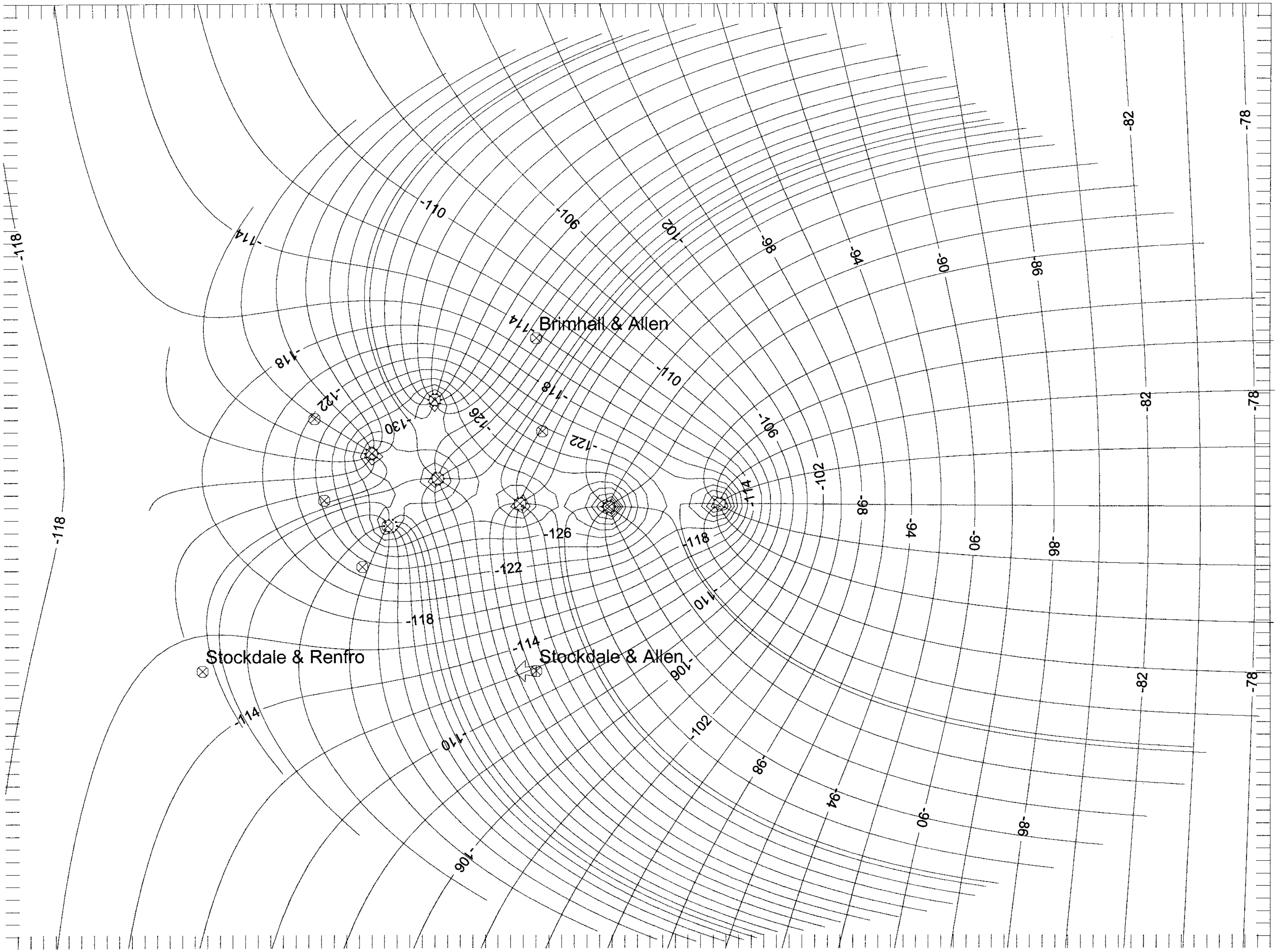
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Appendix 6.

SET 08.

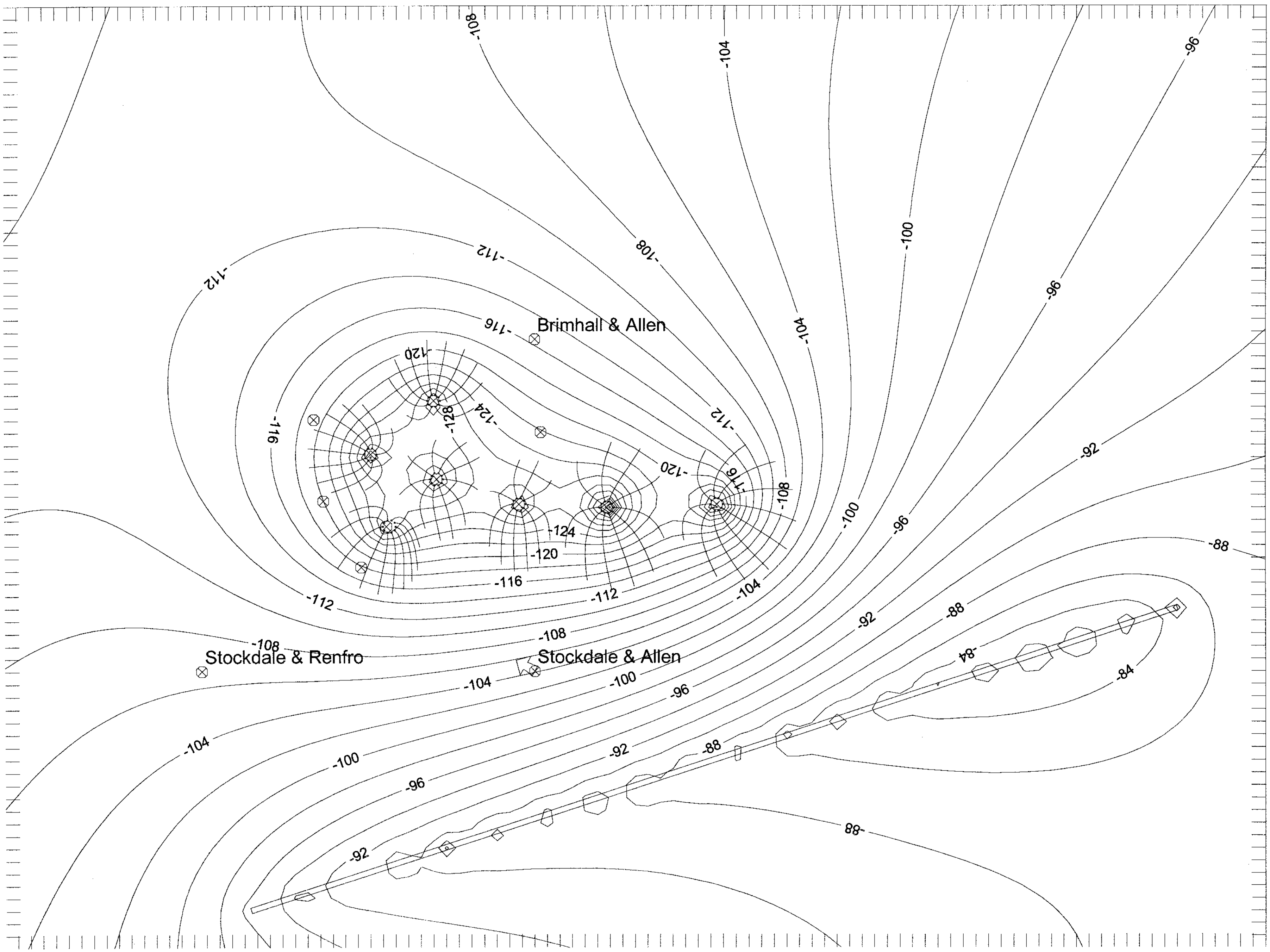
ID4 / KT / RRB Well Field Model Parameters.

Set No. 8.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky	leaky	leaky	leaky	leaky	leaky				
calc		transient	transient	transient	transient	transient	transient	transient	transient	transient				
Run No.		ref.only	801	802	803	804	805	806	807	808				
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0	-100											
Grad	G	0	0.001											
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300		365	731	1096	1826	3653	7305	10958				
Ref Hd	Ref	0	-100											
Grad	G	0	0.001											
Azim	A	135	150											
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300	300	365	731	1096	1826	3653	7305	10958				
				(1 yr)	(2 yr)	(3 yr)	(5 yr)	(10 yr)	(20 yr)	(30 yr)				
Flow Rate	Q	full												
Wells	W	all												
River Rch	Q	0	-210											

river coords: LL (-4500, -3400) UR (10200, 1000)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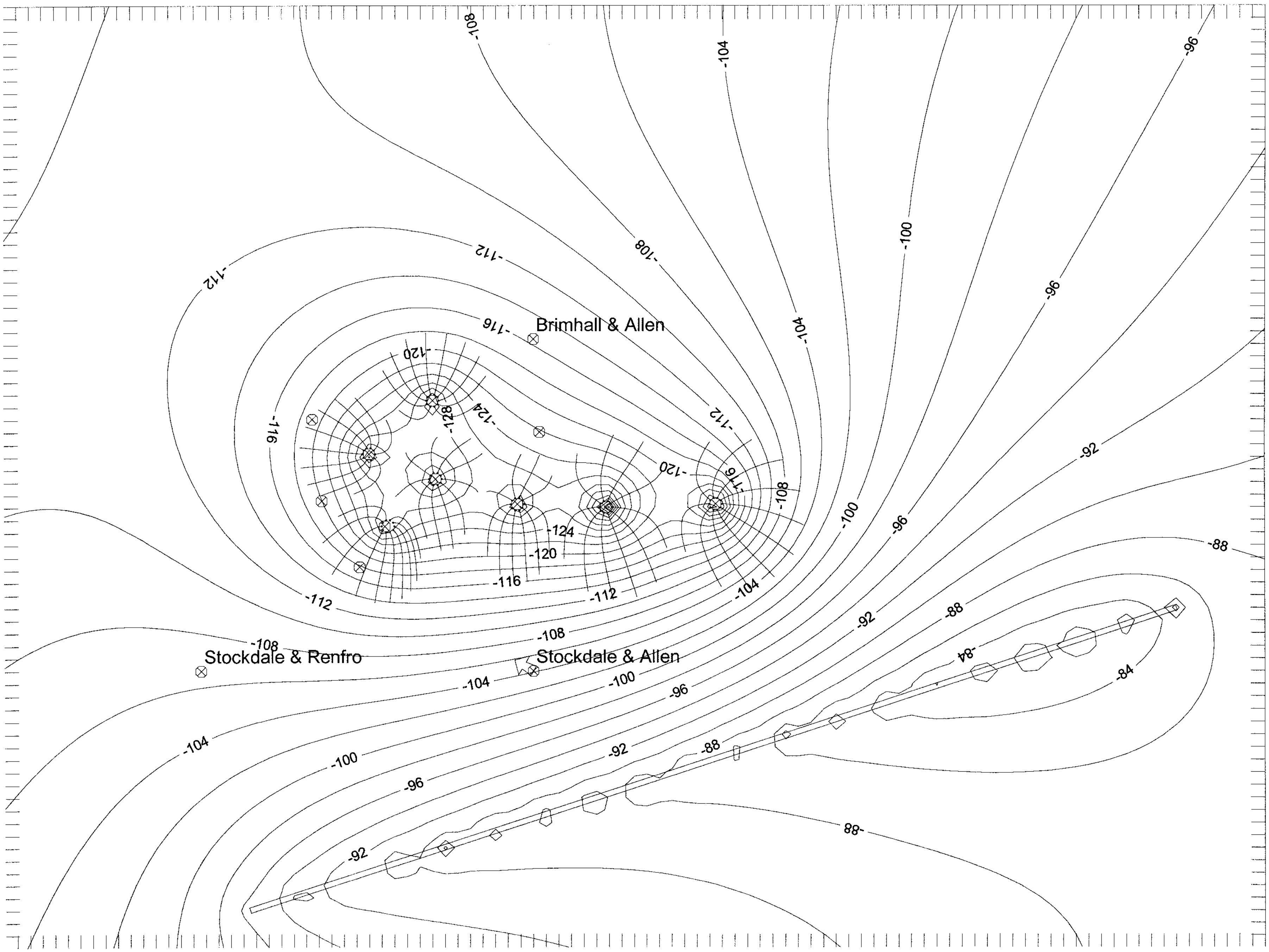
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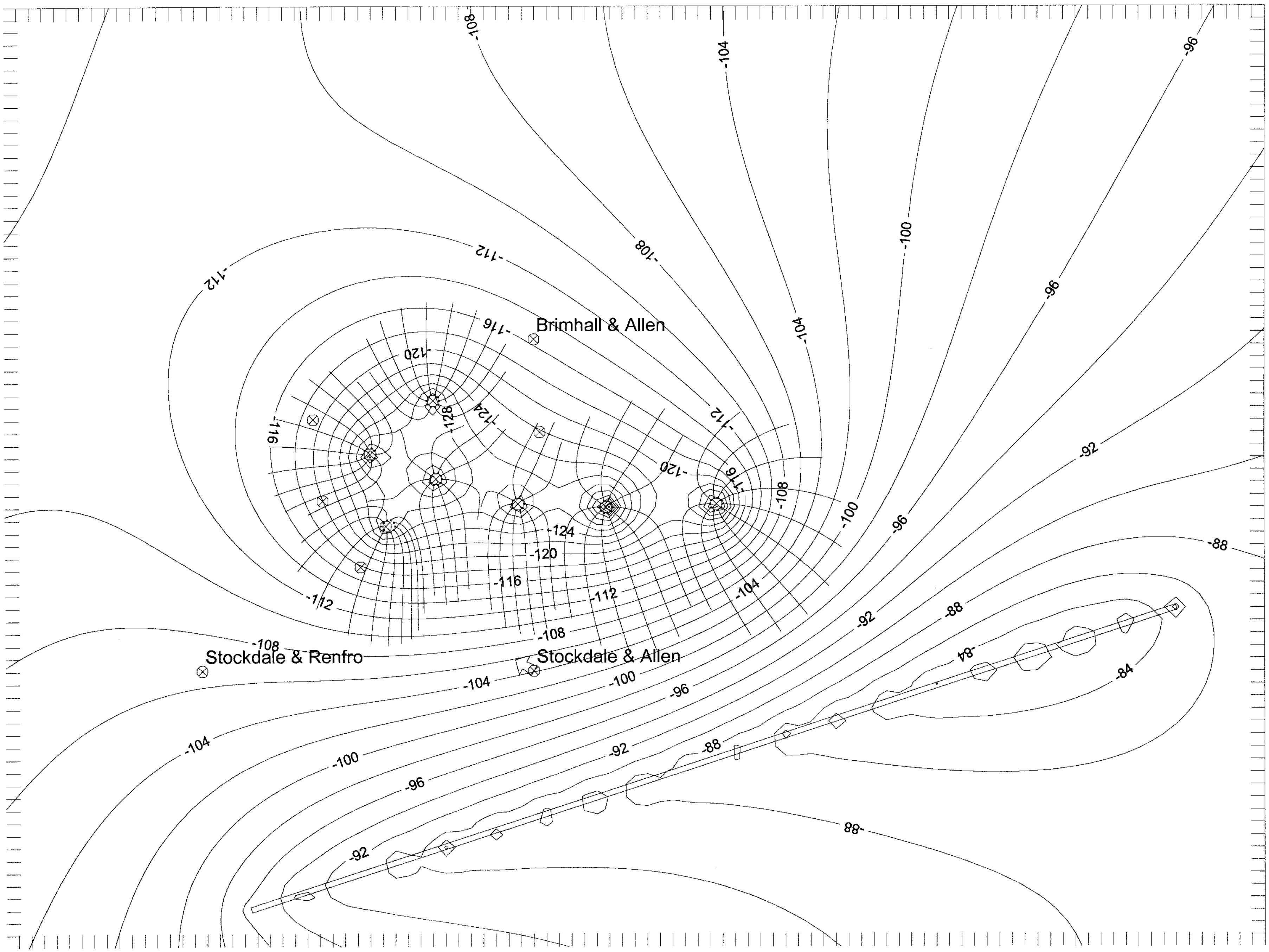
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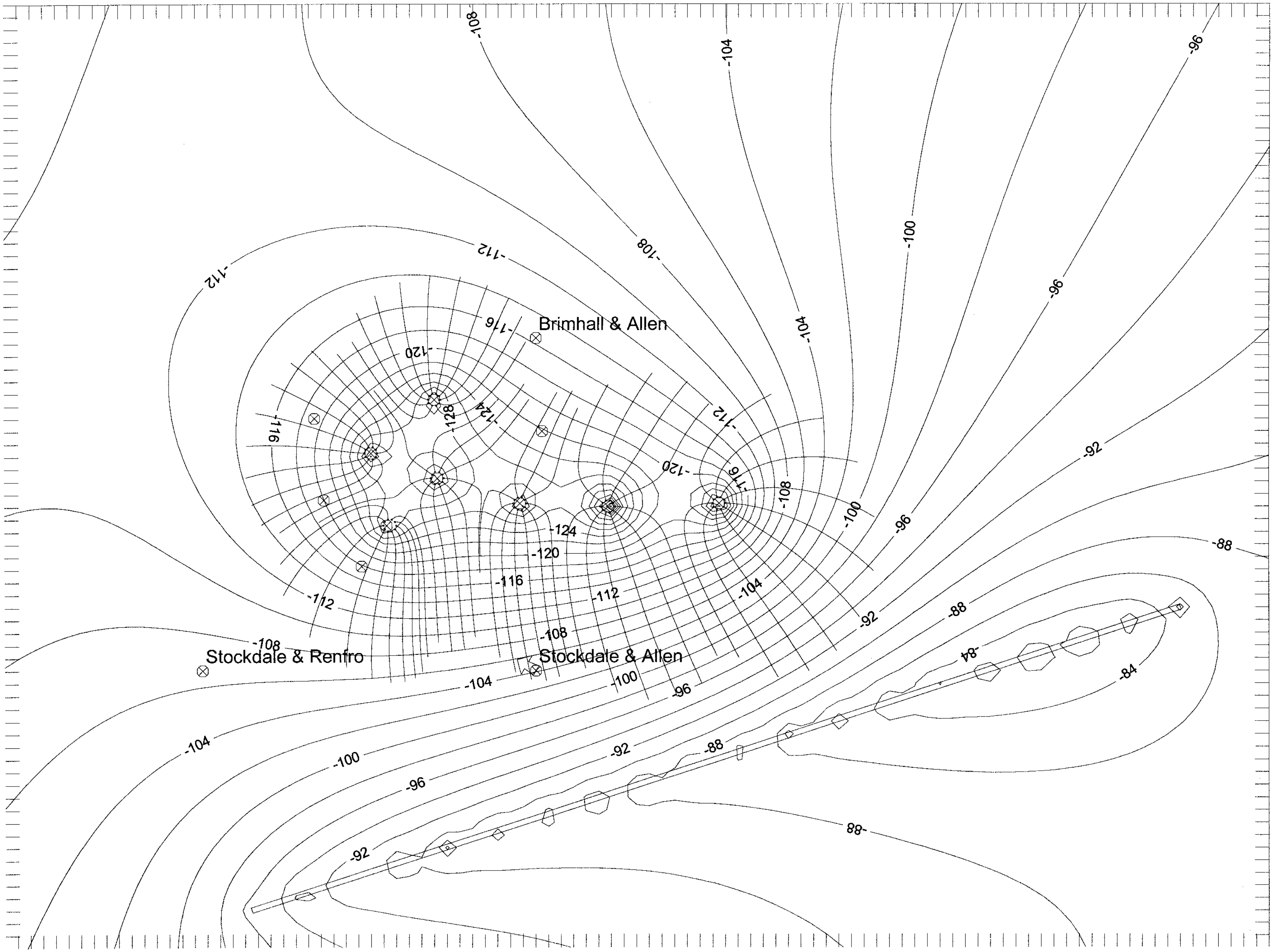
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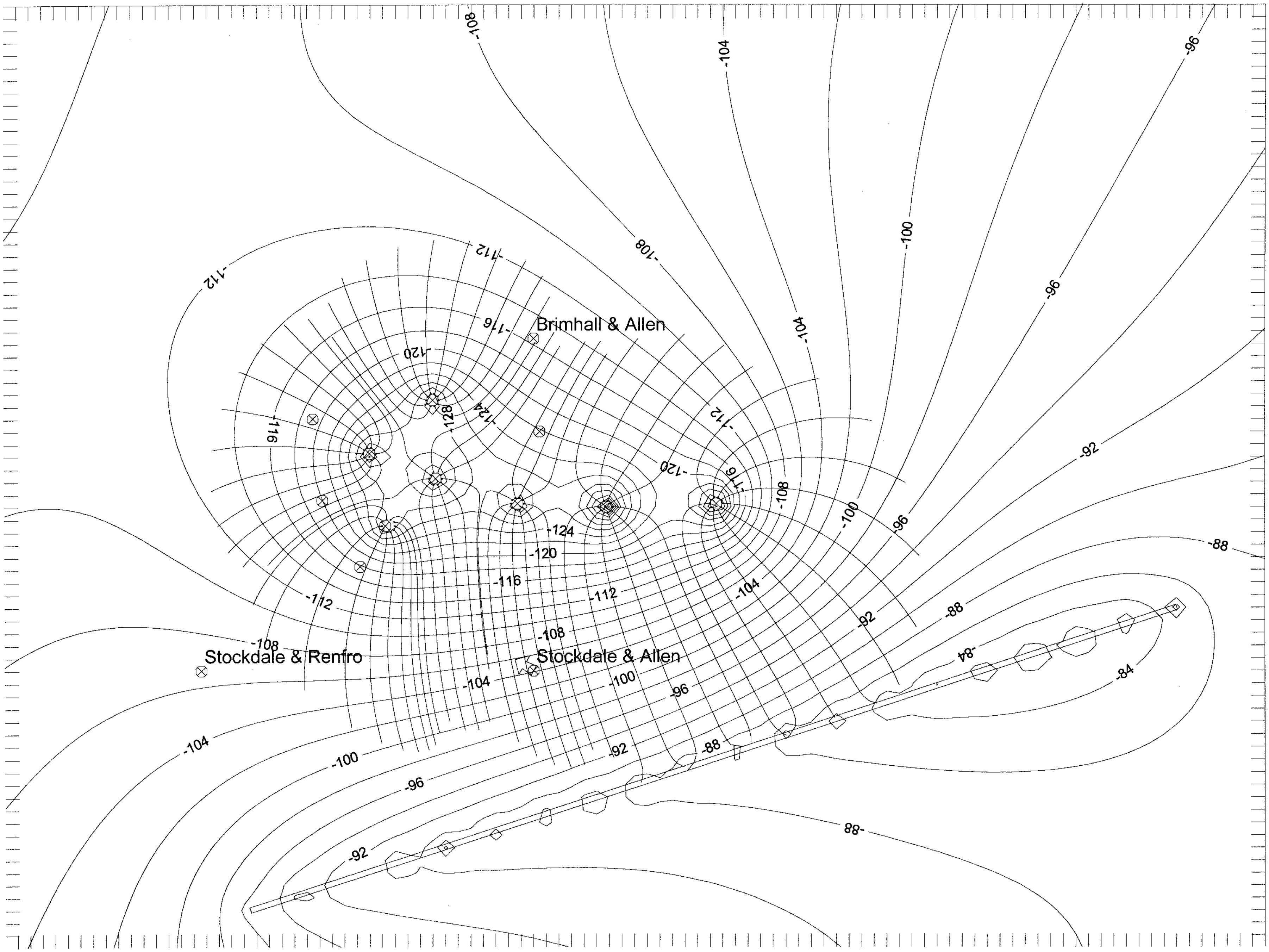
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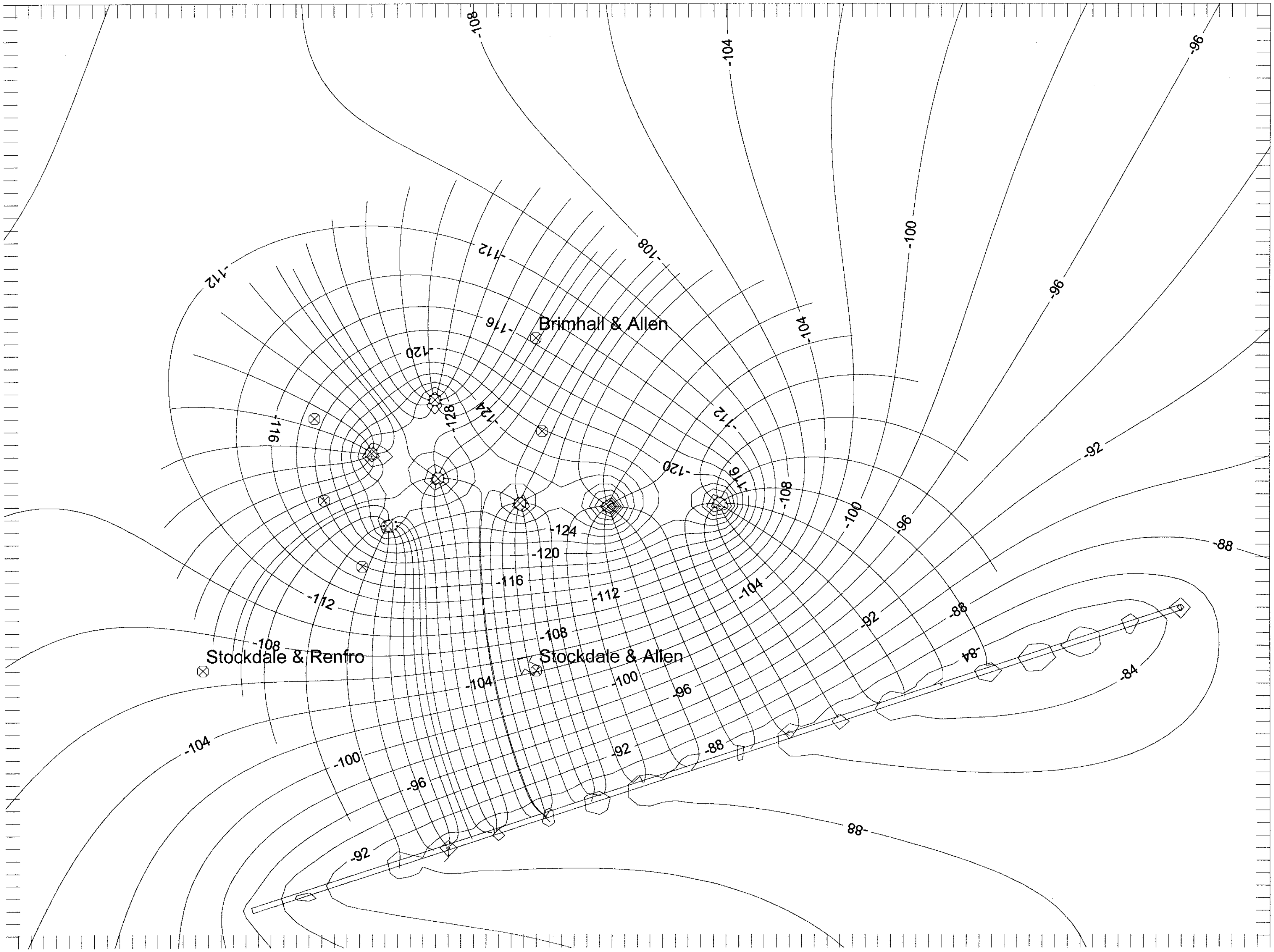
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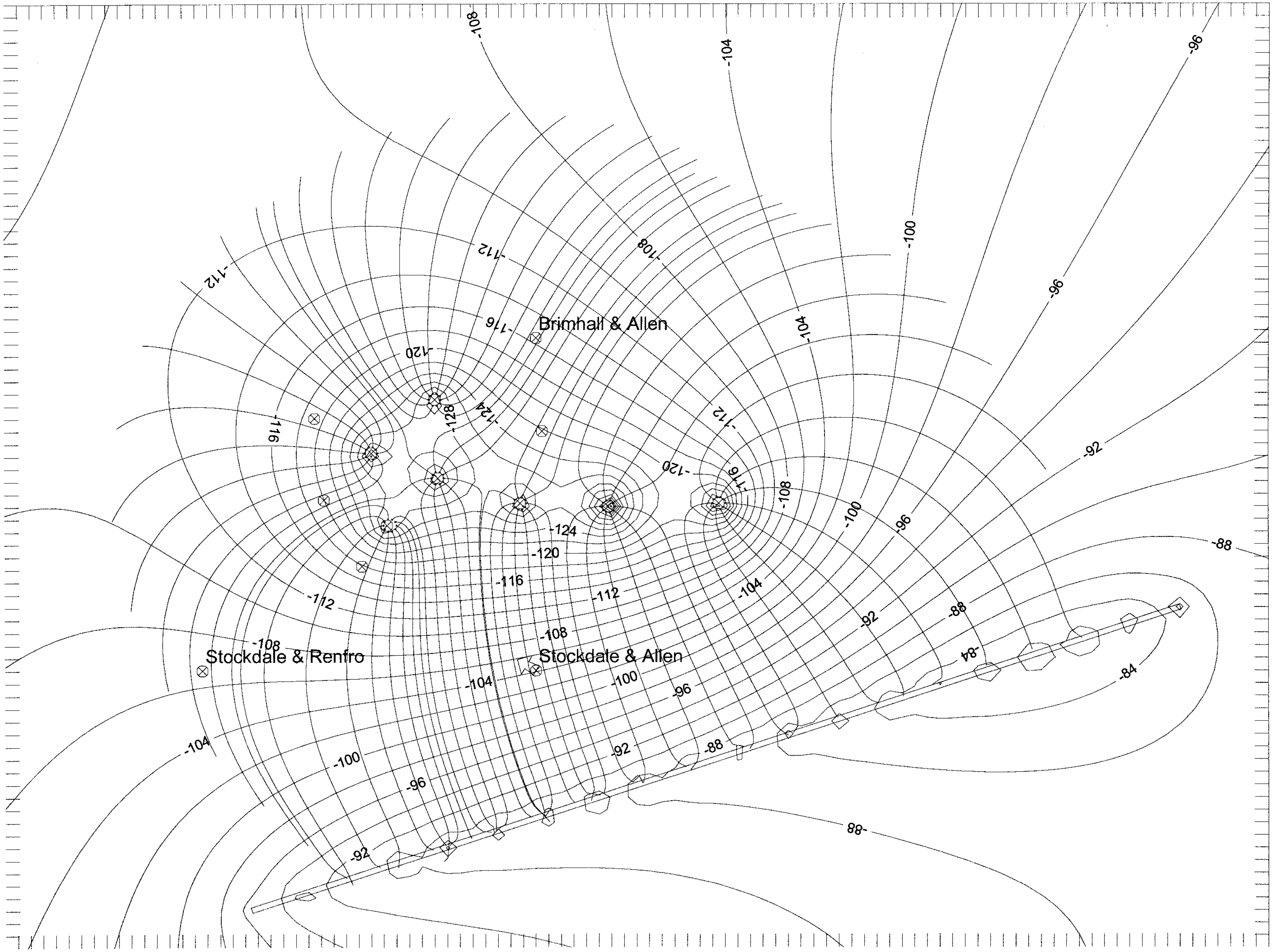
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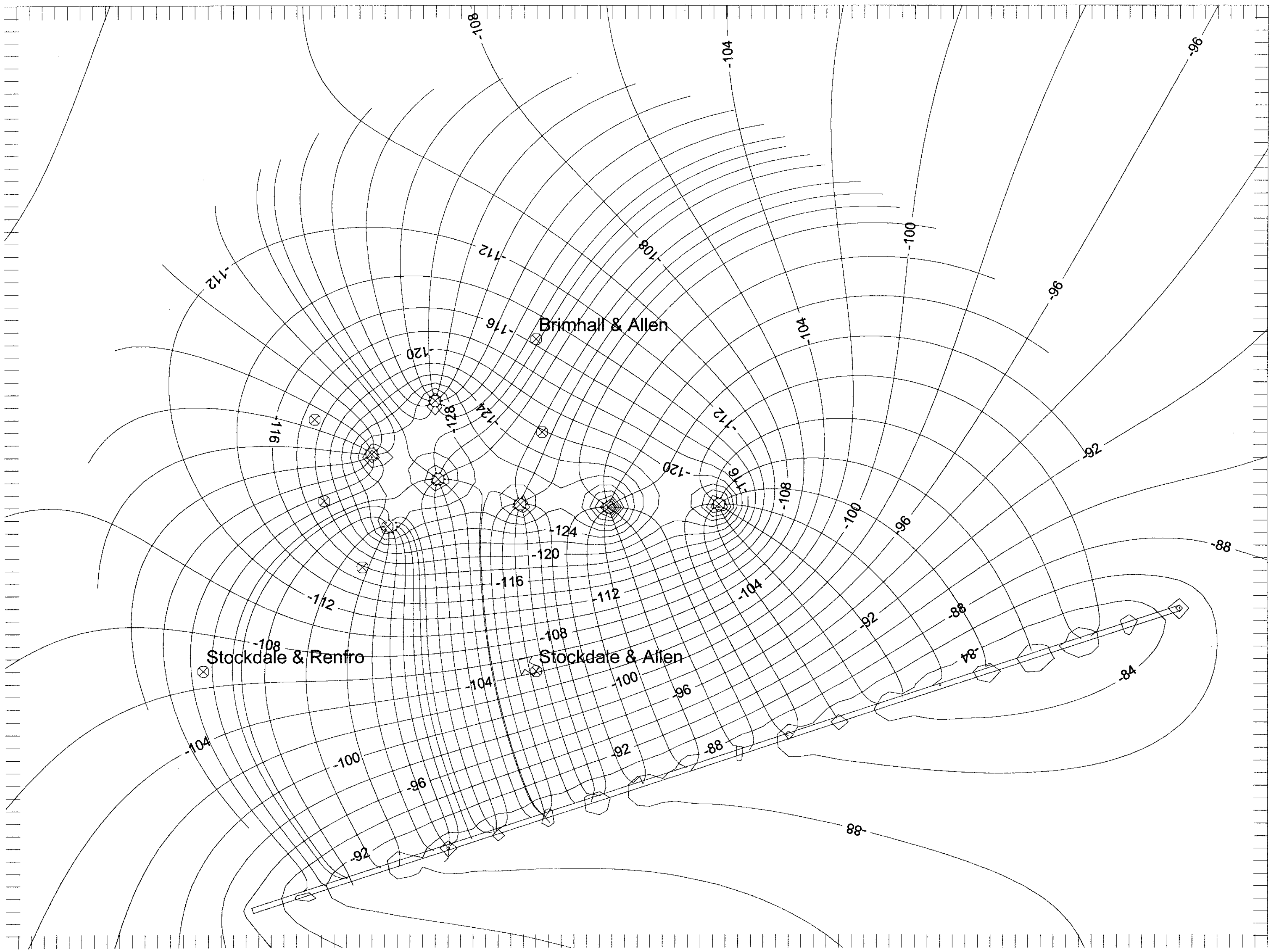
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Appendix 6.

Discussion

SETS 09 - 10.

Summary of Other Analyses, Sets 9 - 10.

The modeling program can be used to analyze other factors and impacts beyond those required for the current scope of work. In set 9 we analyze the differences between the calculated output of the superposition method which SSS uses and the so-called centroid method which has been used by other workers on other projects. In set 10, we generate three hypothetical scenarios which show the impacts of local recharge ponds in addition to the impacts of recovery well pumping. The purpose of these hypothetical scenarios is to show the relative magnitudes of the various impacts in the project area and are not intended to represent any specific, actual operating scenario within this or any other scope of work.

Set 9. Comparison of the superposition method to the "centroid method".

SSS uses the method of superposition to calculate the combined drawdown from multiple pumping wells by calculating the drawdowns from each pumping well individually and then summing them up. SSS disagrees with the use of what is locally referred to as the "centroid method" for the determination of multi-well drawdowns. Instead of adding up the individually calculated drawdowns, the proponents of the centroid method calculate a single drawdown by adding up the individual pumping flow rates and treating the total as a fictitious single well located at the center of the well field. This "weighted average" fictitious well of the centroid method does not correctly compensate for the unique distribution of flow rates and distances of the actual well field, nor does it provide any computational savings in the math. On a theoretical basis, the values of "Q" cannot be added, and the values of "r" cannot be averaged in the logarithmic term of the flow equation and still get the correct result. We recommend that ID4 consider not using any results which may have been based on the centroid method.

We have presented a set of maps which illustrate the differences between the calculated results of the superposition method and the centroid method for the same wells and the same parameters. There is one drawdown map for each method and a third map which shows the numerical difference between the two methods. The difference map represents the error in the centroid method. The positive differences represent locations where the centroid method *underestimates* the true drawdown (particularly the real drawdowns at pumping wells and the ends of the well field) and the negative differences represent locations where the centroid method *overestimates* the true drawdown (particularly the fictitious drawdowns at the centroid and on the sides of the well field). The two zero lines separate the quadrants of too- high and too- low drawdowns and they represent the entire locus of points where the centroid method happens to make the correct prediction.

There is also a significant and perhaps even more important difference between the results of the two methods and that is the difference between the capture zones predicted by the two methods. We present drawdown and particle trajectory maps for t= 300 and 720 days for both methods in the absence of a groundwater gradient and in the presence of a groundwater gradient. The shape and extent of the capture zone calculated with the centroid method is very different than that of the standard method, and the centroid method gives particle trajectories that are completely inaccurate for useful capture analysis.

Set 10. Superposition of hypothetical recharge impacts on hypothetical pumping impacts.

SSS has created three hypothetical recharge scenarios strictly for purposes of illustration. The first scenario is for continuous recharge in just the RRB ponds west of Allen Rd superimposed on river recharge and the regional gradient but without any wells pumping. The second scenario is the same as the first scenario except that the wells are pumped simultaneously for 300 days. The third scenario is the same as the second scenario except that two small recharge ponds have been added to the east of Allen Rd.

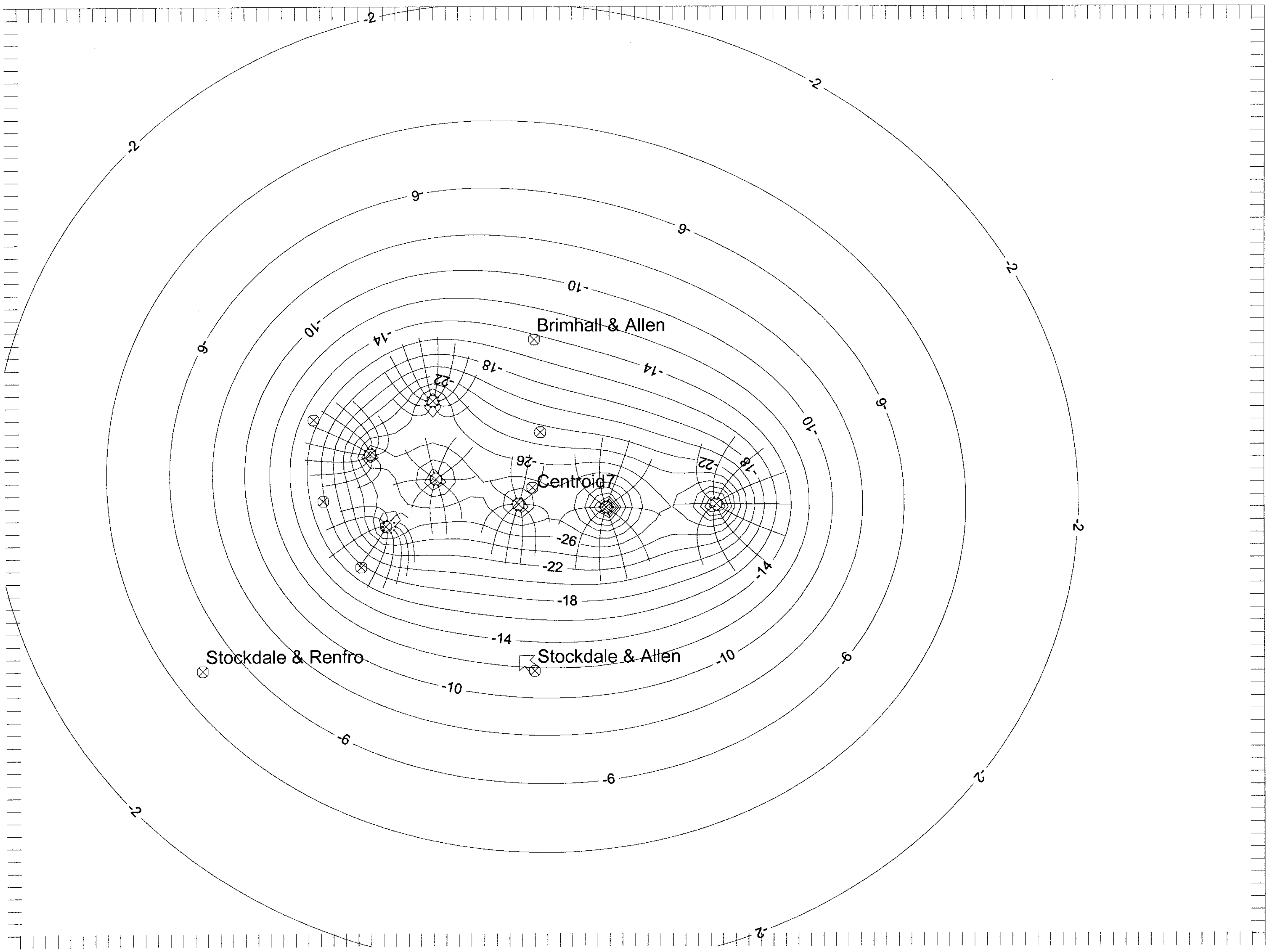
Appendix 6.

SET 09.

ID4 / KT / RRB Well Field Model Parameters.
Set No. 9.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky	leaky	leaky	leaky						
calc		transient	transient	transient	transient	transient	transient	transient						
Run No.		ref.only	901	902	903	904	905	906						
					(diff 1)			(diff 2)						
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0				-100		0						
Grad	G	0				0.001								
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300												
Ref Hd	Ref	0				-100		0						
Grad	G	0				0.001								
Azim	A	135				150								
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300												
Flow Rate	Q	full		0	neg. full		0							
Wells	W	all		none	all		none							
River Rch	Q	0				-210	-210							
Centroid7	Q	0		3888000		0	3888000							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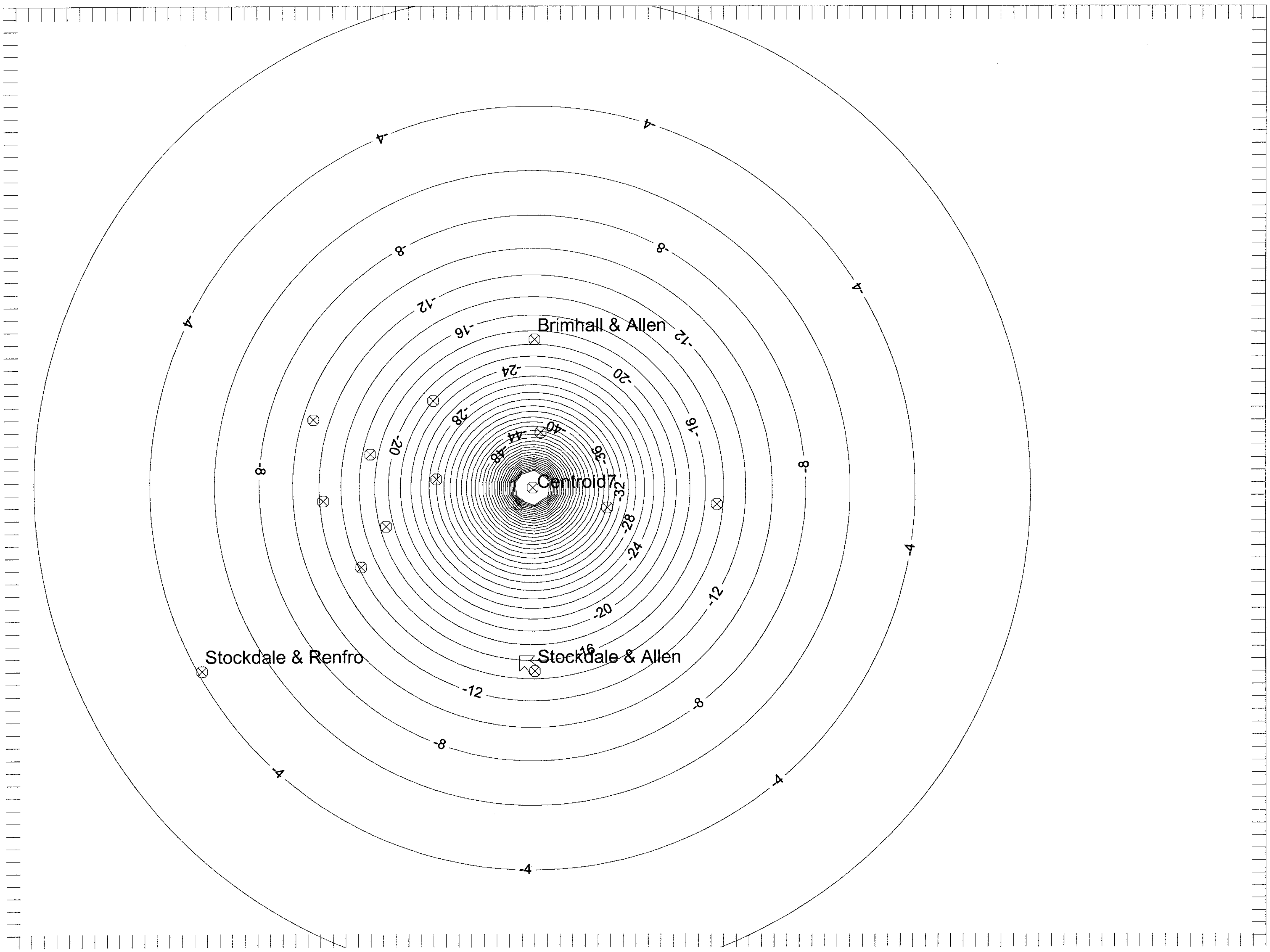
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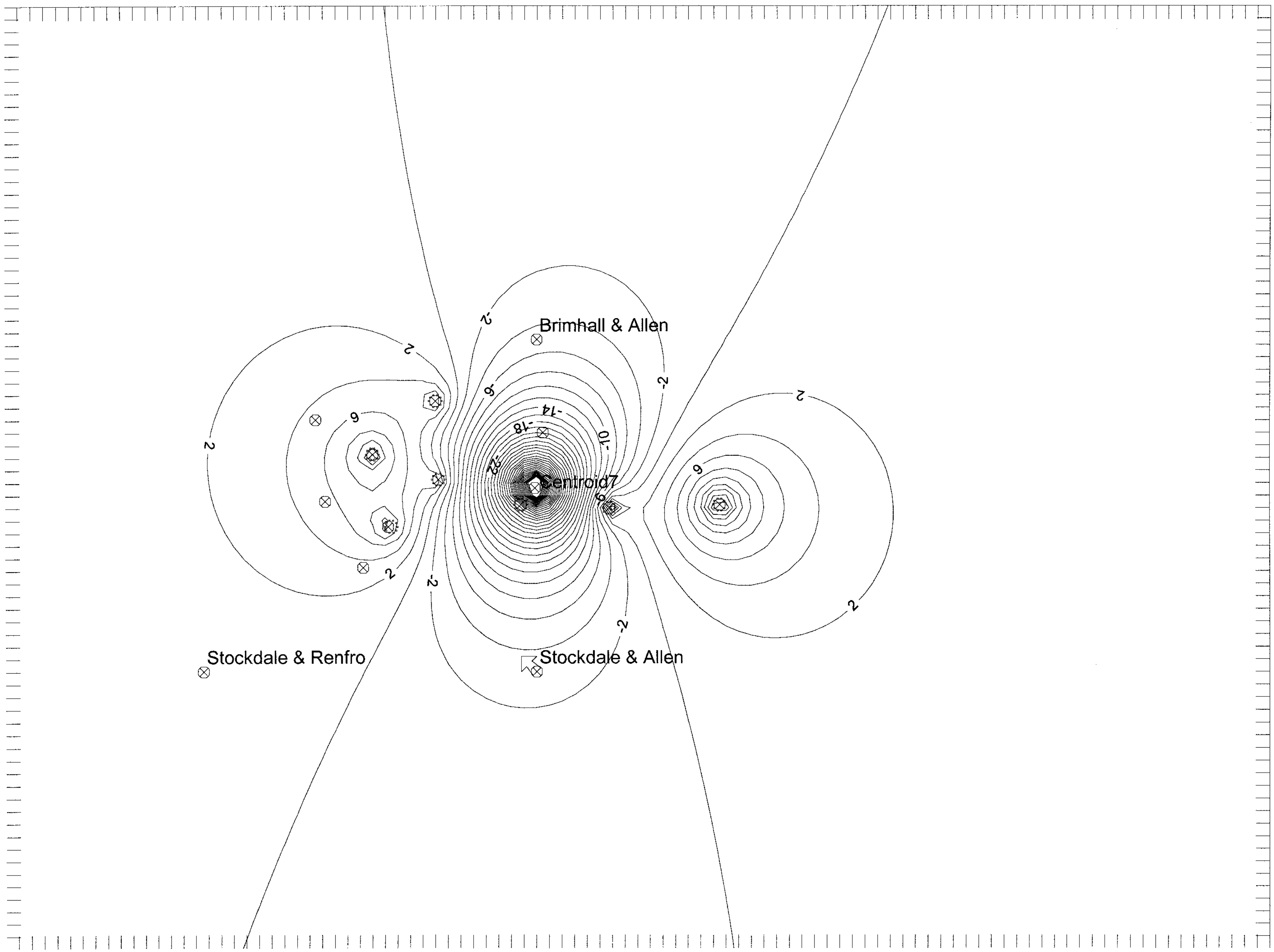
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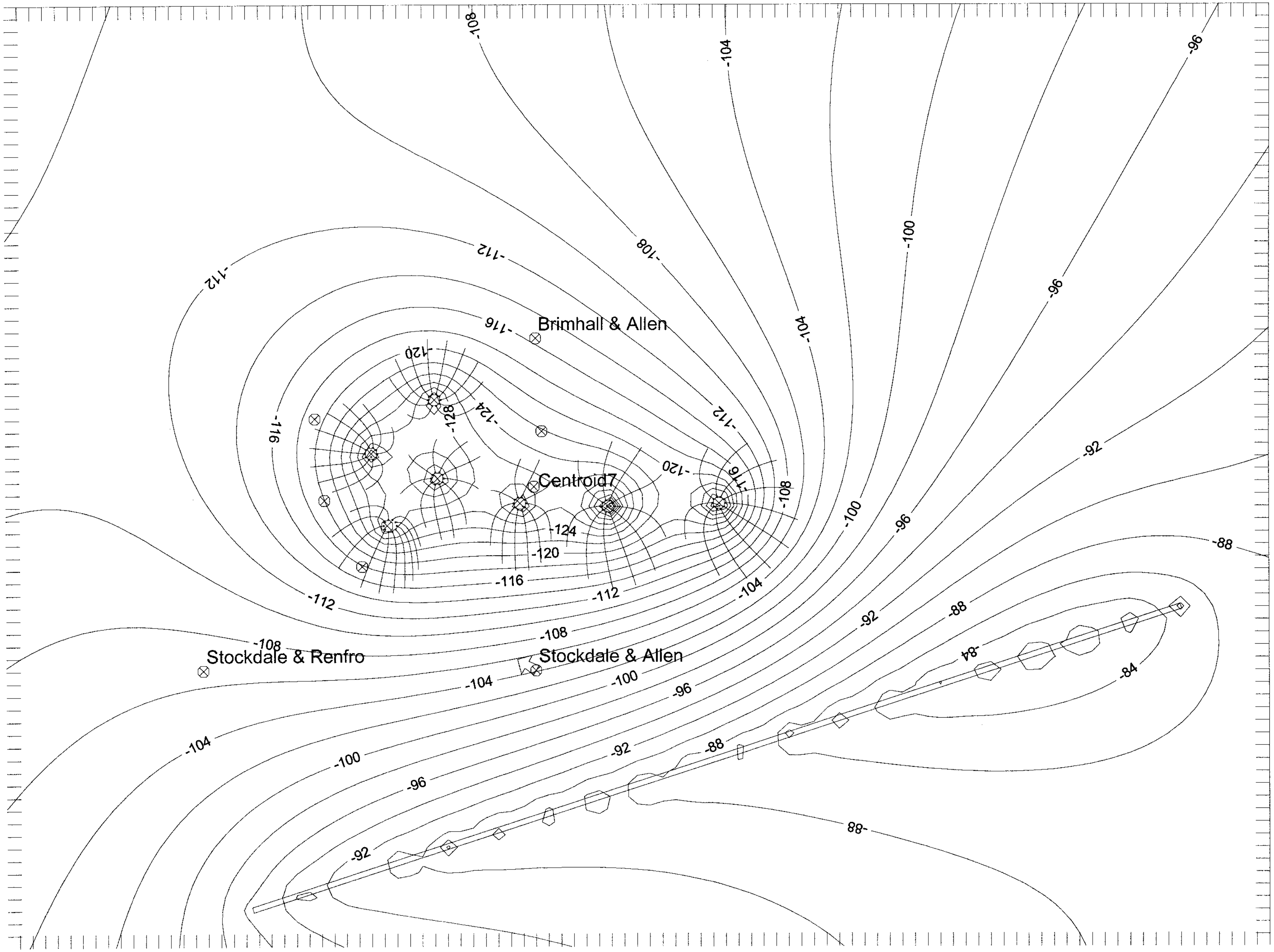
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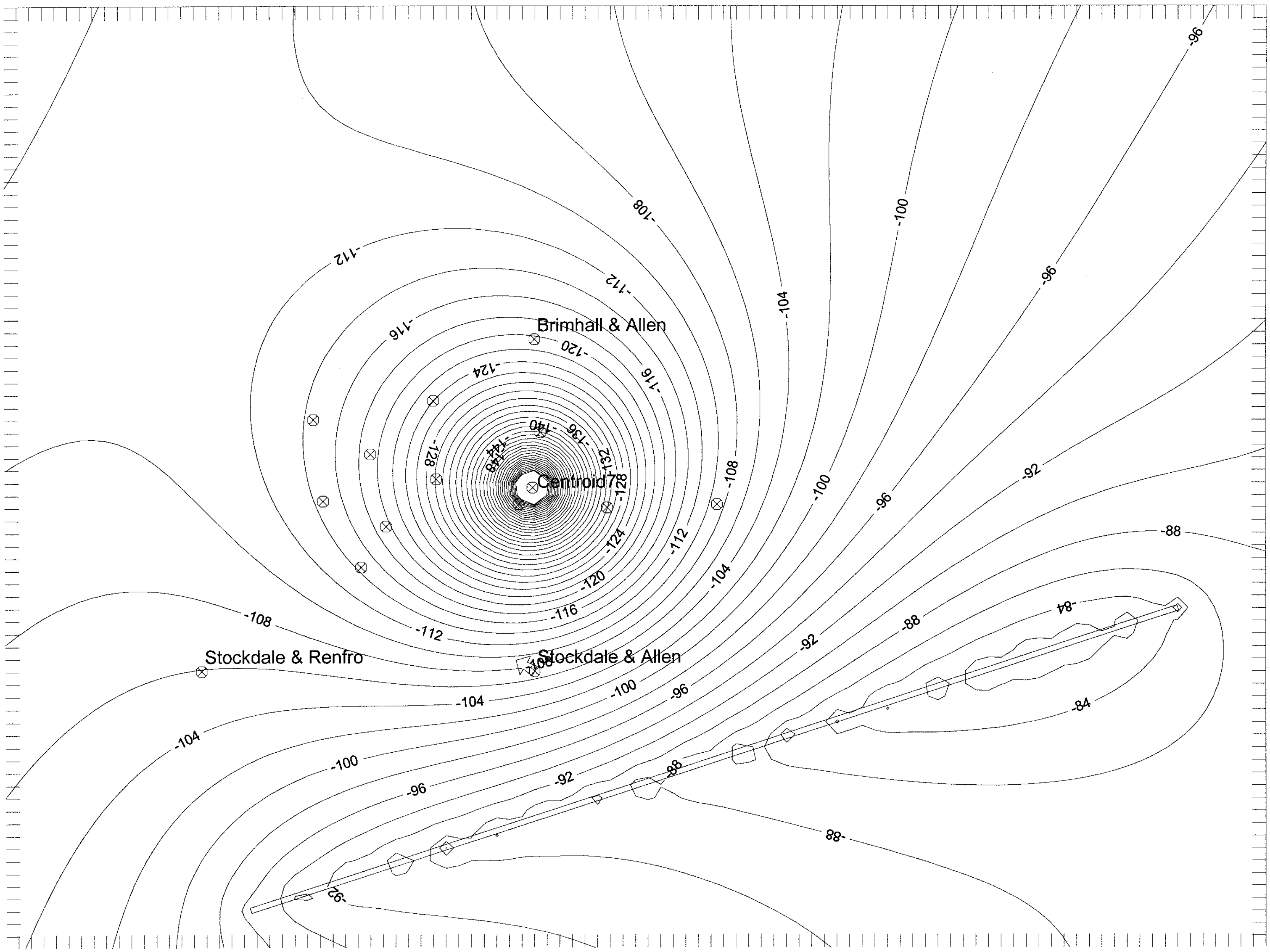
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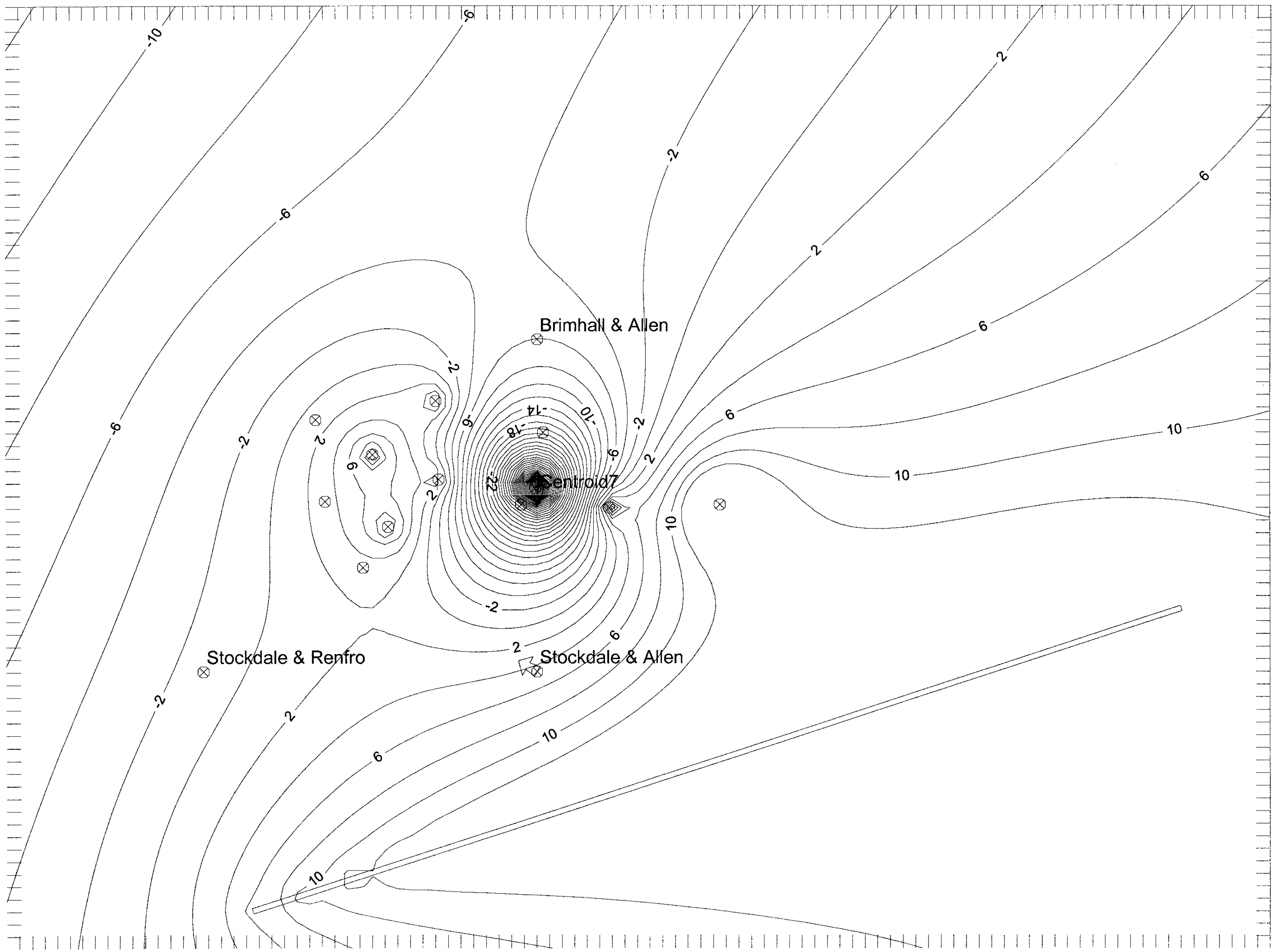
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2
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-18
-22

906

Appendix 6.

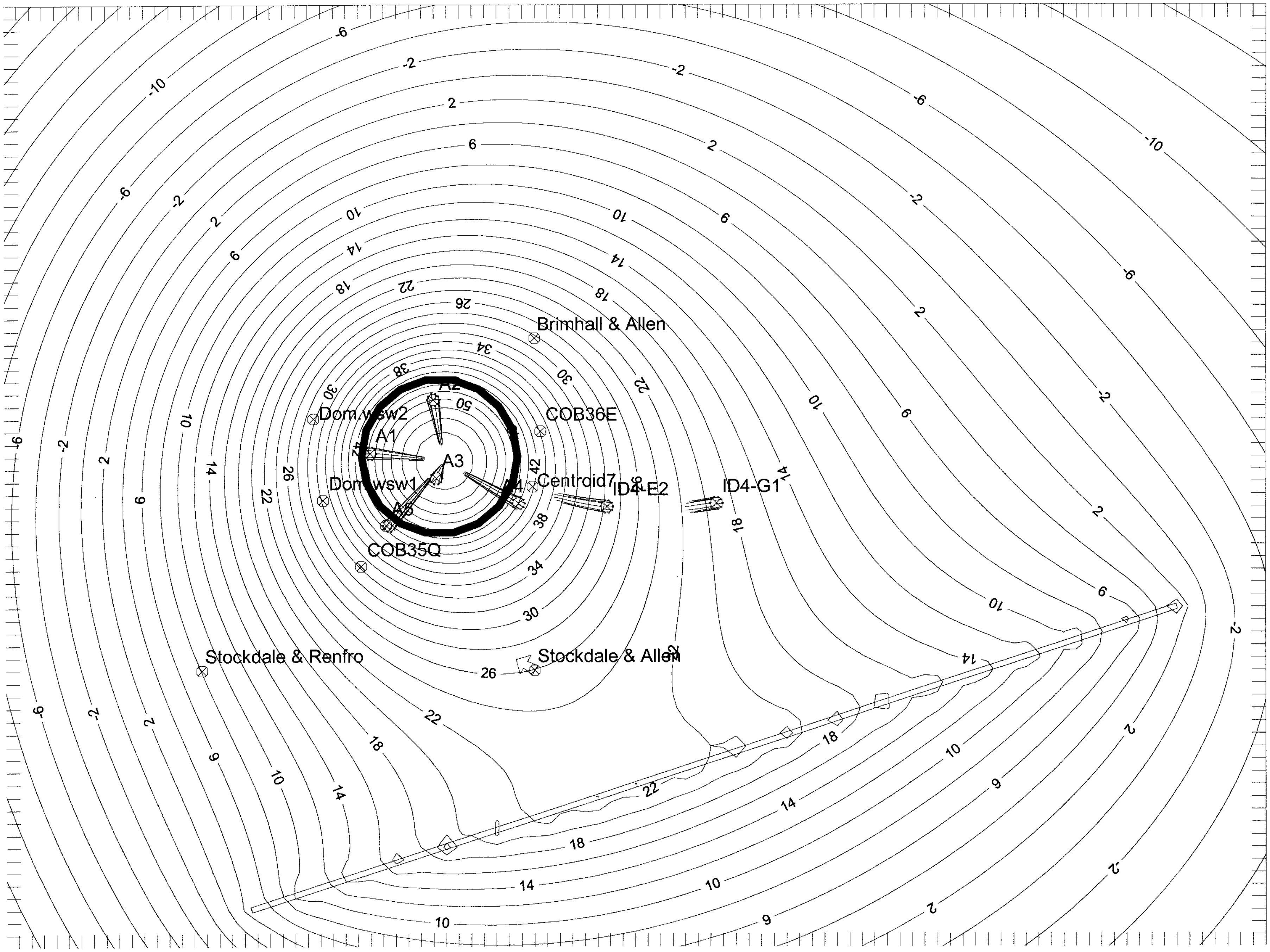
SET 10.

ID4 / KT / RRB Well Field Model Parameters.
Set No. 910.

Note: only CHANGES are tabulated between Runs, from left to right.
Note: once made, CHANGES persist until modifed again.

		base case												
model		leaky	leaky	leaky	leaky	leaky	leaky	leaky				leaky	leaky	leaky
calc		transient	transient	transient	transient	transient	transient	transient				transient	transient	transient
Run No.		ref.only	901	902	903	904	905	906				1001	1002	1003
					(diff 1)			(diff 2)						
H.Cond.	K	80												
Btm	B	-450												
Top	T	-200												
Ref Hd	R	0				-100		0				-100		
Grad	G	0				0.001						0.001		
Rchg	Rch	0												
Por	P	0.3												
Stor	S	5.60E-04												
Lkg	L	3200												
pump-t	t	300												
Ref Hd	Ref	0				-100		0				-100		
Grad	G	0				0.001						0.001		
Azim	A	135				150						150		
Ref-X	X	0												
Ref-Y	Y	0												
Const Hd	CH	no												
trace-t	tt	300												
Flow Rate	Q	full		0	neg. full		0					0	full	full
Wells	W	all		none	all		none					none	all	all
River Rch	Q	0				-210	-210					-210	-210	-210
Centroid7	Q	0		3888000		0	3888000							
Pond Rch	Q	0										pond 1		ponds 1-3

pond 1: 110 ac @ 1 ft/d = 4.71xE06 cf/d; r = 1235 ft, cen @ (-1500, 3400)
pond 2: 4.15 ac @ 1 ft/d = 181xE03 cf/d; r = 240 ft, cen @ (400, 2000)
pond 3: 2.88 ac @ 1 ft/d = 126xE03 cf/d; r = 200 ft, cen @ (2200, 2400)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COB36E
A1
A3
Centroid7
ID4-E2
ID4-G1
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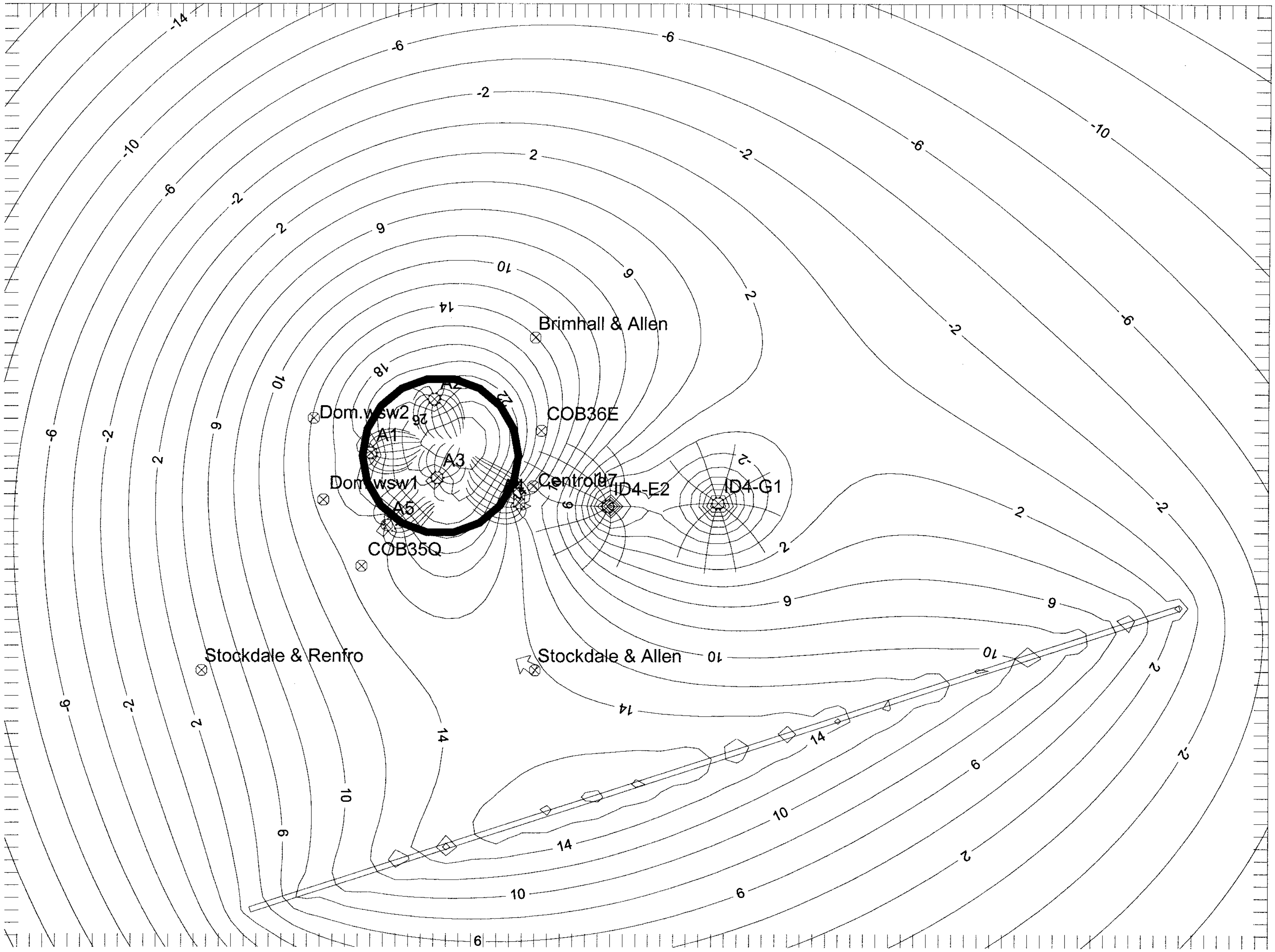
COB35Q
Stockdale & Renfro
Stockdale & Allen

1001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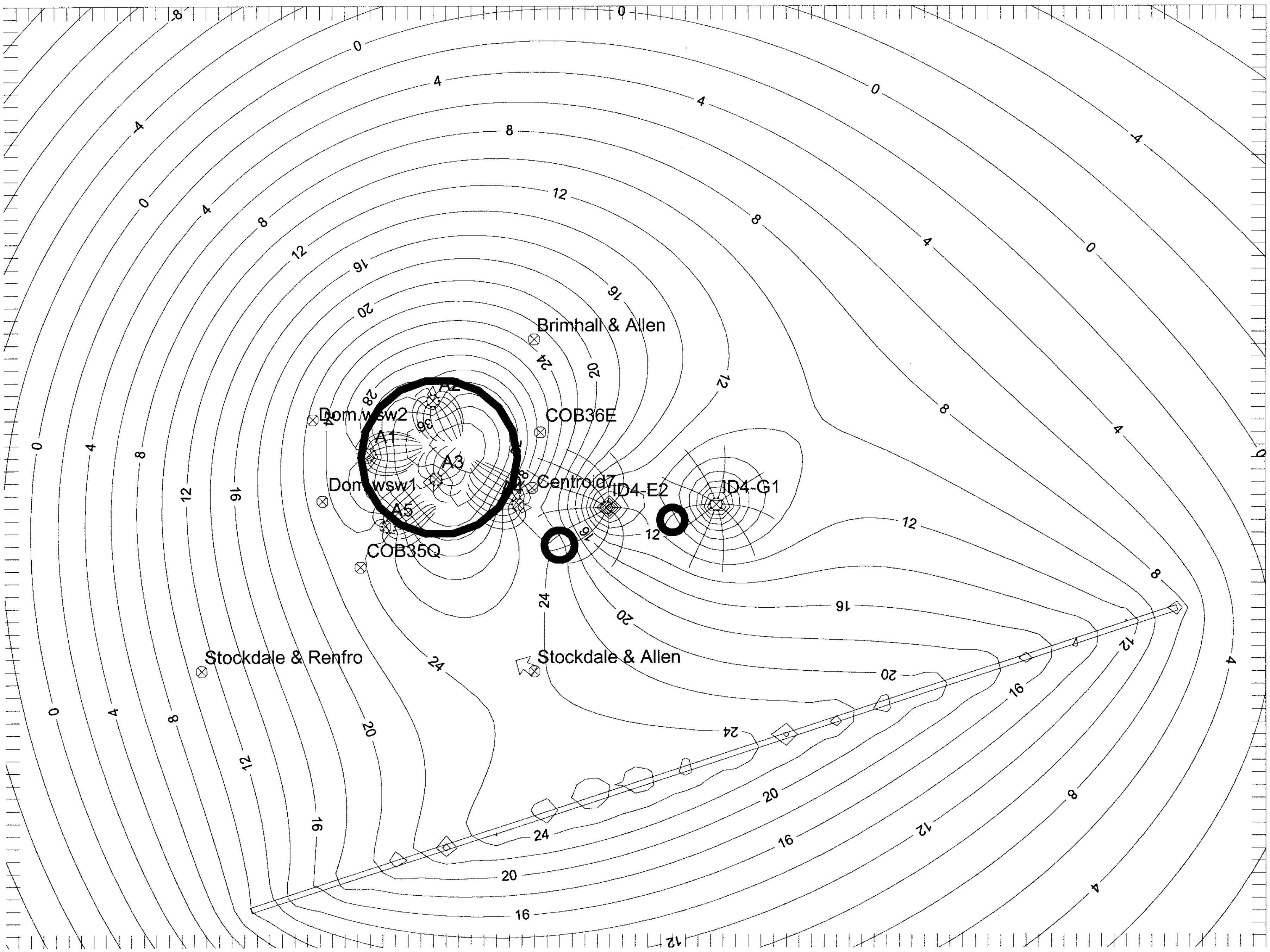
COB35Q
Centroid
ID4-E2
ID4-G1
Stockdale & Renfro
Stockdale & Allen

1002



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A3
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Centroid7
ID4-E2
ID4-G1
A5
COB35Q
Stockdale & Renfro
Stockdale & Allen

1063

Appendix 7.

Limitations of the Analyses.

Appendix 7.

Limitations of the Analyses.

SSS has evaluated several sets of base case and non- base case aquifer conditions to determine the predicted impacts of the proposed pumping program. The uncertainties in the calculated results are due to several factors which we briefly summarize in this Appendix.

Non - project wells.

There are three issues related to the impact of non- project wells in the local area. The first issue is the effect of water table decline due to the pumping of these non- project wells which is in addition to, and superimposed upon, the drawdown caused by the project wells. We have not included any hypothetical scenarios which takes this into consideration.

The second issue is that these non- project wells are removing water from aquifer storage which is not included in the project water balance. Even if the project remains in balance, the local area may still suffer a net shortage of recharge which will create a net decline in water levels, which will ultimately change the aquifer behavior from semi-confined to unconfined. We have already included this hypothetical scenario in our general analysis, and it is important to recognize the potential for shallow aquifer dewatering by pumping non-project wells.

The third issue is that non- project wells create capture zones of their own which extend outward into surrounding areas which are outside of the capture zone limit of just the project well field alone. It is possible that these surrounding wells draw contamination into the project area that would not have arrived here otherwise. Such a capture analysis is outside the scope of this analysis. While there are limits to the possible magnitude of this potential impact, the wells of greatest potential concern would be wells which are close to the project well field and those which are to the east of the well field.

Changes in the groundwater gradient.

Based on KCWA groundwater elevation maps for the area, we have observed an overall change in the groundwater gradient as the climate swings from wet to dry conditions. During a wet cycle, the recharge in the three- mile stretch of the Kern River channel from Allen Rd east to Coffee Rd tends to create a northwesterly component to the overall gradient on the north flank of the river recharge axis (for example, see KCWA maps for 1996 - 1998). During a dry cycle, the absence of recharge in this stretch causes a westerly gradient to dominate due to the effects of aquifer dynamics farther to the east (for example, see KCWA maps for 1991 - 1993).

This shift may cause contaminant plumes located outside of, but close to, the long term capture zone limit to move into the capture zone. The reverse is not really possible, i.e., contaminant plumes leaving the capture zone, because even though particle trajectories say it is possible, actual contaminant migration invariably leaves in situ residues behind in its pathway which linger as continuing in situ sources of low- grade contamination for many years thereafter. We have included the uncertainty in ground water gradient in our analysis by using a long- term background average ground water gradient behavior within the computational model, based on the observed trends from the KCWA historical ground water elevation maps.

Interzonal water quality changes.

Aquifer storage and recovery (ASR) projects in the Kern Fan area generate large and persistent vertical ground water gradients which cause interzonal flow. This flow causes significant interzonal mixing which may be of concern if project pumping causes undesirable impacts on zones which previously had acceptable water quality. We have not included the vertical flow component in our capture zone models or our qualitative comments on the potential for contaminant capture.

In our opinion, which is based on our interpretation of some of the available geochemical data for another project, both the general mineral chemistry and the constituent-of- concern (COC) chemistry varies significantly between some depth zones within the aquifer. In our opinion, this trend is being obscured by the use of blended- water analyses from multi-zonal water wells (often by choice in data- poor areas) and by ignoring the depth dimension in the bulls- eye approach to water quality mapping.

We do not currently have enough baseline water quality data to predict the quantitative water quality changes in the project area due to project pumping. There is a general opinion that the shallow unconfined aquifer has the poorest water quality and that the water quality improves with depth. Such statements have little meaning unless they are qualified as to the water quality criteria of interest, whether it be total dissolved solids, hardness, or some constituent of concern. Some generalizations may help. Good quality water, by local standards, refers to Kern River water which has a low TDS = 150 mg/l, acceptably low concentrations of naturally- occurring objectionable constituents (such as arsenic at 4 ug/l), and no manmade constituents at concentrations of concern, if detectable at all (such as nitrate at _).

In general terms, the groundwater in the shallowest zones in the project area has a constituent chemistry which most- closely reflects the chemistry of the local recharge water combined with shallow local infiltration. The deeper zones increasingly reflect the chemistry of more- distant recharge which travels different and longer flowpaths before arriving under the project area. As long as ground water extraction remains less than the local yield of the aquifer, the differences in water chemistry in different depths zone will persist. But as ASR projects are increasingly operated in the area, the primary direction of recharge will change from lateral flow in the different zones to downward vertical flow from the shallower layers. The recovery pumping will accelerate the downward leaky recharge to the aquifer and the consequent dewatering of the shallow zone will accelerate the lateral inflow of shallow water into the project area. This change in local aquifer dynamics will cause an interzonal blending in which the water chemistry in successively deeper layers will become more like that of the near- surface recharge.

To the extent that this downward flux transports poorer quality water into deeper zones, it represents a water quality degradation of the deeper water. However, it is not clear that all of the objectionable constituents are isolated at the top, so a blending of this type may actually serve to dilute the concentration of certain deeper COCs, perhaps such as arsenic and/or uranium, and/or H_2S gas at depth, with water of overall less objectionable qualities. And it will probably be found that the flux of poorer quality shallow water through the silty aquitards will be cleaned up by the natural filtration effect of the finer- grained sediments.

All of this being said, there is less to be done at this time than there is to be learned by paying careful attention to the effects of this aquifer behavior during the project operation. We recommend that the design of a groundwater monitoring program include multi-zone WQ monitoring in what are identified to be key locations.

Uncertainty in predictive modeling.

There are several causes of uncertainty in the outcome of a predictive forecast and it is useful to keep the relative importance of these causes in perspective.

Natural variability. The single most significant cause of uncertainty is natural variability, i.e., the complexity, heterogeneity, and randomness in the real world which are impossible to fully identify or evaluate at relevant scales of measure. In this project, we know that the aquifer is more complex in ways which we may or may not recognize but can't model because of insufficient data. For example, we know that the silty layers seen in the E-log of one well rarely correlate with the silty layers seen in adjacent wells. But we can't model all of these individual layers because we don't actually know where they start and end in the unobserved spaces between wells. The same is true for boundaries which are there but have not yet been detected by the existing investigations.

We must therefore try to represent the known or suspected complexity with a simpler component within our model which best approximates the expected behavior of the real earth by lumping the complex properties together in the form of a simpler analog. The practice of "lumped parameter" modeling is a simplification of choice as well as necessity. Even if it were possible to represent every sand grain and every pore space in the aquifer, the increase in microscopically detailed complexity may not contribute anything to improve the accuracy or reliability of the results. It is one of the hard-won skills of good modeling to know when and where a simpler approximation will be an effective and accurate representation of the real system.

A corollary effect of natural variability is that the true aquifer parameters will always be somewhat different than those in the model at some place or at some time. Even if we could precisely determine the true average value for every parameter, those local parts of the aquifer which are higher or lower than the average value and have observation wells located in them, will be observed to behave differently than predicted by the model. Since predictive modeling is often used *before* projects have begun, it is often true that a sufficient amount of good data doesn't even exist to estimate the average properties of the aquifer let alone map the full range of variability at all locations. Often a sufficiency of data doesn't exist until such a projected has operated for many years. So, when comparing a predicted behavior to a subsequently observed behavior, it would be a mistake to treat point- by- point differences as a parameter error when those differences can be adequately explained as being caused by simple, undeterminable, natural variability about an average value.

Another effect of natural variability applies to the inability to predict future naturally-occurring or manmade events or behaviors, in addition to the variability in physical properties. For example, highly variable weather conditions can deviate significantly from average behavior without being considered anomalous, so that any *particular* predicted event has a significant chance of being different than the actual occurrence even though the prediction is a "correct" one. For these types of conditions, the correct prediction is actually a set of predictions covering the full range of possible values, with a probability of occurrence attached to each one. So in this project, we predict aquifer drawdowns due to pumping and our model stipulates that the actual future drawdown behavior will be controlled in part by the amount and timing of recharge which is controlled by the climatic weather cycle. So, we have identified a range of possible drawdown scenarios based on two possible weather- controlled recharge scenarios, i.e., sufficient recharge and insufficient recharge.

Judgment. The second significant cause of uncertainty is errors in judgment by the modeler, including such mistakes as selecting an inapplicable model or poor model parameters, doing the work incorrectly, or failing to recognize and correct "catchable" mistakes. These errors in judgment range from making an informed choice under difficult conditions or with very little data to blatant mistakes. There is probably little chance of a non-expert catching errors in judgment other than, perhaps, blatant mistakes.

In our opinion, there are two ways to try to catch judgment errors. The first is to get a second opinion from a qualified expert. The second is to take the time to learn enough basics to make a critical review of the work. After all, the accuracy of your own work may depend on these results. And then, require clear, complete, and verifiable documentation beyond simple numerical QA/QC with any modeling project and simply evaluate the work product for logic, consistency, clarity, and credibility.

Expectation. A third cause of uncertainty is errors of expectation on the part of an inexperienced modeler or the final user of the predictive output. Errors of expectation can include expecting too much and expecting too little. Unreasonably high expectations often come from a lack of understanding of the issues of natural variability. Examples of such errors of expectation include the assumption that there is only a single possible answer or that it is single- valued; that the answer is precise and accurate and, if correct, will be verified to a high degree by the actual observed outcomes; that the answer must be right because modeling is a numerical procedure and computational accuracy is mistaken as being the same as representational accuracy; or that the modeling procedure is wrong or useless or that mistakes must have been made if the predicted results and actual results disagree in some way.

Low expectations often come from a lack of understanding of how powerful and sophisticated predictive modeling can be in the hands of a competent expert. Many business people, policymakers, engineers, and consultants go about their particular business unaware that predictive modeling tools exist for almost every type of process or system including groundwater phenomena such as the flow behavior of rivers, water supply reliability, weather patterns, basin analysis, flow behaviors, and contaminant plume migration.

Unlike errors of judgment by a trained practitioner, errors of expectation are not a matter of right or wrong. Getting it wrong while learning what to expect is the normal process for all of us. The lesson is that if modeling is not part of one's expertise, then 1. hire an expert rather than trying to do it yourself, 2. talk to your expert about reasonable expectations, and 3. learn something about the required inputs, the process itself, and the form of the expected output so you can bring some critical review to the results.

ATTACHMENT 16C

Sierra Scientific Services, 2007a. A Water Quality Evaluation of the Strand Ranch Aquifer Storage and Recovery Project, Kern County, CA., in: Rosedale -Rio Bravo Water Storage District Strand Ranch Integrated Banking Project Environmental Impact Report, January, 2008, prepared by ESA, Los Angeles, CA. December 19.

Sierra Scientific Services

A Water Quality Evaluation of the Strand Ranch Aquifer Storage and Recovery Project, Kern County, Ca.

19 December, 2007

prepared for:

Irvine Ranch Water District
15600 Sand Canyon Avenue
Irvine, California 92618
Mr. Paul Weghorst,
Principal Water Resources Manager
(949) 453 - 5632

prepared by:

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1800 30th Street, Suite 400
Bakersfield, CA 93301- 1932
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(661) 377 - 0123

Table of Contents

Figures.

Tables.

Exhibits.

A Water Quality Evaluation of the Strand Ranch Aquifer Storage and Recovery Project, Kern County, Ca.

1. Summary of Findings

The proposed Strand Ranch Aquifer Storage and Recovery Project is designed to receive surface waters from the State Water Project, the Federal Central Valley Project, and the Kern River and store these waters in the available dewatered storage space of the underlying unconfined aquifer. At some later time, the Project will use high-flow water wells to recover a like volume of groundwater from the underlying aquifer.

All three surface waters are considered to be low-TDS, high-quality water which is acceptable for all uses in Kern County with little or no pre-treatment. The existing groundwater banking projects in the area have been storing these same three surface waters in the aquifer since about 1980. Since these three surface waters have lower TDS concentrations and lower constituent-of-concern concentrations than the groundwaters in the aquifer zones under the Project site, the historical data record shows that all recharge-then-recovery operations in all such projects have a beneficial salt balance impact and a beneficial COC balance impact on the basin.

Based on calculated hypothetical stoichiometry on the proposed Project recharge and recovery (predicted -118 mg/l net loss of salt from the basin), and based on the observed positive impacts from existing projects, we conclude that the water quality impacts from this Project will be significantly positive for the basin as well.

We have observed in the groundwater data that there is a shallow-aquifer brine plume which is migrating under the Project site from an unspecified, upgradient, off-site, source or sources, which is causing a ± 400 mg/l rise in TDS under the site relative to the unimpacted adjacent aquifer water. The suspected sources of the plume are oilfield wastewater disposal ponds which have not been active for more than 30 years, as qualified in this Report.

The plume has been degrading due to natural dispersion and active removal by local water wells. The residual concentrations at all locations in the plume have been declining and are expected to continue to do so, subject to verification of actual conditions over time. The project recharge and recovery operations will both have the immediate, beneficial impacts of remediating the plume in two ways: 1. the addition of lower-TDS surface water to the shallow aquifer during recharge will decrease the in-situ TDS by dilution and 2. the recovery operations will decrease the plume volume by permanently extracting plume water from the aquifer. The basin will benefit from the direct remediation of this plume as an incidental positive impact of Project recharge and recovery operations.

However, as long as the elevated-TDS plume exists and is not fully mitigated, the plume will have an impact on the Project by making it somewhat more difficult for the Project to meet the pump-in criteria for the Cross Valley Canal and the California Aqueduct when they need to recover and return water to end-users. The KWB continues to operate nearby plume-impacted water wells by blending the recovered plume water with other, lower-TDS recovered waters as necessary for their purposes and the same operational mitigation is available to the Strand Ranch Project as well.

We conclude that:

1. The conversion of agricultural land to an aquifer storage and recovery project eliminates the potential future use of Ag chemicals on the property which has been generally recognized in Kern County as a potential source of shallow-aquifer degradation;

2. The surface water sources available to the Project are free of constituents of concern (COCs) and are of lower total dissolved solids (TDS) content than the existing groundwater directly underneath the project site;

3. The recharge cycle will add lower-TDS surface water to the shallow aquifer where it will have the beneficial effect of diluting down the higher-TDS, plume-impacted groundwater;

4. The recovery cycle will remove groundwater which has a higher TDS and COC content than was originally put into the aquifer during recharge;

5. The positive water quality benefits of a full recharge/recovery cycle include a net removal of salt from the basin under the unimpacted natural water quality conditions of the aquifer, as well as an additional net reduction in COCs, and an ongoing dilution and extraction of the migrating brine plume as long as it continues to exist.

Crewdson, Robert, A., 19 December, 2007, A Water Quality Evaluation of the Strand Ranch Aquifer Storage and Recovery Project, Kern County, Ca., Sierra Scientific Services, Bakersfield, Ca.

A Water Quality Evaluation of the
Strand Ranch Aquifer Storage and Recovery Project,
Kern County, Ca.

2. Introduction

Section I - Purpose.

The purpose of this Report is to describe the water quality interactions and impacts which are expected to occur as a result of the operation of the Strand Ranch Aquifer Storage and Recovery Project.

An operational objective of the Strand Ranch ASR Project is to protect and preserve the water quality of the underlying groundwater aquifer while meeting the applicable regulatory and contractual standards of ASR operation. These standards may include the "pump-in criteria" for transporting project water in the Cross Valley Canal and California Aqueduct, the terms of the Memorandums of Understanding (MOUs) with adjacent entities, terms established by contract or other agreement, or the concepts of sustainable groundwater management.

The initial findings of this study may be used as a baseline to begin a voluntary water quality monitoring and reporting program (MRP) for future ongoing water quality evaluations. The purpose of this study and the MRP is to provide a permanent water quality database related to the Project operations which can be used for demonstrating and verifying compliance with the water quality objectives.

Section II - Project Scope - Aquifer Storage and Recovery.

Aquifer storage and recovery (ASR) is the generic term which describes the practice of deliberately putting surface water into a groundwater aquifer through infiltration basins with the intention of recovering a like volume of water from the aquifer at a later date. Such a practice presents a great opportunity to increase the local and statewide capacity to store water. ASR projects help regulate the water supply and demand over time by storing excess water when it is available in wet years for future recovery when water is needed in dry years.

In Kern County, California, there are 3 main components to every ASR facility: recharge basins, water wells, and a conveyance system. The recharge basins are ponds which are constructed to allow ponded water to infiltrate into the groundwater basin. The water wells are conventional high-flow water wells used to pump water out of the underlying aquifer. The project conveyance system consists of one or more canals, ditches, or pipelines used to deliver water to or from the ASR facility by connecting it with the local and regional water conveyance infrastructure.

The Kern County water community generally refers to ASR projects as "banking" projects. According the Kern County Water Agency, "These banking programs are essential to Kern County's water management and future growth[1]" and this is broadly true of the entire State of California water infrastructure. As used in Kern County, the term "banking" is loosely used to describe the act of physically putting water into the underlying aquifer and crediting the owner with the right to remove a like volume of water from the aquifer at a later date. This credit allows the owner to show such a volume of banked water as part of its current water supply. If such water has been "banked" on behalf of another party, then it is considered to be real water held in trust for that party who has an absolute right of recovery.

Section III - Background.

The Irvine Ranch Water District (IRWD) is currently in the process of developing a ±600 acre parcel in Kern County, California, as an Aquifer Storage and Recovery (ASR) Project (Figure 1). The parcel of interest is located in Section 2, Township 30s, Range 25e, MDBM, located at the southwest corner of Stockdale Highway and Enos Lane, several miles west of the City of Bakersfield. The ±600-acre Strand Ranch ASR project will be the latest among several existing ASR projects in the area which currently cover approximately 20,000+ acres and include more than 120 wells. The project site is surrounded in all four compass directions by existing ASR facilities belonging to the Kern Water Bank Authority or to the

[1] Lloyd Fryer, 2005, Kern County Groundwater Banking Projects, KCWA brochure.

Rosedale - Rio Bravo Water Storage District. The parcel has been known historically as the Strand Ranch, so- named for the sand fairways crossing the property, so the project is informally referred to as the Strand Ranch ASR project.

The proposed project is designed to include 450+ acres of recharge ponds and 6 to 8 water recovery wells. The project site currently has approximately 120 ac of existing recharge ponds which were operated in 2006 on a pilot-study basis. The Cross Valley Canal runs through the Strand Ranch parcel which provides potential conveyance capacity to move surface water to and from the Project site. The site currently contains five or more irrigation wells which were installed by the previous owners of the Strand Ranch and are capable of recovering groundwater at this time. The project operator proposes to recondition or replace existing wells, and/or install recovery wells, as necessary or as beneficial, to meet their proposed operating parameters.

The site is flat at an elevation of about 320 ft above msl. The site overlies the prolific aquifers which comprise the so-called Kern Fan which, geologically speaking, is a thick pile of interbedded, fine- to coarse- grained, fluvial/alluvial sediments. The shallow aquifer is recharged by natural and manmade percolation of (mostly) Kern River water. Recharge occurs in the river bottom and nearby recharge ponds which form a 15-mile long, linear recharge axis starting in the city limits of Bakersfield and trending southwest across the southern San Joaquin Valley. When we refer to the Kern Fan in this Report we will generally be referring to the ±12-mile wide elongate area which straddles the recharge axis and includes the river channel, ASR project sites, and related surface infrastructures.

The Strand Ranch ASR Project is near, but northwest of, the recharge axis of the Kern Fan recharge mound. The depths to groundwater under the Project site fluctuate significantly due to the rise and fall of the Kern Fan recharge mound under the influence of the regional climatic wet/dry cycle. During consecutive dry years the groundwater may be 150 - 180 ft deep such as in 1990 - 1995, whereas during consecutive wet years the groundwater under the site may be 20 - 80 ft deep such as in 1995 - 1998. The unimpacted natural groundwater gradients under the Project site consistently trend northwesterly at -10 to -20 ft/mi WNW in dry years and -20 to -30 ft/mi NW in wet years.

The three potential sources of surface water which might be brought to the property include water from the Kern River, water from the Federal Central Valley Project (CVP) via the Friant- Kern Canal, and/or water from the California State Water Project (SWP) via the California Aqueduct. The source of both the Kern River water and CVP water is runoff from the winter snowpack from the highlands of the southern Sierra Nevada mountain range. The primary water source for the SWP is runoff from the greater volcanic highlands surrounding Mt Shasta in northern California. The waters from all three sources are very good quality when they reach their intended points of use within Kern County.

The water chemistries[2] of the surface waters differ somewhat from each other and they differ from the water chemistry of the groundwater. When surface water is stored in the aquifer and commingles with groundwater, the volume of water in the aquifer increases and the water chemistry of the augmented, commingled groundwater changes. The water chemistry of the commingled groundwater is intermediate between the water chemistries of the recharged water and the pre-existing groundwater in the zone of commingling. When groundwater is removed (recovered) from the aquifer, the water chemistry of the recovered water is the intermediate chemistry of the commingled water. For this study, the waters of interest include the following: the shallow, intermediate, and deep groundwaters; the three potential surface-water sources; and a brine plume flowing in the shallow aquifer under the site.

Section IV - Work Program.

Some of the data and findings in this Report have been excerpted and modified from another ongoing water quality study being prepared for the Rosedale - Rio Bravo Water Study District, with their permission. That study is a baseline water quality (BWQ) analysis of the groundwater aquifer in the RRBWSD area of interest, which happens to include the Strand Ranch Project area because of proximity. The RRBWSD baseline water quality analysis will be completed and presented in report form in the Fall, 2007.

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[2]By "water chemistry"we mean all of the individual constituent concentrations of the various dissolved solids, whether natural or manmade, which are of interest for the intended uses of the water.

The ongoing BWQ work program includes groundwater data collection, basic data analysis, and preliminary interpretation. The sources of data include: the Kern County Water Agency water quality database (courtesy of Tom Haslebacher, KCWA Senior Hydrogeologist), Vaughan Water Company water well analyses (courtesy of Mike Huhn, manager, VWC), and the Rosedale - Rio Bravo Water Storage District (courtesy of Robert Coffee, RRBWSD operations manager). Sierra Scientific Services specified the data screening criteria and the methods of data analysis according to accepted standards and practices.

For this study, we have added water sample analyses provided by IRWD collected from the accessible irrigation wells on the Strand Ranch property and analyses obtained by IRWD for other wells located on adjacent property.

Section V - Personnel.

Dr. Robert A. Crewdson is a Bakersfield, California consultant doing business as Sierra Scientific Services (SSS). SSS specializes in quantitative ground water hydrology, applied potential theory and time series analysis, quantitative ground water flow analysis, water quality geochemistry, well testing and monitoring, contaminant transport modeling, and aquifer properties testing. Dr. Crewdson is a research associate and adjunct professor at California State University Bakersfield where he has taught hydrology, contaminant transport, geochemistry and geophysics in upper division and graduate level courses.

Section VI - Methodology.

The primary task of this study was to collect the available data and determine the observed, historical water quality trends in the surface waters and groundwaters which flow into and out of the Kern Fan aquifer system as it relates to the Strand Ranch Project. The complete methodology will be presented in the forthcoming RRBWSD Baseline Water Quality report, but we present a summary in Exhibit 1. We present a tabulation of the surface water and ground water geochemical analyses in Exhibit 2.

Section VII - Water Quality.

There is no single, universal standard for *"water quality"*. But for the purposes of this study, we only need to establish the criteria which are relevant to the Strand Ranch Project. For our purposes, when we refer to "water quality" we really mean "water chemistry", since we are not so much applying criteria of acceptability (good for irrigation, residential, etc) as we are simply referring to the numerical values of the measured constituents. The constituents which we consider sufficient to be broadly representative of the water chemistry in the project area include: total dissolved solids content (TDS), hardness (Hd), hydrogen ion concentration (pH), arsenic concentration (As), alpha-emission radioactivity (α), and nitrate concentration (NO3).

In general, fresh water with a TDS content of 500 mg/l or less is considered to be good or excellent for domestic use and considered to be unacceptable over 1,200 - 1,500 mg/l, depending of course on the specific constituents. Water with a hardness less than 60 mg/l is considered to be "soft" and more than 120 mg/l is considered to be "hard" (120 - 180 mg/l) or "very hard" (>180 mg/l). Hardness is generally considered to be objectionable if it exceeds 100 mg/l. Water with a pH in the range from 5 to 9.0 is considered to be in the acceptable range for a public water supply.

Two naturally-occurring constituents of concern, arsenic and alpha radioactivity, exist in most natural waters at or above trace concentrations. The current federal regulatory maximum concentration limit (MCL) in water for each is 10 ug/l and 15pCi/l, respectively. These standards are set to achieve the following hypothetical objective: that if every person in a community were to drink 2 liters of water with these MCL concentrations daily for 30 years, there would be no more than one additional cancer death from arsenic poisoning and no more than one from alpha radiation poisoning per 10,000 people, on average, than would otherwise be expected in the community population.

The third constituent of concern, nitrate, is manmade in the sense that it occurs significantly in surface water and groundwater only because of manmade activities, i.e., it comes from agricultural use of fertilizers, from wastewater treatment plant effluent, and from stockyards. The federal MCL for nitrate is 10 mg/l.

In the Discussion section of this Report, we present the water chemistry of the surface waters, the ground waters, and the interactions and impacts related to the Strand Ranch Aquifer Storage and Recovery Project.

3. Discussion

The expected water quality interactions and impacts related to the Strand Ranch Project come from the developments and operations which are common to all aquifer storage and recovery (i.e. water banking) projects as designed and operated in Kern County, California. The following discussion includes the relevant surface water and ground water data and parameters which are specific to the Strand Ranch ASR Project.

Section I - Basic Project Development and Operation.

The Strand Ranch ASR Project development involves: 1. converting agricultural land which previously supported almond trees and row crops into infiltration ponds for the purpose of percolating surface water into the underlying aquifer, 2. Maintaining existing water wells and/or installing new water wells for the purpose removing water from the underlying aquifer, 3. installing ditches and/or pipelines to convey water between the Project facilities and the local conveyance infrastructure which, for the Strand Ranch Project, is the Cross Valley Canal, and 4. Installing monitoring wells for the purpose of monitoring water levels and water chemistry in the underlying aquifers.

The Strand Ranch ASR Project physical operation involves: 1. diverting a quantity of water from the local conveyance infrastructure into the Project recharge ponds, 2. maintaining the water depth in the active recharge ponds for maximum infiltration, 3. maintaining the empty and unused ponds when recharge is not occurring, 4. operating the recovery wells and delivering this water back to the local conveyance infrastructure. The maximum rates at which water can be diverted and recharged or recovered and re-conveyed are limited by the maximum physical operating capacities of the particular facilities which are in use. The actual rates and the actual scheduling of these water inflows or outflows may also depend on operating preferences, 3rd party requirements, contractual limits, uncontrollable circumstances, availability of water, and/or limitations due to capacities or priorities in the Cross Valley Canal.

For our purposes, we will assume that any expected interactions or impacts will be maximum when the recharge inflows or the recovery outflows are also at a maximum. This "maximum" scenario is defined by the maximum physical operating capacities of the hypothetical future facilities under consideration. This "maximum' scenario is not necessarily the most- likely scenario, nor should it be assumed that it is a "best-or-worst-case" scenario. The future Project operation currently under consideration in this water quality evaluation is based on hypothetical maximum recharge rates of 80 - 240 af/d (± 400 ac of ponds w/ IR = 0.2 - 0.6 ft/d) and maximum recovery rates of up to 45 cfs (90 af/d).

Section II - Water Chemistry of the Kern County Surface Waters.

All of the existing ASR (banking) projects on the Kern Fan have received their surface waters since 1995 from one of three sources: the Kern River (KR), the Federal Central Valley Project (CVP) via the Friant - Kern canal (FK), and the California State Water Project (SWP) via the California Aqueduct (AQ). The Strand Ranch ASR Project will receive all of its surface water from one or more of these same three sources. We have chosen to report the baseline water quality of each of these surface water sources according to the analyses reported by the KCWA Improvement District No. 4 (ID4) at the inlet to their water treatment plant (data obtained from the KCWA water quality database). We present all analyses from all sources in Exhibit 2.

The Kern River brings an average 772,800[3] af/yr of Sierran snowmelt runoff water into Kern County. Kern River water has an average TDS = 88 mg/l, an average Hd = 39 mg/l, and an average pH = 7.9. The three COCs (As = 5.9ug/l, α = 3.2 pCi/l, NO3 = 1.0 mg/l) are all present at low levels and less than their respective MCL concentrations.

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[3] Source of inflow volumes: KCWA, August 27, 2001, Initial Water Management Plan, Public Review Draft, p. ES-13.

The Friant-Kern Canal brings an average 395,000 af/yr of Sierran snowmelt runoff water from the Federal CVP into Kern County. FK water has an average TDS = 41 mg/l, an average Hd = 22 mg/l, and an average pH = 7.5. The three COCs (As = 2.9ug/l, α = 2.9 pCi/l, NO3 = 1.4 mg/l) are all present at low levels and less than their respective MCL concentrations.

The California Aqueduct brings an average 807,500 af/yr of Northern California snowmelt runoff water from the State SWP into Kern County. SWP water has an average TDS = 334 mg/l, an average Hd = 115 mg/l, and an average pH = 8.3. The three COCs (As = 7.0 ug/l, α = 1.9 pCi/l, NO3 = 2.4 mg/l) are all present at low levels and less than their respective MCL concentrations.

The water chemistry of the SWP water which arrives in Kern County via the aqueduct varies significantly but predictably (Table 1). During climatic dry cycles such as the years 1991 - 1995, the average annual TDS (344 mg/l) is approximately 170% higher than the TDS during climatic wet cycles (208 mg/l) such as the years 1996 - 2000 (Table 1). Within any given year, the average monthly TDS in the winter months is consistently 150% - 190% higher than the TDS in the summer months (Table 1). We do not see a comparable variability in the FK or KR waters. The seasonal and climatic variability of the SWP water chemistry is significant enough that, to the extent possible, the Project can benefit from scheduling its water deliveries to minimize the salt-load impacts on the aquifer and scheduling its returns to maximize the Project's ability to qualify for Tier-1 pump-in to the Aqueduct.

By these measures, the overall Kern County surface water supply is very good quality, even during periods of elevated TDS in the aqueduct. The total dissolved solids contents are quite low, the physical properties are acceptable, suspended solids, if present, can be eliminated by settling or filtration, and the trace occurrences of constituents of concern (COCs) are below MCLs and, so far, of minor concern. As a result, there is a general consensus in the local water community that a source of Kern County surface water and/or ground water is most likely OK as long as does not contain any of the few recognized constituents that locally make the water *unacceptable* for its intended use.

Section III - Water Chemistry of the Kern Fan Aquifer Waters.

The project site overlies a prolific fresh water aquifer which is a 700-ft thick, stratified sequence of interbedded, unconsolidated, sandy and silty alluvial and fluvial sediments. Most groundwater in the basin today originated as Kern River water which infiltrated into the aquifers from areas of natural recharge through a number of different pathways in times past. Today, we recognize that the groundwater is of poorer water quality than the Kern River water from which it comes. Part of the difference comes from a simple increase in the total amount of dissolved solids in the groundwater as a result of passing through the soils and sediments along the groundwater flowpath. Much of this increased "mineralization" of the water is of no consequence for its consumptive use, but some of this mineralization may include naturally-occurring constituents of concern. The main naturally- occurring constituents of concern in the project area have been elevated but non-toxic levels of naturally- occurring arsenic and radioactivity. Both constituents are commonly associated with sediments which have been derived from the erosion of granitic-type rocks, as is the case in the study area. The process of mineralization of percolating water is considered to be a natural and inevitable process and there is currently no known way to prevent this process of mineralization from occurring. The standard measure of this effect is to calculate a "salt balance" for storing and recovering a unit volume of water of known water chemistry in the aquifer.

In the project area, as on adjacent lands and elsewhere, the potential for an additional decrease in aquifer water quality includes the introduction of non-native constituents due to manmade activities and practices. The recognized, potential sources of manmade COCs in and around the Project site may include agriculture, oilfield operations, accidental spills on the nearby highways, and groundwater inflows of COCs from up-gradient sources. The main manmade constituents of concern include nitrates, pesticides, fertilizers, and common mineral salts.

The water chemistry in the groundwater aquifer varies with location and with depth. The total saturated thickness of the commonly-used part of the aquifer is approximately 500 - 700 ft (dry or wet conditions, respectively) and is often described as consisting of shallow, intermediate, and deep producing zones. These three zones cannot be clearly defined based on stratigraphy alone but can be differentiated based on both water chemistry and hydraulic behavior.

Shallow aquifer water chemistry. The shallow aquifer zone (approx. 0 - 300ft deep) contains a vadose (unsaturated) zone overlying an unconfined water table which varies in depth from 10 - 200 ft below ground level depending on the climatic wet/dry cycle. In the project area which is, more specifically, part of the Kern Fan recharge area, the shallow aquifer contains groundwater which comes primarily from downward vertical recharge from overlying surficial sources. Since the source of most of this recharge water is the Kern River through natural and manmade recharge, the water chemistry of the shallow aquifer resembles that of the Kern River except modified by processes of dissolution and reaction accompanying the percolation of this water through the vadose zone. The water chemistry of the unimpacted shallow groundwater zone may be summarized as having moderate TDS (229 mg/l), moderately hard Hd (122 mg/l), somewhat basic pH (7.8), low As (0.7 ug/l), elevated alpha (5.5 pCi/l), and elevated NO3 (9.9 mg/l). These data are presented in Tables 2 & 3 and on maps in Figures 2 - 7.

Brine plume. The shallow aquifer zone in the project area is being impacted by a brine plume which appears to be migrating from an unidentified, off-property, source or sources which are upgradient of- and unrelated to- the Stand Ranch Project site. The source[4] is upgradient to the southeast of the project site, perhaps in section 12 and/or somewhat farther to

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[4] One possible plume source is the so-called Rio Bravo Pump Station which is located in the central-southern portion of Sec 12, T30s/R25e, approximately one mile SE of the SE corner of the project site. The following entry was printed in the Kern Water Bank Authority Monthly Status Report of August 15, 2007: The following item occurs under the heading "Third Parties and Environmental Cleanup" and under the sub-heading "Chevron": *"Rio Bravo Pump Station: Historic use of this facility resulted in the pollution of groundwater with salts. TDS in recent samples have been as high as 1500 mg/l. In correspondence dated November 28, 2006, the RWQCB requested that a groundwater monitoring program be implemented."*

Mr. Jon Parker, KWB Operations Manager, reports that the suspected source of the brine plume is a system of oilfield-wastewater disposal ponds in section 12 that are no longer active. The original plume reportedly never came under regulatory control because the groundwater impact was not considered to be serious enough. The KWB groundwater pumping operations since 1995 have removed a large volume of groundwater with elevated TDS content from within the plume zone of impact, resulting in an improvement to the local water quality of the shallow aquifer. (verbal comm. December, 2007) the southeast. The water chemistry of the shallow groundwater brine plume may be summarized as having elevated levels of most or all constituents relative to the unimpacted shallow groundwater, with moderate to very high TDS (385 - 2380 mg/l), hard to very hard hardness (163 - 991 mg/l), near-neutral, slightly basic pH (7.2 - 7.9), undetermined levels of As and alpha, and elevated NO3 (19 - 28 mg/l). These data are presented in Tables 2 & 3.

The brine plume at MW 12B, the monitoring well closest to the source area, has a TDS content which is approximately 11 times higher than the surrounding shallow aquifer water (2380 mg/l vs. 225 mg/l) and has a clear "fingerprint" indicated by a chloride (Cl) content that is 44 times greater than the chloride content of the surrounding shallow aquifer water. The chloride ion is useful because we can map the presence of excess chloride ion in the aquifer as an indicator of the migrating plume. We have also used the presence of excess calcium to independently map the plume location with similar results (see maps in Figures 8 - 10). Based on this analysis, the brine source appears to be located at or sufficiently close to the axis of recharge that it is actually causing plumes to migrate downgradient into both flanks of the recharge mound. A plume of elevated TDS is migrating to the northwest under the Strand Ranch project site (Figure 10) and a plume of elevated TDS is also migrating southeast away from the same source area. Based on the data in both plume-flow directions, the source(s) of the twin plumes must be located in or near sec 12, T30s/R25e and/or sec 07, T30s, R26e.

In our opinion, based on our own analyses and on credible local sources, the present plume has been in existence for more than 30 years. At an estimated average flow velocity of 1 ft/d, this plume has propagated more than 2 miles downgradient from the source location. However, the oilfield wastewater disposal ponds which were the suspected original sources of the groundwater brine plume are no longer active[5]. Based on theoretical considerations, we conclude that the plume has reached its maximum concentration at all points within its existing perimeter and these concentrations are actively decreasing. We expect that the natural processes of advection and dispersion will cause the perimeter of the remaining residual plume to steadily lengthen and widen and the TDS constituent concentrations to steadily decrease through dilution. The existing KWB operations and the proposed Strand Ranch operations will

[5] Mr. Royce Fast, a long-time local resident farmer, reports that these oilfield wastewater disposal ponds have been inactive for as long as he can remember, and specifically, that he has no recollection of the ponds being active at least as far back as the early 1970s and perhaps earlier. (verbal comm. December, 2007)

continue to remediate the plume with accelerated dilution through surface water recharge and accelerated TDS content removal by groundwater recovery within the plume zone of influence.

It is possible and likely, in our opinion and subject to verification, that low-grade, residual, in-situ salt deposits might still exist within the sediments of the vadose zone underlying the locations of the former disposal ponds. Such a residual, in-situ, source of salts may explain why the tail of the plume has not "disconnected" and migrated downgradient from the source area during the time since the pond use was discontinued, why elevated TDS concentrations still exist in monitoring wells close to the suspected source area, and why the plume has not been completely remediated by local groundwater extraction over the last 30+ years. Nevertheless, the ongoing processes of dilution and extraction will continue to remediate this pre-existing, residual, shallow-aquifer, brine plume.

Deep aquifer water chemistry. The deep zone (approx. 400 - 800 ft deep) contains a semi-confined aquifer which shows hydraulic connection with the overlying zones but with delayed pressure response and little inter-zonal flow in the unimpacted areas with few water wells. In the project area, the unimpacted deep aquifer contains groundwater which comes primarily from lateral recharge from sources of deep infiltration near the upgradient limits of the Kern Fan far to the east, rather than from downward vertical recharge. Since the deep groundwater has traveled a long flowpath with a long subsurface residence time, the water chemistry of the deep aquifer is different than the shallow water as we would expect from geochemical considerations. The water chemistry of the unimpacted deep groundwater may be summarized as having low TDS (119 mg/l), very soft Hd (6 mg/l), basic, elevated pH (9.4), elevated As (10 - 139 ug/l), low alpha (0.8), and low NO3 (± 0.8 mg/l). These data are presented in Tables 2 & 3 and on maps in Figures 11 - 16. According to available data, the brine plume does not currently extend into the deep zone of the aquifer.

Middle aquifer water chemistry. The middle zone (approx. 300 - 500 ft deep) is transitional between the shallow and deep zones in both hydraulic behavior and water chemistry and varies depending on location. The middle zone has a water chemistry which appears to be a stoichiometric blend of the shallow and deep waters. The water chemistry of the upper middle zone looks somewhat more like that of the shallow aquifer water and the water chemistry of the deeper middle zone looks somewhat more like that of the deeper aquifer water. We are limited by the spatial distribution of data points but the middle zone appears to be a thin, unimpacted, transitional zone between the shallow and deep aquifers on the northwest and southeast margins of the Kern Fan whereas the middle zone appears to be a thick zone of manmade blending underneath a contiguous area centered on the fan which includes the Pioneer North Project and the central portion of the Kern Water Bank which is north of the Kern River channel and east of Bussell Road.

Section IV - Water Chemistry of Local Water Wells.

According to public records, there have been eleven (11) water wells drilled or re-drilled between 1950 and 1976 on the Strand Ranch property. The wells were either irrigation wells or shallow domestic water wells which were completed across the shallow zone (5 wells) or both shallow and intermediate aquifer zones (6 wells). None of these wells were completed in the deep zone of the aquifer. IRWD sampled the five currently-existing, accessible wells (W1, W2, W3, W4, and W6) in December, 2003 (Figure 10). As we would expect, the water chemistries in each of the five wells is a plume-impacted blend of shallow and intermediate zone water chemistries (Exhibit 2).

All five wells clearly show the impacts of the brine plume migrating under the Strand Ranch project site. The waters in all five wells have elevated TDS ranging from 410 - 800 mg/l (avg 618 mg/l) and elevated shallow-zone COCs (alpha = 11 pCi/l and NO3 = 24 mg/l) relative to the unimpacted shallow aquifer (TDS = 229 mg/l) which we have mapped in the study area. Based on a simple blending calculation, the waters from these five wells are about two-thirds plume water and one-third non-plume aquifer water. In our opinion, these well-water analyses are representative of the plume-impacted waters in the shallow and upper-intermediate aquifer zones under the Project site.

The water wells in the surrounding sections to the north include 3 irrigation wells in the Rosedale - Rio Bravo Water Storage District (Figure 10), all of which are downgradient from the Project site, approximately ½ - 1 mile NNW of the north Project boundary. We do not know the depth intervals of these three wells (Enns-N, Enns-S, and Nikkel) but all three wells have water chemistries which are typical of a somewhat plume-impacted shallow aquifer: elevated TDS (312 - 448 mg/l), slightly basic pH (7.5 - 7.8), hard to very hard Hd (174 - 236 mg/l), low As (<1 ug/l), elevated alpha (>10 pCi/l), and moderate NO3 (6-7 mg/l). In our opinion, these three well analyses are representative of the plume-impacted shallow aquifer in this area (Exhibit 2).

The water wells in the surrounding sections to the south and west include banking project recovery wells which belong to the Kern Water Bank (Figure 10). The four wells for which we have data are all within ½ -mile of the south or west Strand Ranch property line. Wells 11A and 11C are upgradient from the Project site and wells 03Q and 03R are lateral to the Project site. We do not know the depth intervals of these four KWB wells but based on the reported water chemistries, well 11A appears to produce water from the deep aquifer zone (low TDS, high pH, elevated As, low alpha, and low NO3) and wells 11C, 03Q, and 03R all produce water from the plume-impacted shallow or shallow and intermediate zones (moderate TDS, lower pH, low As; unreported alpha and nitrate). Although well 11A is located substantially inside the recognized plume perimeter, it shows no constituent evidence of plume impacts and therefore, we conclude that it must be completed in a depth interval which is below the depth of recognizable plume impact. The TDS values at the other three locations are elevated with respect to the unimpacted shallow aquifer and therefore are useful in mapping the lateral and downgradient extents of the migrating brine plume. These data have been combined with the monitoring well data and the data from the Strand Ranch and Rosedale irrigation wells and are included in the shallow- aquifer TDS contour map shown in Figure 10.

The KCWA Improvement District No. 4 water treatment plant has historically received inlet water from recovery wells on the Kern Water Bank. The KWB source water (11 analyses over several years) came from unspecified wells but we assume that it was a blend from conveniently-located wells with "acceptable" water quality. This KWB water at the inlet to the ID4 treatment plant had a water chemistry which was consistent with a blend of 17% shallow aquifer water and 83% deep aquifer water: avg TDS (143 mg/l), slightly basic pH (7.6), very hard Hd (445 mg/l), elevated As (9.9 ug/l), low alpha (3.7 pCi/l), and low NO3 (2.7 mg/l). We consider this to be consistent with the KWB preference for deep wells in their project area.

<u>Aqueduct and Cross Valley Canal Pump-in Criteria.</u>

The California Department of Water Resources (DWR) requires that all waters which enter the California Aqueduct must meet their water quality criteria, i.e., that the water is of "consistent, predictable, and acceptable quality"[6]. The Kern County Water Agency has incorporated those same standards for all waters which enter the Cross Valley Canal which serves several member districts within Kern County and connects to the Aqueduct. The DWR water quality criteria establish two levels of acceptable water quality as follows: Tier 2 water is of lesser quality with respect to the DWR standards[7] such that water from a specific source can only be pumped into the aqueduct after the *DWR facilitation group* has reviewed the water quality and approved it on a specific case-by-case basis; Tier 1 water is of better quality with respect to the DWR standards and water *"meeting Tier 1 water quality standards shall be approved* [for delivery into the Aqueduct] *by DWR without further review...".*

It is very desirable for a water source to have a Tier 1 designation because it creates tremendous flexibility in conveyance scheduling which is not subject to review, delay, or perhaps disapproval by the facilitation group. Kern River water meets Tier 1 criteria and Kern Fan groundwater, perhaps with minor blending, can meet Tier 1 criteria as well.

Some of the plume-impacted, shallow aquifer water under the Strand Ranch Project site exceeds the DWR constituent concentration limits and would not meet the Tier 1 water quality criteria unless it was blended with "better quality" water to dilute the objectionable constituents down to acceptable levels. The unimpacted shallow groundwater adjacent to the site is at or near-Tier 1 water quality, so at such time as the brine plume has been fully remediated by natural and/or project operations, the shallow aquifer under the Project will be at or near Tier 1 water quality, all else equal.

Section V - Water Chemistry Interactions and Impacts.

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[6]Interim Department of Water Resources Water Quality Criteria for Acceptance of Non-Project Water into the State Water Project, March 1, 2001.

[7]The March 1, 2001 Interim DWR water quality standards are presented on pp. D-4 through D-7 of the KCWA 2001 Kern Fan Operations and Monitoring Report. Examples of Kern County pump-in water quality from seven different sources is presented on p. E-6 of the same Report.

Land Conversion Impact. The potential water quality impacts from converting the site from agricultural use to an ASR site has two recognized elements. The first element is that by eliminating the Ag use of the land, the site has been eliminated as a potential source of allowable, but potentially undesirable low-grade, agriculture-related, shallow-aquifer degradation. We have no data on what agricultural products may or may not have been used on the property in the past. If such products had been used, then the conversion to project operations represents a cessation of such product use. And the conversion to an ASR project eliminates the potential future use of pesticides, fertilizers, sulfur compounds, and other Ag products from potential use. In our opinion, this element of site conversion is a neutral or positive impact on the aquifer.

The second element is that the future, initial episode of large-volume recharge which will occur as each new recharge pond is put into operation may be the first re-saturation of the underlying sedimentary column from the ground surface to the water table in several years, depending on the climate. Such a re-saturation may result in a short-term flushing of accumulated salts from the shallow strata which will enter the shallow aquifer. We are not aware of any data or any estimates of such impacts for any other ponds in any other projects in Kern County that such impacts exist or have been observed. In our opinion, we do not expect that such re-wetting events will have any significant, long-term impacts.

Moreover, the area experienced two consecutive years of major recharge since 2003 which raised the shallow water table on the entire Kern Fan and to within 5 ft of the ground surface within much of the Strand Ranch site. This major rise in the shallow water table was subsequently followed by the current drought and water levels have since dropped by 100 ft. The point is that this water table fluctuation has thoroughly purged the shallow strata of soluble salts in the recent past, so we conclude that there will be no significant future buildup of shallow salts between now and the start of the project since most of the acreage has already been fallowed.

Recharge and Recovery Salt Balance Impact.

Based on reported historical data, every existing ASR banking project on the Kern Fan (Pioneer, Berrenda Mesa, 2800 acres, and Kern Water Bank) has a positive impact on the basin by removing more dissolved salts in their recovery water than is put into the basin in their stored surface water (Table 4). This is true on a volume-for-volume basis because the average

TDS concentration is lower in the stored surface water and higher in the recovered water. For example, for the 2001 operating year, the reported average TDS of surface waters stored in the basin was 121 mg/l and the average TDS of ground waters removed from the basin was 218 mg/l, and therefore there was an average decrease in basin salt load of -97 mg for every liter of water. That is equivalent to a net removal of 264 lb of salt for every acre-foot of stored-then-recovered water (data from KCWA 2001 Kern Fan Monitoring Report, Figure 5D-1).

Based on the same source of reported historical data (KCWA 2001 KFMR, Tables 5D- to 5D-8), the incoming salt load varies significantly depending on the source of surface water which is stored in the projects. For example, for the reporting period from 1995 through 2001, 29% of all stored water came from the SWP via the Aqueduct, 28% came from the CVP via the FK canal, and 43% came from the Kern River. However, 57% of the total salt load came from the SWP water, only 11% came from the CVP water, and 32% came from the Kern River. Despite the nearly equal surface water volumes coming from the SWP and CVP, the salt load from the SWP was five times higher than that from the CVP because of the 5-fold difference in average TDS contents (227 mg/l vs 43 mg/l) of the respective waters over this time period. The salt load from the imported SWP water for the period was 180% greater than that of the Kern River even though the volume of SWP water was only 67% of the volume of KR water because of the difference in respective TDS contents. It is clear that SWP surface water is the least desirable source of surface water from a TDS salt balance perspective because it brings in the highest concentration of dissolved salts of the three potential sources.

For the Strand Ranch Project, the basic hypothetical salt balance data are as follows. The historical average TDS contents of the three potential sources of surface water are SWP TDS = 227 mg/l, KR TDS = 88 mg/l, and FK TDS = 41 mg/l. The average TDS contents of the local aquifer waters in the study area are: unimpacted shallow TDS = 229 mg/l, plume-impacted area-weighted shallow TDS = 559 mg/l, and unimpacted deep TDS = 119 mg/l.

Based on these data, all of the surface waters have TDS concentrations which are less than the plume-impacted shallow aquifer waters near and under the Project site and both the KR and FK have TDS contents that are less than that in any part of the underlying aquifer. If we look at the historical SWP data for the project operating period from 1995 - 2001, it is clear that the SWP water actually delivered to Kern County with an average TDS = 227 mg/l is much less than the unweighted, long-term, historical average of 334 mg/l (measured at the inlet to the ID4 water treatment plant) so it is possible to obtain large volumes of SWP surface water for banking programs at much less than the historical average TDS.

We have calculated a number of recharge/recovery salt balances for the project and for the wide range of all realistic assumptions, the hypothetical Project salt balances are all positive, i.e., there is a net loss of salt from the groundwater basin because of project recharge and recovery. The calculations yield a base case salt load balance of -118 mg/l (net loss of salt from the basin, equivalent to a loss of -332 lb per acre-foot).

We note that the predicted Strand Ranch Project positive impact (-118 mg/l salt loss) is in the same range as the 2001 reported project impacts from the existing Kern Fan banking projects which ranged from -72 mg/l at the Berrenda Mesa project to -129 mg/l at the Pioneer project. The 2001 Kern Water Bank salt balance was -99 mg/l. And we also point out that since the Strand Ranch Project has the elevated-TDS brine plume to deal with, the predicted Strand Ranch salt balance beneficial impact may be greater depending on the fraction of shallow-aquifer water which is captured in total recovery volume.

The salt balance calculations are included in tables 3.1 - 3.3 of Exhibit 3. Table 3.1 presents the hypothetical long-term average recharge TDS based on various relative mixes of SWP, KR, and FK source waters. Hypothetical inflow blends 11-16 and 21-26 are for assumed SWP TDS conditions of 334 and 227 mg/l, respectively as previously described. We have assumed In-Blend 26 to be our hypothetical base case and an long-term average inflow TDS of 111 mg/l.

Table 3.2 presents the hypothetical long-term average recovery TDS based on various relative mixes of shallow and deep aquifer waters. Hypothetical outflow blends 31-38 and 41-48 are for assumed shallow aquifer TDSD conditions of 559 and 237 mg/l, respectively for brine-plume and non-plume conditions. We have assumed Out-Blend 36 to be our hypothetical base case and a long-term average outflow TDS of 229 mg/l.

Table 3.3 presents a matrix of hypothetical long-term net aquifer salt balance outcomes for the various in-flow conditions listed across the top of the table and the various outflow conditions listed down the left side of the table. The base case conditions (in bold) assume long-term average inflows at +111 mg/l TDS and long-term average outflows at -229 mg/l TDS resulting in a net loss of salt from the basin at a rate of -118 mg/l. The base case assumes that the long-term average surface water inflow to the project is 20% SWP, 70% KR, and 10% FK at TDS contents of 227, 88, and 41 mg/l, respectively. The base case assumes that the long-term average recovered water outflow from the project is 25% shallow aquifer and 75% deep aquifer at TDS contents of 559 and 119 mg/l, respectively. Other possible scenarios may be read directly from the table.

Recharge and Recovery Constituent-of-Concern (COC) Impact.

Based on reported geochemical data, all COC concentrations in the three potential sources of surface water are significantly below the respective MCLs and are at lower concentrations than in the ground waters in the study area. Therefore, we conclude that the COC balance for all species of interest is favorable to the basin, without the need to perform the calculations to demonstrate this.

Figures

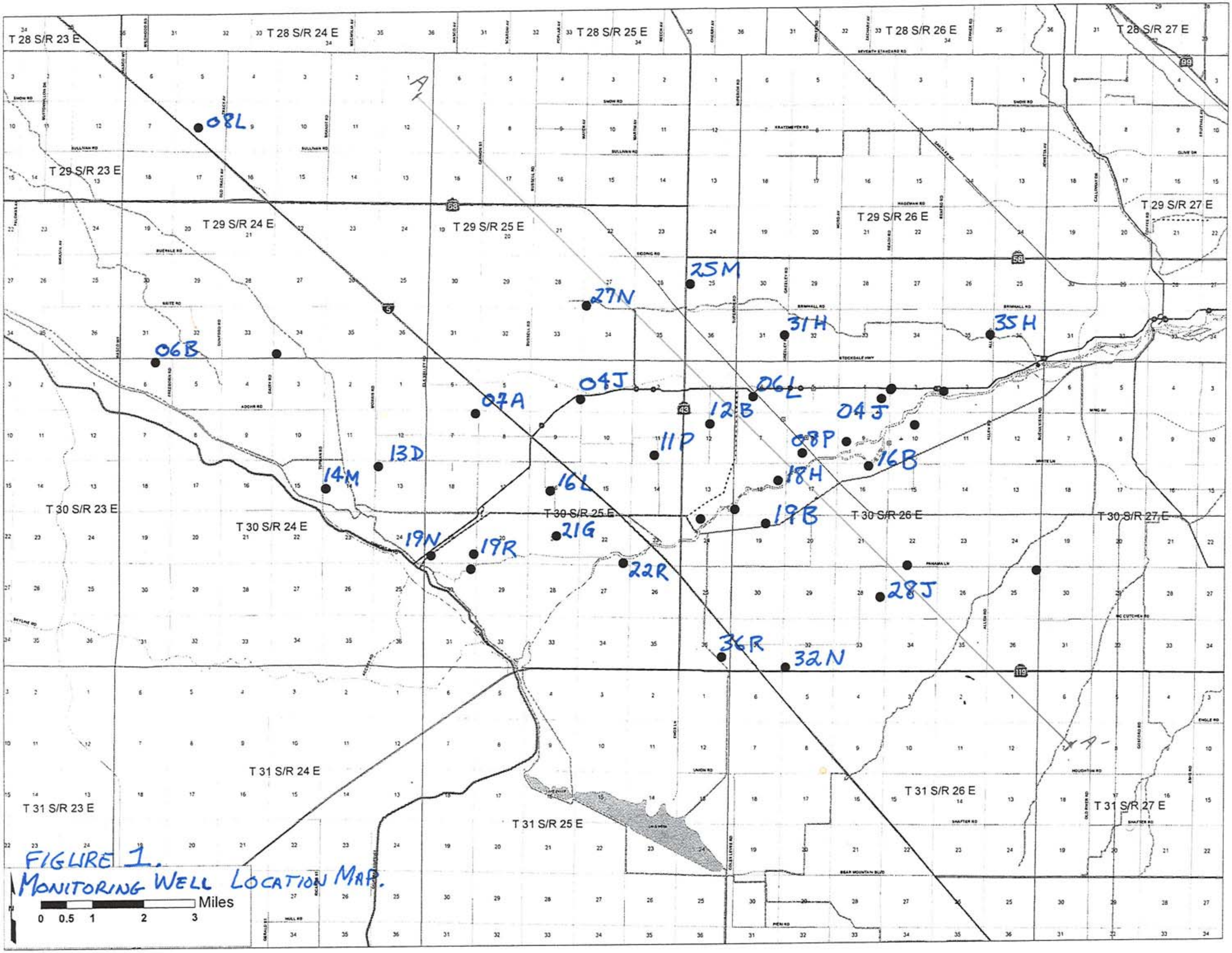


FIGURE 1.
MONITORING WELL LOCATION MAP.

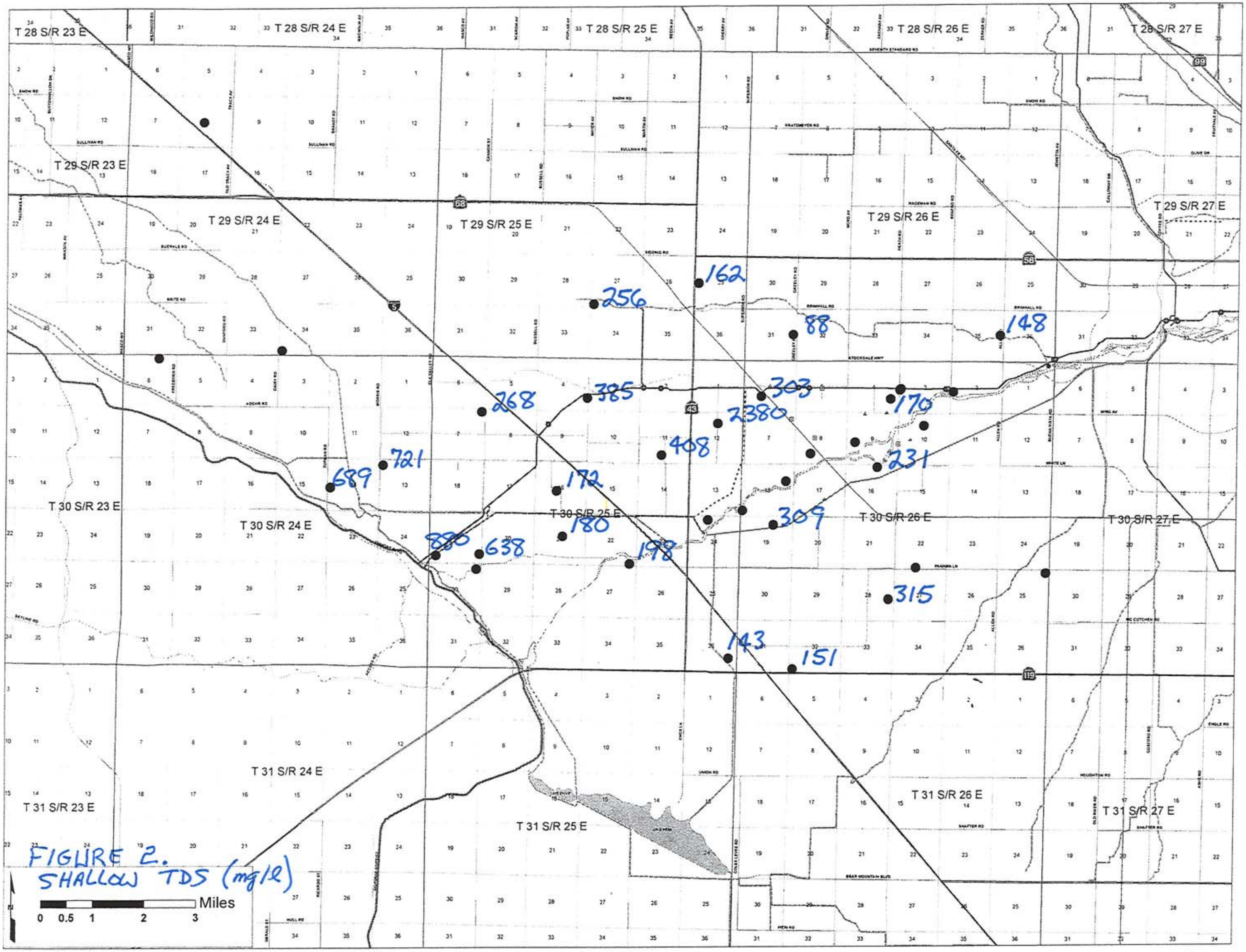


FIGURE 2.
SHALLOW TDS (mg/l)

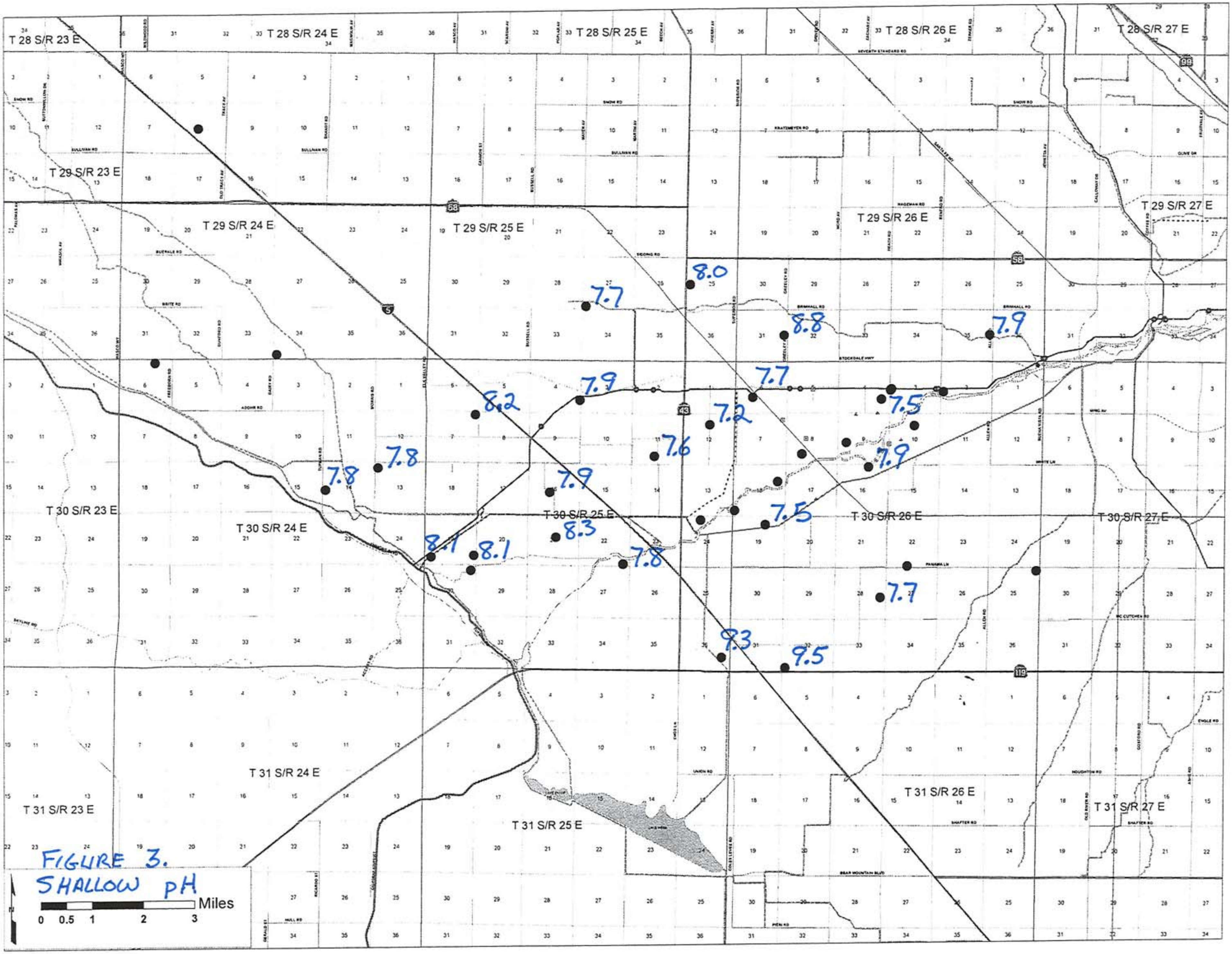


FIGURE 3.
SHALLOW pH

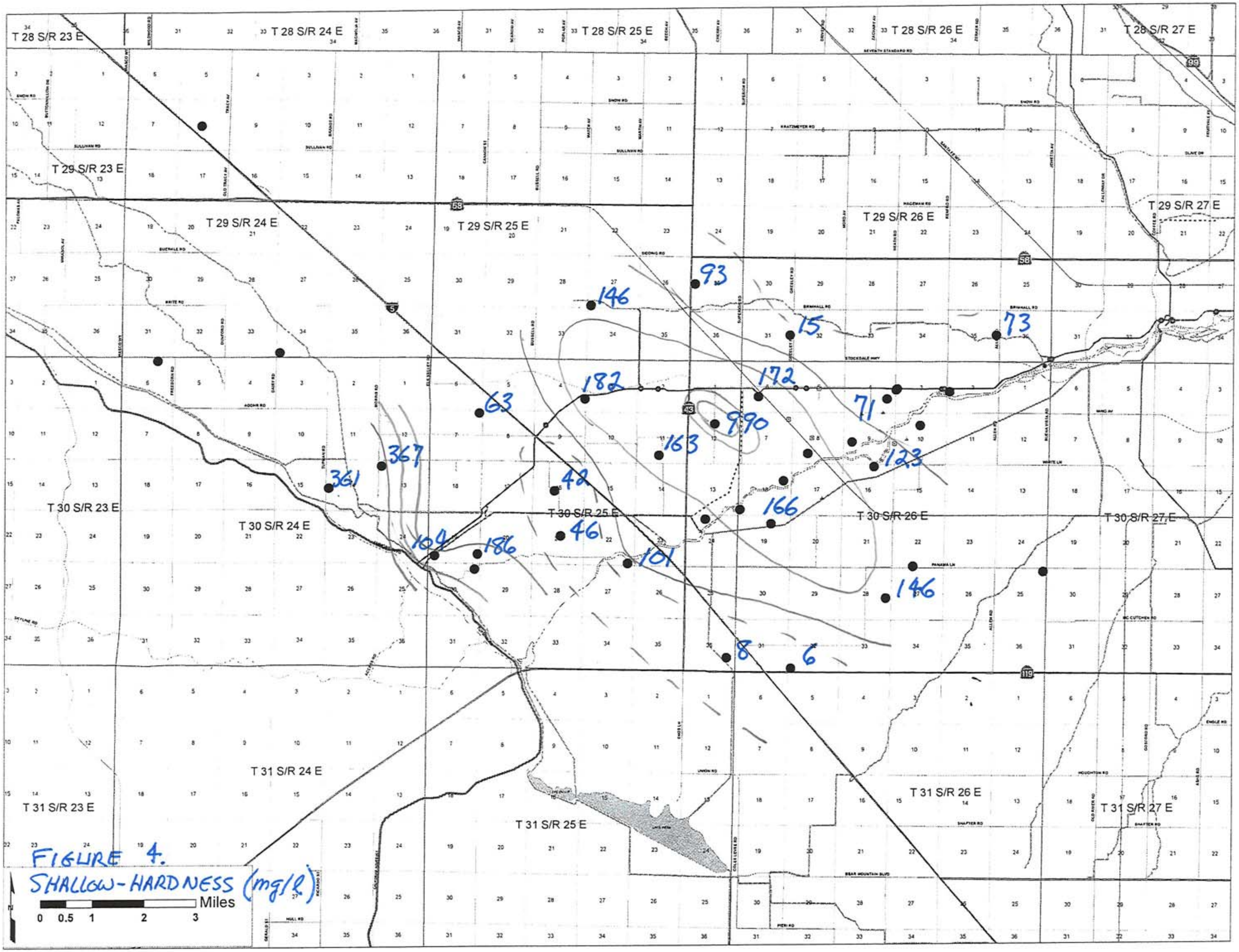


FIGURE 4.
SHALLOW-HARDNESS (mg/l)

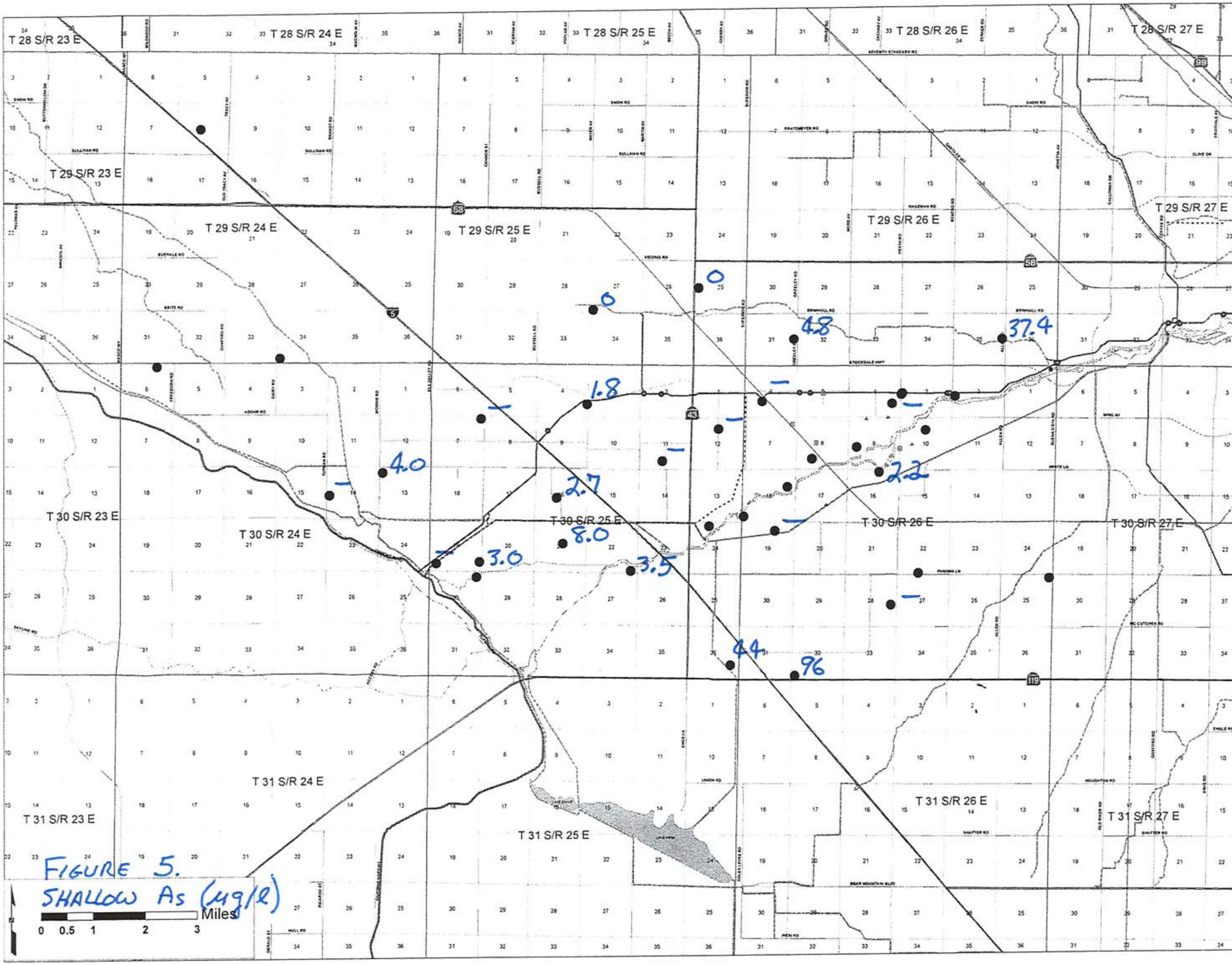


FIGURE 5.
SHALLOW As (ug/l)

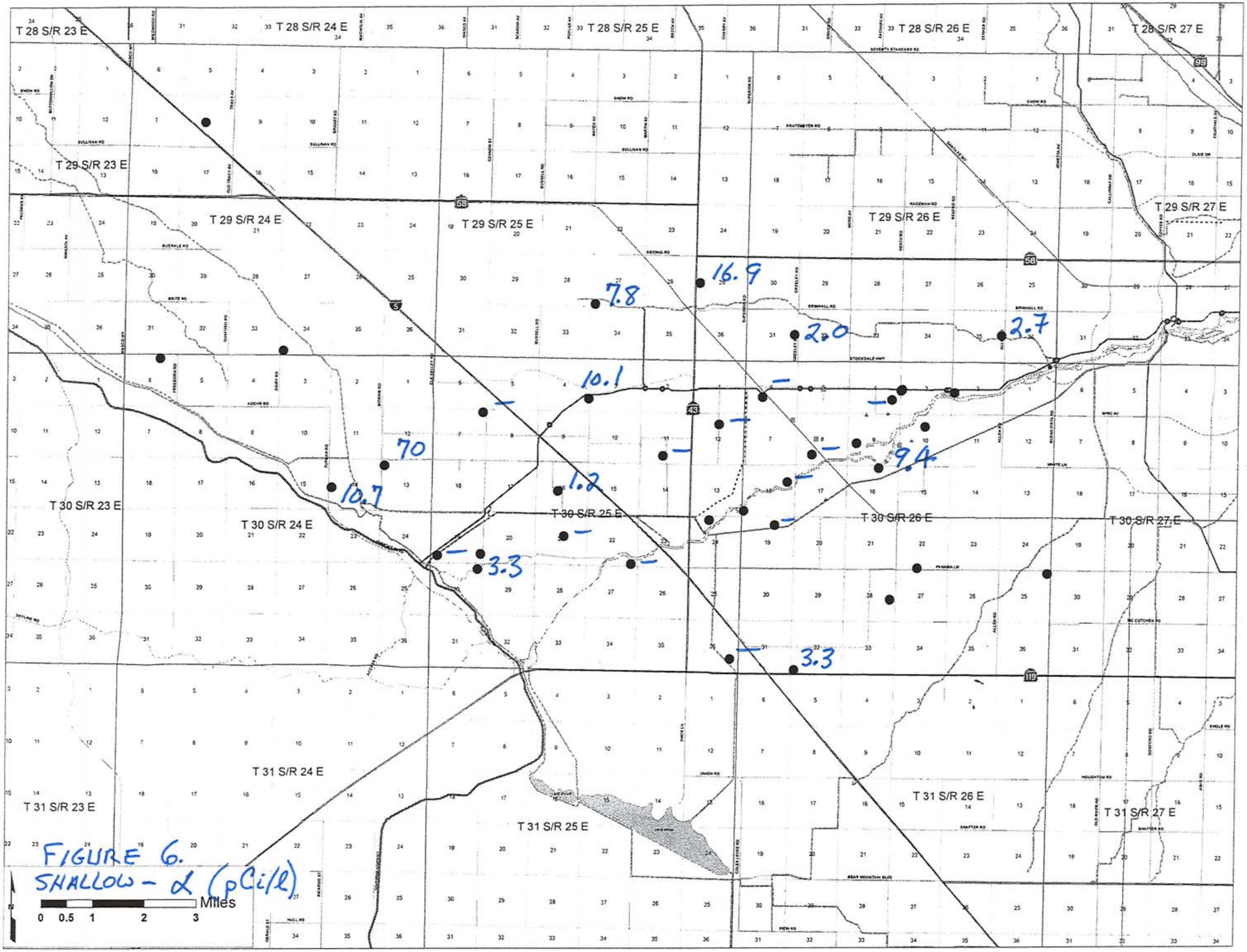


FIGURE 6.
SHALLOW - α (pCi/l)

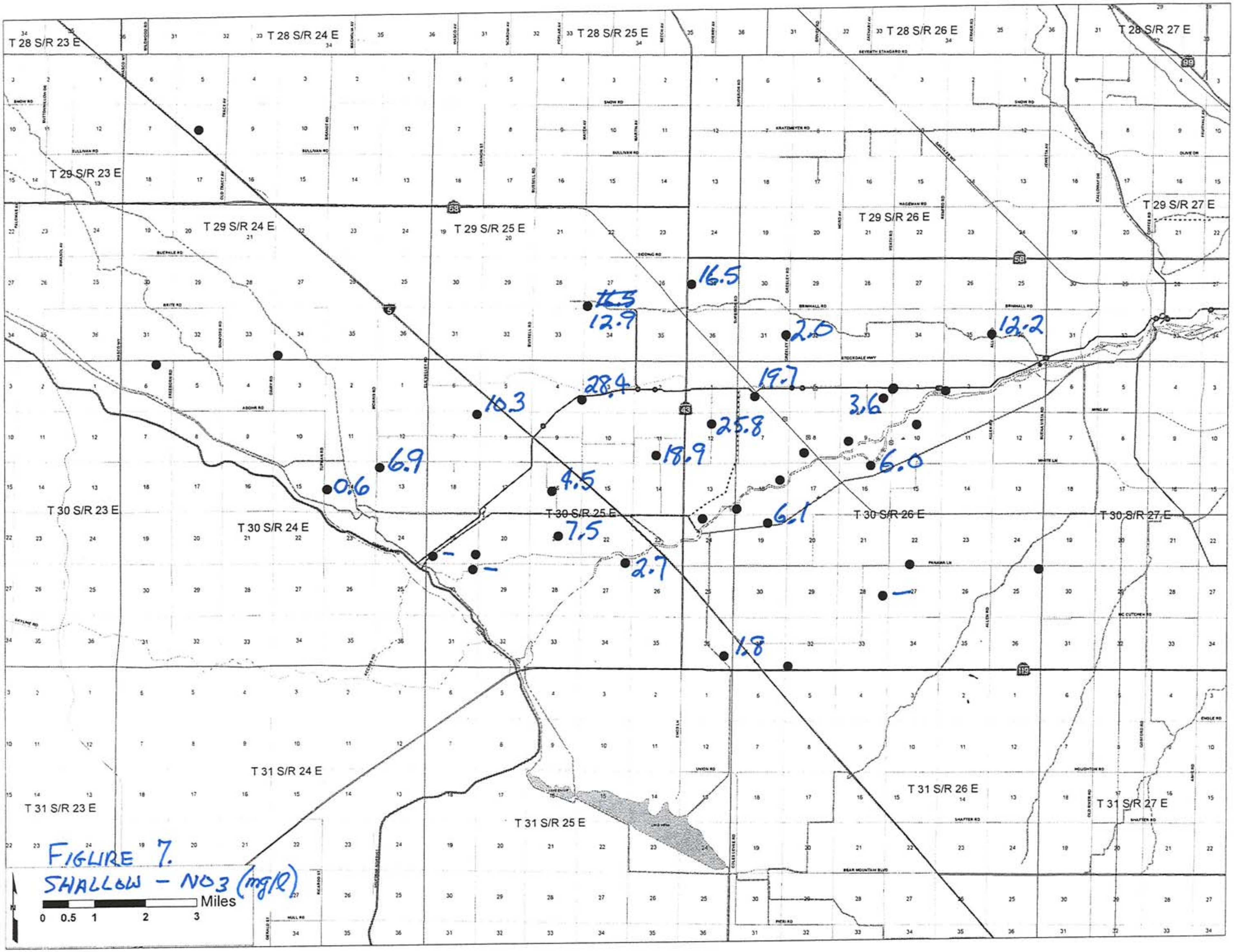
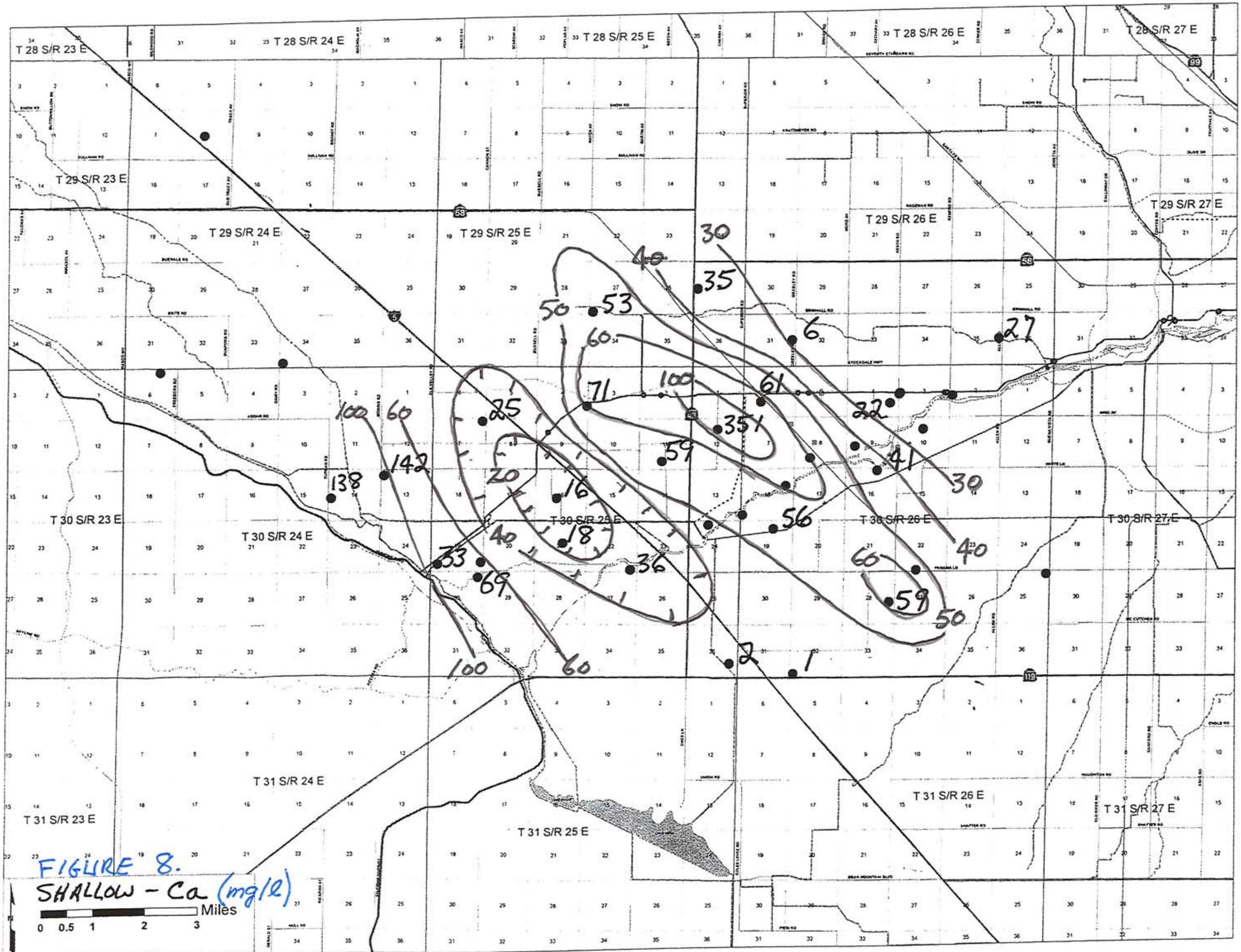


FIGURE 7.
SHALLOW - NO3 (mg/l)


T 28 S/R 23 E
T 28 S/R 24 E
T 28 S/R 25 E
T 28 S/R 26 E
T 28 S/R 27 E
T 29 S/R 23 E
T 29 S/R 24 E
T 29 S/R 25 E
T 29 S/R 26 E
T 29 S/R 27 E
T 30 S/R 23 E
T 30 S/R 24 E
T 30 S/R 25 E
T 30 S/R 26 E
T 30 S/R 27 E
T 31 S/R 23 E
T 31 S/R 24 E
T 31 S/R 25 E
T 31 S/R 26 E
T 31 S/R 27 E
FIGURE 8.
SHALLOW - Ca (mg/l)
0 0.5 1 2 3 Miles

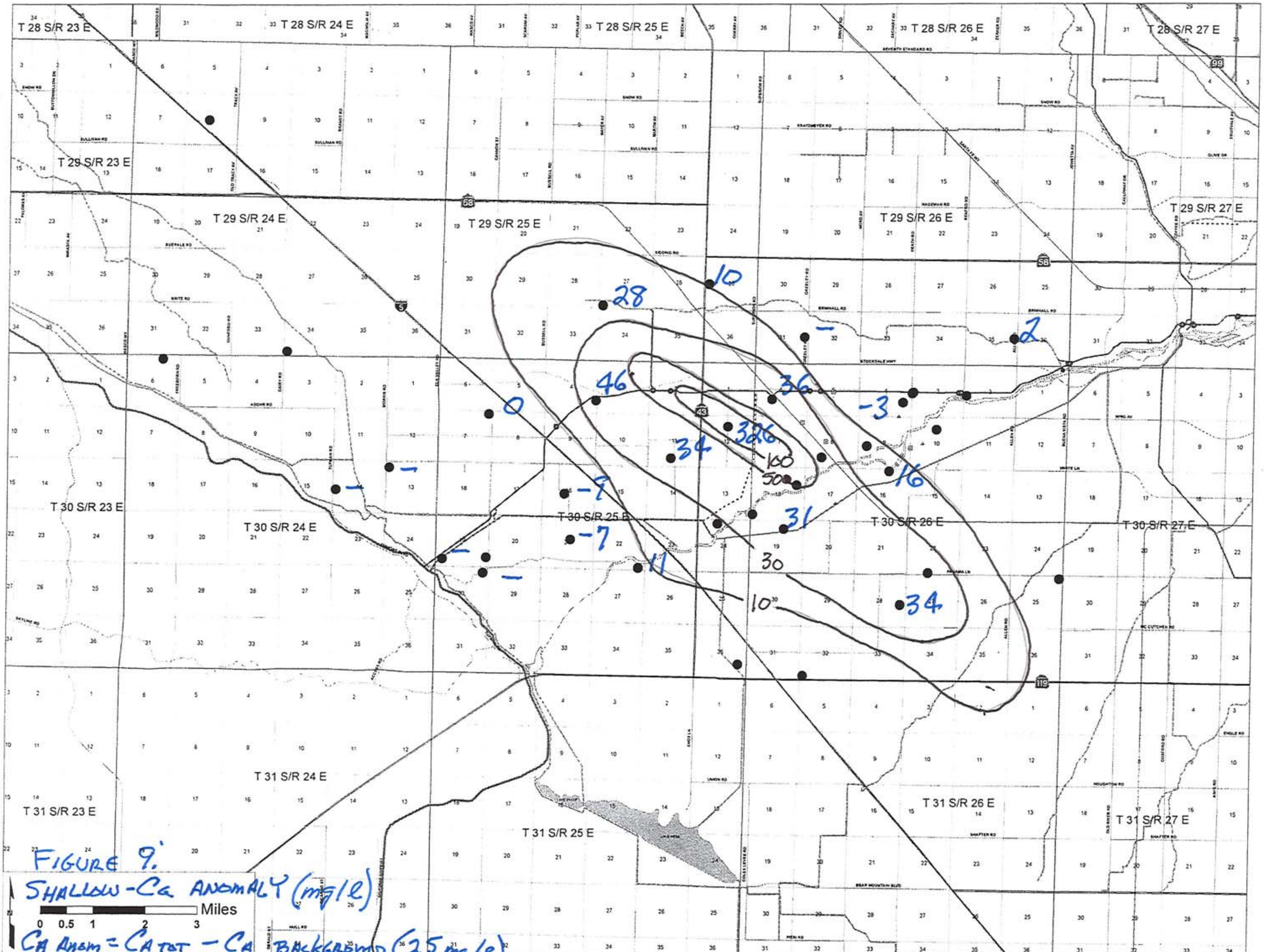
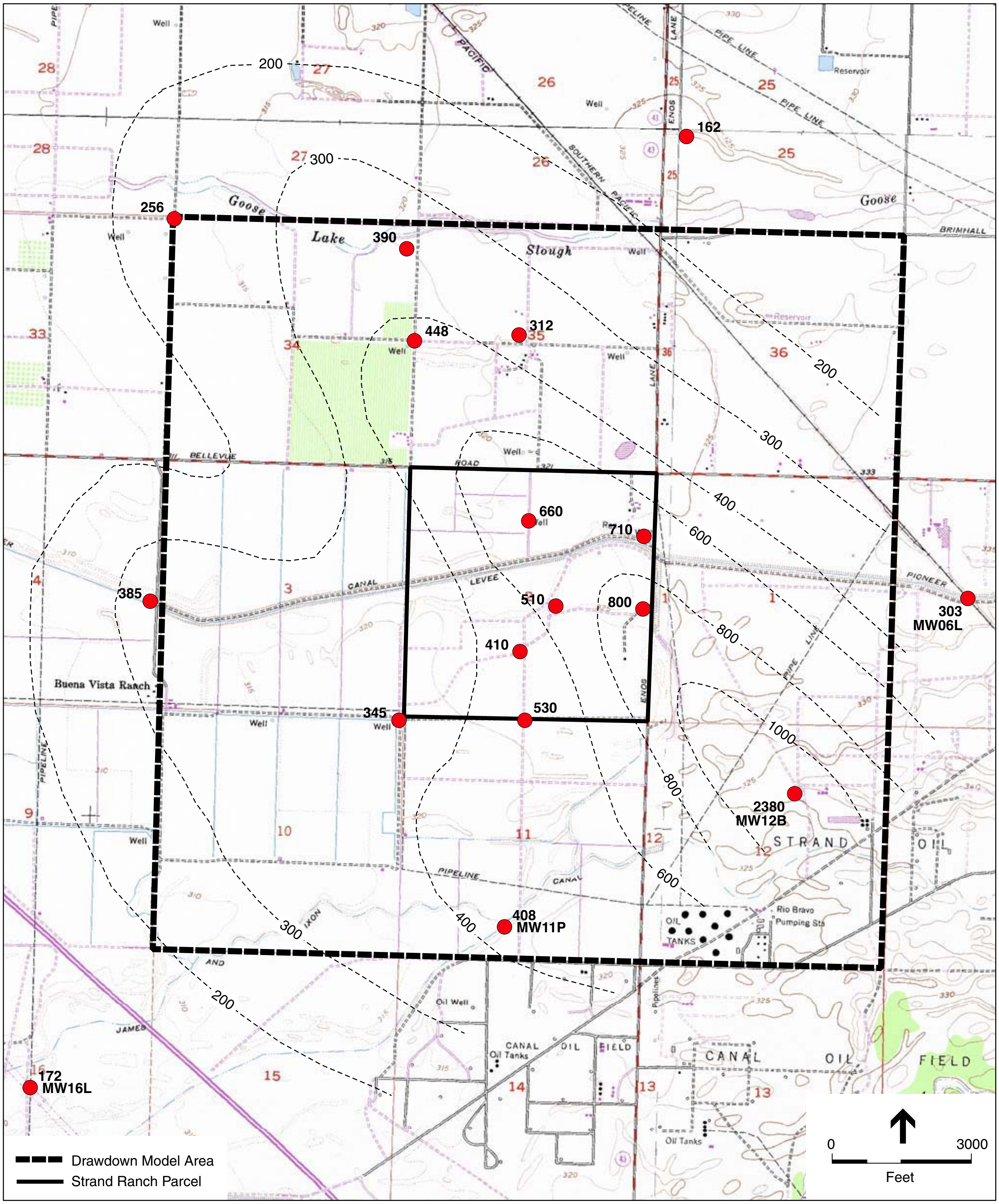


FIGURE 9.
SHALLOW-Ca ANOMALY (mg/l)
Ca Anom = Ca TOT − Ca BACKGROUND (25 mg/l)



SOURCE: USGS; Sierra Scientific Services, 2007; ESA, 2007.

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Figure 10
Contour Map of Shallow Aquifer TDS Content (mg/l) Showing Plume Impact

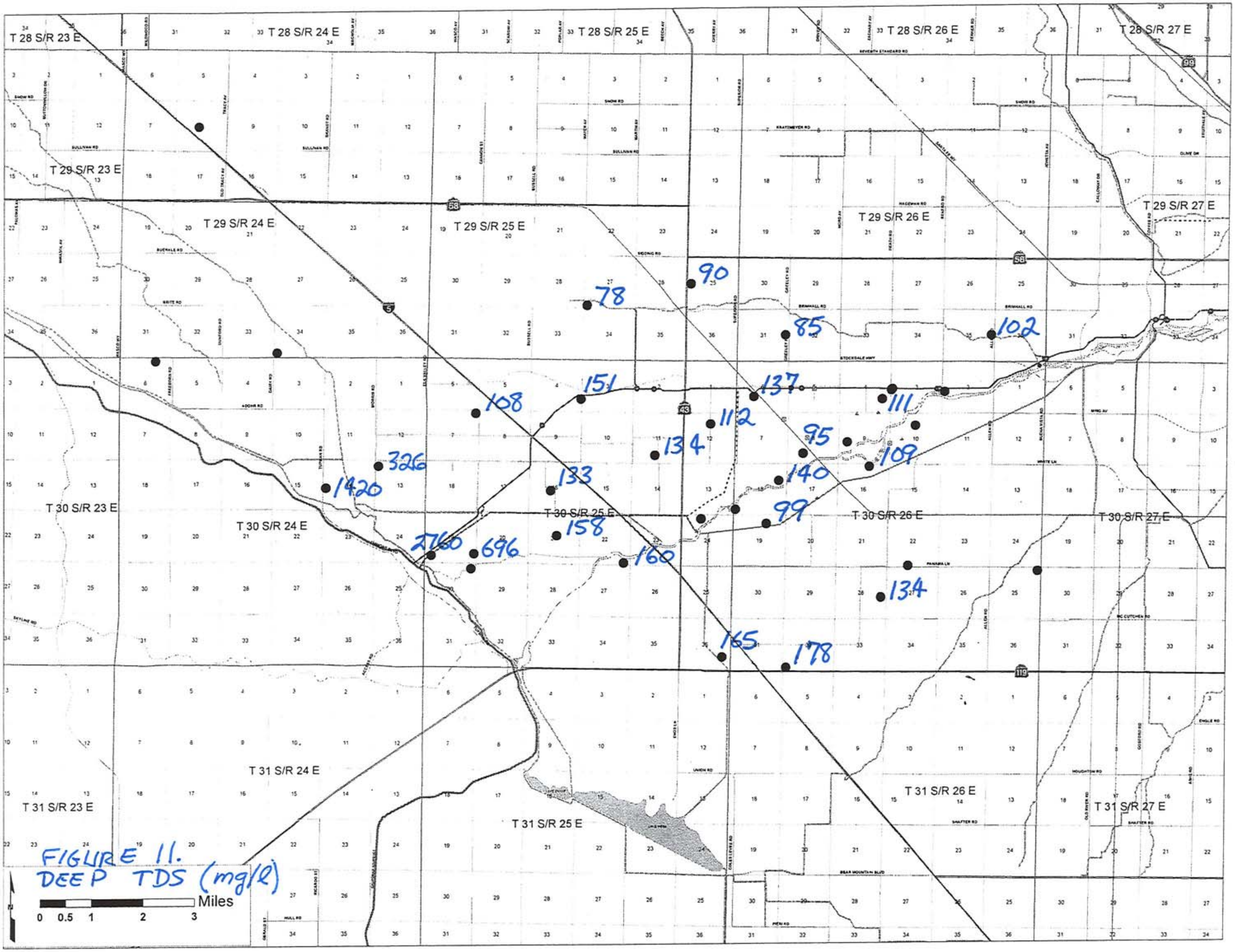


FIGURE 11.
DEEP TDS (mg/l)

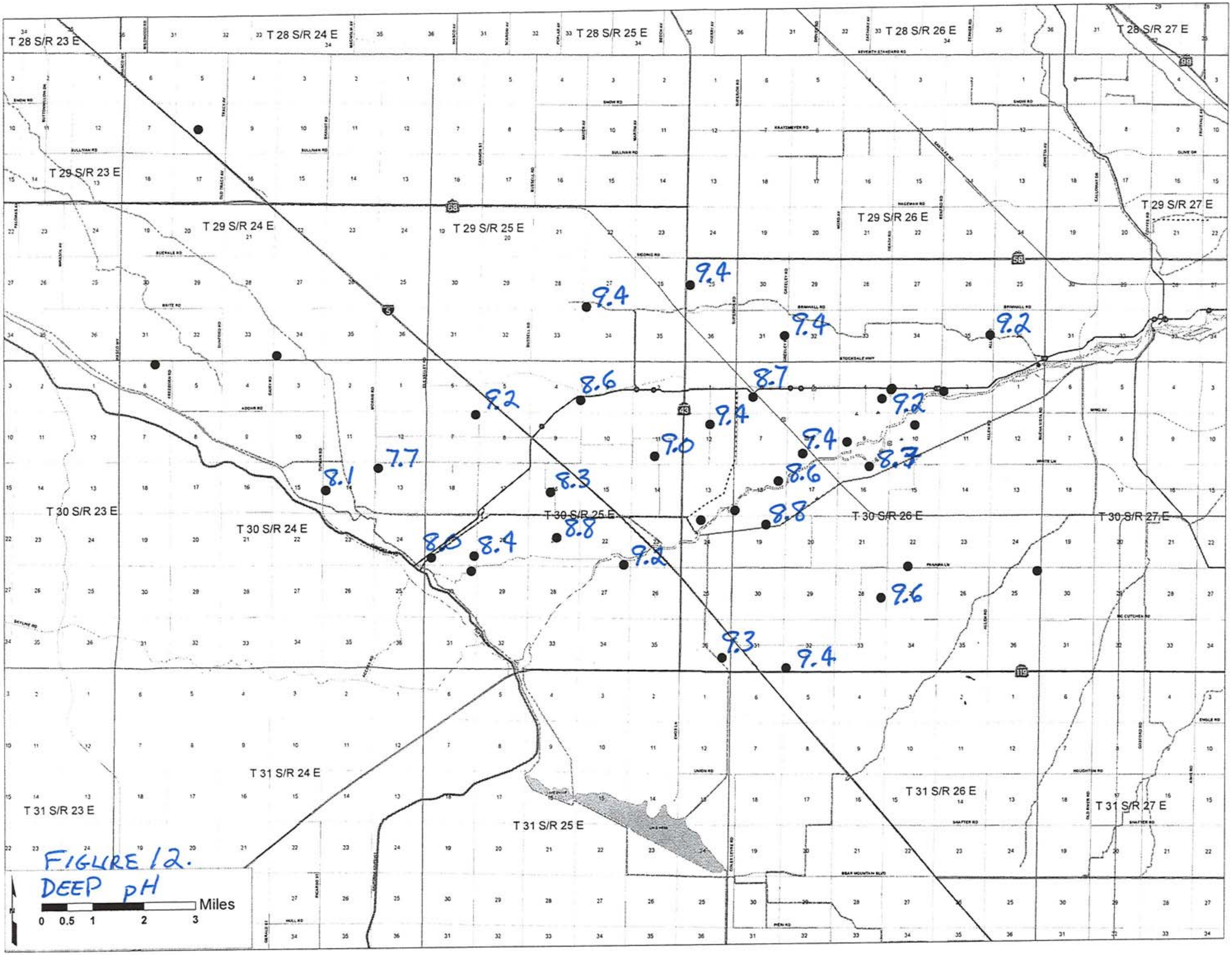


FIGURE 12.
DEEP pH

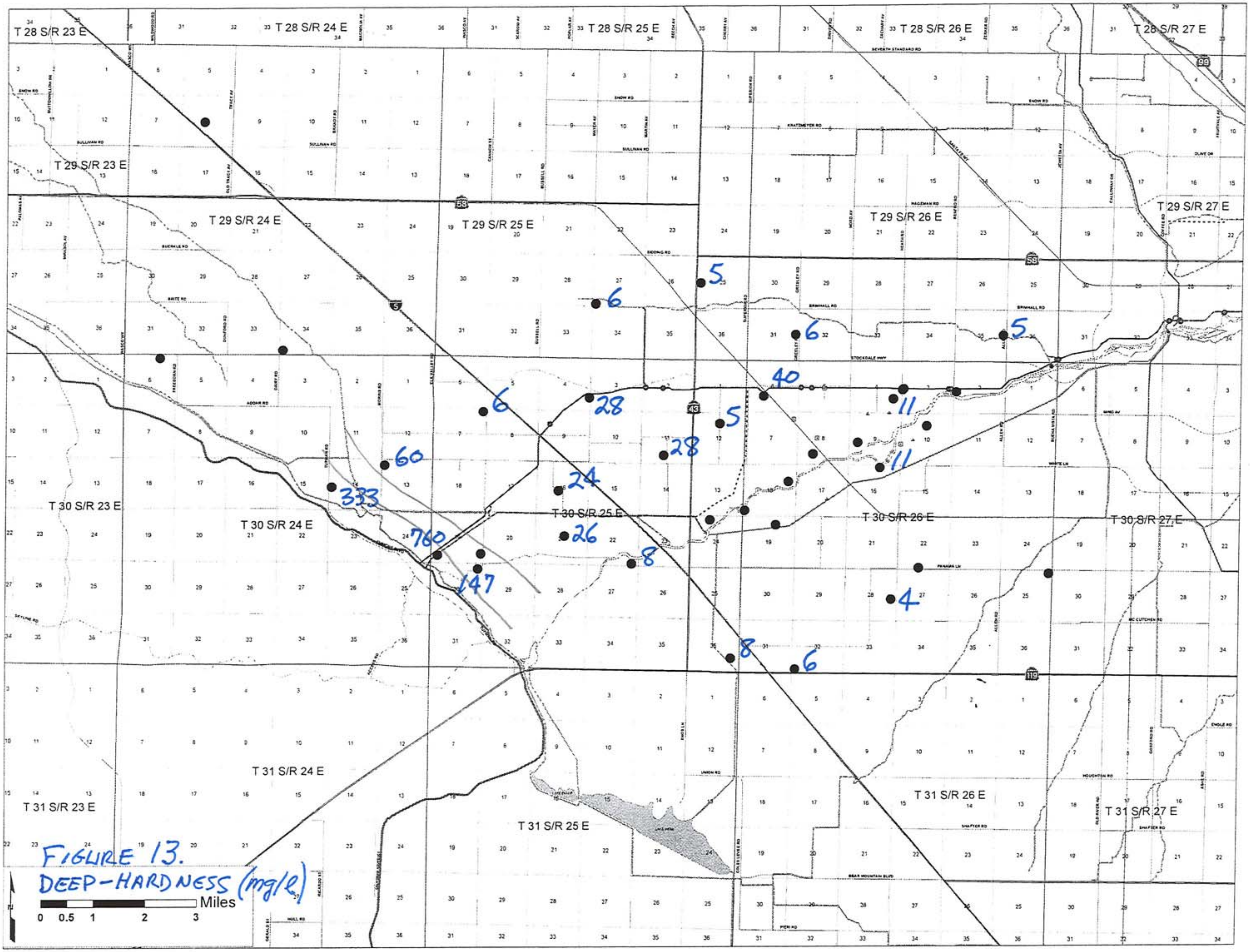


FIGURE 13.
DEEP-HARDNESS (mg/l)

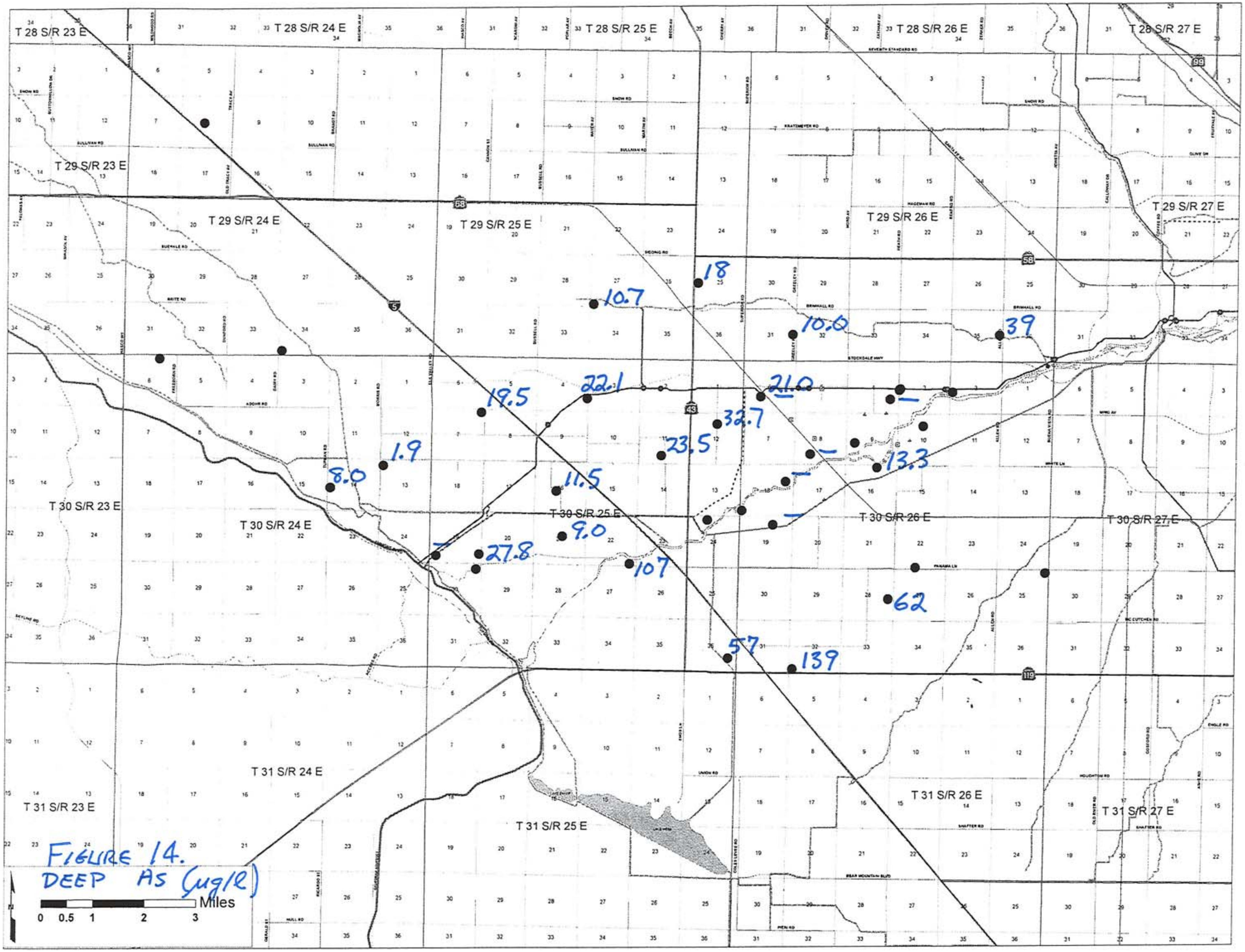


FIGURE 14.
DEEP As (ug/l)

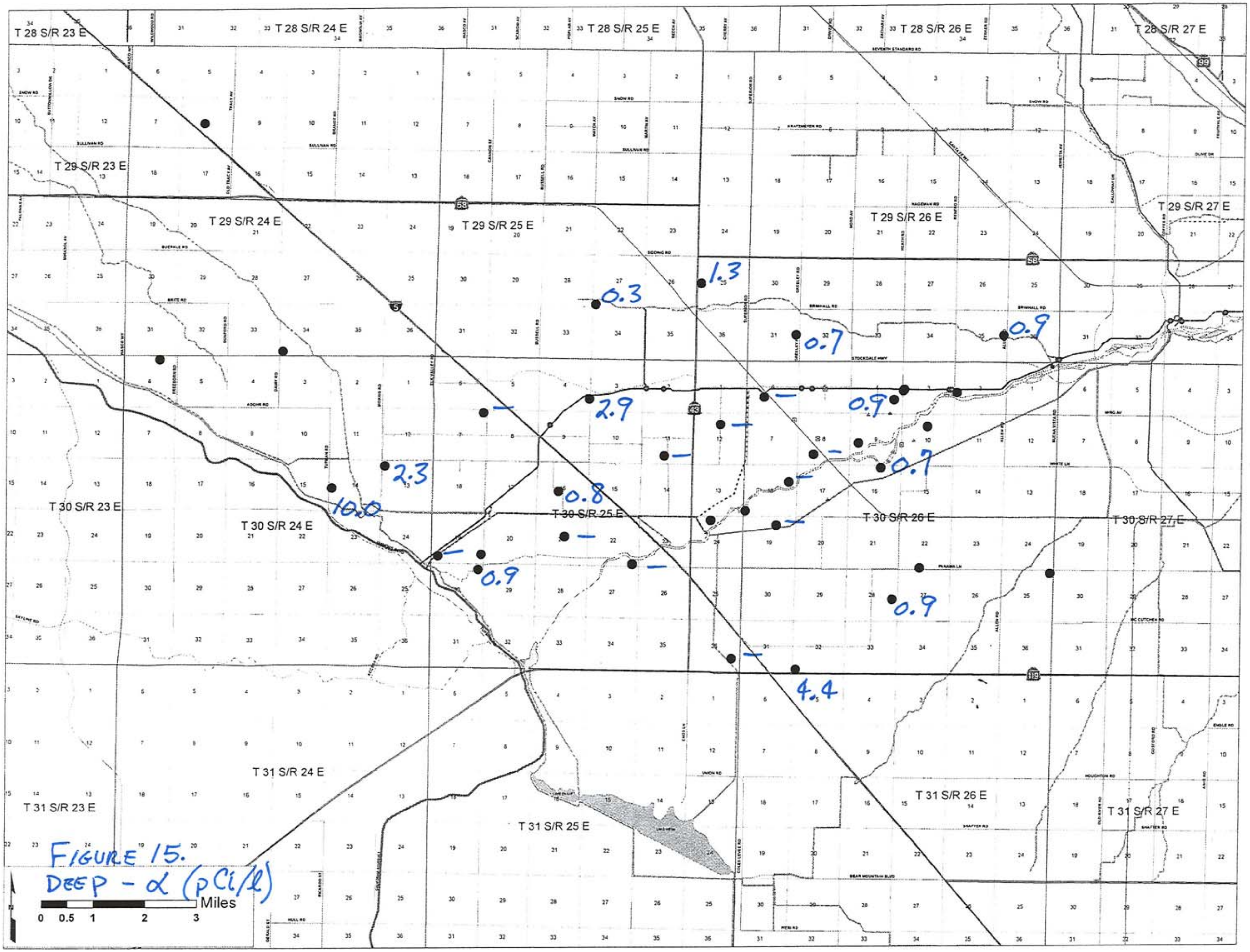


FIGURE 15.
DEEP - α (pCi/l)

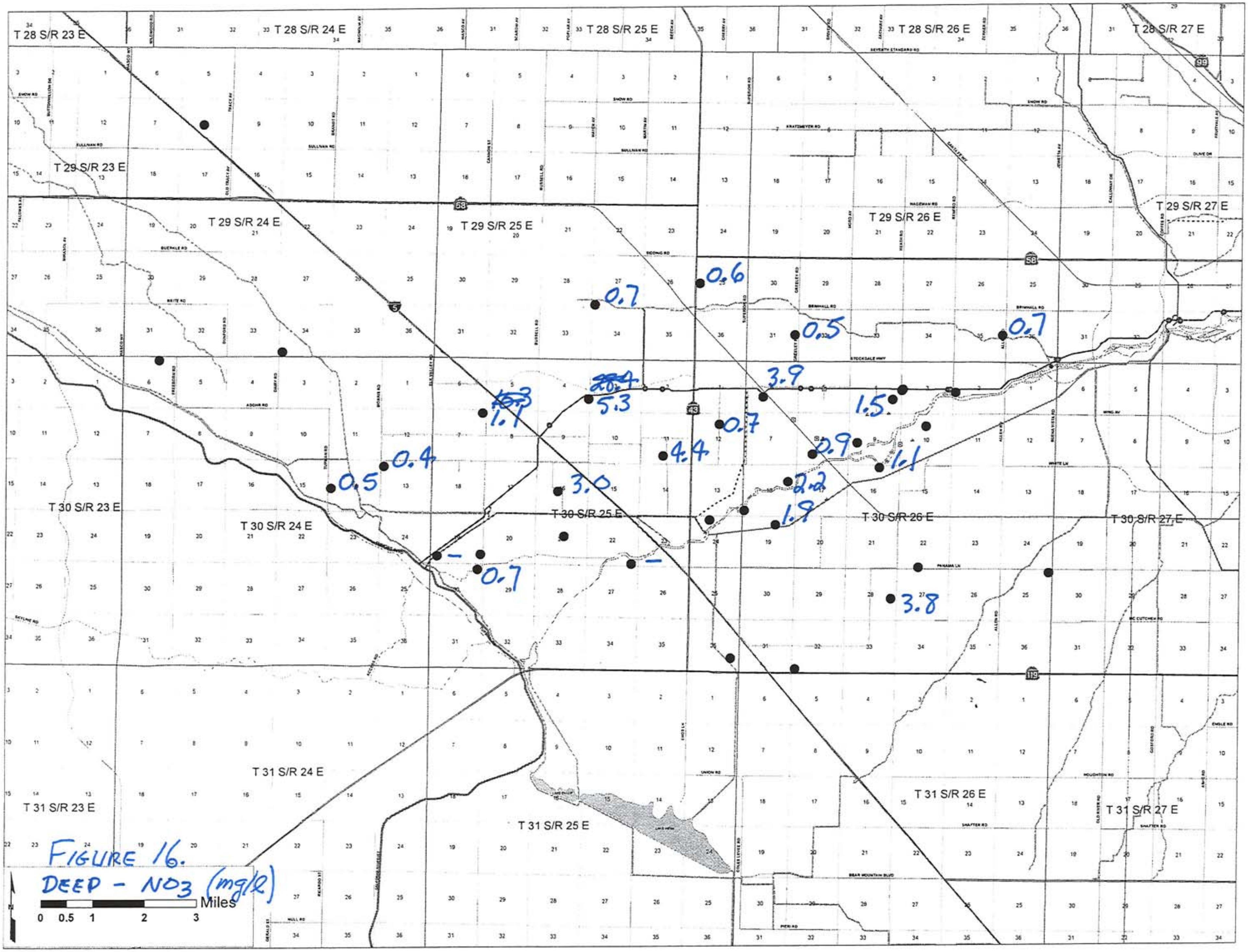


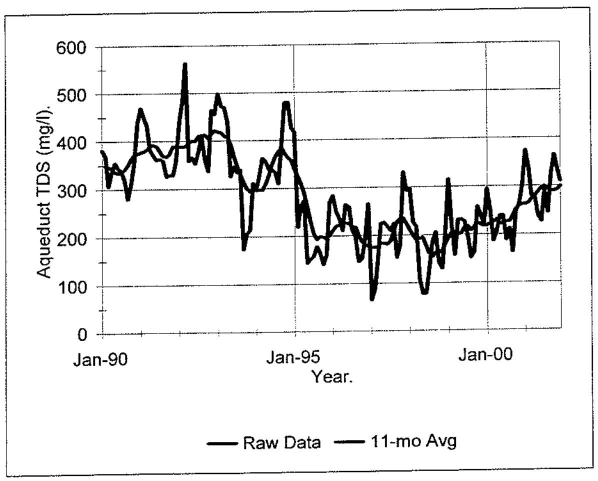
FIGURE 16.
DEEP - NO3 (mg/l)

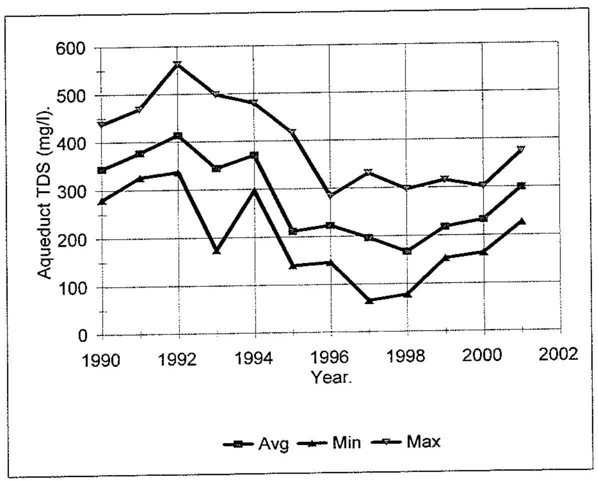
Tables

Table 1. SWP Aqueduct Water TDS content by Year, Month, and Wet/Dry Season.
(Measured in the Ca. Aqueduct at check 29, near Taft Hwy.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001		Avg	Min	Max	Std	5-yr Dry 91-95	5-yr Wet 96-00
Jan	382	469	439	499	297	417	284	66	297	315	295	374	*	345	66	499	110	424	251
Feb	369	448	485	472	328	219	251	88	227	216	250	337	*	308	88	485	116	390	206
Mar	306	433	563	470	363	263	236	147	218	158	187	280	*	302	147	563	125	418	189
Apr	335	382	358	441	357	274	211	225	108	231	206	275	*	284	108	441	90	362	196
May	355	371	366	326	340	144	265	227	78	232	239	239	*	265	78	371	88	309	208
Jun	343	361	353	346	339	152	260	219	78	228	239	227	*	262	78	361	86	310	205
Jul	338	363	377	334	333	158	214	210	124	199	189	291	*	261	124	377	84	313	187
Aug	319	359	410	339	310	178	197	224	186	153	213	245	*	261	153	410	80	319	195
Sep	280	326	361	174	395	165	146	154	206	164	164	323	*	238	146	395	88	284	167
Oct	310	329	337	206	479	141	152	180	142	258	248	365	*	262	141	479	101	298	196
Nov	357	329	464	214	480	160	195	331	130	242	262	333	*	291	130	480	107	329	232
Dec	438	356	456	311	427	270	266	293	207	219	301	310	*	321	207	456	79	364	257
Avg	344	377	414	344	371	212	223	197	167	218	233	300						344	208
Min	280	326	337	174	297	141	146	66	78	153	164	227						284	167
Max	438	469	563	499	480	417	284	331	297	315	301	374						424	257
Std	39	46	65	105	59	79	43	73	64	44	41	47						45	26
Max/Min	1.6	1.4	1.7	2.9	1.6	3.0	1.9	5.0	3.8	2.1	1.8	1.6						1.5	1.5

Data Source: KCWA 2001 Kern Fan Area Operations and Monitoring Report, Table 5D-9, p. 5-32.





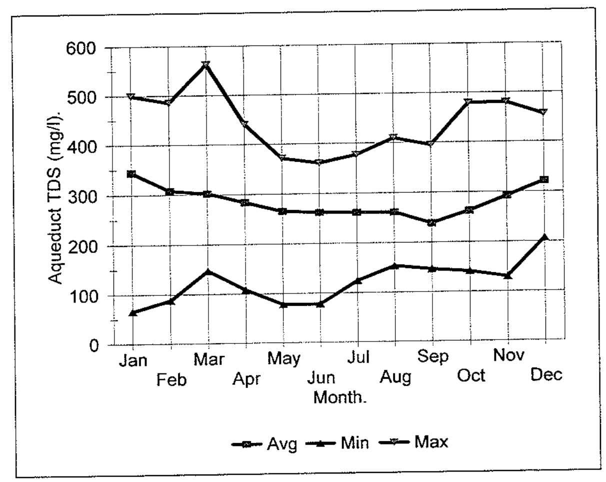


Table 1. SWP Aqueduct Water TDS content by Year, Month, and Wet/Dry Season.

Sierra Scientific Services, 2007. (661) 377 - 0123.)

Table 2. Key Constituents for the Shallow and Deep Aquifer at monitoring Well Locations.

(Avg* excludes MW data west of I-5, excludes 3 plume-related wells (04J, 11P, 12B), and excludes 3 off-fan wells (31H, 36R, 32N).

Shallow Aquifer (excl. west side)		AVG*	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
Well			25M02	27N02	31H02	35H04	13D01	14M03	04J02	07A02	11P01	12B02	16L01	19N02
Depth		Shallow	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh
Domain			Fan-E2	Fan-E2	Fan-E1	Fan-E2	Fan-W1	Fan-W2	Fan-E3	Fan-E2	Fan-E3	Fan-E3	Fan-E3	Fan-W2
# Wells		21												
# Anal.		190	5	8		14	21	6	24	5	5	2	24	1
General Mineral														
TDS	(mg/l)	225.9	162	256		148	721	689	385	268	408	2380	172	880
pH	(pH)	7.8	8.0	7.7		7.9	7.8	7.8	7.9	8.2	7.6	7.2	7.9	8.1
Hd	(mg/l)	103.4	93	146		69	366	375	181	63	163	991	41	100
COCs														
As	(ug/l)	4.1					4.0		1.8				2.7	
Alpha	pCi/l	7.6	7.8	16.9		2.7	69.5	10.7	10.2				1.2	
NO3	(mg/l)	9.3	16.5	12.9		12.2	6.9	0.5	28.4	10.3	18.9	25.8	4.5	

Deep Aquifer. (excl. west side)		AVG*	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
Well			25M01	27N01	31H01	35H03	13D03	14M02	04J04	07A04	11P03	12B04	16L03	19N04
Depth		Deep	De	De	De	De	De	De	De	De	De	De	De	De
Domain			Fan-E2	Fan-E2	Fan-E1	Fan-E2	Fan-W1	Fan-W2	Fan-E3	Fan-E2	Fan-E3	Fan-E3	Fan-E3	Fan-W2
# Wells		24												
# Anal.		208	6	8	7	8	22	8	18	4	5	4	21	2
General Mineral														
TDS	(mg/l)	123.9	90	78	85	102	326	1420	151	108	134	112	133	2760
pH	(pH)	9.1	9.4	9.4	9.4	9.2	7.7	8.1	8.6	9.2	9.0	9.4	8.3	8.0
Hd	(mg/l)	13.6	5	6	6	5	59	333	26	6	28	5	23	760
COCs														
As	(ug/l)	35.0	18.0	10.7	10.0	39.0	1.9	8.0	22.1	19.5	23.5	32.7	11.5	
Alpha	pCi/l	1.3	1.3	0.3	0.7	0.9	2.3	10.0	2.9				0.9	
NO3	(mg/l)	2.1	0.6	0.7	0.5	0.7	0.4	0.6	5.3	1.1	4.4	0.7	3.0	

Table 2. Key Constituents for the Shallow and Deep Aquifer at monitoring Well Locations.

Table 2. Key Constituents for the Shallow and Deep Aquifer at monitoring Well Locations.

Shallow Aquifer (excl. west side)													
		AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
Well		19R02	21G03	22R01	36R02	04J01	06L01	08P04	16B01	18H04	19B01	28J01	32N01
Depth		Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh
Domain		Fan-W2	Fan-E3	Fan-E3	Fan-E1	Fan-E3	Fan-E3	Fan-E2	Fan-E2	Fan-E22	Fan-E22	Fan-E2	Fan-E1
# Wells													
# Anal.		5	5	7	5	4	7		25		9	4	4
General Mineral													
TDS	(mg/l)	638	180	198	143	170	303		231		309	315	151
pH	(pH)	8.1	8.3	7.8	9.3	7.5	7.7		7.9		7.5	7.7	9.5
Hd	(mg/l)	186	46	100	5	70	171		122		166	153	2
COCs													
As	(ug/l)	3.0	8.0	3.5	44.3				2.2				95.5
Alpha	pCi/l	3.3							9.4				3.3
NO3	(mg/l)		7.5	2.7	1.8	3.6	19.7		6.0		6.1		

Deep Aquifer. (excl. west side)													
		AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
Well		19R01	21G02	22R03	36R01	04J03	06L03	08P04	16B03	18H04	19B03	28J03	32N03
Depth		De	De	De	De	De	De	De	De	De	De	De	De
Domain		Fan-W2	Fan-E3	Fan-E3	Fan-E1	Fan-E3	Fan-E3	Fan-E2	Fan-E2	Fan-E22	Fan-E22	Fan-E2	Fan-E1
# Wells													
# Anal.		6	4	7	4	9	7	8	25	7	8	6	4
General Mineral													
TDS	(mg/l)	696	158	160	165	111	137	95	109	140	99	134	178
pH	(pH)	8.4	8.8	9.2	9.3	9.2	8.7	9.4	8.7	8.6	8.8	9.6	9.4
Hd	(mg/l)	146	26	8	8	10	38	9	10	19	26	4	5
COCs													
As	(ug/l)	27.8	9.0	106.5	57.0		21.0	0.0	13.3			62.0	138.5
Alpha	pCi/l	0.9				0.9		0.0	0.7			0.9	4.4
NO3	(mg/l)	0.7	4.0			1.5	3.9	0.9	1.1	2.2	1.9	3.8	

Table 2. Key Constituents for the Shallow and Deep Aquifer at monitoring Well Locations.

Table 3. Key Constituent Summary for Selected Surface Waters and Aquifer Waters.

WQ Summary.									
Type		**SW**	**SW**	**SW**	**GW**	**GW**	**GW**	**Well**	**Well**
Zone		**AQ**	**FK**	**KR**	**Type-D Shallow**	**Type-A Deep**	**Plume Shallow**	**KWB* Blend**	**SR1-6 Blend**
# Wells		na	na	na	8	11	3	?	5
# Analy.		9	6	48	76	66	31	11	5
General Mineral									
TDS	(mg/l)	334	41	88	229	119	1058	143	618
pH	(pH)	8.3	7.5	7.9	7.8	9.4	7.6	8.7	7.9
Hd	(mg/l)	115	22	39	122	6	445	52	272
COCs									
As	(ug/l)	7.0	2.9	5.2	0.7	44.9	0.6	9.9	0.3
Alpha	(pCi/l)	1.9	2.9	3.2	5.1	0.8	3.4	3.7	10.9
NO3	(mg/l)	2.4	1.4	1.0	9.9	0.8	24.4	2.7	24.0
								estimated blend:	
							Vsh/Vtot =	17%	67%
							Vdp/Vtot =	83%	33%

note: Surface water analyses (Aq, FK, KR) from KCWA, ID4 WWTP raw inlet water analyses.
note GW averages from tabulated long -term average monitoring well data.
note: Plume area-avg of 3 MW (neither max nor source): T30s/R25e, 04J, 11P, and 12B.
note: KWB blend from KCWA, ID4 WWTP raw inlet water analyses.
note: Strand Ranch blend from one set of 2003 well water analyses.

Table 3. Key Constituent Summary for Selected Surface Waters and Aquifer Waters.

Table 4. Kern Fan Banking Project Salt Balance Data.

Yr Project	SWP Rchg (af)	FK Rchg (af)	KR Rchg (af)	Total Rchg (af)	SWP Salt (T)	FK Salt (T)	KR Salt (T)	Total Salt (T)	SWP TDS (T/af)	FK TDS (T/af)	KR TDS (T/af)	Total TDS (T/af)	0.0014 SWP TDS (mg/l)	FK TDS (mg/l)	KR TDS (mg/l)	Total TDS (mg/l)	SWP V wtr (%)	FK V wtr (%)	KR V wtr (%)	SWP M salt (%)	FK M salt (%)	KR M salt (%)
1995 BM	11437	18917	4132	34486	4395	1106	472	5972	0.384	0.058	0.114	0.173	283	43	84	127	33.2%	54.9%	12.0%	73.6%	18.5%	7.9%
1995 2800 ac	48287	30020	30908	109215	15860	1754	3529	21143	0.328	0.058	0.114	0.194	242	43	84	142	44.2%	27.5%	28.3%	75.0%	8.3%	16.7%
1995 KWB	70329	47035	104896	222260	18487	2749	11975	33211	0.263	0.058	0.114	0.149	193	43	84	110	31.6%	21.2%	47.2%	55.7%	8.3%	36.1%
1995 Pioneer	10177	35679	33657	79513	2319	2085	3842	8246	0.228	0.058	0.114	0.104	168	43	84	76	12.8%	44.9%	42.3%	28.1%	25.3%	46.6%
1995 KRC	0	2367	891	3258	0	138	102	240		0.058	0.114	0.074		43	84	54	0.0%	72.7%	27.3%	0.0%	57.5%	42.5%
1996 BM	920	6804	2242	9966	332	398	256	985	0.361	0.058	0.114	0.099	266	43	84	73	9.2%	68.3%	22.5%	33.7%	40.4%	26.0%
1996 2800 ac	8799	17737	12947	39483	3153	1037	1478	5667	0.358	0.058	0.114	0.144	264	43	84	106	22.3%	44.9%	32.8%	55.6%	18.3%	26.1%
1996 KWB	87492	49893	36490	173875	26411	2916	4166	33492	0.302	0.058	0.114	0.193	222	43	84	142	50.3%	28.7%	21.0%	78.9%	8.7%	12.4%
1996 Pioneer	6620	20521	18535	45676	2317	1199	2116	5632	0.350	0.058	0.114	0.123	258	43	84	91	14.5%	44.9%	40.6%	41.1%	21.3%	37.6%
1996 KRC	340	11684	6301	18325	118	683	719	1520	0.347	0.058	0.114	0.083	255	43	84	61	1.9%	63.8%	34.4%	7.8%	44.9%	47.3%
1997 BM	52	4476	2027	6555	5	262	231	498	0.096	0.059	0.114	0.076	71	43	84	56	0.8%	68.3%	30.9%	1.0%	52.6%	46.4%
1997 2800 ac	2562	0	3178	5740	1000	0	363	1363	0.390		0.114	0.237	287		84	175	44.6%	0.0%	55.4%	73.4%	0.0%	26.6%
1997 KWB	40049	28806	43407	112262	13931	1683	4955	20569	0.348	0.058	0.114	0.183	256	43	84	135	35.7%	25.7%	38.7%	67.7%	8.2%	24.1%
1997 Pioneer	3632	7328	19125	30085	1406	428	2183	4017	0.387	0.058	0.114	0.134	285	43	84	98	12.1%	24.4%	63.6%	35.0%	10.7%	54.3%
1997 KRC	0	0	6471	6471	0	0	739	739			0.114	0.114			84	84	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%
1998 BM	986	4232	15131	20349	271	247	1727	2246	0.275	0.058	0.114	0.110	202	43	84	81	4.8%	20.8%	74.4%	12.1%	11.0%	76.9%
1998 2800 ac	2647	4245	49505	56397	857	248	5652	6757	0.324	0.058	0.114	0.120	238	43	84	88	4.7%	7.5%	87.8%	12.7%	3.7%	83.6%
1998 KWB	51155	55248	196312	302715	14427	3229	22411	40067	0.282	0.058	0.114	0.132	208	43	84	97	16.9%	18.3%	64.9%	36.0%	8.1%	55.9%
1998 Pioneer	7646	4835	56634	69115	2296	283	6465	9044	0.300	0.059	0.114	0.131	221	43	84	96	11.1%	7.0%	81.9%	25.4%	3.1%	71.5%
1998 KRC	8	600	264	872	2	35	30	67	0.250	0.058	0.114	0.077	184	43	84	57	0.9%	68.8%	30.3%	3.0%	52.2%	44.8%
1999 BM	0	599	34	633	0	35	4	39		0.058	0.118	0.062		43	87	45	0.0%	94.6%	5.4%	0.0%	89.7%	10.3%
1999 2800 ac	3568	3952	2743	10263	1219	231	313	1763	0.342	0.058	0.114	0.172	251	43	84	126	34.8%	38.5%	26.7%	69.1%	13.1%	17.8%
1999 KWB	26011	10563	179	36753	8846	617	20	9483	0.340	0.058	0.112	0.258	250	43	82	190	70.8%	28.7%	0.5%	93.3%	6.5%	0.2%
1999 Pioneer	6736	5892	1104	13732	2387	344	126	2858	0.354	0.058	0.114	0.208	261	43	84	153	49.1%	42.9%	8.0%	83.5%	12.0%	4.4%
1999 KRC	0	2043	0	2043	0	119	0	119		0.058		0.058		43		43	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
2000 BM	0	1027	0	1027	0	60	0	60		0.058		0.058		43		43	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
2000 2800 ac	258	30660	0	30918	78	1792	0	1870	0.302	0.058		0.060	222	43		45	0.8%	99.2%	0.0%	4.2%	95.8%	0.0%
2000 KWB	19455	8124	0	27579	5430	475	0	5905	0.279	0.058		0.214	205	43		158	70.5%	29.5%	0.0%	92.0%	8.0%	0.0%
2000 Pioneer	5589	9707	0	15296	1533	567	0	2100	0.274	0.058		0.137	202	43		101	36.5%	63.5%	0.0%	73.0%	27.0%	0.0%
2000 KRC	0	4073	0	4073	0	238	0	238		0.058		0.058		43		43	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
2001 BM	0	0	0	0	0	0	0	0														
2001 2800 ac	2539	0	0	2539	966	0	0	966	0.380			0.380	280			280	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
2001 KWB	10030	0	0	10030	3817	0	0	3817	0.381			0.381	280			280	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
2001 Pioneer	1253	0	0	1253	477	0	0	477	0.381			0.381	280			280	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
2001 KRC	139	1262	813	2214	53	74	93	219	0.381	0.059	0.114	0.099	281	43	84	73	6.3%	57.0%	36.7%	24.2%	33.8%	42.5%
XXX																						
Sum	428716	428329	647926	1504971	132393	25032	73967	231389	0.309	0.058	0.114	0.154	227	43	84	113	28.5%	28.5%	43.1%	57.2%	10.8%	32.0%
Data from: KCWA 2001 Kern Fan Monitoring Report, tables 5D-1 to 5D-8.																						
'95 - 01 BM	13395	36055	23566	73016	5003	2108	2690	9800	0.373	0.058	0.114	0.134	275	43	84	99	18.3%	49.4%	32.3%	51.1%	21.5%	27.4%
'95 - 01 2800 ac	68660	86614	99281	254555	23133	5062	11335	39529	0.337	0.058	0.114	0.155	248	43	84	114	27.0%	34.0%	39.0%	58.5%	12.8%	28.7%
'95 - 01 KWB	304521	199669	381284	885474	91349	11669	43527	146544	0.300	0.058	0.114	0.165	221	43	84	122	34.4%	22.5%	43.1%	62.3%	8.0%	29.7%
'95 - 01 Pioneer	41653	83962	129055	254670	12735	4906	14732	32374	0.306	0.058	0.114	0.127	225	43	84	94	16.4%	33.0%	50.7%	39.3%	15.2%	45.5%
'95 - 01 KRC	487	22029	14740	37256	173	1287	1683	3142	0.355	0.058	0.114	0.084	261	43	84	62	1.3%	59.1%	39.6%	5.5%	41.0%	53.6%
'95 - 01 Chk Sum	428716	428329	647926	1504971	132393	25032	73967	231389	0.309	0.058	0.114	0.154	227	43	84	113	28.5%	28.5%	43.1%	57.2%	10.8%	32.0%

Table 4. Kern Fan Banking Project Salt Balance Data.

Exhibits

Exhibit 1.

Water Quality Data Collection and Evaluation Methodology.

Exhibit 1.

Water Quality Data Collection and Evaluation Methodology.

Some of the data and findings in this Report have been excerpted and modified from another ongoing water quality study for the Rosedale - Rio Bravo Water Storage District, with their permission. That study is a baseline water quality (BWQ) analysis of the groundwater aquifer in the RRBWSD area of interest, which happens to include the Strand Ranch Project area because of proximity. The RRBWSD baseline water quality analysis will be completed and presented in report form in Winter, 2007-2008.

The BWQ work program includes groundwater data collection, basic data analysis, and preliminary interpretation. The sources of data include: the Kern County Water Agency water quality database (courtesy of Tom Haslebacher, KCWA Senior Hydrogeologist), Vaughan Water Company water well analyses (courtesy of Mike Huhn, manager, VWC), and the Rosedale - Rio Bravo Water Storage District (courtesy of Robert Coffee, RRBWSD operations manager). Sierra Scientific Services specified the data screening criteria and the methods of analysis according to accepted standards and practices.

For this study, we have added water sample analyses provided by IRWD collected from the accessible irrigation wells on the Strand Ranch property and obtained from other wells located on adjacent property.

The primary task of this study is to collect the available data and describe the observed, historical water quality trends in the surface waters and groundwaters which flow into and out of the Kern Fan aquifer system as they relate to the Strand Ranch Aquifer Storage and Recovery Project.

In the BWQ analysis, SSS focused the main data collection effort on obtaining a "complete set" of water-constituent tabulations and the supporting analytical reports for each and every reported analysis. The goal was to compile and tabulate multiple analyses collected over time for each and every sampling location, from which we could determine the average value and range of natural variability for each constituent at each sample location. We applied quantitative quality control/quality assurance indicators to each dataset. Based on these indicators and our own inspection of the data, we compiled every reported analysis into a standardized reporting format, and edited all of the data, including the rejection of any data which were unacceptable for our purposes based upon our criteria. The basic statistical criteria for the acceptability of data which we applied it to the entire database is as follows:

1: Location and Date: The location, well ID, and sampling date must be known;

2: Sufficiency: To obtain no less than four (4) independent analyses at a given sampling location;

3: Timing: Sampling intervals are preferred to be between quarterly and annually;

4: Variability: Constituent coefficients of variation are no more than 0.30, suggesting normality in constituent distributions;

5: Completeness: For the general mineral constituents, all major cations, anions, and physical properties of TDS, EC, and pH must be included in an analysis in order to be included in our compilation;

6: Depth: The completion interval of the well must be known in order for the data to be used. We give high priority to water quality samples from single-zone monitoring wells. Shallow (<250 ft) irrigation and domestic wells might be included in this category subject to review even if the exact completion interval is not known. We give low - medium priority to water quality samples from irrigation and recovery wells with long, multi-zone completion intervals. We give little or no priority to water quality samples from wells with unknown completion intervals.

7: Analytical Error: The data must pass our internal analytical checks for cation/anion balance (basic analytical accuracy check) and TDS/EC balance (basic ion concentration - electric conduction check).

8: Reporting Conventions: For our purposes and for all statistical analyses such as calculating sample averages and variances, we disagree with the reporting convention of giving a "below detection threshold" measurement a numerical value equal to the detection threshold. When we find such values in the data, we reset them to zero in our database. If there is no reported value for a constituent, we leave the value “blank”.

We rejected many individual analyses for failing to meet one or more statistical criteria and rejected other analyses which had no documentation or means of verification. We were reluctant to accept constituent - of - concern (COC) analyses for sample locations which had little or no established general mineral chemistry and did so in only a few case-by-case situations.

Exhibit 2.

Surface Water and Ground Water Geochemical Analyses.

WQ Analyses.

WQ Analyses.		West AVG	West AVG	West AVG	West AVG	West AVG	West AVG	West AVG	West AVG	West AVG	West AVG
Well		30S/24E 13D01 :	30S/24E 13D02 I	30S/24E 13D03 I	30S/24E 14M02	30S/24E 14M03	30S/25E 19N02 :	30S/25E 19N03 I	30S/25E 19N04 I	30S/25E 19R01 I	30S/25E 19R02 :
Twp/Rge		30S/24E	30S/24E	30S/24E	30S/24E	30S/24E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E
Sec/40ac		13D01	13D02	13D03	14M02	14M03	19N02	19N03	19N04	19R01	19R02
Depth		Sh	Mi	De	De	Sh	Sh	Mi	De	De	Sh
Date		21	22	22	8	6	1	3	2	6	5
Domain		Fan-W1	Fan-W1	Fan-W1	Fan-W2	Fan-W2	Fan-W2	Fan-W2	Fan-W2	Fan-W2	Fan-W2
General Mineral											
Ca	(mg/l)	142.2	40.1	23.8	125.0	138.2	33.0	25.3	250.5	56.8	69.2
Mg	(mg/l)	2.8	0.4	0.1	5.1	3.8	5.2	2.5	32.5	1.1	3.1
Na	(mg/l)	71.4	72.2	82.5	284.0	214.1	278.0	208.7	589.5	144.8	126.2
K	(mg/l)	1.5	0.9	0.6	1.8	1.5	1.3		2.3	1.0	1.1
OH	(mg/l)				30.0				0.8		
CO3	(mg/l)							7.3		9.4	
HCO3	(mg/l)	230.0	94.0	41.0	86.5	115.5	156.0	122.0	65.2	41.0	45.6
SO4	(mg/l)	313.1	186.0	167.3	203.4	203.0	221.0	115.3	441.0	93.0	275.4
Cl	(mg/l)	39.6	20.0	28.3	521.4	417.9	262.0	215.0	1223.5	252.0	110.2
NO3	(mg/l)	6.9	1.2	0.4	0.6	0.5				0.7	
NO2	(mg/l)										
F	(mg/l)	0.4	0.3	0.1	0.2			0.5		0.5	0.2
SiO2	(mg/l)	23.8	10.8	13.0							
pH	(pH)	7.8	7.5	7.7	8.1	7.8	8.1	8.4	8.0	8.4	8.1
EC	(uS/cm)	996.1	563.0	533.1	2061.2	1827.7	1480.0	1125.7	4380.0	1068.8	987.6
TDS	(mg/l)	720.7	346.1	326.1	1420.0	689.4	880.0	682.5	2760.0	695.6	638.0
Hd	(mg/l)	366.2	100.3	59.4	333.1	375.4	100.0	73.5	759.5	145.8	185.6
Alk	(mg/l)	139.7	35.9	27.3	72.0	102.5		110.0		35.0	36.7
Water Quality											
TDS	index	Fair-Poor	Xlnt	Xlnt	Unacc.	Good	Fair-Poor	Good	Unacc.	Good	Good
Hard	index	V.Hard	M.Hard	Soft	V.Hard	V.Hard	M.Hard	M.Hard	V.Hard	Hard	V.Hard
SAR	index	Mod	Low	Low	High	High	High	Mod	V.High	Mod	Mod
Calc'd Values											
Cat	(meq/l)	10.47	5.20	4.80	19.05	16.56	14.20	10.55	40.87	9.25	9.23
An	(meq/l)	11.54	6.01	4.97	20.38	17.91	14.55	10.74	44.76	10.07	9.60
Hard	(mg/l)	367	102	60	333	361	104	74	760	147	186
Alk	(mg/l)	188	77	34	247	95	128	106	58	41	37
SAR	ratio	1.62	3.12	4.65	6.77	4.91	11.87	10.58	9.31	5.21	4.03
SUM	(mg/l)	691	367	323	1214	1036	877	635	2572	580	608
ECcalc	(uS/cm)	1275	659	587	2444	2123	1713	1245	5379	1175	1155
TDS/EC	ratio	0.72	0.61	0.61	0.69	0.38	0.59	0.61	0.63	0.65	0.65
Analyt. Checks											
Anal.Com	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL
Cat/An	EV=1	0.90	0.85	0.97	0.93	0.92	0.98	0.98	0.91	0.92	0.96
meq/EC	EV=1	1.10	1.00	0.92	0.96	0.94	0.97	0.95	0.98	0.90	0.95
TDS/SUM	EV=1	1.04	0.94	1.01	1.17	0.67	1.00	1.08	1.07	1.20	1.05
EC/ECcalc	EV=1	0.78	0.85	0.91	0.84	0.86	0.86	0.90	0.81	0.91	0.85
CalcHCO3											
Ternary Ratios		S/24E 13D01 Sh	)S/24E 13D02 Mi	S/24E 13D03 De	S/24E 14M02 De	S/24E 14M03 Sh	S/25E 19N02 Sh	)S/25E 19N03 Mi	S/25E 19N04 De	S/25E 19R01 De	S/25E 19R02 Sh
Ca	(%)	68%	38%	25%	33%	42%	12%	12%	31%	31%	37%
Mg	(%)	2%	1%	0%	2%	2%	3%	2%	7%	1%	3%
Na+K	(%)	30%	61%	75%	65%	56%	85%	86%	63%	68%	60%
SumCat	(%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
HCO3+CO	(%)	33%	26%	14%	7%	11%	18%	21%	2%	10%	8%
SO4	(%)	56%	64%	70%	21%	24%	32%	22%	21%	19%	60%
Cl+NO3	(%)	11%	10%	16%	72%	66%	51%	56%	77%	71%	32%
SumAn	(%)	99.8%	99.8%	99.9%	99.9%	100.0%	100.0%	99.8%	100.0%	99.7%	99.9%
Type	Cat-An	Ca-HCO3/SO4	Na-SO4	Na-SO4	Na-Cl	Ca/Na-Cl	Na-Cl/SO4	Na-mxd	Na-Cl	Na-Cl	Ca/Na-Cl/SO4
Type	A,B,D	D21-SO4	B2-SO4	B2-SO4	B1b	B1b	B1-SO4	B2	B1b	B2	B1-SO4
COCs											
As	(ug/l)	4	2.29	1.93	8					27.75	3
Ba	(ug/l)	63.67									
B	(ug/l)	204.83	50.1	70.62	0.39	0.31	0.69	0.77	1.55	0.22	0.42
Alpha	pCi/l	69.53	1.34	2.29	9.97	10.7				0.93	3.3
Radon	pCi/l										
DBCP	(ug/l)										
EDB	(ug/l)										

WQ Analyses.		East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG
Well		30S/25E 04J02 !	30S/25E 04J03 I	30S/25E 04J04 I	30S/25E 07A02 !	30S/25E 07A03 I	30S/25E 07A04 I	30S/25E 11P01 !	30S/25E 11P02 I	30S/25E 11P03 I	30S/25E 12B02 !
Twp/Rge		30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E
Sec/40ac		04J02	04J03	04J04	07A02	07A03	07A04	11P01	11P02	11P03	12B02
Depth		Sh	Mi	De	Sh	Mi	De	Sh	Mi	De	Sh
Date		24	26	18	5	5	4	5	5	5	2
Domain		Fan-E3	Fan-E3	Fan-E3	Fan-E2	Fan-E2	Fan-E2	Fan-E3	Fan-E3	Fan-E3	Fan-E3
General Mineral											
Ca	(mg/l)	71.0	17.3	10.3	25.0	2.3	2.3	59.4	39.8	10.9	351.0
Mg	(mg/l)	1.2	0.1	0.4	0.1	0.1		3.5	0.2	0.1	27.5
Na	(mg/l)	44.7	64.8	40.5	57.0	29.6	33.0	72.6	57.4	40.8	349.5
K	(mg/l)	1.7	0.9	0.7				1.1	1.0	1.0	2.8
OH	(mg/l)										
CO3	(mg/l)		8.7	14.9		16.3	19.5			6.0	
HCO3	(mg/l)	181.2	56.6	34.6	59.8	42.4	26.3	233.6	107.5	60.7	173.0
SO4	(mg/l)	42.3	24.4	18.2	66.2	10.5	12.0	37.4	29.3	14.1	46.0
Cl	(mg/l)	77.8	79.5	27.9	40.6	5.9	6.7	60.4	68.6	30.8	1135.0
NO3	(mg/l)	28.4	11.7	5.3	10.3	0.7	1.1	18.9	17.2	4.4	25.8
NO2	(mg/l)										
F	(mg/l)	0.2	0.2	0.3		0.3	0.4	0.2		0.3	0.1
SiO2	(mg/l)	20.8	15.3	17.3							
pH	(pH)	7.9	7.7	8.6	8.2	9.1	9.2	7.6	7.9	9.0	7.2
EC	(uS/cm)	596.6	439.4	254.4	401.0	157.4	165.5	663.8	500.8	263.8	3955.0
TDS	(mg/l)	384.5	225.0	151.4	267.7	85.0	107.7	408.0	210.0	133.8	2380.0
Hd	(mg/l)	181.1	43.3	26.2	62.6	5.9	5.7	162.8	99.5	27.6	991.0
Alk	(mg/l)	95.0	42.5	57.6	55.0	56.7	50.0	183.3	106.7	60.0	160.0
Water Quality											
TDS	index	Xlnt	Xlnt	Xlnt	Xlnt	Xlnt	Xlnt	Good	Xlnt	Xlnt	Unacc.
Hard	index	V.Hard	Soft	Soft	M.Hard	Soft	Soft	Hard	M.Hard	Soft	V.Hard
SAR	index	Low	Low	Low	Low	Low	Low	Low	Low	Low	V.High
Calc'd Values											
Cat	(meq/l)	5.62	3.72	2.33	3.73	1.41	1.55	6.44	4.52	2.36	35.05
An	(meq/l)	6.51	4.16	2.33	3.67	1.65	1.56	6.62	4.59	2.44	36.23
Hard	(mg/l)	182	44	28	63	6	6	163	100	28	990
Alk	(mg/l)	148	54	41	49	48	38	191	88	55	142
SAR	ratio	1.44	4.26	3.36	3.13	5.13		2.48	2.50	3.36	4.83
SUM	(mg/l)	356	235	136	229	87	88	368	267	138	2023
ECcalc	(uS/cm)	681	447	235	430	129	129	700	517	254	4420
TDS/EC	ratio	0.64	0.51	0.60	0.67	0.54	0.65	0.61	0.42	0.51	0.60
Analyt. Checks											
Anal.Com	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL
Cat/An	EV=1	0.85	0.89	1.00	1.02	0.85	0.99	0.97	0.99	0.96	0.97
meq/EC	EV=1	1.02	0.90	0.92	0.92	0.97	0.94	0.98	0.91	0.91	0.90
TDS/SUM	EV=1	1.08	0.96	1.12	1.17	0.98	1.22	1.11	0.79	0.97	1.18
EC/ECcalc	EV=1	0.88	0.98	1.08	0.93	1.22	1.28	0.95	0.97	1.04	0.89
CalcHCO3											
Ternary Ratios		30S/25E 04J02 Sh	0S/25E 04J03 Mi	)S/25E 04J04 De	S/25E 07A02 Sh	)S/25E 07A03 Mi	S/25E 07A04 De	S/25E 11P01 Sh	)S/25E 11P02 Mi	S/25E 11P03 De	S/25E 12B02 Sh
Ca	(%)	63%	23%	22%	33%	8%	7%	46%	44%	23%	50%
Mg	(%)	2%	0%	1%	0%	1%	0%	4%	0%	0%	6%
Na+K	(%)	35%	76%	76%	66%	91%	93%	49%	56%	76%	44%
SumCat	(%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
HCO3+CO	(%)	46%	29%	46%	27%	75%	69%	58%	38%	49%	8%
SO4	(%)	14%	12%	16%	38%	13%	16%	12%	13%	12%	3%
Cl+NO3	(%)	41%	58%	37%	36%	11%	13%	30%	48%	38%	90%
SumAn	(%)	99.9%	99.8%	99.3%	100.0%	99.0%	98.6%	99.9%	100.0%	99.4%	100.0%
Type	Cat-An	Ca-HCO3/Cl	Na-HCO3/Cl	Na-HCO3/Cl	Na-mxd	Na-HCO3	Na-HCO3	Ca/Na-HCO3/Cl	Ca/Na-HCO3/Cl	Na-HCO3/Cl	Ca/Na-Cl
Type	A,B,D	D21	B2	B2	B2-SO4	A	A	B1a	B2	B2	D20
COCs											
As	(ug/l)	1.8	2.5	22.07		23	19.5			23.5	
Ba	(ug/l)	127.15		52							
B	(ug/l)	137.56	80.03	100.01	0.11	0.1	0.09	0.51	0.25	0.15	4.81
Alpha	pCi/l	10.15	1.12	2.88							
Radon	pCi/l										
DBCP	(ug/l)										
EDB	(ug/l)										

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APP 2

WQ Analyses.		East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG
Well		30S/25E 12B03 I	30S/25E 12B04 I	30S/25E 16L01 !	30S/25E 16L02 I	30S/25E 16L03 (	30S/25E 21G02 I	30S/25E 21G03 !	30S/25E 22R01 !	30S/25E 22R02 I	30S/25E 22R03 I	30S/25E 36R01 I	30S/25E 36R02 !	30S/26E 04J01 !	30S/26E 04J02 I	30S/26E 04J03 (	30S/26E 04J05 (	30S/26E 06L01 !	30S/26E 06L02 I	30S/26E 06L03 (	30S/26E 08P04 (	30S/26E 16B01 !
Twp/Rge		30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/25E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E
Sec/40ac		**12B03**	**12B04**	**16L01**	**16L02**	**16L03**	**21G02**	**21G03**	**22R01**	**22R02**	**22R03**	**36R01**	**36R02**	**04J01**	**04J02**	**04J03**	**04J05**	**06L01**	**06L02**	**06L03**	**08P04**	**16B01**
Depth		Mi	De	Sh	Mi	De	De	Sh	Sh	Mi	De	De	Sh	Sh	Mi	De	06	Sh	Mi	De	De	Sh
Date		4	4	24	21	21	4	5	7	5	7	4	5	4	3	9	2	7	5	7	8	25
Domain		Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E1	Fan-E1	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E3	Fan-E2	Fan-E2
General Mineral																						
Ca	(mg/l)	8.5	2.0	16.4	4.1	9.2	10.3	18.2	36.1	3.1	3.1	3.2	2.0	21.8	39.0	4.1	42.5	60.7	26.0	14.9	3.3	40.5
Mg	(mg/l)	0.1	0.1	0.2		0.1	0.1	0.2	2.5	0.1	0.1	0.1	0.1	4.1	4.1	0.2	3.5	4.9	0.3	0.8	1.2	5.3
Na	(mg/l)	34.5	33.8	44.0	31.5	37.0	38.5	42.0	18.3	30.2	50.9	47.8	41.6	27.3	26.0	37.0	22.5	28.0	26.4	27.0	33.8	26.7
K	(mg/l)			0.6	1.8	0.8									1.2		1.0		1.0			1.1
OH	(mg/l)																					
CO3	(mg/l)		15.0	2.6	17.3	8.2	10.5	2.6		10.1	15.1	16.8	20.4			13.2				9.4	18.6	
HCO3	(mg/l)	68.2	51.2	56.5	50.5	48.0	54.5	75.9	125.8	60.7	48.2	49.5	46.2	89.2	149.3	44.2	130.0	152.7	79.4	57.3	38.0	137.0
SO4	(mg/l)	15.0	9.5	16.7	11.9	14.4	20.2	23.9	12.6	10.3	15.4	24.6	12.7	18.6	19.0	16.8	24.0	43.5	16.2	15.3	9.7	23.7
Cl	(mg/l)	18.5	5.9	52.6	8.6	28.8	22.1	30.0	17.7	5.4	29.1	12.5	7.0	22.9	19.0	14.8	26.5	36.1	25.2	16.0	5.5	26.5
NO3	(mg/l)	3.0	0.7	4.5	0.7	3.0	4.0	7.5	2.7	0.9			1.8	3.6	3.4	1.5	6.0	19.7	4.4	3.9	0.9	6.0
NO2	(mg/l)																					
F	(mg/l)	0.2	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.4	0.9	1.1	0.6	0.1	0.2	0.3	0.2	0.2	0.1	0.3	0.3	0.1
SiO2	(mg/l)			17.3	23.3	15.7																21.6
pH	(pH)	8.6	9.4	7.9	8.9	8.3	8.8	8.3	7.8	8.5	9.2	9.3	9.3	7.5	7.8	9.2	7.8	7.7	8.0	8.7	9.4	7.9
EC	(uS/cm)	218.0	173.0	311.8	179.5	234.1	242.8	301.6	282.4	158.0	264.4	244.8	202.0	276.5	348.3	198.4	347.0	485.0	266.6	214.4	172.8	364.9
TDS	(mg/l)	121.0	111.6	172.2	109.5	133.2	157.9	179.5	198.4	82.0	160.0	165.0	142.5	170.3	216.0	110.5	215.0	302.6	151.3	136.6	95.0	231.0
Hd	(mg/l)	21.4	5.0	41.0	10.3	22.9	26.0	45.7	100.1	8.0	7.7	8.1	4.8	70.3	113.1	10.3	120.6	171.4	65.4	38.3	8.7	122.1
Alk	(mg/l)	60.0	60.0	44.1	56.0	47.2	55.0	63.3	105.0	60.0	60.0	70.0	70.0	80.0	110.0	48.3	120.0	130.0	70.0	50.0	60.0	112.9
Water Quality																						
TDS	index	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**	**XInt**
Hard	index	**Soft**	**Soft**	**Soft**	**Soft**	**Soft**	**Soft**	**Soft**	**M.Hard**	**Soft**	**Soft**	**Soft**	**Soft**	**M.Hard**	**M.Hard**	**Soft**	**M.Hard**	**Hard**	**M.Hard**	**Soft**	**Soft**	**Hard**
SAR	index	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**
Calc'd Values																						
Cat	(meq/l)	1.93	1.58	2.76	1.62	2.10	2.19	2.75	2.81	1.48	2.37	2.24	1.91	2.61	3.44	1.83	3.41	4.65	2.49	1.98	1.73	3.64
An	(meq/l)	2.01	1.73	2.92	1.92	2.24	2.36	2.80	2.88	1.73	2.48	2.29	1.96	2.56	3.44	1.97	3.48	4.75	2.43	2.10	1.63	3.59
Hard	(mg/l)	22	5	42	10	23	26	46	101	8	8	8	5	71	114	11	121	172	66	40	13	123
Alk	(mg/l)	56	54	48	56	46	53	64	103	58	52	54	55	73	122	47	106	125	65	55	47	112
SAR	ratio	3.22	6.31	2.97		3.33	3.29	2.68	0.79	4.59	7.82	7.23	8.04	1.40	1.06	4.84	0.89	0.93	1.41	1.85	4.06	1.05
SUM	(mg/l)	113	92	165	101	125	133	162	152	90	138	130	109	142	185	110	190	268	139	116	92	197
ECcalc	(uS/cm)	211	142	322	155	226	231	301	293	145	237	210	164	276	355	181	367	512	268	202	140	382
TDS/EC	ratio	0.56	0.64	0.55	0.61	0.57	0.65	0.60	0.70	0.52	0.61	0.67	0.71	0.62	'0.62	0.56	0.62	0.62	0.57	0.64	0.55	0.63
Analyt. Checks																						
Anal.Com	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL
Cat/An	EV=1	0.96	0.91	0.94	0.83	0.94	0.93	0.98	0.98	0.84	0.96	0.98	0.97	1.02	1.00	0.93	0.98	0.98	1.03	0.94	1.06	1.02
meq/EC	EV=1	0.90	0.95	0.91	0.99	0.93	0.94	0.92	1.01	1.02	0.92	0.93	0.96	0.93	0.99	0.96	0.99	0.97	0.92	0.95	0.97	0.99
TDS/SUM	EV=1	1.07	1.21	1.04	1.08	1.06	1.19	1.11	1.30	0.91	1.16	1.27	1.31	1.20	1.16	1.01	1.13	1.13	1.09	1.18	1.03	1.17
EC/ECcalc	EV=1	1.03	1.22	0.97	1.16	1.04	1.05	1.00	0.96	1.09	1.12	1.16	1.23	1.00	0.98	1.10	0.95	0.95	1.00	1.06	1.23	0.95
CalcHCO3																						
Ternary Ratios		)S/25E 12B03 Mi	S/25E 12B04 De	)S/25E 16L01 Sh	)S/25E 16L02 Mi	)S/25E 16L03 De	S/25E 21G02 De	S/25E 21G03 Sh	S/25E 22R01 Sh	)S/25E 22R02 Mi	S/25E 22R03 De	S/25E 36R01 De	S/25E 36R02 Sh	)S/26E 04J01 Sh	)S/26E 04J02 Mi	)S/26E 04J03 De	)S/26E 04J05 06	)S/26E 06L01 Sh	)S/26E 06L02 Mi	)S/26E 06L03 De	S/26E 08P04 De	S/26E 16B01 Sh
Ca	(%)	22%	6%	30%	13%	22%	23%	33%	64%	11%	6%	7%	5%	42%	56%	11%	62%	65%	52%	37%	9%	55%
Mg	(%)	1%	1%	0%	0%	0%	0%	1%	7%	0%	0%	0%	0%	13%	10%	1%	8%	9%	1%	3%	6%	12%
Na+K	(%)	78%	93%	70%	87%	78%	76%	66%	28%	89%	93%	93%	95%	45%	34%	88%	29%	26%	47%	59%	85%	33%
SumCat	(%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
HCO3+CC	(%)	56%	77%	35%	73%	47%	53%	47%	72%	77%	52%	60%	73%	57%	71%	59%	61%	53%	54%	60%	76%	63%
SO4	(%)	15%	11%	12%	13%	13%	18%	18%	9%	12%	13%	22%	13%	15%	11%	18%	14%	19%	14%	15%	12%	14%
Cl+NO3	(%)	28%	10%	53%	13%	38%	29%	34%	19%	10%	33%	15%	12%	28%	17%	22%	24%	28%	32%	24%	10%	24%
SumAn	(%)	99.5%	99.2%	99.7%	99.1%	99.2%	99.6%	99.6%	99.7%	98.9%	98.1%	97.5%	98.3%	99.8%	99.8%	99.2%	99.7%	99.8%	99.7%	99.2%	99.1%	99.8%
Type	Cat-An	Na-HCO3/Cl	Na-HCO3	Na-HCO3/Cl	Na-HCO3	Na-HCO3/Cl	Na-HCO3/Cl	Na-HCO3/Cl	Ca-HCO3	Na-HCO3	Na-HCO3/Cl	Na-HCO3/SO4	Na-HCO3	Ca/Na-HCO3/Cl	Ca/Na-HCO3	Na-HCO3/Cl	Ca-HCO3	Ca-HCO3/Cl	Ca/Na-HCO3/Cl	Ca/Na-HCO3/Cl	Na-HCO3	Ca/Na-HCO3
Type	A,B,D	**B2**	**A**	**B2**	**B2**	**B2**	**B2**	**B2**	**D1**	**B2**	**A**	**A**	**A**	**B1a**	**D1**	**B2**	**D1**	**D1**	**D20**	**B1b**	**A**	**D1**
COCs																						
As	(ug/l)		32.67	2.7	19.57	11.5	9	8	3.5		106.5	57	44.33						0	21	0	2.22
Ba	(ug/l)																42.85		0		0	58.6
B	(ug/l)	1.47	0.1	75.03	87.52	73.72	0.11	0.12	0.09	0.1	0.22	0.28	0.13	0.11	0.13	0.08	0.12	0.21	0.12	0.11	0.09	0.14
Alpha	pCi/l			1.16	0.58	0.85									19	0.9	10.58		0		0	9.41
Radon	pCi/l																					
DBCP	(ug/l)																		0		0	0
EDB	(ug/l)																		0		0	0

WQ Analyses.

WQ Analyses.		East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG	East AVG
Well		30S/26E 16B02 I	30S/26E 16B03 (	30S/26E 16B04 :	30S/26E 18H04 I	30S/26E 19B01 :	30S/26E 19B02 !	30S/26E 19B03 I	30S/26E 28J01 S	30S/26E 28J02 I	30S/26E 28J03 [	30S/26E 32N01	30S/26E 32N02 I	30S/26E 32N03 De
Twp/Rge		30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E	30S/26E
Sec/40ac		**16B02**	**16B03**	**16B04**	**18H04**	**19B01**	**19B02**	**19B03**	**28J01**	**28J02**	**28J03**	**32N01**	**32N02**	**32N03**
Depth		Mi	De	Sh	De	Sh	Mi	De	Sh	Mi	De	Sh	Mi	De
Date		21	25	1	7	9	2	8	4	5	6	4	4	4
Domain		Fan-E2	Fan-E2	Fan-E2					Fan-E2	Fan-E2	Fan-E2	Fan-E1	Fan-E1	Fan-E1
General Mineral														
Ca	(mg/l)	9.2	3.9	35.0	7.6	56.0	7.5	9.3	58.5	3.4	1.6	0.8	0.5	1.9
Mg	(mg/l)	0.0	0.3	3.9	0.1	6.2		1.3		0.1	0.1			0.2
Na	(mg/l)	26.8	33.4	23.0	33.3	37.9	40.0	35.5	44.3	50.4	44.3	62.8	52.8	63.0
K	(mg/l)	1.2	0.6			1.0								
OH	(mg/l)													
CO3	(mg/l)	10.0	16.6		5.1			18.7		16.3	22.3	28.8	42.9	23.2
HCO3	(mg/l)	56.7	45.3	117.0	67.6	216.8	75.0	66.4	149.5	50.8	44.2	53.7	37.9	63.8
SO4	(mg/l)	14.6	10.4	19.0	16.6	33.3	30.0	15.9	77.0	30.0	12.8	17.4	11.4	19.7
Cl	(mg/l)	11.0	7.8	22.0	12.7	23.4	17.5	10.5	26.3	15.5	7.0	20.4	7.7	16.0
NO3	(mg/l)	1.7	1.1	3.5	2.2	6.1	4.3	1.9			3.8			
NO2	(mg/l)													
F	(mg/l)	0.2	0.3	0.2	0.2	0.3	0.2	0.4	0.2	0.2	0.6	1.5	0.8	2.4
SiO2	(mg/l)	18.0	16.3											
pH	(pH)	8.3	8.7	8.2	8.6	7.5	8.7	8.8	7.7	9.3	9.6	9.5	9.6	9.4
EC	(uS/cm)	180.2	173.5	240.0	203.9	487.6	257.0	218.4	512.5	267.0	214.3	307.0	250.0	301.5
TDS	(mg/l)	112.7	108.9	223.0	140.0	309.0		99.0	314.7	120.5	134.2	151.0	127.0	178.0
Hd	(mg/l)	22.9	10.4	104.0	19.2	166.5	18.8	25.8	152.5	8.5	4.0	2.1	1.6	4.8
Alk	(mg/l)	52.4	57.9		60.0	168.3	60.0	78.0	140.0	53.3	77.5	90.0	110.0	95.0
Water Quality														
TDS	index	XInt	XInt	XInt	XInt	XInt	XInt	XInt	XInt	XInt	XInt	XInt	XInt	XInt
Hard	index	Soft	Soft	M.Hard	Soft	Hard	Soft	Soft	Hard	Soft	Soft	Soft	Soft	Soft
SAR	index	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Calc'd Values														
Cat	(meq/l)	1.65	1.68	3.07	1.84	4.98	2.11	2.11	4.84	2.37	2.01	2.77	2.32	2.85
An	(meq/l)	1.91	1.77	3.00	2.03	5.02	2.42	2.39	4.81	2.45	2.02	2.86	2.55	2.81
Hard	(mg/l)	23	11	103	19	165	19	28	146	9	4	2	1	5
Alk	(mg/l)	55	51	96	60	178	61	70	122	55	55	68	67	71
SAR	ratio	2.43	4.45	0.98	3.29	1.28		2.90		7.44	9.44			11.71
SUM	(mg/l)	103	97	164	111	271	136	126	280	141	114	158	135	158
ECcalc	(uS/cm)	172	150	319	195	515	247	201	528	232	169	245	175	250
TDS/EC	ratio	0.63	0.63	0.93	0.69	0.63		0.45	0.61	0.45	0.63	0.49	0.51	0.59
Analyt. Checks														
Anal.Com	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL
Cat/An	EV=1	0.85	0.95	1.02	0.90	0.99	0.86	0.88	1.01	0.97	0.99	0.97	0.91	1.02
meq/EC	EV=1	0.99	0.99	1.26	0.95	1.03	0.88	1.03	0.94	0.90	0.94	0.92	0.97	0.94
TDS/SUM	EV=1	1.10	1.13	1.36	1.26	1.14		0.79	1.12	0.86	1.17	0.95	0.94	1.13
EC/ECcalc	EV=1	1.05	1.16	0.75	1.05	0.95	1.04	1.09	0.97	1.15	1.27	1.25	1.43	1.21
CalcHCO3														
Ternary Ratios		)S/26E 16B02 Mi	S/26E 16B03 De	S/26E 16B04 Sh	S/26E 18H04 De	S/26E 19B01 Sh	S/26E 19B02 Mi	S/26E 19B03 De	S/26E 28J01 Sh	S/26E 28J02 Mi	S/26E 28J03 De	S/26E 32N01 Sh	S/26E 32N02 Mi	32N03 De
Ca	(%)	28%	11%	57%	21%	56%	18%	22%	60%	7%	4%	2%	1%	3%
Mg	(%)		1%	10%	0%	10%	0%	5%	0%	0%	0%	0%	0%	1%
Na+K	(%)	72%	87%	33%	79%	34%	82%	73%	40%	93%	96%	98%	99%	96%
SumCat	(%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
HCO3+CC	(%)	66%	73%	64%	63%	71%	51%	72%	51%	56%	73%	64%	80%	65%
SO4	(%)	16%	12%	13%	17%	14%	26%	14%	33%	26%	13%	13%	9%	15%
Cl+NO3	(%)	18%	13%	23%	19%	15%	23%	14%	15%	18%	13%	20%	9%	16%
SumAn	(%)	99.5%	99.1%	99.6%	99.5%	99.7%	99.7%	99.2%	99.8%	99.6%	98.5%	97.2%	98.3%	95.5%
Type	Cat-An	Na-HCO3	Na-HCO3	Ca/Na-HCO3	Na-HCO3	Ca/Na-HCO3	Na-mxd	Na-HCO3	Ca-HCO3/SO4	Na-HCO3/SO4	Na-HCO3	Na-HCO3	Na-HCO3	Na-HCO3
Type	A,B,D	**B2**	**B2**	**D1**	**B2**	**D1**	**B2-SO4**	**B1b**	**D21-SO4**	**A-SO4**	**A**	**A**	**A**	**A**
COCs														
As	(ug/l)	4.35	13.33	0							62	95.5		138.5
Ba	(ug/l)			0										
B	(ug/l)	0.1	0.07	0.16	0.1	0.2	0.1	0.12	0.31	0.1	0.1	0.35	0.17	0.38
Alpha	pCi/l	1.17	0.7	4							0.91	3.31		4.43
Radon	pCi/l													
DBCP	(ug/l)	0	0	0										
EDB	(ug/l)	0	0	0										

WQ Analyses.		RRB AVG	RRB AVG	RRB AVG	RRB AVG	RRB AVG	RRB AVG	RRB AVG
Well		29S/25E 25M02	29S/25E 25M01	29S/25E 27N02 :	29S/25E 27N01 I	29S/26E 31H02 :	29S/26E 31H01 I	29S/26E 35H04 :
Twp/Rge		29S/25E	29S/25E	29S/25E	29S/25E	29S/26E	29S/26E	29S/26E
Sec/40ac		**25M02**	**25M01**	**27N02**	**27N01**	**31H02**	**31H01**	**35H04**
Depth		Sh	De	Sh	De	Sh	De	Sh
Date		5	6	8	8	14	7	14
Domain		Fan-E2	Fan-E2	Fan-E2	Fan-E2	Fan-E1	Fan-E1	Fan-E2
General Mineral								
Ca	(mg/l)	35.4	1.9	53.1	2.3	6.1	2.2	27.3
Mg	(mg/l)	1.2	0.0	3.2	0.0	0.1	0.0	1.1
Na	(mg/l)	27.0	32.5	33.1	28.1	27.1	29.7	23.8
K	(mg/l)	1.2	0.0	1.0	0.0	0.1	0.0	1.5
OH	(mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	
CO3	(mg/l)	0.0	19.0	0.0	15.3	4.2	16.3	6.0
HCO3	(mg/l)	102.6	33.8	155.8	28.7	64.4	33.3	78.3
SO4	(mg/l)	33.4	8.7	25.8	8.8	8.8	8.4	19.4
Cl	(mg/l)	16.0	5.8	36.4	5.1	4.6	5.3	22.4
NO3	(mg/l)	16.5	0.6	12.9	0.7	2.0	0.5	12.2
NO2	(mg/l)	1.7	0.1	1.3	0.2	0.4	0.1	2.6
F	(mg/l)	0.1	0.4	0.1	0.4	0.1	0.5	0.2
SiO2	(mg/l)							
pH	(pH)	8.0	9.4	7.7	9.4	8.8	9.4	7.9
EC	(uS/cm)	321.4	164.0	444.4	144.6	152.2	151.6	276.4
TDS	(mg/l)	161.7	89.8	255.8	78.0	87.9	84.8	148.0
Hd	(mg/l)	93.0	4.7	145.6	5.7	15.4	5.6	69.4
Alk	(mg/l)	86.7	46.0	128.0	50.0	57.5	50.0	66.3
Water Quality								
TDS	index	XInt	XInt	XInt	XInt	XInt	XInt	XInt
Hard	index	M.Hard	Soft	Hard	Soft	Soft	Soft	M.Hard
SAR	index	Low	Low	Low	Low	Low	Low	Low
Calc'd Values								
Cat	(meq/l)	3.07	1.51	4.38	1.34	1.49	1.40	2.53
An	(meq/l)	3.10	1.57	4.33	1.34	1.55	1.45	2.73
Hard	(mg/l)	93	5	146	6	15	6	73
Alk	(mg/l)	84	43	128	36	56	41	69
SAR	ratio	1.22	6.52	1.19	5.11	3.00	5.47	1.21
SUM	(mg/l)	183	86	244	75	85	79	155
ECcalc	(uS/cm)	334	125	467	112	146	118	276
TDS/EC	ratio	0.50	0.55	0.58	0.54	0.58	0.56	0.54
Analyt. Checks								
Anal.Com	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL
Cat/An	EV=1	0.99	0.96	1.01	1.00	0.96	0.97	0.92
meq/EC	EV=1	0.96	0.94	0.98	0.92	1.00	0.94	0.95
TDS/SUM	EV=1	0.88	1.05	1.05	1.04	1.03	1.07	0.95
EC/ECcalc	EV=1	0.96	1.31	0.95	1.30	1.05	1.29	1.00
CalcHCO3								
Ternary Ratios		29S/25E 2	29S/25E 2	29S/25E 2	29S/25E 2	29S/26E 3	29S/26E 3	29S/26E 3
Ca	(%)	58%	6%	60%	9%	20%	8%	54%
Mg	(%)	3%		6%		0%	0%	4%
Na+K	(%)	39%	94%	33%	91%	79%	92%	42%
SumCat	(%)	100%	100%	100%	100%	100%	100%	100%
HCO3+CC	(%)	54%	76%	59%	73%	77%	75%	54%
SO4	(%)	22%	12%	12%	14%	12%	12%	15%
Cl+NO3	(%)	23%	11%	28%	12%	11%	11%	30%
SumAn	(%)	99.8%	98.5%	99.8%	98.6%	99.6%	98.3%	99.6%
Type	Cat-An	**Ca/Na-mxd**	**Na-HCO3**	**-HCO3/Cl**	**Na-HCO3**	**Na-HCO3**	**Na-HCO3**	**-HCO3/Cl**
Type	A,B,D	**D21**	**A**	**D1**	**A**	**B2**	**A**	**D20**
COCs								
As	(ug/l)		18		10.67	4.75	10	
Ba	(ug/l)	57.5	4.2	70.93	2.27	7.07	1.17	37.53
B	(ug/l)	0.11	0.08	0.14	0.03	7.75	0.02	0.1
Alpha	pCi/l	7.83	1.28	16.93	0.26	2.04	0.68	2.69
Radon	pCi/l							
DBCP	(ug/l)	0.05						
EDB	(ug/l)	0.088		0.054				

WQ Analyses.		RRB	ID4RAW	ID4RAW	ID4RAW	ID4RAW													
		AVG	AVG	AVG	AVG	AVG						AVG	KWB	KWB	KWB	KWB	Enns-N	Enns-S	Nikkel
Well		29S/26E 35H03 De	KWB	CAL AQ	FK	KR	SR 1	SR 2	SR 3	SR 4	SR 6	SR1-6	30s/25e 0:	30s/25e 0:	30s/25e 1	30s/25e 11C	29s/25e 3	29s/25e 3	29s/25e 35F01 ??
Twp/Rge		29S/26E	*KWB	*MCH	*MFK	*MKR	T30s/R25e	T30s/R25e	T30s/R25e	T30s/R25e	T30s/R25e	T30s/R25e	30s/25e	30s/25e	30s/25e	30s/25e	29s/25e	29s/25e	29s/25e
Sec/40ac		35H03	KWB	CAL AQ	FK	KR	02B01	02H01	02J01	02K	02L	02x	03Q01	03R01	11A01	11C01	34A01	34H01	35F01
Depth		De					99	504	251	504	504	99 - 504	SD	SD	SD	SD	??	??	??
Date		8	11	9	6	48	12/03	12/03	12/03	12/03	12/03	12/03	37727	37732	37732	36916	37272	37272	37272
Domain		Fan-E2	KWB	AQ	FK	KR													
General Mineral																			
Ca	(mg/l)	2.1	17.7	26.7	6.5	12.3	110	110	130	85	78	103	43	63	12	110	75	83	62
Mg	(mg/l)		1.8	12.6	1.9	2.5	4.4	2.7	4.8	3.2	4.3	3.9	0.78	2.6	bdt	4.7	6.1	9.8	3.6
Na	(mg/l)	37.6	31.1	63.8	5.8	10.8	52	75	83	52	49	62	49	44	33	51	41	43	33
K	(mg/l)		1.2	2.9	1.1	1.4	1.7	1.7	1.8	1.4	1.3	1.6				1.6	1.6	1.1	1.5
OH	(mg/l)	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	0.01	0.01	0.01	114						
CO3	(mg/l)	14.8	12.6	0.9	0.5	0.7	0.568	0.345	0.447	0.604	0.783	0.55	0.74	0.58	3.3				
HCO3	(mg/l)	55.5	69.6	97.1	30.2	58.1	110	66.8	109	117	191	119	114	179	64	207	140	179	121
SO4	(mg/l)	9.1	19.2	44.6	5.0	9.0	37	21	28	30	82	40	28	32	16	53	51	70	49
Cl	(mg/l)	5.1	16.8	84.1	3.9	3.8	180	260	270	140	200	210	65	65	22	98	65	70	42
NO3	(mg/l)	0.7	2.7	2.4	1.4	1.0	28				19	24					6.2	6.7	6
NO2	(mg/l)	0.2															bdt	bdt	bdt
F	(mg/l)	0.4	0.2	0.3	0.1	0.9	0.05	0.08	0.08	0.06	0.05	0.06	0.06	0.07	0.16	bdt	bdt	bdt	bdt
SiO2	(mg/l)		6.2	6.7	4.7	4.8													
pH	(pH)	9.2	8.7	8.3	7.5	7.9	7.9	7.9	7.8	7.9	7.8	7.9	8	7.7	8.9	7.4	7.5	7.5	7.8
EC	(uS/cm)	182.0	230.9	483.9	77.6	128.0	944	1070	1190	775	683	932	487	546	221	730	631	742	510
TDS	(mg/l)	102.0	142.8	334.0	41.5	87.7	660	710	800	510	410	618	285	345	140	530	390	448	312
Hd	(mg/l)	5.1	51.8	115.3	22.0	39.3	293	286	344	225	212	272	111	168	30	294	216	236	174
Alk	(mg/l)	70.0	67.8	79.3	22.8	48.0	90.1	54.9	89.6	95.9	157	98	94	147	54	170	140	179	121
Water Quality																			
TDS	index	**Xlnt**	**Xlnt**	**Xlnt**	**Xlnt**	**Xlnt**	**Good**	**Fair-Poor**	**Fair-Poor**	**Good**	**Good**	**Good**	**Xlnt**	**Xlnt**	**Xlnt**	**Good**	**Xlnt**	**Good**	**Xlnt**
Hard	index	**Soft**	**Soft**	**M.Hard**	**Soft**	**Soft**	**V.Hard**	**V.Hard**	**V.Hard**	**V.Hard**	**V.Hard**	**V.Hard**	**M.Hard**	**Hard**	**Soft**	**V.Hard**	**V.Hard**	**V.Hard**	**Hard**
SAR	index	**Low**	**Low**	**Low**	**Low**	**Low**	**Mod**	**Mod**	**Mod**	**Low**	**Mod**	**Mod**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**	**Low**
Calc'd Values																			
Cat	(meq/l)	1.74	2.42	5.22	0.76	1.32	8.16	9.02	10.54	6.80	6.41	8.18	4.34	5.27	2.03	8.13	6.07	6.85	4.86
An	(meq/l)	1.77	2.49	4.97	0.76	1.33	8.12	8.88	10.00	6.51	10.81	9.10	4.31	5.46	2.12	7.26	5.29	6.47	4.28
Hard	(mg/l)	5	52	119	24	41	293	286	345	226	213	272	111	168	30	294	212	248	170
Alk	(mg/l)	58	67	80	25	48	91	55	90	96	157	98	764	147	55	170	115	147	99
SAR	ratio		1.88	2.55	0.52	0.74	1.32	1.93	1.95	1.51	1.46	1.64	2.03	1.48		1.29	1.22	1.19	1.10
SUM	(mg/l)	97	138	286	41	71	468	504	572	370	529	502	357	295	118	420	315	372	257
ECcalc	(uS/cm)	151	240	580	78	132	970	1096	1235	776	1039	1039	483	584	219	855	633	740	507
TDS/EC	ratio	0.56	0.62	0.69	0.53	0.69	0.70	0.66	0.67	0.66	0.60	0.66	0.59	0.63	0.63	0.73	0.62	0.60	0.61
Analyt. Checks																			
Anal.Com	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL-min	FULL-min	FULL-min	FULL	FULL	FULL-min	FULL-min	FULL-min	FULL-min	FULL-min	FULL-min	FULL-min
Cat/An	EV=1	0.98	0.97	1.05	1.00	0.99	1.00	1.02	1.05	1.04	0.49	0.89	1.01	0.97	0.96	1.11	1.14	1.06	1.13
meq/EC	EV=1	0.96	1.06	1.05	0.98	1.04	0.86	0.84	0.86	0.86	1.26	0.93	0.89	0.98	0.94	1.05	0.90	0.90	0.90
TDS/SUM	EV=1	1.05	1.04	1.17	1.01	1.24	1.41	1.41	1.40	1.38	0.78	1.23	0.80	1.17	1.19	1.26	1.24	1.21	1.22
EC/ECcalc	EV=1	1.21	0.96	0.83	1.00	0.97	0.97	0.98	0.96	1.00	0.66	0.90	1.01	0.94	1.01	0.85	1.00	1.00	1.01
CalcHCO3																			
Ternary Ratios		35H03 De	KWB	CAL AQ	FK	KR	SR 1	SR 2	SR 3	SR 4	SR 6	SR1-6	30s/25e 03Q	30s/25e 03R	30s/25e 11A	30s/25e 11C01 :	29s/25e 34A	29s/25e 34H	29s/25e 35F01 ??
Ca	(%)	6%	37%	26%	43%	46%	67%	61%	62%	62%	61%	63%	49%	60%	29%	67%	62%	60%	64%
Mg	(%)	0%	6%	20%	21%	15%	4%	2%	4%	4%	6%	4%	1%	4%	0%	5%	8%	12%	6%
Na+K	(%)	94%	57%	55%	37%	38%	28%	37%	35%	34%	34%	34%	49%	36%	71%	28%	30%	28%	30%
SumCat	(%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
HCO3+CC	(%)	79%	63%	33%	68%	73%	22%	12%	18%	30%	29%	22%	44%	54%	55%	47%	43%	45%	46%
SO4	(%)	11%	16%	19%	14%	14%	9%	5%	6%	10%	16%	9%	14%	12%	16%	15%	20%	23%	24%
Cl+NO3	(%)	9%	21%	48%	18%	9%	68%	83%	76%	61%	55%	69%	43%	34%	29%	38%	37%	32%	30%
SumAn	(%)	98.9%	99.5%	99.7%	99.2%	96.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.6%	100.0%	100.0%	100.0%	100.0%
Type	Cat-An	Na-HCO3	Ca/Na-HCO3	Ca/Na-HCO3/Cl	mxd-HCO3	Ca/Na-HCO3	Ca-Cl	Ca-Cl	Ca-Cl	Ca-Cl	Ca-HCO3/Cl	Ca-Cl	Ca/Na-HCO3/Cl	Ca/Na-HCO3/Cl	Na-HCO3/Cl	Ca-HCO3/Cl	Ca-mxd	Ca-mxd	Ca-mxd
Type	A,B,D	**A**	**B1b**	**B1a**	**B1a**	**B1a**	**D21**	**D21**	**D21**	**D21**	**D21**	**D21**	**D20**	**D21**	**B2**	**D21**	**D1**	**D1**	**D1**
COCs																			
As	(ug/l)	39	9.85	6.97	2.9	5.17	0	1.4	0	0	0	0.28	1.2	3.1	6.6	1.8	0.8	0.8	0.8
Ba	(ug/l)	1.57					170	170	200	130	100	154	66	93	16	170	110	88	86
B	(ug/l)	0.09															200	300	200
Alpha	pCi/l	0.92	3.67	1.89	2.87	3.18	7.8	9.2	7.6	8	22	10.92				40	20.5	30.8	21.4
Radon	pCi/l																679	664	667
DBCP	(ug/l)															0	0.05	0.36	0.11
EDB	(ug/l)															0	0	0	0.02

Exhibit 3.

Strand Ranch ASR Project
Salt Balance Analysis.

Exhibit 3. IRWD Strand Ranch Salt Balance.

Table 3.1 Hypothetical Recharge-TDS Blends.

Hypothetical Instantaneous Recharge TDS for Various Recharge Blends.

Source:	SWP1	KR	FK	Blend
Source TDS:	334	88	41	(mg/l)
In-Blend 11	100%	0%	0%	334
In-Blend 12	60%	30%	10%	231
In-Blend 13	30%	60%	10%	157
In-Blend 14	20%	70%	10%	133
In-Blend 15	10%	80%	10%	108
In-Blend 16	0%	100%	0%	88

Note: SWP1 at 334 mg/l is the long-term average in-aqueduct TDS.
Note: Blend is positive to represent salt added to aquifer.

Hypothetical Instantaneous Recharge TDS for Various Recharge Blends.

Source:	SWP2	KR	FK	Blend
Source TDS:	227	88	41	(mg/l)
In-Blend 21	100%	0%	0%	227
In-Blend 22	60%	30%	10%	167
In-Blend 23	30%	60%	10%	125
In-Blend 24	20%	70%	10%	**111**
In-Blend 25	10%	80%	10%	97
In-Blend 26	0%	100%	0%	88

Note: SWP2 at 227 mg/l is the 5-year average wet-cycle SWP TDS delivered to the Kern Fan.
Note: Blend is positive to represent salt added to aquifer.

Table 3.2 Hypothetical Recovery-TDS Blends.

Hypothetical Instantaneous Recovery TDS for Various Recovery Blends.

Source:	Shal Aq	Deep Aq	Blend
Source TDS:	559	119	(mg/l)
Out-Blend 31	100%	0%	(559)
Out-Blend 32	80%	20%	(471)
Out-Blend 33	60%	40%	(383)
Out-Blend 33	40%	60%	(295)
Out-Blend 35	30%	70%	(251)
Out-Blend 36	25%	75%	**(229)**
Out-Blend 37	10%	90%	(163)
Out-Blend 38	0%	100%	(119)

Note: Shallow Aq at 559 mg/l is the average plume-impacted TDS.
Note: Blend is negative to represent salt removed from aquifer.

Hypothetical Instantaneous Recovery TDS for Various Recovery Blends.

Source:	Shal Aq	Deep Aq	Blend
Source TDS:	237	119	(mg/l)
Out-Blend 41	100%	0%	(237)
Out-Blend 42	80%	20%	(213)
Out-Blend 43	60%	40%	(190)
Out-Blend 44	40%	60%	(166)
Out-Blend 45	30%	70%	(154)
Out-Blend 46	20%	80%	(143)
Out-Blend 47	10%	90%	(131)
Out-Blend 48	0%	100%	(119)

Note: Shallow Aq at 237mg/l is the average unimpacted TDS.
Note: Blend is negative to represent salt removed from aquifer.

Exhibit 3. IRWD Strand Ranch Salt Balance.

Table 3.3 Hypothetical Project Salt Balance Matrix.

	Recharge	SWP1	227	100%	60%	30%	**20%**	10%	0%
	Recharge	KR	88	0%	30%	60%	**70%**	80%	100%
	Recharge	FK	41	0%	10%	10%	**10%**	10%	0%
	Recharge	Blend	(mg/l)	227	167	125	**111**	97	88

	Shal Aq	Deep Aq	Blend						
Recovery	559	119	(mg/l)						
Out-Blend 31	100%	0%	(559)	(332)	(392)	(434)	(448)	(462)	(471)
Out-Blend 32	80%	20%	(471)	(244)	(304)	(346)	(360)	(374)	(383)
Out-Blend 33	60%	40%	(383)	(156)	(216)	(258)	(272)	(286)	(295)
Out-Blend 33	40%	60%	(295)	**(68)**	(128)	(170)	(184)	(198)	(207)
Out-Blend 35	30%	70%	(251)	**(24)**	(84)	(126)	(140)	(154)	(163)
Out-Blend 36	**25%**	**75%**	**(229)**	**(2)**	**(62)**	(104)	**(118)**	(132)	(141)
Out-Blend 37	10%	90%	(163)	**64**	**4**	(38)	(52)	(66)	(75)
Out-Blend 38	0%	100%	(119)	**108**	**48**	**6**	**(8)**	(22)	(31)

Note: Shallow Aq at 559mg/l is the average plume-impacted TDS.

	Shal Aq	Deep Aq	Blend						
Recovery	237	119	(mg/l)						
Out-Blend 41	100%	0%	(237)	**(10)**	(70)	(112)	(126)	(140)	(149)
Out-Blend 42	80%	20%	(213)	**14**	**(47)**	(88)	(102)	(116)	(125)
Out-Blend 43	60%	40%	(190)	**37**	**(23)**	(65)	(79)	(93)	(102)
Out-Blend 44	40%	60%	(166)	**61**	**1**	(41)	(55)	(69)	(78)
Out-Blend 45	30%	70%	(154)	**73**	**12**	**(29)**	(43)	(57)	(66)
Out-Blend 46	20%	80%	(143)	**84**	**24**	**(18)**	(32)	(45)	(55)
Out-Blend 47	10%	90%	(131)	**96**	**36**	**(6)**	**(20)**	(34)	(43)
Out-Blend 48	0%	100%	(119)	**108**	**48**	**6**	**(8)**	(22)	(31)

Note: Shallow Aq at 237mg/l is the average unimpacted TDS.

ATTACHMENT 16D

Sierra Scientific Services, 2007b. An Evaluation of Well Placements and Potential Impacts of the proposed Strand Ranch Well Field, Kern County, California, in: Rosedale - Rio Bravo Water Storage District Strand Ranch Integrated Banking Project Environmental Impact Report, January 2008, prepared by ESA, LA., CA. December 20.

Sierra Scientific Services

An Evaluation of Well Placements and Potential Impacts of the Proposed Strand Ranch Well Field, Kern County, California.

20 December, 2007

prepared for:

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Table of Contents

<u>List of Figures.</u>

Note: The Exhibit 5 Catalog is presented in a large, separately-bound volume which is available at the main office of the Irvine Ranch Water District in Irvine, Ca, or the main office of the Rosedale - Rio Bravo Water Storage District in Bakersfield, Ca. A table of contents of the Exhibit 5 Catalog is presented at the end of this Report in place of the complete Catalog.

Sierra Scientific Services

An Evaluation of Well Placements and Potential Impacts
of the Proposed Strand Ranch Well Field, Kern County, California.

1. Summary of Findings

The purpose of this Report is to present the findings of a water-level-drawdown impact evaluation for a proposed well field which is a part of the Strand Ranch aquifer storage and recovery (ASR) project. The study includes the computer simulation of predicted water level drawdowns in the local aquifer due to project pumping and the evaluation of the predicted impacts within the area of influence. The study also includes the computer simulation and evaluation of predicted water table mounding due to project recharge as part of a total-project-impact analysis. The Strand Ranch project area covers nearly a full section of land, a square area of approximately 611 acres. The study area includes the project site plus the eight (8) contiguous adjoining sections, i.e., a square study area covering a total of nine (9) square miles. The Strand Ranch project site is surrounded by other existing ASR projects which overlie the prolific fresh water aquifer referred to locally as the Kern Fan in Kern County, California.

We calculated and summarized the drawdowns and mounding in several ways by mapping the actual drawdown as a function of location and distance from the operating wells, by calculating the average drawdown within the well field and within each of the eight adjacent sections, and by calculating the specific drawdowns at selected locations of interest in the surrounding sections.

<u>Well Field and Aquifer Model.</u>

For this study, we calculated the water level drawdowns for three hypothetical well-field operating scenarios of 9-, 7-, or 5- wells. Each scenario is designed to recover 17,500 af of ground water from the underlying aquifer in a year, with all wells pumped at a nominal 5 cfs. The criteria which we used for well placements serve to: 1. minimize well interference, 2. distribute the drawdown impacts as uniformly as possible across the largest possible area, and 3. minimize the drawdown impacts to non-project wells in the surrounding area. Based on these criteria, we used a uniform square grid of 9 possible well locations with a well spacing of

1/3-mile (1,760 ft) and a property line setback of 1/6-mile (880 ft). These dimensions are consistent with existing well-field practices in other ASR projects located in the local area.

The Kern Fan aquifer behaves and is modeled as a 3-layer, semi-confined, i.e. "leaky", aquifer in which the shallow zone is unconfined, the deep zone is semi-confined, and the intermediate zone acts as a leaky aquitard between the other two. The base case aquifer parameters were the same for each case, i.e., a 300-ft thick, semi-confined aquifer with T = 17,100 ft^2/d, S = 0.02, and porosity = 30%; an overlying aquitard with L' = 0.000475 d^{-1} which is gives a Hantush leakage factor of B = 6,000 ft; and an overlying unconfined aquifer with a specific yield of Sy = 21%.

The unimpacted, natural groundwater gradient was assumed to be zero unless otherwise specified. For capture zone and particle trajectory calculation we used a groundwater gradient of -25 ft/mi to the northwest (-0.0048 at a left aximuth of 135 degrees from east) and we assumed a corresponding reference groundwater elevation at 100 ft below GL at the southeast corner of the project area (i.e., the SE cor Sec 02, T30s, R25e). We calibrated the results by varying selected parameters to provide a sensitivity analysis to estimate the effects of parameter uncertainty. The modeling parameters have been summarized in Table 1 and described in detail in the text and Exhibit 2.

Calculated Drawdowns.

We calculated the leaky- aquifer, transient and steady-state (maximum) water level drawdowns, capture zones, and particle trajectories using the commercially-available analytic computer model "WinFlow" by Environmental Solutions, Inc. We present a discussion of computer models in Exhibit 1, aquifer parameters and parameter values in Table 1 and Exhibit 2, limitations of the analysis in Exhibit 3, and a catalog of all model outputs in Exhibit 5. We present the primary results of interest below.

Nine- well scenario: q = 90 af/d, pumping t = 194 d, V = 17,500 af/yr.

The hypothetical steady-state drawdowns created by the Strand Ranch, *9-well, 194-day*, pumping scenario are presented on the map in Figure 5 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 43 ft and the average drawdowns in the surrounding 8 sections are in the range of 12 - 20 ft. The drawdowns along the perimeter of the study area are in the range of 5 - 9 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter. The drawdowns for the 9-well case superimposed on a northwesterly groundwater gradient are shown on the map in Figure 9.

Under these assumptions, the area will achieve steady-state within about 100 days after pumping begins and the water levels will begin to recover after 194 days when pumping ceases. As long as the leaky-aquifer assumptions continue to be met, the water levels in the study area will recover to pre-pumping levels in another 100 days or less, in the absence of other influences.

<u>Seven - well scenario:</u> q = 70 af/d, pumping t = 250-day, V = 17,500 af/yr.

The hypothetical steady-state drawdowns created by the Strand Ranch, *7-well, 250-day*, pumping scenario are presented on the map in Figure 6 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 34 ft and the average drawdowns in the surrounding 8 sections are in the range of 9 - 14 ft. The drawdowns along the perimeter of the study area are in the range of 3 - 8 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter.

Under these well field assumptions, the area will achieve steady-state within about 100 days after pumping begins and the water levels will begin to recover after 350 days when pumping ceases. As long as the leaky-aquifer assumptions continue to be met, the water levels in the study area will recover to pre-pumping levels in another 100 days or less, in the absence of other influences.

The hypothetical drawdowns created by the Strand Ranch *7-well, 250-day scenario* are approximately 78% of the hypothetical drawdowns for the 9- well scenario but the duration of impact lasts about 56 days longer because the wells must operate longer to recover the same total volume of water (17,500 af/yr) at the lower recovery rate (70af/d vs. 90 af/d).

<u>Five - well scenario:</u> q = 50 af/d, pumping t = 350-day, V = 17,500 af/yr.

The hypothetical steady-state drawdowns created by the Strand Ranch, *5-well, 350-day*, pumping scenario (wells 1, 3, 5, 7, 9) are presented on the map in Figure 7 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 24 ft and the average drawdowns in the surrounding 8 sections are in the range of 7 - 11 ft. The drawdowns along the perimeter of the study area are in the range of 2 - 6 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter.

Under these well field assumptions, the area will achieve steady-state within about 100 days after pumping begins and the water levels will begin to recover after 350 days when pumping ceases. As long as the leaky-aquifer assumptions continue to be met, the water levels in the study area will recover to pre-pumping levels in another 100 days or less, in the absence of other influences.

The hypothetical drawdowns created by the Strand Ranch *5-well, 350-day scenario* are approximately 56% of the hypothetical drawdowns for the 9- well scenario but the duration of impact lasts about 156 days longer because the wells must operate longer to re-cover the same total volume of water (17,500 af/yr) at the lower recovery rate (50 vs 90 af/d).

We have also calculated the hypothetical, steady-state drawdowns for an alternate Strand Ranch, *5-well, 350-day*, pumping scenario the same as above except using wells at locations 1,2,3,4,5 instead of 1,3,5,7,9. The drawdowns for this case are presented on the map in Figure 8 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 24 ft and the average drawdowns in the surrounding 8 sections are in the range of 7 - 11 ft. The drawdowns along the perimeter of the study area are in the range of 2 - 6 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter.

The project has considerable flexibility in delivering less than the full recovery rate of 45 cfs and/or the annual recovery volume of 17,500 af. The project may meet reduced delivery rates and volumes by choosing to pump for less time, and/or at lower pumping rates, and/or using fewer wells. Each of these possible alternatives provides reduced drawdowns, somewhat smaller areal distributions, and faster aquifer- recovery times.

<u>Capture Zone.</u>

For 300 days of pumping, the hypothetical capture perimeter surrounding the entire well field extends only a few hundred ft outward from the individual wells and remains entirely within the property boundary of the Strand Ranch. For a hypothetical 1000 days (approx. 3 yr) of continuous pumping, the hypothetical capture perimeter extends about 1,800 ft from the individual wells. For a hypothetical 3650 days (10 yr) of continuous pumping, the capture zone would extend about 2,300 ft down-gradient to the northwest and would extend about 4,500 ft up-gradient to the southeast under conditions of long-term groundwater gradient of 25 ft/mi to the northwest. Pumping by non-project wells in the surrounding areas will change the shape and extent of this capture zone, as shown in the various model runs.

A capture zone analysis requires that we model the aquifer behavior as realistically as possible, since true particle trajectories will respond to all influences on the potentiometric pressure field and not just those generated by the Strand Ranch wells. Therefore, the most realistic scenario assumes that the Strand Ranch wells will most likely be pumping in a dry year when all of the neighboring wells are pumping as well. The combined pumping effects of these wells superimposed on the natural groundwater gradient will determine the locations of capture zone and particle trajectories with time.

The water level elevation map in Figure 10 shows the steady-state impacts of the nine Strand Ranch wells and eleven Kern Water Bank wells superimposed on the local groundwater gradient. The five wells located at the center and corners of the Strand Ranch well field (wells 1, 3, 5, 7, 9) have 1,000-day reverse particle trajectories attached to them which define the shape and areal extents of the "3-year" capture zones for continuous pumping at these locations. For reference purposes, the section corners have been labeled on the map. We have mapped the locations of the capture zone perimeter for pumping times of 300-, 1000-, 1825-, and 3650-days superimposed on 10-year continuous particle trajectories in Figure 11.

We have also mapped (Figure 12) the 10-year forward particle trajectories of a hypothetical line source located in the southwest quarter of section 12, T30s, R25e under conditions of continuous pumping of both the Strand Ranch and Kern Water Bank wells. Any groundwater contamination which comes from a source located on or near this line will follow the same trajectories. A slug or plume of contamination will eventually be captured by wells located on the Kern Water Bank and/or Strand Ranch depending on the particular location of the source and its downgradient trajectories.

Based on available existing water quality data, the shallow aquifer under the project site (compared to the nearby, unimpacted shallow aquifer) has elevated concentrations of total dissolved solids and several constituents of concern due to the inflow of a brine plume from an unspecified, up-gradient source or sources in or near the southwest quarter of Section 12, T30s/25e. This brine plume represents a source of water quality degradation that falls within the predicted capture zone of the well field under conditions of natural groundwater gradient and under conditions of pumping. There is no recognized way of positioning the proposed Strand Ranch wells to avoid the water quality impacts of this brine plume. The quantitative analysis of the potential impacts of this brine plume on the Strand Ranch well field is outside the scope of this study.

Calculated Recharge Mounding.

We calculated the unconfined- aquifer, transient, water table drawdowns using the commercially-available analytic computer model "WinFlow" by Environmental Solutions, Inc. We calculated the transient water level rises due to mounding assuming that the project recharges 17,500 af in a single episode using 450 acres of ponds. For the range of expected infiltration rates of 0.20, 0.25, and 0.30 ft/d, a recharge episode will last 129 - 194 days. We present the primary results of interest below.

For the three recharge scenarios, the calculated maximum mound heights under the project range from 32 - 40 ft and the maximum water level rises in the surrounding 8 sections ranges from 6 - 14 ft.

As discussed in the Report, the positive impact of recharge mounding fully compensates for recovery drawdown in all except the "least-favorable" case of a recharge/recovery cycle at minimum recharge rates and maximum recovery rates. In this one case, the maximum uncompensated net temporary drawdown in the surrounding eight sections is in the range of -6 to -7 ft. All other, more-favorable, scenarios result smaller net water level declines and/or net water level rises at all locations surrounding the project site for comparable time periods.

Project Impact.

The proposed Strand Ranch ASR project operation is designed to always maintain a positive project balance, i.e., a volume of water must always be stored in the aquifer prior to removing a like volume from the aquifer. ASR projects usually operate by putting water into the ground in a wet year and then recovering it as needed in some future dry year, so there is little likelihood of recharge and recovery happening simultaneously. As long as the project puts as much water in the ground as it takes out, the net basin impact from water level drawdown will be pre-compensated for by the water-level rise due to recharge mounding, so there will be no net long term effect on the basin no matter how far apart recharge and recovery are separated in time.

In the case of the proposed Strand Ranch project, both recharge and recovery facilities will be co-located on the project site such that the approximately equal and opposite impacts of both recharge and recovery will be superimposed on the same area and same aquifer zones.

The Project operators have voluntarily established operating limits which preclude the occurrence of an unacceptable, unbalanced recharge/recovery cycle. The project is voluntarily designed so that 1. the Strand Ranch project will not have more than 50,000 af of water in basin storage, and 2. the project will not recharge or recover more than a maximum of 17,500 af of groundwater per year during normal operations. The computer models of both recharge and recovery have demonstrated that by capping the maximum inflow/outflow at 17,500 af/yr, that 1. the beneficial impacts of recharge are approximately equal to the potentially detrimental impacts of recovery, and 2. by spreading the recovery of the maximum allowable volume of water in storage over a 3-year period the individual and combined net impacts of the total operation avoids and prevents unacceptable impacts to the aquifer and the basin.

Conclusions and Recommendations.

We conclude that the Strand Ranch well-field scenarios minimize the respective predicted drawdown impacts by putting the maximum available distances between wells over the widest available area by using well spacings and property line setbacks which are no less than those being used successfully in other ASR projects in the Kern Fan project area. We conclude that the project design results in approximately balanced recharge/recovery cycles so that the transient water level rises due to recharge mounding episodes are approximately equal and opposite to the transient water level declines due to recovery drawdown episodes.

We conclude that for this project to operate as predicted and desired, the total recharge to this area must start out and remain in long term balance with total recovery in this area, as the project is designed to do.

We conclude that under existing and foreseeable circumstances, the Strand Ranch, 9-well, 45 cfs, maximum-recovery scenario is an acceptable short-term and long-term operating scenario which does not create a net impact on the basin if recharge precedes recovery, as proposed.   All other Strand Ranch scenarios using fewer wells, and/or lower total recovery rates, and/or lower total recovery volumes are also acceptable by the same criteria.

We conclude that the brine plume which is flowing under the Strand Ranch from an unspecified upgradient source or sources is a cause for concern which cannot be mitigated through well placements within the project area. However, the plume is a residual effect from oilfield-brine discharge sources which are no longer active and both periodic recharge and periodic shallow groundwater extraction by the Kern Water Bank on adjacent lands is remediating the plume by diluting and permanently removing groundwater with elevated TDS content from within the plume perimeter. We note that the Kern Water Bank's operation of these wells is voluntary; the KWB was not responsible for the brine discharge nor are they being held responsible for its cleanup. Future Strand Ranch project operations will have the same beneficial impacts on the brine plume.

We recommend that the project test each new water well individually with a testing program which will provide for aquifer parameter measurement as well as pump parameter measurement. Such data will be useful and essential for a future aquifer model calibration. We recommend that the project partners consider contracting with SSS to help design, observe, and interpret the well tests.

We recommend that the project impacts be carefully monitored from startup so that we can calibrate and verify the results of this work program and then make refinements in our model of the aquifer behavior for future use.

We recommend installing monitoring wells to satisfy four different purposes, including well testing, model calibration and verification, long- term operational water level monitoring, and contaminant- detection monitoring. We recommend as many monitoring well installations as are necessary to cover all of these functions at all important locations and in all necessary aquifer zones. It may be necessary to install some monitoring wells which are useful for only one of these functions, since a single well placement may not be effective for all purposes. We recommend that the project consider designing the completion depth interval of each monitoring well depending on the intended purpose for the well. We also recommend that the project be willing to use multiple monitoring wells which are completed in different depth intervals where potentially effective or necessary.

We recommend that the project consider using the drawdown maps from this study to locate the placement of monitoring wells for water level monitoring especially in and around the recharge/recovery zones. We recommend that the project consider using the particle trajectory and capture zone maps from this study to locate the placement of monitoring wells for contaminant detection monitoring, especially to the east of the well field. We again recommend that the project consider restricting the completion depth interval of each monitoring well depending on the intended purpose for the well.

Crewdson, Robert, A., 20 December, 2007, An Evaluation of Well Placements and Potential Impacts of the proposed Strand Ranch Well Field, Kern County, California., Sierra Scientific Services, Bakersfield, CA.

2. Introduction

Purpose.

The main purpose of this Report is to describe the water level drawdown impacts which are expected to occur as a result of the operation of the Strand Ranch Aquifer Storage and Recovery Project. The potential drawdown impacts of interest are the impacts created by pumping the proposed Strand Ranch recovery wells. The locations of interest include the project site and the eight sections adjacent to the project and more specifically any existing water wells in those sections. We have evaluated and summarized these drawdowns in several ways by mapping the actual drawdown as a function of location and distance from the operating wells, by calculating the average drawdown within the well field and within each of the eight adjacent sections, and by calculating the specific drawdowns at selected locations in the surrounding sections.

The findings of this study may be used to 1. evaluate the alternatives for numbers and locations of water recovery wells in the future Strand Ranch well field, 2. evaluate the numbers and locations of monitoring wells which are desired or required for purposes of water level and water quality monitoring, and 3. evaluate the potential interactions and impacts between the Strand Ranch project and adjacent entities.

Project Scope - Aquifer Storage and Recovery.

Aquifer storage and recovery (ASR) is the generic term which describes the practice of deliberately putting surface water into a groundwater aquifer through infiltration basins with the intention of recovering a like volume of water from the aquifer at a later date. Such a practice presents a great opportunity to increase the local and statewide capacity to store water. ASR projects help regulate the water supply and demand over time by storing excess water when it is available in wet years for future recovery when water is needed in dry years.

In Kern County, California, there are 3 main components to every ASR facility: infiltration basins, water wells, and a conveyance system. The infiltration basins, also referred to as recharge basins[1], are ponds which are constructed to allow ponded water to infiltrate into the groundwater basin. The water wells, also referred to as recovery wells[2], are conventional high-flow water wells used to pump water out of the underlying aquifer. The project conveyance system consists of one or more canals, ditches, or pipelines used to deliver water between the ASR facility and the local or regional water conveyance infrastructure.

The Kern County water community generally refers to ASR projects as "banking" projects. According the Kern County Water Agency, "These banking programs are essential to Kern County's water management and future growth"[3] and this is broadly true of the entire State of California water infrastructure. As used in Kern County, the term "banking" is loosely used to describe the act of physically putting water into the underlying aquifer and crediting the owner with the right to remove a like volume of water from the aquifer at a later date. This credit allows the owner to show such a volume of banked water as part of its current water

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[1]We prefer the terms "infiltration basin" or "percolation basin" rather than "recharge basin" since the former terms are neutral and descriptive while the latter term needlessly implies, contrary to intent, that we are putting water back into the aquifer ***after*** it has been taken out, as has historically been the case in some conjunctive-use projects in Kern County, Ca. The primary distinction, in our opinion, is that the concept of "recharge" might be appropriate in a conjunctive-use context where water borrowed from the basin must subsequently be replaced, i.e., the aquifer must be replenished or recharged as a means of overdraft correction whereas "groundwater banking", by definition, requires storing water prior to removing it. Nevertheless, we recognize the common local use of "recharge" to mean any addition of water to an aquifer.

[2]We prefer the term "water well" rather than "recovery well" since the former term is neutral and descriptive while the latter term needlessly suggests, contrary to intent, that such a "recovery" well may be different than other water wells and perhaps restricted to the extraction of some particular water or water for some particular use.

[3]Lloyd Fryer, 2005, Kern County Groundwater Banking Projects, KCWA brochure.

supply. If such water has been "banked" on behalf of another party, then it is considered to be real water held in trust for that party who has an absolute right of recovery.

<u>Local Operating Rules.</u> The local water community in Kern County has established certain conventions regarding the design, operation, and monitoring of aquifer storage and recovery projects, i.e., "water banking" operations. The rules are the guiding principles which are contained in the Memorandums of Understanding (MOUs) between Kern County project operators and adjacent entities. The rules provide for creating intended project benefits while eliminating or minimizing potentially significant adverse impacts. The MOUs elaborate on these principles which are paraphrased below (the numbers below are for reference for our convenience only):

1. A project should not degrade the basin and should enhance it when possible;
2. A project should minimize the impacts on the environment and adjacent entities;
3. A project should provide mitigation for unavoidable adverse impacts;
4. A project mitigation can give consideration to the compensating aspects of recharge and recovery operations;
5. A project site should be monitored for water levels and water quality;
6. A project should take water out where it puts water in;
7. A project should account for losses to the basin.

Project Background.

<u>Location.</u> The Irvine Ranch Water District (IRWD) is currently in the process of developing a ±600 acre parcel in Kern County, California, as an Aquifer Storage and Recovery (ASR) Project. The parcel of interest is located in Section 2, Township 30s, Range 25e, MDBM, located at the southwest corner of Stockdale Highway and Enos Lane, several miles west of the City of Bakersfield. The ±600-acre Strand Ranch ASR project will be the latest among several existing ASR projects in the area which currently cover approximately 20,000+ acres and include more than 120 wells. The project site is surrounded in all four compass directions by existing ASR facilities belonging to the Kern Water Bank Authority or to the Rosedale - Rio Bravo Water Storage District. The parcel has been known historically as the Strand Ranch, so-named for the sand fairways crossing the property, so the project is informally referred to as the Strand Ranch ASR project.

Facilities. For this study we have assumed that the proposed project is designed to include approximately 450 acres of recharge ponds at full build-out which are expected to be able to recharge as much as 150 af per day. The estimated maximum site recharge capacity is 57,500 af per year, assuming a 365-day, wet-year, water supply and an average infiltration rate of 0.35 ft/d. The project site currently has approximately 117 ac of existing recharge ponds which were operated in 2006 on a pilot-study basis.

The Strand Ranch project plans to deliver water to and from the project site through the Cross Valley Canal which runs through the Strand Ranch property. The project owner is currently cooperating with the Kern County Water Agency for the installation of a CVC turnout to service the project site. During the 2006 pilot phase, the project received water deliveries through a cooperative agreement with the Kern Water Bank.

The site currently contains five or more irrigation wells which were installed by the previous owners of the Strand Ranch and are capable of recovering groundwater at this time. The project owner proposes to recondition or replace existing wells, and/or install recovery wells, as necessary or as beneficial, to meet their proposed operating parameters. To date, no recovery wells or pipelines have been installed on the property but the operational objective of the Strand Ranch ASR well field is to recover water which has been previously stored in the underlying groundwater aquifer. The project design objective is to store a sufficient volume of water in the aquifer over the long term to be able to recover a maximum 17,500 af/yr with a total in-ground storage limit of 50,000 af.

Aquifer. The site is flat at an elevation of about 320 ft above msl. The site overlies the prolific aquifers which comprise the so-called Kern Fan which, geologically speaking, is a thick pile of interbedded, fine- to coarse- grained, fluvial/alluvial sediments. The shallow aquifer is recharged by natural and manmade percolation of (mostly) Kern River water. Recharge occurs in the river bottom and nearby recharge ponds which form a 15-mile long, linear recharge axis trending southwest across the southern San Joaquin Valley starting in the city limits of Bakersfield, Ca. When we refer to the Kern Fan in this Report we will generally be referring to the ±15- mile wide elongate area which straddles the recharge axis and includes the river channel, ASR project sites, and related surface infrastructures.

The Strand Ranch ASR Project is near, but northwest of, the recharge axis of the Kern Fan recharge mound. The depths to groundwater under the Project site fluctuate significantly due to the rise and fall of the Kern Fan recharge mound under the influence of the regional climatic wet/dry cycle. During consecutive dry years the groundwater may be 150 - 170 ft deep such as in 1990 - 1994, whereas during consecutive wet years the groundwater under the site may be 20 - 70 ft deep such as in 1995 - 1998. The unimpacted, natural groundwater gradient under the Project site in dry years trends northwesterly at -10 to -15 ft/mi WNW and in wet years trends northwesterly at -20 to -30 ft/mi NW.

Surface Water Supply. The three potential sources of surface water which might be brought to the property include high-flow water from the Kern River, water from the Federal Central Valley Project (CVP) via the Friant- Kern Canal, and/or water from the California State Water Project (SWP) via the California Aqueduct, etc. The source of both the Kern River water and CVP water is runoff from the winter snowpack from the highlands of the southern Sierra Nevada mountain range. The primary water source for the SWP is runoff from the greater volcanic highlands surrounding Mt Shasta in northern California. The waters from all three sources are very good quality when they reach their intended points of use within Kern County.

Work Program.

The components of the work program for this study included designing realistic well-field alternatives based on the well-field spacing and operating practices within existing local ASR projects, determining the aquifer parameters for the study area, calculating the water level drawdowns and particle flow-trajectories for base case and non-base case scenarios, and evaluating the project water level impacts, including consideration of the beneficial impacts of project recharge operations. This Report presents the findings of the work program.

Personnel.

Dr. Robert A. Crewdson is a Bakersfield, California consultant doing business as Sierra Scientific Services (SSS). SSS specializes in quantitative ground water hydrology, applied potential theory and time series analysis, quantitative ground water flow analysis, water quality geochemistry, well testing and monitoring, contaminant transport modeling, and aquifer properties testing. Dr. Crewdson is a research associate and adjunct professor at California

State University Bakersfield where he has taught hydrology, contaminant transport, geochemistry and geophysics in upper division and graduate level courses.

SSS would like to thank Kellie Welch of the Irvine Ranch Water District and Jennifer Jacobus of ESA, Inc. for their help preparing several maps and figures in this Report.

Methodology.

SSS obtained and reviewed well field data, historical recharge, pumping volume and recovery rate data, and water level hydrographs for the ASR projects located on the Kern Fan supplied by IRWD and as published in the KCWA 2001Kern Fan Area Operations and Monitoring Report, April, 2005 and from other data sources generated for the bimonthly Kern Fan Monitoring Committee. SSS used these data to define alternative hypothetical well-field scenarios for the Strand Ranch ASR project which would be consistent with existing well field practices in these other ASR projects. SSS obtained and reviewed the available sources of aquifer parameter data which are referenced in this Report and selected a suite of aquifer parameter values for use in the drawdown calculations. SSS used the "WinFlow" digital computer program by Environmental Simulations, Inc. to model the two dimensional groundwater flow, including the calculation of transient and steady-state water level drawdowns and the calculation of particle flow trajectories for all of the cases of interest.

3. Discussion

Section I - Project and Study Area.

The Strand Ranch (SR) project covers essentially all of Section 02, T30s, R25e. The drawdown- impact study area covers a 3x3 sq. mi area which is centered on the project site in section 02 and includes the surrounding eight contiguous sections, 34, 35, 36 (T29s,R25e) and 1, 3, 10, 11, 12 (T30s, R25e). The three sections to the north (34, 35, 36) are part of the Rosedale - Rio Bravo Water Storage District (RRB). These sections include 3 existing farm irrigation wells but no RRB district project wells. Parts or all of the other five sections to the east, south, and west (1, 3, 10, 11, 12) are part of the Kern Water Bank (KWB). These sections contain eleven (11) operable banking project recovery wells.

For this study, one hypothetical project well-field alternative is 90 af/d (approx. 45cfs) which includes nine wells each pumping water at a nominal rate of at 5 cfs. The proposed maximum annual recovery of 17,500 af/yr requires pumping for 194 days. The two other hypothetical well-field alternatives we considered are 7 wells pumping at 70 af/d for 250 days or 5 wells pumping at 50 af/d for 350 days. The final number and locations of wells in the proposed Strand Ranch well field have not yet been determined.

The surrounding area contains three known private irrigation or domestic water wells within the Rosedale - Rio Bravo Water Storage (RRBWSD) district approximately ½ - 1 mile from the project site and eleven known banking project recovery wells which belong to the Kern Water Bank Authority, two of which are located very close to the property boundary between the Strand Ranch and the Kern Water Bank. The three private wells have an estimated pumping capacity of 10 cfs and the eleven KWBA wells have a published average pumping capacity of 62 cfs. Under the Strand Ranch (SR) hypothetical operating scenario of 45 cfs, the total recovery capacity in the 9 sq. mi. study area is 117 cfs, equivalent to 232 af/d. This maximum recovery scenario represents 38% of the total recovery capacity in the study area.

Under the hypothetical 5-well and 7-well operating scenarios of 25 and 35 cfs each, the project recovery would represent 26% or 33%, respectively, of the total recovery capacity in the study area.

Water level changes in the study area can be potentially effected by any or all of these wells. We also note, based on historical data, that the basinwide water level response to the climatic wet/dry cycle alone can be larger than the pumping drawdowns and may dominate the water level fluctuations in some years, independent of the project operations. Since project impacts may well occur at the same time as the water level impacts from other causes, the combined year-to-year water level declines due to both climate and non-project pumping may be significantly greater than the declines we have projected due to project pumping alone.

The potential drawdown impacts of interest are the impacts created by pumping the Strand Ranch recovery wells. These impacts include both permanent, basinwide impacts and local, temporary impacts and, according to the local MOU, the analysis of total net project impact may also consider the compensating, beneficial impacts of water level rises due to recharge mounding. The locations of interest include the eight sections adjacent to the project. We have evaluated and summarized these drawdowns in several ways by mapping the predicted drawdowns within the well field, by calculating the average drawdown within the well field and within each of the adjacent eight sections, and by calculating the drawdowns at specific locations of interest within the study area. We have evaluated water level rises due to recharge mounding in the same way as a part of a total net project impact analysis.

Apart from selecting the proposed well locations, the drawdown impact analysis is the main objective of this evaluation. This analysis assumes that the wells are drilled, completed, and developed properly so that they are efficient and productive water wells, limited only by the delivery capacity of the aquifer. The drawdown impact analysis requires several types of essential information including operating parameters, well parameters, aquifer model and aquifer parameters. We describe each of these parameter sets below.

Section II - Well Placement Analysis.

<u>Placement criteria.</u> The three primary criteria for locating the Strand Ranch water recovery wells are to meet project objectives and to 1. minimize well interference, 2. minimize the magnitude of the water level drawdown at all locations by distributing the drawdown impacts as uniformly as possible across the largest possible area, and 3. minimize the drawdown impacts to non-project wells in the surrounding area. The first two criteria are best met by placing the wells on the nodes of a uniform grid at the largest possible spacing and operating all wells simultaneously at the same flow rate. The third is best met by orienting and sizing the grid so that every possible well node is no closer to the nearest surrounding well of concern than a minimum specified property-line setback distance.

There are several secondary constraints and operating criteria which limit the selection of the proposed project well locations including: well spacing, voluntary property line setback distance, water quality issues, and accommodating the existing and proposed surface facilities including the CVC and the project recharge ponds and levees.

Based on our review of the well fields in other nearby ASR projects, we can achieve acceptable well spacings for purposes of meeting the primary criteria and be consistent with existing well placement practices, by using well spacings of 1/4 to 1/3-mile (1,320 to 1,760 ft) and a property-line setback distance of 1/8 to 1/6-mile (660 to 880 ft). Based on our review of these other fields, existing well placements in certain locations have ignored primary spacing and/or setback criteria in favor of optimizing the placement with respect to secondary criteria such as proximity to conveyance systems, total gathering system pipeline length, and/or drainage of otherwise inaccessible areas, all of which are related to capital and operating costs, and other factors. Therefore, all proposed well-field designs are based on 9 possible well locations on an equi-spaced 3x3 grid (i.e., a 9-spot pattern) with 1/3-mile spacings and 1/6-mile property line setbacks.

<u>Proposed Water Recovery Operations.</u> For the purposes of this study, we have selected three hypothetical well-field configurations for impact analysis on the Strand Ranch project site. All three well-field patterns are based on the positions of an equi-spaced “9-spot” pattern of NS/EW rows of wells centered on the project site. The first well-field scenario is 9 wells fully occupying the “9-spot” pattern. An alternate, 5-well field uses 5 wells located at the corner- and center- locations of the 9-spot pattern, and an alternate 7-well field uses 7 wells located at all locations except the southwest and south-central positions.

The proposed wells are designed to be 1,760 ft away from each other and 1,760 ft or more away from the nearest non- project wells based on a voluntarily 880-ft setback from the Strand Ranch property line. The projected recovery capacities of the three hypothetical well fields are 90af/d, 70 af/d, and 50 af/d for 9, 7, and 5 wells operating at a nominal 5 cfs each. The operating scenarios involve continuous pumping to recover a maximum 17,500 af/yr from the groundwater aquifer. This represents projected pumping durations of 194 days, 250 days, and 350 days for the 9, 7, and 5-well scenarios respectively.

The project has considerable flexibility in delivering less than the full recovery rate of 45 cfs and/or the annual recovery volume of 17,500 af. The project may meet reduced delivery rates and volumes by choosing to pump for less time, and/or at lower pumping rates, and/or using fewer wells. Each of these possible alternatives provides reduced drawdowns, somewhat smaller-, or differently located-, areas of impact, and faster aquifer- recovery times.

The project may have the operational flexibility to operate in cooperation with nearby project operators so as to mitigate, minimize or eliminate the mutual impacts and interactions between parties. One additional potential mitigation measure may include exercising an opportunity to recover project water from up to three wells located in a proposed Rosedale - Rio Bravo WSD well field about 1.4 miles north-northwest of the Strand Ranch well field. The hypothetical impacts of such recovery pumping are substantially removed from the Strand Ranch project site and adjacent properties; nevertheless, we have modeled the drawdown from four such scenarios and have included that analysis in Exhibit 4. The water level impact analysis for all on-site operations are presented in subsequent sections of this Report.

<u>Total Study-area Recovery Capacity.</u> The total recovery capacity in the 9-sq.mi. study area due to the proposed SR wells and the other existing wells is an estimated 117 cfs, which includes 45 cfs for the Strand Ranch 9-well maximum- recovery scenario, 62 cfs from the 11 surrounding KWB wells, and 10 cfs from the three RRB irrigation wells. The hypothetical future SR maximum recovery scenario represents 38% of the total recovery capacity in the study area . Alternately, the hypothetical 7-well and 5-well SR scenarios, at 25 and 35 cfs respectively, would represent 26% or 33% of the total recovery capacity in the study area.

The final numbers and locations of wells in the proposed Strand Ranch well field have not been determined as of this Study. But the new wells will represent only about 5% of the more than 120 existing or currently planned project recovery wells in the ASR projects on the overall Kern Fan.

Well Placement and Water Quality. Based on available existing water quality data, the shallow aquifer under the project site (compared to the nearby, unimpacted shallow aquifer) has residual, elevated concentrations of total dissolved solids and several constituents of concern due to the inflow of an old brine plume from an unspecified, historic, up-gradient source or sources in or near Section 12, T30s/25e. This brine plume represents a source of water quality degradation that falls within the predicted capture zone of the well field under conditions of natural groundwater gradient and under conditions of pumping. There is no recognized way of positioning the proposed Strand Ranch wells to avoid the water quality impacts of this brine plume. The quantitative analysis of the potential impacts of this brine plume on the Strand Ranch well field is outside the scope of this study.

Section III - Aquifer Model and Parameter Selection.

There are several different computation methods for predicting water-level drawdown from a pumping well in space and time and every method requires that the user select the equations which are most appropriate for the user's preferred model of the aquifer. In essence, the user must try to select the set of mathematical expressions which best represent the user's physical model of the aquifer. The calculated results, if done correctly, always represent the mathematical model and also represent the real aquifer behavior to the extent that the parameters, simplifications and assumptions of the mathematical model reflect the true workings of nature. The selection of the mathematical model and the equations, the accuracy of the parameter values, and the representativeness of the calculated output all reflect the correctness of- and uncertainty in- the judgments of the user. These judgments cannot be made by the computer and the two critical judgments include the choice of mathematical model and the choice of aquifer parameters.

The Real Aquifer. Based on our analysis of the local hydrogeology in the Strand Ranch project area, the local aquifer is a semi-confined (leaky) aquifer which is recharged from the sides and from the overlying layers. For a very small area such as the Strand Ranch project site, it is relatively easy to define a constant-property aquifer model which is representative of the entire area of interest. Our interpretations and our choices of model and parameter values differ from those of Schmidt in 1997 & 1998 and of the Department of Water Resources (DWR) in 1995, which we discuss in Exhibits 2 and 3. The aquifer consists of a sequence of nearly- horizontal, laterally discontinuous, interbedded, unconsolidated, sandy and silty sediments but there is no widespread, laterally continuous impermeable confining layer anywhere under the area of interest. Horizontal ground water flow occurs almost entirely within the sandy units. The shallow sands behave as an unconfined aquifer, but deeper sands show increasing amounts of delayed yield and confinement, according to KCWA hydrographs.

The total thickness of the commonly-used part of the aquifer is approximately 700 ft and, for modeling purposes, assumed to consist of shallow, intermediate, and deep producing zones. The shallow zone exhibits unconfined-aquifer behavior and is approximately 250 ft thick. The middle zone which exhibits intermediate behavior is considered to be the retarding layer and is approximately 100 ft thick. The deep zone exhibits short-term confined behavior and long-term semi-confined behavior and is approximately 300 ft thick. Essentially all of the existing recovery wells on the Kern Fan are completed across the intermediate and deep zones and exhibit semi-confined, aka “leaky”, aquifer water-level behaviors. We have tabulated the aquifer properties which we have used in our modeling in Table 1 and discussed them in Exhibit 2.

Because the inter-bedded silts have some permeability of their own, and because pumping in the deeper zones causes significant downward vertical gradients, the deeper sands obtain a significant fraction of their recharge from the overlying layers. This “leakage recharge” through the permeable silts is augmented by higher- speed, vertical flow at the lateral margins of the silty layers through the more permeable sand facies between layers. The multi-zone hydrographs which are prepared and presented by the Kern County Water Agency on a monthly basis corroborate the widespread and persistent presence of downward vertical gradients between successively deeper depth intervals which are indicative of leaky aquifers.

We also note, based on historical data, that the basinwide water level response to the climatic wet/dry cycle alone can be larger than the pumping drawdowns and may dominate the water level fluctuations in some years, independent of the project operations. Since project impacts may well occur at the same time as impacts from other causes, the combined year- to-year water level declines due to both climate and non- project pumping may be significantly greater than the declines we have predicted due to project pumping alone.

The Model Aquifer. For this scope of work, we have a choice of computational method (analytical or numerical) and a choice of three mathematical aquifer models, i.e., a confined aquifer, an unconfined aquifer, or a semi-confined, or "leaky", aquifer. We chose to use "Winflow", a commercially-available analytical computational model written by ESI, as discussed in Exhibit 1.

Based on the observed stratigraphy and aquifer hydrology, the aquifer underlying the project site and study we chose to use a semi-confined-aquifer model. For the purpose of computer modeling, we represented the local aquifer as three zones; a shallow, 250-ft thick, unconfined aquifer, an intermediate, 100-ft thick "leaky" aquitard, and a deep, 300-ft thick semi-confined aquifer. We assume in the computer model that all project water recovery wells are completed across the full 300-ft thickness of the semi-confined zone. We have summarized the relevant aquifer parameters in the next section of this report and have discussed them in more detail in Exhibit 2.

There are other modeling variables besides the physical aquifer parameters which affect, and could perhaps even dominate, the water levels under the site, and which are easy to calculate but difficult to forecast in advance. The natural factors include the depth to the water table at project startup, the magnitude and direction of the ground water gradient, and the large water level fluctuations within the recharge area due to the climatic wet/dry cycle. The manmade variables include non-project impacts caused by other recharge or pumping operations in the surrounding area. The evaluation of these variables is outside the scope of work, however, they are not relevant to the basic determination of water level drawdown impacts due to Project well field operations. We have included a general discussion of the limitations of computer modeling in Exhibit 3.

Aquifer Parameters. For the leaky aquifer model, we must specify the aquifer dimensions, regional gradient, aquifer storage properties, and aquifer flow properties in both the horizontal and vertical directions. There is a scarcity of reliable parameter data in the Kern Fan area. We have reviewed all of the available data and have found just enough data to make an estimate of every required parameter. Because of the lack of replicate data, there is an unknown amount of uncertainty in the representativeness of these single parameter values, which is in addition to the uncertainty in the accuracy of these measurements themselves. We have accommodated the recognized uncertainty by repeatedly running the computer model with different sets of aquifer parameter values to generate sets of predicted drawdowns for the full range of possible parameter values in the Kern Fan area. We have discussed the aquifer parameters in more detail in Exhibit 2 and elements of the concept of uncertainty in the Exhibits 1 - 3.

From top to bottom, the shallow, unconfined zone is 250-ft thick, the middle "leaky" zone is 100-ft thick, and the deep semi-confined zone is 300 ft thick. All wells are assumed to be completed across the full 300-ft thickness of the bottom, semi-confined zone. All zones are assumed to have an average porosity of 30%.

The base case parameter values for the deep, semi-confined zone are as follows: the value of horizontal hydraulic conductivity is K_h = 57 ft/day, and the sensitivity analysis was run for 40 < K < 100 ft/day; the value of specific storage is $S_s = 6.67x10^{-5}\ ft^{-1}$ and was not re-calculated in the sensitivity analysis although the range of possible values could be half to twice the selected value. These valuers of K_h and S_s give equivalent values of semi-confined aquifer transmissivity and storativity of T = 17,100 ft^2/day and S = 0.02.

The base case parameter values for the middle, "leaky" zone are as follows: the value of leakance is assumed to be L' = 0.000475 d^{-1} which yields a Hantush leakage factor of B = 6,000 ft, and the sensitivity analysis was run for B = 3200, 6000, 10,000 ft. These values of B are equivalent to values of weighted-average vertical hydraulic conductivities (K_v') in the 100-ft thick aquitard of K_v' = 0.17, 0.0475, and 0.017 ft/day. However, for reasons of equivalence, we place little significance in these specific values of K_v' and prefer to limit the discussion of aquitard behavior to expected leakance in the range 0.00017 < L' < 0.0017.

The base case value of average specific yield for the shallow unconfined zone is 21%. This parameter is not actually involved in the drawdown models of this study since none of the calculated cases actually dewaters the shallow aquifer.

For the calculation of drawdown impacts, we have initially assumed that the regional gradient in the test area is zero so that all model impacts are superimposed on an initially flat water table. We set our reference elevation to be zero at the initial water table rather than at ground level or at mean sea level so that all calculated drawdowns are relative to the initial water table. This device allows us to easily observe just the predicted pumping- induced drawdown at any location without the complicating effects of the natural gradient.

However, in order to perform particle trajectory and capture zone analyses, we must superimpose the calculated pumping- induced drawdowns on a realistic approximation of the natural water table gradient. We have based our approximations on observed historical water table behavior in the study area. We assume a groundwater gradient of -0.0048 at a left azimuth angle of 135 degrees from east which is equivalent to a water table slope of 25 ft per mile to the northwest. We set our reference water level elevation at a depth of 100 ft at the southeast corner of section 02, T30s, R25e, which is the southeast corner of the Strand Ranch project site.

Section IV - Drawdown Analysis.

When we speak of *water level*, we are always referring to the water level which would be observed in a hypothetical monitoring well which is completed in the aquifer at the specified location and depth interval of interest. The water level in such a monitoring well represents the elevation of the potentiometric surface, sometimes referred to as the pressure head, in the aquifer at that location. A map of such water levels represents the distribution of pressure head in the aquifer. When we speak of *drawdown*, we are always referring to a decline in potentiometric water level caused by one or more pumping wells.

When an episode of groundwater pumping removes water from the underlying aquifer the potentiometric water level changes in response to the decreasing volume of water in aquifer storage. This water level behavior has both transient and permanent components, including the temporary creation and then dissipation of a local cone of depression ending with a permanent, small, net drop in the basinwide water table. We can predict the height, areal extent, and rate of change of this falling, rising, and then re-equilibrating water table if we know the aquifer properties and the location, volumetric rate, and duration of pumping.

<u>Expected Results.</u> The drawdowns related to the proposed Strand Ranch pumping operations are temporary rather than permanent water level impacts. We expect at any moment after pumping has begun that a cone of depression will form around each well and that the cone of depression will deepen and expand outward with time, subject to certain limits. This

depression is a drop in the pressure levels (equivalent to potentiometric water levels in properly-placed monitoring wells) within the aquifer but there is no corresponding creation of an actual physical void space of the same shape within the aquifer under semi-confined (or confined) conditions. The drop in pressure within this cone of depression is what causes groundwater to flow along inward radial paths to the well. The actual region of the aquifer from which water is removed by pumping is called the "capture zone". The shape of the capture zone is a vertical cylinder centered on the well and the radius of the capture zone is much smaller than the radius of the cone of depression. As steady pumping continues, the capture zone increases in radius, albeit at a continuously decreasing rate of expansion since the radius is a function of the square root of pumping time and not directly of time itself. When pumping ceases, the cone of depression immediately begins to shrink inward toward the central well until the pressure levels have recovered to their pre-pumping state and the cone of depression is gone.

A cone of depression in a semi-confined aquifer is a temporary condition in which the depression deepens and widens only as long as the total well-field pumping rate exceeds the downward vertical recharge from the overlying layers. Once those rates are equal (vertical recharge rate increases as the size of the depression increases), the depression stops growing. Then when pumping ceases, vertical recharge continues, causing the depression to shrink until gone and the water levels are indistinguishable from the background water table behavior. Since there is now less water in the basin than before pumping, all else equal, the average water level in the basin is slightly lower than before pumping took place.

We expect at any moment, that the drawdowns will be larger close to the wells and smaller farther away from the wells. We expect at any location that pressure drawdown increases as the duration of pumping increases. We also expect for any specified time and location, that the drawdown will be larger for higher pumping rates and smaller for lower pumping rates. We also expect that for any location that is within the radii of influence of more than one pumping well, that the observed drawdown will be the sum of the individual drawdowns caused by every pumping well superimposed at that location.

What may not be as intuitive is the expected drawdown behavior depending on the choice of aquifer model. If the aquifer is fully confined or fully unconfined, the drawdowns will continue to decline indefinitely and the radius of the capture zone expands indefinitely. If the aquifer is semi-confined with leakage recharge from the overlying layers as we expect in this area, then the observed qualitative behavior will be more complicated. For a short period of time, the aquifer will behave as a confined aquifer, meaning that the observed drawdowns near each of the wells will decline quickly and with the same time - distance relationship as is predicted for a confined aquifer with the same values of T & S. Thereafter, the piezometric water levels will decline at a decreasingly slower rate than predicted by the confined- aquifer model until the water levels stop falling altogether. Once the water levels quit falling, the capture zone will have reached its maximum radius and will quit expanding. At this time, all recharge will flow vertically downward into the top surface of the cylindrical capture zone and no flow will come from inward radial flow through its sides, i.e., there is no mining of water from the adjacent areas outside the capture zone.

After an undetermined time period of leaky behavior during which there is little or no observed drawdown despite continued pumping, we expect that the water table will once again start to decline at a rate which is consistent with the de-watering of the overlying unconfined aquifer. The durations of each of these behavioral phases may be estimated but the calculated times of transition are not particularly precise because of the inability to predict future recharge. This project can be in leaky steady state for a very long time if the shallow aquifer is consistently recharged. Once this program has begun, a properly designed well- testing and monitoring program will provide a wealth of new understanding of the aquifer, well beyond what we are able to model with the small parameter set which is available at this time. We such a program, we will be able to perform aquifer parameter test within the project area to verify ad improve our current, limited knowledge of the aquifer.

The predicted drawdowns from this work program are significantly different than the predicted drawdowns from three other recent impact analyses for entities on the Kern Fan by other workers in five respects. First, SSS modeled the aquifer as a leaky aquifer rather than as a confined aquifer. Second, SSS used the superposition method versus the so-called centroid method used in the other studies. Third, SSS's parameter values are different than those of the other studies, and incidentally are different in such a way as to increase the calculated drawdowns, all else being equal. Fourth, the leaky aquifer model which SSS used predicts that the water levels will decline and then stabilize at a static, steady- state drawdown at least for a while, compared to the other forecasts which predict that water levels will continue to decline as long as pumping is continued. Fifth, for SSS's choices of aquifer model and aquifer parameters, the predicted drawdowns are significantly less than the predicted drawdowns from these other studies.

Modeling Scenarios. The first hypothetical operating scenario is to pump 9 wells at a combined rate of 90 af/d (based on a nominal rate of 5 cfs per well) for 194 days to recover a total 17,500 af per year. For a given well-field configuration, the project has considerable flexibility in delivering less than the hypothetical full 9-well, recovery rate of 45 cfs and/or the annual recovery volume of 17,500 af. The project may also meet reduced delivery rates or volumes by choosing to pump for less time, and/or at lower pumping rates, and/or using fewer wells. Each of these possible alternatives provides reduced drawdowns, somewhat different drawdown distributions, and faster aquifer- recovery times. The two alternate scenarios of primary interest in this study are: pumping 7 wells at a combined rate of 70 af/d for 250 days to recover a total 17,500 af in a year, or pumping 5 wells at a combined rate of 50 af/d for 350 days to recover a total 17,500 in a year.

In each case, the operating well field establishes a steady-state condition of no further drawdown between 30 and 100 days of pumping due to leaky recharge. Therefore, pumping more than 100 days and even multi- year continuous pumping will not increase the drawdown as long as the project maintains its recharge commitment and the immediate area also continues to receive sufficient total recharge to re-supply all non-project wells in the area. The key to moderating the aquifer behavior is to keep the local area adequately recharged over time. If recharge does not match recovery, then the predicted drawdowns within the aquifer after 300 days of pumping may be as much as twice as much as predicted or more, depending on the rate of depletion of the shallow, unconfined aquifer. However, by design and by requirement, this project will always recharge prior to recovery.

For 300 days of pumping, the hypothetical capture perimeter surrounding the entire well field extends only a few hundred ft outward from the individual wells and remains entirely within the property boundary of the Strand Ranch. For a hypothetical 1000 days (approx. 3 yr) of continuous pumping, the hypothetical capture perimeter extends about 1,800 ft from the individual wells. For a hypothetical 3650 days (10 yr) of continuous pumping, the capture zone would extend about 2,300 ft down-gradient to the northwest and would extend about 4,500 ft up-gradient to the southeast under conditions of dry-year groundwater gradient of 25 ft/mi to the northwest.

For the given set of aquifer conditions, the water-level drawdowns caused by the Strand Ranch recovery well operations vary with our choices aquifer parameters, well parameters, pumping duration, and location. Therefore, there is no way to represent the multiple potential impacts with a single number unless we specify a single set of aquifer and well parameters, a single pumping duration, and a single location.

We can reduce the number of possible operating scenarios by using a single "base case" operating scenario. We can reduce the time variable by using a single pumping duration, and we have chosen to compute drawdown for a time after which the drawdowns at all locations have reached "steady-state", i.e., maximum drawdown. At this point, the evaluation of impacts is reduced to observing the predicted drawdowns simply as a function of location.

The three main cases of interest include the 9-well scenario, the 7-well scenario, and the 5-well scenario, each of which is evaluated with and without the presence of a superimposed natural groundwater gradient. All drawdowns for all cases and all locations within the study area are presented in a Catalog of Drawdown Maps in Exhibit 5, one case at a time.

Computed Results. The basic output from each drawdown analysis is a contour map of the predicted water levels in and around the area of the well field. Each map shows the well locations, the contours representing the water levels for a specified set of pumping parameters, and flowpath particle trajectories, if included, for a specified duration of pumping. The computer-generated maps cover a square, 3x3- mile area centered on the project area. Using local (east, north) coordinates in units of feet, the local origin (0,0) is at the intersection of Stockdale Hwy and Enos Lane, the southwest map corner is located at (-10,600, -10,600), and the northeast corner (+5,400, +5,400) since the model uses an 80x80- cell model space with each cell representing 200x200 ft in real space. The map scale of the computer printouts is approximately 1 inch = 2290 ft. Additional map information is included at the beginning of Exhibit 5 where we have compiled a catalog of all maps for all scenarios in a catalog of results. The Catalog includes more modeling scenarios than were necessary for this study. They were run as a diligent effort to investigate transient conditions, non-base case parameter impacts, sensitivity analysis, comparisons with alternate aquifer models, etc. The maps which are included as Figures in this Report cover everything discussed in the text and are derived from the model runs in the Catalog.

For this study, we have calculated the water level drawdowns for the three main hypothetical well-field operating scenarios of 9-, 7-, or 5- wells each, each of which is designed to recover 17,500 af of ground water from the underlying aquifer in a year. All three scenarios used the same set of aquifer parameters. We calculated additional results by varying selected parameters to provide a sensitivity analysis.

The base case aquifer parameters were the same for every case, i.e., a 300-ft thick, semi-confined aquifer with T = 17,100 ft^2/d, S = 0.02, and porosity = 30%; an overlying aquitard with L' = 0.000475 d^{-1} which is gives a Hantush leakage factor of B = 6,000 ft; and an overlying unconfined aquifer with Sy = 15%. The unimpacted, natural groundwater gradient was assumed to be zero unless otherwise specified. For capture zone and particle trajectory calculation we used a groundwater gradient of -25 ft/mi to the northwest (-0.0048 at a left aximuth of 135 degrees from east) and we assumed a corresponding reference groundwater elevation at 100 ft below GL at the southeast corner of the project area (i.e., the SE cor Sec 02, T30s, R25e). All of the modeling parameters have been summarized in Table 1 and are discussed in detail in Exhibit 2..

We present the calculated drawdown results for the three hypothetical operating scenarios in the next three sections below.

<u>Nine- well scenario:</u> q = 90 af/d, pumping t = 194 d, V = 17,500 af/yr.

The hypothetical steady-state drawdowns created by the Strand Ranch, *9-well, 194-day*, pumping scenario are presented on the map in Figure 5 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 43 ft and the average drawdowns in the surrounding 8 sections are in the range of 12 - 20 ft. The drawdowns along the perimeter of the study area are in the range of 5 - 10 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter. The drawdowns for the 9-well case superimposed on a northwesterly groundwater gradient are shown on the map in Figure 9.

Under the base case assumptions, the area will achieve steady-state within about 100 days after pumping begins and the water levels will begin to recover after 194 days when pumping ceases. As long as the leaky-aquifer assumptions continue to be met, the water levels in the study area will recover to pre-pumping levels in another 100 days or less, in the absence of other influences.

Seven - well scenario: q = 70 af/d, pumping t = 250-day, V = 17,500 af/yr.

The hypothetical steady-state drawdowns created by the Strand Ranch, *7-well, 250-day*, pumping scenario are presented on the map in Figure 6 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 34 ft and the average drawdowns in the surrounding 8 sections are in the range of 9 - 17 ft. The drawdowns along the perimeter of the study area are in the range of 3 - 8 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter.

Under the modified well field assumptions, the area will achieve steady-state within about 100 days after pumping begins and the water levels will begin to recover after 350 days when pumping ceases. As long as the leaky-aquifer assumptions continue to be met, the water levels in the study area will recover to pre-pumping levels in another 100 days or less, in the absence of other influences.

The hypothetical drawdowns created by the Strand Ranch *7-well, 250-day scenario* are approximately 78% of the hypothetical drawdowns for the 9- well scenario but the duration of impact lasts about 56 days longer because the wells must operate longer to recover the same total volume of water (17,500 af/yr) at the lower recovery rate (70af/d vs. 90 af/d).

Five - well scenario: q = 50 af/d, pumping t = 350-day, V = 17,500 af/yr.

The hypothetical steady-state drawdowns created by the Strand Ranch, *5-well, 350-day*, pumping scenario (wells 1, 3, 5, 7, 9) are presented on the map in Figure 7 and summarized in Tables 2 & 3. At steady-state, the average drawdown under the project site is 24 ft and the average drawdowns in the surrounding 8 sections are in the range of 7 - 11 ft. The drawdowns along the perimeter of the study area are in the range of 2 - 6 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter.

Under the modified well field assumptions, the area will achieve steady-state within about 100 days after pumping begins and the water levels will begin to recover after 350 days when pumping ceases. As long as the leaky-aquifer assumptions continue to be met, the water levels in the study area will recover to pre-pumping levels in another 100 days or less, in the absence of other influences.

The hypothetical drawdowns created by the Strand Ranch *5-well, 350-day scenario* are approximately 56% of the hypothetical drawdowns for the 9- well scenario but the duration of impact lasts about 156 days longer because the wells must operate longer to recover the same total volume of water (17,500 af/yr) at the lower recovery rate (50 vs. 90af/d).

<u>Base Case Specific Capacity of the Pumped Wells.</u> Specific capacity (SC) is defined as the ratio of pumping rate to drawdown within a pumping well and is used by local engineers as a measure of well performance from which other parameters are calculated. Unfortunately SC is not a constant and varies with pumping time, length of completion interval, hole diameter, and well efficiency, so it is not an effective measure of anything without making the corrections for each of these factors. We can calculate the theoretical specific capacity (SC) of the project wells for the steady- state leaky aquifer condition from the selected base case parameters for purposes of preliminary pump parameter selection. Normally for pump design purposes, we would recommend using actual drawdown data from nearby pumping wells as the best predictor of well performance, but we can calculate a value as well.

For the base case semi-confined aquifer parameters, we estimate the expected *steady-state* project- well specific capacity to be about SC = 0.14 cfs/ft, which is equivalent to 63 gpm/ft, for a 100% efficient well. For all pumping times less than the time required to reach steady- state, the observed SC will appear to be larger and, in the first few hours and days, perhaps much larger than this predicted final value.

<u>Sensitivity Analysis.</u> Because of the uncertainties in the actual aquifer conditions, the actual operating drawdowns when the well field is finally installed and operated may be different than the calculated base case values. We have already acknowledged that there is considerable uncertainty in the few data available to us. Since the accuracy of the impact calculations for the leaky aquifer model depends primarily on the values of T and B, we have varied the base case parameters within the credible ranges of possible values and have re-calculated the drawdowns for these other parameter values (Figure 13 and Table 4). We used the Hantush & Jacob, 1955 formula to calculate the steady-state drawdowns for various T & B for leaky-aquifer conditions.

We selected a base case value of aquifer transmissivity T = 17,100 ft^2/d for the computer modeling based on a hydraulic conductivity of 57 ft/d and an aquifer thickness of h = 300 ft. This T-value is at the lower end of the reported range of possible T-values in the Kern Fan area. If the true aquifer transmissivity (T) is higher than our base case value, then the actual observed drawdowns will be less than predicted drawdowns, all else equal. We have calculated the hypothetical steady-state drawdowns for the 9-well, 194-day scenario using T-values ranging from 12,000 ft^2/d to 30,000 ft^2/d. If the true transmissivity is15,000 ft^2/d rather than 17,100 ft^2/d, then the actual drawodows across the study area will be about 15% higher than predicted but if the actual transmissivity is 24,000 - 30,000 ft^2/d, then the actual drawdowns across the study area will be only 72% - 58%, respectively, of the predicted drawdowns. Since the sensitivity to T is a multiplicative effect, the greatest differences will tend to occur in the areas of greatest drawdown and vice versa, that is, an error in T-value make the biggest difference in and near the well field, and have a decreasing difference between predicted and corrected drawdowns with distance away from the project area.

We selected a base case value of aquitard leakage factor B = 6,000 ft for the computer modeling based on an aquitard leakance of L' = 0.000474 d^{-1}. This mid-range L- value is consistent with the expected vertical hydraulic conductivities for sandy silts and/or silty sands of the Kern Fan area. If the true aquitard leakage factor (B) is lower than our base case value, then the real aquifer is less-confined than calculated which would cause smaller drawdowns than calculated for B = 6,000. If the true aquitard leakage factor (B) is higher than our base case value, then the real aquifer is more-confined than calculated which would cause larger drawdowns than calculated for B = 6,000. If the actual leakage factor is B = 3,200 ft (L' = 0.0017 d^{-1}), then the actual drawdowns across the study area will be about 2.5 ft less than predicted and if the actual leakage factor is B = 10,000 ft (L' = 0.00017 d^{-1}), then the actual drawdowns across the study area will be about 2.1 ft more than predicted. Since the sensitivity to B is an additive effect, the same differences will tend to occur across the entire area of interest, that is, an error in B-value makes the same difference in and near the well field as it does between predicted and corrected drawdowns in the surrounding sections.

Section V - Flow Trajectory and Capture Analysis.

Particle trajectories. A particle trajectory represents the hypothetical flowpath of a water molecule under ideal flow behavior, i.e., ignoring the effects of dispersion, flowpath tortuosity, heterogeneity, etc. We can calculate particle trajectories in downgradient or upgradient directions, which we refer to as forward or reverse particle tracking, respectively. In our computational models we assume that the aquifer is horizontally isotropic so that particle trajectories are always perpendicular to water level contours. For this project we used reverse particle trajectories to determine the shapes and extents of the capture zones for each of the pumping wells in the well field for different pumping durations. We also used one forward-particle tracking model to the general pathway of contaminant flow from the southwest quarter of section 12, T30s, R25e. An important use of particle trajectory mapping is for designing contaminant- detection monitoring programs so that the operator can place the monitoring wells in the likely flowpaths from known or suspected contaminant sources.

<u>Capture zones.</u> A capture zone is the enclosing perimeter of the actual bulk volume of the aquifer from which a pumping well extracts water over a specified time period. The shape and lateral extent of a capture zone is very different than that of the cone of depression. For a confined or semi- confined aquifer, the capture zone is a vertical cylinder centered on the well and bounded by the confining layers at the top and bottom of the aquifer. The radius of the capture zone increases as long as pumping continues. The shape of the capture zone will be distorted by the presence of other wells and/or recharge boundaries but it will always have a fully enclosing perimeter. The method of reverse particle tracking will always provide a means to map the shape and extent of the capture zone for a specified pumping duration.

Mapping a capture zone analysis requires that we model the aquifer behavior as realistically as possible, since true particle trajectories will respond to all influences on the real potentiometric pressure field and not just those generated by the Strand Ranch wells. Therefore, we assume that the most realistic scenario will occur in a dry year when the Strand Ranch wells will most likely be pumping and all of the neighboring wells are pumping as well. The combined pumping effects of these wells superimposed on the natural groundwater gradient will determine the locations of capture zone and particle trajectories with time.

The water level elevation map in Figure 10 shows the steady-state impacts of the nine Strand Ranch wells and eleven Kern Water Bank wells superimposed on the local groundwater gradient. The five wells located at the center and corners of the Strand Ranch well field (wells 1, 3, 5, 7, 9) have 1,000-day reverse particle trajectories attached to them which define the shape and areal extents of the "3-year" capture zones for continuous pumping at these locations.

For reference purposes, the section corners have been labeled on the map. We have mapped the locations of the capture zone perimeter for pumping times of 300-, 1000-, 1825-, and 3650-days superimposed on 10-year continuous particle trajectories in Figure 11.

The individual capture zones of widely-spaced wells, such as in the Strand Ranch project, do not merge unless pumping continues for a relatively long time . The importance of mapping the capture zone is for purposes of evaluating water quality, particularly the potential for contaminant capture. We have mapped (Figure 11) the approximate locations of the particle trajectories and expanding capture zone for continuous pumping of both the Strand Ranch and Kern Water Bank wells for pumping times of 300-, 1000-, 1825-, and 3650- days for an aquifer with a northwesterly water table gradient, as described below.

For 300 days of pumping, the hypothetical capture perimeter surrounding the entire well field extends only a few hundred ft outward from the individual wells and remains entirely within the property boundary of the Strand Ranch. For shorter pumping durations, such as our hypothetical 9- and 7-well operating scenarios, the capture zones around each well would be proportionately smaller. For a hypothetical 1000 days (approx. 3 yr) of continuous pumping, the hypothetical capture perimeter extends about 1,800 ft from the individual wells. For a hypothetical 3650 days (10 yr) of continuous pumping, the capture zone would extend about 2,300 ft down-gradient to the northwest and would extend about 4,500 ft up-gradient to the southeast under conditions of groundwater gradient of 25 ft/mi to the northwest. Pumping by non-project wells in the surrounding areas will change the shape and extent of this capture zone, as shown in the various model runs.

We have also mapped (Figure 12) the 10-year forward particle trajectories of a hypothetical line source located in the southwest quarter of section 12, T30s, R25e under conditions of continuous pumping of both the Strand Ranch and Kern Water Bank wells. Any groundwater contamination which comes from a source located on or near this line will follow the same trajectories. A slug or plume of contamination will eventually be captured by wells located on the Kern Water Bank and/or Strand Ranch depending on the particular location of the source and its downgradient trajectories.

The time it takes contaminants to flow from the source to the well field perimeter will be approximately equal to the capture-zone time-radius (approx. 8 years under continuous pumping of all wells) that crosses the source area assuming that the contaminant moves at the same speed as the groundwater. For many contaminant constituents, this assumption is false, since the processes of dispersion, retardation, and attenuation slow the flow velocity of contaminants in ground water. There are no rules of thumb in this regard without specifying the contaminant of concern, but the capture zones which are based on the flow velocity of the ground water form the base case of any contaminant capture analysis. Sierra Scientific Services has performed contaminant transport modeling for other clients, but it is outside this scope of work.

Section VI - Recharge Mound Analysis.

When an episode of groundwater recharge adds water to the underlying unconfined aquifer the water table changes in response to the increasing volume of water in aquifer storage. This water level behavior has both transient and permanent components, including the temporary rise and fall of a local water mound ending with a permanent, small, net rise in the basinwide water table. We can predict the height, areal extent, and rate of change of this rising, falling, and then re-equilibrating water table if we know the aquifer properties and the location, volumetric rate, and duration of recharge.

Expected Results.

The initial recharge will create a fully-saturated, vertical column of water through the vadose zone from the base of the recharge pond to the top of the water table. This column of "falling" water is not part of a recharge mound per se. Once the flow front reaches the water table, a water mound will begin to develop above the water table as downward-moving water spreads out laterally into available space. The mound will continue to rise and widen as recharge progresses until the rate of lateral mound outflow matches the rate of downward vertical recharge.

The mound is a temporary condition in which the mound rises and widens only as long as the continuing downward vertical flow of water into the mound exceeds the lateral flow out of the mound. Once those rates are equal, the mound stops rising but continues to widen. Then when recharge ceases, lateral outflow continues, causing the mound to flatten and widen until the mound is indistinguishable from the background water table. Since there is now more water in the basin than before recharge, all else equal, the average water level in the basin is slightly higher than before recharge took place.

The pond infiltration rate will be a maximum at the beginning of recharge and will decrease continuously and perhaps quickly (perhaps over a few days or a couple of weeks) until the pond infiltration rate is numerically equal to the vertical hydraulic conductivity of the underlying flow path. The infiltration rate will remain steady at this value as long as the water table (and associated capillary fringe) is far below the base of the infiltration pond. As the water table rises during the time of recharge, the infiltration rate will also decrease accordingly as the volume of available, unsaturated storage space decreases. If and when the rising water table approaches the ground surface, the infiltration rate will be a minimum equal to some fraction of the value of the hydraulic conductivity of the underlying flow path.

Modeling Scenarios.

The hypothetical base case recharge scenario is to maintain water in approximately 450 acres of recharge ponds on the Strand Ranch at an overall average infiltration rate (IR) estimated to be between 0.2 - 0.4 ft/d. The duration of recharge will depend on the availability of a surface water supply. In a maximum recharge scenario, recharge ceases when the cumulative recharge volume equals 17,500 af in a given year, which requires recharge durations in the range of 100 - 200 days for the reported range of parameter values. We assume in our model for convenience and without a loss of generality that the recharge pond is circular with a radius of 2,500 ft and centered in the Project site.

The key parameter controlling pond recharge is the long term infiltration rate which we have estimated to be in the range from 0.2 - 0.4 ft/d on the Strand Ranch property, assuming that the ponds are maintained in a clog-free state. The lowest recharge rate will occur when the water table is very shallow and highest recharge rate will occur when the water table is very deep. With respect to design, operations, and impact issues the critical project recharge performance is the recharge which occurs at the lowest infiltration rate.

During 2006, the project operated a pilot recharge test which consisted of filling a 117-acre pond from mid-July to mid-December. By September, the pond inflow had stabilized at a steady recharge rate of 12 cfs, meaning that 23.8 af of water per day infiltrated from the 117 ac pond, giving a computed infiltration rate of IR = 0.20 ft/d. Since the water table for the entire duration of the pilot test was very shallow (less than a few feet deep) we conclude that the observed infiltration rate of 0.2 ft/d was a minimum rate and that future operations with a deeper water table will experience higher infiltration rates, perhaps as high as 0.40 ft/d. For modeling purposes, we made mound calculations for infiltrations rates of 0.20, 0.25, and 0.30 ft/d since all critical issues are related to mounding in the lower range of possible infiltration rates.

For this study, we calculated the water level rises for a 450-acre recharge pond which is designed to put 17,500 af of ground water into the underlying aquifer in a single recharge episode per year. All three scenarios used the same set of aquifer parameters. We calculated additional results by varying selected parameters to provide a sensitivity analysis.

Except for the infiltration rate, the base case aquifer parameters were the same for every case, i.e., a 300-ft thick, unconfined aquifer with K = 57 ft/d, Sy = 0.21, and porosity = 30%. The unimpacted, natural groundwater gradient was assumed to be zero and we assumed a corresponding reference groundwater elevation at 100 ft below GL at the southeast corner of the project area (i.e., the SE cor Sec 02, T30s, R25e). The modeling parameters have been summarized in Table 1.

<u>Computed Recharge Results.</u>

The basic output from each mound analysis is a contour map of the predicted water levels in and around the area of the recharge pond. Each map shows the pond location, the recovery well locations for convenience, and contours representing the water levels for a specified set of recharge parameters. The computer-generated maps cover the same square, 3x3- mile area as used for the drawdown analyses. The map scale of the computer printouts is approximately 1 inch = 2290 ft. Additional map information is included at the beginning of Exhibit 5 where we have compiled all maps for all scenarios in a catalog of results.

<u>Pond recharge at IR = 0.20 ft/d:</u> q = 90 af/d, recharge t = 194 d, V = 17,460 af/yr.

The maximum water level rises created by the Strand Ranch, *90-af/d, 194-day*, recharge scenario are presented on the map in Figure 14 and summarized in Tables 5 & 6. The average water level rise under the project site is 32 ft and the average rises in the surrounding 8 sections are in the range of 6 - 13 ft. The drawdowns along the perimeter of the study area are in the range of 1 - 5 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter. These water level rises are within a few percent of the maximum, steady-state mounding rises which are predicted for this scenario under infinite recharge duration. However, the mound in this scenario will begin to decline as soon as recharge has stopped at t = 194 days.

<u>Pond recharge at IR = 0.25 ft/d:</u> q = 112.5 af/d, recharge t = 155 d, V = 17,438 af/yr.

The maximum water level rises created by the Strand Ranch, *112.5-af/d, 155-day* recharge scenario are presented on the map in Figure 15 and summarized in Tables 5 & 6. The average water level rise under the project site is 36 ft and the average rises in the surrounding 8 sections are also in the range of 6 - 13 ft. The drawdowns along the perimeter of the study area are in the range of 1 - 5 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter. These water level rises would continue to rise if recharge continued after t = 155 days, and are not close to the steady-state mound heights which are predicted for this scenario under infinite recharge duration. However, the mound will begin to decline as soon as recharge has stopped at t = 155 days.

<u>Pond recharge at IR = 0.30 ft/d:</u> q = 135 af/d, recharge t = 129 d, V = 17,444 af/yr.

The maximum water level rises created by the Strand Ranch, *135-af/d, 129-day*, recharge scenario are presented on the map in Figure 16 and summarized in Tables 5 & 6. The average water level rise under the project site is 40 ft and the average rises in the surrounding 8 sections are in the range of 6 - 14 ft. The drawdowns along the perimeter of the study area are in the range of 1 - 5 ft and drawdowns decrease to negligible levels with increasing distance from the perimeter. These water level rises would continue to rise if recharge continued after t = 129 days, and are not close to the steady-state mound heights which are predicted for this scenario under infinite recharge duration. However, the mound will begin to decline as soon as recharge has stopped at t = 129 days.

We also note that if the actual infiltration rate is higher than IR = 0.30 ft/d, then the project will be able to recharge water at a higher volumetric rate than we have modeled here (135 af/d at IR = 0.30 ft/d) and the time needed to recharge 17,500 af/yr will be less than t = 129 days.

Based on the results of modeling, we observe that the water level rises in the 8 sections surrounding the project site project area for all 3 scenarios are almost identical, i.e., in the range of 6 - 13 ft, even though the recharge occurs at different rates for different durations for the three scenarios. We note that the predicted maximum water level rises from recharge mounding under the adjacent lands are essentially the same regardless of the infiltration rate, for these cases where the total recharge volume is the same.

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Maximum Recharge.

The 30-year period from 1969 - 1998, was a period of above-average high flows and floods on the Kern River and CVP Friant-Kern systems. There were nine such high-flow episodes during that time period in which Kern County suffered damages and/or water left the county and was lost to local beneficial use[4]. Based on the experiences of this period, Kern County has placed a high priority on using all available facilities to minimize the potential impacts of high-flow/flood conditions and minimize the amount of water which is lost to beneficial use by diverting as much water as possible from the Kern river channel under such conditions. The capacity to divert water from the Kern River channel has substantially increased since 1990 by the development of recharge facilities for district water banking programs. The benefits of diverting high-flow water to recharge ponds include lowering the threat of flooding, improving the in-ground water supplies for districts which rely on conjunctive use programs to deliver water to their farmers, reducing overdraft through losses to the basin paid by project operators, and capturing water for unrestricted local use, water which might otherwise have left the county.

In the case of the proposed Strand Ranch project, the addition of 450 acres of recharge ponds represents a significant increase in potential local flood mitigation by high-flow capture and recharge. To our knowledge, Kern County has never restricted or prevented the use of any recharge pond for the unrestricted capture of high-flow water. The benefits to the County and the basin are large, obvious, but relatively infrequent. Nevertheless, we include here a water level impact analysis for a maximum recharge scenario in which 450 acres of recharge ponds are kept full for a period of 365 days at maximum recharge rates. Since we do not yet know what the maximum recharge rate might be on the Strand Ranch project site, we have done four such analyses for infiltration rates of IR = 0.20, 0.30, 0.35, and 0.40 ft/d.

[4]KCWA, August 27,2001, Initial Water Management Plan, Public Review Draft, p. T26.

Maximum recharge-1: IR= 0.20 ft/d, q= 90 af/d, recharge t= 365 d, V= 32,850 af/yr.

Maximum recharge-2: IR= 0.30 ft/d, q= 135 af/d, recharge t= 365 d, V= 49,275 af/yr.

Maximum recharge-3: IR= 0.40 ft/d, q= 180 af/d, recharge t= 365 d, V= 65,700 af/yr.

The water level rises created by the preceding three hypothetical maximum recharge scenarios are presented on the maps in Figures 17 - 19 and in Tables 9 - 10. The average water level rise after 365 days of recharge under the project site for each IR scenario is 39-, 58-, or 76-ft, respectively. The average rises in the surrounding 8 sections are in the range of 11 to 19-, 18 to 28-, or 23 to 36-ft, respectively. These full-year water-level rises are approximately 6-, 13-, or 18- ft higher in the surrounding 8 sections than would be encountered for recharge at the same infiltration rates (Figures 20 - 22), respectively, except that each scenario had stopped after 17,500 af had been recharged (as presented in earlier in this report).

A natural, high-flow event of sufficient magnitude to generate a 365-day capture and recharge episode may have a recurrence probability of only once-per-century, more or less, so any such event is unlikely to occur over a given 30-year project forecast. Nevertheless, given the reduced storage capacity in the Lake Isabella reservoir due to engineering issues, the lower Kern River may experience more-frequent, higher-volume releases of water during a multiple wet-year period than might otherwise be the case. These mounding calculations demonstrate that the range of water level impacts from any realizable 365-day recharge scenario are not objectionably different than other, smaller-recharge scenarios of the same rate but of shorter duration currently under consideration.

Section VII - Total Project Water Level Impact Analysis.

The following analysis assumes that all of the proposed operational design recharge- and recovery- rates and caps apply to the project operation except that there is no cap on the capture and recharge of high-flow water, such as is discussed in the preceding section.

The essence of full ASR project operation is the ongoing cycle of adding water to- and subsequently removing water from- aquifer storage. These processes have both local and basinwide impacts. The basinwide impact is a small, widespread, cumulative, and permanent, water level rise. The magnitude of the basinwide water level rise is proportional to the cumulative net volume of water which is left in the basin over time and is insensitive to the number, frequency, or size of the many individual project recharge and recovery episodes. The basinwide project impact is positive meaning that the project permanently adds water to the basin and that a water level rise is considered to be beneficial.

In contrast, the local impacts are larger, localized, and temporary but recurring. Adding water to the local aquifer causes a temporary water level mound and removing water from the local aquifer causes a temporary water level depression. Such a mound or depression only lasts as long as a recharge or recovery operation takes place, respectively, plus a re-equilibration time during which the mound or depression dissipates. The magnitude of an individual local mound or depression is proportional to the *rate* at which water is added to or removed from the local aquifer, i.e., the higher the volumetric flow rate in or out of the aquifer (in acre-feet per day) the greater the temporary water level impact, all else equal. A water level mound or depression may be seen as either a beneficial or detrimental impact depending on whether the operations would be seen as improving or worsening some pre-existing condition, such as water levels being already too high or too low to begin with.

In Kern County, there are three potential water level impacts of concern, one of which is a long-term, basinwide impact and two of which are short-term, local impacts. The long-term basinwide impact of concern is a dewatering of the aquifer. The short-term local impacts of concern include raising the water table close to the ground surface such that crops or manmade structures may be threatened, or lowering the aquifer water levels such that local water wells go dry and/or it costs more to pump water from the greater depths. The most frequent and greatest single impact of concern to landowners in Kern County is the increased cost to pump water wells due to manmade water level declines.

Permanent Water Level Impacts. By design and by requirement, the Strand Ranch Project must first put water into aquifer storage before it can recover any groundwater from storage. Moreover, since the Project is not allowed to borrow water from the basin, i.e., the project may not remove more water than its net current balance, the project will start with and always maintain a positive balance[5] relative to the basin. If we were to look only at the impact of

[5]Strictly speaking, the Project must maintain a non-negative balance, locally referred to as a “positive balance”, a condition

groundwater pumping, we would only see the impacts due to the extraction of groundwater. But in the context of the total project, it is clear that the project will only take water out of the basin that will have been previously put in so that the basin never has less water in storage than would have been there in the absence of the project.

According to the local MOUs, a project which directly recharges water for an out-of-county entity must permanently leave 5% of all such water in the ground. This volume of water is referred to as a *"loss to the basin"* and is a form of in-kind usage tax paid by all banking projects on all out-of-county water as a component of basinwide overdraft correction. For the Strand Ranch project it is likely that the great majority of all future stored and recovered water will be for the Irvine Ranch Water District which is an out-of-county entity. Therefore, this 5% loss to the basin may represent a significant volume of water. For example, if IRWD were to store and recover an average of 50,000 af every decade, then the cumulative losses paid to the basin would amount to 2,500 af per decade. This water is non-bankable and non-recoverable by IRWD. This "loss to the basin" represents a real, beneficial, cumulative, and permanent addition of water to the basin by the proposed Strand Ranch ASR project.

The permanent water level impacts are related to the project volumetrics. Over the long term, the addition and removal of like volumes of project water from the basin would result in no net cumulative change in basinwide water levels. However, as a result of the 5% losses paid to the basin, there will be a small, permanent rise in basinwide water levels. In the hypothetical case of adding an average 2,500 af per decade, the average long-term water level rise under the Kern Fan recharge area would be about 0.10 ft. This permanent water level rise is so small only because of the great size of the basin. Still, we conclude that even with the addition of significant amounts of water (2500 af/decade) to the basin, there is only a negligibly small but positive long term water level impact of the project on the basin.

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which is assumed to also include or allow the condition of zero balance.

Aquifer Dewatering. Since the proposed Strand Ranch project and other existing ASR projects must always maintain a positive balance relative to the basin, overall basin overdraft simply cannot occur as a result of direct-recharge ASR project operations. Never-theless, the potential still exists for an ASR project to dewater a portion of the aquifer if the location of groundwater recovery is in a completely different location and/or is completely isolated from the location of groundwater recharge. Such a condition might also exist if an ASR project includes in-lieu banking[6] operations which may have the effect of changing the time and location of recharge and/or recovery from when or where it would otherwise have occurred, perhaps causing an unbalanced groundwater extraction and local dewatering.

In the case of the proposed Strand Ranch project, both recharge and recovery facilities will be co-located on the project site such that the approximately equal and opposite impacts of both recharge and recovery will be superimposed on the same area and same aquifer zones. The requirement that the Strand Ranch project always maintain a positive balance relative to the basin precludes the potential dewatering impacts of in-lieu banking from occurring. Therefore, we conclude that conditions do not exist at the Strand Ranch site which could permit dewatering of the aquifer by these mechanisms.

The potential also exists for an ASR project to dewater a portion of the aquifer if the climatic wet/dry cycle causes, or if the ASR project operator chooses to operate, a severely unbalanced recharge and recovery cycle. For example, consider a hypothetical scenario in which an ASR project stored 50,000 af of water in the aquifer and then removed 47,500 af (50kaf net of 2.5 kaf losses to the basin) under the following conditions. Let us suppose that over a 7-year period, the Project stored, on average,10,000 af per year in each of five years for a total of 50,000 af of water in storage. For the duration of the wet period, the impact on the basin would be as if the project recharged at an average rate of 7,100 af per year. The

[6] In-lieu banking, as practiced in Kern County, includes the act of consuming bankable surface water instead of (in-lieu of) delivering it to ASR ponds for recharge and/or the act of delivering surface water from some alternate source to an end-user instead of (in-lieu of) pumping it out of groundwater storage. With these types of physical water movements it is possible to operate a banking program in which storage and/or recovery may occur without any water actually entering or leaving the aquifer, and such operations must be associated with bookkeeping transactions which move water credits between different accounts.

accumulation of a cumulative water supply in periodic, small increments is typical of the Kern County climatic cycle.

However, let us also suppose that after 3 critically dry years during which water levels declined and during which the water owners used up all of their other available sources of water, the project then extracted all 47,500 af in storage in a single year. This recovery rate is over 6 times higher than the average recharge rate and since impacts are proportional to rates, recovery may be expected to produce drawdown impacts that may be six times greater in magnitude than the beneficial impacts of recharge. We call this an unbalanced recharge/ recovery cycle because the rate of recharge and the rate of recovery are so different.

The impacts of such an unbalanced recharge/recovery cycle cannot be fully evaluated without specifying all of the actual aquifer parameters, but for the aquifer underlying the Kern Fan, there is every likelihood that the unbalanced groundwater extraction could dewater at least the shallow zone of the aquifer. This water level drawdown, like other drawdowns, is local and temporary and will re-equilibrate with time. In this hypothetical case, however, the magnitude of this individual drawdown episode is of sufficient magnitude to temporarily dewater the aquifer which might be of sufficient concern to establish other limiting criteria on an individual impact event.

The foregoing hypothetical example of multi-year climatic wet or dry cycles is based on the actual wet/dry cycles that Kern County has experienced since 1960, and particularly since 1995 when major water-banking operations began in Kern County. In the future, if such a climatic wet/dry cycle causes several ASR projects on the Kern Fan to operate unbalanced recharge and recovery cycles at the same time, then the composite impacts of all such operations may dewater much of the Aquifer under the Kern Fan for a considerable time period until an equilibration of basinwide proportions can take place.

In the case of the proposed Strand Ranch project, the operators have voluntarily established operating limits which preclude the occurrence of an unacceptable, unbalanced recharge/recovery cycle. The project is voluntarily designed so that 1. the Strand Ranch project will not have more than 50,000 af of water in basin storage, and 2. the project will not recharge or recover more than a maximum of 17,500 af of groundwater per year during normal operations. The computer models of both recharge and recovery have demonstrated that by capping the maximum inflow/outflow at 17,500 af/yr, that 1. the beneficial impacts of recharge are approximately equal to the potentially detrimental impacts of recovery, and 2. by spreading the recovery of the maximum allowable volume of water in storage over a 3-year period the individual and combined net impacts of the total operation avoids and prevents unacceptable extreme impacts to the aquifer and the basin.

Temporary Water Level Impacts. The impact of recharge is a temporary, local rise in water levels and the impact of recovery is a temporary, local drop in water levels. ASR projects usually operate by putting water into the ground in a wet year and then recovering it as needed in some future dry year, so there is little likelihood of recharge and recovery happening simultaneously. The two potential temporary impacts of concern include the decline in water levels due to project pumping and a rise in the water table up to the ground surface due to project recharge. A manmade water level drawdown increases the vertical distance that groundwater must be lifted and therefore increases the cost to pump a well over what would otherwise have occurred. A standing water table within a few feet of the ground surface creates potentially adverse impacts to many types of crops and to the foundations of manmade structures including building and/or tower foundations, roads, and lined and unlined canals, ponds, and ditches.

Water Level Declines. Since the Strand Ranch project is fundamentally designed to store and recover like volumes of water within the same project area, at similar rates, and at different times but over periods of similar duration, the expected impacts from recharge and then recovery are approximately equal and opposite. This is not to say that the recharge impacts and recovery impacts therefore "cancel" each other out, especially since they impact somewhat different aquifer zones, occur separately in time and not simultaneously, and perhaps under different types of pre-existing conditions. Nevertheless, the local MOUs have made a provision (rule 4) that the beneficial impacts from recharge may be taken into consideration if and when it is necessary to consider mitigating the detrimental drawdown impacts of pumping. To the extent that this is an agreed-upon local principle which has been established among the participants of the banking project MOUs, then we can evaluate the potential drawdown impact by evaluating the cumulative net impact within the context of the total Strand Ranch project impact.

As previously discussed, the project has been designed so that the maximum expected recharge or recovery volumes are both equal to 17,500 af/yr and the total volume might be 50,000 af every decade. The expected project recharge rates range from 90 - 150 af/d and the expected recovery rates range from 50 - 90 af/d. Since the expected recharge rates are slightly higher than the expected recovery rates, the project will be in recharge 10 - 15% of the time, in recovery 15 - 20% of the time, and idle 65 - 75% of the time. Since we do not know in advance what the actual aquifer parameters will be, we can predict a least-favorable impact scenario by assuming minimum recharge rates and maximum recovery rates. For the Strand Ranch project, this would be a recharge scenario of storing 17,500 af in the aquifer at a rate of 90 af/d for 194 days (194.4 days to be exact) and a recovery scenario of pumping 17,500 af from the aquifer, coincidentally, also at a rate of 90 af/d for 194 days.

Based on the computer modeling, the transient water table mound is comparable in shape, magnitude, and duration to the cone of depression due to pumping but of opposite sense, i.e., rising-then-falling water levels rather than falling-then-rising water levels. All else, equal, if we consider a drop in water levels due to pumping to be a negative impact then we may consider a rise in water levels due to recharge to be a positive impact. The question is therefore, If the cycle of recharge and recovery operations causes both positive and negative water level changes of comparable size and duration, then can we say that there is little or no net impact on water wells in the area?

The local MOU provides for such consideration. Based on one possible interpretation of "rule 4" of the MOU, one foot of daily water level rise due to project recharge may be considered as a possible mitigation of one foot of daily water level decline due to project pumping. If we apply such an interpretation to the total net impact from the Strand Ranch "least-favorable" hypothetical scenario, then there may be a near-project, maximum overall -6 to -7 ft temporary decline in water levels which remains uncompensated by any equivalent water level rise. Such an uncompensated, temporary water level decline might exist in 2 years out of ten in each of the eight sections surrounding the project. In all more-favorable, hypothetical, scenarios (with higher-than-minimum recharge rates and/or lower-than-maximum recovery rates) the total net impact from project recharge and recovery operations is calculated to be nearly completely balanced or actually to have created a net positive mitigation in excess of the total temporary drawdown at all locations in all surrounding sections, depending on the specific scenario (Tables 7, 8).

Near-surface Water Levels. A hypothetical standing water table within a few feet of the ground surface creates potentially adverse impacts to many types of crops and to the foundations of manmade structures including building and/or tower foundations, roads, and lined and unlined canals, ponds, and ditches. Within a year or two, row crops and almond trees will no longer exist on the Strand Ranch so there will be no possible agricultural impact from a shallow water table under the Strand Ranch. The only structure of concern which will remain on or near the Strand Ranch project site is the KCWA Cross Valley Canal that might be impacted by a shallow water table. The KCWA operates a monitoring program using an array of shallow piezometers along the Cross Valley Canal (CVC) to monitor water levels for potential conditions of concern.

In 2006, the Strand Ranch constructed and operated a pilot recharge facility on the site. As it so happened, the water table in 2006 was already within 1 - 2 ft of the ground surface on the Strand Ranch due to extended, large-volume, recharge operations on the Kern Fan by other project operators. This very shallow standing water table was already being monitored for potential impacts to the CVC. The constructors of the pilot-test recharge ponds encountered the water table when they excavated about 3 ft deep into the shallow sediment to make the ponds. When excavation was completed, the site had standing water along the new pond levees[7] from the presence of the very shallow water table. The pilot recharge test lasted about 5 months (mid-July - mid-December, 2006) and stored approximately 3,000 af in the ground. This recharge did not serve to raise the pre-existing water table since it was already at the ground surface but it extended by some undetermined amount, the length of time required for the shallow strata to dewater after recharge on the Kern Fan stopped. During this entire period, the KCWA did not issue any requests for mitigation or notices of observed impacts to the CVC, as far as we know.

The proposed operation of the Strand Ranch project is of sufficiently small recharge volume that it cannot threaten to create such a shallow water table unless a project recharge episode between about 10 - 17.5 kaf occurs at a time when the pre-existing water table is already less than about 30 ft deep due to other causes. Such a pre-existing, shallow water table

[7] Robert Coffee, RRBWSD operations manager, verbal communication, November, 2007.

has only occurred twice since 1960 (1999 and 2006) and will not recur unless and until a multi-year climatic wet period creates sufficient surface water supplies to re-fill the Kern Fan recharge mound. Based on the experience of 2006, we conclude that a shallow water table can exist under the Strand Ranch property without necessarily observing any adverse impacts, at least not necessarily regarding mitigation for the durations of shallow table table of a year or less. Nevertheless, a monitoring program is already in place which specifically tests for conditions which might have a potentially adverse impact on the Cross Valley Canal.

Summary of Project Impact Findings.

Basinwide, Permanent Impact. The proposed Strand Ranch ASR project operation is designed to always maintain a positive project balance, i.e., a volume of water must always be stored in the aquifer prior to removing a like volume from the aquifer. The long-term basinwide water level impact from the project is a negligibly small rise in overall water levels due to the MOU-required permanent addition of a few thousand acre-feet of overdraft correction water to the basin over the project life. There is no possibility of overdraft or aquifer dewatering under any proposed Strand Ranch scenario.

Local, Temporary Mounding Impact. The project has the potential to temporarily raise the local water table a maximum of 30 to 40 ft under the project site and 6 to 14 ft in the surrounding eight sections due to project recharge operations. The water level rise only lasts for the duration of recharge and begins to re-equilibrate to its previous level when recharge ceases. Such a rise in water levels is considered to be beneficial except, perhaps, if the water table rises so high that it rises up to or close to the ground surface under the project site only if the pre-existing water table is already very shallow due to non-project causes. This condition is unlikely and mitigation monitoring already exists on the project site. One such episode occurred during a pilot recharge test in 2006 and no adverse impacts were observed or reported in the area.

Local, Temporary Drawdown Impact. The project has the potential to temporarily lower the local water levels a maximum of -24 to -43 ft under the project site and a maximum of -7 to -20 ft at operating non-project water well locations in the vicinity of the project. These temporary, localized impacts can occur even though there is a continuous, permanent, long-term, net increase in the total amount of water left in the basin. Such a temporary lowering of water levels lasts only as long as pumping lasts plus a recovery period. Such a drawdown is considered to be an undesirable impact because a non-project operating well would experience a higher lifting cost to pump water than would be the case in the absence of project pumping. However, this impact may be mitigated by the beneficial impacts of mounding as summarized below.

Compensated Net Local, Temporary Project Impacts. As previously discussed, the positive impact of recharge mounding fully compensates for recovery drawdown in all except the "least-favorable" case of a recharge/recovery cycle at minimum recharge rates and maximum recovery rates. In this one case, the maximum uncompensated net temporary drawdown in the surrounding eight sections is in the range of -6 to -7 ft. All other, more-favorable, scenarios result smaller net water level declines and/or net water level rises at all locations surrounding the project site for comparable time periods.

Comparative Project Impacts. The local project mounding and drawdown water-level impacts are small, local, and temporary relative to the 100+ ft magnitude of the historically observed water level fluctuations due to the climatic wet/dry cycle. The impacts of the proposed Strand Ranch Project are also small relative to the scale of impacts due to some other banking project and district operations on the Kern Fan and in Kern County which store and recover larger water volumes at higher rates. The project mounding and drawdown impacts are temporary; for example, the drawdown impacts from one seasonal pumping cycle will fully equilibrate prior to the beginning of the next seasonal pumping cycle. The project impacts are local in the sense that there is no significant water-level impact beyond 1 - 1.5 miles from the project site.

4. References.

<u>local work products</u>

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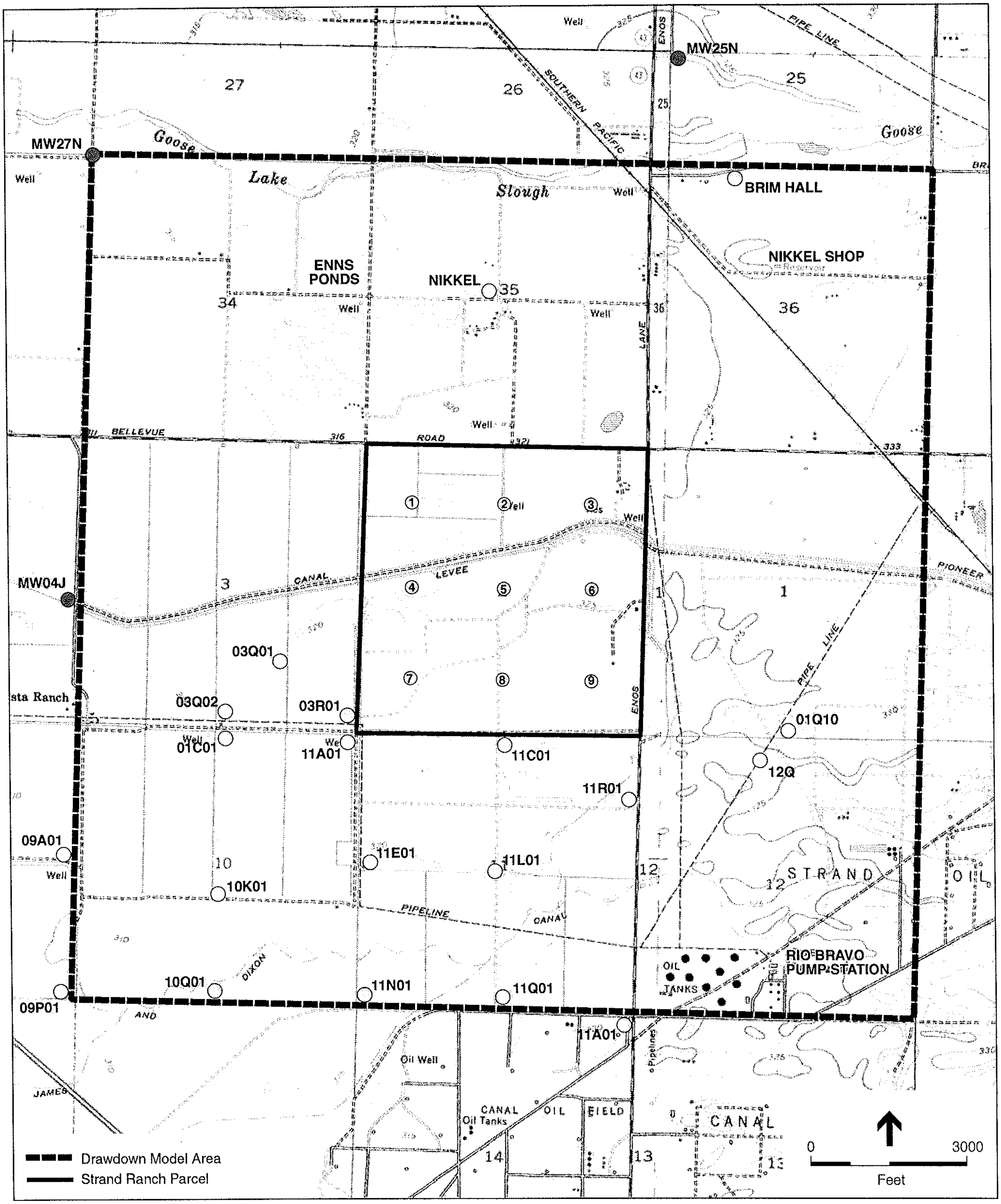
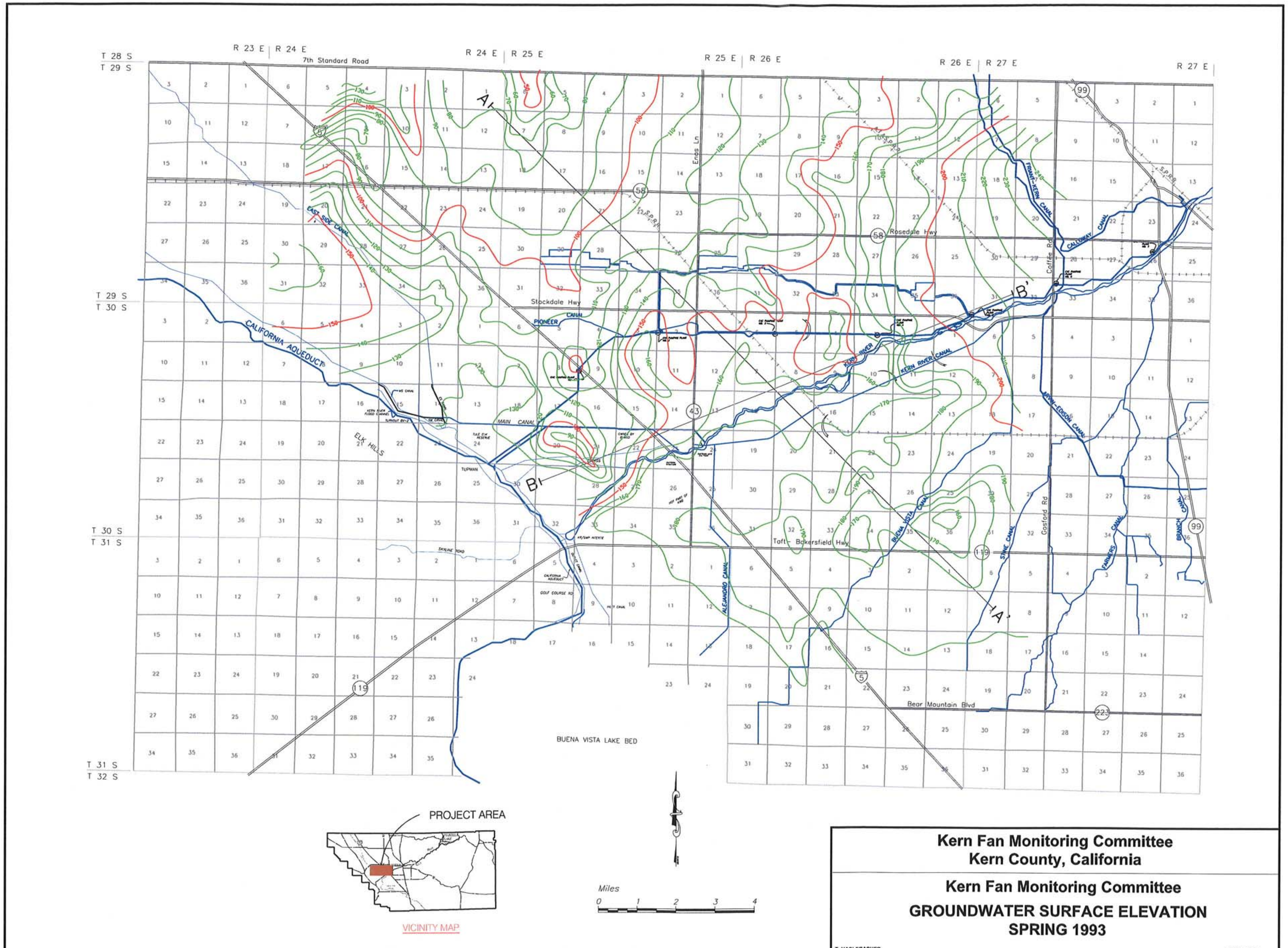
Figures.



SOURCE: USGS; ESA, 2007.

Irvine Ranch Water District . 205426

Figure 1
Project Location



Kern Fan Monitoring Committee
Kern County, California

Kern Fan Monitoring Committee

GROUNDWATER SURFACE ELEVATION
SPRING 1993

T. HASLEBACHER

APRIL, 1993

FIG 2

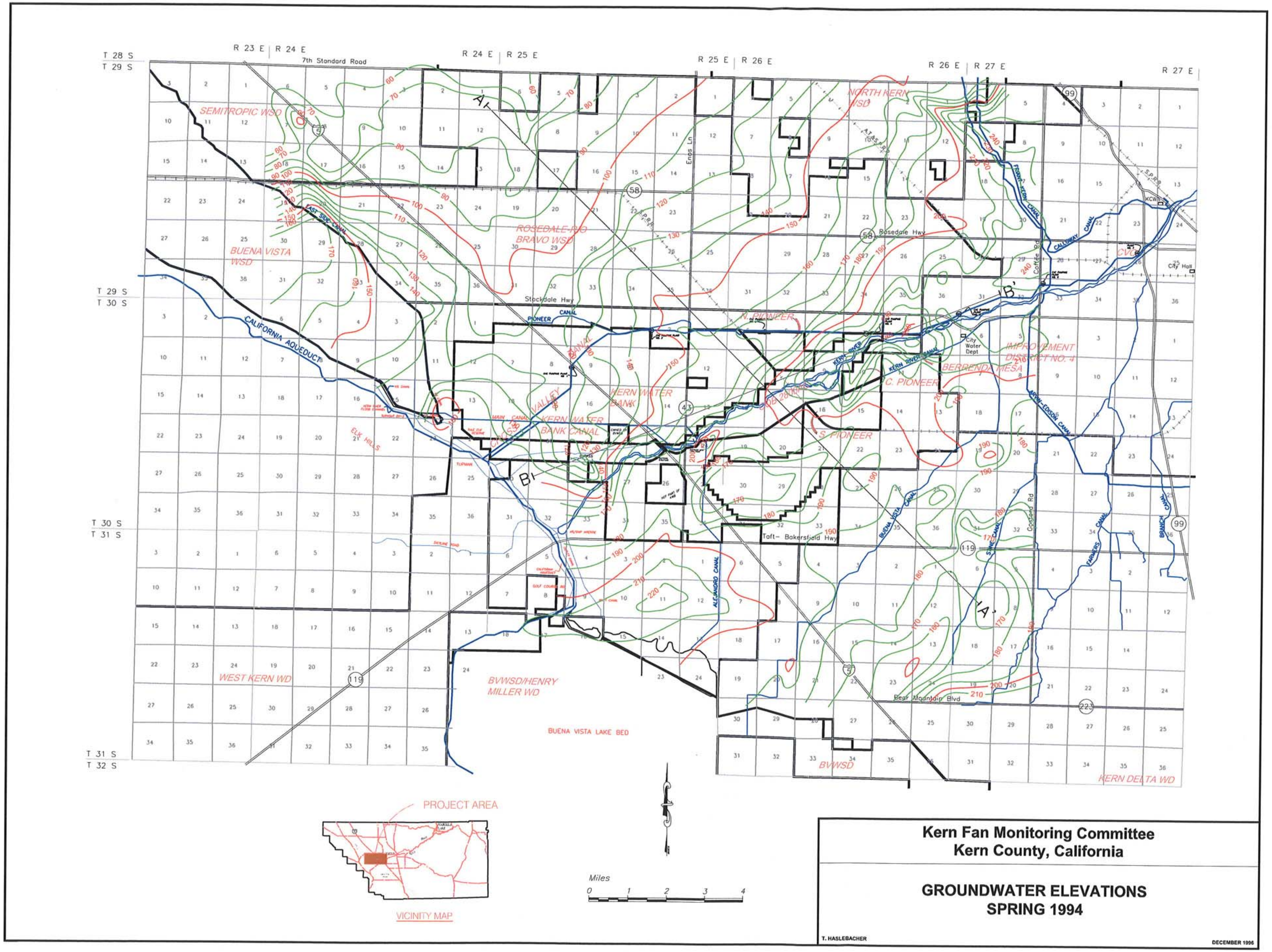

Kern Fan Monitoring Committee
Kern County, California
GROUNDWATER ELEVATIONS
SPRING 1994
T. HASLEBACHER
DECEMBER 1996
PROJECT AREA
VICINITY MAP
Miles
0 1 2 3 4
SEMITROPIC WSD
NORTH KERN WSD
ROSEDALE-RIO BRAVO WSD
BUENA VISTA WSD
KERN WATER BANK
N. PIONEER
C. PIONEER
S. PIONEER
IMPROVEMENT DISTRICT NO. 4
BERRENDA MESA
CVC
ELK HILLS
WEST KERN WD
BVWSD/HENRY MILLER WD
BUENA VISTA LAKE BED
BVWSD
KERN DELTA WD
CALIFORNIA AQUEDUCT
PIONEER CANAL
KERN WATER BANK CANAL
CROSS VALLEY CANAL
EAST SIDE CANAL
FRIANT-KERN CANAL
CALLOWAY CANAL
ARVIN-EDISON CANAL
BUENA VISTA CANAL
ALEJANDRO CANAL
FARMERS CANAL
BRANCH CANAL
KERN RIVER
7th Standard Road
Rosedale Hwy
Stockdale Hwy
Taft- Bakersfield Hwy
Bear Mountain Blvd
Enos Ln
Gosford Rd
Coffee Rd
City Hall
City Water Dept
KCWA
T 28 S
T 29 S
T 30 S
T 31 S
T 32 S
R 23 E
R 24 E
R 25 E
R 26 E
R 27 E

FIG 3

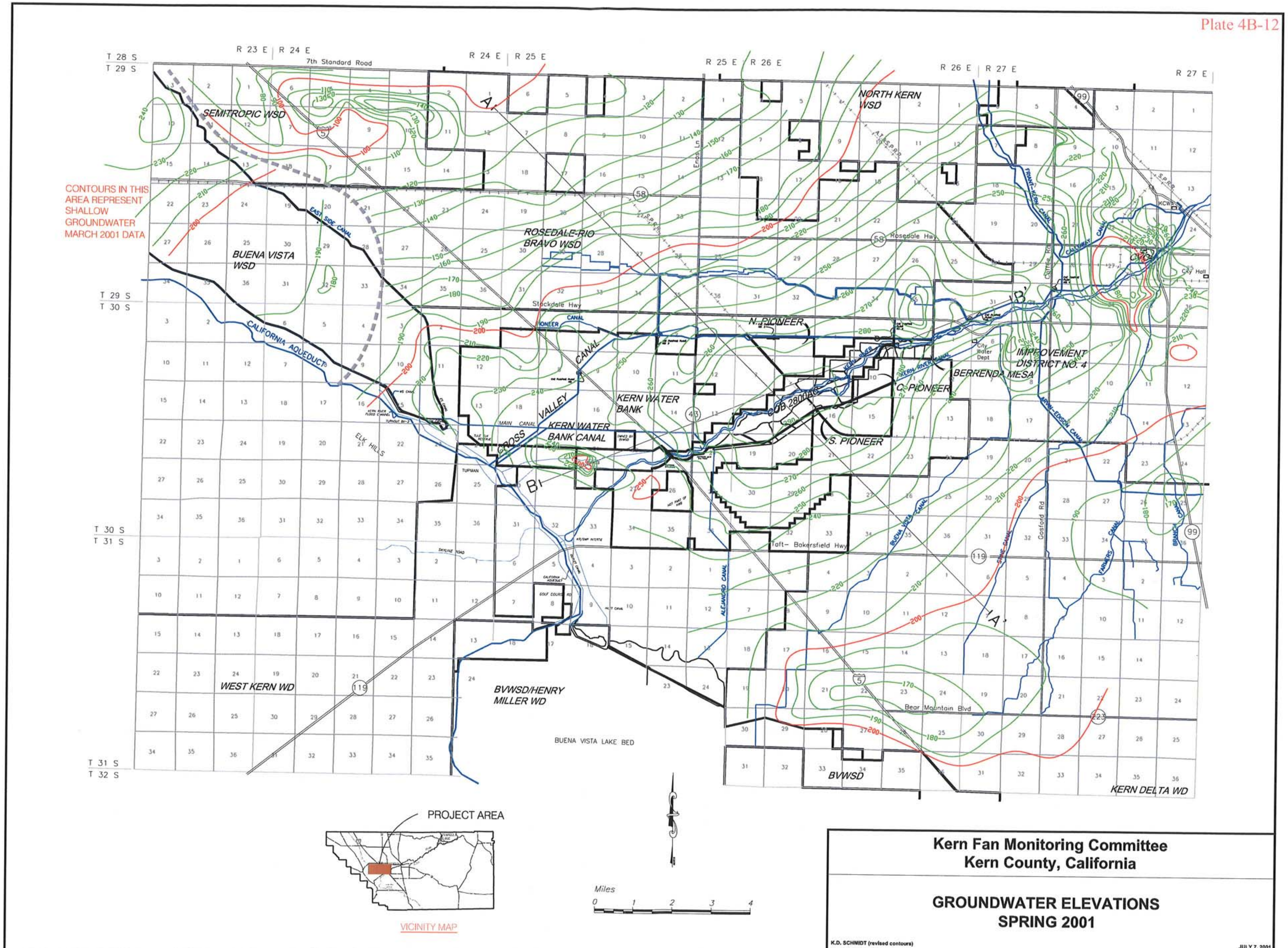
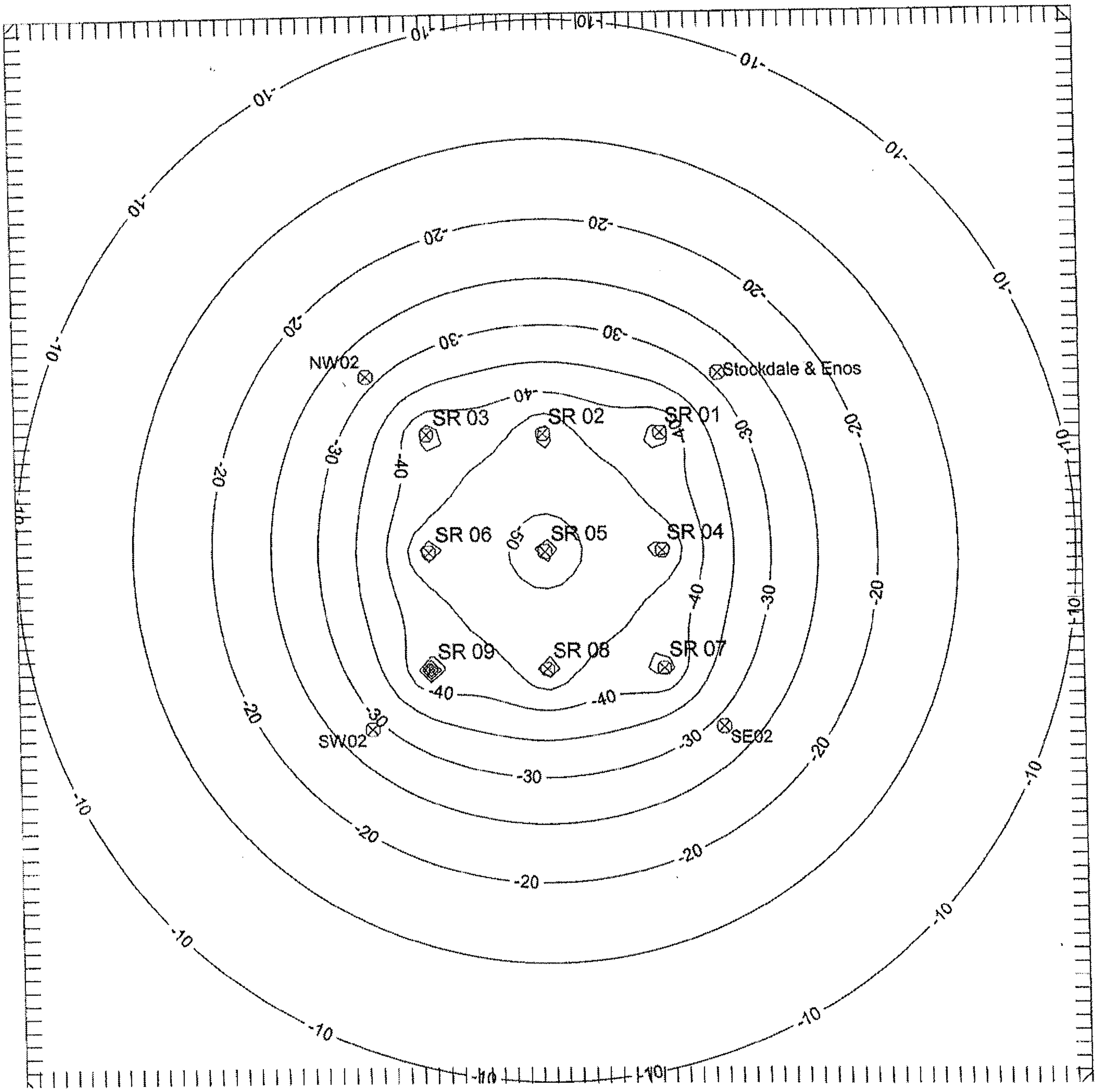

CONTOURS IN THIS AREA REPRESENT SHALLOW GROUNDWATER MARCH 2001 DATA
SEMITROPIC WSD
BUENA VISTA WSD
ROSEDALE-RIO BRAVO WSD
NORTH KERN WSD
KERN WATER BANK
CROSS VALLEY CANAL
KERN WATER BANK CANAL
N. PIONEER
C. PIONEER
S. PIONEER
BERRENDA MESA
IMPROVEMENT DISTRICT NO. 4
CALIFORNIA AQUEDUCT
EAST SIDE CANAL
ELK HILLS
WEST KERN WD
BVWSD/HENRY MILLER WD
BUENA VISTA LAKE BED
BVWSD
KERN DELTA WD
7th Standard Road
Rosedale Hwy
Stockdale Hwy
Taft-Bakersfield Hwy
Bear Mountain Blvd
Gosford Rd
City Water Dept
PROJECT AREA
VICINITY MAP
Miles
0 1 2 3 4
T 28 S
T 29 S
T 30 S
T 31 S
T 32 S
R 23 E
R 24 E
R 25 E
R 26 E
R 27 E
Kern Fan Monitoring Committee
Kern County, California
GROUNDWATER ELEVATIONS
SPRING 2001
K.D. SCHMIDT (revised contours)
T. HASLEBACHER
JULY 7, 2001
MAY, 2001

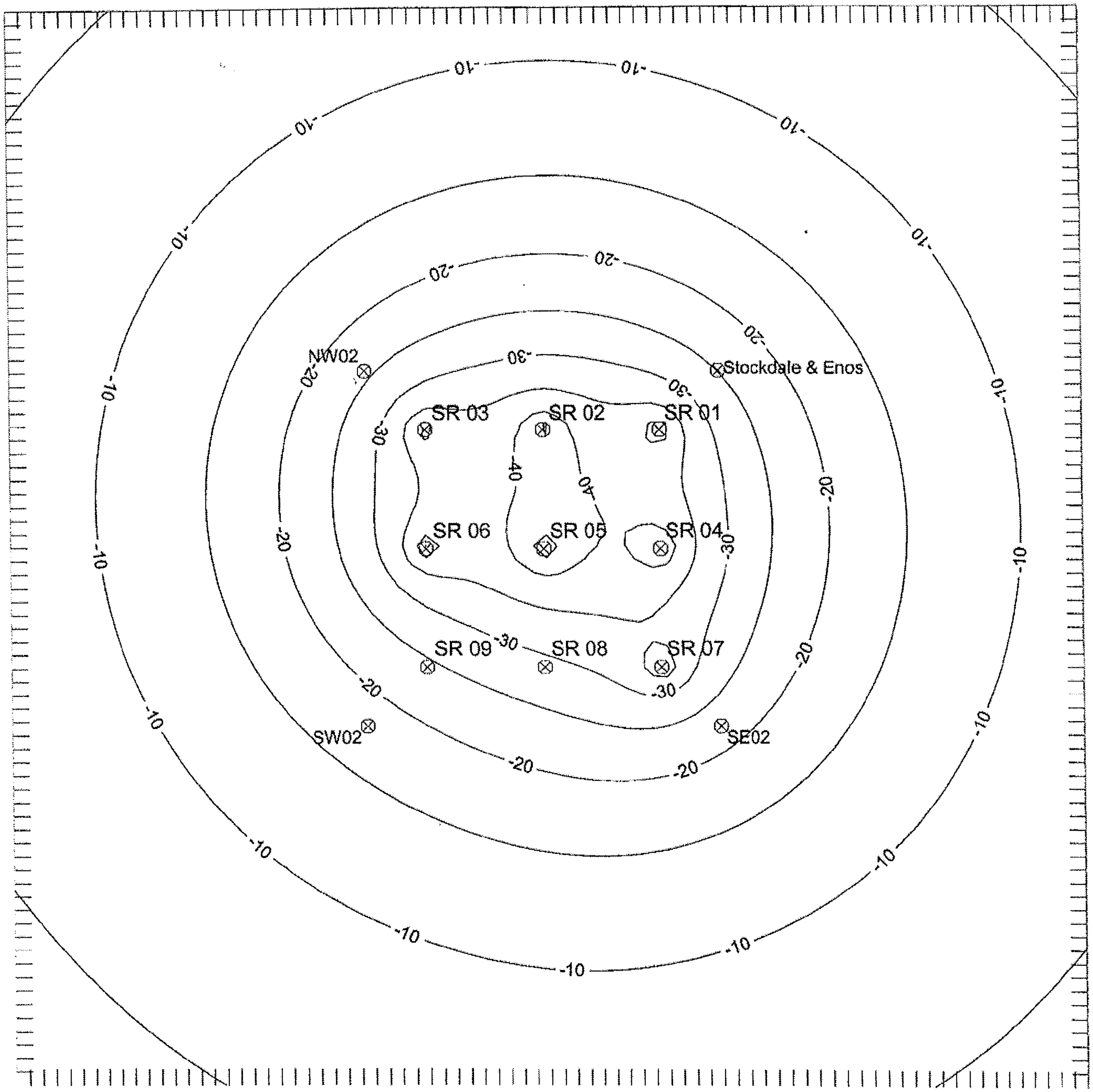
FIG 4



SOURCE: Geomatrix, 2007.

Irvine Ranch Water District . 205426

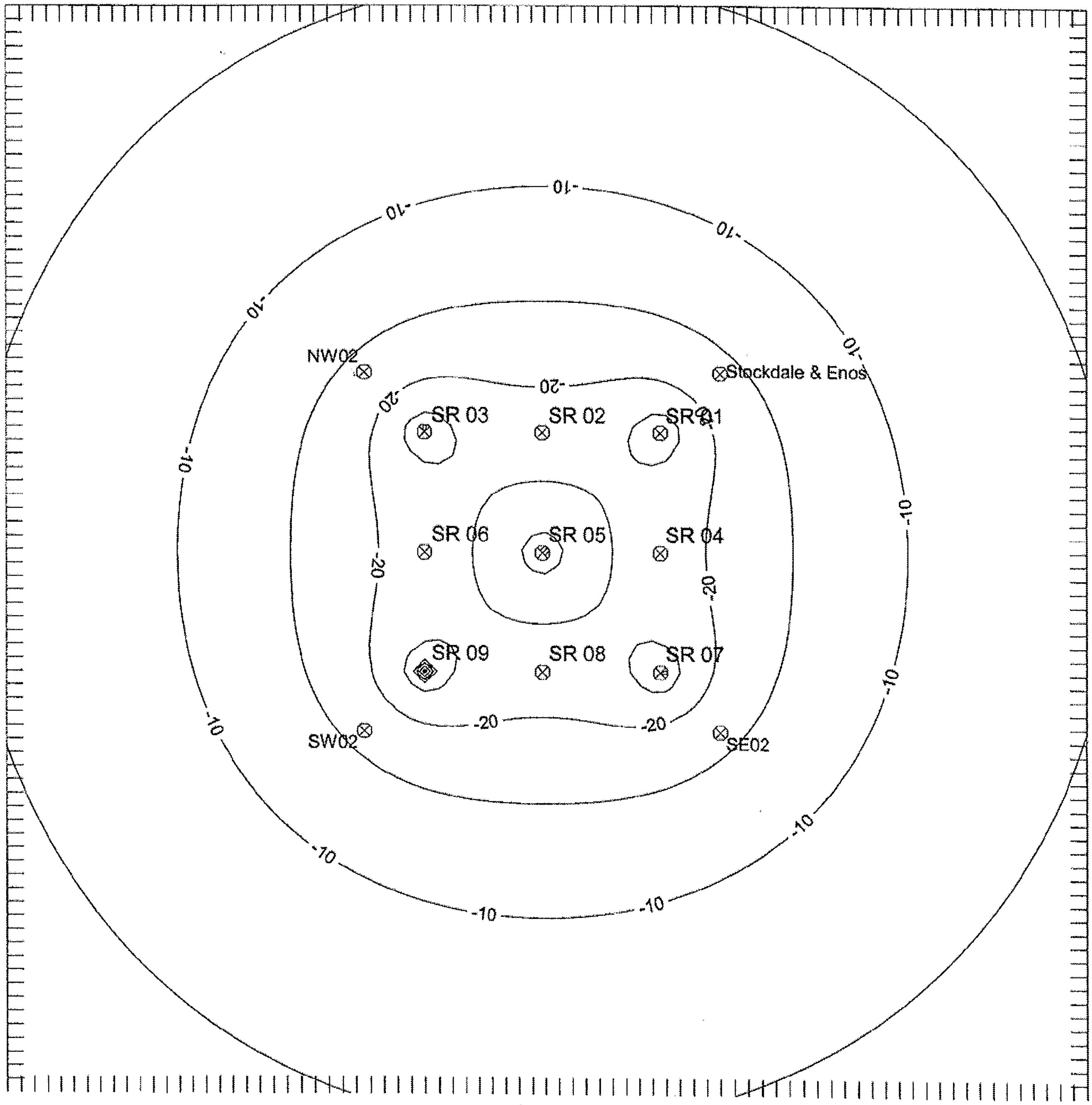
Figure 5
Predicted Water Level Drawdown Map,
9-Well Scenario (Wells 1-9),
Base Case Aquifer Parameters



SOURCE: Geomatrix, 2007.

Irvine Ranch Water District . 205426

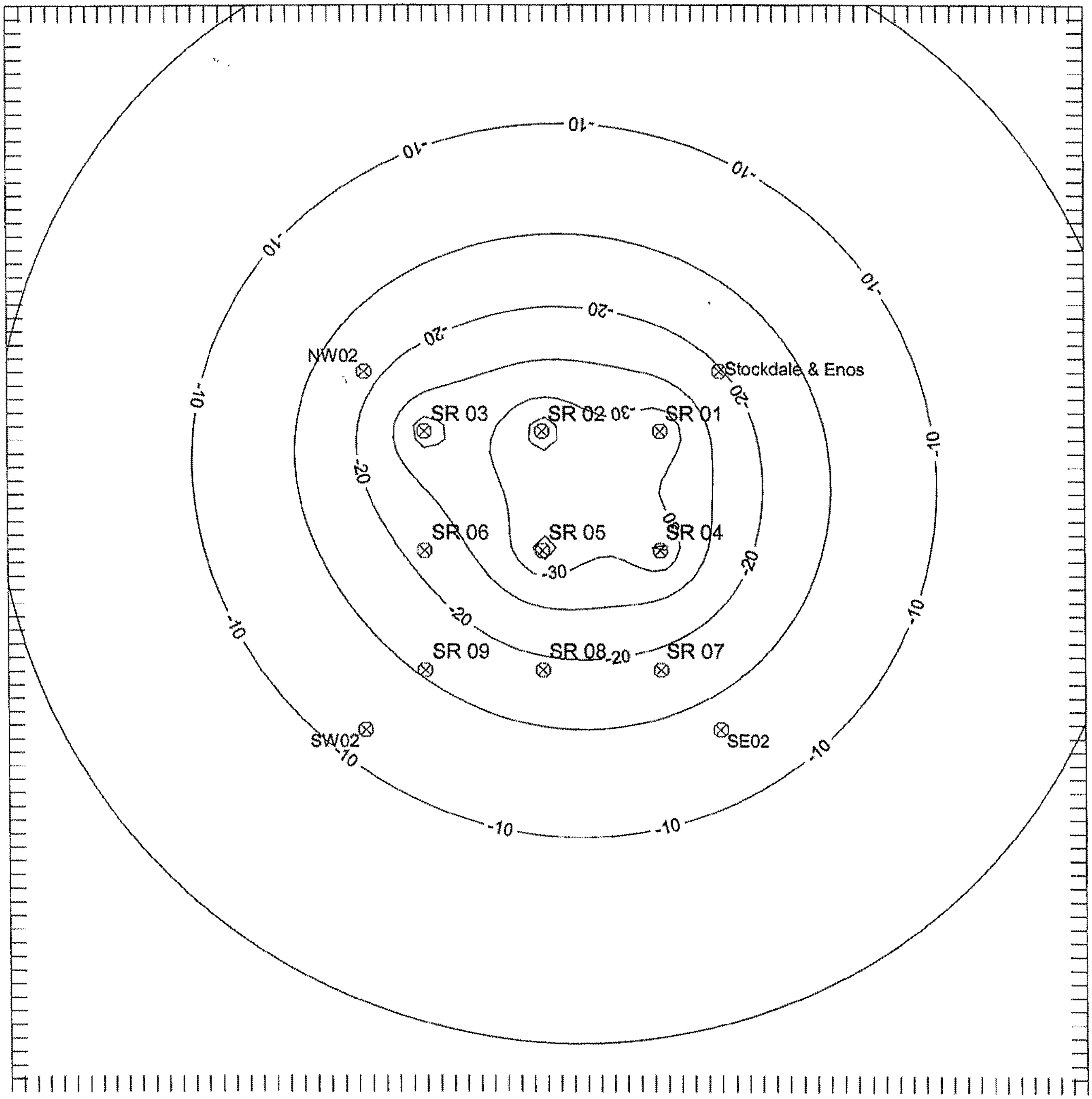
Figure 6
Predicted Water Level Drawdown Map, 7-Well Scenario (Wells 1-7), Base Case Aquifer Parameters



SOURCE: Geomatrix, 2007.

Irvine Ranch Water District . 205426

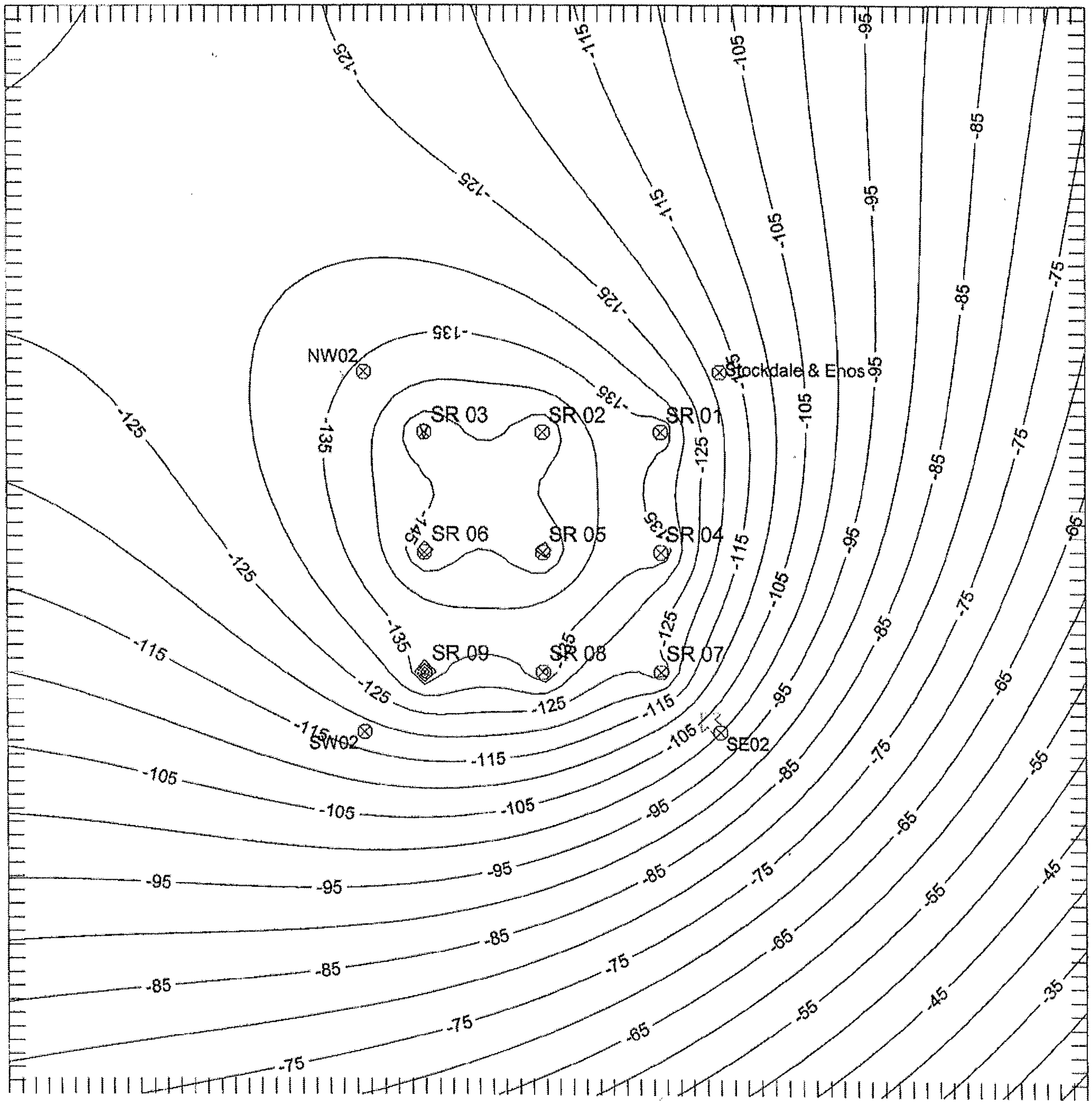
Figure 7
Predicted Water Level Drawdown Map,
5-Well Scenario (Wells 13579),
Base Case Aquifer Parameters



SOURCE: Geomatrix, 2007.

Irvine Ranch Water District . 205426

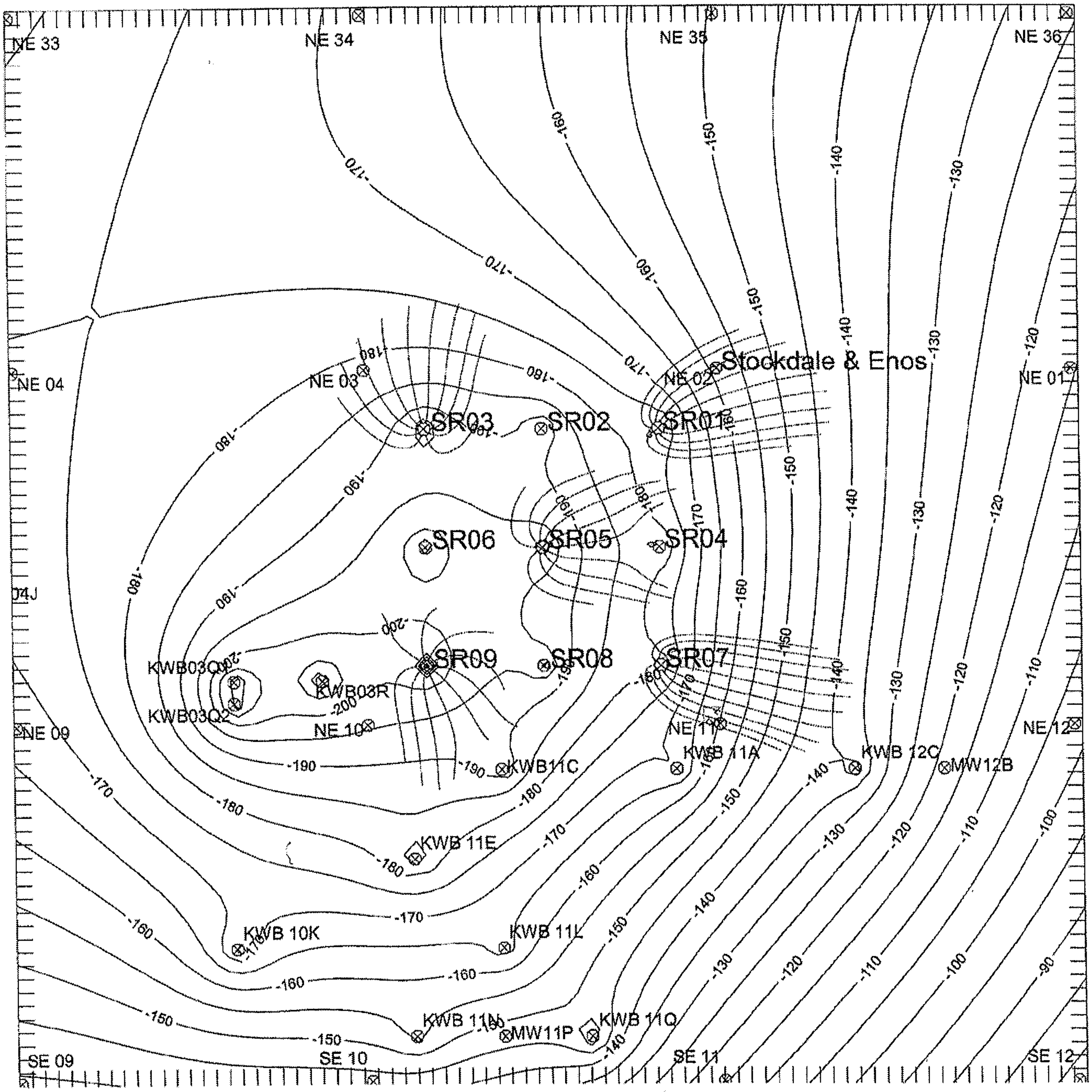
Figure 8
Predicted Water Level Drawdown Map,
5-Well Scenario (Wells 12345),
Base Case Aquifer Parameters



SOURCE: Geomatrix, 2007.

Irvine Ranch Water District . 205426

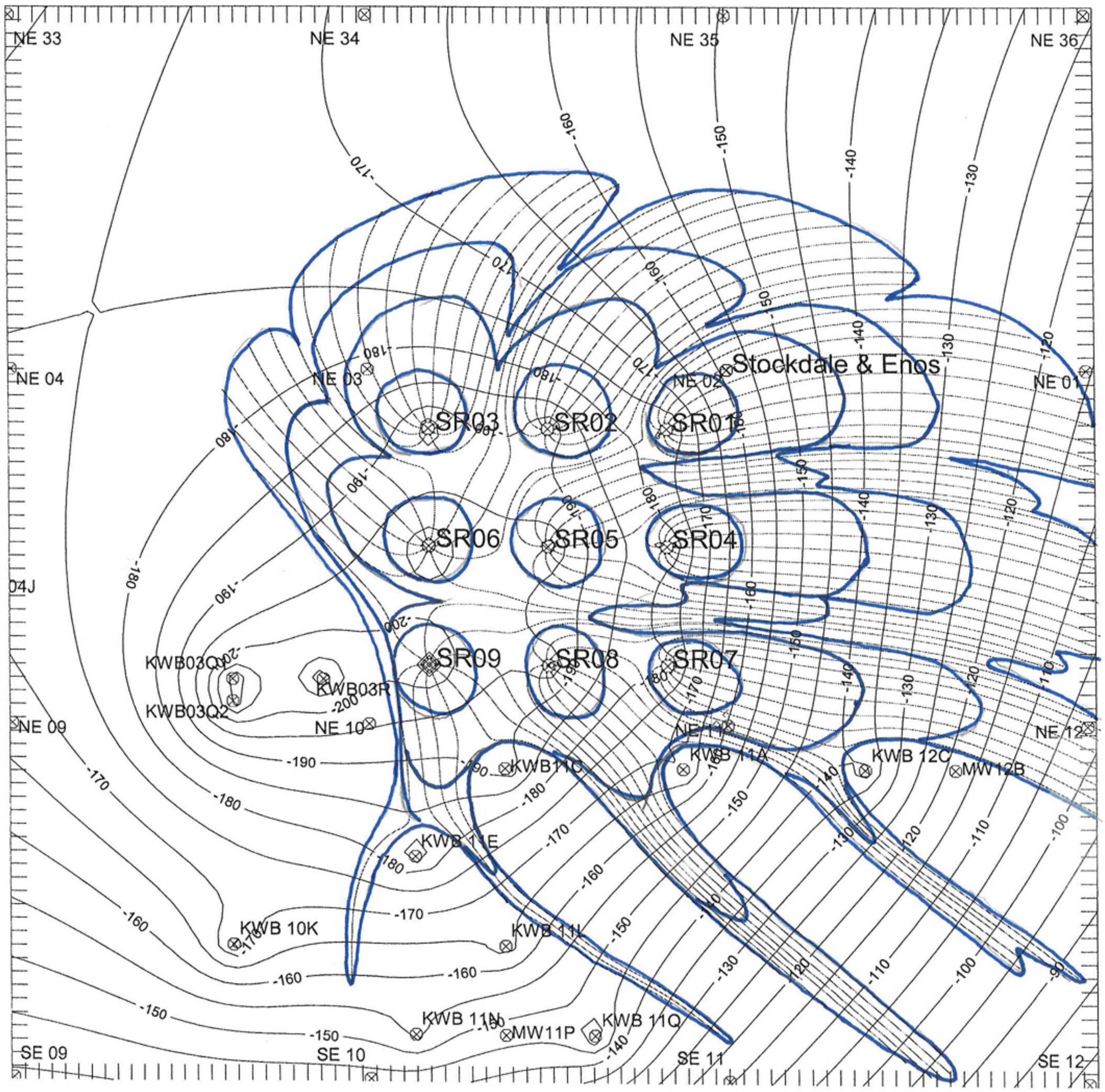
Figure 9
Predicted Water Level Elevation Map,
9-Well Scenario (Wells 1-9),
Base Case Aquifer Parameters with Wet-Year Groundwater Gradient



SOURCE: Geomatrix, 2007.

Irvine Ranch Water District . 205426

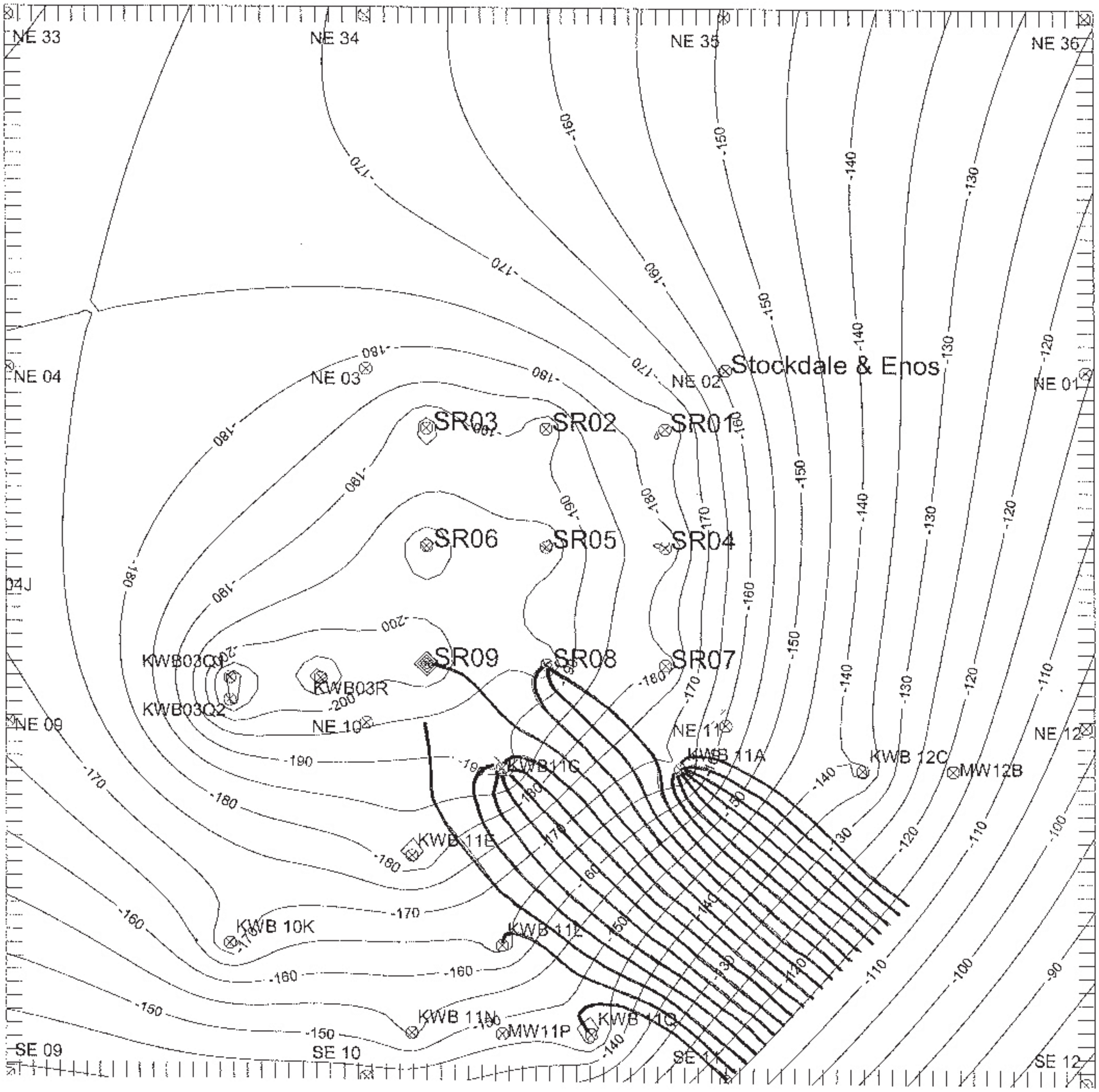
Figure 10
Predicted Water Level Elevation Map,
20-Well Scenario (Wells 1-9 and KWB Wells 1-11),
Base Case Aquifer Parameters with Wet-Year Groundwater Gradient



SOURCE: Sierra Scientific Services, 2007

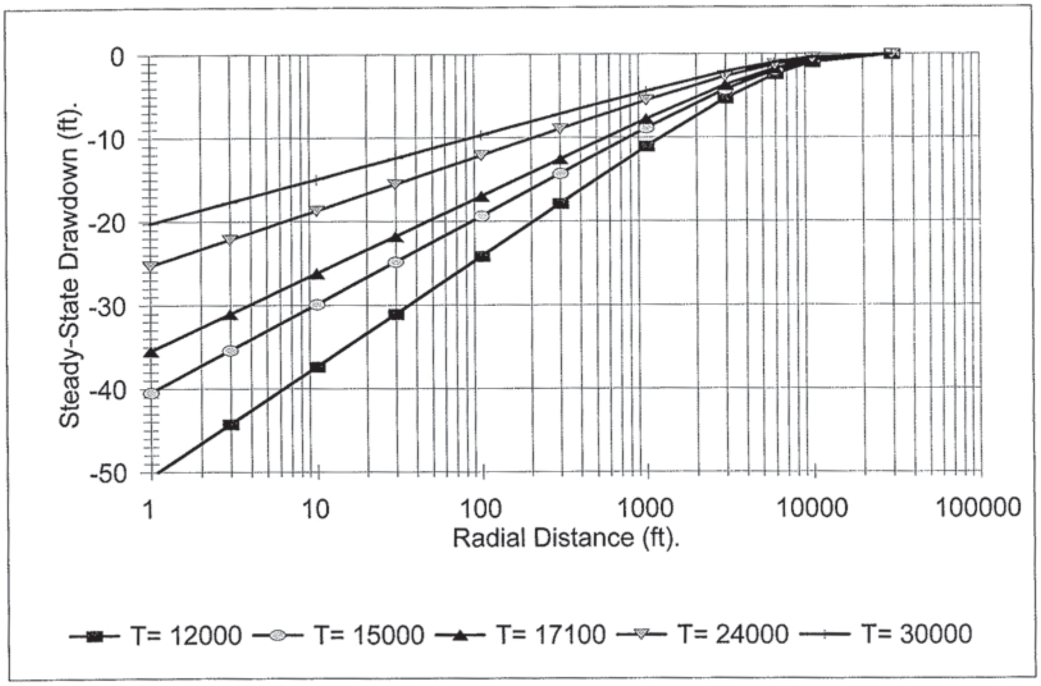
Irvine Ranch Water District . 205426

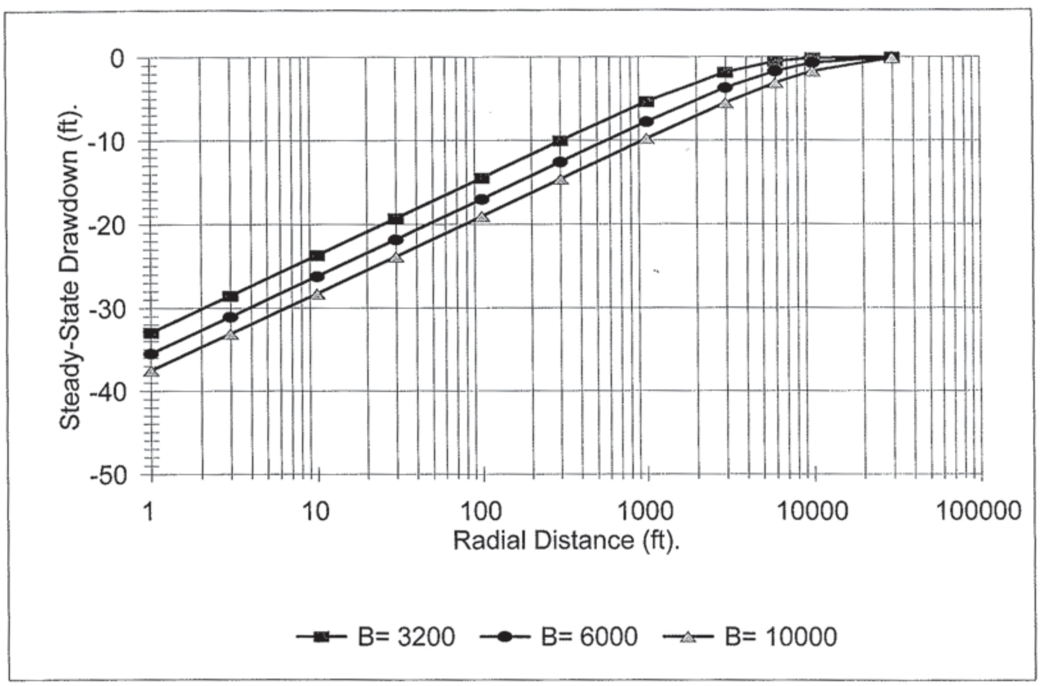
Figure 11
Particle Trajectory and Capture Zone Perimeter Map;
t = 300, 1000, 1825, and 3650d



SOURCE: Sierra Scientific Services, 2007

Figure 12
Particle Trajectory Map;
Hypothetical Contaminant Source in
Sec 02, T30s, R25e

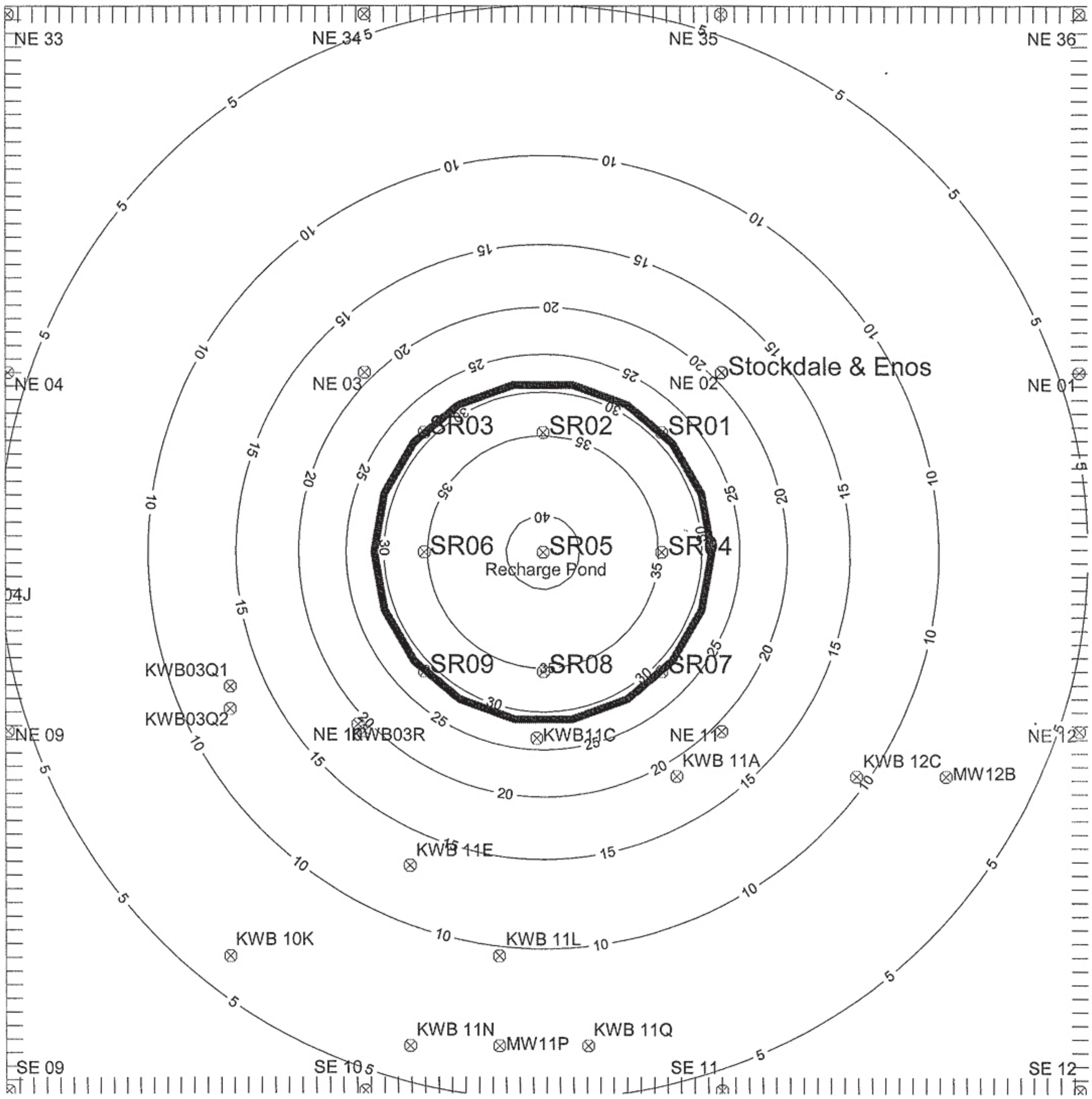




SOURCE: Sierra Scientific Services, 2007

Irvine Ranch Water District . 205426

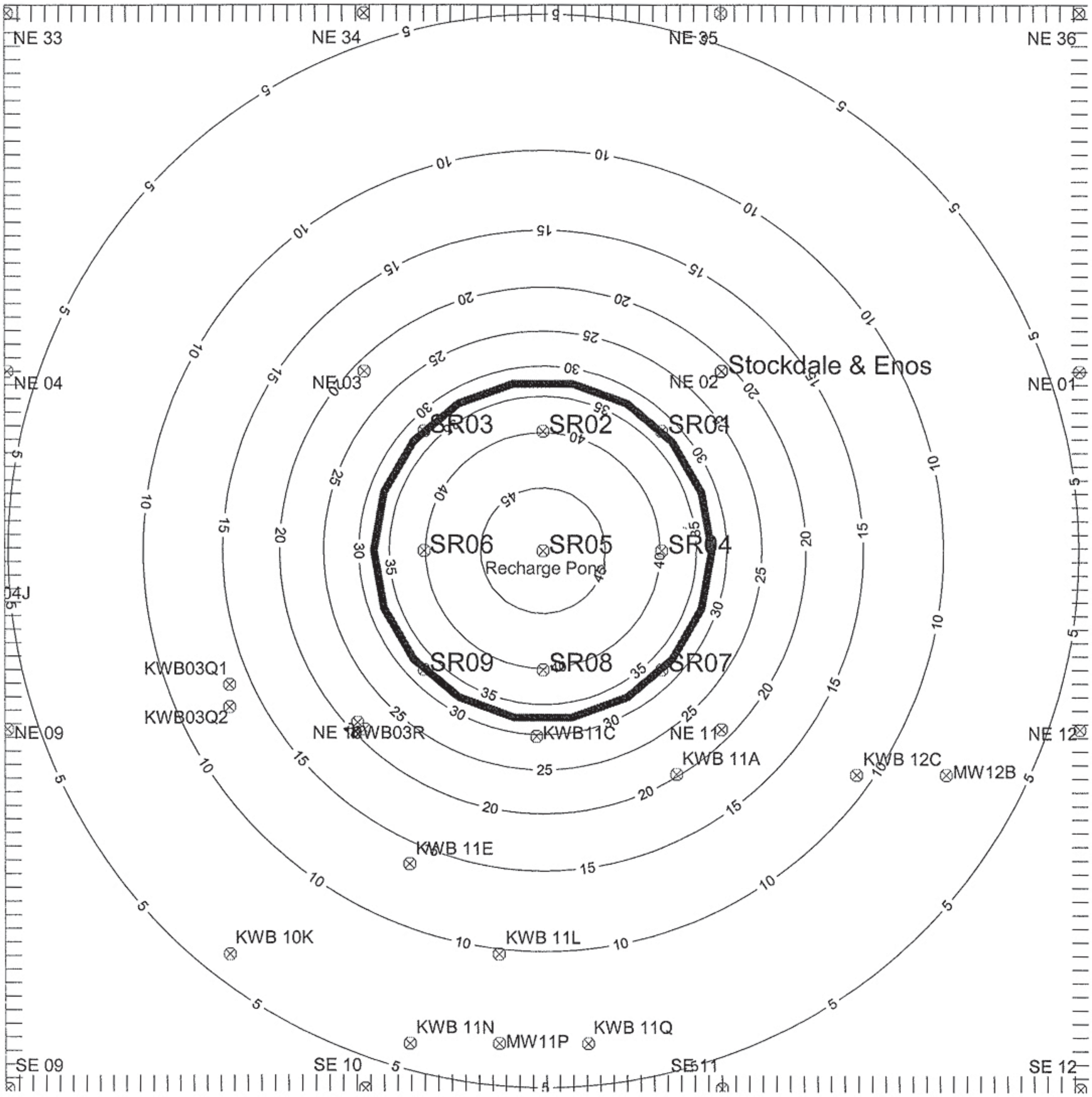
Figure 13
Strand Ranch Base Case Sensitivity Analysis
Steady-State Drawdowns for
Variations in T or B



SOURCE: Sierra Scientific Services, 2007

Irvine Ranch Water District . 205426

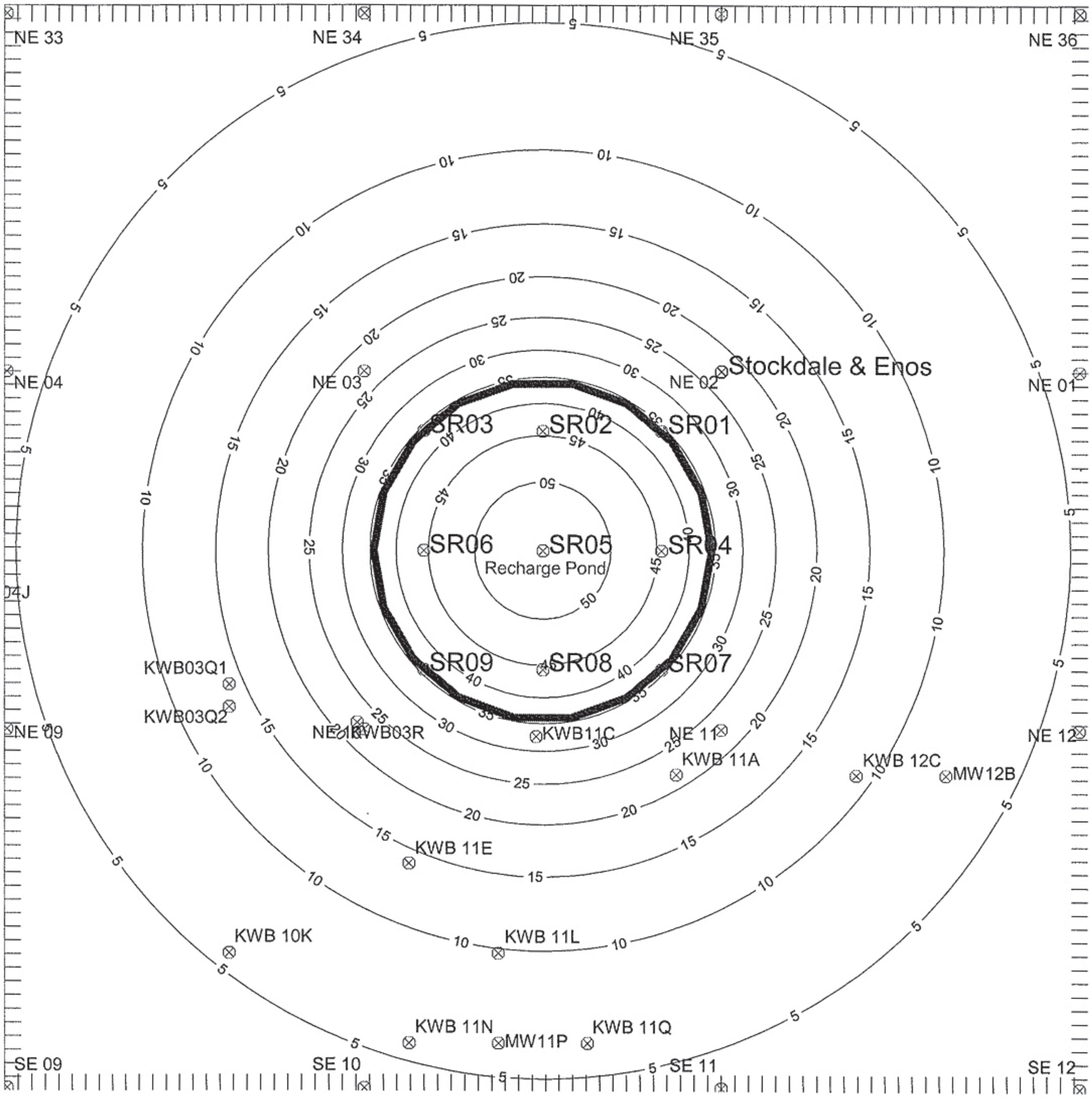
Figure 14
Water Level Rise Map,
Pond Recharge at IR = 0.20,
Base Case Aquifer Parameters



SOURCE: Sierra Scientific Services, 2007

Irvine Ranch Water District . 205426

Figure 15
Water Level Rise Map,
Pond Recharge at IR = 0.25,
Base Case Aquifer Parameters



SOURCE: Sierra Scientific Services, 2007

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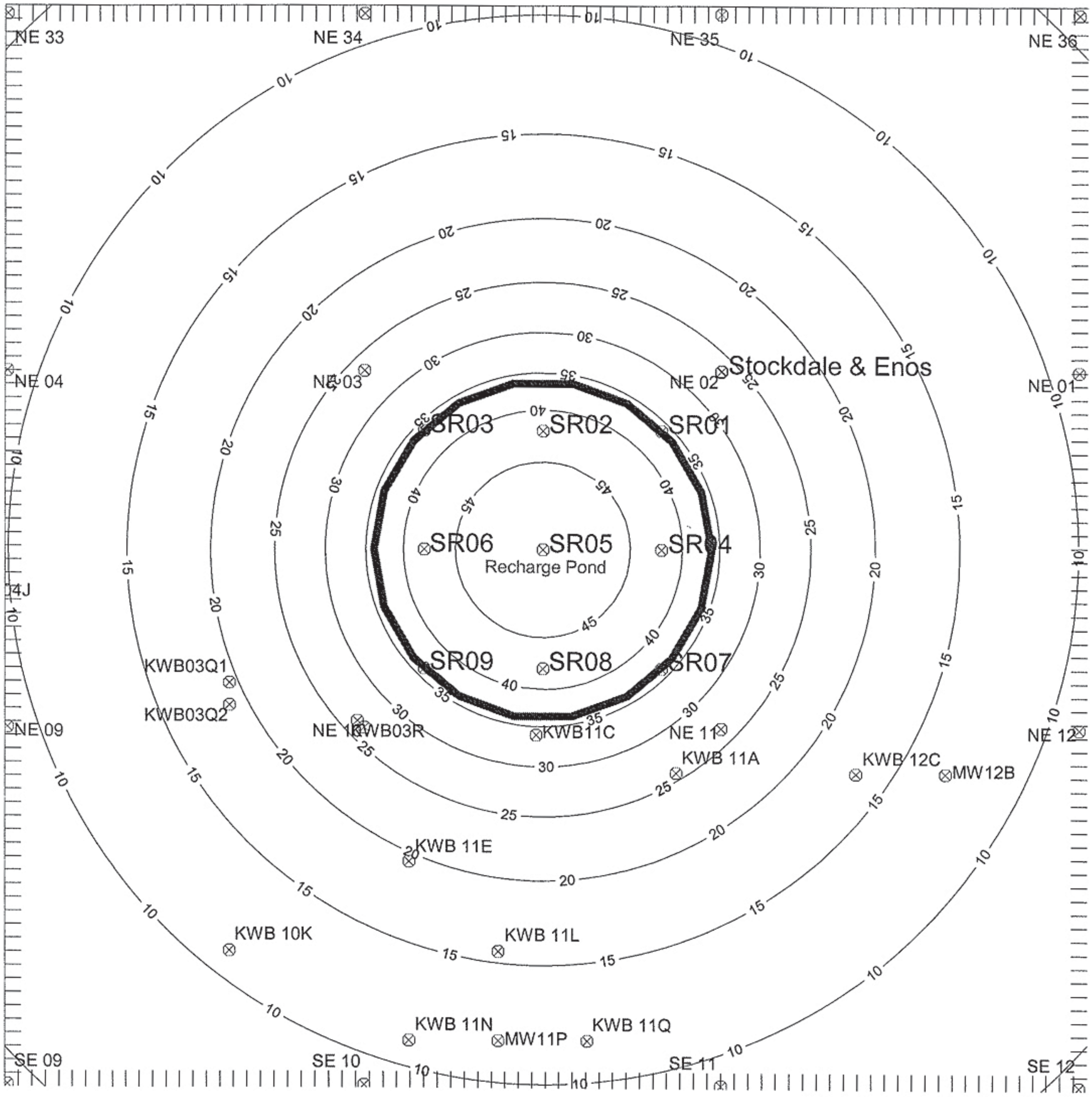
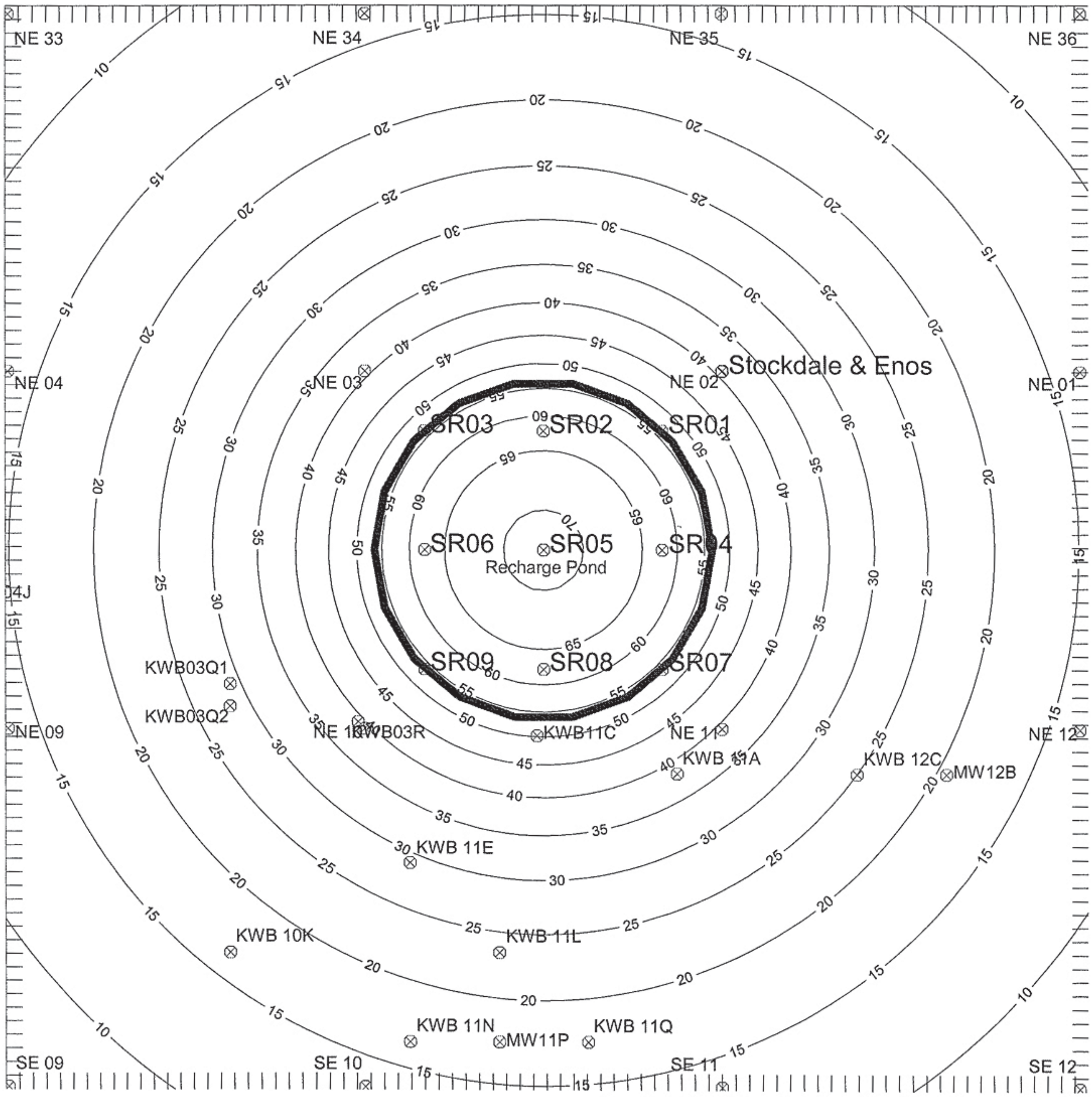
Figure 16
Water Level Rise Map,
Pond Recharge at IR = 0.30,
Base Case Aquifer Parameters



SOURCE: Sierra Scientific Services, 2007

Irvine Ranch Water District . 205426

Figure 17
Water Level Rise Map,
Maximum Recharge at IR = 0.20,
Base Case Aquifer Parameters



SOURCE: Sierra Scientific Services, 2007

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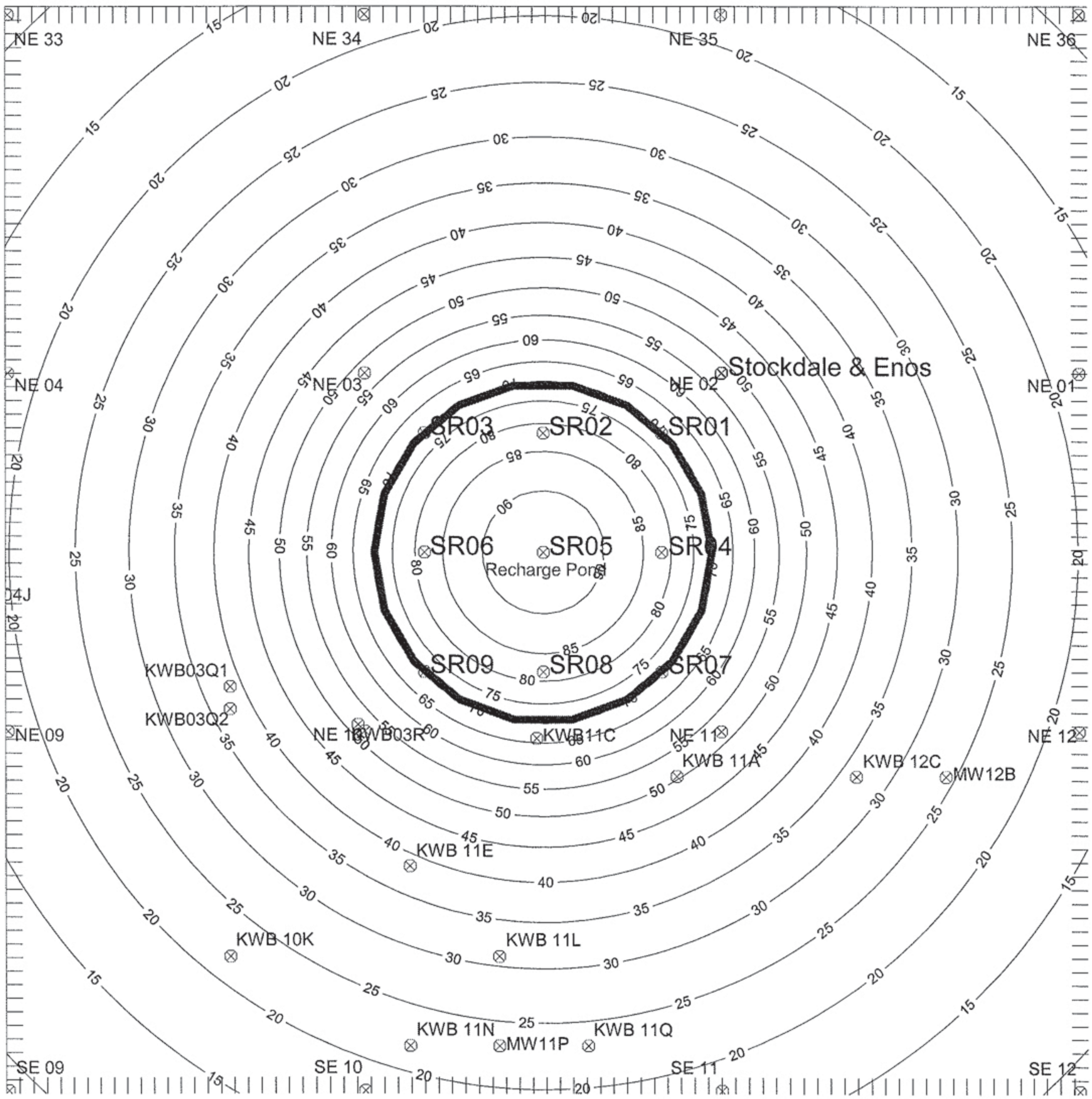
Figure 18
Water Level Rise Map,
Maximum Recharge at IR = 0.30,
Base Case Aquifer Parameters



SOURCE: Sierra Scientific Services, 2007

Irvine Ranch Water District . 205426

Figure 19
Water Level Rise Map,
Maximum Recharge at IR = 0.40,
Base Case Aquifer Parameters

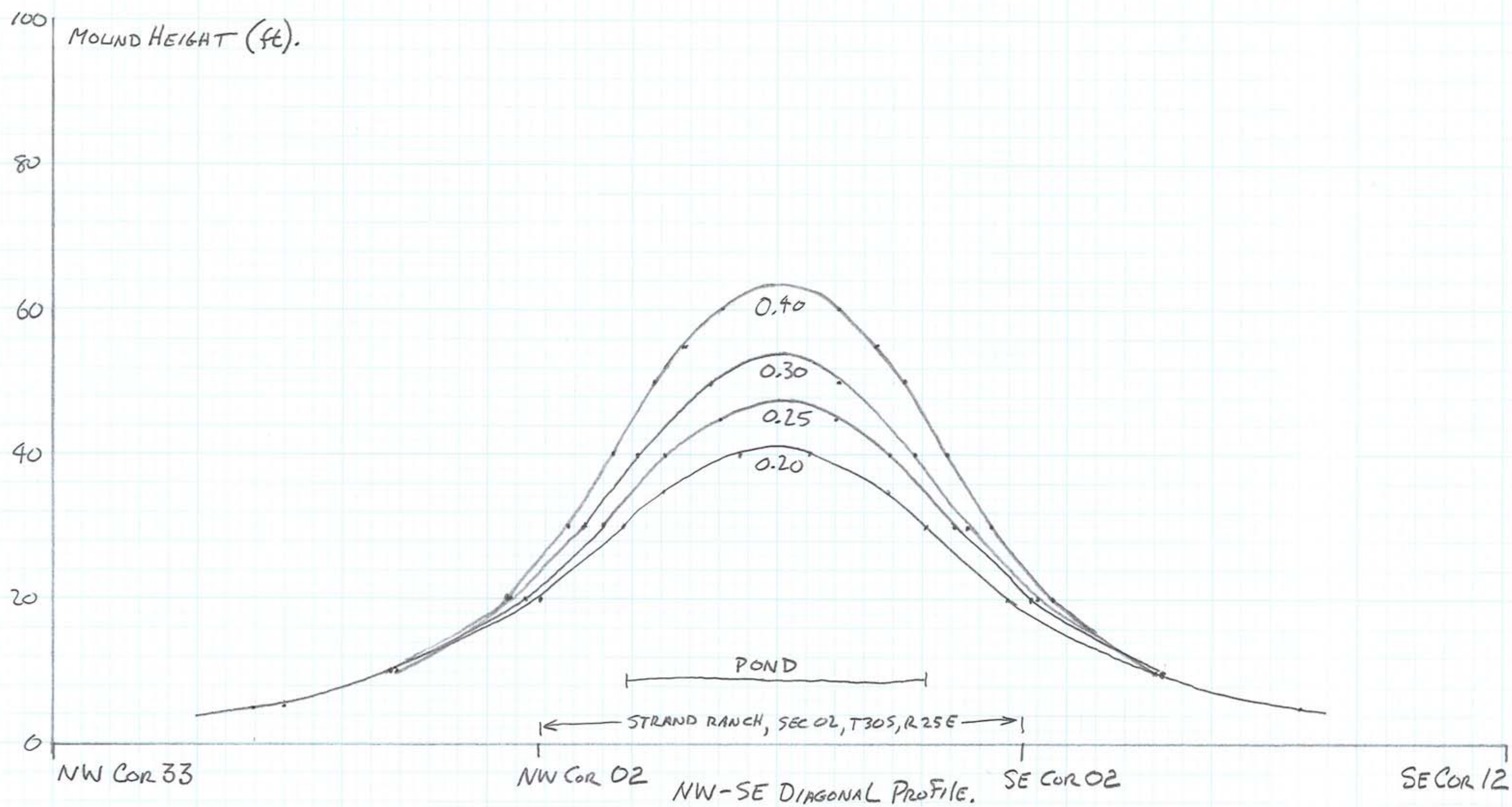


FIGURE 20. WATER LEVEL PROFILES, POND RECHARGE AT IR = 0.20, 0.25, 0.30, 0.40 ft/d; TOTAL VOLUME = 17,500 af, ALL CASES.

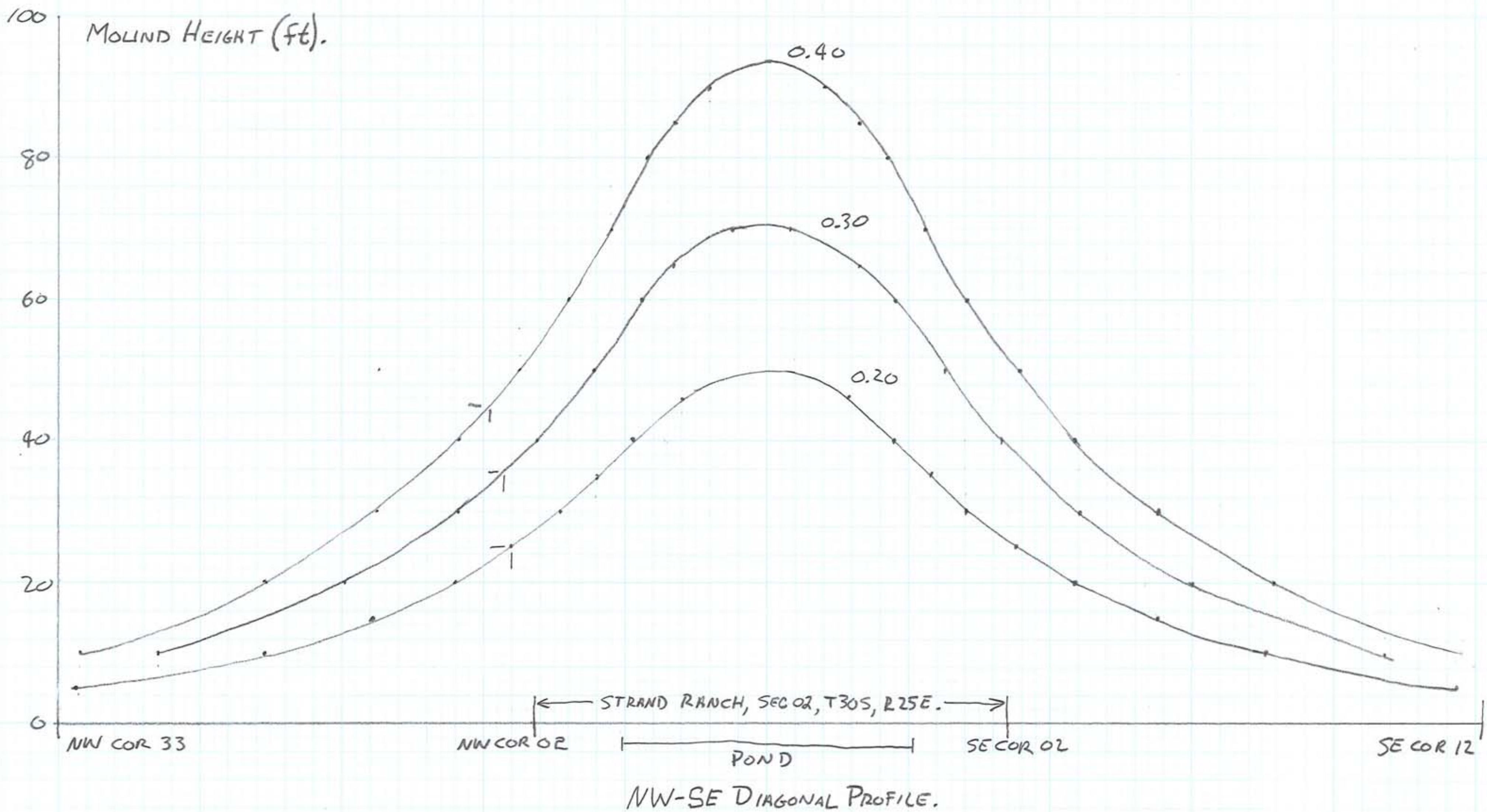


FIGURE 21. WATER LEVEL PROFILES, POND RECHARGE AT IR = 0.20, 0.30, 0.40 ft/d; TOTAL TIME = 365 days, ALL CASES.

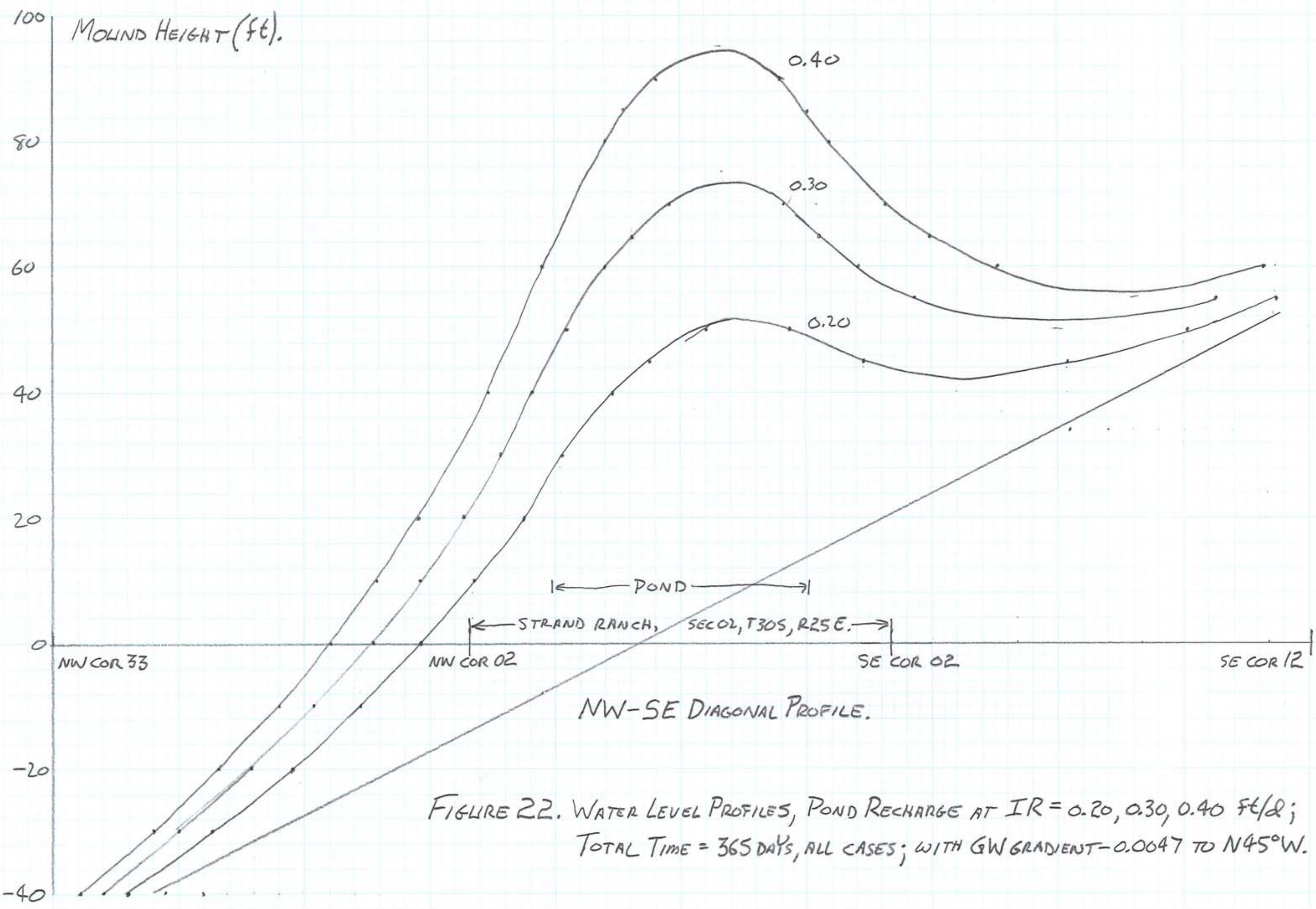


Figure 22. Water Level Profiles, Pond Recharge at IR = 0.20, 0.30, 0.40 ft/d; Total Time = 365 days, all cases; with GW gradient-0.0047 to N45°W.

Tables.

Table 1. IRWD Strand Ranch Drawdown Model Parameters.

Property	Sym.	Value	Units
Aquifer Parameters			
Aquifer Hy. Conductivity (Hor)	K(h)	57	ft/d
Aquifer Hy. Conductivity (Vert)	K(v)	n/d	ft/d
Aquifer Thickness	H	300	ft
Aquifer Transmissivity	T	17100	ft^2/d
Aquifer Specific Yield	Sy	0.15	v/v
Aquifer Specific Storage	Ss	0.000067	ft^-1
Aquifer Storativity	S	0.02	v/v
Aquifer Porosity	phi	0.3	v/v
Aquitard Hy. Conductivity (Vert)	Kv'	0.0475	ft/d
Aquitard Thickness	H'	100	ft
Aquitard Leakance	L'	0.000475	d^-1
Hantush Factor	B	6000	ft
GW gradient	G	0.0048	N 45 W
SR Well Recovery Rate	Q	432000	cf/d

Well Parameters (X, Y) coordinates in feet wrt local origin (0,0) at NE cor Sec 02, T30s, R25e.

Well	Q (cfs)	Q (cf/d)	Q (af/d)	X (ft)	Y (ft)
SR 01	5	432000	9.9	-880	-880
SR 02	5	432000	9.9	-2640	-880
SR 03	5	432000	9.9	-4400	-880
SR 04	5	432000	9.9	-880	-2640
SR 05	5	432000	9.9	-2640	-2640
SR 06	5	432000	9.9	-4400	-2640
SR 07	5	432000	9.9	-880	-4400
SR 08	5	432000	9.9	-2640	-4400
SR 09	5	432000	9.9	-4400	-4400
Nikkel (RRB)	3.3	285120	6.5	-3300	3300
Nikkerl Shop (RRB)	3.3	285120	6.5	1980	4620
Brimhall (RRB)	3.4	293760	6.7	3300	5940
KWB 03Q1	6.3	544320	12.5	-7260	-4620
KWB 03Q2	7.0	604800	13.9	-7260	-4950
KWB 03R	7.1	613440	14.1	-5940	-4620
KWB 10K	6.6	570240	13.1	-7260	-8580
KWB 11A	4.7	406080	9.3	-660	-5940
KWB 11C	5.3	457920	10.5	-3300	-5940
KWB 11E	5.4	466560	10.7	-4620	-7260
KWB 11L	3.7	319680	7.3	-3300	-8580
KWB 11N	3.7	319680	7.3	-4620	-9900
KWB 11Q	7.2	622080	14.3	-1980	-9900
KWB 12C	4.5	388800	8.9	1980	-5940

Note: KWB includes all 11 listed wells, each centered on their respective 40-acre designations.
Note: KWB well flow rates (Q, cfs) taken from KWBA production data; Jan - Apr, 2003, 4-mo avg flow rate.
Note: RRB irrigation wells centered on their 40-acre designations.
Note: SR well flow rates assumed to be 5 cfs, according to proposed project design specification.

Table 2. Strand Ranch Calculated Water Level Drawdown Summary.
3x3-mi Project Study Area centered on Sec 02, T30s, R25e.

9-well Scenario, Wells 1-9.
Average Drawdown per Section (ft).

12	20	12
20	43	20
12	20	12

9-well Scenario, Wells 1-9.
Range of Drawdowns per Section (ft).

5 to 28	9 to 36	5 to 28
9 to 36	29 to 55	9 to 36
5 to 28	9 to 36	5 to 28

7-well Scenario, Wells 1-7.
Average Drawdown per Section (ft).

9	21	10
14	34	17
8	13	9

7-well Scenario, Wells 1-7.
Range of Drawdowns per Section (ft).

3 to 23	8 to 31	3 to 24
8 to 29	17 to 45	8 to 30
7 to 18	7 to 25	3 to 23

5-well Scenario, Wells 13579.
Average Drawdown per Section (ft).

7	11	7
11	24	11
7	11	7

5-well Scenario, Wells 13579.
Range of Drawdowns per Section (ft).

2 to 16	6 to 19	2 to 16
6 to 19	17 to 30	6 to 19
2 to 16	6 to 19	2 to 16

Table 3. Strand Ranch Calculated Water Level Drawdowns at Selected Locations.

WELL GROUP:	9 wells	7 wells	5 wells-A	5 wells-B	4 wells
Well numbers:	SR 1-9	SR 1-7	SR 13579	SR 12345	SR 2468
see map =	F2	F3	F4	F5	B20
Total Drawdown at:	(ft)	(ft)	(ft)	(ft)	(ft)
well SR 01	-45	-40	-25	-30	-17
well SR 02	-50	-40	-22	-35	-25
well SR 03	-45	-40	-25	-35	-17
well SR 04	-50	-40	-22	-22	-25
well SR 05	-55	-45	-30	-35	-20
well SR 06	-50	-40	-22	-35	-25
well SR 07	-45	-35	-25	-16	-17
well SR 08	-50	-29	-22	-19	-25
well SR 09	-45	-24	-25	-18	-17
well Nikkel (RRB)	17	14	9	12	8
well Nikkel Shop (RRB)	9	8	5	7	4
well Brimhall (RRB)	7	6	3	4	2
well KWB 03Q1	-20	-14	-12	-11	-9
well KWB 03Q2	-19	-14	-11	-10	-9
well KWB 03R	-27	-18	-15	-14	-12
well KWB 10K	-12	-8	-7	-5	-5
well KWB 11A	-28	-20	-15	-12	-12
well KWB 11C	-30	-20	-16	-13	-15
well KWB 11E	-20	-13	-12	-9	-9
well KWB 11L	-16	-11	-8	-7	-8
well KWB 11N	-11	-7	-6	-5	-5
well KWB 11Q	-12	-8	-7	-5	-5
well KWB 12C	-17	-13	-10	-8	-8
NE cor study area (NE sec 36)	5	4	2	3	1
SE cor study area (SE sec 12)	5	3	2	2	1
SW cor study area (SW sec 10)	5	2	2	2	1
NW cor study area (NW sec 34)	5	3	2	3	1
Center, north side study area	10	8	6	7	4
Center, east side study area	10	8	6	7	4
Center, south side study area	10	5	6	4	4
Center, west side study area	10	7	6	5	4

Table 4. Strand Ranch Water Level Drawdown Sensitivity Analysis.

Table 4a. Base case Drawdowns with Variations in Aquifer Model.
(base case in **bold**.)

Aquifer Model =	**Semi-confined**	Confined	Unconfined
see Map =	**B0**	B11	B12 (only wells 13579)
Drawdown at:	**(ft)**	(ft)	(ft)
within the SR well field	**-40 to -55**	-85 to -100	-100 to -115
within the SR property (sec 02)	**-30 to -55**	-70 to -100	-87 to -115
within 1 mile of SR (adj. sections)	**-10 to -30**	-40 to -70	-65 to -87
beyond 1 mile from SR	**0 to -10**	0 to -40	0 to -65

Table 4b. Base case Drawdowns with Variations in degree of Confinement.
(base case in **bold**.)

confinement:	less	**base case**	more
Variation in confinement: B = ft	3200	**6000**	10000
see Map =	B1	**B0**	B2
Drawdown at:	(ft)	**(ft)**	(ft)
within the SR property (sec 02)	-15 to -35	**-30 to -55**	-45 to -70
within 1 mile of SR (adj. sections)	0 to -10	**-10 to -30**	-20 to -45
beyond 1 mile from SR	0	**0 to -10**	0 to -20

Table 4c. Base case Drawdowns with Variations in Aquifer Permeability.
(base case in **bold**.)

permeability:	more	more	**base case**	less	less
Variation in conductivity: K = ft/d	100	80	**57**	50	40
see Map =	B3	B4	**B0**	B5	B6
Drawdown at:	(ft)	(ft)	**(ft)**	(ft)	(ft)
within the SR property (sec 02)	-15 to -30	-20 to -40	**-30 to -55**	-35 to -60	-45 to -75
within 1 mile of SR (adj. sections)	-5 to -15	-7 to -20	**-10 to -30**	-12 to -35	-15 to -45
beyond 1 mile from SR	0 to -5	0 to -7	**0 to -10**	0 to -12	0 to -15

Table 4d. Base case Drawdowns with Variations in Pumping Duration.
(base case in **bold**.)

duration:	less	less	less	**base case**	more
Pumping Duration, t = days	10	30	100	**300**	1000
see Map =	B7	B8	B9	**B0**	B10
Drawdown at:	(ft)	(ft)	(ft)	**(ft)**	(ft)
within the SR property (sec 02)	-15 to -35	-25 to -50	-30 to -55	**-30 to -55**	-30 to -55
within 1 mile of SR (adj. sections)	-1 to -15	-5 to -25	-10 to -30	**-10 to -30**	-10 to -30
beyond 1 mile from SR	0 to -1	0 to -5	0 to -10	**0 to -10**	0 to -10

Table 5. Strand Ranch Calculated Water Level Mounding Summary.

3x3-mi Project Study Area centered on Sec 02, T30s, R25e.

Recharge 17,500 af in 194 days (IR=0.20)
Average WL Rise per Section (ft).

6	13	6
13	32	13
6	13	6

Recharge 17,500 af in 194 days (IR=0.20)
Range of WL Rise per Section (ft).

1 to 18	5 to 27	1 to 18
5 to 27	20 to 43	5 to 27
1 to 18	5 to 27	1 to 18

Recharge 17,500 af in 155 days (IR=0.25)
Average WL Rise per Section (ft).

6	13	6
13	36	13
6	13	6

Recharge 17,500 af in 155 days (IR=0.25)
Range of WL Rise per Section (ft).

1 to 21	4 to 30	1 to 21
4 to 30	22 to 48	4 to 30
1 to 21	4 to 30	1 to 21

Recharge 17,500 af in 129 days (IR=0.30)
Average WL Rise per Section (ft).

6	14	6
14	40	14
6	14	6

Recharge 17,500 af in 129 days (IR=0.30)
Range of WL Rise per Section (ft).

1 to 22	4 to 33	1 to 22
4 to 33	23 to 53	4 to 33
1 to 22	4 to 33	1 to 22

Table 6. Strand Ranch Calculated Water Level Mounding Rise at Selected Locations.

Recharge Case	base	alt 1	alt 2
recharge rate (ft/d) =	0.20	0.25	0.30
recharge duration (d) =	194	155	129
recharge volume (af) =	17489	17467	17444
Total Water Level Rise at:	(ft)	(ft)	(ft)
well SR 01	28	32	35
well SR 02	35	40	44
well SR 03	28	32	35
well SR 04	35	40	44
well SR 05	43	48	53
well SR 06	35	40	44
well SR 07	28	32	35
well SR 08	35	40	44
well SR 09	28	32	35
well Nikkel (RRB)	12	12	12
well Nikkel Shop (RRB)	3	3	3
well Brimhall (RRB)	2	2	2
well KWB 03Q1	13	14	14
well KWB 03Q2	13	13	13
well KWB 03R	19	21	22
well KWB 10K	6	6	6
well KWB 11A	18	20	22
well KWB 11C	27	30	33
well KWB 11E	13	14	14
well KWB 11L	9	10	10
well KWB 11N	6	6	6
well KWB 11Q	7	7	7
well KWB 12C	11	11	11
NE cor study area (NE sec 36)	1	1	1
SE cor study area (SE sec 12)	1	1	1
SW cor study area (SW sec 10)	1	1	1
NW cor study area (NW sec 34)	1	1	1
Center, north side study area	5	5	5
Center, east side study area	5	5	5
Center, south side study area	5	5	5
Center, west side study area	5	5	5

Table 7. Strand Ranch Calculated Net Water Level Impact Summary.

3x3-mi Project Study Area centered on Sec 02, T30s, R25e.

Recharge: 90 af/d x 194 d.
Recovery: 9-wells @ 90 af/d.
Avg Net Impact per Section (ft).

-6	-7	-6
-7	-11	-7
-6	-7	-6

Recharge: 90 af/d x 194 d.
Recovery: 7-wells @ 70 af/d (1-7).
Avg Net Impact per Section (ft).

-3	-8	-4
-1	2	-4
-2	0	-3

Recharge: 90 af/d x 194 d.
Recovery: 5-wells @ 50 af/d (13579).
Avg Net Impact per Section (ft).

-1	3	-1
3	16	3
-1	3	-1

Table 8. Strand Ranch Calculated Net Water Level Impact at Selected Locations.

Recharge Case	base	base	base	= 194 d @ 90 af/d.
Recovery Case	9-well	7-well	5-well	= #wells @10 af/d/w.
Nominal Rcharge/Recovery Volume	17500	17500	17500 af	
Net Water Level Impact at:	(ft)	(ft)	(ft)	
well SR 01	-17	-12	3	
well SR 02	-15	-5	13	
well SR 03	-17	-12	3	
well SR 04	-15	-5	13	
well SR 05	-12	-2	13	
well SR 06	-15	-5	13	
well SR 07	-17	-7	3	
well SR 08	-15	6	13	
well SR 09	-17	4	3	
well Nikkel (RRB)	29	26	21	
well Nikkel Shop (RRB)	12	11	8	
well Brimhall (RRB)	9	8	5	
well KWB 03Q1	-7	-1	1	
well KWB 03Q2	-6	-1	2	
well KWB 03R	-8	1	4	
well KWB 10K	-6	-2	-1	
well KWB 11A	-10	-2	3	
well KWB 11C	-3	7	11	
well KWB 11E	-7	0	1	
well KWB 11L	-7	-2	1	
well KWB 11N	-5	-1	0	
well KWB 11Q	-5	-1	0	
well KWB 12C	-6	-2	1	
NE cor study area (NE sec 36)	6	5	3	
SE cor study area (SE sec 12)	6	4	3	
SW cor study area (SW sec 10)	6	3	3	
NW cor study area (NW sec 34)	6	4	3	
Center, north side study area	15	13	11	
Center, east side study area	15	13	11	
Center, south side study area	15	10	11	
Center, west side study area	15	12	11	

Table 9. Strand Ranch Maximum Water Level Mounding Summary.

3x3-mi Project Study Area centered on Sec 02, T30s, R25e.

Recharge 32,850 af in 365 days (IR=0.20)
Average WL Rise per Section (ft).

12	19	11
19	39	19
11	19	12

Extra Recharge = 15,350 af.
Extra Rise from 194 to 365 days (IR=0.20)
Average WL Rise per Section = 5 - 6 ft.

6 to 12	13 to 19	6 to 11
13 to 19	32 to 39	13 to 19
6 to 11	13 to 19	6 to 12

Recharge 49,275 af in 365 days (IR=0.30)
Average WL Rise per Section (ft).

18	28	18
28	58	28
18	28	18

Extra Recharge = 31,775 af.
Extra Rise from 129 to 365 days (IR=0.30)
Average WL Rise per Section = 12 - 14 ft.

6 to 18	14 to 28	6 to 18
14 to 28	40 to 58	14 to 28
6 to 18	14 to 28	6 to 18

Recharge 65,700 af in 365 days (IR=0.40)
Average WL Rise per Section (ft).

23	36	23
36	76	36
23	36	23

Extra Recharge = 48,200 af.
Extra Rise from 97 to 365 days (IR=0.40)
Average WL Rise per Section = 16 - 20 ft.

7 to 23	16 to 36	7 to 23
16 to 36	40 to 76	16 to 36
7 to 23	16 to 36	7 to 23

Table 10. Strand Ranch Maximum Water Level Mounding Rise at Selected Locations.

365-day Recharge Case	IR = 0.20	IR = 0.30	IR = 0.40
pond acreage (ac) =	450	450	450
recharge rate (ft/d) =	0.20	0.30	0.40
recharge duration (d) =	365	365	365
recharge volume (af) =	32850	49275	65700
Total Water Level Rise at:	(ft)	(ft)	(ft)
well SR 01	36	54	70
well SR 02	42	62	82
well SR 03	36	54	70
well SR 04	42	62	82
well SR 05	48	71	93
well SR 06	42	62	82
well SR 07	36	54	70
well SR 08	42	62	82
well SR 09	36	54	70
well Nikkel (RRB)	19	27	36
well Nikkel Shop (RRB)	7	10	13
well Brimhall (RRB)	6	9	12
well KWB 03Q1	19	29	38
well KWB 03Q2	18	28	37
well KWB 03R	26	39	52
well KWB 10K	11	17	22
well KWB 11A	26	38	50
well KWB 11C	34	50	66
well KWB 11E	19	29	38
well KWB 11L	16	23	31
well KWB 11N	11	17	22
well KWB 11Q	12	18	23
well KWB 12C	17	19	26
NE cor study area (NE sec 36)	4	6	9
SE cor study area (SE sec 12)	4	6	9
SW cor study area (SW sec 10)	4	6	9
NW cor study area (NW sec 34)	4	6	9
Center, north side study area	10	15	20
Center, east side study area	10	15	20
Center, south side study area	10	15	20
Center, west side study area	10	15	20

Exhibits.

Exhibit 1.
Mathematical Aquifer Models.

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Mathematical Aquifer Models.

<u>Aquifer behavior.</u>

An aquifer is a porous medium consisting of one or more layers of rock or sediment which can store and transmit water in useful quantities. In the simplest terms, ground water aquifers function in two ways: an aquifer functions as a reservoir to store water and an aquifer functions as a pathway for ground water flow. Changes in aquifer storage or aquifer flow are caused by either gains or losses of water from the aquifer due to any of several natural or manmade actions. These changes are always manifested as changes in the elevation, orientation, and/or gradient of the potentiometric surface (i.e, water levels) in the aquifer.

In the case of aquifer storage, hydrologists evaluate ground water storage with a map of the water level elevation which basically represents how "full" the aquifer is at any particular location and time. If a hydrologist wants to determine the hypothetical impacts of gaining or losing water from the aquifer due to, for example, recharge ponds or pumping wells, then the impacts would be represented by changes in the configuration of the water table as presented in one or more maps or cross sections. All estimates of the change in aquifer storage use the area-weighted vertical changes in this water surface to calculate the volumetric change in storage.

In the case of aquifer flow, hydrologists evaluate ground water flow in the aquifer by determining the flow paths (which we call particle trajectories) and flow rates (particle velocities) that describe the movement of water molecules in the aquifer. If a hydrologist wants to determine the hypothetical impacts of changing the aquifer dynamics due to, for example, recharge ponds or pumping wells, then the impacts would be represented by changes in the lengths and directions of the flow paths as presented in one or more maps or cross sections.

<u>Computer Modeling.</u>

Hydrologists use mathematical aquifer models (sets of equations including sets of conditions and parameters) to calculate the hypothetical water level elevation maps and the ground water flow velocities and flow path maps which are predicted to result from the aquifer dynamics related to recharge ponds, pumping wells, streams, springs, and/or any other natural inflow/outflow or manmade action of interest. Since many aquifers and types of aquifer dynamics have been thoroughly studied and modeled, many computer models exist which can be used to model many classes of aquifer behaviors. Many such aquifer behaviors may be easily, quickly, and reliably studied with the right choices of model and parameters.

Modeling is an exercise in cause-and-effect. In modeling, we consider the natural or manmade flows of water into and out of an aquifer to be “causes” and the resulting water level behaviors observable in the aquifer to be “effects”. Causes are the inputs to a model and the effects are the intended output of the model. The model itself is our mathematical representation of the real aquifer and we will consider a model to be a good model if a set of model inputs and outputs satisfactorily resembles a set of known cause-and-effect flows and water level behaviors actually observed in the aquifer.

Water Level Drawdown Analysis.

Let us consider the special case of potential water table drawdown and inward radial flow of ground water due to installing and then pumping a new water well. Hydrologists often refer to this type of evaluation as a drawdown analysis or impact analysis. Our desired output is a map which shows the hypothetical water table drawdown and ground water flow paths within the capture zone surrounding one or more wells. We can calculate a predicted aquifer behavior for one or as many wells as we are interested in, since the mathematics of modeling provides for an unlimited number of causes and effects, depending only on computer memory and processing speed.

There are many computation methods for predicting drawdown from a pumping well in space and time and every method requires that the user select the equations which are most appropriate for the user’s preferred model of the aquifer. In essence, the user must try to select the set of mathematical expressions which best represents the user’s physical model of the aquifer. The hydrologist’s physical model of the aquifer includes knowledge of the geology and hydrology including the layering, structure, depths, dimensions and physical properties of the aquifer as well as the locations and flow rates of all sources of inflow and outflow to the aquifer such as wells, streams, ponds, etc.

The calculated result, if done correctly, always represents the workings of the mathematical equations but only represents the behavior of the real aquifer to the extent that the parameters, simplifications and assumptions of the mathematical model reflect the true workings of nature. The selection of the mathematical model, the equations, the accuracy of the parameter values, and the representativeness of the calculated output all reflect the experience, expertise, correctness of- and uncertainty in- the judgments of the hydrologist. These judgments cannot be made by the computer and the two main judgments include the choice of mathematical model and the choice of a set of aquifer parameters.

There is no such thing as a simple calculation. A good impact analysis rests at least as much on a hydrologist's competence in understanding equations, validity tests, boundary conditions, and model parameterization as it does on the determination of aquifer properties. In our opinion, many hydrologists and engineers who use mathematical models to compute aquifer impacts would benefit from a better background and understanding of the proper use and pitfalls of such models because, from experience, we have observed the results of many aquifer modeling efforts which are unusable because they demonstrably fall into one or more of the obvious and avoidable pitfalls of the method.

Analytical Models.

For any scope of work, there are two basic choices of mathematical model. The first choice is to select a "canned" analytical computer model which best approximates the interpreted aquifer conditions and then supply the user's best estimates of the required aquifer parameter values. The great advantage to this alternative is that the models are fast, convergent, easy to customize and operate, and the models result in a *unique* set of solutions because the degrees of freedom in the model are the same as the number of available parameters. SSS selected an analytical model since it was very well suited to the aquifer characteristics for this particular project scope of work.

The general disadvantage of an analytic computer model is that the mathematical model may not represent all of the known or suspected complexities of the real aquifer and the user must evaluate the relevance and magnitude of the possible errors in the results due to the simplifications in the mathematical model. The analytical models which are frequently used today include the familiar equations attributed to Theis, Cooper - Jacob, Hantush, Hantush - Jacob, Neuman, Strack, etc., for all of the useful recharge and recovery interactions (wells, ponds, rivers, surface recharge, etc) for transient and steady- state conditions in unconfined, confined, and leaky aquifers. Analytical models are particularly well-suited to the prediction and simulation of water levels and flow trajectories related to recharge mounds and water level depressions due to the operations of aquifer storage and recovery (ASR) projects.

Numerical Models.

The second choice, which SSS did not choose for this project, is to design and program a numerical computer model which best approximates the interpreted aquifer conditions in all its 3-dimensional detail and then supply the user's best estimates of the required aquifer parameter values. The only advantage to this alternative is that the model may be designed to any degree of complexity in order to approximate the true aquifer structure and dynamic inflow/outflow elements.

The disadvantages of numerical modeling are numerous and punishing. The models are tedious and difficult to build and verify; the models require an impossibly vast knowledge of the aquifer properties because the user must define the value of every aquifer parameter at every depth at every location; the hundreds or thousands of degrees of freedom always outnumber the amount of real data which causes non-uniqueness[8] and equivalence[9] in the model outputs; and there is a significant likelihood that numerical complexity does nothing to improve the quality or accuracy of the output of the calculation compared to analytical models while giving a false sense of precision in the effort.

One of the most popular numerical models is actually a number of programs which are all referred to by the name *Modflow* (a trademark of the United States Geological Survey), which are based on a publicly- available computer code developed by the U.S.G.S. and commercialized in several proprietary forms by different scientific software companies. Sierra Scientific Services owns a complete set of Modflow simulators for groundwater flow, contaminant transport modeling, and parameter estimation but SSS favored the analytic model to be better suited to this particular project scope of work.

Model Calibration.

Modeling is commonly thought of as specifying a set of inflows and/or outflows to a parameterized aquifer model and then calculating the predicted water level fluctuations which are expected at various locations over time. The locations, magnitudes, and durations of the calculated water levels depend on the choices of the numerical values of the various aquifer

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[8] Uniqueness is a computational condition in which a given set of inputs can result in only a single, fully determined output. Non-uniqueness is a computational condition in which a given set of inputs can result in two or more different, fully- determined possible outputs.

[9] Equivalence is a computational condition in which two or more different set of inputs can result in exactly the same, fully determined output.

properties that govern such behavior. Calibration is commonly thought of as tweaking the model parameters until the predicted water levels match the actual, observed water levels for the case being simulated.

The study of the movement of water through permeable aquifers is referred to as ground water hydraulics and *"the principle method of analysis in ground water hydraulics is the application ... of equations derived for particular ... conditions."*[10] *"The flow of fluids through porous media ... can be described by differential equations."*[11] *"These mathematical ideas are among the most abstract that we will encounter in hydrogeology."*[12] Groundwater modeling, therefore, is a process which requires expertise in mathematics as well as expertise in hydrogeology.

The use of computers and computer models has vastly revolutionized groundwater hydraulics by speeding up calculations, by improving computational accuracy, and providing for models that would have been impossibly complex to calculate by non-computer methods. This level of automation has *not* reduced the need for human judgment; rather, it has *increased* the need for operator education and expertise to correctly match the computational systems to the real-earth counterparts. The fact that nearly every model run by nearly every consultant still needs to be "calibrated" suggests that the models and/or the operators have not yet succeeded in correctly matching the computational systems to the real-earth counterparts.

"Model calibration" is a popular catch phrase which implies that there exists some special method of post-processing which can be used to independently verify, improve, or optimize the computational results of a modeling effort after a computer model has been "run". Let us consider what workers commonly mean by calibration.

Groundwater modeling is an exercise in simulating the connection between cause-and-effect in a natural aquifer system. For example, we know that pumping a water well causes water levels in an aquifer to decline. We can select one of many available commercial computer models and "parameterize" it to represent the aquifer of interest. If we use this

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[10] Lohman, S.W., 1972, Ground-water Hydraulics, USGS Professional Paper 708, Washington, D.C., p. 1.

[11] Fetter, C.W., 1994, Applied Hydrogeology, 3rd Ed., Prentice-Hall, p. 146.

[12] Domenico, Patrick, A., and Schwartz, F. W., 1990, Physical and Chemical Hydrogeology, John Wiley & Sons, p. 104.

computer model to predict the water level declines for a certain water well and then measure the actual water level behavior for that well under the same conditions, and if the predicted and actual water level behaviors are the same to within some acceptably small margin of error, then we might say that the model is correctly parameterized.

If the predicted and actual water level behaviors do not agree, then we assume that one or more of the model parameters may be incorrect. The process of calibration serves to adjust the model parameterization and we "calibrate" the model by changing selected parameter values until the predicted and actual behaviors agree for a specified calibration event. We then say that the model has been calibrated and we are thereby implying that the model now is an accurate representation of the aquifer. We are also implying that if we model and then observe a different set of cause-and-effect conditions, then the new set of predicted and observed results would agree since the model had been correctly parameterized through the process of calibration. We are further implying that, if we choose to model another set of cause-and-effect conditions which we are unable to verify by direct experiment or observation, we can place high confidence in the accuracy of the calculated results since the model has been calibrated. The real importance is not whether a model has been "calibrated" but whether some set of measures has been used to support an acceptable level of confidence in the accuracy of the predicted results.

In this study we used a computer model to calculate the hypothetical water level declines under the area of interest that would accompany a proposed project water well pumping scenario involving multiple operating wells. We cannot calibrate our computer model at this time with predicted and actual drawdowns because the well field doesn't actually exist so we have no actual cause-and-effect scenario.

Instead, we have used another set of measures to support an acceptable level of confidence in the accuracy of the predicted results. The actual area of interest is small enough that, based on experience and theoretical considerations, we expect each aquifer parameter to be constant across the entire "model space". Therefore, by eliminating spatial heterogeneity as a model factor, we have reduced the potential uncertainties to just a few degrees of freedom. Those degrees of freedom are the few aquifer parameter values which we need to perform our water level calculations.

We put a large effort into determining good values for the required aquifer parameters. We only have one aquifer parameter value which was measured within the actual area of interest but we can assign each of the other parameters to its own limited range of possible values based on our study of reported parameter data from similar geology in the surrounding area. We selected a single set of parameter values from these ranges of values to be used as a base case scenario and we analyzed the sensitivity of the calculated water level drawdowns to variations in each of the parameters. Since we conclude that it is very unlikely that any actual parameter value lies outside its specified range of possible values, we can calculate a limited range of possible water level drawdowns such that the true, but unobserved, drawdowns will most likely be within that range.

For the purpose of this study, we are primarily interested in whether or not the predicted water level drawdowns will be acceptable or mitigate-able according to some set of criteria. It may not be so important to accurately know the exact water level drawdowns if we can determine that the entire range of calculated water level impacts are acceptable by the relevant criteria.

Exhibit 2.

Aquifer Parameters and Parameter Values.

Exhibit 2.

Aquifer Parameters and Parameter Values.

The aquifer parameters of interest for mathematical modeling include those *intrinsic* physical properties of the porous media which determine the volume- specific storage and unit flow properties of the aquifer. These intrinsic properties are then combined with the physical dimensions (depths, thicknesses, boundaries, inflows, outflows, and gradients) of the aquifer media to determine the full- aquifer behavior. The storage properties include the specific storage (S_s) and specific yield (S_y) of each of the porous media. The required flow properties include the hydraulic conductivity (K), porosity (φ), and dispersivity (α) of each of the porous media. The hydraulic conductivity is required for volumetric flux and flow rate in directions of interest (K_h for horizontal flow and K_v for vertical flow), the porosity is required for particle tracking, and dispersivity (both longitudinal α_L and transverse α_T) is required for contaminant transport.

These properties are normally determined either by physical properties measurements on actual rock or sediment samples or by special types of pumping tests on water wells which have been completed across the thickness of the aquifer. Some of these properties vary by several orders of magnitude for common aquifer rock- and sediment- types, so for aquifer materials which have not been measured or tested, there is little likelihood that a best- guess "textbook" value which is based on rock type or another index property will be very close to the actual value. We recommend that the careful determination of the relevant physical properties be an essential and early part of any groundwater program.

It is important to emphasize that the values of these physical properties are all constants for each of the respective aquifer media and that they do not vary with changes in either the water table, or in the pump rate or completion interval of a well, or with any other observed variable, apart from the natural variability of the property within the porous medium itself. It is good practice to measure these properties as many times as possible to determine the average value and range of natural variability for each. And since hydrologists recognize that the natural variability of these parameters may be large, it is best to obtain measured values which are representative of the aquifer under the entire area of interest for which impact analyses are desired, and measured in ways which minimize the unassociated variance in the determination. It is also important to emphasize that few of these properties can be determined directly from well tests and must instead be derived indirectly from well test data by also using other information. The ability to do this is governed by cost, access to wells, and the expertise of the hydrologist to perform the right test and to make the necessary corrections for factors and interferences which otherwise cause errors in the values.

Aquifer storage properties.

Water is stored in an aquifer by occupying the intergranular void spaces of the porous aquifer material. The physical amount of water which can be stored in and recovered from a porous medium is the sum of two components; the fillable void space remaining in a rock or sediment which is at residual saturation, and a very much smaller component which is a result of the minute elastic dilation of this void space when the water in the aquifer is under pressure combined with the slight compression of the water itself.

When water is released or recovered from an aquifer, the first water recovered is always that which is released due to the elastic rebound of the pore space and the water. The last water recovered is always that which drains from the pore space and dewaters the aquifer. When water is stored in the aquifer, the reverse actions occur, i.e., water first fills the void spaces and then dilates the void space as the fluid pressure increases.

<u>Specific yield.</u> The first component is termed the *specific yield (S_y)* and is the amount of water produced by "de-watering" the aquifer void space as the water table falls within the aquifer. This term effectively determines the amount of water which is gained or lost under the project area or some specific area due to the rising or falling water table. The values for well sorted sandy sediments[13], such as in the area of interest may range from $0.10 \leq S_y \leq 0.35$. The formula for calculating the volume of water released by dewatering is $V_w = A \cdot S_y \cdot \_h$ for a drop in water table of _h. The aquifer thickness is not a term in this calculation.

[13] Fetter, C. W., 1994, Applied Hydrogeology, 3rd ed., Prentice - Hall, Inc., Table 4.4, p.91.

Specific storage and Storativity. The second component is termed the *specific storage (S_s)* and is the much smaller amount of water produced by contraction of the dilated pore space and expansion of the water as the pressure drops within the aquifer. The values for loose- to well-packed silty or sandy sediments[14], such as in the area of interest may range from $0.00017 \le S_s \le 0.0032$ ft^{-1}. This property is related to the in situ bulk compressibility of the aquifer media and the water itself. The compressibility of water is known and we can measure the compressibility of sediment samples, as SSS has done for RRBWSD on another project.

The formula for calculating the volume of water released from the aquifer by de-pressuring is $V_w = A \cdot H \cdot S_s \cdot$_h for a drop in head of _h in an aquifer of thickness H. The product of aquifer thickness and specific storage in this equation is defined as *storativity*, $S = H \cdot S_s$, and it is obvious that if the thickness of an aquifer changes, then the value of S will change, even though the intrinsic property of the porous medium, i.e., the specific storage, remains constant. It should also be noted that if only a portion of the full thickness of an aquifer is relevant to a particular problem, then the appropriate value of S to be used in any calculation is the value for the interval of interest.

The specific storage term is also an essential term in the flow equations which describe transient, i.e. non steady- state, aquifer flow. The ratio of hydraulic conductivity to specific storage is defined as the hydraulic diffusivity and this ratio explicitly occurs in all non steady-state equations of flow. Therefore, while it is tempting to dismiss the need for an accurate value of S_s because it is negligible for the calculation of aquifer storage, it is important to obtain as good a value as is possible because it occurs directly in the flow equations along with conductivity. For example, the 20-fold difference between low and high values of S_s will make only a negligible difference in the calculated storage capacity of the aquifer, but will significantly alter the calculated results of the flow equations.

Available storage capacity (SC). The available storage capacity, which is not relevant to this particular scope of work, is defined as the volume of water that could be stored in the unsaturated zone above the water table within the boundaries of the project area up to within a few feet of the ground surface. This working definition is usually used to calculate a change in aquifer storage due to a rise or fall of the water table over some time period, and is not an important or even relevant part of many types of aquifer modeling. In practice, the specific

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[14] Domenico, P.A. and Schwatrz, F.W., 1990, Physical and Chemical Hydrogeology, John Wiley, Inc, Table 4.1, p.111.

storage (S_s) is negligible compared to the specific yield (S_y) ($0.0005 < S_s/S_y < 0.00005$) so, unless an aquifer is very thick, we do not consider the specific storage in the calculation of storage capacity and just use the specific yield formula.

Layered- aquifer storage properties. For aquifers which are either heterogeneous or layered, we must determine the storage properties of each type of sediment within the aquifer and the proportions of each, and perhaps even the sequence in which they are successively filled and/or dewatered. For a layered aquifer, the volumetric storage capacity under an area (A) is defined as being equal to the volumetric integral: $SC = \int^A \int \varphi(1 - S_r)dAdh$, which simplifies to a summation which looks like: $SC = A\Sigma(h_i \cdot Sy_i)$, that is, the total Project area times the sum of products of the individual layer thicknesses and specific yields which, finally, is often more-conventionally written as: $SC = A \cdot H \cdot Sy_{eq}$, the product of total Project area area times total aquifer thickness times the "average" or equivalent specific yield. We must always remember that the correct values for determining an actual change in storage must be those values of $h_i \cdot Sy_i$ which represent the actual interval being filled or dewatered, and not the "full- aquifer" average value. Any modeling effort which simplifies the aquifer stratigraphy by reducing the number of layers must address the issue of determining the equivalent parameters of each layer model relative to the actual parameters of the actual stratigraphy.

The same additive property is true of storativity (S) for a sequence of layers in an aquifer. The value of storativity is a summation which looks like: $S = \Sigma(h_i \cdot Ss_i) = \Sigma(S_i)$, that is, the storativity of any depth interval is the sum of the individual- layer storativities for all layers within the interval. This additive property is important to consider when interpreting well tests which are not completed across the full layered- aquifer thickness.

Aquifer flow properties.

Water flows down-gradient in an aquifer from higher to lower potential. Groundwater flow may be horizontal or vertical or have components of both. The externally applied forces which cause water to move come primarily from gravity and secondarily from manmade actions. In other words, left to itself, the groundwater in aquifers and in basins "seeks its own level" and always prefers the path of least resistance. Water will stop moving when there is no change in potential along a pathway. Otherwise, water is moving in one of two type of conditions, either steady- state flow or transient flow. In steady state flow, water passing any location continues to flow in the same direction at the same flow rate and at the same head without any change over time. In transient flow, water passing any location will not be steady in direction, flow rate, or head because of dis-equilibrium somewhere in the system. Transient flow may be non-Darcy flow and this is the condition of the aquifer in the project area most of the time.

The persistent re-equilibration of a groundwater system toward a no-flow condition takes time. Often the cycle of recharge to- and recovery of- water from the system is faster than the ability of the groundwater system to either re-balance or even achieve a steady- state. As in most cases, the groundwater system is always dynamic and in a transient state, even if it appears to respond slowly and steadily by human perception.

The groundwater flow behaviors of interest include flow direction and flow rate. Flow direction may be visualized as an arrow pointing in the down- direction of the potential gradient, since water moves in the direction of the applied force. Flow direction may also be visualized as a hypothetical flowline that a single water molecule would follow under steady-state. A contour map of the water table or piezometric surface is a map of the groundwater potential in the aquifer, and the direction of flow at any location will be perpendicular to the contours and pointing in the direction of lower potential.

Flow rate can be described as the average flow speed of a water molecule at a specified place and time or as the "instantaneous" volumetric flux of a volume of water through a specified cross sectional area (W·H) of the aquifer over a short period of time. Apart from the externally applied driving forces and the physical dimensions of the aquifer, these measures of ground water flow depend only on the hydraulic conductivity and porosity of the porous medium.

<u>Hydraulic conductivity.</u> The *hydraulic conductivity (K)* is a measure of the ease with which *water* flows through an aquifer. In general, the natural flow of a fluid through a porous medium depends on the density (ρ) and viscosity (μ) of the fluid, the intrinsic *permeability (k)* of the porous medium, and the driving force of gravity (g) which causes fluid to move. Since the value of gravity and the values of density and viscosity of water are nearly constant for the usual range of aquifer conditions, the only variable property which controls the fluid flow in an aquifer is the permeability. So, for mathematical convenience hydrologists have combined the

value of gravity, the properties of water, and the measure of aquifer permeability into a single, new property which is defined as the hydraulic conductivity, where $K = k(\rho g)/\mu$. The units of this "aquifer" property are length per time, i.e., units of velocity such as ft/day.

This term effectively determines the flow rate or volumetric flux of water through the aquifer under whatever potential gradient exists at the time and place of interest. The K values for silty and sandy sediments, such as occur in the area of interest may range from $0.001 \leq K \leq 300$ ft/d, a range covering more than five orders of magnitude. The formula for calculating the steady- state volumetric flux of water (Q_w) in an aquifer is $Q_w = W \cdot H \cdot K \cdot G$ for a groundwater potential gradient G = _h/_x, through an aquifer cross sectional area of width W and thickness H. If the aquifer is not in steady- state, then the calculation represents only the "instantaneous" flow at that moment at that location under those conditions and the full equation of flow must instead be used to describe the transient flow behavior over time.

The steady- state flux equation applies to both horizontal and vertical groundwater flow with the condition that the values of K and G are the values of hydraulic conductivity and gradient in the direction of flow. Most aquifer materials, whether unconsolidated sediments or sedimentary rocks, are anisotropic and are commonly 5 - 20 times more permeable in flow directions parallel to the bedding planes than in flow directions perpendicular to the bedding planes. Thus, in order to quantify or model aquifer flow with both horizontal and vertical components, it is necessary to specify both the horizontal and vertical hydraulic conductivities of relevant aquifer materials.

<u>Transmissivity.</u> A term representing hydraulic conductivity occurs in all groundwater flow equations. This term also occurs in the solutions to many flow problems as the product of conductivity (K) times aquifer thickness (h) which we define as transmissivity, $T = Kh$. The significance to the hydrologist is that an aquifer pump test often results in providing a value for the thickness-conductivity product Kh, which we've defined as transmissivity T, but the aquifer test does not provide a means of separately determining the values of K or h alone. We normally measure the aquifer thickness (h) directly in a well, on an outcrop, or from geophysical data, and then obtain a calculated value of $K = T/h$ from the independently measured values of T and h.

We point out that aquifer transmissivity is not an intrinsic property of an aquifer or aquifer material since its value depends on the saturated vertical thickness of the aquifer, i.e., transmissivity will vary from place to place as the saturated aquifer thickness varies, even where the intrinsic permeability of the aquifer remains constant. We strongly prefer and recommend that it is better to specify the aquifer properties of K and h separately rather than specifying only a value of transmissivity.

Leakance. The *leakance (L′)* is a property which determines the rate of downward vertical flow of water from a water table aquifer, through a somewhat-permeable aquitard, and into an underlying semi-confined aquifer due to head differences across the aquitard. Such head differences are common in many aquifer systems. The value of L′ is determined as the ratio of vertical hydraulic conductivity to the thickness of the aquitard, $L' = K_v'/h'$. (The prime (′) in the abbreviations symbolize that these are properties of the *aquitard* and not of the underlying aquifer). We refer to aquifers which show this type of recharge behavior as semi-confined or "leaky" aquifers and one flow equation which describes this type of flow behavior is the Hantush - Jacob equation, named after its authors.

The mathematics of leakage occurs in the flow equation in the form of what is referred to as the Hantush leakage factor (B) and B is related to known parameter values according to the formula $B = (T/L')^{½}$. In the project area, the high- permeability zones of the aquifer are sandy sediments and the low-permeability zones are silty sediments. These silty sediments are the aquitards which retard the vertical flow of water between the sandy layers of the aquifer. Based on our measurements and estimates of the relevant properties, we estimate that the value of B varies in the range of about $3200 \leq B \leq 10000$ and we have used a value of B = 6000 as our base case value.

Porosity. The *porosity* (φ) is the dimensionless ratio specifying the fraction of void space to total space in a unit volume of a porous medium. As a flow property, it determines the amount of intergranular flowpath within the porous medium that is available to the water. The formula for calculating the steady- state flow velocity of water (v_w) in an aquifer is $v_w = K \cdot G/\varphi$. If the aquifer is not in steady- state, then the calculation represents only the "instantaneous" flow speed at that moment at that location under those conditions and the full equation of flow must instead be used to describe the transient flow behavior over time. Well-sorted, unconsolidated,

sands and silts commonly have porosities ranging from 10 - 30%. Porosity decreases as the degree of sorting decreases, i.e., as the range of grain sizes increases in the stratum.
Layered- aquifer flow properties. For aquifers which are either heterogeneous or layered, we must determine the hydraulic conductivity and porosity of each type of sediment within the aquifer and the proportions of each. For a layered aquifer, the total average horizontal hydraulic conductivity of the full saturated aquifer thickness is defined as being equal to a summation which looks like: $K_{avg} = \Sigma(h_i \cdot K_i)/H$, that is, the sum of products of the individual layer thicknesses and hydraulic conductivities divided by the total aquifer thickness. Since the product of thickness and conductivity in this equation is defined as transmissivity (T), this is often more-conventionally written as: $T_{eq} = H \cdot K_{avg} = \Sigma(h_i \cdot K_i) = \Sigma(T_i)$, i.e., the equivalent aquifer transmissivity is the sum of the individual layer transmissivities.

The average conductivity and equivalent aquifer transmissivity refer to a hypothetical, homogenous aquifer which would deliver the same total volumetric flux as the specified layered aquifer. However, it must be remembered that the true flow behavior and volumetric fluxes are different in the individual layers of the actual aquifer than in the hypothetical equivalent- layer model and that the average or equivalent properties represent a mathematical fiction which is usable only in certain specific ways.

Aquifer Transport properties.

Transport in this context refers to the motion of constituents which are dissolved and/or suspended in ground water, especially the movement of unregulated contaminant releases which propagate as slugs or plumes within the aquifer. The important transport processes are advection, dispersion, retardation, and attenuation which might be defined as follows. Advection is the physical transport of a constituent by the flow of water within a porous medium. Retardation includes all processes which cause a plume or constituents to move slower than the ground water. Dispersion includes all processes which re-distribute constituents away, i.e., spreads them out, from the center of mass of a plume. Attenuation includes all processes which permanently remove constituent mass from a ground water plume.

These processes affect contaminant transport and plume behavior in specific ways. Mathematically, they may all be represented by terms in the transport equation which describes the location, speed, amount and distribution of contamination within a plume in space and time. Advection refers to groundwater flow which we have already discussed. Both retardation and attenuation may be thought of as properties related to the type of constituent rather than as properties of the aquifer. Dispersion is related to dispersivity which is strictly an aquifer property which can be measured with special types of well test or estimated from theoretical considerations. Since the treatment of transport is outside this project scope of work, we omit the discussion of these processes from this report. However, it is important to note that most contaminants travel at different flow speeds and different particle trajectories than the ground water and must be modeled in different ways.

Sources of data.

Sierra Scientific Services (SSS) used four sources of information for the aquifer properties within the area of interest (AOI) including:

1. SSS physical property data (S_y, S_s, φ, K, H, F_{sd}) measured on surface and borehole samples or determined from electric logs from locations within the Rosedale - rio Bravo Water Storage District,
2. ID4 December, 2001, well test data (T & S) from wells near the intersection of Stockdale Hwy and Allen Rd at the northeast end of the Kern Fan,
3. C.o.B. infiltration test data (Kv) for large test ponds also near the intersection of Stockdale Hwy and Allen Rd at the northeast end of the Kern Fan,
4. KCWA water table elevation maps covering the Kern Fan area of interest.

SSS carefully reviewed and chose not to use the data from two other sources including:

5. DWR aquifer model data (Sy, S, K & T) for the Kern Fan area,
6. KWBA and Pioneer Project pump test data from various reports by Kenneth Schmidt and Associates (KDSA) of Fresno, Ca.

SSS did not use the data from these two sources for several reasons, chief among them is that we obtained a minimum but sufficient amount of well- documented, actual measurements for the necessary parameters of interest from the first four sources. However, with all due respect, we also consider the data from both of these other two sources to be questionable because of a lack of data, poor documentation, questionable or incorrect calculation methodologies, lack of corroboration, supporting discussions which are inconsistent with basic principles of hydrology, and/or internal inconsistencies. We recommend that readers carefully evaluate the data from these sources against their own technical and theoretical criteria before they use them in their own analyses. We offer some of our observations regarding the data from these two sources below, for purposes of clarification since we consider the selection (or rejection) of parameter values to be an important, documentable, exercise of judgment in a modeling program.

The DWR parameter data[15]. In 1988, the California Department of Water Resources (DWR) purchased approximately 20,000 acres of land in Kern County for an aquifer storage and recovery (ASR) program. The area has since changed ownership and is now known as the Kern Water Bank. In the early 1990's, the DWR attempted to develop a numerical computer model to simulate the aquifer behavior and evaluate various aspects of their project. The modeling effort concluded in early 1996 with the publication of the footnoted DWR memorandum which summarized the work. The memorandum included a discussion and summary of all the aquifer parameter values that the DWR used, and these parameter values have been referenced and used by some workers in the local water community.

In the process of parameterizing their computer model of the Kern Fan area, the DWR never actually measured a single value of any parameter in preparation for what became a massive modeling effort. The DWR assigned "textbook" values of specific yield obtained from the general literature (but not specific to the study area) to each of 55 different types of drill cuttings reported in driller's reports. Then, after blundering through a simplistic and erroneous application of trend analysis in which they assigned book values of K_h, K_v and S to these same drill cuttings and then numerically correlated to the assigned textbook values of specific yield, they proceeded to put these values into their computer model.

For example, the DWR assigned values of Sy ranging from 12 - 27% to drill cuttings described as water gravel, dry gravel, heavy gravel, heaving gravel, hard gravel, dead gravel, and cemented gravel. The DWR assigned values of Sy ranging from 12 - 20% to drill cuttings described as hard sand, heaving sand, dirty pack sand, tight sand, and quick sand. The DWR assigned values of Sy ranging from 3 - 6% to drill cuttings described as sediment, soil, loam, hard clay, cemented clay, adobe, and muck.

The DWR then used driller's logs and electric logs to basically assign all of the Kern County geology to one of the 3 previously-described sediment groupings, i.e., gravel, sand, or

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[15] Swartz, Robert, 1995, Development and Calibration of the Kern Fan Ground Water Model, DWR San Joaquin District Report, July, 1995.

silt/clay and then proceeded to apply their fabricated numerical parameter values to their geological model.

Apart from the aquifer parameter values, the DWR approach to developing the basic computer model appears to be consistent with many of their model simplifications which were required in order to approximate the true physical aquifer behaviors within the constraints of the model. However, in our opinion, their treatment of aquifer parameters shows poor judgment perhaps stemming from an insufficient understanding of the physical properties and property interrelationships of porous media and geological materials and, in our opinion, their poor parameterization showed up in their modeling as poor results.

DWR reported that the model calibration results were unsatisfactory based on their initial parameter values so they arbitrarily changed the parameter values around their control points to improve the outcome. Unfortunately, the DWR computer model never provided good results, which we attribute to incorrect parameter values, poor assumptions and poor choices of free parameters in the "calibration" tests.

Since the initial parameter values were questionable on petrophysical and theoretical grounds, since their choices of driller's explanations of the geological materials are unrepresentative of the local stratigraphy, and since the model results were unsatisfactory, we conclude that there is very little credibility in the representativeness of any of the DWR parameter values except to the extent that they fall within the wide ranges of published values for generic geological materials. We therefore, place no credibility whatsoever in any of the initial or subsequent textbook parameter values that the DWR assigned to any aquifer layer at any location as have chosen to not use their data or modeling results.

Kern Water Bank and Pioneer Project well test data[16]. The operators of these two sites have conducted a number of pump tests on wells in these areas over the years, and the test data have been interpreted and reported by Kenneth Schmidt and Associates (KDSA) of Fresno, Ca

[16] Schmidt, Kenneth D., November 27, 1997, Hydrogeologic Conditions for Development of the Maximum Recovery Plan for the Kern Water Bank Authority, revised report, Kenneth D. Schmidt & Associates, Fresno, CA.

Schmidt, Kenneth D., September 22, 1998, Maximum Recovery Plan for the Pioneer Kern Fan Project, draft report, Kenneth D. Schmidt & Associates, Fresno, CA.

on behalf of and under contract to the Kern County Water Agency to provide estimates of the aquifer parameters T & S. Part of the issue with these well tests as a source of aquifer parameters is that the test operations and test data are only poorly documented in these reports. But based on our review of the scant information in these reports, we can make the following observations.

The pump tests appear to have been designed and operated by engineers in order to determine pump-parameter values rather than aquifer parameter values. Many of these tests had multiple wells pumping simultaneously and most tests lasted for only short durations (as little as 20 minutes or 1 - 2 hours), both of which make it difficult to determine aquifer properties. Moreover, all of the reported drawdowns were measured in the pumping wells and not in adjacent monitoring wells, so none of the data meet the standard validity criteria for aquifer analysis.

Our main objections to the findings of the two KDSA reports include: no presentation of test data or calculations, no discussion of where the data came from, no discussion of the assumptions or the methods of calculation of T or S, the acknowledged dependence on uncorrected discharge/drawdown ratios for a number of pumping wells to estimate values of T without providing calculations or making corrections for even the most basic and most obvious variations in well conditions, many explanatory statements that are inconsistent with fundamental principles of hydrology, a heavy reliance on the DWR parameter values which we have reviewed, criticized, and rejected (see previous section) and, finally, an unexpectedly large range of reported values for T which is inconsistent with our own independent data. We therefore give very little credibility to the KDSA parameter data for these reasons.

Aquifer Parameter Values used in this Study.

<u>Aquifer Dimensions.</u> The aquifer model includes a 300-ft thick shallow unconfined zone, a 50-ft thick middle aquitard zone, and a 300-ft thick deep semi-confined zone. All wells are assumed to be completed across the full aquifer thickness of the deep zone, i.e., a producing interval 300-ft long.

Porosity (φ). The source of porosity values for this scope of work is the field work that SSS[17] completed for the Rosedale - Rio Bravo Water Storage District (RRBWSD) and reported in 2003. RRBWSD contracted SSS to drill coreholes, collect sediment samples and obtain laboratory analyses for specific yield and a set of other useful physical properties. One suite of samples came from the RRBWSD recharge pond area less than 1 mile north of the Strand Ranch project site. Based on those samples, the measured average porosity of well sorted sandy sediments is 37% and the measured average porosity of the silty sediments is 34% and give a weighted average porosity for the aquifer media of 30% for this project.

Specific yield (S_y). Specific yield is a function of the porosity and grain surface area of porous media and is a property which varies over only a limited range of values for the few aquifer materials of interest. The source of specific yield values for this scope of work is also from the 2003 field work that SSS completed for the Rosedale - Rio Bravo WSD.

Based on the RRB study, the average specific yield of the sandy and silty sediments in the area of interest are 33% and 8.6%, respectively. Based on the relative fractions of each in the upper aquifer, the average specific yield of the interval is about 21%.

In contrast, KDSA (1998, p. 15) reported that:
"The average specific yield of Layer 1 is estimated to be about 17%, based on DWR groundwater modeling. The best specific yield value that can be used ... is 10%. This is thus considered to be an appropriate value to use to estimate future water level declines due to recovery pumpage..."

And in contradiction, KDSA (1997, p. 11) reported that:
"... long term tests in [the KWB] area in 1990 - 1991... generally indicated that [the] unconfined aquifer could be assumed with a storage coefficient of about 0.01 to 0.02 .."

Our measured values are considerably different than the fabricated DWR values and the KDSA values of unknown origin. We therefore, have rejected the DWR and KDSA values in favor of our own data. In the case of specific yield (Sy), this has no impact on the drawdown analysis since dewatering of the aquifer does not enter into the calculation and therefore the value of Sy is not used in the determination.

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[17] Crewdson, Robert A., 20 January, 2003, Determination of Aquifer Storage Capacity for the Rosedale - Rio Bravo Water Storage District, Bakersfield, California., Sierra Scientific Services, Bakersfield, Ca.

Specific storage (S_s) and Storativity (S). Specific storage is a function of the porosity and bulk compressibility of porous media and is a property which varies over only a limited range of values for the packed, unconsolidated sandy and silty media of interest. The source of specific storage values for this scope of work is from the 2003 field work that SSS completed for the Rosedale - Rio Bravo WSD. Based on compressive stress tests on samples of poorly sorted sand and silty sand, the bulk compressibilities of these samples range from 4.5 - 7.9 x 10^{-8} m^2/N from which we have derived the values for the dense, compacted equivalents of these sediments as 1 - 1.8 x 10^{-8} m^2/N which are in the expected range of compressibilities for dense sands. From these values we have calculated the corresponding values of S_s ranging from 0.000030 to 0.000053 ft^{-1} and averaging 0.000041 ft^{-1}. This range of S_s values is entirely consistent with the range of published values expected for dense sands and silts.

Based on these values of S_s, the equivalent values of storativity for a 300-ft thick aquifer range from 0.009 to 0.016 and if we add a factor for water released from storage in the overlying aquitard, the expected value of aquifer storativity is expected to be in the range from 0.012 to 0.021. Based on this analysis, we would have chosen to use an average value of S = 0.016 for our modeling but, as presented in the following discussion, we have used a value of S = 0.020 as our base case value of storativity.

We have reviewed the available published sources of parameter values and we consider the ID4 well test of December, 2002 to be the best available source of a verifiable T & S value from an actual aquifer pump test for the Kern Fan area of interest. KDSA[18] originally interpreted the data and reported a transmissivity T = 476,000 gpd/ft [equivalent to 63,600 ft^2/d] and a storage coefficient S = 0.0008. However, based on our own independent analysis, we found that the KDSA calculations were incorrect due to a failure to meet the validity criteria of the method and, after our own reformulation, the corrected aquifer test yielded values of T = 20,000 ft^2/d and a storage coefficient S = 0.00056. We also disagreed with the entire KDSA distance - drawdown interpretation presented in the same report because of an incorrect application of the Cooper - Jacob (single-well) method to a cluster of several pumping wells. As a result, we have chosen not to use the KDSA reported values of T & S, in favor of our own reinterpretation of the data.

[18] Schmidt, Kenneth D., February 28, 2003, Supplement to the Groundwater Conditions and Potential Impacts of Pumping for the ID-4 Kern Parkway and Rosedale - Rio Bravo WSD Projects, aka Allen Road Well Field December 2002 Pump Test, Kenneth D. Schmidt & Associates, Fresno, CA.

Despite the calculation error, the original KDSA values and our recalculated values of T & S from the 2002 ID4 well test differ significantly from those values published in the KDSA report of 1997 (KDSA did not report values of storativity in their 1998 report). With respect to storativity, KDSA (1997, p. 20) reported:

> *"Past pumping in the COB 2,800-area and the Kern Water Bank area indicate a value for storage coefficient of 0.02, which is considered applicable for most of the existing recovery wells. With continued pumping, (i.e. greater than six months), the storage coefficient is expected to gradually increase, to about 0.05, and to possibly as high as 0.10."* (Curiously, KDSA does not report any S values in their 1998 study, stating that (p. 15) *"The storage coefficient can't be readily determined from the available pump tests, mainly because the tests could not be run for long enough periods in the absence of interference.."*)

On the one hand, we are prepared to accept a reported value of S = 0.02 as being close to our expected range of values (0.009 to 0.016) for the deep aquifer zone except that the KDSA value was intended to represent the entire aquifer across all three zones, so there is less agreement here than it appears. We would expect a deep zone value, based on the KDSA full-aquifer number, to be more in the range of 0.001 to 0.01. However, the value of S = 0.02 is completely uncorroborated since KDSA did not provide any data, calculations, or discussions so we are unable to place any credibility in the value. Moreover, their claim that the value of S will increase with time due to continued pumping is not only unsupported with any discussions or calculations, it is contrary to expectation and incorrect based on the most fundamental theoretical considerations. We therefore reject the credibility of the KDSA parameter values as being questionable or at least unverifiable.

Nevertheless, since the KDSA 1997 Report was written for and presented to the Kern Water Bank Authority, we assume that the KWBA is using these parameter data for their own modeling calculations. Lacking any corroborating data to improve the reliability in the parameter value, we have chosen to use the KDSA reported value of S = 0.02 anyway as our base case value for storativity because it was close to our expected range of values and it was also the value reported and used by the Kern Water Bank, the nearest neighbor to the Strand Ranch project Our use of the 1997 KWB storativity value of S = 0.02 is for attempted consistency with previous work for-, and for general acceptability to-, the Kern Water Bank and is neither intended to be construed as our acceptance nor our verification that these values represent the true values within the aquifer.

Transmissivity (T) and Conductivity (K). One T-value for this scope of work is based on our re-interpretation[19] of the ID4 well test of December, 2002. As previously mentioned, we reviewed the KDSA report, disagreed with the KDSA findings, and re-calculated the T & S values using the correct theoretical assumptions and validity conditions for the method.

Based on our re-analysis, the correctly determined value of transmissivity is T = 20,000 ft^2/d. The chief concern is that the test well covers a different completion interval and is about 6 miles from our current area of interest so that the T & S values may not be representative of the conditions near the Strand Ranch. Based on an unpublished, proprietary study by SSS, we have data which tentatively suggests that the average aquifer transmissivity under the Rosedale - Rio Bravo Water Storage District under the east half of township 29s/25e and the west half of 29s/25e is in the range of 18,000 - 24,000 ft^2/d. This large area is immediately north of the current project site and suggest that perhaps an aquifer transmissivity around 18,000 - 20,000 ft^2/d within ± 20% may be representative of the producing zone in the study area as well.

We also reviewed the 1997 KDSA Report and focused on the T and K data which they attributed specifically to the areas of the Kern Water Bank immediately adjacent to the Strand Ranch project site, i.e., KWB Area 3, Area E, and Area S. The reported K values for the three surrounding areas (1997, Table 1, p. 14) have an average value of K = 57 ft/d which is the same as the KDSA reported K-value for the shallow aquifer under Area E alone (1997, p. 13, HCvert = 430 gpd/ft). The values are reportedly calculated from the observed rise in water levels under recharge ponds in 1995 - 1996, using the 1978 Bouwer formula. Unfortunately, KDSA provided no data, formulas, or calculations so these findings are completely uncorroborated. Based on our familiarity with the Bouwer method (Bouwer, 1978, section 8.3.1, pp. 279-288) we observe that such a calculation would be very much more complex than the otherwise simplistic handling of data presented in the rest of the KDSA report. Nevertheless, if these findings were to be accepted as is, they would appear to be unique in that they represent a departure from using the DWR computer model data that is the basis for all of the other reported parameters (1997, p.12).

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[19] Crewdson, robert, A., 20 July, 2004, An Evaluation of Well Placements and Potential Impacts of the ID4 / Kern Tulare / Rosedale - Rio Bravo Aquifer Storage and Recovery Project, Bakersfield, California, Sierra Scientific Services, Bakersfield, Ca.

In our attempt to use aquifer parameter values that will be found acceptable by the Kern Water Bank Authority, we chose to use this reported value of K = 57 ft/d and have calculated an aquifer transmissivity for the 300 ft thickness of the producing zone of T = 17,100 ft^2/d. This value is close to, but less than our range of expected values of T for the same interval. Given the complete lack of verifiable data in the area, we have no basis to prefer one set of parameter values over another. If this T-value proves to be too low in subsequent testing, then the predicted hypothetical drawdowns will have been too large. For all T-values in the real aquifer that are larger than our assumed base case value of 17,100 ft^2/d, the actual drawdowns will be less than those we have calculated in this study. Since there is a body of other data, even though of questionable value in our opinion, which reports a wide range of possible and particularly much higher values of T, we have treated T as one of our free parameters which we vary in our modeling sensitivity analysis. The sensitivity analysis was based on a range of hydraulic conductivity values of $40 < K < 100$ ft/d.

Aquitard leakage factor (B). The mathematics of leakage occurs in the flow equation in the form of what is referred to as the Hantush leakage factor (B) and B is related to known parameter values according to the formula $B = (T/L')^{1/2}$. In the project area, the high-permeability zones of the aquifer are sandy sediments and the low-permeability zones are silty sediments. These silty sediments are the aquitards which retard the vertical flow of water between the sandy layers of the aquifer. Based on our measurements and estimates of the relevant properties, we estimate that the value of B varies in the range of about $3200 \leq B \leq 10{,}000$ and we have used a value of B = 6000 as our base case value.

Both Swartz (1995) and Schmidt (1997) quote generic values for vertical hydraulic conductivity (K_v)for the Kern Water Bank area (see Exhibit 2) ranging from .0004 - .0027 ft/d which are within the two orders of magnitude of typical textbook values for silty sediments. Swartz (1995, p.116) indicated that the selected DWR values were guessed at and did not work very well in their computer models and had to be changed to other, unreported values. Schmidt reported (1997, p.11) that their K_v values were determined from long- term well tests performed in the KWB area in 1990 - 1991 but we do not know how this might have been done, since Kv cannot normally be determined from a well test. Moreover, Schmidt did not present either the well locations, test methods, test data, or calculations so we cannot independently verify the reported values or their relevance to the project area. Except that these reported values fall within the range of expected textbook values for silty sediments, we place no particular credibility in the representativeness of these particular values of K_v. We do not know of any other reported pump test data which provide a determination of the vertical hydraulic conductivity of the local sediments.

There are several reported measured values of vertical hydraulic conductivity Kv_{sand} for both sand and silt samples collected in the area of interest. RRB (Crewdson, 2003) and the City of Bakersfield (COB, 2000) separately reported independent sediment permeability data which are based on laboratory core analyses of shallow unconsolidated sediments which have been retrieved from boreholes down to 120 ft deep. The RRB sand samples had a Kv_{sand} = 18 ft/d and the COB sand samples had a Kv_{sand} = 112 ft/d. The RRB silt samples had a Kv_{silt} = 0.038 ft/d and the COB silt samples had bimodally distributed values of Kv_{silt} = 0.3 and Kv_{silt} = 0.03 ft/d. Based on these core- sample data, we observe that the local silty sediments are about 500 - 1000 times less permeable than the local sandy sediments.

Based on the Kv/Kh ratio for these sediment analyses and the well-test value of K_{Hsand} = 80 ft/d, we estimate that the range of vertical hydraulic conductivity of the silty intervals is about $0.04 < K_{Vsilt} < 0.16$ ft/d with an average estimated value of K_{Vsilt} = 0.08 ft/d . Finally, we have estimated the aquitard thickness (b′) based on E-logs and dimensional considerations to be 50 - 100 ft thick and have calculated a range of values of leakance (L′) and Hantush leakage factor (B) accordingly. We have selected an average value of B = 6000 ft for base case drawdown calculations and a range of $3200 \leq B \leq 10{,}000$ for sensitivity analyses.

<u>Water Levels and Groundwater Gradients.</u> For the calculation of drawdown impacts, we have initially assumed that the regional gradient in the test area is zero so that all model impacts are superimposed on an initially flat water table. We set our reference elevation to be zero at the initial water table rather than at ground level or at mean sea level so that all calculated drawdowns are relative to the initial water table. This device allows us to easily observe just the predicted pumping- induced drawdown at any location without the complicating effects of the natural gradient.

However, in order to perform particle trajectory and capture zone analyses, we must superimpose the calculated pumping- induced drawdowns on a realistic approximation of the natural water table gradient. We based our approximations on observed historical water table behavior for wet and dry climatic conditions in which the unimpacted natural groundwater gradient is northwesterly at -10 to -30 ft/mile. The greater impact during dry conditions is the distortions in the water levels due to pumping of non-project wells in the immediate area so we have prepared one scenario in which the impacts of the local Kern Water Bank wells were included in the drawdown model. The pumping rates for the KWB wells were obtained from KWB published data.

Exhibit 3.

Limitations of the Analyses.

Exhibit 3.

Limitations of the Analyses.

SSS has evaluated several sets of base case and non- base case operating scenarios and aquifer conditions to determine the predicted impacts of a hypothetical Strand Ranch pumping program. The uncertainties in the calculated results are due to several factors which we briefly summarize in this Exhibit.

Non - project wells.

There are three issues related to the impact of non- project wells in the local area. The first issue is the effect of water table decline due to the pumping of these non- project wells which is in addition to, and superimposed upon, the drawdown caused by the project wells. We have not included any hypothetical scenarios which takes this into consideration.

The second issue is that these non- project wells are removing water from aquifer storage which is not included in the project water balance. Even though the project, by design, will remain in balance, the local area may still suffer a net shortage of recharge depending on the operations of other parties which may create a net decline in water levels, which will ultimately change the aquifer behavior from semi-confined to unconfined. We have already recognized this hypothetical condition in our general analysis, and it is important to recognize the potential for shallow aquifer dewatering by the pumping of non-project wells.

The third issue is that non- project wells create capture zones of their own which extend outward into surrounding areas which are outside of the capture zone limit of just the project well field alone. It is possible that these surrounding wells may draw contamination into the project area that would not have arrived here otherwise. Such a capture analysis is outside the scope of this analysis. While there are limits to the possible magnitude of this potential impact, the wells of greatest potential concern would be wells which are close to the project well field and those which are to the east or south of the well field.

Changes in the groundwater gradient.

The Strand Ranch ASR Project is near, but northwest of, the recharge axis of the Kern Fan recharge mound. Based on KCWA groundwater elevation maps for the area, we have observed historical changes in overall water levels and changes in the groundwater gradients as the climate swings from wet to dry conditions.

The depths to groundwater under the Project site fluctuate significantly due to the rise and fall of the Kern Fan recharge mound under the influence of the regional climatic wet/dry cycle. During consecutive dry years the groundwater may be 150 - 170 ft deep such as in 1990 - 1994, whereas during consecutive wet years the groundwater under the site may be 20 - 70 ft deep such as in 1995 - 1998. The unimpacted, natural groundwater gradient under the Project site in dry years trends northwesterly at -10 to -15 ft/mi WNW and in wet years trends northwesterly at -20 to -30 ft/mi NW.

The unimpacted, natural groundwater gradient under the Project site in wet years trends -20 to -30 ft/mi NW'ly (for example, see KCWA groundwater elevation map for Spring, 2001.) During a dry cycle, the absence of recharge in this stretch causes a shallower, more westerly -10 to -15 ft/mi WNW unimpacted, natural gradient to dominate. However, dry years are also characterized by heavy pumping in the Kern Fan banking projects. The groundwater pumping within the Kern Water Bank in the areas adjacent to the Strand Ranch project site has historically been observed to cause reversals, depressions, and/or other complexities in the groundwater gradient under the Strand Ranch project site (for example, see KCWA groundwater elevation maps for Spring, 1993 or Spring, 1994).

Similar large water level fluctuations in the future will create potential design and operating challenges for the placement and operation of downhole pumps in the Strand Ranch water recovery wells. The evaluation of such potential factors is entirely outside the scope of this work program.

We also recognize that such historical water level fluctuations and gradient changes have already affected the downgradient location of the observed shallow-aquifer brine plume which has migrated under the project site from an unspecified off-site, upgradient location. We expect that future gradient changes will continue to impact the known plume and may cause potential but as-yet unrecognized contaminant plumes located outside of, but close to, the long term project well-field capture zone limit to move into the capture zone. The reverse is not really possible, i.e., contaminant plumes leaving the capture zone, because even though particle trajectories say it is possible, actual contaminant migration invariably leaves in situ residues behind in its pathway which linger as continuing in situ sources of low- grade contamination for many years thereafter. We have not included the unknown future fluctuations in water levels or ground water gradient in our analysis.

Uncertainty in predictive modeling.

There are several causes of uncertainty in the outcome of a predictive forecast and it is useful to keep the relative importance of these causes in perspective.

Natural variability. The single most significant cause of uncertainty is natural variability, i.e., the complexity, heterogeneity, and randomness in the real world which are impossible to fully identify or evaluate at relevant scales of measure. In this project, we know that the aquifer is more complex in ways which we may or may not recognize but can't model because of insufficient data. For example, we know that the silty layers seen in the E-log of one well rarely correlate with the silty layers seen in adjacent wells. But we can't model all of these individual layers because we don't actually know where they start and end in the unobserved spaces between wells. The same is true for boundaries which are there but have not yet been detected by the existing investigations.

We must therefore try to represent the known or suspected complexity with a simpler component within our model which best approximates the expected behavior of the real earth by lumping the complex properties together in the form of a simpler analog. The practice of "lumped parameter" modeling is a simplification of choice as well as necessity. Even if it were possible to represent every sand grain and every pore space in the aquifer, the increase in microscopically detailed complexity may not contribute anything to improve the accuracy or reliability of the results. It is one of the hard-won skills of good modeling to know when and where a simpler approximation will be an effective and accurate representation of the real system.

A corollary effect of natural variability is that the true aquifer parameters will always be somewhat different than those in the model at some place or at some time. Even if we could precisely determine the true average value for every parameter, those local parts of the aquifer which are higher or lower than the average value and have observation wells located in them, will be observed to behave differently than predicted by the model. Since predictive modeling is often used *before* projects have begun, it is often true that a sufficient amount of good data doesn't even exist to estimate the average properties of the aquifer let alone map the full range of variability at all locations. Often a sufficiency of data doesn't exist until such a project has operated for many years. So, when comparing a predicted behavior to a subsequently observed behavior, it would be a mistake to treat point- by- point differences as a parameter error when those differences can be adequately explained as being caused by simple, undeterminable, natural variability about an average value.

Another effect of natural variability applies to the inability to predict future naturally-occurring or manmade events or behaviors, in addition to the variability in physical properties. For example, highly variable weather conditions can deviate significantly from average behavior without being considered anomalous, so that any *particular* predicted event has a significant chance of being different than the actual occurrence even though the prediction is a "correct" one. For these types of conditions, the correct prediction is actually a set of predictions covering the full range of possible values, with a probability of occurrence attached to each one. So in this project, we predict aquifer drawdowns due to pumping and our model stipulates that the actual future drawdown behavior will be controlled in part by the amount and timing of recharge which is controlled by the climatic weather cycle.

Judgment. The second significant cause of uncertainty is errors in judgment by the modeler, including such mistakes as selecting an inapplicable model or poor model parameters, doing the work incorrectly, or failing to recognize and correct "catchable" mistakes. These errors in judgment range from making an informed choice under difficult conditions or with very little data to blatant mistakes. There is probably little chance of a non- expert catching errors in judgment other than, perhaps, blatant mistakes.

In our opinion, there are three ways for a client to try to minimize judgment errors. The first is to use a modeler who clearly has the education, the background, and the experience to do the job correctly to begin with. The second is to get a thorough presentation of the work (model and results) and, if necessary, get second opinion from a qualified expert. The third is to take the time to learn enough basics to make a critical review of the work. After all, the accuracy of your own work may depend on these results. And then, require clear, complete, and verifiable documentation beyond simple numerical QA/QC with any modeling project and simply evaluate the work product for logic, consistency, clarity, and credibility.

Expectation. A third cause of uncertainty is errors of expectation on the part of an inexperienced modeler or the final user of the predictive output. Errors of expectation can include expecting too much and expecting too little. Unreasonably high expectations often come from a lack of understanding of the issues of natural variability. Examples of such errors of expectation include the assumption that there is only a single possible answer or that it is single- valued; that the answer is precise and accurate and, if correct, will be verified to a high degree by the actual observed outcomes; that the answer must be right because modeling is a numerical procedure and computational accuracy is mistaken as being the same as representational accuracy; or that the modeling procedure is wrong or useless or that mistakes must have been made if the predicted results and actual results disagree in some way.

Low expectations often come from a lack of understanding of how powerful and sophisticated predictive modeling can be in the hands of a competent expert. Many business people, policymakers, engineers, and consultants go about their particular business unaware that predictive modeling tools exist for almost every type of process or system including groundwater phenomena such as the flow behavior of rivers, water supply reliability, weather patterns, basin analysis, flow behaviors, and contaminant plume migration.

Unlike errors of judgment by a trained practitioner, errors of expectation are not a matter of right or wrong. Getting it wrong while learning what to expect is the normal process for all of us. The lesson is that if modeling is not part of one's expertise, then 1. hire an expert rather than trying to do it yourself, 2. talk to your expert about reasonable expectations, and 3. learn something about the required inputs, the process itself, and the form of the expected output so you can bring some critical review to the results.

Exhibit 4.

Drawdown Analysis of Proposed Wells Located Within the RRBWSD Service Area.

Exhibit 4.

Drawdown Analysis of Proposed Wells Located Within the RRBWSD Service Area.

One of the design objectives of the proposed Strand Ranch Aquifer Storage and Recovery Project is to provide all of the project benefits to the project participants while minimizing the potential, adverse, impacts on the environment, the project itself, and on adjacent entities. The adverse impacts of primary concern include well interference within the project well field and drawdown impacts to non-project wells in the surrounding area.

We have already discussed the proposed design practices for the Strand Ranch well field to minimize these impacts in the main text of the Report. The project also proposes to use an additional, available, alternate mitigation measure as necessary or as beneficial which is to reduce the rate and/or duration of pumping from the Strand Ranch onsite project wells which would otherwise be necessary by recovering water, by mutual agreement, from up to three wells located off the project site and within the adjacent Rosedale - Rio Bravo Water Storage District serv ice area.

As part of a pre-existing proposed well field program, RRBWSD agrees to provide a priority right of use to up to three wells located on or near the existing Paul Enns Recharge Ponds Facility (in Sec 34, T29s/R25e) or along the Goose Lake Slough upstream of the Enns Facility (on or near the north section lines of Sec 35 or 36, T29s/R25e).

We have modeled the predicted recovery-well drawdowns for four hypothetical well scenarios on the RRBWSD property. All scenarios assume that every well pumps at a nominal rate of 10 af/d (5 cfs). The four scenarios include: 1. five wells (5-spot pattern in a 160-acre area) in the Enns Recharge Pond Facility; 2. three wells (3 in-line at 1/3-mile spacing) just south of the north section line of Sec 35; 3. three wells (3 in-line at 1/3-mile spacing) just north of the north section line of Sec 36; or 4. All eleven wells operating simultaneously.

The drawdowns have been calculated and plotted on a rectangular base map covering a 2-mile N/S by 5-mile E/W area centered on the 11-well array (see, at the end of this text, Maps 4-1, 4-2, 4-3, & 4-4, for the pumping scenarios 1 - 4, respectively). This study area is bounded on the north side by Rosedale Highway and on the south side by Stockdale Highway. The main impact-areas-of-concern include the northernmost portions of the Kern Water Bank which lie to the south of the proposed RRBWSD well field. The northernmost boundary of the Kern Water Bank in Twp 25E runs E/W parallel to- and ½-mile south of- Stockdale Highway.

In all well-field pumping scenarios, the maximum predicted drawdown at or just south of Stockdale Highway is 5 ft and by easy extrapolation, the maximum predicted drawdown ½-mile south of Stockdale Highway is less than 2 ft (Maps A01, A14, A15, and A21, included in this Exhibit). The northernmost three KWB wells are all 3/4 to 1-mile south of Stockdale Highway where we predict that the maximum drawdown (from the 11-well scenario) would be less than 1 ft, and for any three-well scenario, the maximum predicted drawdown at the closest KWB wells is a fraction of 1 ft. We conclude that there will be no significant adverse impact to any non-project wells outside of the District due to the hypothetical case of pumping of all eleven wells in the proposed RRBWSD well field.

We also conclude that the expected impacts due to pumping of any three wells at any three locations within the proposed RRBWSD well field, whether clustered or separated, will have maximum drawdown impacts of less than 2 ft south of Stockdale Highway, and less than 1 ft at locations within the boundary of the Kern Water Bank.

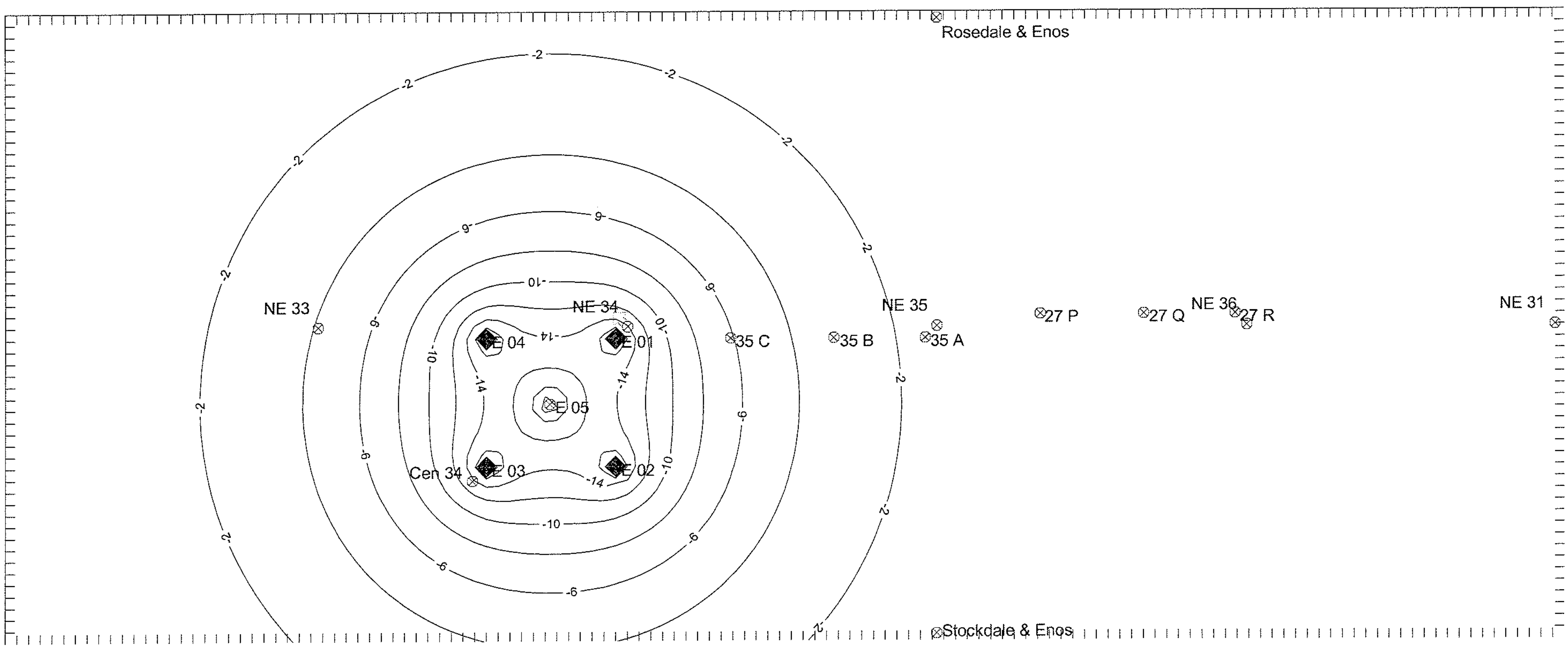

EXHIBIT 4. MAP 4-1.

A01

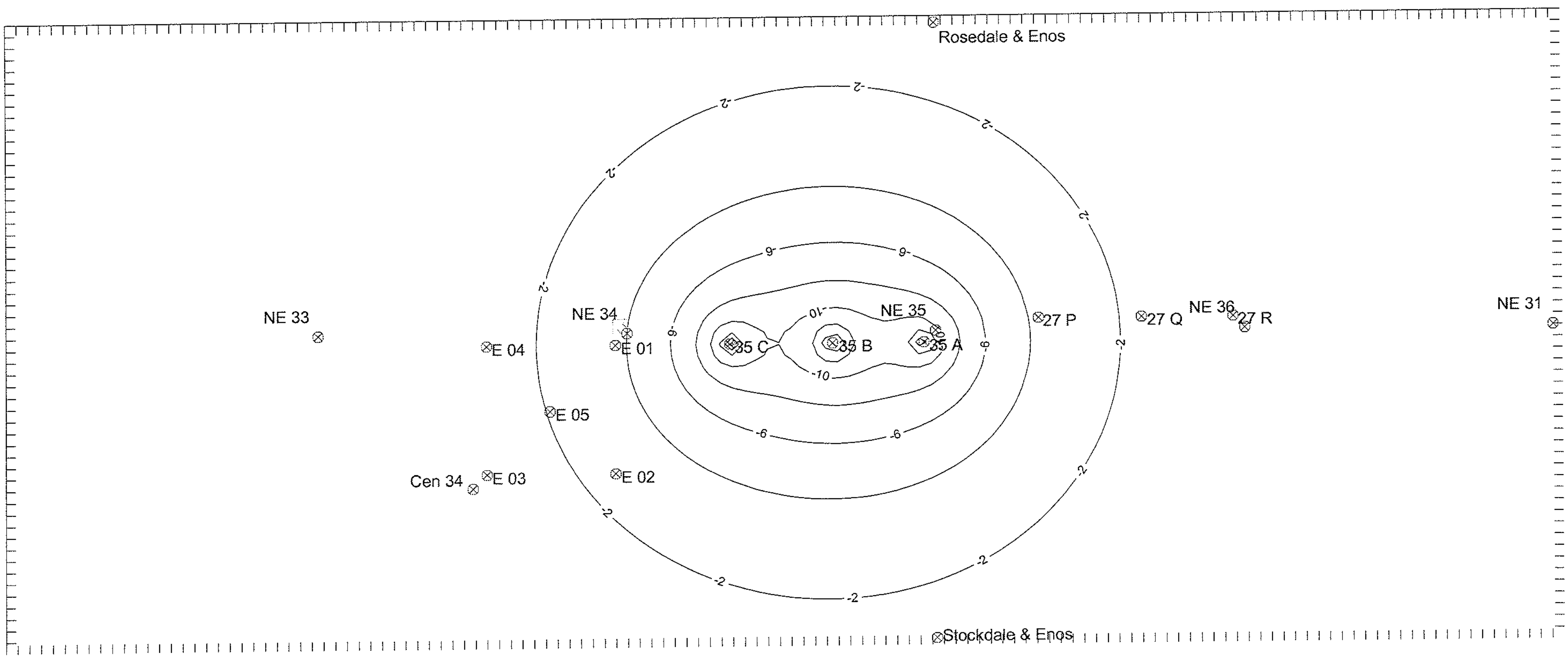

EXHIBIT 4. MAP 4-2.

A14

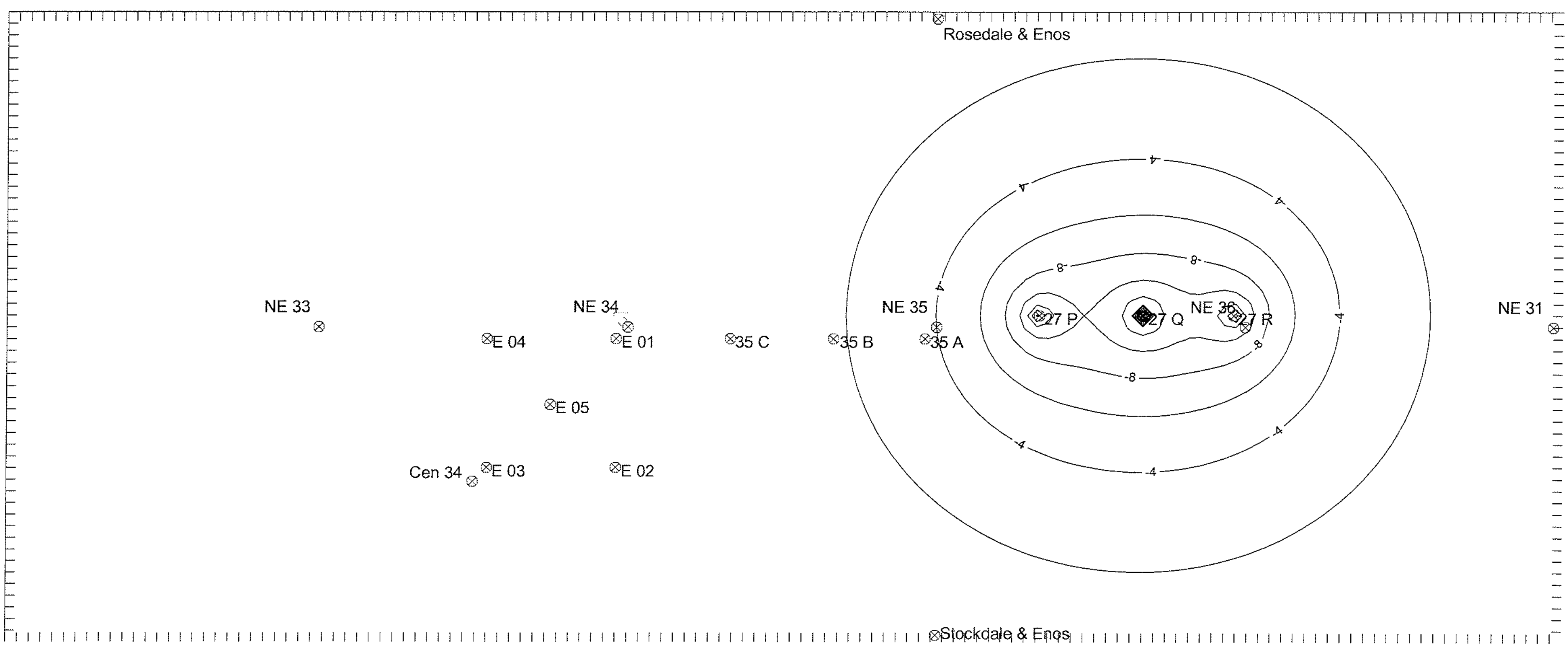

EXHIBIT 4. MAP 4-3.

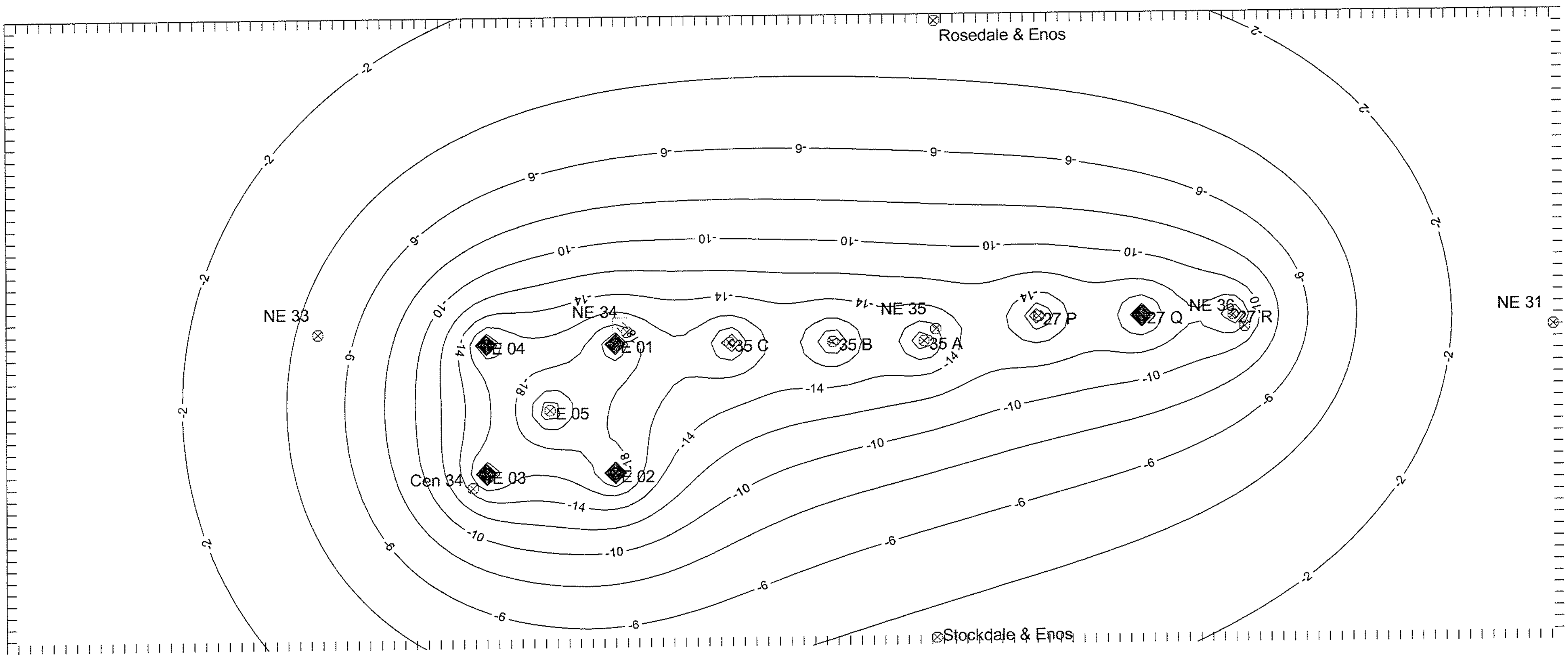

EXHIBIT 4. MAP 4-4.

A21

Exhibit 5.

Catalog of Drawdown and Mound Analyses.

Exhibit 5.

Catalog of Drawdown and Mound Analyses.

SSS evaluated several sets of base case and non- base case conditions to illustrate the calculated drawdowns for purposes of comparison and evaluation. The best way to compare variations is to look at the maps to observe the changes in drawdown at locations of interest with respect to the changes in the free parameters and remember that the parameter changes are intended to reflect hypothetical changes in the real aquifer properties which affect the groundwater behavior. All maps cover nine sections centered on sec 02, T30s, R25e at a scale of approximately 1inch = 2290 ft. The model space is an 80x80-cell grid which is marked on the map margins; each cell represents 200x200 ft in real space. All maps include reference markers at the NE, SE, SW, and NW corners of section 02.

We have compiled a set of introductory maps (Set 0) showing the well locations, groundwater gradient scenarios, and parameter sensitivity variations in the absence of project pumping. We have compiled the data sets into groups of drawdown analyses (Sets 1 - 3) with or without particle trajectories, and a group of other special-case analyses (Sets 4 - 7) which are illustrative of other issues but not necessary to the basic drawdown impact scope of work. From the drawdown analyses, we have tabulated the observed drawdowns within the Strand Ranch well field, within the overall Strand Ranch project site, within the surrounding eight sections which comprise the study area, and outside the study area perimeter.

We list the complete set of drawdown analyses in the catalog below.

Set 0. Basic model data.

- Map B40 - B43, well location maps.
- Map B0, B22, base case drawdown, w/o and w/ GW gradient.
- Map B39, GW gradient (GWG) only.

Set 1. Variations in aquifer model.

- Map B0 - B2; B = 3200, 6000, 10,000.
- Map B0, B3 - B6; K = 57, 100, 80, 50, 40 ft/d.
- Map B0, B7 - B10; t = 300, 10, 30, 100, 1000 days.
- Map B0, B11 - B12; leaky, confined, unconfined.

Set 2. A. Variations in well operation *without* GW gradient.

- Map B0, B14, B16, B18, B20, D1; wells 1-9, 12356, 4789, 13579, 2468, 1-7.

B. Variations in well operation *with* GW gradient.

- Map B22, B15, B17, B19, B21, D2; wells 1-9, 12356, 4789, 13579, 2468, 1-7.

Set 3. Variations in particle tracking.

- Map B23 - B25; steady-state 10 & 5-yr, transient 10-yr.

Set 4. Special cases comparing 1760-ft and 1320-ft Strand Ranch well spacing.

- Map B26, B38; WL diff between SR 1-9 (1760-ft) and SR 11-19 (1320-ft).
- Map B27 - B28; wells SR 11 - 19, 1320-ft spacing, w/o and with GW gradient.

Set 5. Special cases comparing Strand Ranch drawdowns with Kern Water Bank drawdowns.

- Map C1-C3; SR only, SR & KWB1, KWB1 only,
- Map C4 - C6; KWB1 w/GWG, SR & KWB1 w/GWG, SR only w/GWG
- Map B29 - B31; KWB1 no GWG, ref change, KWB1 w/GWG
- note: KWB1 - 03R and 11C at setback locations.

Set 6. Special cases comparing Strand Ranch drawdowns with Kern Water Bank drawdowns.

- Map B33; KWB2 drawdown. (KWB2 - 03R & 11C on property boundary).
- Map B34 - B35; diff calc shows net areas of SR or KWB drawdowns.
- Map B36 - B37; SR & KWB2 total drawdown, with & w/o GWG.

Set 7. Drawdown impacts on Strand Ranch related to KWB wells 11C and 03R.

- Map E1 - E2; old locations, setback locations.
- Map E3 - E4; net diff calc, transient & steady-state.
- Map E5 - E6; same except for 11C only.

Set 8. Re-run of key models.

- Map F1 - F15; 9-,7-, & 5-well cases w/wo GWG & particle trajectories.

ATTACHMENT 16F

Kern County Water Agency, 1991: Study of the Regional Geologic Structure Related to Groundwater Aquifers in the Southern San Joaquin Valley Groundwater Basin, Kern County, California (September, 20, 1991).

KERN COUNTY WATER AGENCY
STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUND WATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUND WATER BASIN, KERN COUNTY, CALIFORNIA

September 20, 1991

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TABLE OF CONTENTS

TABLE OF CONTENTS (CON'T.)

TABLE OF CONTENTS (CON'T.)

FIGURES

PLATES (in pockets)

APPENDIX

Project Authorization

The Agency Board of Directors on January 25, 1990, authorized a clay map study of the San Joaquin Valley portion of Kern County.

Kern County Water Agency Act 9098 Section 4.6 Surveys and Investigations

"The Agency shall have the power to make surveys and investigations for works and projects and of the water supply and resources of the Agency, and to carry on and perform technical and other investigations of all kinds, make measurements, collect data and make analyses, studies and inspections pertaining to water supply, water, water rights, control of flood and storm water and use of water both within and without the Agency, and for these purposes the Agency shall have the right to access through its authorized representative, to all properties within the Agency; provided, that the existence of such right of access shall not relieve the Agency from liability for damage sustained by any property owner by reason of the exercise of said right."

1.0 CONCLUSIONS

1.1 The shallow structure (less than 2,000 feet below surface) in the study area is more complex than previously mapped, as established by the following:

a. Extensive subsurface deformation exists, and shallow structural highs can be used to subdivide the valley into ten structural subbasins.
b. Some of the subsurface structures have little or no surface expression (e.g. Paloma anticline, Bakersfield Arch).
c. There are several regional and many local unconformities.
d. Faulting is observed which extends into the near surface sediments.

1.2 The "E" Equivalent Clay as identified in well 23S/24E-16B can be mapped as far south as T.30S.-R.24E., MDB&M, within the Buttonwillow trough. The clay can be correlated with confidence from the deepest part of the basin eastward to a line that extends roughly from Delano through McFarland and west of Shafter. The clay reaches depths of -900 feet subsea (1,100± feet subsurface) in T.25S.-R.20E., MDB&M, at the Kern County line.

1.3 A widespread clay informally named the "Paloma" Clay is mappable south of the Bakersfield arch. It is identified in wells 31S/25E -15R, 31S/25E - 36A, and 32S/25E-1H in the Buena Vista lake bed area. This clay is eroded to the north (including the Kern Water Bank area) and is deeper than 4,400 feet below sea level in the depocenter at the southern end of the valley near Mettler (Plate X). Stratigraphic correlations indicate the "Paloma" Clay is older than the the "E" Equivalent Clay as mapped in this study.

1.4 There are other shallow correlatable units in the southern San Joaquin Valley. None of these clays appear to be as areally extensive as the "E" Equivalent and "Paloma" clays mapped in this study. However, some of these clays may have significant hydrogeologic importance to local ground water conditions.

1.5 Seismic surveys can be an effective (and sometimes essential) tool for mapping the shallow subsurface.

2.0 PURPOSE AND SCOPE OF STUDY

2.1 PURPOSE

As ground water management pressures have increased, a need has developed within the Kern County Water Agency for a geologic evaluation of the regional clay layer which separates the confined and unconfined aquifers in the San Joaquin Valley portion of Kern County south of Township 24 South, MDB&M. The previous maps of the clay were made using electric log correlations, and due to the subjective nature of the correlations, they have been the subject of much controversy. The current clay map most widely used was prepared by the Department of Water Resources and is more regional in nature. A more detailed evaluation of the clay layer would benefit the Agency, County, State and public for general planning and development of ground water resource projects. Primary use would be for water well, recharge development and development of a general ground water management plan for the valley.

The first phase of the clay study was to make a structure map on the clay itself. Subsurface structure mapping provides basic information for hydrogeologic analysis. This is especially true in the young sediments of the San Joaquin Valley. Two passages from the widely used text, Groundwater (Freeze & Cherry, 1979) support this concept,

> "In unconsolidated deposits, the lithology and stratigraphy constitute the most important controls. In most regions knowledge of the lithology, stratigraphy, and structure leads directly to an understanding of the distribution of aquifers and aquitards." (page 145)

> "In terrain that has been deformed by folding and faulting, aquifers can be difficult to discern because of the geologic complexity. In these situations the main ingredient in groundwater investigations is often large-scale structural analysis of the geologic setting." (page 147)

The "confining clay" was generally called the Corcoran or "E" clay by the ground water community because it had been loosely correlated with the formation known as the Corcoran Clay (Frink and Kues, 1954) north of Kern County.

This study was not intended to identify or name specific clays in the southern San Joaquin Valley, nor to confirm or disprove the existence or competency of individual clays as confining barriers. This study concentrated on subsurface structural and stratigraphic relationships.

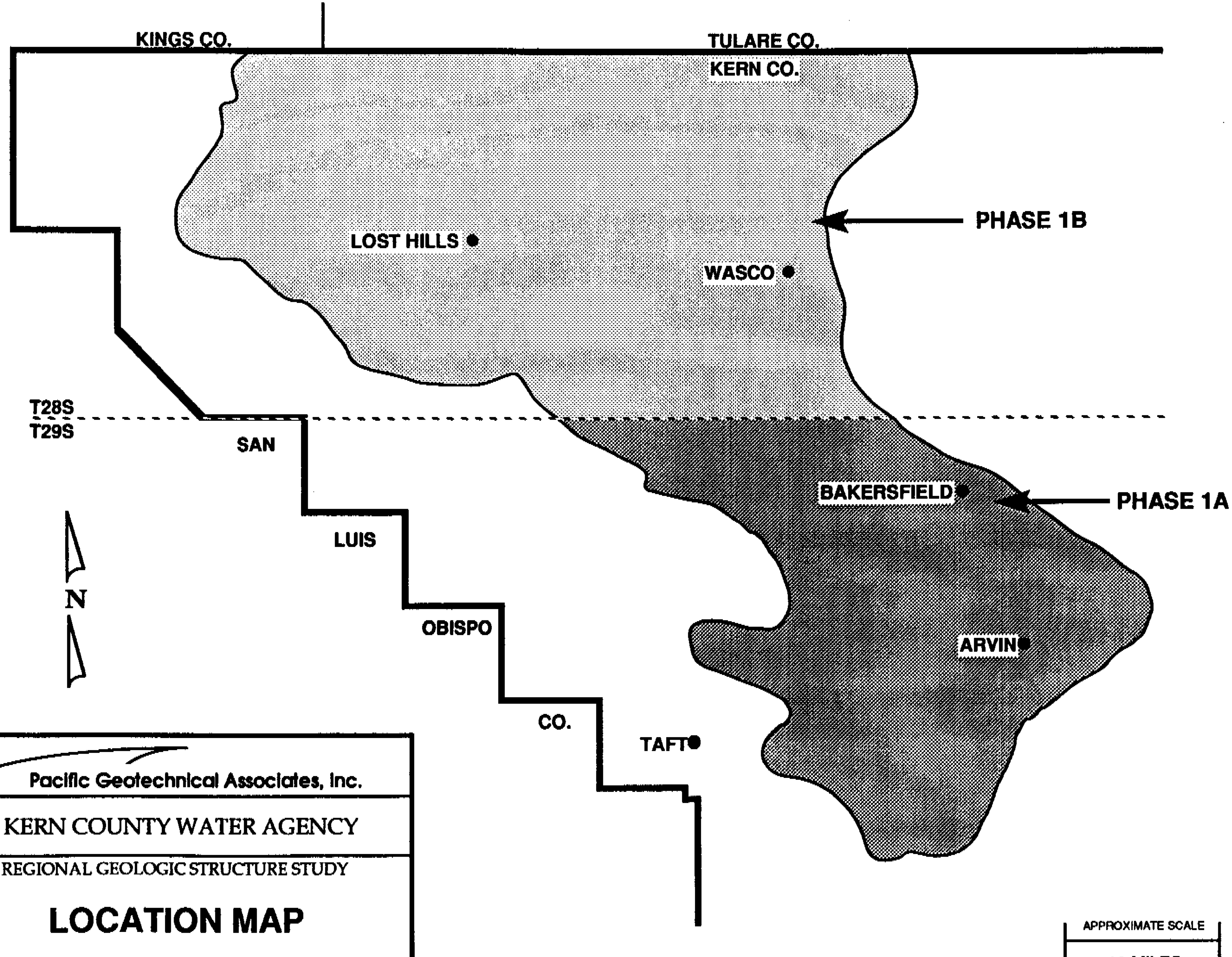
All formation and member names used herein have been adopted from work by previous authors (Page, 1986, Rector, 1982, Croft, 1972 and Brown, 1969) with the exception of the term "Paloma" which has been informally adopted to distinguish it from the "E" Equivalent and Corcoran clays. The horizons found on this report have been identified through correlation with existing reports, well logs and seismic data. No other means such as paleontology or age dating have been employed to independently establish the identity of the mapped clays.

2.2 SCOPE OF PHASE 1A

Pacific Geotechnical Associates, Inc., was contracted by the Kern County Water Agency to construct a geologic structure map and an isopach map of a regional "confining clay" in the San Joaquin Valley within Kern County. Phase 1A of the study covered the valley south of Township 28 South, MDB&M, while Phase 1B covered the area northward to the Kern County line (Figure 1).

2.3 EARLY DISCOVERIES OF PHASE 1A WORK

Phase 1A of the project began with a data base of 870± well logs and the construction of five geologic cross sections. Approximately 800 well logs were provided by the Kern County Water Agency with the remainder from other sources including ARCO Oil & Gas Company and the authors' files. Initial well correlations were made using depositional sequence analysis (i.e. fining upward and coarsening upward sequences). Due to the interbedded sand/clay deposition of alluvial, lacustrine, and fluvial environments as identified on wireline and drillers logs, numerous correlation choices existed for every well (see Figure 2). Poor log quality was also a problem in many of the water well



Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

LOCATION MAP

Date: July 1991	By: PGA
Project: KCWA P.O. 10376	Revised:

Figure 1

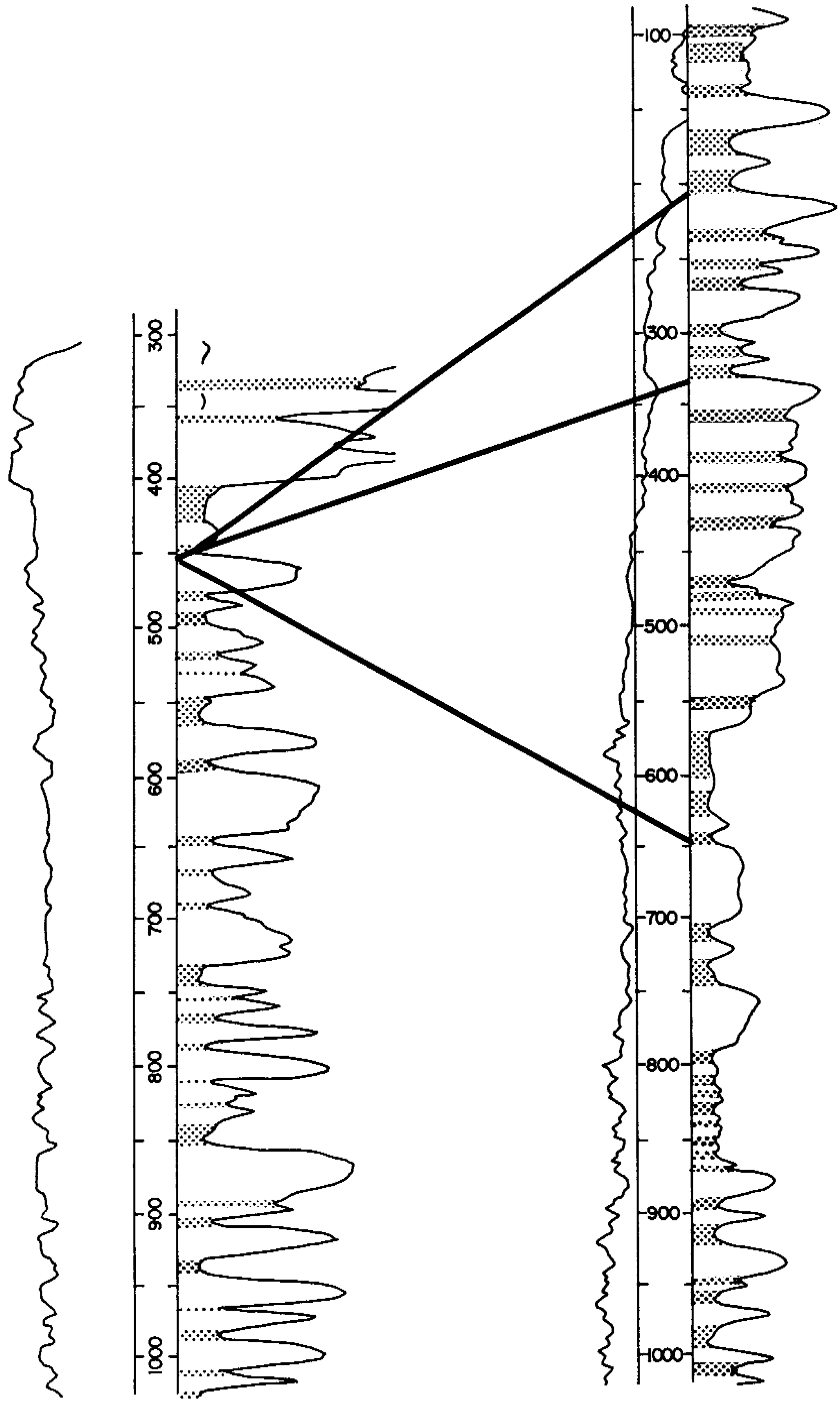


Figure 2. Example of possible correlation options.

logs. Because of the heterogeneous geologic environment and questionable log validity, little confidence could be put in many electric log correlations.

In order to make confident correlations and produce a defendable "confining clay" map, the Kern County Water Agency secured permission for the authors to utilize ARCO Oil & Gas Company's proprietary seismic data base. This data base was integrated with well logs to map the base of the "Paloma" Clay (originally thought to be the "E" Equivalent Clay) and later used to con-struct a regional "structural form map" on the shallowest mappable seismic horizons.

The seismically integrated structure map on the base of the "Paloma" Clay (included in this report as Plate X) led to a new understanding of the subsurface: 1) the "Paloma" Clay which was consistently correlated as "E" Equivalent Clay by previous authors in the area around the Buena Vista lake bed is not present on the Bakersfield Arch due to erosion, and 2) the clay is not relatively flat-lying but displays as much as 4,000 feet of structural relief between the Paloma and Mettler areas.

From these discoveries it was concluded that there is more than one significant clay in the study area, and that there is much more relief in the subsurface structure than had been previously mapped.

2.4 FINAL PHASE 1A WORK

Due to this new perspective on the nature of the subsurface, two new maps were constructed so that a better understanding of the subsurface structure and stratigraphy could be obtained:

a. An integrated seismic/well log structure map on the base of the "E" Equivalent Clay (herein informally called the "Paloma" Clay, Plate X).

b. A Structural Form Map on shallow seismic horizons (Plate I).

2.5 SCOPE OF PHASE 1B

Phase 1B tasks included extending the Structural Form Map northward to the Kern County line, constructing two east-west (dip) and one north-south (strike) structure cross sections, correlate at least one of the sections northward to tie into the "E" Equivalent or Corcoran Clay in the type or typical area, construct a structure map on the base of the "E" Equivalent Clay, and compose a report of techniques, findings, conclusions and recommendations for further work.

2.6 STUDY PERSONNEL

The geological analyses and well log correlations were performed by E. Kevin Beacom, Brian M. Hirst (Calif. Reg. Geol. #4583), Michael R. McGrath and Patricia J. Bell. Geophysical analyses were performed by Robert D. Dennis (Calif. Reg. Geop. #911) and Tom D. Fassio. The project was under the supervision of Randall T. Metz (Calif. Reg. Geol. #3995).

3.0 PURPOSE AND SCOPE OF REPORT

The purpose of this report is to document the methods and procedures used to make the maps and cross sections presented herein and to describe their uses and significance.

This report incorporates the findings and conclusions of both Phase 1A and Phase 1B work. The interpretation and integration of more than 1,250 miles of seismic data, hundreds of well logs and numerous check shot surveys has produced the Structural Form Map, Base "E" Equivalent Clay structure contour map, Base "Paloma" Clay structure contour map and correlations presented on the geologic cross sections.

4.0 STRUCTURAL FORM MAP

The Structural Form Map is a structure contour map on the shallowest mappable seismic horizons (Plate I). It presents a regional structural picture of the shallow sediments in the valley. This map is an aid to

1) understanding structural influences on regional ground water conditions,
2) making well log correlations and
3) developing ground water models.

Based on this map and other information, ten structural subbasins can be inferred for the southern San Joaquin Valley.

4.1 BACKGROUND

Ambiguous well log correlations in the early phase of this study lead the authors to seek other types of analyses to aid in the mapping of subsurface structures. Seismic reflection surveys are one of the most widely used geophysical methods employed by geoscientists to probe the structure and stratigraphy of sedimentary basins. Oil companies operating in the San Joaquin Valley have many miles of seismic data lines in the area of study. An arrangement was made with ARCO Oil & Gas Company to use their seismic data base. These data were used to generate a map which is made on a number of shallow reflection horizons. This map has been given the title Structural Form Map (Plate I).

The Structural Form Map was constructed from a large data base of structural information related to the shallow sediments which is independent of well information. Early attempts at correlating well logs over large distances failed to provide unique and defendable solutions even when depositional sequences were correlated. This is largely a result of the alluvial, lacustrine, and fluvial environments of deposition of the sediments being studied. Seismic data is more suited to reliably and unambiguously indicating the structural nature of these sediments.

4.2 DESCRIPTION OF SEISMIC DATA SET

Approximately 1,250 miles of ARCO Oil & Gas Company proprietary seismic data were used to generate the Structural Form Map. These data were generously provided by ARCO Oil & Gas Company through an agreement established with the Kern County Water Agency. Due to its proprietary and confidential nature, the seismic data set was interpreted in ARCO's office, and the locations of the lines have not been posted on the interpreted maps.

The density of coverage varied locally from a two mile grid to a six mile grid of seismic profiles (a two mile grid meaning two miles distance between parallel lines). The average grid was approximately two miles by three miles. This density of data is sufficient to develop a good regional understanding of the structural style. It is not sufficient to map local structural features covering less than a square mile or resolving the trends of small shallow faults.

Numerous faults with offsets on the order of a few tens of feet were observed extending to the shallowest horizons in the seismic data. With the exception of those faults shown on the map near Buena Vista Hills, Elk Hills and McFarland these faults were unmappable because they were seen on only one profile or could not be confidently correlated with fault breaks on adjacent lines. These faults may or may not appear on Kern County seismic hazards maps, and the potential hazard they represent is not known by the authors.

These seismic lines are part of a large data base collected for the exploration of oil and gas. This data set has been acquired over a number of years, by different contractors with different objectives, techniques and vintages of equipment. These data are typically designed, collected, and processed for information on the deeper stratigraphic section (2500 feet below sea level and deeper). However, the newer, high frequency data does record and show the structural configuration of the relatively shallow sediments (300 feet to 1,500 feet below sea level).

The data set is not uniform in data quality, frequency content or processing techniques. In spite of this caveat, the data base as a whole shows from good to excellent quality in most areas, with the area proximal to the Bakersfield City limits showing only fair to good quality.

Typical acquisition parameters include a vibroseis source with medium frequency sweeps (10 to 60 Hertz), 110 foot group intervals, and 12 to 30 fold (although the very shallow data in the mute zone is only two to six fold). Near offsets on the seismic cable range from 300 to 700 feet, and the far offsets range from 3,600 to 12,000 feet.

Various programs have been used in the computer processing of the data to attain higher frequency resolution. These include spiking deconvolution, statics, residual statics, predictive deconvolution, and increased stacking velocity control.

4.3 SEISMIC METHODOLOGY

The Structural Form Map was made by beginning in a subsurface depression and mapping the shallowest seismic reflector as far up structure as the data allowed, then dropping down to the next suitable reflector and mapping it in a similar fashion, and continuing this technique until the entire study area was mapped (see Figure 3).

The sequence of steps used to generate the Structural Form Map (Plate I) was as follows:

a. Beginning with the synclinal axes of the study area, the shallowest continuous reflective horizon was chosen to tie and correlate from seismic profile to profile.

b. When the horizon became too shallow to follow with confidence, the interpretation was shifted down to the next horizon that showed continuous reflections. This procedure was repeated as often as necessary throughout the mapped area (Figure 3).

c. Several of these horizons were chosen because seismic stratigraphic analysis indicated they were significant sedimentary sequence boundaries (ie. angular unconformities, previously mapped clays, etc.).

d. Seismic times of the interpreted horizons were annotated and contoured on a regional base map.

e. The interpreted time map was converted back to depth using available velocity information.

The structure contours over the top of Elk Hills, Buena Vista Hills, and northwest of Bakersfield are on the approximate top of the Pliocene Etchegoin formation as generally accepted by petroleum geologists. This correlation was made by comparing the mapped seismic horizons with electric logs which had been converted from drill depth to two-way seismic travel time. The structure contours over the Bakersfield Arch in the vicinity of the Kern Water Bank are on the approximate base of Tulare formation based on seismic ties to wells at South Belridge oil field. At the north end of the map northeast of Lost Hills the contours are on the approximate base of the "E" Equivalent or Corcoran Clay. The seismic tie to this formation is discussed in Section 5.2.3.

Structure contours on these various horizons have been combined onto one map with no overlap, giving the appearance of a single contoured horizon. Horizon changes are noted by a heavy broken line on Plate I.

4.4 GEOLOGIC SIGNIFICANCE

4.4.1 Basic Structural Uses

The Structural Form Map (Plate I), although changing contour horizons many times, is useful for characterizing the structure of the shallow sedimentary deposits (less than 2,000 feet below surface). The con-tours range from -200 to -1,800 feet subsea or approximately 400 to 2,100 feet below the surface with most contours being between -600 and -1,000 feet subsea or approximately 800 to 1,200 feet below the surface.

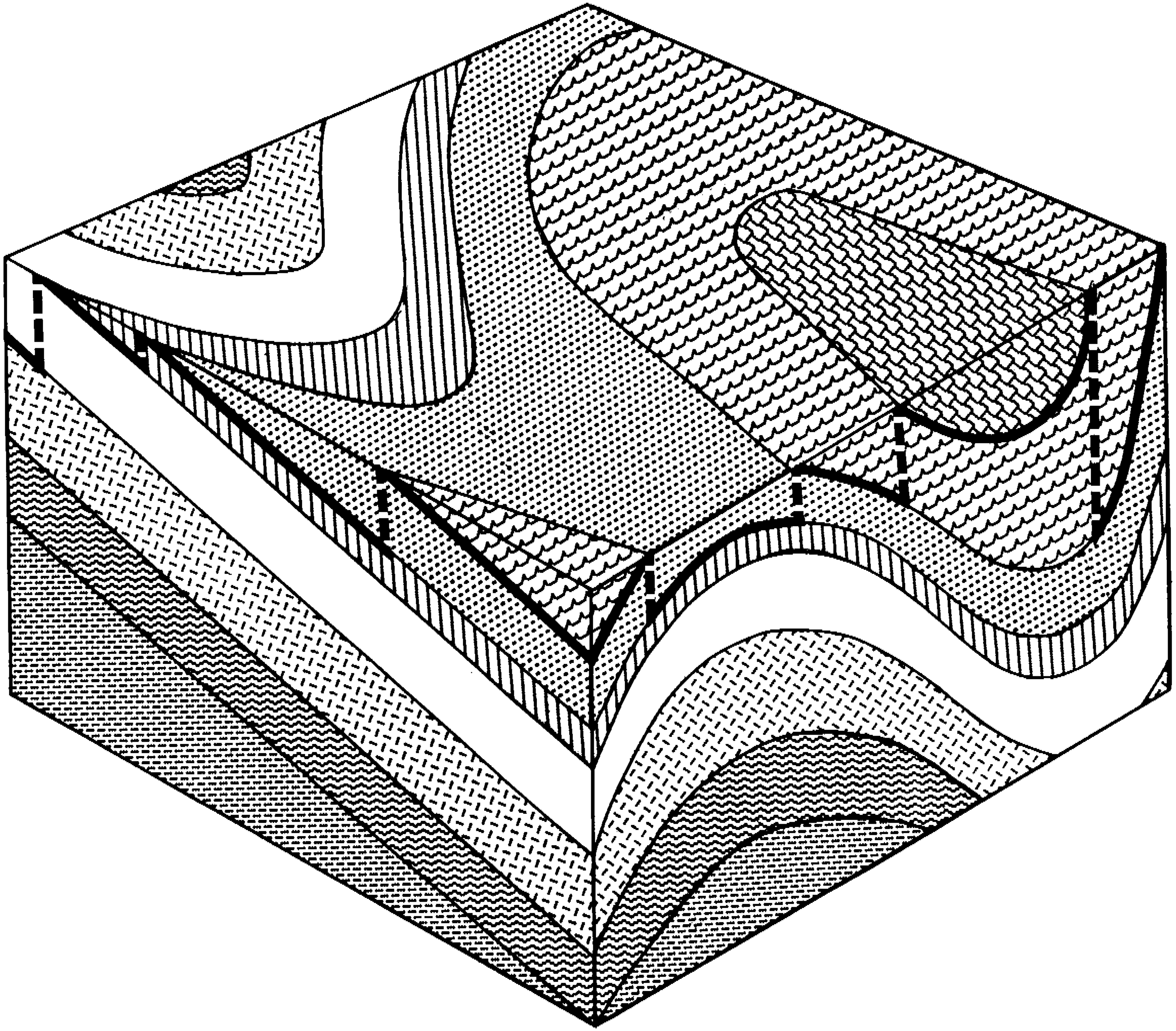


FIGURE 3 Conceptual view of method used in constructing structural form map. Top of block represents limit of seismic data resolution. Heavy lines represent contoured horizon. Dashed lines indicate where contour horizon changes.

It is important to note that structural dip in the subsurface generally increases with depth. This was observed consistently in the seismic profiles used in this study. Therefore, local sediments which are at a shallower depth than indicated by a given structural form contour horizon will be expected to dip less steeply than implied by the map. Conversely, sediments that are deeper than indicated by a given structural form contour horizon may be expected to have a greater magnitude of structural dip. However, the direction of dip should not deviate greatly in either case.

In general, the map is most accurate when used to judge the structural attitude of sediments at the depth indicated by the structural form contour lines. Dips defined on the Structural Form Map represent a maximum value that younger, shallower sediments may attain.

4.4.2 Regional Implications

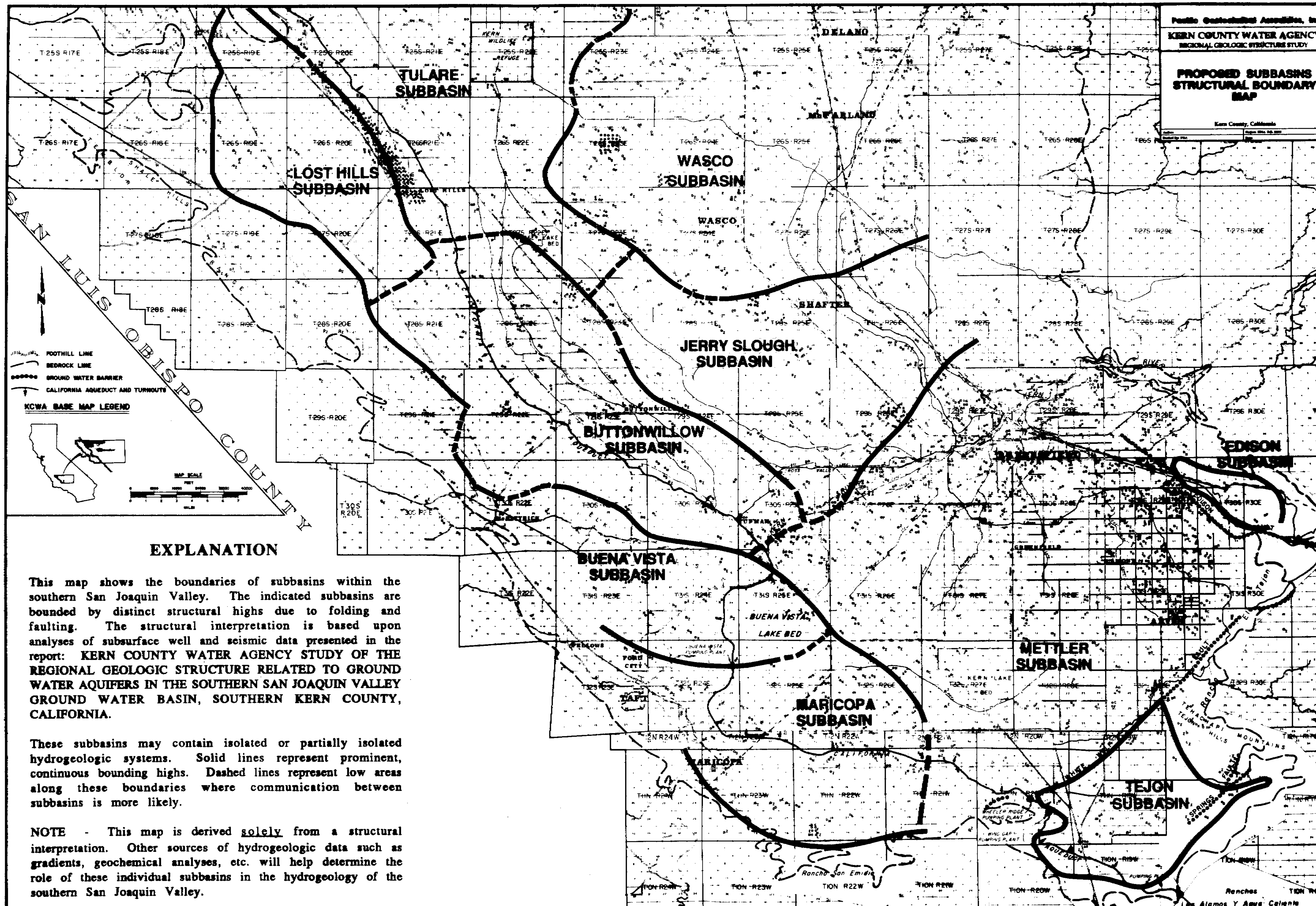
One of the most significant aspects of the Structural Form Map is the regional picture it presents for the shallow sediments of the southern San Joaquin Valley. These include:

a. There are long prominent structural highs (anticlines) and lows (synclines) which may subdivide the southern San Joaquin Valley into hydrogeologic subbasins (see Section 8.0).

b. The east-west trending Bakersfield Arch structurally divides the southern San Joaquin Valley into two large structural subbasins.

c. There is an increasing intensity of structuring westward across the valley.

d. The synclines or troughs contain a significantly thicker sequence of young sediments than do the anticlines or broad highs. This is dramatically evidenced by the numerous seismic horizon changes when coming up structure out of these troughs.



EXPLANATION

This map shows the boundaries of subbasins within the southern San Joaquin Valley. The indicated subbasins are bounded by distinct structural highs due to folding and faulting. The structural interpretation is based upon analyses of subsurface well and seismic data presented in the report: KERN COUNTY WATER AGENCY STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUND WATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUND WATER BASIN, SOUTHERN KERN COUNTY, CALIFORNIA.

These subbasins may contain isolated or partially isolated hydrogeologic systems. Solid lines represent prominent, continuous bounding highs. Dashed lines represent low areas along these boundaries where communication between subbasins is more likely.

NOTE - This map is derived solely from a structural interpretation. Other sources of hydrogeologic data such as gradients, geochemical analyses, etc. will help determine the role of these individual subbasins in the hydrogeology of the southern San Joaquin Valley.

FIGURE 4

e. Many of the structural highs do not have a surficial expression such as the Paloma structure.

4.4.3 Stratigraphic Correlations

The Structural Form Map can be used as an aid to stratigraphic correlation between wells. By knowing the approximate direction and rate of dip between two wells it is possible to project approximate stratigraphic correlations between them. This is a great advantage in areas of the valley where well correlations are ambiguous. The Structural Form Map was effectively used for this purpose in correlating the geologic cross sections and well picks for the "E" Equivalent Clay Map as discussed in Sections 5.0 and 6.0.

4.4.4 Hydrogeologic Models

The Structural Form Map can provide valuable structural information in areas where hydrogeologic models are being developed. Structural information in conjunction with a stratigraphic interpretation provides the basis for modeling natural and man made effects on the hydrogeologic system.

5.0 REGIONAL STRATIGRAPHIC CORRELATIONS

5.1 INTRODUCTION

The stratigraphy of the shallow sediments (less than 2,000 feet) is typical of clastic dominated alluvial, fluvial, and lacustrine environments. Generally, the section is composed of sands and silts with a lesser percentage of clay. Typically, sandy and silty layers are many tens to hundreds of feet thick whereas, clay layers are seldom more than a few tens of feet thick (Plates IV - VIII). Depositionally, the clays are associated with fluvial systems such as abandoned channels (oxbow lakes) or small lakes in basin lows which migrated with continued tectonic shifting of the basin. Only rarely did conditions permit the formation of a large lacustrine setting where regionally extensive clays could be deposited.

During the course of this study two regionally mappable clays, the "E" Equivalent Clay and the "Paloma" Clay, were recognized. Integration of structural information derived from seismic data with regional geologic cross sections verified the regional extent of these units. The stratigraphic and historical significance of these clays is discussed in the following Subsections.

5.2 "E" EQUIVALENT CLAY

5.2.1 Historical Significance

The Corcoran Clay was identified as a distinctive mappable unit in water wells and core holes as early as the 1920's. The first comprehensive discussion of the clay was by Frink and Kues (1954). Their paper summarized previous investigations (which were of limited scope) and presented regional maps of the clay which extended from southern San Joaquin County to northern Kern County.

Croft (1972) presented expanded studies of late Tertiary and Quaternary lacustrine and marsh deposits in the Tulare lake bed area. He defined six clays of Quaternary age which were designated "A" (youngest) through "E"(oldest). The "E" clay is equivalent to the Corcoran Clay and was mapped further south by Croft (1972) to the Buena Vista and Kern Lake beds. Page (1986) presented updated maps on the "E" clay which differed most notably from those of Croft (1972) in the Buena Vista and Kern Lake beds area. In recognition of these differences Page (1986) introduced the name "modified E clay" to describe the mapped clay unit.

Historically the "E" clay has attained much attention in the literature. This is primarily due to the fact that it is the most regionally mappable Quaternary unit in the San Joaquin Valley, and it was perceived as a significant aquitard early in the history of the basin's ground water development. As a mappable unit it provides information about the structure and stratigraphy of sediments above and below it. As an aquitard it has significant importance to hydrogeologic dynamics of the basin.

5.2.2 Type Well Documentation

Well 23S/24E-16B was selected as a type well for correlating the "E" clay into the study area. This well located approximately four miles southwest of

Pixley was drilled to a depth of 1,400 feet by the U.S. Bureau of Reclamation in 1951. The well was included in the cross section D-D' of Frink and Kues (1954). It was selected as a type log for the present study because:

a. It provided a tie with the Corcoran Clay mapping of Frink and Kues (1954);

b. Subsequent work by Croft (1972) and Page (1986) correlated "E" clay at the same depth as the Corcoran of Frink and Kues (1954) in this well;
c. It is in an area with the best well density north of the study area, thus providing the highest quality and confidence in correlating the wells to the south into the study area.

Type well 23S/24E-16B is presented in Geologic Cross Section B'-B" (Plate VII). The well correlations southward from this well into the study area are excellent and demonstrate the quality of mapping possible where the "E" clay is well developed.

5.2.3 Geologic Cross Section Correlations

Geologic cross section B'-B" (Plate VII) has been extended north of the study area to tie the Type Well (well 23S/24E -16B). Correlation of the "E" Equivalent Clay southward in the cross section towards the study area is facilitated by the relatively thick nature (60 to 90 feet) of the clay in this area. In the study area, "E" Equivalent Clay correlation confidence is supported by the seismic form lines taken from the Structural Form Map. The contoured horizons from the Structural Form Map have been placed on all the cross sections for correlation purposes.

The "Paloma" Clay thins southwestward towards B' and comes within 100 feet of the surface over the Trico and Semitropic anticlinal structures. At B' the cross section ties with geologic cross section A-A' and B-B' (Plates IV and VI). As seen in section B-B', the clay is believed to outcrop or subcrop beneath surface alluvium along the east flank of the Lost Hills anticline.

Cross section A-A' was laid out to follow the structurally lowest portion of the basin as indicated on the Structural Form Map. The "E" Equivalent Clay can be correlated to the north end of section A-A'. Here the clay has thickened to approximately 140 feet. These clay correlations match the structure suggested by the Structural Form Map well. The seismic form line at the north end of section A-A' plots near the base of the "E" Equivalent Clay. As described in Subsection 5.2.4, this should be anticipated because this seismic horizon was selected by tying the seismic data to previous "E" Equivalent Clay studies north of the Kern County line. Two different methods to tie into two different areas of the previous studies of the "E" Equivalent Clay north of the Kern County gave consistent results.

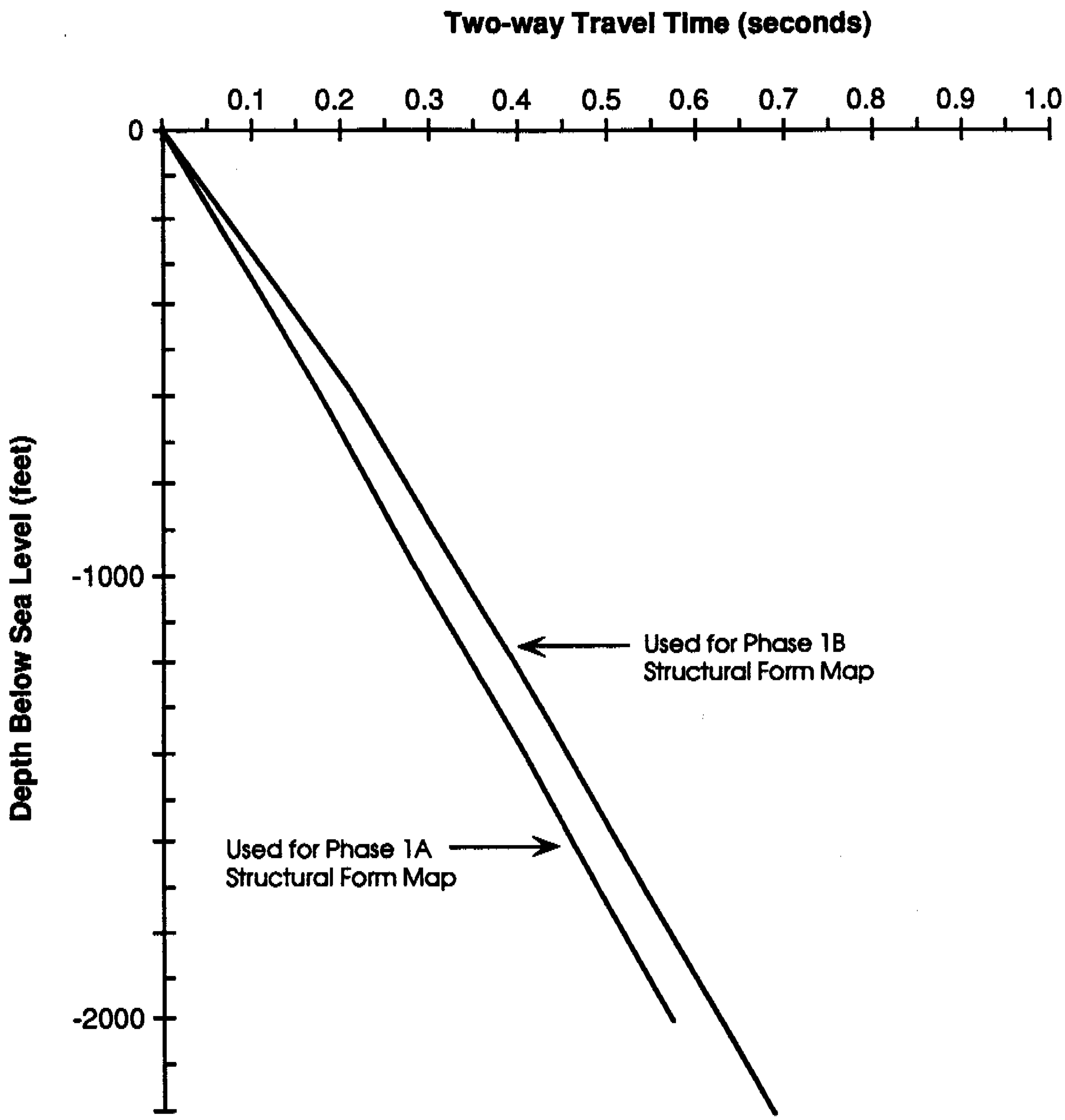
Southward along cross section A-A' the "E" Equivalent Clay is correlated to dip into the Buttonwillow Trough where it is seen to thicken to approximately 60 feet. It then rises out of the trough and outcrops or subcrops on the north flank of the Bakersfield Arch.

Cross section C-C' shows several "E" Equivalent Clay correlations. These are based on correlation work performed in making the Base "E" Equivalent Clay Structure Map (Plate IX).

5.2.4 Seismic Correlation to Previous Studies

Regional north-south seismic lines were used to tie into well defined clays mapped by Croft (1972) north of Kern County. The "Best Fit" velocity function shown in Figure 5 was used to convert the depths and isopachs of Croft's maps to two-way seismic travel time. These times were then transferred to the corresponding seismic profiles to select the seismic horizon that corresponded to the base of the "E" clay. This horizon was mapped as the northern most, shallowest seismic horizon on the Structural Form Map (Plate I).

In addition, the type well (23S/24E-16B), shown on Geologic Section B'-B" was also posted in the same manner on a regional seismic line. This pick was tied seismically into the seismic data grid and confirms the continuity of this particular unit in a limited northern portion of the study area.



Generalized graph showing the relationship between depth below sea level and two-way seismic travel time in shallow sediments in the southern San Joaquin Valley.

Pacific Geotechnical Associates, Inc.	
KERN COUNTY WATER AGENCY	
REGIONAL GEOLOGIC STRUCTURE STUDY	
TIME vs DEPTH GRAPH	
Date: July 1991	By: PGA
Project: KCWA P.O. 10376	Revised:

Figure 5

5.3 "PALOMA" CLAY

5.3.1 Background

Previous studies consistently agree that a thick clay found in wells near the Buena Vista lake bed area is the Corcoran or "E" Equivalent Clay. Because of this agreement, three key wells were selected as type wells and a structure map was constructed on the base of this clay during phase 1A of this study. These wells and the measured depth to the base of the clay is as follows: 31S/25E-15R at 840 feet; 31S/25E-36A at 810 feet; 32S/25E-1H at 960 feet.

Subsequent work during phase 1B of the study has led to the conclusion that this is an older clay and not related to the "Corcoran" or "E" Equivalent Clay. The name "Paloma" Clay has been informally assigned to this unit for purposes of this study.

5.3.2 Stratigraphic Relationship To "E" Equivalent Clay

The "Paloma" Clay appears to be significantly older than the "E" Equivalent Clay as defined in this report. This conclusion is based on the correlations presented in geologic cross sections A-A' and A'-A" (Plates IV and V).

As shown in these cross sections and the structure map on the base of the "Paloma" Clay (Plate X) the "Paloma" Clay rises northward out of the Maricopa basin and is truncated along the southern flank of the Bakersfield Arch and Elk Hills structures beneath the "Paloma" unconformity. This unconformity was recognized in seismic profiles and later in well correlations. Similarly, the younger "Buena Vista" unconformity was recognized in seismic data and later in well correlations. These unconformities have been named for well developed expressions in seismic lines in the vicinities of the Paloma and Buena Vista structures respectively. These names are strictly informal for purposes of this study and no attempt was made to correlate the unconformities with previously named features which may occur in the literature.

An unnamed clay is found 300 to 400 feet above the "Buena Vista" unconformity as seen in Geologic Cross Section A'-A" (lightly shaded on Plate V). This clay is correlated approximately 350 feet below the "E" Equivalent Clay on Geologic Cross Section A-A', Well T30S/R24E/4C (Plate IV). Based on the intervening position of the unidentified clay to the "E" Equivalent and "Paloma" clays, the "Paloma" Clay is stratigraphically below and older than the "E" Equivalent Clay. It is not known if this clay has hydrogeologic significance. These regional correlations would be difficult to make and to justify were it not for the seismic data base.

6.0 "E" EQUIVALENT CLAY STRUCTURE MAP

6.1 INTRODUCTION

Section 5.0 provides the stratigraphic documentation for the "E" Equivalent Clay. The base of the clay was selected for constructing a structure contour map based on stratigraphic reasons such as its consistency as a marker and its relationship to the units above and below the clay. The resulting Structure Contour Map on Base "E" Equivalent Clay is presented as Plate IX.

6.2 WELL LOG CORRELATIONS

As seen in Geologic Cross Section A-A' and B-B' (Plates IV and VI), well log correlation of the "E" Equivalent Clay can be relatively straight forward when the clay is more than 30 feet thick. More than 100 well logs were correlated. In general, the best correlations with the highest degree of confidence were in the northern most regions of the study area (within 10 miles of the Kern County line between Lost Hills oil field and the town of Delano). The lowest confidence in correlations is found along the eastern margin of the area from McFarland to Shafter and south of Wasco. In these areas the clay is very thin and difficult to distinguish from other clays in the stratigraphic section.

Correlations were guided by two principle criteria; overall correlation of the lithologic units above and below the clay and basic structural conformity with the Structural Form Map . The electric log "signature" of the thick enough to display it. Attempts to expand the correlated limits of the clay were stopped when the clay was indicated to be within approximately 50 feet of ground level and/or the thin (less than ten feet) nature of the clay and nondistinctive encompassing lithologies made further correlation indefensible.

6.3 INTEGRATION WITH STRUCTURAL FORM MAP

The subsea depths for the base of the "E" Equivalent Clay were posted on a base map and contoured. Where well control was sparse or multiple contouring options existed, contouring was guided by the Structural Form Map. The map is therefore based on an integration of well data and seismic data and is structurally consistent with the Structural Form Map.

6.4 GEOLOGICAL SIGNIFICANCE

Historically, the "E" Equivalent Clay has significance to ground water issues in the San Joaquin Valley. There has been debate as to the areal extent of the clay and its' importance as an aquitard in Kern County. The areal extent and structure of the clay presented here differ to varying degrees with previous studies. This map is unique in that it incorporates a regional seismic data base to guide well correlation and structural interpretation. As such it is possibly the most accurate in depicting the structure of the clay and hopefully will be useful in understanding the role of the "E" Equivalent Clay in the ground water hydrology of the southern San Joaquin Valley.

7.0 " PALOMA" CLAY STRUCTURE MAP

7.1 INTRODUCTION

The "Paloma" Clay was selected for mapping early in the project based on previous studies (see Section 5.0). The base of the clay was chosen because it tied well with the seismic data, it was easier to correlate in well logs compared to the top of the clay and it could be correlated over a wider area on the seismic data. The "Paloma" Clay is located south of Township 29 South, MDB&M (see Plate X).

7.2 DESCRIPTION OF SEISMIC DATA SET

Approximately 425 miles of the seismic data used in making the Structural Form Map were used to construct the Structure Contour Map on Base "Paloma" Clay (Plate X).

7.3 SEISMIC METHODOLOGY

The base of the clay in the key wells (31S/25E-15R, 31S/25E-36A and 32S/25E-1H) was tied into adjacent seismic lines (Plate II) using velocity surveys in nearby wells. This graphical and numerical depth conversion changes the measured depths to seismic two-way travel time. At these depths, it is normally accurate to within ten percent (plus or minus 85 feet). However, in conjunction with the numerical conversion, the stratigraphic interpretation of the seismic profile reflection coefficients reduces the possible mis-tie to less than 25 feet. Once this seismic horizon was identified, it, as well as other seismic horizons were correlated and tied around on the seismic database.

The sequence of steps used to make the Structure Contour Map on Base "Paloma" Clay (Plate X) was as follows:

a. Interpret the "top" and "base" of the base "Paloma" Clay in wells that contain generally accepted correlations (31S/25E-15R, 31S/25E-36A, and 32S/25E-1H).

b. Convert the depths to seismic two-way travel time by compiling and plotting velocity survey information from petroleum wells in the general vicinity.

c. Post the converted horizon times of the base "Paloma" Clay onto the nearest seismic profile and select the most appropriate reflector for interpretation.

d. Interpret the seismic reflector over the study area.

e. Annotate and contour the interpreted horizon times on a regional base map.

f. Convert the interpreted time map to depth using the velocity information from Step b.

7.4 GEOLOGIC SIGNIFICANCE

The Base "Paloma" Clay map shows that the base of the clay varies in depth from very shallow to over 4,400 feet below sea level in the southern end of the valley near the town of Mettler. This horizon has been eroded and underlies one or more unconformity as it approaches the Bakersfield Arch to the north (Subsection 5.3.2.)

This map is an excellent example of how units encountered at relatively shallow depths on the west side of the San Joaquin Valley may be related to significantly deeper sediments in the structural lows or troughs. The more intense structural development found on the west side of the valley is not always apparent at the surface as shown by the Paloma anticline. It is important therefore, to have a good understanding of the structure before undertaking stratigraphic studies using well correlation techniques.

The Base "Paloma" Clay map also illustrates the importance of local and semi-regional unconformities in the shallow sediments particularly along the west side of the valley. These unconformities require that a number of structural/stratigraphic maps be made in order to adequately describe critical relationships governing the hydrogeology of the area.

A summary of the geologic observations made while constructing this map includes:

a. The Base "Paloma" Clay Structure Map shows that the clay exists in only a portion of the study area.

b. At least two significant unconformities can be mapped in the shallow sediments in the southwest portion of the study area.

c. The Elk Hills, Buena Vista Hills, and Paloma structures are still active, and have had a major influence on Pliocene to Recent deposition and shallow faulting.

8.0 PROPOSED STRUCTURAL SUBBASINS

8.1 INTRODUCTION

The shallow sediments of the southern San Joaquin Valley constitute a large ground water basin which has been heavily utilized for agricultural, industrial and domestic uses for decades. These uses in conjunction with natural and planned recharge of the aquifers has created dynamic ground water conditions. There is ample evidence showing this basin is more complex than a simple isotropically homogeneous aquifer. Many analytical disciplines can be called upon to measure and study the anisotrophy and inhomogeneity of a ground water basin (ie., stratigraphy, sedimentology, geochemistry, structural geology, aquifer analysis etc.). This section will discuss how the regional structure of the shallow sediments, as mapped in this study, can be used to characterize and divide the basin into structurally defined subbasins.

8.2 PROPOSED SUBBASINS

The Structural Form Map (Plate I) presents a seismic interpretation of the shallow regional structure (less than 2,000 feet subsurface) of the basin. Structural highs seen in this map along with other well known structural features (such as major faults) have been used to divide depressions in the basin into ten subbasins as presented in Figure 4 and Plate XI.

These ten subbasins have been named informally as follows:

Buena Vista Subbasin	Buttonwillow Subbasin
Edison Subbasin	Jerry Slough Subbasin
Lost Hills Subbasin	Mettler Subbasin
Maricopa Subbasin	Tejon Subbasin
Tulare Subbasin	Wasco Subbasin

Solid lines between the subbasins on Plate XI indicate the areas with prominent structural highs and represent the greatest structural potential for hydrologic barrier development. The dashed lines are the lowest areas along the structural highs and represent areas with the greatest potential for hydrologic migration between subbasins.

8.3 IMPLICATIONS TO FUTURE STUDIES

The importance of structural attitude on hydraulic gradients and flow within an aquifer system is dependent on the degree to which horizontal conductivity exceeds vertical conductivity. The exact dependence of hydraulic gradients and flow on structure in the southern San Joaquin Valley is not known, however some level of dependence surely exists. To this extent a structural high (such as Paloma anticline) should act as a partial or total barrier to ground water migration across the high.

While these structurally defined subbasins address only one aspect of control on the hydrologic system, they do provide a basis for areal division of the valley. The hydrologic characterization of these smaller units will provide a more focused investigation which can address the anomalies and questions associated with a particular subbasin.

9.0 RECOMMENDED FUTURE WORK

This report represents a first step toward attaining an understanding of the hydrogeology of the southern San Joaquin Valley and the development of a meaningful ground water management plan. The next steps involve gathering other types of data and integrating them with the structural and stratigraphic data. The final steps will be to interpret the data and to create maps and illustrations useful for preparation and implementation of a plan.

9.1 DELINEATE SUBBASINS USING SEISMIC, WELL AND WATER DATA

The limits of the subbasins defined by the Structural Form Map should be refined by integrating additional seismic data with well log correlations, water quality values from electric log calculations, ground water chemistry, pressure, and other ground water data. This will allow researchers to better determine the extent to which structural subbasins act as hydrologic subbasins. If current data bases (such as the water quality data base) are inadequate or incomplete, they should be upgraded.

9.2 MAP THE CONFINING CLAY(S) IN INDIVIDUAL SUBBASINS

Once identified, confining clays or significant clays should be mapped using seismic, well log, water and other data in individual subbasins. This will directly assist in enforcing water well ordinances and in managing ground water resources.

9.3 CONSTRUCT A REGIONAL "CONFINING CLAY" MAP WHICH SHOWS ALL SUBBASINS (BOTH STRUCTURAL AND DEPTH-TO MAPS)

Combine the Confining Clay(s) maps described in Section 9.2 to create one map showing all of the subbasins. The map will be a convenient resource to those who must enforce and those who must adhere to water well ordinances. The increasing emphasis or ground water recharge and withdrawal in the San Joaquin Valley will necessitate an improved understanding at hydrologic controls on groundwater movements.

10.0 CLOSING

This investigation was conducted for the Kern County Water Agency in accordance with generally recognized geological and geophysical procedures. The conclusions of this preliminary study are based solely on the work described herein and should not be used as a basis for final decisions.

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Randall T. Metz, R.G.

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GLOSSARY

alluvial, lacustrine and fluvial environments — Valley floor, lake and stream and river depositional settings respectively.

anticline — A fold that is convex upward.

checkshot — Measurement taken in a well bore of the travel time required to transmit energy from the ground surface to a measured depth. This information is necessary to convert seismic travel time to depth.

confining clay — Sedimentary clay deposit which has the ability to greatly retard the transmission of fluid, even when a pressure gradient is applied.

"E" Equivalent Clay — Name adopted by Page for a widespread shallow clay in the San Joaquin Valley. It is identified in well 23S/24E-16B.

Etchegoin — Pliocene age formation in the San Joaquin Valley which is generally thought to represent the transition from marine or brackish conditions to a nonmarine lake and fluvial environment of deposition.

fold, seismic — Redundancy in the data. High fold is desirable for most applications as it eliminates ambient "noise" and has the effect of strengthening the returning seismic signal.

frequency — Characteristic of energy waves measured in cycles per second (Hertz). Generally speaking the higher the frequency the thinner the bed which can be resolved on seismic data.

group interval — Spacing between seismic recording stations on the ground surface. Generally speaking the larger group intervals are used to image deeper data.

isopach map — A map showing points of equal thickness of a particular unit.

mute zone	Area of a seismic record which represents the time between imparting the energy into the earth and the return energy from the nearest reflector.
offsets	Distance between the source of the energy being imparted into the ground and the various geophones (energy sensor).
"Paloma" Clay	Informal name coined for a mappable clay south of the Bakersfield Arch. It is identified in wells 31S/25E-15R, 31S.25E - 36A and 32S/25E-1H
Pleistocene	The earlier of the two epochs which comprise the Quaternary period. It covers a period approximately 1.6 to 0.01 million years before present (Geol. Soc. America).
Pliocene	The latest of the epochs comprising the Tertiary period. It covers a period approximately 5.3 to 1.6 million years before present (Geol. Soc. America).
reflection horizon	Plane beneath the surface (usually the contact between two parallel strata) which has the ability to reflect seismic energy back to the surface when a surface seismic energy source is employed.
seismic data base	Collection of seismic lines and checkshot surveys of different vintage, collection parameters and acquisition companies.
seismic travel time	Time it takes for seismic energy to go from the source into the subsurface and reflect back to the surface at a recording device. It is commonly measured in milliseconds.
spiking deconvolution, statics, residual statics, predictive deconvolution, increased stacking velocity control	Mathematical manipulations of the raw data applied during processing to make seismic cross sections more useable.

structural subbasin	A feature which is a depression that is defined by its structural shape. It can be elongate or equant or irregular.
syncline	A fold that is concave upward.
Tulare	Pleistocene age formation in the San Joaquin Valley which is composed of nonmarine deposits. The Corcoran Clay of Frink and Kues (1954) is believed to have been deposited near the middle of Tulare formation.
unconformity	A surface or erosion of nondeposition which separates younger strata from older strata.
vibroseis	Energy source which involves one or more truck mounted vibrating pads which act in concert to impart energy of desired frequency and strength into the earth.

APPENDIX A

Data Base of wells available for Kern County Water Agency Regional Structure Study
Note: Log depth listed is either, total depth from the log header, or greatest depth of the log copy on file.

Township 10N

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
RICHFIELD OIL CORP	TEJON	TEJON# 61-6	6	A	10N	19W	2729
BRITISH AMERICAN OIL CO.	TEJON	#81-6	6	Z	10N	19W	2751
CALIFORNIA DEPT OF WATER	GRAPEVINE CREEK	#A1	8	A1	10N	19W	1775
B.K.S. OIL COMPANY	TEJON RANCH	PILGRIM #11A-12	12	Z	10N	19W	2796
N.H.K. OIL COMPANY	S.E. TEJON	TEJON# 84-14	14	H	10N	19W	3875
CALIFORNIA DEPT OF WATER	WHEELER RIDGE AREA	#H1	1	H1	10N	20W	1770

Number of wells in this Township 6

Township 11N

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
EWAN OIL COMPANY	TEJON HILLS	COREHOLE #.3	2		11N	18W	591
FRED A MILLER	TEJON HILLS	MILLER#2	2	Z	11N	18W	574
JOHN C. JOHNSTON FARMS	SOUTH ARVIN		6	Z	11N	18W	1200
JERGINS OIL COMPANY	TEJON HILLS	TEJON # 1	10	Z	11N	18W	1255
RAINBOW OIL CO.	TEJON HILLS	RAINBOW #5	11	Z	11N	18W	615
RAINBOW OIL CO.	TEJON HILLS	RAINBOW #15	11	Z	11N	18W	637
TEJON RANCH CO.	TEJON RANCH	TEST HOLE# D	12	L1	11N	18W	751
TEJON RANCH CO.	TEJON RANCH	TEST HOLE-A	14	N1	11N	18W	1175
SUNSET OIL CO.	TEJON HILLS	WATER WELL #1	14	Z	11N	18W	1313
STEELE PETROLEUM CO.	TEJON HILLS	TEJON# 1	14	Z	11N	18W	1080
STEELE PETROLEUM	TEJON HILLS	ROCO# 54	15	Z	11N	18W	508
VAN GLAHN OIL CO., INC.	COMANCHE PT.	TEJON # 1	18	Z	11N	18W	1485
	TEJON HILLS	#46	19	Z	11N	18W	457
D.K. PARTNERSHIP	TEJON HILLS	#67-20	20	Z	11N	18W	3791
O.M. SLOSSON OIL COMPANY	TEJON HILLS	#37	21	G	11N	18W	2554
TEJON RANCH CO.	TEJON RANCH	TEST HOLE C	22	Z	11N	18W	1035
TEJON RANCH CO.	TEJON RANCH	TEST HOLE "E"	28	G1	11N	18W	911
D.K. PARTNERSHIP NO.2	TEJON HILLS	CORRAL# 273-29	29	Z	11N	18W	2000

Data Base of wells available for Kern County Water Agency Regional Structure Study

D.K. PARTNERSHIP-2	SPRINGS FAULT	D.K. PARTNERSHIP-2	29	Z	11N	18W	1680
PURCELL FARMS	METTLER	#1	7		11N	19W	1310
U.S. BUREAU OF	TEJON	11-19-7E	7	R	11N	19W	1100
RESERVE OIL AND GAS CO.	TEJON FLATS	BUTLER 44-17	17	E	11N	19W	8550
FRED KRAFT	WHEELER RIDGE	W.W. #1	20	H1	11N	19W	940
RESERVE OIL & GAS CO.	TEJON	21A	21	Z	11N	19W	3400
RESERVE OIL AND GAS	TEJON RESERVE	BUCHHOLZ WATER WELL	23	H1	11N	19W	942
			23	Z	11N	19W	1000
MOORS, PERMEATER &	E WHEELER RIDGE	WATER WELL #1	24	H1	11N	19W	926
RESERVE OIL AND GAS CO.	TEJON RANCH	TEJON POTATO CO. (WATER	25	D	11N	19W	984
MOODY & JONES	TEJON	WATER WELL TEJON NO. 1	25	F1	11N	19W	966
RESERVE OIL & GAS CO.	TEJON RESERVE	BOLLER & NEUFELD WATER	26	F1	11N	19W	1007
ROY SANDERS	TEJON	WATER WELL	26	R1	11N	19W	990
RESERVE OIL & GAS CO.	TEJON	KOUCKY WATER WELL	28	G1	11N	19W	1094
RESERVE OIL AND GAS CO.	TEJON	HIGHLAND FARMS INC	28	K1	11N	19W	1084
BAUMEL AND KURTZ	TEJON	WATER WELL #1	29	G1	11N	19W	930
STOLLER BROTHERS	WHEELER RIDGE	TEJON LEASE #3	29	Z	11N	19W	1324
RICHFIELD OIL CORP	TEJON	TEJON 11-19-31	31	R	11N	19W	2705
PETROL CORP.	TEJON	RES. PETROL 32-2	32	Z	11N	19W	6022
RESERVE OIL & GAS	TEJON	TEJON 33-14	33	Z	11N	19W	2685
RIDGE HILL OIL CO	TEJON	34-4	34	Z	11N	19W	2693
ENTERPRISE OIL COMPANY	TEJON HILLS	R.E. 57-34	34	Z	11N	19W	4631
RESERVE OIL AND GAS	TEJON RANCH	#45-34	34	Z	11N	19W	2838
KERN CO. LAND COMPANY	WHEELER RIDGE	K.C.L. 10-G-5-3	5	J	11N	20W	2020
RENALD M. METTLER	WHEELER RIDGE	W. W. #10	10	C2	11N	20W	2129
KERN COUNTY LAND CO.	WHEELER RIDGE	10 G-13-3	13	M1	11N	20W	1301
DEPT OF WATER RESOURCES		G. W. OBSERV WELL	15	D1	11N	20W	242
ARCO OIL & GAS CO.	TEJON	KCL SWS 86-24	24	Z	11N	20W	5400
KERN ROCK	WHEELER RIDGE	W.W. C-83	25	K1	11N	20W	1202
RICHFIELD OIL CORP.	WHEELER RIDGE	W. W. #1	34	J	11N	20W	1202
EASTON AND SHUMAN	SAN EMIGDIO	WATER WELL# 2	2	G1	11N	21W	1200
U.S. GEOLOGICAL SURVEY	SAN EMIGDIO AREA	LAKEVIEW TEST #1	3	B1	11N	21W	1500
		KCL 87-3	3	R	11N	21W	3570

Data Base of wells available for Kern County Water Agency Regional Structure Study

SAM ANDREWS & SONS	LAKEVIEW	ANDREWS RANCH	3	Z	11N	21W	1823
STATE OF CALIFORNIA D.W.R.	OLD RIVER	SITE NO. 16	4	F2	11N	21W	642
W.P. ROMERO	SAN EMIGDIO	KCL W. W. #1	6	K1	11N	21W	1190
SWEET BROS. DRILLING CO	SAN EMIGDIO AREA	K.C.L -#1 10 F7-2	7	D1	11N	21W	2215
RICHFIELD OIL CORPORATION	SAN EMIGDIO	K.C.L.-H-81-8	8	A	11N	21W	1200
KERN COUNTY LAND CO	SAN EMIGDIO AREA	KCL 10F8-3	8	H1	11N	21W	2408
KERN COUNTY LAND CO.	SAN EMIGDIO NOSE	10 F 9-1	9	F	11N	21W	2200
REYNOLD METTLER	SAN EMIGDIO	WATER WELL	11	G1	11N	21W	2000
KERN COUNTY LAND CO.	SAN EMIGDIO NOSE	10F 11-	11	NP	11N	21W	2509
RICHFIELD OIL CORPORATION	PLEITO HILLS	SAN EMIDIO D-3	32	Q	11N	21W	6397
HUMBLE OIL AND REFINING	PLEITO CREEK	KCL B-1	35	Z	11N	21W	4342
HUMBLE OIL AND REFINING	PLEITO CREEK	KCL B-13	36	Z	11N	21W	4505
ROBERT PELLETIER	SAN EMIGDIO	WATER WELL #20	1	F1	11N	22W	2570
ROBERT PELLETIER	SAN EMIGDIO	W.W. #16	1	L2	11N	22W	1250
ROBERT PELLETIER	SAN EMIGDIO	WATER WELL #3	1	Z	11N	22W	1007
TENNECO OIL CO	YOWLUMNE LEASE	WW #45-4B	4	Z	11N	22W	2005
THE OHIO OIL CO.	EAST MARICOPA	KCL-O #15-5	5	M	11N	22W	10533
CONTINENTAL OIL CO.	SAN EMIGDIO	SANTIAGO #1	8	E	11N	22W	2600
TENNECO OIL CO.	YOWLUMNE LEASE	W.W. 83-17	9	A	11N	22W	1665
TENNECO	"YOWLUMNE"	88-10	10	R	11N	22W	12100
RICHFIELD OIL CORP.	KCL "M"	#21-16	16	D	11N	22W	11715
RICHFIELD OIL CORPORATION	LOS LOBOS	SAN EMIDIO A 25-19	19	M1	11N	22W	6780
TENNECO WEST		ARCO #48	21	P	11N	22W	8500
CONTINENTAL OIL CO	SAN EMIGDO	KCL M-1	27	G	11N	22W	8341
RICHFIELD OIL CORPORATION	LOS LOBOS -SAN EMIGDIO	A-25-28	28	M	11N	22W	3311
STANDARD OIL CO OF	PIONEER	KCL 44-32	32	C	11N	22W	4760
STANDAR OIL CO OF	PIONEER	KCL 44-12	32 ?	D	11N	22W	750
STANDARD OIL CO. OF CAL.	PIONEER	KCL 44-23	32	E	11N	22W	896
STANDARD OIL COMPANY	PIONEER ANTICLINE	KCL 44-34	32	F	11N	22W	10017
STANDARD OIL CO. OF	PIONEER	KCL 44-43	32	F	11N	22W	5850
STANDARD OIL CO OF	PIONEER	KCL 44-45	32	L	11N	22W	4325
STANDARD OIL CO. OF	PIONEER	KCL 44-25	32	M	11N	22W	4330
UNION OIL CO	SUNSET	INTST. 22-A-4	4	D	11N	23W	4300

Data Base of wells available for Kern County Water Agency Regional Structure Study

TRACY DEV CORP.	MIDWAY SUNSET	INTST.#22-T	4	Z	11N	23W	3019
STANDARD OIL COMPANY OF	SUNSET	129	5	K	11N	23W	2740
STANDARD OIL COMPANY	SUNSET	125	5	K	11N	23W	2452
STANDARD OIL CO	SUNSET	131	5	K	11N	23W	3400
STANDARD OIL CO.	MIDWAY-SUNSET	9A	5	K	11N	23W	4319
STANDARD OIL CO	SUNSET	119	5	K	11N	23W	2112
UNION OIL CO.	MIDWAY	SLOAN FLACK	7	A	11N	23W	2396
UNION OIL CO.	SUNSET	SLOAN FLACK #3	7	H	11N	23W	2580
COAST EXPLORATION CO.	MARICOPA	BRONCO # 1	8	Z	11N	23W	2572
RICHFIELD OIL CORPORATION	SANTIAGO	LEUTHOLTZ A-20	22	Z	11N	23W	3330
BANKLINE OIL COMPANY	MARICOPA	57-23	23	Q	11N	23W	1104
BANKLINE OIL COMPANY	MARICOPA	24-24	24	E	11N	23W	4325

Number of wells in this Township 96

Township 12N

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
LEE AULT & ASSOCIATES	COMANCHE POINT	AULT # 2	29	Z	12N	18W	873
MCFARLAND ENERGY	COMANCHE POINT	"BROWN" 4	32	Z	12N	18W	1565
SIERRA OIL CO.	COMANCHE POINT	SIERRA # 1	25	Z	12N	19W	1594
R.A. HILDEBRAND	HILDEBRAND RANCH	#4	29	J1	12N	19W	1010
WILLIAM MOORE	TEJON	MOORE #1	34	H	12N	19W	1204
JOE FANUCCHI & SONS	ADOBE & DAVID RDS		25	Q	12N	20W	1041
WESTERN GULF OIL CO.	SAND HILLS	S.P. #1	25	Z	12N	20W	3500
PUREGRO	BAKERSFIELD	#1	28	Z	12N	20W	1050
PARKS BROS. & GARLOW	LAKEVIEW AREA	STANDARD #2	29	R1	12N	20W	1408
			30	N1	12N	20W	1195
R.L. SANDERS	SAN EMIGDIO	WATER WELL #2	27	N2	12N	21W	1440
TENNECO-CHEVRON		TENNECO #77X	28	R	12N	21W	14775
STANDARD OIL CO OF	LAKEVIEW AREA	W.W. #10	31	F1	12N	21W	1400
PARKS BROTHERS	LAKEVIEW	W.W. #10	31	P2	12N	21W	2504
PARKS BROTHERS	LAKEVIEW	WATER WELL #1	33	P1	12N	21W	1516
ART SANDERS	SAN EMIGDIO	WATER WELL #2	35	P1	12N	21W	1493
STANDARD OIL CO.	SAN EMIGDIO	FRICK # 4	25	Z	12N	22W	1407

Data Base of wells available for Kern County Water Agency Regional Structure Study

DEPT OF WATER RESOURCES		G. W. OBSERV. WELL	32	D1	12N	22W	242
PACIFIC COAST DRILLING CO.	SAN EMIGDIO	WATER WELL#11	33	R	12N	22W	985
ROBERT PELLETIER	PELLETIER RANCH	TEST HOLE #1	34	K	12N	22W	800
ROBERT PELLETIER	PELLETIER RANCH	WATER WELL	34	M1	12N	22W	1266
	SAN EMIGDIO	WHARTON #2	35	R1	12N	22W	1736
DEPT OF WATER RESOURCES		G. W. OBSERV. WELL	26	N3	12N	23W	242
	MARICOPA	2A SEC 31-E	31	E	12N	23W	785
	GARDNER FIELD		33	H1	12N	23W	1000

Number of wells in this Township 25

Township 25S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
WHEELABRATOR	DELANO	#1	25	L	25S	25E	775
CALIFORNIA VINEYARD	DELANO	#22-A-2	4	A2	25S	26E	1450
PINKHAM PROPERTIES, INC.	DELANO	WATER WELL #4	4	F	25S	26E	1346
M. CARATAN	DELANO	WATER WELL #6	8	C1	25S	26E	1304
PACIFIC OIL AND GAS CO.	JASMINE	SALCO-BOONE # 44	1	Z	25S	27E	2100
A.K. DAWSON	RICHGROVE AREA	# 1	3	G	25S	27E	1950
HILTON DRLG. CO.	RICHGROVE-BENNETT	#4 W.W. #2	4	C1	25S	27E	1903
JEFFERY HERRICK	RICHGROVE	WELL #1	4	P	25S	27E	632
			4	Q	25S	27E	
HYLTON DRLG.	RICHGROVE	BENNETT RANCH # 4 ,	4	Z	25S	27E	1905
			5	A	25S	27E	1830
B.M. NEILSEN FARMS	RICHGROVE AREA	WATER WELL	6	A1	25S	27E	1202
H.M. HOLLOWAY, JR.	JASMINE	HOLLOWAY # 2	8	H1	25S	27E	2003
H.M. HOLLOWAY RANCH	RICHGROVE AREA	#4	8	P	25S	27E	2198
WHITTEN BROTHERS	RICHGROVE	H.M. ROLLOWAY # 3	8	R1	25S	27E	2140
TIDEWATER ASSOCIATED OIL	RICHGROVE	QUINN #46	8	Z	25S	27E	3786
			10	F	25S	27E	1750
HARP & BROWN	JASMINE AREA	QUINN # 1	11	A	25S	27E	2347
PACIFIC OIL & GAS DEV.	JASMINE	QUINN # 1	13	D	25S	27E	2170
AMERADA	RICHGROVE	JASMINE F	13	D	25S	27E	1906
PACIFIC OIL & GAS CO.	JASMINE	QUINN # 3	14	Z	25S	27E	2266

Data Base of wells available for Kern County Water Agency Regional Structure Study

PACIFIC OIL AND GAS	JASMINE	QUINN # 2	14	Z	25S	27E	2286
L.C. GOULD OPERATOR	JASMINE	RICHARDSON # 16-1	16	Z	25S	27E	2300
RUBY OIL CO.	QUINN AREA	QUINN # 17	17	P	25S	27E	2500
			18	A	25S	27E	2320
WHITTEN PUMPS INC.	JASMINE	GRIGGS & HARDEN #2	18	Z	25S	27E	2104
PACIFIC OIL & GAS	JASMINE	CANTLEBERRY # 74	22	Z	25S	27E	2320
PACIFIC OIL & GAS DEV.	JASMINE	JOL # 1-23	23	Z	25S	27E	2200
ROTHSCHILD OIL CO.	JASMINE AREA	McDEVITT # 1	24	N	25S	27E	2060
S.A. CAMP PUMP CO.	RAFTER "F" RANCH	WATER WELL	28	Z	25S	27E	2039
WARREN CARTER FARMS	JASMINE		31	Z	25S	27E	
HANCOCK OIL CO.	JASMINE	MARQUIS # 1	31	Z	25S	27E	4500
BRITISH AMERICAN OIL PROD.	JASMINE	DAVIS # 36	32	Z	25S	27E	3180
BANDINI PET. CO.	JASMINE AREA	JASMIN # 1	35	B	25S	27E	2010
COUNTY OF KERN	KERN VALLEY LAND FIELD	TEST WELL # 2	35	Z	25S	33E	153

Number of wells in this Township 35

Township 26S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
RICHARD S. RHEEM	RAVENS PASS	AMBROSE # 1	25	Z	26S	17E	1453
YELLOWSTONE OIL CO.	DEVIL'S DEN	STILL MABURY 0-12-1	1	J	26S	18E	457
			9	E1	26S	18E	
WOODWARD & REYNOLDS	BLACKWELLS CORNER	MABURY # 4	25	N	26S	18E	1400
HANCOCK OIL CO.	SHALE POINT	MABURY # 1	36	Z	26S	18E	1376
HAMILTON & SHERMAN	BLACKWELLS CORNER	BEER AREA B # 6	7	B	26S	19E	815
BRITISH AMERICAN	BLACKWELLS CORNER	BEER B # 58	8	Z	26S	19E	3175
HAMILTON & SHERMAN	BLACKWELLS CORNER	BEER B # 2	17	Z	26S	19E	1043
SEABOARD OIL CO.	DEVIL'S DEN AREA	BEER # 66	17	Z	26A	19E	8821
HAMILTON & SHERMAN	BLACKWELLS CORNER	BEER # 7	19	Z	26S	19E	1218
BRITISH AMERICAN OIL CO.	BLACKWELLS CORNER	BEER B # 85	21	Z	26S	19E	3542
PATRICK A. DOHENY	BLACKWELLS CORNER	CROSBY-BEER # 1	21	Z	26S	19E	5881
BRITISH AMERICAN OIL CO.	BLACKWELLS CORNER	BEER # 11	22	Z	26S	19E	8351
BERRENDA MESA WATER	NA	TEST WELL	28	A	26S	19E	1332
ARCHIE MYERS	BLACKWELLS CORNER	WATER RESOURCES	36	Q	26S	19E	655

Data Base of wells available for Kern County Water Agency Regional Structure Study

TIDE WATER OIL CO.	LOST HILLS	?-#2	2	L1	26S	20E	300
MARYLYN COMPANY	LOST HILLS	WEST COAST #5-L	2	L2	26S	20E	1686
ENERGY DEV. OF CA INC.	LOST HILLS	WEST COAST 5M3	2	L4	26S	20E	1372
ENERGY DEV. OF CA INC.	LOST HILLS	WEST COAST #1-3	2	L5	26S	20E	1629
TEXACO INC.	LOST HILLS	"THETA NCT-1" #2-20	2	M1	26S	20E	1423
TEXACO INC.	LOST HILLS	"THETA NCT-1" #2-27	2	M2	26S	20E	1129
TEXACO INC.	LOST HILLS	"THETA NCT-1" #2-23	2	M2	26S	20E	1255
MARYLYN CO.	LOST HILLS	"THETA NCT-1" #2-33	2	M4	26S	20E	1122
CHEVRON U.S.A. INC.	LOST HILLS	UNITED#1	2	N2	26S	20E	810
STANDARD OIL CO.	LOST HILLS	UNITED #6	2	N3	26S	20E	1166
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #?	2	P1	26S	20E	1293
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #1-50	2	P2	26S	20E	1570
CHEVRON U.S.A. INC.	LOST HILLS	UNITED # 2	2	P3	26S	20E	1585
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #3	2	P4	26S	20E	1401
CHEVRON USA INC.	LOST HILLS	UNITED # 7	2	P5	26S	20E	1296
	LOST HILLS	UNITED #6	2	Q1	26S	20E	1582
ENERGY DEV. OF CA INC.	LOST HILLS	WILLIAMSON #4	2	Q3	26S	20E	1016
PETRO LEWIS CORP.	LOST HILLS	WILLIAMSON #1	2	Q4	26S	20E	697
	LOST HILLS	WILLIAMSON #10-R	2	Q8	26S	20E	1440
	LOST HILLS	WILLIAMSON #11	2	Q9	26S	20E	1500
RANDAN PETROLEUM CORP.	LOST HILLS	THETA #3	3	H	26S	20E	1731
TEXAS CORP.	LOST HILLS	THETA #3 11-9	11	A	26S	20E	2048
TEXAS CORP.	LOST HILLS	THETA #8 1113	11	A	26S	20E	1149
ENERGY DEV. OF CA INC.	LOST HILLS	B-11	11	B	26S	20E	1098
GENERAL PETRO. CO	LOST HILLS	WILLIAMSON # 33-11	11	F	26S	20E	1800
MOBILE OIL CORP.	LOST HILLS	WILLIAMSON # 3-11	11	F	26S	20E	1634
MOBILE OIL CORP.	LOST HILLS	WILLIAMSON # 1-11	11	G	26S	20E	1650
CHEVRON USA INCROP.	LOST HILLS	CHEVRON WILLIAMSON	11	G	26S	20E	1430
CHEVRON U.S.A.	LOST HILLS	UNITED #4	11	H	26S	20E	1293
MARYLN CO.	LOST HILLS	THETA # 11-20	11	J	26S	20E	1717
ARCO OIL & GAS CO.	LOST HILLS	LOST HILLS FEE "E" # 301	11	L	26S	20E	2200
RICHFIELD OIL CORP.	LOST HILLS	FEE "E" # 1	11	L	26S	20E	2600
THE TEXAS CO.	LOST HILLS	THETA # 12-16	12	E	26S	20E	2000

Data Base of wells available for Kern County Water Agency Regional Structure Study

MARLYN AO.	LOST HILLS	THETA NCT 3-12-5	12	E	26S	20E	2435
MOBILE OIL CO.	LOST HILLS	WILLIAMSON # 1-12	12	F	26S	20E	1550
ATLANTIC CO.	LOST HILLS	FEE D-2	12	M	26S	20E	1920
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #23	12	P	26S	20E	1899
STANDARD OIL CO.	LOST HILLS	UNITED 2-29	12	P	26S	20E	2495
SUPERIOR OIL CO.	LOST HILLS	TOL #3	12	Q	26S	20E	1450
MOBIL OIL CORP.	LOST HILLS	THETA #34	13	A	26S	20E	1550
MOBILE OIL CO.	LOST HILLS	THETA THREE # 17	13	B	26S	20E	1500
MOBIL OIL CORP.	LOST HILLS	LOST HILLS THREE #5	13	C	26S	20E	2500
MOBIL OIL CORP.	LOST HILLS	LOST HILLS THREE #3	13	D	26S	20E	1598
ARCO	LOST HILLS	LOST HILLS C-21	13	E	26S	20E	655
GETTY OIL CO	LOST HILLS	# 14A	13	E	26S	20E	947
GETTY OIL CO.	LOST HILLS	# 2-5	13	G	26S	20E	536
GETTY OIL CO.	LOST HILLS	GETT-1 # 502	13	G	26S	20E	508
GETTY OIL CO.	LOST HILLS	# 307	13	H	26S	20E	402
TEXACO PRODUCING INC.	LOST HILLS	# 525	13	J	26S	20E	586
GETTY OIL CO.	LOST HILLS	# 506	13	K	26S	20E	458
GETTY OIL CO.	LOST HILLS	# 108	13	L	26S	20E	689
FERGUSEN AND BOSWORTH	LOST HILLS	FEE # 1	14	J	26S	20E	1900
MOBILE OIL CO.	LOST HILLS	#170	19	E	26S	20E	1324
GENERAL PETROLEUM	LOST HILLS	LOST HILLS TWO # 40	19	K	26S	20E	1950
M.M. WHITTIER	LOST HILLS	STAR # 102	24	A	26S	20E	1250
M.M. WHITTIER	LOST HILLS	STAR # 105?	24	A	26S	20E	1300
M.M. WHITTIER	LOST HILLS	STAR # 114	24	H	26S	20E	1433
M.M. WHITTIER	LOST HILLS	STAR # 112	24	H	26S	20E	1324
CA LANDS INC.	LOST HILLS	C.L.C. # 1	24	L	26S	20E	1400
	LOST HILLS		24	L	26S	20E	1600
			24	M	26S	20E	1330
MOBILE OIL CORP.	LOST HILLS	BLACKWELL # 1	25	B	26S	20E	5075
WM. M. THORNBURY	KERN COUNTY	SUPERIOR-OCCIDENTAL # 1	27	R	26S	20E	1650
GETTY OIL CO.	BEER NOSE AREA	5 & 6 #1	30	N	26S	20E	1640
GETTY OIL CO.			31	D	26S	20E	1380
GULF OIL CORP.	BLACKWELLS CORNER	TENBY OLC # 1	31	K	26S	20E	11100

Data Base of wells available for Kern County Water Agency Regional Structure Study

WEST FARMERS	LOST HILLS	#3	5	K	26S	21E	1794
TEJON HILLS OIL CO.	LOST HILLS	#1	12	C	26S	21E	3592
ARTHUR C. FISHER			14	G	26S	21E	3000
JOHN J. FRANTZ	LOST HILLS	WATER WELL # 1	14	Z	26S	21E	316
		26S/21E-17D	17	D	26S	21E	237
SUPERIOR OIL CO.	LOST HILLS	LOST HILLS # 3	18	E	26S	21E	1500
MOBILE OIL CO.	LOST HILLS	LOST HILLS TWO # 126	19	C	26S	21E	1450
MOBILE OIL CORP.	LOST HILLS	LOST HILLS TWO # 125	19	D	26S	21E	1669
MOTOR OIL CO.	LOST HILLS	LOST HILLS TWO # 108	19	F	26S	21E	1900
	LOST HILLS	LOST HILLS TWO # 94	19	F	26S	21E	1750
	LOST HILLS		19	G	26S	21E	1650
MOBILE OIL CO.	LOST HILLS	#1	19	G	26S	21E	1750
	LOST HILLS	LOST HILLS TWO	19	J	26S	21E	2300
GENERAL PET. CORP.	LOST HILLS	LOST HILLS TWO # 69	19	K	26S	21E	1900
GENERAL PETROLEUM CORP.	LOST HILLS	LOST HILLS TWO #67	19	L	26S	21E	1800
MOBIL OIL CO.	LOST HILLS	LOST HILLS TWO #47	19	M	26S	21E	1683
MOBILE OIL CO.	LOST HILLS	LOST HILLS TWO # 22	19	N	26S	21E	1664
MOBIL CO.	LOST HILLS	LOST HILLS TWO #21A	19	P	26S	21E	1740
MOBIL OIL CORP.	LOST HILLS	LOST HILLS TWO #182	19	Q	26S	21E	1804
GENERAL PETROLEUM CORP.	LOST HILLS	LOST HILLS TWO #34	19	R	26S	21E	1718
STANDARD OIL	LOST HILLS	GALBREATH #14	20	E	26S	21E	1800
	LOST HILLS	GALBREATH #3	20	N	26S	21E	1470
			28	N	26S	21E	700
CHEVRON USA INC.	LOST HILLS	# 4-3A	29	C-F	26S	21E	1400
CHEVRON U.S.A. INC.	LOST HILLS	#1-1	29	D	26S	21E	1400
CHEVRON U.S.A. INC.	LOST HILLS	#2-2	29	D	26S	21E	2150
	LOST HILLS		29	E	26S	21E	1930
CHEVRON U.S.A. INC.	LOST HILLS	#3-49?	29	E	26S	21E	1500
CHEVRON U.S.A. INC.	LOST HILLS		29	F	26S	21E	2080
STANDARD OIL CO.	LOST HILLS	#7-6A	29	K	26S	21E	1700
CHEVRON U.S.A. INC.	LOST HILLS	#4-7	29	L	26S	21E	1740
CHEVRON U.S.A. INC.	LOST HILLS	#4-8	29	L	26S	21E	1837
			29	M	26S	21E	1750

Data Base of wells available for Kern County Water Agency Regional Structure Study

CHEVRON U.S.A. IN	LOST HILLS	#2-8	29	M	26S	21E	1700
			29	N	26S	21E	1700
CHEVRON U.S.A. INC.	LOST HILLS	#1-?	29	N	26S	21E	1750
CHEVRON U.S.A. INC.	LOST HILLS	#3-10	29	P	26S	21E	1700
CHEVRON USA INC.	LOST HILLS	# 6-8A	29	P-Q	26S	21E	1500
CHEVRON U.S.A. INC.	LOST HILLS		29	Q	26S	21E	1900
GULF OIL CORP.	LOST HILLS	#11-3	30	A	26S	21E	1722
GULF OIL CORP.	LOST HILLS	#10-1	30	A	26S	21E	1778
GULF OIL CORP.	LOST HILLS	#7-1	30	B	26S	21E	1653
GULF OIL CO.	LOST HILLS	#8-1X	30	B	26S	21E	1620
GULF OIL CORP.	LOST HILLS		30	C	26S	21E	1600
GULF OIL CORP.	LOST HILLS	#4-2	30	C	26S	21E	1900
GLF OIL CORP.	LOST HILLS	# 5-1-30	30	C	26S	21E	1700
GULF OIL CO.	LOST HILLS		30	C-D	26S	21E	1900
GULF OIL CORP.	LOST HILLS		30	D	26S	21E	1700
CHEVRON USA INC.	LOST HILLS	# 3-5-30	30	E	26S	21E	1500
GULF OIL CORP.	LOST HILLS	#5-4?	30	F	26S	21E	1550
GULF OIL CORP.	LOST HILLS	#6-5A	30	F	26S	21E	1600
GULF OIL CORP.	LOST HILLS	#7-4	30	G	26S	21E	1400
GULF OIL CORP.	LOST HILLS	#7-6	30	G	26S	21E	1875
GULF OIL CORP.	LOST HILLS	#110-4	30	H	26S	21E	826
GULF OIL CORP.	LOST HILLS	#11-6	30	H	26S	21E	1754
GULF OIL CORP.	LOST HILLS	#11-10X	30	J	26S	21E	1865
GULF OIL CORP.	LOST HILLS	#10-7	30	J	26S	21E	1780
GULF OIL CORP.	LOST HILLS	#8-8	30	K	26S	21E	1500
GULF OIL CO.	LOST HILLS	# 5-7	30	K	26S	21E	1850
FERRELL G. NIXON	LOST HILLS	USL #1-30	30	L	26S	21E	1650
GULF OIL CORP.	LOST HILLS	# 12A	30	Q	26S	21E	1500
GULF OIL CORP.	LOST HILLS	# ?-10	30	Q	26S	21E	1800
GULF OIL CO.	LOST HILLS	# 32-12	30	R	26S	21E	1921
GULF OIL CO.	LOST HILLS	# 11-11B	30	R	26S	21E	1550
GULF OIL CORP.	LOST HILLS	# 5-1-30	30	Z	26S	21E	1707
CHEVRON USA	LOST HILLS	# 10-2C	31	A	26S	21E	1500

Data Base of wells available for Kern County Water Agency Regional Structure Study

GULF OIL CORP.	LOST HILLS	# 10-1	32	A	26S	21E	1400
GULF OIL CORP.	LOST HLLS	# 11-3	32	A	26S	21E	1460
GULF OIL CORP.	LOST HILLS	# 7-14	32	B	26S	21E	1850
GULF OIL CORP.	LOST HILLS		32	B	26S	21E	1840
GULF OIL CORP.	LOST HILLS	# 5-1	32	C	26S	21E	1812
GULF OIL CORP.	LOST HILLS	# 5-3	32	C	26S	21E	1800
GULF OIL CORP.	LOST HILLS	# 3-2	32	D	26S	21E	1800
GULF OIL EXPLORATION	LOST HILLS	# 2-6	32	E	26S	21E	1150
GULF OIL CO.	LOST HILLS	# 1-4	32	E	26S	21E	1080
GULF OIL CORP.	LOST HILLS	# 4-4	32	F	26S	21E	1500
GULF OIL CORP.	LOST HILLS	# 5-5	32	F	26S	21E	1890
GULF OIL CORP.	LOST HILLS	# 7-5	32	G	26S	21E	1834
GULF OIL CORP.	LOST HILLS		32	G	26S	21E	1800
GULF OIL CORP.	LOST HILLS	# 11-4	32	H	26S	21E	1550
UNIVERSAL CONS. OIL CO.	LOST HILLS	# 71-32	32	J	26S	21E	1800
GULF OIL CORP.	LOST HILLS	# 11-8	32	J	26S	21E	1895
GULF OIL CORP.	LOST HILLS		32	J	26S	21E	1860
GULF OIL CORP.	LOST HILLS		32	K	26S	21E	1830
GULF OIL CORP.	LOST HILLS		32	K	26S	21E	1940
GULF OIL CORP.	LOST HILLS	# ? 5-7	32	L	26S	21E	1460
GULF OIL CORP.	LOST HILLS		32	M	26S	21E	1720
GULF OIL CORP.	LOST HILLS		32	M	26S	21E	1560
GULF OIL CORP.	LOST HILLS	# 5-10	32	P	26S	21E	1480
GULF ENERGY & MINERAL OIL	LOST HILLS	# 6-11	32	P	26S	21E	1130
GULF OIL CORP.	LOST HILLS	# 2-1	32	Q	26S	21E	1810
GULF OIL CORP.	LOST HILLS		32	Q	26S	21E	1340
GULF OIL CORP.	LOST HILLS	# 12-11	32	R	26S	21E	1940
GULF OIL CORP.	LOST HILLS	# 11-104	32	R	26S	21E	1070
STANDARD OIL CO.	LOST HILLS	# 1-3	33	D	26S	21E	1900
CHEVRON USA INC.	LOST HILLS	# 1-5	33	E	26S	21E	2190
CHEVRON USA INC.	LOST HILLS	# 1-4	33	E	26S	21E	2350
CHEVRON USA INC.	LOST HILLS		33	L	26S	21E	1560
CHEVRON USA INC.	LOST HILLS	# 2-8	33	M	26S	21E	1650

Data Base of wells available for Kern County Water Agency Regional Structure Study

CHEVRON USA INC	LOST HILLS	# 1-6A	33	M	26S	21E	1500
CHEVRON USA INC.	LOST HILLS	# 2-10A	33	N	26S	21E	2325
CHEVRON USA INC.	LOST HILLS	# 1-9A	33	N	26S	21E	1550
CHEVRON USA INC.	LOST HILLS	# 4-11	33	P	26S	21E	1580
CHEVRON USA INC.	LOST HILLS	# 3-9A	33	P	26S	21E	1680
			5	P	26S	22E	500
	LOST HILLS AREA	WATER WELL # 1	5	Z	26S	22E	547
KERN GAS ASSOC.	NW SEMITROPIC	# TW-SP 1-9	9	Q	26S	22E	2500
GENERAL PERTOLEUM CORP.	N. SEMITROPIC	K.P.C. # 1	16	Z	26S	22E	6025
CHEVRON USA	SEMITROPIC	#3	25	H	26S	22E	720
D.D. AND DORTHY DUNLAP	SEMITROPIC	# 45-26	26	Z	26S	22E	8500
			27	Q2	26S	22E	
ANDERSON	WEST END ELMO HWY	#3	1	Z	26S	23E	740
POND HEIFER RANCH	WASCO SHERWOOD RANCH	#5	11	R	26S	23E	842.2
JACOBSEN FARMS INC.	WASCO		13	H	26S	23E	845
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING H-11	15	A	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING H-11	15	D	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-21	15	E	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-23	15	F,G,L	26S	23E	520
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING H-9	15	K-J	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-8	15	M	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-1	15	N	26S	23E	501
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-14	15	N	26S	23E	470
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-19	16	D	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-26	16	G-H	26S	23E	522
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-27	16	G-K	26S	23E	515
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-17	16	H	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-7	16	J	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-33	16	J-K	26S	23E	518
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-32	16	K	26S	23E	520
ALVERUS JANSSEN	WASCO	# 1	18	Z	26S	23E	504
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-15	21	B	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-31	21	B,A,	26S	23E	520

Data Base of wells available for Kern County Water Agency Regional Structure Study

CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-22	21	B-A	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-30	21	C-B	26S	23E	520
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-20	21	D	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-29	21	G	26S	23E	518
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-28	21	G-H	26S	23E	524
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-12	22	A	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-6	22	C-B	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-2	22	C-B	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-5	22	C-D	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-3	22	D	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-25	22	F-G	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-18	22	R	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-34	27	D	26S	23E	520
		FANNIN WW # 1	27	P	26S	23E	700
			27	P1	26S	23E	700
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-13	28	D	26S	23E	500
			29	J	26S	23E	700
NATIONAL ROYALTIES	SEMITROPIC	WATER WELL # 1	29	Z	26S	23E	680
			32	F	26S	23E	
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-16	21/22	21 HJ	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-4	21/22	21A	26S	23E	500
LAYNE-WESTERN	POND	# 2C10-4	10	F	26S	24E	1010
BAKERSFIELD WELL & PUMP	POND	# 2C11-5	11	F	26S	24E	993
DENNIS & MARY ALLEN	WASCO	DENNIS & MARY ALLEN	13	K	26S	24E	401
S.A. CAMP PUMP CO.	POND	# 2C 12-4	14	H	26S	24E	989
			15	F	26S	24E	1000
GRUNDT BROTHERS	WASCO	WATER WELL # 1	15	Z	26S	24E	1000
TENNECO WEST	WASCO	# 2C 27-4	27	F	26S	24E	1005
			27	R	26S	24E	
KERN COUNTY LAND	WASCO AREA	# 2C 31-4	31	F1	26S	24E	761
			31	P	26S	24E	700
KERN COUNTY LAND CO.	WASCO AREA	# 2C 31-3	31J	Z	26S	24E	731
KERN COUNTY LAND CO.	SEMITROPIC AREA	# 2C 31-2	31	Z	26S	24E	724

Data Base of wells available for Kern County Water Agency Regional Structure Study

	MCFARLAND	#1	2	A	26S	25E	1300
ATHA SARIS	McFARLAND	NELLA # 1	2	A	26S	25E	3776
ALINA FARMS	MCFARLAND	DOMESTIC	2	Z	26S	25E	653
ALINA FARMS	McFARLAND	DOMESTIC	2	Z	26S	25E	653
JERRY DAVIS	McFARLAND	88-05	3	R	26S	25E	820
ALINA FARMS	McFARLAND	DOMESTIC	7	Z	26S	25E	653
LARRY MUNGIA	McFARLAND	# 1	8	Z	26S	25E	530
BAKERSFIELD WELL & PUMP	CITY OF MCFARLAND WEST	#6	11	B	26S	25E	1400
BAKERSFIELD WELL & PUMP	McFARLAND	McFARLAND # 6	11	B	26S	25E	1380
BAKERSFIELD	McFARLAND	CITY OF McFARLAND # 6	12	D	26S	25E	1380
BAKERSFIELD WELL & PUMP	McFARLAND	CITY OF McFARLAND # 5	12	Z	26S	25E	1376
J.B. WALDRIP	POND	WALDRIP # 2	18	PON	26S	25E	1008
NORTH KERN WATER	McFARLAND	#9	27	C	26S	25E	998
H & G OPERATING CO.		EAST SLOPE #3	30	Q	26S	25E	3515
S.A. CAMP PUMP CO.		WATERWELL	2	Z	26S	26E	1897
PETROLEUM CORP.		#1	11	E	26S	26E	2250
TESORO PETROLEUM CORP.	STRINE NOSE	# 74-11	11	H	26S	26E	3200
			11	H	26S	26E	2100
			11	Z	26S	26E	
SHELL OIL CO.	WOODY ROAD AREA	GUTH McCALES COMM. # 1	12	Z	26S	26E	5280
	MCFARLAND AREA	BORGEN #26-26	15	C	26S	26E	1600
TIDE WATER ASSOC. OIL CO.	McFARLAND AREA	#32	15	C	26S	26E	
SUPERIOR FARMING CO.	FOMOSA AREA	# 12-3D	17	Z	26S	26E	1196
SUPERIOR FARMING CO.	FAMOSA AREA	# 12-4	17	Z	26S	26E	2007
SUPERIOR FARMING CO.	FAMOSA AREA	# 12	17	Z	26S	26E	2300
ATLANTIC OIL CO.	McFARLAND	DEL FORTUNA # 1	21	P	26S	26E	6850
SUPERIOR FARMING	FAMOSA AREA	W. W. #13-3	22	E	26S	26E	2030
SUPERIOR FARMS		SUPERIOR ALMONDS	23	A	26S	26E	800
GEORGE D. BROWN		ROBERTS - COX # 1	23	Z	26S	26E	2000
SUPERIOR FARMING	FAMOSA AREA	#14-6	24	Z	26S	26E	2030
COX - FERGUSON		# 1	24	Z	26S	26E	5960
MARIE FARR	FAMOSA	# 2	25	L	26S	26E	990
SUPERIOR FARMING	FAMOSA AREA	WATER WELL 14-7	27	Z	26S	26E	2030

Data Base of wells available for Kern County Water Agency Regional Structure Study

TRICO OIL & GAS	FAMOSA	KCL # 16 M	30	M	26S	26E	3500
SUPERIOR FARMING	FAMOSA FIELD	# 14-6	34	Z	26S	26E	2028
SUPERIOR OIL CO.	FAMOSA AREA	WATER WELL # 20-2	35	F	26S	26E	2032
SUPERIOR OIL CO.	FAMOSA AREA	WATER WELL # 20-3	35	N	26S	26E	2042
			36	C	26S	26E	2200
S.A. CAMP PUMP CO.	FAMOSA AREA	WATERWELL	36	Z	26S	26E	1923
SUPERIOR FARMING CO.	FAMOSA AREA	# 24-1	36	Z	26S	26E	2338
SUPERIOR FARMING	FAMOSA AREA	# 24-2	36	Z	26S	26E	2013
H.M. HOLLOWAY	JASMINE	#2	8	H1	26S	27E	2003
MARIE FARR	FAMOSA	# 1	21	P	26S	27E	456
		# 5	24	B	26S	27E	
GETTY OIL		# 27-1	27	F	26S	27E	1245
MARIE FARR	FAMOSA	# 1	28	E	26S	27E	456
SEMI - TROPIC	SEMITROPIC	# 5	32	F	26S	27E	619
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE# 33-1	33	L	26S	27E	1003
TRICO OIL & GAS	N. MT. POSO	VILLARD # 1	17	Z	26S	28E	1778
INTEX OIL CO.	MT. POSO	GLIDE # 1	19	Z	26S	28E	1820
GLEN H. MITCHELL	MT. POSO AREA	S.P. # 2	33	Z	26S	28E	2055

Number of wells in this Township 297

Township 27S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
MACSON OIL CO.	SHALES HILLS	TWISSELMAN COMMUNITY	16	Z	27S	18E	1887
THE TEXAS CO.	SHALE HILLS	McLENNAN # 1	19	A	27S	19E	1750
BRITISH AMERICA	ANTELOPE PLAIN	US GOVT. 66-20	20	N	27S	19E	2731
INDEPENDENT EXPLORATION	WILLEAMS AREA	GRABE # 85X	20	R	27S	19E	1731
SHELL OIL CO.	ANTELOPE HILLS	CORE HOLE # 66-21	21	Q	27S	19E	3567
INDEPENDENT EXPLORATION	ANTELOPE PLAINS 27	WILLIAMSON # 1	27	Z	27S	19E	3066
JACOBSON OIL CO.	SHALE HILLS	STEWART # 1	32	Z	27S	19E	2066
ATLAS PRODUCTION	McDONALD ANTICLINE	US # 1	33	A	27S	19E	1500
		# 44	33	F	27S	19E	
ASSSOCIATED OIL CO.	NORTH BELRIDGE	# 5	34	Z	27S	19E	7975
YIRSAL OIL CO.	NORTH BELRIDGE	REYNOLDS & KNUDSEN # 5	36	Z	27S	20E	660

Data Base of wells available for Kern County Water Agency Regional Structure Study

VIRSAL OIL CO.	NORTH BELRIDGE	REYNOLDS & KNUDSEN # 9	36	Z	27S	20E	830
CHEVRON USA INC.	LOST HILLS	"CAHN" # 7-2	4	B	27S	21E	1620
CHEVRON USA INC.	LOST HILLS	" CAHN " # I47	4	C	27S	21E	1600
	LOST HILLS	LOST HILLS ONE # 101	4	D	27S	21E	1800
MOBILE OIL CORP.	LOST HILLS	LOST HILLS ONE # 102	4	E	27S	21E	2215
CHEVRON USA INC.	LOST HILLS	" CAHN " # 136	4	F	27S	21E	1535
STANDARD OIL CO.	LOST HILLS	" CAHN " # 7-3A	4	G	Q27S	21E	1320
CHEVRON USA INC.	LOST HILLS	" CAHN" # 9-7	4	J	27S	21E	1370
CHEVRON USA INC.	LOST HILLS	"CAHN" # 7-7A	4	K	27S	21E	1540
CHEVRON USA INC.	LOST HILLS	"CAHN" # ? - 7A	4	L	27S	21E	1490
CHEVRON USA INC.	LOST HILLS	"CAHN " # I-38	4	N	27S	21E	1660
	LOST HILLS		4	P	27S	21E	1490
CHEVRON USA INC.	LOST HILLS	"CAHN" # 4-?	4	P	27S	21E	1760
CHEVRON USA INC.	LOST HILLS	"CAHN" # 7-9	4	Q	27S	21E	1640
CHEVRON USA INC.	LOST HILLS	"CAHN" # 8-10	4	Q	27S	21E	1530
CHEVRON USA INC.	LOST HILLS	"CAHN" # 10-10	4	R	27S	21E	1460
ARCO OIL & GAS CO.	LOST HILLS		5	A	27S	21E	2300
GULF OIL CO.	LOST HILLS	# 1-C-5	5	A	27S	21E	1600
GULF OIL CO.	LOST HILLS		5	B	27S	21E	1530
GULF OIL CO.	LOST HILLS	# 25-1	5	C	27S	21E	1750
GULF OIL EPL. & PROD.	LOST HILLS	# 3-6 (FEE)	5	E	27S	21E	1440
CHEVRON USA INC.	LOST HILLS	VULCAN # 11-B	5	G	27S	21E	1550
	LOST HILLS	VULCAN # 1-A	5	H	27S	21E	1680
MOBILE OIL CO.	LOST HILLS	LOST HILLS ONE # 100B	5	J	27S	21E	2490
ATLANTIC CO.	LOST HILLS	"BUCK" # 1	6	R	27S	21E	1770
GETTY OIL CO.	LOST HILLS	# A-231	8	C	27S	21E	1700
DWR SAN JOAQUIN DISTRICT		# 11C1	11	C	27S	21E	240
DWR			20	H	27S	21E	1500
			25	D	27S	21E	
DWR			25	D	27S	21E	1300
BELLRIDGE OIL CO.	NORTH BELRIDGE	# 85A-34	34	J	27S	21E	1620
TORIGIANI FARMS	LOST HILLS	#4	5	Z	27S	22E	613
	LOST HILLS	BROOKS-WALKER WW#1	7	D?	27S	22E	603

Data Base of wells available for Kern County Water Agency Regional Structure Study

C.A. SPICER	SEMI-TROPIC	W.W.	11	K	27S	22E	611
	SEMI-TROPIC	#2	12	K	27S	22E	535
	SEMI-TROPIC	MCLAIN #1	13	A	27S	22E	605
B.B. BALDWIN FARMS	BUTTOWILLOW		20	Z	27S	22E	382
			22	F	27S	22E	1220
NICKEL ENTERPRISES	CARMEL RANCH	#36	22	Z	27S	22E	526
DWR			23	D	27S	22E	510
TEXACO INC.	BUTTOWILLOW	MITCHEL #1	26	D	27S	22E	1500
DWR	LOST HILLS		31	N?	27S	22E	603
DWR			31	N	27S	22E	580
BLOEMHOF AG	BUTTONWILLOW	DELFINO #3	33	H	27S	22E	557.8
CARR & WRATH	BUTTOWILLOW	"PERDIDO #1	36	B	27S	22E	1650
CARR & WRATH	BUTTOWILLOW	MOBIL #1	36	R	27S	22E	1550
U.S. BUREAU OF	WASCO		1	A	27S	23E	1164
			2	Z	27S	23E	700
SEMI TROPIC SCHOOL	SEMI TROPIC	#2	4	P	27S	23E	505
CHEVRON	SEMITROPIC	#1	5	N?	27S	23E	2000
			6	G2	27S	23E	430
			6	Q	27S	23E	1190
CHEVRON	SEMITROPIC	TOWLE ESTATE # 32	7	C	27S	23E	1500
HARVESTER CO.	SEMITROPIC	TOWLE ESTATE # 3-7	7	C	27S	23E	1400
	SEMITROPIC	TOWLE TRUST # 01	7	J	27S	23E	1700
FALCON PETROLEUM CO.	SEMITROPIC	HILL # 55	8	K	27S	23E	1800
			8	P1	27S	23E	540
HUMBLE OIL	SEMITROPIC		9	J	27S	23E	1500
FALCON PETROLEUM CO.	SEMITROPIC		9	N	27S	23E	1800
T & T OIL CO.	SEMITROPIC	CONN # 1	9	R	27S	23E	1850
ARGOSY OIL CO.	SEMITROPIC	S.A.M. UNIT # 1	10	C	27S	23E	1750
			14	Q	27S	23E	1500
	SEMITROPIC		15	Q	27S	23E	1500
	SEMITROPIC		16	H	27S	23E	1600
			17	F	27S	23E	540
			17	H1	27S	23E	780

Data Base of wells available for Kern County Water Agency Regional Structure Study

			18	H2	27S	23E	620
			18	L	27S	23E	1000
			18	L3	27S	23E	1000
VISTA PETROLEUM CO.	SEMITROPIC	GOVT. # 3 ?	22	A	27S	23E	1700
	SEMITROPIC		22	G	27S	23E	
VISTA PETRO. CO.	SEMITROPIC	BRADFORD # 24	23	A	27S	23E	2000
VISTA PETRO. CO.	SEMITROPIC	BRADFORD #66 ?	23	K	27S	23E	1650
MITCHELL CO.	SEMITROPIC	MITCHELL- BRADFORD # 24-	23	N	27S	23E	1850
MITCHELL CO.	SEMITROPIC	MITCHELL - BRADFORD #	23	P	27S	23E	1650
BOOKLAND FARMS	SEMITROPIC	# 18	23	Z	27S	23E	785
	SEMITROPIC	WILLIAMS # 1	24	R	27S	23E	1800
McCULLOCH OIL CORP. OF CA	SEMITROPIC	# 1 W	25	A	27S	23E	1850
STANDARD OIL CO.	SEMITROPIC	FULERTON # 2	25	C	27S	23E	2000
	SEMITROPIC		25	D	27S	23E	1380
			25	E	27S	23E	1200
NEUFELD	SHAFTER	# 4	25	P1	27S	23E	480
			26	F1	27S	23E	400
RICHARD S. PRATHER CO.	SEMITROPIC	GULF # 1	26	L	27S	23E	1950
ROBERT NUEMAN & SONS	SEMITROPIC	WATERWELL # 1	27	J1	27S	23E	502
RUSS BARLING	SEMITROPIC	# 2	27	Z	27S	23E	927
			34	A1	27S	23E	740
U.S. BUREAU OF	WASCO QUAD	# 1G	1	G	27S	24E	1125
	DUCOR	JOSEPHSEN & CARATANN	3	M	27S	24E	1219
CITY OF WASCO PUBLIC	WASCO	WASCO GOLF COURSE	4	Z	27S	24E	829
KCL	SEMITROPIC AREA	# 3C 6-4	6	P1	27S	24E	730
CONTINENTAL OIL CO.	WASCO	MEYER # 1	7	L	27S	24E	2830
	WASCO	" KCL LEASE # 40 " 32-17	17	C	27S	24E	1960
STANDARD OIL CO. OF CA	WASCO	KCL # 41- ?	18	C	27S	24E	2130
BEAR CREEK PROD.	BEAR CREEK	# 89-20	23	L	27S	24E	625
KCL	SEMITROPIC	# 2 C	27	Z	27S	24E	707
KERN COUNTY LAND CO.	SEMITROPIC	# 2C 27-2	27	Z	27S	24E	700
PATRICK A. DONERY	SOUTH WASCO	UNIT # 28-1	28	A	27S	24E	1730
SUPERIOR OIL CO.	WASCO	C.F. #75 WATER WELL	29	C1	27S	24E	800

Data Base of wells available for Kern County Water Agency Regional Structure Study

McCULLOCH OIL EXP. CO. OF	SEMITROPIC	McCULLOCH ARROWHEAD #	30	A	27S	24E	1880
CARR & WRATH		MITCHELL # F3-32	32	L	27S	24E	2000
MILLER & YORK		SUPERIOR - CALDWELL # F-3	33	N	27S	24E	2000
GEOCHEMICAL SURVEYS INC.		KCL - # 23-35	35	E	27S	24E	1750
MOBIL PAN PETROLEUM	SHAFTER AREA	KCL 86-35	35	J	27S	24E	2020
U.S. BUREAU OF	FAMOSO AREA	27-25-1	1	A	27S	25E	1460
N. KERN WATER STORAGE	WASCO	#3D1-4	1	Z	27S	25E	1040
SUPERIOR FARMING CO.		73-8R	5	R	27S	25E	910
MOBIL PAN AMERICAN	WASCO	KCL #31-15	15	C	27S	25E	13373
S.A. CAMP PUMP CO	WASCO	NKWSD#3D 15-5	15	C	27S	25E	996
	WASCO	BEAR CREEK NURSERY	17	H	27S	25E	1005
S.A. CAMP	SUN WORLD WASCO	SUN WORLD INC.	17	L	27S	25E	1028
PETERS FARMS	WASCO	#1 MAPLE LEAF	19	C	27S	25E	805
SUPERIOR FARMING CO.	SHAFTER	#88-8R	22	J	27S	25E	1040
JACKSON & PERKIN CO.	WASCO		30	D	27S	25E	1020
SUPERIOR FARMING	SHAFTER	70-2R	32	A	27S	25E	1031
McCARTHY OIL & GAS CORP.		BERGMAN TRUST #1	2	Z	27S	26E	1560
STEELE PETROLEUM CO.	FAMOSO AREA	#4-1	4	R	27S	26E	7488
SUPERIOR FARMING CO.	FAMOSA	#09A-6	9	P	27S	26E	1335
RILEY BARNES		"BARNES-HARNER" #1	13	P	27S	26E	4066
SUPERIOR FARMING CO.	FAMOSA	#25-3	14	F	27S	26E	2050
SUPERIOR FARMING CO.	FAMOSA AREA	WATER WELL 25-4	14	P	27S	26E	2040
SUPERIOR FARMING CO.	FAMOSA AREA	RANCH 25-4	14	R	27S	26E	1768
TESORO PETROLEUM CORP.	PREMIER AREA	15A	15	A	27S	26E	6930
TEXACO INC.		? #1	16	A	27S	26E	1540
SUPERIOR FARMING CO.	FAMOSA AREA	#27-5	17	Z	27S	26E	2030
N. KERN WATER STORAGE	PAMONA	#3E18-7	18	C	27S	26E	995
N. KERN WATER STORAGE	FOMOSA	#3E18-6	18	N	27S	26E	990
MORTON & SONS		BENDER WEST #1	20	N	27S	26E	1650
			20	N	27S	26E	6001600
LANE FARMS	FAMOSO	WATER WELL #1	21	A	27S	26E	1159
STANDARD OIL COMPANY	SLATER AREA	CWOD #87	22	R	27S	26E	1820
GARNER-LANCE OIL CO.	(WEST POSO CREEK)	NEWHOUSE #1	24	E	27S	26E	1640

Data Base of wells available for Kern County Water Agency Regional Structure Study

McCOLLUCH OIL & GAS CORP.	POSO CREEK WEST	"McCULLOCH #105 ?	26	C-B	27S	26E	1680
		"MOBIL FLORIDA #1-23"	27	R	27S	26E	1580
JOHN & IKA PETERS FARMS	KIMBERLINA	TEST HOLE #1	28	Z	27S	26E	1015
JOHN & IKE PETERS FARMS	KIMBERLINA AREA	TEST HOLE #1	28	Z	27S	26E	970
SECURITY PACIFIC BANK	FAMOSA	#1	29	C	27S	26E	817
SUPERIOR FARMING CO.	WASCO	#61-9R	30	C	27S	26E	920
SECURITY PACIFIC NAT. BANK	FAMOSO-CAWELO		30	H	27S	26E	875
N. KERN WATER STORAGE		#3E31-5 (?9A)	31	R	27S	26E	1020
SUPERIOR FARMING CO.	FAMOSA AREA	WATER WELL #51-3	34		27S	26E	2000
SHEPARD & ROBERTSON	POSO CREEK	CARTER #1	7	Z	27S	27E	3050
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE #9-1	9	K	27S	27E	1400
TIDEWATER OIL CO.	MT. POSO	WATER PROBE 11-1	11	G	27S	27E	1100
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE 15-1	15	E	27S	27E	1250
	POSO CREEK	SALLY #1	20	Z	27S	27E	1948
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE #21-1	21	L	27S	27E	1400
CHEVRON U.S.A.	POSO CREEK	2-4	25	D	27S	27E	1500
GOLDEN BEAR OIL CO.	NORTH POSO CREEK AREA	AGEY #3	28	C	27S	27E	2046

Number of wells in this Township 160

Township 28S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
LAYMAC CORPORATION	MC DONALD ANTICLINE	SAN JAUQUIN #11	12	Q	28S	19E	2000
GOLDEN BEAR OIL COMPANY	ANTELOPE HILLS	VOIGT # 1	5	Z	28S	20E	3359
PALOMAR OIL AND REFINING	ANTELOPE HILLS	VOIGHT # 2	6	B	28S	20E	2540
BELRIDGE OIL COMPANY	SOUTH BELRIDGE	# 46	7	F	28S	20E	1175
BELRIDGE OIL CO.	SOUTH BELRIDGE	# 57	12	Z	28S	20E	1555
GENERAL PETROLEUM	BELRIDGE	ST. HELENS # 1	12	Z	28S	20E	
FERGUSON AND BOSWORTH	McDONALD ANT.	LAYMAN # 16	18	Z	28S	20E	2190
WILRICH DEVELOPMENT	BACON HILLS	THETA # 1	20	Z	28S	20E	1540
SEABOARD OIL CO.	BACON HILLS	BANDINI 58-21	21	Z	28S	20E	8754
MITCHELL REALITY	BACON HILLS	G.H. MITCHELL 77-22	22	Z	28S	20E	878
BELRIDGE OIL CO.	N. BELRIDGE	BELRIDGE # 24-1	1	E	28S	21E	1603
BELRIDGE OIL CO.	N. BELRIDGE	# 45-2	2	Z	28S	21E	2000

Data Base of wells available for Kern County Water Agency Regional Structure Study

BELRIDGE OIL CO.	S. BELRIDGE	# ?1 N 9	9	Z	28S	21E	2500
BELRIDGE OIL CO.	S. BELRIDGE	# 15 M 9	9	Z	28S	21E	2503
			11	Z	28S	21E	
SHELL CA PROD. INC.	LOST HILLS	# 12P	12	P1	28S	21E	250
SCPI PROD.	BELRIDGE	MONITOR E-SHALLOW-2	13	E	28S	21E	260
SCPI PROD.	BELRIDGE	E-SHALLOW-2	13	E	28S	21E	260
SHELL CA PROD.	BELRIDGE	# 13F-SHALLOW	13	F1	28S	21E	175
SHELL CA PROD. INC.	BELRIDGE	# 13F-DEEP	13	F2	28S	21E	265
SHELL CA PROD. INC.	BELRIDGE	# 13H	13	H1	28S	21E	235
SCPI	BELRIDGE	BELRIDGE MONITOR E	13	Z	28S	21E	500
SHELL CA PROD. INC.	BELRIDGE	# 14D	14	D1	28S	21E	258
SHELL CA PROD. INC.	BELRIDGE	# 14M	14	M	28S	21E	252
SHELL CA PROD. INC.	BELRIDGE		14	N	28S	21E	245
SHELL CA PROD. INC.	BELRIDGE	# 14P	14	P1	28S	21E	270
SHELL CA PROD. INC.	BELRIDGE	# 15P	15	P	28S	21E	260
SAN JOAQUIN VALLEY OR H20			17	B1	28S	21E	251.5
STANDARD OIL CO.	S. BELRIDGE	HILL # 73	19	Z	28S	21E	1155
STANDARD OIL CO.	S. BELRIDGE	HILL # 48	19	Z	28S	21E	650
B & L PROD.	S. BELRIDGE	KING # 58A-19	19	Z	28S	21E	950
B & L PROD. CO.	S. BELRIDGE	ELLIS # 76A-19	19	Z	28S	21E	1500
SCPI	BELRIDGE FARMS	MONITER-A	21	C	28S	21E	500
SCPI PROD.	BELRIDGE	A-SHALLOW	21	C	28S	21E	285
SHELL CA PROD. INC.	BELRIDGE AREA	# 21 C2 NORTH	21	C2	28S	21E	360
BELRIDGE OIL CO.	S. BELRIDGE	WATER WELL # 46-22	22	K	28S	21E	655
SCPI PROD.	BELRIDGE	MONITOR B	22	K	28S	21E	220
SHELL CA PROD. INC.	BELRIDGE AREA	# 22 K2	22	K2	28S	21E	624
SHELL CA PROD. INC	BELRIDGE	# 22M	22	M1	28S	21E	260
SHELL CA PROD. INC.	BELRIDGE	# 22P	22	P1	28S	21E	270
SHELL CA PROD. INC.	BELRIDGE	# 23B	23	B1	28S	21E	258
SHELL CA PROD. INC.	BELRIDGE	# 23J	23	J1	28S	21E	265
SCPI BELRIDGE	SPICER CITYQ24	MONITOR C	24	P	28S	21E	496
SCPI PROD.	BELRIDGE	C-SHALLOW	24	P	28S	21E	265
SHELL CA PROD. INC.	BELRIDGE AREA	# 24 P2 NORTH	24	P2	28S	21E	404

Data Base of wells available for Kern County Water Agency Regional Structure Study

SHELL CA PROD. INC.	BELRIDGE	# 25G	25	G1	28S	21E	145
SHELL CA PROD. INC.	BELRIDGE	# 25G-DEEP	25	G2	28S	21E	275
SHELL CA PROD. INC.	BELRIDGE	# 25J-SHALLOW	25	J1	28S	21E	179
SHELL CA PROD. INC.	BELRIDGE	# 25J-DEEP	25	J2	28S	21E	315
SCPI PROD.	BELRIDGE	MONITOR D	28	J	28S	21E	380
B & L PROD.	S. BELRIDGE	KING # 51A-30	30	Z	28S	21E	875
B & L PROD.	S. BELRIDGE	KING # 71A-30	30	Z	28S	21E	770
SCPI PROD.	BELRIDGE	MONITOR F	32	N	28S	21E	320
SCPI PROD.	BELRIDGE	MONITOR F	32	P	28S	21E	320
MOBILE OIL CORP.	BELRIDGE AREA	28/21- 36K2	36	K2	28S	21E	249
MOBILE OIL CORP.	BELRIDGE	# 36Q-SHALLOW	36	Q1	28S	21E	282
MOBILE OIL CORP.	BELRIDGE	# 36Q	36	Q2	28S	21E	312
BALL& GGRANITE	WEST LERDO	LERDO WELL	7	N	28S	22E	619
SHELL CA PROD. INC.	BELRIDGE AREA	MONITOR G	7	N	28S	22E	300
SHELL CA PROD. INC.	BELRIDGE AREA	MONITOR G	7	N2	28S	22E	300
BALL & GRANITE	W. LERDO HIGHWAY	LERDO WELL	7	Z	28S	22E	619
SHELL CA PROD. INC.	BELRIDGE AREA	MONITOR G	7	Z	28S	22E	300
U.S. BUREAU OF	SPICER CITY	# 28-22-9B	9	B	28S	22E	1300
BUTTONWILLOW GINING CO.	SPICER CITY	WATERWELL	9	R	28S	22E	704
			10	P4	28S	22E	420
			10	Z	28S	22E	
GOOSE LAKE FARMS	GOOSE LAKE	# 12-1	12	Z	28S	22E	390
			13	K	28S	22E	
HOUCHIN BROS.	BUTTONWILLOW	T.H. RANCH # 11	15	M?	28S	22E	650
ELMO BELLUOMINI	BUTTONWILLOW	W.W. # 3	22	D	28S	22E	700
			22	D1	28S	22E	
ELMO BELLUOMINI	BUTTONWILLOW	WATER WELL	22	E1	28S	22E	600
ELMO BELLUOMINI	BUTTONWILLOW	WATER WELL	22	Z	28S	22E	600
HOUCHIN BROS.	BUTTONWILLOW	DOMESTIC	26	Z	28S	22E	425
MOBILE OIL CORP.	BELRIDGE AREA	28/22/31G2	31	G2	28S	22E	268
MOBILE OIL CORP.	BELRIDGE AREA	28/22/31Q2	31	Q2	28S	22E	259
CALIF. DEPT. OF WATER	AQUADUCT "OUTSIDE"	28/22-33N1	33	N1	28S	22E	227
MOBILE OIL CORP.	BELRIDGE AREA		33	N1	28S	22E	259

Data Base of wells available for Kern County Water Agency Regional Structure Study

			35	G1	28S	22E	
JOHN ROMANINI FARMS	WASCO - BUTTONWILLOW	#2	1	A	28S	23E	648
S.A. CAMP	BUTTONWILLOW - SHAFTER	#2	2	J	28S	23E	620
	BUTTONWILLOW		5	E	28S	23E	1570
	BUTTONWILLOW		5	M	28S	23E	1770
	BUTTONWILLOW		5	Q	28S	23E	1550
SEABOARD OIL CO.	BUTTONWILLOW	KERN # 7	5	Q	28S	23E	3517
			6	D	28S	23E	1800
TEXACO INC.	BUTTONWILLOW		6	E	28S	23E	1750
CARR & WRATH	BUTTONWILLOW		6	G	28S	23E	1950
	BUTTONWILLOW		6	J	28S	23E	2000
CARR & WRATH	BUTTONWILLOW	DAVIS # 14-6	6	K	28S	23E	1780
	BUTTONWILLOW	DERN # 3	6	Z	28S	23E	3800
	BUTTONWILLOW		7	A	28S	23E	
KENNETH A. ROSS JR.	BUTTONWILLOW	"SP" # 13-A7	7	B	28S	23E	1820
MILHAM FARMS	BUTTONWILLOW RIDGE	WATER WELL # 3	7	C2	28S	23E	612
MILHAM FARMS	BUTTONWILLOW RIDGE	WATER WELL # 9	7	H1	28S	23E	612
MILHAM FARMS	BUTTONWILLOW RIDGE	WATER WELL # 9	7	Z	28S	23E	612
DUAL PETROLEUM	BUTTONWILLOW	KCL # 1	8	G	28S	23E	2500
CARR & WRATH	BUTTONWILLOW	? UNIT # 1	8	L	28S	23E	2320
MOBILE OIL CORPORATION	BUTTONWILLOW	MOBILE-GULF-TUPMAN-USL	10	N	28S	23E	1750
THE TEXAS CO.	BUTTONWILLOW	BREEN # 1	14	P	28S	23E	13733
JACK WOOD OPR.	BUTTONWILLOW	JACK WOOD, HYDE KIM #	16	J	28S	23E	2270
JACK WOOD OPR.	BUTTONWILLOW	JACK WOOD, HYDE-KIM #	16	J	28S	23E	3997
JACK WOOD OPR.	BUTTONWILLOW	JACK WOOD, HYDE KIM #	16	Z	28S	23E	4005
MOBILE OIL CORP.	WEST ELM HILLS	BRAVO # 1	17	Q	28S	23E	2200
B & B BALDWIN	BEL RIDGE	# 5	29	N	28S	23E	514
	BUTTONWILLOW	ELMER SUOREY	31	R	28S	23E	475
	BUTTONWILLOW	ELMER SUOREY	32	N	28S	23E	475
DAVID BLOEMHOF	BUTTONWILLOW	# 4	33	G	28S	23E	840
GOLDEN BEAR OIL	W. SHAFTER	KCL # 55 X-2	2	K	28S	24E	1980
			4	N	28S	24E	
			4	R	28S	24E	

Data Base of wells available for Kern County Water Agency Regional Structure Study

CARR & WRATH	GARRISON CITY 5-28S	MITHCELL # F-2-5	5	A	28S	24E	2320
			7	P1	28S	24E	600
GOLDEN BEAR OIL CO.	SHAFTER	GARRISON CITY UNIT # 1	9	F	28S	24E	1500
RICHFIELD OIL CORP.	GARRISON CITY	ROCO MITCHELL ? # 1	9	H	28S	24E	1960
GOLDEN BEAR OIL	GARRISON CITY	OHIO-MITCHELL # 66X-9	9	J	28S	24E	1920
GOLDEN BEAR OIL CO.	GARRSION CITY	KCL# 66X-10	10	K-J	28S	24E	2100
GOLDEN BEAR OIL CO.	GARRISON CITY	KCL # 26X-10	10	M	28S	24E	2050
TED BLOEMHOFF	SHAFTER	REPLACEMENT #1	13	C	28S	24E	720
		WATER WELL	13	C	28S	24E	
TEXACO, INC.	GARRISON CITY	SEMITROPIC RIDGE # 1	15	H	28S	24E	1990
LAYNE WESTERN CO.	SHAFTER	WOOD STONE RANCHES #	17	A	28S	24E	726
U.S. BURAEU OF	W. OF SHAFTER		23	D	28S	24E	702
			23	D1	28E	24S	
U.S. BUREAU OF	W. OF SHAFTER		23	P	28S	24E	702
GOLDEN BEAR OIL CO.	GARRISON CITY	GARRISON CITY UNIT	5	K-J	28S	25E	2300
PUBLIC PETROLEUM CO.	SHAFTER	# 63	7	G	28S	25E	1950
McFARLAND ENERGY INC.	SHAFTER	JONES # 1	7	K	28S	25E	2000
TIDEWATER ASSOCIATED OIL	SHAFTER FIELD	PENNER # 37-7	7	P	28S	25E	2000
GEOCHEMICAL SURVEY &	SHAFTER	SHAFTER GAS UNIT # 67-7	7	Q	28S	25E	1850
GEOCHEMICAL SURVEYS &	SHAFTER	SHAFTER GAS UNIT # 67-7	7	Z	28S	25E	4320
RAPP OIL CO.	SHAFTER	KIRSCHENMAN # 32 X-8	8	C	28S	25E	1680
WASCO DRILLING CO.	SHAFTER	JAMES W. BRYANT WELL	14	E	28S	25E	626
TEEN CHALLENGE	SHAFTER	# 1	16	P	28S	25E	718
HUMBLE OIL & REFINING CO.	SHAFTER	GEO. W. WATSON ET UX 1	17	E	28S	25E	1800
GEOCHEMICAL SURVEYS	SHAFTER	NEUMAN # 26X-17	17	P	28S	25E	1900
TIDEWATER ASSOC. OIL CO.	SHAFTER	STONE # 1-18-1	18	D-E	28S	25E	2200
TIDEWATER OIL CO. &	SHAFTER AREA	LOEPP # 63-18	18	G	28S	25E	2600
TIDEWATER ASSOC. OIL CO.	SHAFTER	CLARK # 67-18	18	Q	28S	25E	1550
S.A. CAMP	SHAFTER	KERMETH ANDERSON	20	D	28S	25E	713
UNION OIL CO.	RIO BRAVO	KERNCO # 25X	26	M	28S	25E	1680
SUPERIOR OIL CO.	RIO BRAVO	BURNER # 6G	27	P	28S	25E	1800
SUPERIOR OIL CO.	RIO BRAVO	FINK # 5-K	27	Q	28S	25E	1740
RICHARD S. RHEEM ,	PARALLEL AREA	PARALLEL UNIT B # 1	31	G	28S	25E	1830

Data Base of wells available for Kern County Water Agency Regional Structure Study

SUPERIOR OIL CO.	RIO BRAVO	PASADENA REALITY # 8	33	J	28S	25E	1500
UNION OIL	RIO BRAVO	KERNCO # 6IX - 34	34	A	28S	25E	1850
SUPERIOR OIL CO.	RIO BRAVO	KERNCO # 41X - 34	34	C	28S	25E	1860
SUPERIOR OIL	RIO BRAVO	WATERWELL # 2	35	M	28S	25E	800
S.A. CAMP PUMP CO.	CAWELO AREA	W.W. R 74 F9	2	Z	28S	26E	1301
	CAWELO AREA	W.W. # R7F9	2	Z	28S	26E	1300
	COWELO AREA	WATERWELL	4	H	28S	26E	2510
N. KERN WATER STROAGE	MINTER FIELD	# 4E-56	5	L	28S	26E	1095
SUPERIOR FARMS	SHAFTER	# 65-5R	7	D	28S	26E	1000
UNION OIL CO.			13	G	28S	26E	3923
UNION OIL CO. OF CA		MATTEL FEE	13	G	28S	26E	1920
KCL	BEARDSLEY	KCL OXIDENTAL # 18X-13	13	N	28S	26E	2010
J.G. DYER	LERDO	LERDO # 1	15	P	28S	26E	1850
CHEVRON USA INC.		KCL # 38-22-16	16	D	28S	26E	1600
E.A. BENDER	LERDO	KCL # 47-20	20	P	28S	26E	1650
N. KERN WATER STORAGE	ROSEDALE	# 4E20-1 (7)	20	Z	28S	26E	958
U.S. BUREAU OF REC.	SOUTH SHAFTER	# 21	21	H	28S	26E	900
MORTON & SONS	LERDO AREA	LERDO COMM. 1-5	25	D	28S	26E	1600
MORTON & SONS	LERDO AREA	LERDO COMM. # 1-5	25	D	28S	26E	2020
N. KERN WATER STORAGE	ROSEDALE	# 4E26-4 (6)	26	G	28S	26E	888
WESTERN GULF OIL CO.	N. ROSEDALE RANCH	KCL LERDO # 1	26	J	28S	26E	1580
PROFESSIONAL OIL		" BUTTES AVEDIAN " # 25X	26	M	28S	26E	1950
STANDARD OIL CO.	N. LERDO	KCL 37-33-27	27	F	28S	26E	1820
N. KERN WATER STORAGE		# 4E 27-3	27	H	28S	26E	938
STANDARD OIL CO.	7TH STANDARD AREA	KCL 68 # 28	28	Q	28S	26E	1760
ROY & GEORGE FANUCCHI	PANAMA	#4	30	Z	28S	26E	825
EUGENE FANUCCHI	PANAMA	# 1	30	Z	28S	26E	825
TESORO PET CORP	ROSEDALE	KCL 46-33	33	L	28S	26E	7724
INTEX OIL CO.	RODEDALE	INTEX-HANCOCK KCL #	33	L	28S	26E	1700
CHEVRON USA INC.	ROSEDALE RANCH	KCL 64 # 167-35	35	Q	28S	26E	1820
STANDARD OIL CO.	ROSEDALE RANCH	KCL 50 # 17-36	36	N	28S	26E	1380
NE- TEX OIL CO.	ROSEDALE	NE- TEX LERDO LAND # 1-36	36	P	28S	26E	1900
M.H. WHITTIER CORP.	KERN FRONT	"STAR ROBINSON" #3		Z	28S	27E	1190

Data Base of wells available for Kern County Water Agency Regional Structure Study

C.D. DRAUCKER	KERN FRONT	"CARIBOU" 2	2	P	28S	27E	1050
CAWELO WATER DIST.		#1 ?(EHA40-90)	6	C	28S	27E	1211
POWER SYSTEM	OILDALE	DOUBLE "C"	11	Z	28S	27E	1228
OXY USA , INC.	KERN FRONT	WATER WELL # 3	11	Z	28S	27E	1508
FENIAN OIL CORP.	KERN RIVER	"LATIMER" 9	13	C	28S	27E	730
ANGUS PETROTECH CORP.	KERN RIVER	#5	13	R	28S	27E	1197
CHEVRON U.S.A. INC.	KERN FRONT	WATER WELL #2	15	G	28S	27E	1460
NOEL WILSON	LERDO	#1	18	E	28S	27E	605
PAN AMERICAN PET. CO.	KERN RIVER	#24	22	S	28S	27E	2019
OILFIELD TRANSPORTATION &	BAKERSFIELD	#2	32	Z	28S	27E	620
EMCON ASSOC.		# WS-1	2	Z	28S	28E	802
SHELL CA PROD. INC.	KERN RIVER	RAMBLER # 71W	19	R	28S	28E	1250
SHELL CA PROD. INC.	KERN RIVER	RAMBLER # 102W	19	R	28S	28E	1120
SHELL OIL CO.	KERN RIVER	WATER PROBE # 6	20	H	28S	28E	940
SHELL CA. PROD. INC.	KERN RIVER	MARCO # 30W W.W.	20	N	28S	28E	1250
SHELL OIL CO.	KERN RIVER	WATER PROBE # 5	20	Z	28S	28E	950
A.M. VAN FLICK	SHARKTOOTH AREA	USL VAN RAY # 1	22	H	28S	28E	2670
E.A. BENDER	ROUND MTN.	BENDER BARLOW # 1	24	Z	28S	28E	2397
TENNECO OIL CO.	KERN RIVER	"COMET" # 24	28	D	28S	28E	890
GETTY OIL CO.	KERN RIVER	# 601	33	M	28S	28E	972
TIDEWATER OIL CO.	KERN RIVER	GREEN & WHITTIER # 104	34	N	28S	28E	805

Number of wells in this Township 198

Township 29S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
MOBILE OIL CORP.	BELRIDGE		1	M1	29S	21E	395
MOBILE OIL CORP.	BELRIDGE	# 12R	12	R1	29S	21E	304
MOBILE OIL CORP.	BELRIDGE	# 12R-DEEP	12	R2	29S	21E	498
STATE OF CALIFORNIA, DWR	SOUTH BUTTONWILLOW	#35K1	35	K1	29S	23E	603
KERN COUNTY LAND CO.	RIO BRAVO	5C 25-1	25	Z	29S	24E	610
JOHN BLAIR WELL			32	K	29S	24E	575
FRANCESCHI & SON	BUTTONWILLOW	#88-39 #2 PERMIT	32	Z	29S	24E	490
EDWARD KOSAREFF	BUTTONWILLOW	DOMESTIC	33	Z	29S	24E	410

Data Base of wells available for Kern County Water Agency Regional Structure Study

				29	Z	29S	25E	
KERN COUNTY LAND CO.	WATER WELL	JD 30-2		30	H	29S	25E	600
KERN COUNTY WATER AGENCY		L.S. DWR #1	TASK ORD	36	H	29S	25E	605
	ROSEDALE	KCL C-6		14	R	29S	26E	6804
LAYNE WESTERN CO.	ROSEDALE	HAHER MUTUAL WATER CO.		24	M/N	29S	26E	684
BROCK WATER CO.	ROSEDALE	#3		25	Z	29S	26E	639
CARR & WRATH	BELLEVUE	BRANDT #1		27	P	29S	26E	7400
JIM GARSIDE	ROSEDALE	TW 2		28	D	29S	26E	607
WEGIS WATER CO. -WASCO	ROSEDALE	#1		28	K	29S	26E	670
MIKE'S FENCE CO.	ROSEDALE	#1		29	E	29S	26E	600
VEROS ENTERPRISE	SOUTH OREFLEY	#86		29	H	29S	26E	1200
JOHN ROMANINI & SONS	BAKERSFIELD	88-40		31	J	29S	26E	830
DRILLING EXPLORATION &	BAKERSFIELD	WATER 1		33	F	29S	26E	488
CHEVRON U.S.A. INC.	BELLEVUE	KARPE #2-53		34	G	29S	26E	8420
BOYLE ENGINEERING CORP.	FRUITVALE	MNTR. WELL #B		15	L	29S	27E	204
J.A. WATERS	FRUITVALE	WATERS #7		15	P1	29S	27E	3993
J.A. WATERS CO.	FRUITVALE	J.A. WATERS #2		22	D1	29S	27E	4005
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 120-01		25	B2	29S	27E	601
CALIFORNIA WATER SERVICE	BAKERSFIELD	W. W. #126-01		25	G	29S	27E	605
DUMM BROTHERS PETROLEUM	FRUITVALE	#1 HARDING-DOUGLAS		26	D1	29S	27E	3717
CALIF WATER SERVICE CO.		STATION 152-01		26	N-50	29S	27E	288
SIERRA BAG CO.	FRUITVALE	STRIP #1		27	M	29S	27E	4015
MOHAWK PETROLEUM CORP.	REFINERY YARD	W. W. #2		27	Z	29S	27E	790
GOLDEN BEAR OIL CO.	FRUITVALE	ARMSTRONG #1		28	D	29S	27E	4361
	FRUITVALE	KCL 83A-28		28	H	29S	27E	4060
SIGNAL OIL & GAS CO.	FRUITVALE	W.W. #114		28	J52	29S	27E	1260
TOSCO PETRO REFINERY	BAKERSFIELD	#5		28	J53	29S	27E	800
TOSCO PETRO CORP.	FRUITVALE	INJECTION WELL #2		28	K	29S	27E	3710
AJAN OIL CO.	FRUITVALE	SCHULZ #1 (BLACKENED)		28	P	29S	27E	4473
BANKLINE OIL CO.	GREENACRES	PLANK COM#28		29	N1	29S	27E	7397
SHELL OIL CO.	JASTRO AREA	"K.C.L."#1		31	Z	29S	27E	3510
S.A. CAMP PUMP CO.	BAKERSFIELD	#25		32	C	29S	27E	750
GOLDEN BEAR OIL CO.	STOCKDALE	KCL 87-33		33	R	29S	27E	4675

Data Base of wells available for Kern County Water Agency Regional Structure Study

LEBOW AND MCNEE	FRUITVALE	KCL 78-4A	34	H1	29S	27E	4016
U.S. BUREAU OF	FRUITVALE	29-27-34	34	N1	29S	27E	799
CITY OF BAKERSFIELD	ASHE	#13	34	Z	29S	27E	710
CALIFORNIA WATER SERVICE	SW BAKERSFIELD	W. W. #81-2	36	K2	29S	27E	612
HANCOCK OIL CO.	N.E. BAKERSFIELD	KAAR #1	26	Z	29S	28E	6503
HANCOCK OIL CO.	NILES RIDGE	KAAR #1	26	Z	29S	28E	8500
KERN GENERAL HOSPITAL	BAKERSFIELD	WATER WELL	28	Z	29S	28E	1220
CALIFORNIA WATER SERVICE	BAKERSFIELD	WATERWELL 40-02	31	B1	29S	28E	658
H.H. MAGEE OPER & MOHAWK	EDISON	OSBORN #1	36	P	29S	28E	5196
RICHARD S. RHEEM OPERATOR	RACETRACK HILL	HAGOOD #44A-26	26	F	29S	29E	4718
W.K. GILLETT	RACETRACK-EDISON	U.S.L. FIELD #11	26	F	29S	29E	776
	EDISON	S.-C.#J8-26	26	Z	29S	29E	4987
RICHARD S. RHEEM	RACETRACK HILLS	J.-W.#35-26	26	Z	29S	29E	4730
STANDARD OIL CO. OF CALIF.	RACETRACK	#48-27	27	Z	29S	29E	4735
STANDARD OIL CO. OF CALIF.	RACETRACK	#45-27	27	Z	29S	29E	4625
STANDARD OIL CO. OF CALIF	RACE TRACK	#65-27	27	Z	29S	29E	4680
KERN OIL CO. LTD	EDISON GROVES	COHN #6D	28	B	29S	29E	1079
KERN OIL CO LTD.	EDISON GROVES	COHN #3-A	28	G	29S	29E	1211
KERN OIL CO. LTD	EDISON GROVES	COHN 3-E	28	H	29S	29E	1087
KERN OIL CO LTD.	EDISON GROVES	ROSS #2-B	28	P	29S	29E	1334
CALIFORNIA WATER SERVICE	BAKERSFIELD AREA	STATION 140-01	30	A	29S	29E	822
TRICO OIL & GAS	EDISON GROVES	HOTCHKISS #1	30	Z	29S	29E	5278
TEXACO OIL CORP	EDISON	G.-D.#1	30	Z	29S	29E	4103
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 43-02	31	F1	29S	29E	800
KERN OIL CO. LTD.	RACE TRACK HILLS	#1-Z	33	A	29S	29E	960
KERN OIL CO LTD.	RACE TRACK HILL	PORTALS 82	33	Z	29S	29E	4968
CALIFORNIA WATER SERVICE	E. BAKERSFIELD	514 BATES AVE.	33	Z	29S	29E	700
CALIF WATER SERVICE CO.	EDISON	#155-01	34	J	29S	29E	660
VACA DRILLING CO.	N.E. EDISON	CORE HOLE#1	36	D	29S	29E	730
HADDAD BROTHERS	EDISON	WATER WELL #5	36	M	29S	29E	1881

Number of wells in this Township 71

Data Base of wells available for Kern County Water Agency Regional Structure Study

Township 30S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
	ELK HILLS NORTH	BRIGHT #1	1		30S	23E	2210
STANDARD OIL CO OF CALIF	ELK HILLS	62-23R	23	B	30S	23E	2727
STANDARD OIL CO OF CALIF	ELK HILLS	88-24R	24	R	30S	23E	2838
STANDARD OIL CO. OF CALIF	ELK HILLS	46-29R	29	L	30S	23E	2745
STANDARD OIL CO OF CALIF	ELK HILLS	44-34R	34	F	30S	23E	2672
STANDARD OIL CO OF CALIF	ELK HILLS	44-36R	36	F	30S	23E	2860
U.S. BUREAU OF	BUTTONWILLOW	30-24-4C	4	C	30S	24E	800
			5	Z	30S	24E	
GENERAL PET. CORP.	SO. BUTTONWILLOW	DOYLE-MCKEON 1	6	B	30S	24E	6149
JOHN ROMANINI & SONS	BUTTONWILLOW	#2	8	Z	30S	24E	302
PALM FARMS	BUTTONWILLOW	DOMESTIC	10	Z	30S	24E	366
TENNECO WEST	ELK RESERVE		12	H	30S	24E	640
JOHNSON	TUPMAN	SUSIE #1	14	L	30S	24E	505
STANDARD OIL CO.	ELK HILLS	3-45-19S	19	L	30S	24E	11161
			22	A	30S	24E	430
			22	H	30S	24E	
DEPT OF WATER RESOURCES		30-24-23D1 GRND WATER	23	D1	30S	24E	200
UO-NPR NO.1	ELK HILLS	51-36S	36	B	30S	24W	3360
WEST KERN WATER CO	WEST KERN WATER	#6-02	?	Z	30S	25E	840
WEST KERN WATER DISTRICT	NORTH COLES LEVEE	2-01 N. COLES LEVEE	?	Z	30S	25E	1008
ARTHUR & ORUM	BUENA VISTA RANCH	KWB DRILL HOLE 1	4	J	30S	25E	690
THE TEXAS CO.	GOOSLOO AREA	KCL #1 GOOSLOO SO.	8	B	30S	25E	9504
UNIVERSAL CONSOLIDATED	N. CANAL	KCL #13-10	10	E	30S	25E	10204
KERN COUNTY WATER AGENCY	K.W.B.	30/25-11 L1	11	L1	30S	25E	626
			11	Z	30S	25E	600
KERN COUNTY WATER AGENCY	STRAND OIL FIELD	12AE (DWR 8253)	12	A1	30S	25E	143
S.A. CAMP PUMP CO	BUENA VISTA	TENNECO 6D 16-2	16	B	30S	25E	646
S.A. CAMP PUMP CO.	PALM RANCH	W. W. A2461 PALM FARMS	18	P	30S	25E	600
ARTHUR & ORUM WELL	TULE ELK RESERVE	KWB DRILL HOLE 2	19	N	30S	25E	675
STANDARD OIL CO.	TUPMAN	KCL 21-1	19	P	30S	25E	9900

Data Base of wells available for Kern County Water Agency Regional Structure Study

WEST KERN COUNTY WATER		#7-01	21	Z	30S	25E	920
WEST KERN WATER DISTRICT	NORTH COLES LEVEE	2.01 NORTH COLES LEVEE	21	Z	30S	25E	1008
WEST KERN WATER CO.	WEST KERN WATER	#6-02	21	Z	30S	25E	840
SHELL	NORTHWEST TEN SECTION	"KCL" 74 WS-23	23	H	30S	25E	2800
STATE OF CALIFORNIA	2800 ACRES	30-25-24C4	24	C	30S	25E	708
CTIY OF BAKERSFIELD	2800 ACRES	30-25-24C1	24	C1	30S	25E	250
DEPT WATER RESOURCES		DESTAFANI	26	J	30S	25E	406
RICHFIELD OIL CO	COLES LEVEE	CL-A 56-27	27	K	30S	25E	9351
ARCO OIL & GAS	NORTH COLES LEVEE	CL-A-555-27	27	L	30S	25E	2204
WESTERN WATER WORKS	COLES LEVEE	WATER WELL #7	28	C3	30S	25E	675
RICHFIELD OIL CORP.	N. COLES LEVEE	"KCL" A 14-28	28	E	30S	25E	1400
RICHFIELD OIL CORPORATION	N. COLES LEVEE	KCL B 74-28	28	H	30S	25E	9491
RICHFIELD OIL CORP	COLES LEVEE	KCL A 56-28	28	K	30S	25E	9502
RICHFIELD OIL CORP	N. COLES LEVEE	A 36-28	28	L	30S	25E	9200
ATLANTIC RICHFIELD	NORTH COLES LEVEE	C. L. A. 577-28	28	R	30S	25E	2310
WEST KERN COUNTY WATER	COLES LEVEE	#6-01 REPLACEMENT WELL	28	Z	30S	25E	825
RICHFIELD OIL CORP	COLES LEVEE	KCL A-56-29	29	K	30S	25E	9150
DEPT OF WATER RESOURCES		30S/25E-30A1	30	A1	30S	25E	200
RICHFIELD OIL CORP	N. COLES LEVEE	KCL 21-30	30	D	30S	25E	9790
			30	Z	30S	25E	1300
RICHFIELD OIL CORP	COLES LEVEE	KCL B-85-31	31	J	30S	25E	9000
RICHFIELD OIL CORP.	N. COLES LEVEE	WATER WELL #5	32	B	30S	25E	506
			32	C	30S	25E	1000
RICHFIELD OIL CORP	NORTH COLES LEVEE	CLA-27-32	32	N	30S	25E	9260
RICHFIELD OIL CORP.	COLE'S LEVEE	KCL A-72-33	33	A	30S	25E	9480
RICHFIELD OIL CORP.	N. COLES LEVEE	A-12-33	33	D	30S	25E	8148
ATLANTIC RICHFIELD CO.	NORTH COLES LEVEE	CLA-543-33	33	F	30S	25E	1562
RICHFIELD OIL CORP.	COLES LEVEE	KCL A 54-33	33	G	30S	25E	9350
ATLANTIC RICHFIELD CO.	NORTH COLES LEVEE	CLA #12-33 RD#3	33	Z	30S	25E	9197
ARCO OIL & GAS CO	N. COLES LEVEE	584-34	34	H	30S	25E	3700
RICHFIELD OIL CORP.	COLES LEVEE	C.L.A. 54-34	34	K	30S	25E	9349
KERN COUNTY LAND CO	NORTH COLES LEVEE	WATER WELL #6D-35-1	35	B	30S	25E	1400
RICHFIELD OIL CORP	COLES LEVEE	K.C.L. 54-35	35	Z	30S	25E	9818

Data Base of wells available for Kern County Water Agency Regional Structure Study

KCWA/DWR	SOUTH COLES LEVEE/KWB	ARCO #74X-36	36	G	30S	25E	1423
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 145-01	1	B	30S	26E	675
KERN COUNTY LAND CO.	BELLEVUE	6 E U-4	1	J	30S	26E	706
ZUBLIN WELL LOGGING		KCL GE 1-4	1	J	30S	26E	600
JACOBASON, JOHN F. LIVING		#12 ASH WATER	2	A	30S	26E	
CALIFORNIA WATER	BAKERSFIELD	STATION 1701	2	F	30S	26E	678
CITY OF BAKERSFIELD	2800 ACRES	30-26-3J1	3	J1	30S	26E	268
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#4	3	L1	30S	26E	678
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#5	3	L2	30S	26E	738
KERN COUNTY WATER AGENCY	BAKERSFIELD	TW 1	3	M1	30S	26E	690
KERN COUNTY WATER AGENCY	BAKERSFIELD	8601 EAST OBS WELL	3	M2	30S	26E	710
KERN COUNTY WATER AGENCY	BAKERSFIELD	8601 #2 S OBS WELL	3	M3	30S	26E	730
KERN COUNTY WATER AGENCY	BAKERSFIELD	#8601 N PROD. WELL	3	M4	30S	26E	688
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	8701-2	3	P	30S	26E	715
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#8701-OBS. WELL	4	J	30S	26E	670
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#1	4	R	30S	26E	718
ARTHUR & DRUM WELL	CROSS VALLEY CANAL RR	KWB D. H.#3	6	Z	30S	26E	695
CITY OF BAKERSFIELD	2800 ACRES	30-26-8P1	8	P1	30S	26E	260
STATE OF CALIFORNIA	2800 ACRES	30-26-8P4	8	P4	30S	26E	710
STATE OF CALIFORNIA	2800 ACRES	30-26-9M4	9	M4	30S	26E	710
CONTINENTAL OIL CO.	GREELEY-ROSEDALE	KCL-D-1	10	G	30S	26E	7199
CITY OF BAKERSFIELD	2800 ACRES	30-26-10C1	10	Q	30S	26E	260
HANCOCK OIL CO.	GOSFORD	KCL 28-11	11	N	30S	26E	8200
	BELLEVUE AREA	KCL ?	12	H?	30S	26E	600
SIGNAL OIL & GAS CO.	GOSFORD	KCL 28X-12	12	N	30S	26E	7948
CITY OF BAKERSFIELD	STOCKDALE	#20	13	J	30S	26E	760
S.A. CAMP PUMP CO	BAKERSFIELD	STATION #195-01	14	Z	30S	26E	815
DEPT. WATER		CBK-22	16	A	30S	26E	710
CITY OF BAKERSFIELD	KERN RIVER SPREADING	OBS WELL #2	16	B	30S	26E	700
OLCESE WATER DISTRICT	BAKERSFIELD FLOOD	#1	16	E	30S	26E	730
CONTINENTAL OIL CO.	STRAND	E-1	17	H	30S	26E	7742
OLCESE WATER DIST	BAKERSFIELD	#2	17	K	30S	26E	636
OLCESE WATER DISTRICT	BAKERSFIELD	#3	17	M	30S	26E	720

Data Base of wells available for Kern County Water Agency Regional Structure Study

OLCESE WATER DISTRICT	BAKERSFIELD	#3	17	PN	30S	26E	720
CONTINENTAL OIL CO.	SOUTH STRAND	KCL H-1	18	G	30S	26E	7995
CITY OF BAKERSFIELD	2800 ACRES	30-26 18 H 1	18	H1	30S	26E	265
STATE OF CAL DWR	2800 ACRES	30-26-18H4	18	H4	30S	26E	710
CITY OF BAKERSFIELD	2800 ACRES	30 26 18 N1	18	N1	30S	26E	260
BOLSA CHICA OIL	STRAND	KCL 82-18	18	Z	30S	26E	8350
OLCESE WATER DISTRICT	BAKERSFIELD	#4	19	A	30S	26E	640
CITY OF BAKERSFIELD	KERN RIVER SPREADING	OBS WELL #1	19	B	30S	26E	703
OLCESE WATER DISTRICT	BAKERSFIELD	#5	19	C1	30S	26E	660
TENNECO WEST	STRAND	WATER WELL #4	21	G	30S	26E	728
BUREAU OF RECLAMATION	TEN SECTION	WATER WELL 30-26-22	22	P	30	26E	794
HANCOCK OIL CO.	CANFIELD RANCH FIELD	63-23	23	G	30S	26E	9540
LAYNE-WESTERN CO		TOM BRIGGS #1	24	C	30S	26E	685
			25	G	30S	26E	1262
			25	L	30S	26E	700
THE TEXAS CO.	OLD RIVER	COULTER #1	25	Q	30S	26E	8314
HANCOCK OIL CO	GOSFORD	KCL 44-26	26	Z	30S	26E	8500
SHELL OIL CO.	TEN SECTIION	KCL A-52-29	29	B	30S	26E	8235
ARTHUR & ORUM WELL	KERN WATER BANK	KWB-DH-5 32N-1,2,3	32	N	30S	26E	700
KERN COUNTY LAND CO.	TEN SECTION	KCY 44-33	33		30S	26E	8665
RICHARD S. RHEEM,	CANFIELD RANCH	KCL 32X-34 NORRIS	34	C	30S	26E	10687
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 145-01	1	C	30S	27E	675
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 139-01	1	J50	30S	27E	710
CALIFORNIA WATER SERVICE	S.W. BAKERSFIELD	STATION 144-01	1	J51	30S	27E	650
CALIFORNIA WATER SERVICE	W. BRUNDAGE	STATION 106-01	2	D1	30S	27E	602
CALIFORNIA WATER SERVICE	S. STINE ROAD	STATION 130-01	2	P1	30S	27E	675
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 134-01	2	R50	30S	27E	750
ROBERTSON DRILLING CO.	WEST HIGH SCHOOL	TEST HOLE #1	3	J2	30S	27E	526
S.A. CAMP PUMP CO.	BAKERSFIELD	CBK #19-01	5	A	30S	27E	770
			5	H	30S	27E	1185
WESTERN GULF	STOCKDALE AREA	KCL "STOCKDALE "	5	H	30S	27E	5992
CEMCO-EDISON NO.1 (F.R.)	EDISON	PORTALS	5	N	30S	27E	4220
KCWA/DWR	OCEANIC PACIFIC GOLF	30/27/7E	7	E	30S	27E	723

Data Base of wells available for Kern County Water Agency Regional Structure Study

BANKLINE OIL CO	GOSFORD NORTH	KCL 35-7	7	Z	30S	27E	8008
S.A. CAMP PUMP CO.	BAKERSFIELD	ASHE W. W.#10	8	J	30S	27E	701
KERN COUNTY LAND CO.	BELLVUE AREA	6F94	9	JP	30S	27E	763
CALIFORNIA WATER SERVICE	HUGHES LANE & WILSON RD	W. W.#112-01	12	L2	30S	27E	617
CALIF. WATER SERVICE CO.	BAKERSFIELD (CITY	STATION #137-01	12	Z	30S	27E	668
CALIF WATER SERVICE CO.	SO. H. NO. OF WHITE LANE	W.W. #123-02	13	C	30S	27E	790
CALIF WATER SERVICE CO.	SO.H. NO. OF WHITE LANE	W. W. #123-01	13	H51	30S	27E	750
KLEINFELDER & ASSOC	NALCO CHEMICAL,	M.W.#2	15	R	30S	27E	160
UNIVERSAL CONSOLIDATED	GOSFORD	STATEX KCL DW #1 19	19	E	30S	27E	4460
CALIF WATER SERVICE CO.	BAKERSFIELD	#89	19	N	30S	27E	663
S.A. CAMP PUMP CO.	BAKERSFIELD	STATION #16	20	D	30S	27E	746
SIGNAL OIL & GAS CO	GOSFORD	E.C.L.A.-1	21	M	30S	27E	1600
S.A. CAMP PUMP CO.	BAKERSFIELD	TWI#4167	21	N	30S	27E	730
CALIF WATER SERVICE CO.	S.W. BAKERSFIELD AREA	WW 146-03	23	C-50	30S	27E	650
SLOCUM WW DRILLING CO	BAKERSFIELD	WW 146-02	23	C51	30S	27E	650
CALIF WATER SERVICE CO.	BAKERSFIELD	146-01	23	C52	30S	27E	642
CALIF WATER SERVICE CO.	BAKERSFIELD	STATION 146-05	23	D50	30S	27E	660
CALIF WATER SERVICE CO.	BAKERSFIELD	STATION 146-04	23	D51	30S	27E	710
CALIF WATER SERVICE CO.	BAKERSFIELD	#189	24	FL	30S	27E	663
CITY OF BAKERSFIELD	BAKERSFIELD	1801	26	D	30S	27E	680
UNIVERSAL CONSOLIDATED	GOSFORD	KCY-O'HARE 1X-30	30	D	30S	27E	10765
CALIFORNIA WATER SERVICE	BAKERSFIELD	145-01	1	B	30S	28E	675
CALIFORNIA WATER SERVICE	4 NO OF WHITE LANE	W. W. 123-01	1	B	30S	28E	750
MORTON AND DOLLEY	EDISON	PORTER #1	1	H	30S	28E	4735
I.E. TYNER BX 3831 E.	BRUNDAGE & STERLING	#1 BAKERSFIELD	2	C2	30S	28E	1250
STANDARD OIL CO.	MCGUNDEN	ROUTZONG #1	2	J	30S	28E	5787
SIGNAL OIL & GAS	EDISON	#1 SIGNAL-DEL PAPA	2	Q	30S	28E	6037
KERN HIGH SCHOOL	MT. VERNON & 58	#1	3	D	30S	28E	800
WESTERN GULF	BRUNDAGE AREA	BLOEMER #1	3	J	30S	28E	6026
WESTERN GULF	MAGUNDEN AREA	COHN EST.#1	3	R	30S	28E	6278
LAYNE WESTERN DRILLING	MOUNT		3	Z	30S	28E	420
GENERAL PETROLEUM CORP.	EAST UNION AVE	BANKHAM 56X-4	4	K	30S	28E	4927
CALIFORNIA WATER SERVICE	COTTONWOOD AREA	W.W. #132-01	5	B1	30S	28E	690

Data Base of wells available for Kern County Water Agency Regional Structure Study

CALIFORNIA WATER SERVICE	BAKERSFIELD	#102-01	5	C	30S	28E	603
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION #138-01	5	N1	30S	28E	1000
HANCOCK OIL CO.	UNION AVENUE AREA	JEWETT COMM #1	5	Z	30S	28E	7874
CALIF. WATER SERVICE	EDISON	#153-01	6	C50	30S	28E	710
THE HANCOCK OIL CO.	UNION AVENUE AREA	ROBERTS #3	6	H	30S	28E	4243
THE HANCOCK OIL CO.	UNION AVENUE	ROBERTS #4	6	J	30S	28E	5056
C.R. JAMES	BAKERSFIELD	W.W. # A5	7	C1	30S	28E	670
CALIFORNIA WATER SERVICE		125-01	8	B50	30S	28E	604
CALIFORNIA WATER SERVICES	BAKERSFIELD	#187-01	8	E	30S	28E	745
U.S. BUREAU OF	MT. VIEW	30-28-10	10	N	30S	28E	1199
DEBBIE TASK	BAKERSFIELD	#1	11	Z	30S	28E	465
THE HANCOCK OIL CO.	EDISON	MULLER #1	12	B	30S	28E	6100
ROTHCHILD OIL CO.	EDISON	MCCLEAN #1	12	L	30S	28E	4010
J. PAUL GETTY	MT. VIEW	FAURE #44	13	F	30S	28E	4706
J. PAUL GETTY	MT. VIEW	FAURE #33	13	F	30S	28E	4697
J. PAUL GETTY	MT. VIEW	COREY 74	13	H	30S	28E	4550
PARAMJTT DOSANJH	EDISON	#1	13	Z	30S	28E	513
OMAR CARMONA	BAKERSFIELD	#1	13	Z	30S	28E	400
HORACE STEELE GOLDEN	MT. VIEW	NUNAZ #1 YOUNG KWON	14	C	30S	28E	5000
			14	P	30S	28E	1600
CALIFORNIA WATER SERVICES	BAKERSFIELD	#187	16	E	30S	28E	745
			16	J	30S	28E	1400
RICHFIELD OIL CO.	MT. VIEW	M.V. #1	16	K	30S	28E	4800
			18	E	30S	28E	
CALIFORNIA WATER WELL		STATION 143-01	18	K50	30S	28E	655
KERN COUNTY UNION HIGH	SOUTH HIGH SCHOOL	WATERWELL	18	L	30S	28E	535
S.A. CAMP PUMP CO	BAKERSFIELD	CAL WATER STATION	19	A	30S	28E	770
GENERAL PETR CORP	WEST MT. VIEW	KERN SUMNER 27	22	N	30S	28E	6800
MR. SOTO	HILLTOP	# 1	24	A	30	28	503
MORTON & DOLLEY	MT. VIEW	MOHAWK-VINEYARD	24	Z	30S	28E	4967
HOGAN PETROLEUM	MT. VIEW	WIBLE #1	26	N	30S	28E	6619
MT. VERNON -PANORAMA	HILL TOP	27-1	27	A	30S	28E	820
GENERAL PET CORP.	EDISON AREA	K.SUMNER 8-27	27	N	30S	28E	7178

Data Base of wells available for Kern County Water Agency Regional Structure Study

CALIFORNIA WATER WELL	S.E. BAKERSFIELD	M.SANCHEZ W.W. #1	28	A	30S	28E	300
KIRSCHENMAN RANCH	EDISON	W.W. #1	3	A1	30S	29E	1688
BOLSA CHICA OIL CO.	RACETRACK HILL	HADDAD-BUTLER#1	3	B	30S	29E	4900
BRITISH-AMERICAN OIL CO.	RACE TRACK HILLS	PORTALS#34-3	3	F	30S	29E	4787
BRITISH AMERICAN OIL CORP	RACE TRACK HILLS	PORTALS#26-A-3	3	M	30S	29E	4765
DUMM BROS. AND MACRATE	EDISON	G.-W.#1	3	Z	30S	29E	4928
RICHARD S. RHEEM	RACE TRACK HILL		4	C	30S	29E	5475
THE OIL CO.	EDISON	EDISON 4	4	G	30S	29E	2490
FRED R. WILLIAMS	EDISON	4-30-29	4	J	30S	29E	2100
BRITISH AMERICAN OIL CO.	EDISON	P. BERRY 9A-4	4	J	30S	29E	1600
A.F.C. INC	EDISON	W.W.#2	4	LM	30S	29E	711
GOLDEN BEAR OIL CO.	EDISON	SEALE #1	5	D	30S	29E	4117
REPUBLIC PET. CO. (SHELL)	EDISON	PORTALS #2	5	K	30S	29E	3855
OHIO OIL CO.	EDISON	PORTAL COMM#2	5	Z	30S	29E	3972
PETREX INC.	EDISON	#2	6	A	30S	29E	2592
MRS. SYNDICATE	EDISON	REUTER #1	6	G	30S	29E	2000
MORTON AND DOLLEY CO.	EDISON	EDISON COMM#1	6	L	30S	29E	4500
LAYNE-WESTERN CO. INC.	KERRNITA FIELD	W-A T. H. #1 WESTERN	6	Q	30S	29E	700
LAYNE WESTERN CO.	EDISON	W.-A.#1 WESTERN	6	Z	30S	29E	716
WILSON ROAD WATER ASSOC.	WEEDPATCH & WILSON	#1	7	Z	30S	29E	602
PAUL GETTY	EDISON	ROAGLAND#2	8	C	30S	29E	
GENERAL PETROLEUM	EDISON	SPEED 10-8	10	Z	30S	29E	1855
GOLDEN BEAR OIL CO.	EDISON	GRAYSON 45-10	10	Z	30S	29E	4985
AL HADDAD	EDISON	W.W. #1	11	H1	30S	29E	2296
GENERAL PETROLEUM	EDISON	SPEED 28-11	11	N	30S	29E	3013
GENERAL PETROLEUM	EDISON	SPEED 38-11	11	P	30S	29E	2970
GENERAL PETROLEUM	EDISON	SPEED 58-11	11	Q	30S	29E	2050
F.G. WALKER	EDISON AREA	EDI-RITA #1	12	D	30S	29E	1708
UNION OIL CO.	EDISON	BROCKMAN 2A	13	E	30S	29E	3810
JERGINS OIL CO.	EDISON	MCCOWAN 13B-3	13	K	30S	29E	1830
AT JERGINS TRUST	EDISON	MCCOWAN 13-A-8	13	L	30S	29E	1502
JERGINS OIL CO.	EDISON	MCCOWAN 13A-1	13	L	30S	29E	1781
JERGINS OIL CO.	EDISON	MCCOWAN 13A-7	13	L	30S	29E	1786

Data Base of wells available for Kern County Water Agency Regional Structure Study

JERGINS OIL CO.	EDISON	MCCOWAN A5	13	M	30S	29E	1587
JERGINS OIL CO.	EDISON	MCCOWAN 13 A S-5	13	M	30S	29E	1545
JERGINS OIL CO.	EDISON	"FEE 13" S-1	13	N	30S	29E	2901
JERGINS OIL CO.	EDISON	CORP.FEE S-2	13	N	30S	29E	2150
A.T. JERGINS TRUST	EDISON	FEE 13-8	13	P	30S	29E	1291
JERGINS OIL CO.	EDISON	CORP.FEE 13 S-3	13	P	30S	29E	1662
JERGINS OIL CO.	EDISON	MCCOWAN 13-B-5	13	Q	30S	29E	1626
JERGINS OIL CO.	EDISON	MCCOWAN 13B-7A	13	Q	30S	29E	1345
HARRY H. MAGEE	EDISON	DOUGHERTY #6	14	A	30S	29E	2000
H.H. MAGEE	EDISON	DOUGHERTY #8	14	A	30S	29E	2100
H.H. MAGEE	EDISON	DOUGHERTY #1	14	A1	30S	29E	2847
H.H. MAGEE	EDISON	DOUGHERTY #9	14	B	30S	29E	2600
H.H. MAGEE OPER	EDISON	BROWN#4	14	C	30S	29E	2593
JERGINS OIL CO.	EDISON	HERSHEY #7	14	J	30S	29E	1511
JERGINS OIL CO.	EDISON	HERSHEY# S-5	14	J	30S	29E	2031
JERGINS OIL CO.	EDISON	HERSHEY #8	14	J	30S	29E	1399
			14	K	30S	29E	1300
GENERAL PET. CORP	EDISON	L-N.#3	14	L	30S	29E	2770
GENERAL PETROLEUM CO.	EDISON	LEDDY #1	14	M	30S	29E	2108
JERGINS OIL CO.	EDISON	HERSHEY #S-2	14	Q	30S	29E	2623
JERGINS OIL CO.	EDISON	HERSHEY #14	14	Q	30S	29E	2427
JERGINS OIL CO.	EDISON	HERSHEY #9	14	R	30S	29E	1673
NORTH AMERICAN	EDISON	BROWN # 8	14	Z	30S	29E	2934
JEKINS OIL COLGATE	EDISON	CLIFTON	15	K	30S	29E	2058
GENERAL PET CORP	EDISON 1	JED 1	15	R	30S	29E	2806
GENERAL PETROLEUM CORP.	EDISON	C. FEE 42-16B	CAULEY 16	B	30S	29E	6029
RICHFIELD OIL CORP	EDISON	CAULEY 43-16	16	F	30S	29E	
GENERAL PETROLEUM	EDISON	CAULEY 53-16	16	G	30S	29E	4901
DES MOINES OIL CO.	EDISON	CAULEY #8	16	P	30S	29E	2200
J. PAUL GETTY	EDISON	ALEXIS# 2	17	B	30S	29E	2800
J. PAUL GETTY	WEST EDISON	ALEXIS #1	17	B	30S	29E	2200
FIRST NATIONAL FINANCE	EDISON	DEMILLE FIRST	17	C1	30S	29E	3598
FIRST NATIONAL FINANCE	EDISON AREA	DEMILLE BIGGAR#1	17	D	30S	29E	3629

Data Base of wells available for Kern County Water Agency Regional Structure Study

PACIFIC WESTERN	EDISON	PORTER # 2	17	E	30S	29E	3909
PACIFIC WESTERN	EDISON	PORTER#1	17	E	30S	29E	2300
WASCO DRILLING CO	EDISON	PORTER FARMS	17	H	30S	29E	900
DES MOINES CO	EDISON	PORTER	17	R	30S	29E	1954
J. PAUL GETTY	EDISON	PORTER#17-6	17	Z	30S	29E	3935
J. PAUL GETTY	EDISON	PORTER#17-4	17	Z	30S	29E	4078
MAREX OIL CO	MT. VIEW	MCDONALD#18	18	N	30S	29E	1700
A.1. CORPORATION	MT VIEW	A.1 #1	18	Z	30S	29E	4144
GILMOUR	MT. VIEW	NICHOLS #1	19	P	30S	29E	3000
STANDARD OIL CO OF CALIF	MT. VIEW	NICHOLS COMM #3	19	Z	30S	29E	5120
			20	A	30S	29E	1950
SHELL OIL CO. INC.	MT. VIEW	VOARHOSE#1	20	E	30S	29E	4958
WOOD-CALLAHAN	EDISON	21 COMMUNITY 6	21	B	30S	29E	3664
WOOD-CALLAHAN	WEST EDISON	21 COMMUNITY 8	21	B	30S	29E	4460
ROTHSCHILD-BENDER	EDISON	HEYDEN#4	21	BD	30S	29E	2100
ROTHSCHILD BENDER	EDISON	HEYDEN#2	21	C	30S	29E	2000
ROTHSCHILD-BENDER	EDISON	HEYDEN#1	21	C	30S	29E	3390
ROTHSCHILD OIL CO.	EDISON	BOYCE#1	21	D	30S	29E	
ROTHCHILD OIL CO.	EDISON	OMAHA# 3	21	F	30S	29E	3896
WOOD-CALLAHAN	EDISON	KRANZ #1	21	H	30S	29E	3650
WOOD-CALLAHAN OIL CO.	EDISON	HEYDEN #1	21	H	30S	29E	4369
WOOD CALLAHAN	EDISON	FEE# 3	21	H	30S	29E	2200
WOOD CALLAHAN OIL CO. LTD	EDISON	MAGOFFIN#1	21	J	30S	29E	3200
RING OIL CO.	EDISON	WILKIE #1	21	L	30S	29E	1600
ROTHSCHILD-BENDER	EDISON	HEYDEN# 3	21	Z	30S	29E	1500
RING OIL CO.	EDISON	PORTER# 1	21	Z	30S	29E	4175
MORRIS	EDISON	BRANDT #1	22	E	30S	29E	3375
MARK MORRIS	EDISON	BRANDT #. 2	22	E	30S	29E	3379
JERGINS OIL CO.	EDISON	TEXAS FEE 23#13	23	B	30S	29E	2408
			23	E	30S	29E	
JERGINS OIL CO.	EDISON	TEXAS FEE 23#20	23	G	30S	29E	2183
THE TEXAS CO.	EDISON	HINTZ #2	23	J	30S	29E	2586
THE TEXAS CO.	EDISON	HINTZ# 3	23	J	30S	29E	1600

Data Base of wells available for Kern County Water Agency Regional Structure Study

JERGINS A.T.	EDISON	ANDREWS #7	23	N	30S	29E	3287
THE TEXAS CO.	EDISON	HINTZ #1	23	R	30S	29E	1600
GEN PET CORP	EDISON	KNAPP#5	24	C	30S	29E	1428
GENERAL PETR	EDISON	KNAPP #9	24	F	30S	29E	1458
	EDISON	JOHNSON #1	24	Z	30S	29E	1525
THE TEXAS CO.	EDISON	METTLER # 1	24	Z	30S	29E	2200
THE TEXAS CO.	EDISON	METTLER # 2	25	D	30S	29E	2813
EM H. METTLER & SONS	EDISON	METTLER#1	25	K	30S	29E	1501.77
THE CAPITAL CO.	EDISON	L.-B. 3-38	26	P	30S	29E	3250
CAPITAL COMPANY	EDISON	L.-B. 36-26-2 LAWSON	26	Z	30S	29E	3280
KUNDERT BROS FRM.	LAMONT	BA-2538	27	K	30S	29E	800
SEABOARD OIL CO	EDISON	PORTER # 1	28	G	30S	29E	5166
UNION OIL CO	MT. VIEW	PORTER 74-28	28	H	30S	29E	4240
STULL & STULL	HILLTOP	#501	29	D	30S	29E	804
PACIFIC WESTERN	MT. VIEW	KOEHLER #2	29	R	30S	29E	5563
BENDER OIL OPERATIONS	MT. VIEW	B.A. CO # 1	29	Z	30S	29E	5400
MOHAWK PETROLEUM CORP	MT. VIEW	CLENDENEN #10	30	F	30S	29E	6012
HOGAN PET CO.	MT. VIEW	WHARTON #10	32	B	30S	29E	5100
SHELL OIL CO.	MT. VIEW	PORTER# 2-2	32	J	30S	29E	5868
SHELL OIL CO.	MT. VIEW	PORTER TWO-7	32	J	30S	29E	5200
L.F. GILMOUR	MOUNTAIN VIEW	DERBY#22	33	D	30S	29E	8833
GETTY	MT VIEW AREA	DERBY #23	33	E	30S	29E	
J. PAUL GETTY	MT. VIEW	DERBY #53	33	G	30S	29E	8963
MORTON & DOLLEY	MT. VIEW	DERBY#1	33	L	30S	29E	5421
RING OIL CO.	EDISON	#3	33	Z	30S	29E	4600
BARNHART-MORROW	MT VIEW	KOVACEVICH #1	34	Q	30S	29E	4812
DIGIORGIO FRUIT CORP	ARVIN	W.W.#36-H	36	B	30S	29E	830
DI GIORGIO FRUIT CORP.	SO. EDISON	W.W.#36-G	36	E1	30S	29E	1052
WESTERN GULF OIL CO.	CALIENTE CREEK	DI GIORGIO #44-36	36	F	30S	29E	2108
DI GIORGIO FRUIT CORP.	DI GIORGIO FARMS	W.W.#36-F	36	J2	30S	29E	1029
SOUTHERN CALIF PETROLEUM	RACE TRACK HILLS	#44-5 BROWN PALLETTE	5	Z	30S	30E	4768
GIUMARRA VINEYARDS	EDISON	W.W. (DEEPENING)	6	J1	30S	30E	2389
DAVIS INVESTMENT CO.	EDISON AREA	BADMAN 1101	8	R	30S	30E	2456

Data Base of wells available for Kern County Water Agency Regional Structure Study

HARLEY BARLING	EDISON AREA	W.W.#1	17	A1	30S	30E	1591
T.H. METTLER	EDISON	W.W.#1	18	G2	30S	30E	2770
			19	M	30S	30E	1125
			20	C	30S	30E	1400
BRYAN SMITH FARMS	EDISON	W.W. #3	20	D1	30S	30E	2191
GROSHEN OIL CO.	CALIENTE CREEK AREA	GROSHEN #1	22	Z	30S	30E	3830
			23	Z	30S	30E	1800
R.H.L. OIL CO.	EDISON AREA	R.H.L. 2	27	B	30S	30E	1720
ATLANTIC OIL CO.	MT. VIEW	MOHAWK #1	29	Z	30S	30E	5146
BRYAN SMITH	EDISON	LAUGHLIN#1	30	B	30S	30E	790
DIGIORGIO	EDISON	W.W,# 31A	31	B1	30S	30E	909
SAN JOAQUIN DRILLING CO.	EDISON	DI GIORGIO #5	32	N	30S	30E	682
KERN COUNTY WATER AGENCY	HECK FARM	DWR 8366	8	D	30S	32E	460

Number of wells in this Township 340

Township 31S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
UO-NPR No 1	ELK HILLS	#18-14B	14	B	31S	22E	3760
CALIFORNIA SOUTHERN OIL	NORTH MIDWAY	#2	16	Z	31S	22E	1030
SANTA FE ENERGY CO.	MIDWAY SUNSET	AMBER# 99 (WATER WELL)	26	F	31S	22E	1981
UO-NPR #1 (SOCO OF CALIF	ELK HILLS	#84-2B	2	H	31S	23E	2100
WILLIAMS BROTHERS	NPR #1	#84W - 13B	13	B	31S	23E	1900
WILLIAMS BROTHERS	NPR #1	#82W-14B	14	A	31S	23E	2000
CHEVRON U.S.A. INC	FAIRWEATHER	18-16B	16	B	31S	23E	3166
EMCON ASSOCIATES	TAFT SANITARY LANDFILL	B-1/MW-1	25	H	31S	23E	439
S.A. CAMP PUMP CO	BV GOLF COURSE	B.V.G.C. #1	12	E	31S	24E	822
JACK WOOD	NO. TAFT	W.W.# 1	20	K1	31S	24E	410
JACK WOOD	NORTH TAFT	W.W.#2	21	Z	31S	24E	393
W.W. HOLMES	ELK HILLS	W.P.53-22	22	G	31S	24E	5725
ARCHIE MYERS DRILLING CO	BUENA VISTA LAKE WEST	WATER WELL	25	E	31S	24E	560
NORTH AMERICAN OIL CONS	BUENA VISTA HILLS	#35-32	32	B	31S	24E	5600
STANDARD OIL	MIDWAY	# 4106	33	G	31S	24E	4529
TEXACO INC		THOURNBER #A-10	34	N	31S	24E	4500

Data Base of wells available for Kern County Water Agency Regional Structure Study

KERN COUNTY LAND COMPANY	S. COLES LEVEE	KCL #38X-1	1	Z	31S	25E	10143
MJM&M OIL CO	S. COLES LEVEE	KCL #54-2	2	G	31S	25E	10050
UNION OIL COMPAMY	S. COLES LEVEE	KERNCO # 56-2	2	K	31S	25E	10096
RICHFIELD OIL CO	S. COLES LEVEE	SLC #32-3	3	C	31S	25E	10005
			3	D	31S	25E	1050
MARATHON		SCLU #12	3	D	31S	25E	9790
RICHFIELD OIL CORP	COLES LEVEE	2ND-B-14-3	3	E	31S	25E	9695
MARATHON		SCLU #67-4	4	Q	31S	25E	9881
OHIO OIL CO	S. COLES LEVEE	SCLU #74-5	5	Z	31S	25E	5998
ATLANTIC OIL COMPANY	S. COLES LEVEE	KCL #11	9	D	31S	25E	4200
CARR & WRATH		KCL #101	10	B	31S	25E	2200
HYLTON WATER WELL	BUENA VISTA PARK	#12A	14	L	31S	25E	749
J. G. BOSWELL	S. COLES LEVEE	ML #7	15	R1	31S	25E	965
THE OHIO OIL CO.	SOUTH COLES LEVEE	K.C.L.-F. U-15	15	Z	31S	25E	9748
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.# ML-2	16	A	31S	25E	1253
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	31/25/16D	16	D	31S	25E	1375
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	W.W.# ML-3	16	H	31S	25E	900
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	M.L.#4	16	J ?	31S	25E	1140
RICHFIELD OIL CO.	PALOMA	#78	24	R	31S	25E	11337
RICHFIELD OIL CO.	PALOMA	#72	25	A	31S	25E	11115
RICHFIELD OIL CO.	PALOMA	BVA#52	25	B	31S	25E	11178
RICHFIELD OIL CO.		BVA #61	25	B	31S	25E	11280
RICHFIELD OIL CO.	PALOMA	#41	25	C	31S	25E	13103
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.#16	26	A	31S	25E	1474
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.#7	26	C	31S	25E	1474
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.#10	26	D1	31S	25E	1476
TEXACO	PALOMA	BVA#1	26	E	31S	25E	11501
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	WATER WELL	26	Z	31S	25E	1066
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.# 19	27	D	31S	25E	1476
U.S. BUREAU OF	PALOMA	31-25-27F1	27	F1	31S	25E	1000
E.A. BENDER	PALOMA	BVA#88	31	R	31S	25E	9510
BUTTES GAS & OIL CO.		BVF#1	36	A	31S	25E	10887
			36	A	31S	25E	1010

Data Base of wells available for Kern County Water Agency Regional Structure Study

RICHFIELD OIL CO.	BUENA VISTA LAKE	BVA #81		36	A	31S	25E	11329
STANDARD	N.W. PALOMA	BVA#52		36	B	31S	25E	5785
S.A. CAMP	OLD RIVER	W.W.# 7E2-1		2	J1	31S	26E	634
TENNECO	LAKESIDE	KCL#15		2	M	31S	26E	8893
S.A. CAMP	OLD RIVER	#7E-2-2		2	Z	31S	26E	644
JOHN MOLATORE	OLD RIVER AREA	WATER WELL	NE	3	AI	31S	26E	600
RICHFIELD OIL CORP	TEN SECTION AREA	OLD RIVER KCL 1		3	D	31S	26E	3815
TIDEWATER	OLD RIVER	KCL#86		3	J	31S	26E	10809
RICHARAD S. RHEEM	JAMES SLOUGH	KCL#31		4	C	31S	26E	8724
RICHFIELD OIL CO.	JAMES SLOUGH	KCL#1		6	M	31S	26E	10250
				9	B	31S	26E	1100
				13	Z	31S	26E	672
RICHFIELD	PALOMA	KCL "O"#18		14	N	31S	26E	12033
WESTERN GULF OIL COMPANY	PALOMA	KCL-NW#18-19		19	N	31S	26E	11288
KERN COUNTY LAND CO	PALOMA	#7E 20-1		20	C	31S	26E	624
HAMILTON DOME OIL CO.	PALOMA	KCL 'A'#23		20	F	31S	26E	10896
RICHFIELD OIL CO.	PALOMA	KCL-N#54		23	G	31S	26E	13252
				27	L	31S	26E	510
THE SUPERIOR OIL CO.	PALOMA AREA	W.W.#I-27		27	L1	31S	26E	515
WESTERN GULF OIL	PALOMA	#52		29	B	31S	26E	11576
WESTERN GULF OIL	PALOMA	#12		29	D	31S	26E	11244
WESTERN GULF OIL CO	PALOMA			29	Q	31S	26E	10990
OHIO OIL CO	PALOMA	MILLER& LUX #3		29	Z	31S	26E	10861
MARATHON	PALOMA	KCL-B#81		30	A	31S	26E	11408
MARATHON	PALOMA	KCL-B#41		30	C	31S	26E	11167
MARATHON	PALOMA	KCL-B#12		30	D	31S	26E	11376
MARATHON	PALOMA	KCL-B#23		30	E	31S	26E	10958
TENNECO	PALOMA	TOC 73X31		31	C	31S	26E	5800
OHIO OIL CO	PALOMA	KCL "N" 53-31		31	G	31S	26E	5620
TENNECO	PALOMA	MITCHELL KCL#201		31	J	31S	26E	5608
GENERAL PET CORP.	TUPMAN	#18		36	N	31S	26E	11549
COUNTY OF KERN	PUMPKIN CENTER	CURNOW YARD #1			H	31S	27E	320
BEATRICE FOOD CO.	PANAMA	#38-2		2	P	31S	27E	9529

Data Base of wells available for Kern County Water Agency Regional Structure Study

MEADOW GOLD FARMS	OLD RIVER AREA	K.C.L. 7 F 7-4		7	Z	31S	27E	722
ROCKY MOUNTIAN DRILLING	PANAMA SLOUGH	#78		9	R	31S	27E	13215
	OLD RIVER AREA	KCL 7F 19-2		19	DI	31S	27E	704
RIO COLORADO SEED LTD	OLD RIVER	#1		24	Z	31S	27E	616
SUNDANCE CATTLE		#1146		28	F	31S	27E	662
FREITAS FARMS	GREENFIELD	PERMIT 8823		6	C	31S	28E	680
THE TERMO OIL CO	LAMONT	TRM.-S.RAY#53X		12	G	31S	28E	13000
JAMES MATHIS	LAMONT	NEW WELL		13	Z	31S	28E	400
COSTERISAN FARMS	BEAR MOUNTAIN	PERMIT 8826		20	N	31S	28E	760
PORTER LAND CO`	WEEDPATCH	WATER WELL #1		23	A	31S	28E	1321
F AND K FRICK	WEEDPATCH	#3		26	Z	31S	28E	1355
FRANCES BAILEY	BAKERSFIELD	#1		28	A	31S	28E	800
EDMOND BESHARA	GREENFIELD	KARPE #1		29	D	31S	28E	5000
VALWOOD KARPE				29	Z	31S	28E	5000
HANK ROZENBERG	BAKERSFIELD			30	R	31S	28E	410
KERN COUNTY LAND COMPANY	KERN LAKE	7 G 31-4		31	E	31S	28E	702
DR. BURGER	WEST ARVIN	#1		31	R	31S	28E	500
EL RANCHO DE LOS PATOS		WATER WELL		33	Z	31S	28E	1106
DI GIORGIO	ARVIN AREA	WATER WELL 1-E		1	A1	31S	29E	1070
JERGINS OIL CO	EDISON AREA	BIGELOW #17		1	D	31S	29E	3030
V & C OIL CO.	ARVIN AREA	#1		1	Q	31S	29E	2091
DI GIORGIO FRUIT CORP	ARVIN	WATER WELL 2-E		2	M1	31S	29E	810
DI GIORGIO FRUIT CORP	ARVIN AREA	WATER WELL #3D		3	A2	31S	29E	780
DI GIORGIO FRUIT	SOUTH EDISON	WATER WELL 3C		3	C1	31S	29E	700
PATRICK A. DONENY	MT. VIEW	DI GIORGIO #1		3	G	31S	29E	4922
TERMINAL OIL CO	MT. VIEW	DI GIORGIO 1-3		3	P	31S	29E	500
DI GIORGIO FARMS		WATER WELL #4-A		4	J1	31S	29E	760
HOGAN PETROLEUM CO.	MT. VIEW	S.-B.#1	SYMONS	4	P	31S	29E	6967
MORTON N D'EVELYN OPR.	MT. VIEW	EARL FRUIT #5		4	Q	31S	29E	5981
MOHAWK PET. CORP	MT. VIEW	EARL FRUIT #4		4	Z	31S	29E	5446
	MT. VIEW	PETERS #4		5	H	31S	29E	5588
FLORENE PLEDGER	LAMONT	#1		5	R	31S	29E	484
HAZEL MOORE	LAMONT	#1		5	Z	31S	29E	517

Data Base of wells available for Kern County Water Agency Regional Structure Study

SECTION 6 OIL CO	MT. VIEW	JOHNSTON #1	6	D	31S	29E	6002
MT. VIEW SCHOOL DISTRICT	LAMONT	HALL&MRYTLE	6	F1	31S	29E	500
P. H. GREER	MT. VIEW	PERREL #2	9	B	31S	29E	5697
TIDE WATER ASSOC	ARVIN POOL AREA	TUPMAN#43-9	9	F	31S	29E	8704
DIGIORGIO FRUIT CORP		W.W.#10 A-3	10	A1	31S	29E	800
WESTERN GULF OIL CO.	MT. VIEW	DI GIORGIO #1	10	Z	31S	29E	6677
DIGIORGIO FRUIT CORP	EDISON	W.W.#11-AA	11	B1	31S	29E	1143
DI GIORGIO FRUIT CORP	ARVIN	# 11-A-3	11	D1	31S	29E	927
THE TEXAS COMPANY	ARVIN	DI GIORGIO "A" 2	11	E	31S	29E	4661
DI GIORGIO FARMS		W.W. 12-11-2	12	B1	31S	29E	930
DI GIORGIO FRUIT CORP	EDISON	DI GIORGIO 12-B	12	L1	31S	29E	1039
SUPERIOR ALMOND	ARVIN	BUENA VISTA RD	13	C	31S	29E	900
THE TEXAS COMPANY	KRAUTER	#2	14	M	31S	29E	6139
DEREY FARMS	EDISON	W.W.# 15-11	15	C3	31S	29E	804
APEX PETROLEUM CORP LTD.	MT. VIEW	CATTANI #5	15	N	31S	29E	6723
UNIVERSAL CONSOLIDATED	ARVIN	DERBY #1	15	Z	31S	29E	6173
STANDARD OIL CO	ARVIN	JEWETT COMM 2-4	16	A	31S	29E	4247
THE TEXAS COMPANY	ARVIN	JEWETT 2	16	B	31S	29E	3100
TIDEWATER	LAMONT	FRICK 22	16	D	31S	29E	9259
S.A. CAMP PUMP CO	WEED PATCH	FRICK WELL	16	F	31S	29E	816
STANDARD OIL CO	ARVIN	JEWETT COMM 2#8	16	J	31S	29E	6700
DIGIORGIO FRUIT	ARVIN AREA	W.W.#17A	17	Z	31S	29E	760
S.A. CAMP PUMP CO	WEEDPATCH	#2	19	D	31S	29E	326
STANDARD OIL CO	MT. VIEW ARVIN AREA	TUPMAN# 2	22	C	31S	29E	7567
GUIMARRA FARMS	ARVIN	PETERS#1	22	J	31S	29E	1025
HUGH S. JEWETT	ARVIN	W.W.#3	23	L2	31S	29E	1196
THE TEXAS COMPANY	NORTH ARVIN	GEORGE#19	23	Z	31S	29E	5650
LINDLEY C. MORTON	MT. VIEW	BARLOW #1	25	G	31S	29E	5942
GRIMMWAY FARMS	ARVIN	#1	25	Z	31S	29E	840
THE TEXAS COMPANY	ARVIN	ARVIN UNIT 3#4	26	A	31S	29E	6250
BRITISH AMERICAN OIL	MT. VIEW	ARVIN 8-14 26	26	D	31S	29E	7717
ARVIN HIGH SCHOOL	ARVIN	WATER WELL	26	E1	31S	29E	1202
BRITISH AMERICAN CAPITAL	MT. VIEW	ARVIN 47A-28	26	P	31S	29E	7944

Data Base of wells available for Kern County Water Agency Regional Structure Study

WOOD-CALLAHAN	ARVIN MT. VIEW	HOUCHIN #1	27	A	31S	29E	7354
			28	Z	31S	29E	
KERN COUNTY	ARVIN LANDFILL	ARVIN #1	31	C	31S	29E	137
KERN COUNTY	ARVIN	ARVIN# 1	31	D	31S	29E	125
KERN COUNTY	ARVIN	AR-1-03-9/87-W	31	E	31S	29E	122
KERN COUNTY	ARVIN	ARVIN # 2	31	Z	31S	29E	125
BRITISH AMERICAN OIL PROD	ARVIN	KOVACEVICH	35	B	31S	29E	7551
DI GIORGIO FRUIT CORP		W.W. #36-S-5	36	B2	31S	29E	820
CHARLES MALOVICH	ARVIN	#1	36	D	31S	29E	905

Number of wells in this Township 157

Township 32S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
STANDARD OIL CO. OF	BUENA VISTA HILLS	1C-2-8A	1	M	32S	23E	3265
NORTH AMERICAN CONS OIL	BUENA VISTA HILLS	#41-2	2	Z	32S	23E	4086
OCEANIC OIL CO	MIDWAY	D-1-7	7	Z	32S	23E	3556
OCEANIC OIL COMPANY	MIDWAY	GEN.AMER.#76-X	16	Z	32S	23E	4336
MILLERFRAX	BUENA VISTA	H.M.#1 HAROLD	24	R	32S	23E	914
NATIONAL OIL CO.	MIDWAY	GOVT # 41	25	Z	32S	23E	1710
GENERAL PETROLEUM CORP.	BUENA VISTA AREA	B.V.A. #1	1	N	32S	24E	11686
NORTH AMERICAN OIL CO.	BUENA VISTA HILLS	#6-2	2	E	32S	24E	3862
STANDARD OIL CO OF CALIF	BUENA VISTA HILLS	#429 - 7D	7	D	32S	24E	2473
HONOLULU OIL COMPANY	MIDWAY-SUNSET	10-25-P	10	M	32S	24E	12825
STATE OF CALIFORNIA, DWR	BUENA VISTA HILLS	BV-1106	12	B1	32S	24E	135
STATE OF CALIFORNIA, DWR	BUENA VISTA	BV-1107	12	G1	32S	24E	190
STATE OF CALIFORNIA, DWR	BUENA VISTA HILLS	BV-1108	12	G3	32S	24E	228
MURVALE OIL CO	MIDWAY-SUNSET	#46	20	D	32S	24E	2100
MURVALE OIL CO.	MIDWAY SUNSET	#56-20	20	Z	32S	24E	2300
CHEVRON U.S.A. INC.	MIDWAY SUNSET	#6	21	D	32S	24E	3342
CHAS. JACOBSON VISTA	B.V. HILLS	G.P.-V. G. #1	22	A	32S	24E	8153
STATE OF CALIFORNIA	SANDY CREEK	32S-24E-26A	26	A1	32S	24E	625
EXETER OIL COMPANY	MIDWAY SUNSET	MURPHY FEE 13 J	28	N	32S	24E	6000
CHEVRON U.S.A., INC.	MARICOPA	#1-35D	35	N	32S	24E	850

Data Base of wells available for Kern County Water Agency Regional Structure Study

DEPT OF WATER RESOURCES		OBS. W.#36L1	36	L1	32S	24E	242
			1	H1	32s	25E	
ROBERTSON DRILLING	GARDNER FIELD AREA	WATER WELL	2	Z	32s	25E	675
WESTERN GULF OIL CO	BUENA VISTA	BVA#18-3	3	N	32S	25E	12464
MONTEREY OIL CO	BUENA VISTA	INDIAN OIL	7	L	32S	25E	6050
SHELL OIL CO.	BUENA VISTA LAKE	B.V. A. #1	9	M	32S	25E	6112
GETTY OIL COMPANY	BUENA VISTA	BVA#22	11	D	32S	25E	11374
BUENA VISTA FARMS	BUENA VISTA	# 27	13	R	32S	25E	1215
SEABOARD OIL CO	B.V. LAKE BED	#73-14	14	H	32S	25E	12558
FERGUSON AND BOSWORTH	BUENA VISTA HILLS	BVA#1	15	A	32S	25E	10493
FERGUSON AND BOSWORTH	BUENA VISTA	BVA#142	16	H	32S	25E	8086
DEPT OF WATER RESOURCES	BUENA VISTA LAKE	#P1	16	P1	32S	25E	745
			25	Q	32S	25E	1010
SINCLAIR OIL & GAS	BUENA VISTA	E. JOHNSON #1	28	C	32S	25E	12548
			29	N2	32S	25E	1000
GENE REID DRILLING CO.	BUENA VISTA HILLS	DOUGHERTY #1	30	M	32S	25E	5947
			31	B	32S	25E	960
J. T. HERROD	GARDNER FIELD	W.W.#1	32	Z	32S	25E	1010
STANDARD OIL LAND CO.	GARDNER FIELD	FRICK # 2	35	N2	32S	25E	1650
KERN COUNTY LAND CO	SAN JOAQUIN VALLEY	#882-4	2	Z	32S	26E	875
OHIO OIL COMPANY	PALOMA	KCL #B 3	3	Z	32S	26E	10288
			4	Q	32S	26E	1180
STANDARD OIL CO.	PALOMA	KCL#43-57	4	Q	32S	26E	10336
TEXACO, INC.	PALOMA	KCL#1	6	K	32S	26E	12701
HUMBLE OIL & REFINING CO.	PALOMA	KCL #54-9	9	G	32S	26E	11467
SUPERIOR	PALOMA	ST. SURE# 27X-11	11	N	32S	26E	10372
WESTERN GULF OIL	PALOMA UNIT	#32	12	C	32S	26E	11104
WESTERN GULF OIL CO.	PALOMA	P.U.# 54-12	12	G	32S	26E	11304
UNION OIL CO	PALOMA	MORGAN# 81-14	14	A	32S	26E	11456
BONANZA FARMS	BUENA VISTA LAKE	# 3 REPLACEMENT	16	E	32S	26E	1020
	PALOMA	#3	16	G	32S	26E	1573
CHEVRON			17	Z	32S	26E	1050
4 H FARMS	BUENA VISTA	8908	18	K	32	26E	943

Data Base of wells available for Kern County Water Agency Regional Structure Study

4 H FARMS	BUENA VISTA	#89-19	18	K Q	32S	26E	849
TRI-SERVICE DRILLING	S. PALOMA	COOPER#1	21	B	32S	26E	1406
ROCKY MT. DRILLING	S. PALOMA	MOHAWK#1	24	D	32S	26E	13604
			25	P	32S	26E	2100
			27	B	32S	26E	1484
ANDREWS BROS OF			28	Z	32S	26E	1040
FERGUSON & BOSWORTH	S. PALOMA	SHELL-FEE #1	30	A	32S	26E	13612
	SAN EMIGDIO	THOMPSON #2	31	P1	32S	26E	1505
	SAN EMIGDIO	FRICK #1	33	N1	32S	26E	1560
C.J. SANDERS	LAKEVIEW	WATERWELL #1	35	N1	32S	26E	2412
PARKS BROS EVANS	LAKEVIEW AREA	#2	36	P2	32S	26E	1820
			4	J	32S	27E	600
KERN COUNTY LAND COMPANY	KERN LAKE	#8 F 4	4	L	32S	27E	710
LAYNE-WESTERN CO	BUENA VISTA	L.A. ATHLETIC CLUB	6	E	32S	27E	902
HUMBLE OIL & REFINING		KCL J-1	8	N	32S	27E	1040
ATLANTIC OIL CO	S.E PALOMA	KCL #83-12	17	H	32S	27E	2050
HUMBLE OIL & REFINING CO.	PALOMA	KCL (41-18) #2	18	C	32S	27E	12333
KENNETH DUFF	OLD RIVER-HERRING	#1	20	Z	32S	27E	805
KENNETH DUFF	OLD RIVER/ HERRING	#1	20	Z	32S	27E	425
			21	A	32S	27E	15360
ATLANTIC OIL CO.		GEN. PET.#71	21	A	32S	27E	1350
PARKS BROS AND GARLOW	LAKEVIEW AREA	STANDARD #1	35	R1	32S	27E	1210
KERN COUNTY LAND COMPANY	KERN LAKE	W.W. 8F 36-1	36	FI	32S	27E	216
S.A.CAMP PUMP CO	ARVIN	SKI WEST #2	1	D	32S	28E	858
RANDY HEINRICK-TERRY RAYE	ARVIN		1	F	32S	28E	847
S.A. CAMP PUMP CO.	ARVIN	KD AQUA FARMS	2	K	32S	28E	826
J. H. SMITH	ADOBE ROAD AREA	W.W.# 3	4	H	32S	28E	960
KERN COUNTY LAND CO		8-G 6-4	6	Z	32S	28E	950
THOMAS P. MENZIES	MENZIES RANCH	WATER WELL	10	R1	32S	28E	745
SIG HOFFMAN	ARVIN	IRRIG. WELL	15	J	32S	28E	827
TENNECO WEST	BRAVO RANCH	#8G 22-4	22	R	32S	28E	1050
GEORGE NOROIAN (KCWA	ARVIN	#88-52	25	F	32S	28E	1000
NOROIAN FARMS	LAMONT	PERMIT #87-36	27	B	32S	28E	1000

Data Base of wells available for Kern County Water Agency Regional Structure Study

			28	H	32S	28E	1386
			29	Z	32S	28E	1500
U.S. BUREAU OF		32-28-30D	30	D	32S	28E	1460
WHEELER FARMS	METTLER STATION	W.W.#4	30	H2	32S	28E	2805
S.A. CAMP PUMP CO.	MERIDIAN	PERMIT #84-57	34	D	32S	28E	1030
CHAPARRAL PET .INC	SANDHILLS	#75	34	J	32S	28E	7941
SIGNAL OIL & GAS CO.		MITCHELL #11X	3	D	32S	29E	12826
S.A. CAMP PUMP CO.	ARVIN	QUMARN INVEST. N.V.	4	K	32S	29E	832
MITCHELL BROS.	ARVIN	W.W. #94	4	R	32S	29E	1315
NEWSTONE CORP.	ARVIN		7	H	32S	29E	922
L.W. FRICK & SONS	ARVIN	W.W. #1	7	R1	32S	29E	1198
ERBERT AND BRANDT		#1	9	N	32S	29E	16614
POMEROY AND JEWETT	ARVIN	W.W.#7	10	H	32S	29E	1504
W.B. CAMP RANCH	ARVIN	#7-5A	11	G	32S	29E	1005
POMEROY & JEWETT		W.W.# 6	11	J	32S	29E	1187
OCCIDENTAL PETROLEUM	COMANCHE LAND	#45X	11	L	32S	29E	12737
POMEROY AND JEWETT	S. ARVIN	W.W.# 8	11	N1	32S	29E	1005
POMROY JEWETT	ARVIN	W.W. #5	11	P1	32S	29E	1014
GULF WEST CORPORATION	ARVIN	#1	12	B	32S	29E	700
CHEVRON USA INC	TEJON	CORE H. #2	13	K	32S	29E	2590
LEE HERRING	ARVIN	WATER WELL	14	F1	32S	29E	972
ARVIN-EDISON WSD	TEJON WELL FIELD	AE #78 -15NI	15	N1	32S	29E	1040
ARVIN-EDISON WSD	TEJON WELL FIELD	AE #79-15P2	15	P2	32S	29E	1045
U. S. BUREAU OF	SO. WEEDPATCH	32-29-19A	19	A	32S	29E	1000
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #74 -21G	21	G	32S	29E	1083
		REX-ROTH#83	21	H	32S	29E	11738
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #75	21	H1	32S	29E	1100
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #73 -22C	22	C	32S	29E	1087
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #77 -22DI	22	D1	32S	29E	1040
GLEN HERRING	TEJON HILLS	WW #2	22	F1	32S	29E	1463
WHITE WOLF ASSOC.	TEJON	#43	23	F	32S	29E	1696
INTEX OIL CO.	TEJON	#2	23	G	32S	29E	1175
CCMO	COMANCHE POINT	TEJON RANCH #2	23	H	32S	29E	1282

Data Base of wells available for Kern County Water Agency Regional Structure Study

			23	N	32S	29E	2000
GENE REID DRILLING CO	COMMANCHE PT.	TEJON #3	25	F	32S	29E	1031
OIL SCOUT INC	COMANCHE POINT	#1	27	E1	32S	29E	5505
SUPERIOR FARMING CO		# 10F 209-10 TEST	27	L	32S	29E	1320
HADDAD FARMS	SW ARVIN	#81-13	30	F	32S	29E	1020
CARLA STAFFORD LEWIS	COMANCHE POINT	CARFRAN #1	35	Z	32S	29E	2910
HENRY LUBKING ASSOCIATES	COMANCHE POINT	#1	36	F	32S	29E	1045
L.C. GOULD	TEJON RANCH	#36-1	36	K	32S	29E	1244
B.C. MACKEY	COMANCHE POINT	COLLINS#1	31	F	32S	30E	714
LEROY C GOULD	TEJON HILLS	TEJON #31-1	31	N	32S	30E	1861
B.C. MACKEY	TEJON HILLS	TEJON CREEK#1	31	P	32S	30E	846

Number of wells in this Township 130

EXPLANATION

This map shows structure form contours (subsea depth) from various seismic reflectors and represents the present structural setting of the sediments in the southern San Joaquin Valley. The structural trends have been identified by selecting the most continuous seismic events present over broad areas of the valley. The methodology is detailed in the report: STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUNDWATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUNDWATER BASIN, SOUTHERN KERN COUNTY, CALIFORNIA.

This map was constructed using an integrated approach utilizing seismic data and well data for velocity control. The seismic data set was made available generously by ARCO Oil and Gas Company through an agreement with the Kern County Water Agency.

PLATE II

SP 140			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
408	1240	6080	6084
504	1561	6200	6686
576	1846	6440	7919
672	2206	6600	7489
912	3260	7240	8787
1200	4483	7560	8494
1416	5482	7840	9242
1536	5982	7880	8338
1848	7483	8200	9621
2064	8658	8520	10880
2232	9674	8840	12099
2400	10991	9480	15673
2640	12802	10120	15095
2784	13584	10160	10867
2928	14372	10200	10945
5000	33077	14000	18054

SP 172			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
384	1175	6120	6124
504	1617	6440	7371
696	2390	6920	8045
1056	3893	7440	8354
1608	6224	7800	8446
1896	7655	8160	9933
1968	8050	8280	10978
2424	10543	8840	10933
2712	12156	9120	11203
3120	15573	10440	16752
3336	17783	11360	20463
4056	24216	12760	17868
5000	32901	14000	18400

SP 217			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
192	572	5960	5965
288	892	6200	6654
528	1824	6960	7775
840	3008	7200	7589
1176	4334	7440	8009
1344	5055	7560	8352
1632	6398	7760	8632
1728	6866	8040	11826
2016	8476	8560	11183
2232	9566	8720	10092
2520	11412	9280	12816
2664	12425	9600	14067
2760	13280	10000	17820
3168	16183	10640	14233
5000	33053	14000	18416

SP 260			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
360	1073	5960	5963
520	1679	6500	7576
768	2718	7160	8377
840	3036	7320	8848
1056	3868	7400	7703
1176	4418	7600	9174
1464	5679	7840	8752
1680	6819	8240	10559
2016	8730	8840	11375
2232	9851	9000	10375
2448	11045	9200	11057
2904	14210	10080	13881
3240	17064	11000	16989
3504	18948	11280	14278
3768	21014	11640	15653
5000	33039	14000	19521

SP 290			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
300	930	6200	6206
504	1696	6760	7508
840	3008	7200	7814
960	3478	7280	7817
1104	4084	7440	8429
1200	4528	7600	9243
1512	5913	7880	8875
1776	7407	8480	11319
1920	8218	8720	11267
2064	9060	8960	11699
2760	13657	10200	13210
3360	17942	11040	14281
5000	33235	14000	18651

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY
REGIONAL STRUCTURE STUDY

South-North Seismic Line TOC-PAL-85-19

Sample of data used in study.
Courtesy of ARCO Oil and Gas Company

Author	EKB & RDD	Project	KWA P.O. 7933
Drafted by	PGA	Date	7/90

Seiscom Delta United

Line:	TOC-PAL-85-19
Shotpoints:	114-337
Area:	PALOMA
Location:	KERN CO., CALIFORNIA
Client:	TENNECO OIL
	N →
Process:	FINAL STRUCTURE - AGC

(017)

Acquisition: PRAIRIE EAGLE EXPLORATION
PARTY NUMBER: V601 DATE: DECEMBER 1984

ENERGY SOURCE:
- type: VIBROSEIS
- direction of shooting: N
- shotpoint interval: 220 ft
- source array: 4 vibs inline
- sweep frequency: 12-64 Hz
- sweep length: 16 sec.

RECEIVING ARRANGEMENT:
- fold of recording: 24 — type: off end
- no. of groups: 96 — interval: 110 ft
- cable length: 10450 ft
- near trace: 1 — offset: 440 ft
- far trace: 96 — offset: 10890 ft

INSTRUMENTATION:
- geophones: MARK L21A
- recording system: MDS 10
- gain type: IFP
- filters: low cut: 9 Hz — slope 18 dB/octave
- high cut: 62.5 Hz — slope 72 dB/octave
- record format: SEGB
- record length: 21 sec
- sample interval: 4 ms

PROCESSING: SEISCOM DELTA UNITED
CENTER: BAKERSFIELD, CALIFORNIA DATE: MARCH 1985
COMPUTER SYSTEM: MEGASEIS

INITIAL PROCESS:
- demultiplex
- Vibroseis correlation
- sample interval: 4 ms

PULSE COMPRESSION:
- statistical wavelet shaping

DATUM STATICS:
- datum: 240 ft
- datum velocity: 3000 ft/sec

DECONVOLUTION BEFORE STACK:
- deconvolution type: predictive
- operator length: 124 ms
- prediction lag: 36 ms

VELOCITY ANALYSES:
- velocities: from Seiscom's Dove Velocity Spectra
- computed: before and after DEWL

DEWL:
- surface consistent statics adjustent

TRACE AMPLITUDE BALANCING:

STACK:
- type: standard CDP
- fold: 24

FILTER:
- apply times, beginning at SP 114
- A) 2000 ms: 18-64 Hz
- B) 4000 ms: 14-36 Hz

DISPLAY SYSTEM: SEISCHROME II
- type: trace equalized
- vertical scale: 5 inches/sec
- horizontal scale: 12 traces/inch
- peaks represent: positive digital numbers

QUALITY CONTROL: [signature] APPROVED: [signature]

PLATE III

SP 465			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
360	1058	5880	5882
504	1627	6520	7896
624	2110	6840	8046
816	2945	7320	8699
984	3687	7600	8835
1128	4256	7640	7908
1464	5625	7760	8150
1704	6685	7920	8833
1944	7636	7920	7920
2256	9634	8760	12808
2928	13377	9360	11140
3024	14026	9520	13519
5000	32700	14000	18901

SP 426			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
288	828	5750	5751
432	1302	6040	6582
576	1802	6280	6950
648	2136	6680	9279
912	3189	7080	7977
1272	4770	7600	8781
1440	5540	7800	9174
1848	7506	8240	9634
1992	8243	8400	10234
2184	9349	8720	11527
2448	11236	9480	14293
2592	12182	9720	13146
3072	16042	10960	16081
5000	33203	14000	17802

SP 396			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
624	2009	6440	6444
744	2465	6640	7596
864	2943	6840	7969
1248	4525	7300	8242
1416	5256	7480	8701
1608	6201	7800	9844
1824	7243	8040	9641
2160	9372	8920	12672
2280	10030	9040	10978
2640	12452	9760	13453
2736	13063	9880	12745
2904	14277	10200	14446
3096	15579	10440	13562
5000	33068	14000	18371

SP 360			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
408	1200	5880	5882
720	2347	6560	7355
792	2627	6680	7779
1080	3771	7040	7946
1224	4325	7120	7694
1296	4651	7240	9039
1560	5808	7520	8766
1680	6291	7560	8062
1968	7598	7800	9074
2616	12357	9960	14687
2976	14581	10280	12359
3384	17931	11200	16419
3792	22455	12840	22178
5000	32807	14000	17139

SP 322			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
768	2488	6480	6484
912	3086	6800	8301
1008	3412	6800	6800
1128	3958	7080	9098
1296	4737	7400	9267
1728	6805	8000	9577
2112	8964	8680	11242
3432	18158	11000	13930
5000	33036	14000	18978

SP 296			
TIME MS	DEPTH FT	V-RMS FT/S	V-INT FT/S
4	11	5700	5700
912	3155	6920	6925
1224	4627	7640	9435
1632	6491	8040	9136
1848	7561	8280	9907
2040	8997	9120	14962
2232	10518	9880	15844
2544	12821	10600	14760
2928	16431	12000	18805
5000	33438	14000	16416

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY
REGIONAL STRUCTURE STUDY

West-East Seismic Line TOC-PAL-85-15

Sample of data used in study.
Courtesy of ARCO Oil and Gas Company

Author	EKB & RDD	Project	KWA P.O. 7933
Drafted by	PGA	Date	7/90

Seiscom Delta United

Line: TOC-PAL-85-15
Shotpoints: 505-270
Area: PALOMA
Location: KERN CO., CALIFORNIA
Client: TENNECO OIL
E →
Process: FINAL STRUCTURE – AGC

0 .25 .5 mile

(001)

Acquisition: PRAIRIE EAGLE EXPLORATION

PARTY NUMBER: V601 DATE: FEBRUARY 1985

ENERGY SOURCE:			
type	VIBROSEIS		
direction of shooting	W		
shotpoint interval	220 ft		
source array	4 vibs inline		
sweep frequency	12–64 Hz		
sweep length	16 sec.		
RECEIVING ARRANGEMENT:			
fold of recording	24	type	off end
no. of groups	96	interval	110 ft
cable length	10450 ft		
near trace	1	offset	440 ft
far trace	96	offset	10890 ft
INSTRUMENTATION:			
geophones	MARK L21A		
recording system	MDS 10		
gain type	IFP		
filters: low cut	9 Hz	slope 18 dB/octave	
high cut	62.5 Hz	slope 72 dB/octave	
record format	SEGB		
record length	21 sec		
sample interval	4 ms.		

PROCESSING: SEISCOM DELTA UNITED

CENTER: BAKERSFIELD, CALIFORNIA DATE: APRIL 1985
COMPUTER SYSTEM: MEGASEIS

INITIAL PROCESS:	
demultiplex	
Vibroseis correlation	
sample interval	4 ms
PULSE COMPRESSION:	
statistical wavelet shaping	
DATUM STATICS:	
datum	240 ft
datum velocity	3000 ft/sec
DECONVOLUTION BEFORE STACK:	
deconvolution type	predictive
operator length	124 ms
prediction lag	36 ms
VELOCITY ANALYSES:	
velocities	from Seiscom's Dove Velocity Spectra
computed	before and after DEWL
DEWL:	
surface consistent statics adjustent	
TRACE AMPLITUDE BALANCING:	
STACK:	
type	standard CDP
fold	24
FILTER:	
apply times, beginning at SP 505	
A) 2000 ms	18–64 Hz
B) 4000 ms	14–36 Hz
DISPLAY SYSTEM: SEISCHROME II	
type	trace equalized
vertical scale	5 inches/sec
horizontal scale	12 traces/inch
peaks represent	positive digital numbers
QUALITY CONTROL:	APPROVED: Scott [illegible]


A
N
S
A'
INTERSECTION WITH B - B' B' - B''
INTERSECTION WITH A' - A'' C - C'
T25S R21E 5B
T25S R21E 8A
T25S R21E 17R
T26S R21E 5A
T26S R21E 14G
T27S R22E 7D
T27S R22E 22F
T27S R22E 33H
T28S R22E 9B
T28S R22E 9R
T28S R22E 15M
T28S R22E 22D
T28S R22E 28G
T28S R22E 35G
T29S R22E 12B
T29S R23E 16Z
T29S R23E 26A
T29S R24E 32K
T30S R24E 4C
T30S R24E 12H
GROUND LEVEL
SEA LEVEL DATUM
Upper portion of well 14E has been stratigraphically projected into the 14G location
Upper portion of well 22Z has been projected into the 22F location along Sea Level Datum
"E" EQUIVALENT CLAY
CONTOURED HORIZON
SEISMIC FORM LINE
FORM LINE DATUM CHANGE
SEISMIC FORM LINE
CONTOURED HORIZON
"E" EQUIVALENT CLAY
SEISMIC FORM LINE
FORM LINE DATUM CHANGE
-2,000'
-2,000'
BUTTONWILLOW ANTICLINE
BUTTONWILLOW SUBBASIN
SCALE
500'
0
0
6,000'
15:1 Vertical Exaggeration
Pacific Geotechnical Associates, Inc.
KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY
GEOLOGIC CROSS SECTION
A - A'
Kern County, California
Author: PGA
Project: KWA P.O. 10376
Drafted By: PGA
Date: 6/91
PLATE IV

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

A' - A"

Kern County, California

Author: PGA	Project: KWA P.O. 10376
Drafted By: PGA	Date: 6/91

PLATE V

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

B - B'

Kern County, California

Author: PGA	Project: KWA P.O. 10376
Drafted By: PGA	Date: 6/91

PLATE VI

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

B' - B''

Kern County, California

Author: PGA	Project: KWA P.O. 10376
Drafted By: PGA	Date: 6/91

PLATE VII

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

C - C'

Kern County, California

Author: PGA	Project: KWA P.O. 10376
Drafted By: PGA	Date: 6/91

PLATE VIII

PLATE IX


Pacific Geotechnical Associates, Inc.
KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY
STRUCTURE CONTOUR MAP
BASE "E" EQUIVALENT CLAY
NOTE: As defined in well 23S/24E-16B at a measured depth of 550 feet.
Integrated Well and Seismic Interpretation
CONTOUR INTERVAL = 100 FEET
Kern County, California
Author:
Drafted By: PGA
Project: KWA P.O. 10376
Date:
FOOTHILL LINE
BEDROCK LINE
GROUND WATER BARRIER
CALIFORNIA AQUEDUCT AND TURNOUTS
KCWA BASE MAP LEGEND
MAP SCALE
FEET
0 8000 16000 24000 32000 40000
MILES
MAP INSET
LEGEND
DATUM = SEA LEVEL
C.I. = 100 FEET
FAULT
CROSS SECTION
SAN LUIS OBISPO COUNTY
SEE MAP INSET B''
DELANO
McFARLAND
WASCO
SHAFTER
BUTTONWILLOW
LOST HILLS
BAKERSFIELD
GREENFIELD
LAMONT
ARVIN
TUPMAN
McKITTRICK
FELLOWS
FORD CITY
TAFT
MARICOPA
BUENA VISTA LAKE BED
BUENA VISTA PUMPING PLANT
KERN LAKE BED
KERN WILDLIFE REFUGE
DEVILS DEN
TEMBLOR RANGE
KERN RIVER
EDISON FAULT
WHITE WOLF FAULT
TEHACHAPI MOUNTAINS
WHEELER RIDGE PUMPING PLANT
WIND GAP PUMPING PLANT
CALIFORNIA AQUEDUCT
Rancho San Emidio
Los Alamos Y Agua Caliente
Ranchos


T28S R22E
T28S R23E
T28S R24E
T28S R25E
T28S R26E
T28S R27E
T28S R28E
T28S R29E
T28S R30E
T28S R31E
BUTTONWILLOW
T29S R22E
T29S R23E
T29S R24E
T29S R25E
T29S R26E
T29S R27E
T29S R28E
T29S R29E
T29S R30E
T29S R31E
KERN
RIVER
BAKERSFIELD
EDISON
AQUEDUCT
CROSS VALLEY CANAL
A'
T30S R22E
McKITTRICK
T30S R23E
T30S R24E
T30S R25E
T30S R26E
T30S R28E
T30S R29E
T30S R30E
T30S R31E
ERODED
TUPMAN
GREENFIELD
LAMONT
FAULT
CALIENTE
EDISON
TOC-PAL-85-19
T31S R22E
T31S R23E
T31S R24E
T31S R25E
T31S R26E
T31S R27E
T31S R28E
T31S R29E
T31S R30E
T31S R31E
ARVIN
BUENA VISTA LAKE BED
BUENA VISTA PUMPING PLANT
FELLOWS
FORD CITY
TOC-PAL-85-15
TAFT
T32S R23E
T32S R24E
T32S R25E
T32S R26E
T32S R27E
T32S R28E
T32S R29E
T32S R30E
T32S R31E
KERN LAKE BED
TEHACHAPI MOUNTAINS
TEJON HILLS
Rancho
T12N R24W
T12N R23W
T12N R22W
T12N R21W
T12N R20W
T12N R19W
T12N R17W
MARICOPA
CALIFORNIA
T11N R24W
T11N R23W
T11N R22W
T11N R21W
T11N R20W
T11N R19W
T11N R17W
SPRINGS FAULT
A''
WHEELER RIDGE PUMPING PLANT
WIND GAP PUMPING PLANT
AQUEDUCT
Rancho San Emidio
T10N R24W
T10N R23W
T10N R22W
T10N R21W
T10N R20W
T10N R19W
T10N R18W
T10N R17W
PUMPING PLANT
Ranchos
Los Alamos Y Agua Caliente
LEGEND
"Datum Is Mean Sea Level"
FOOTHILL LINE
BEDROCK LINE
GROUND WATER BARRIER
CALIFORNIA AQUEDUCT AND TURNOUTS
SCALE 1" = 8,000'
8000' 0' 8000'
Pacific Geotechnical Associates, Inc.
KERN COUNTY WATER AGENCY
REGIONAL STRUCTURE STUDY
STRUCTURE CONTOUR MAP
BASE "PALOMA" CLAY
NOTE: As defined in wells 31S/25E-15R at a measured depth of 840 feet, 31S/25E-36A at a measured depth of 810 feet, and 32S/25E-1H at a measured depth of 960 feet.
Integrated Well and and Seismic Interpretation
CONTOUR INTERVAL = 100 FEET
Kern County, California
Author PGA
Project KWA P.O. 7933
Drafted By PGA
Date 6/91

PLATE X

PLATE XI

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

PROPOSED SUBBASINS STRUCTURAL BOUNDARY MAP

Kern County, California

Author:	Project: KWA P.O. 10376
Drafted By: PGA	Date:

EXPLANATION

This map shows the boundaries of subbasins within the southern San Joaquin Valley The indicated subbasins are bounded by distinct structural highs due to folding and faulting.The structural interpretation is based upon analyses of subsurface well and seismic data presented in the report: STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUNDWATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUNDWATER BASIN, SOUTHERN KERN COUNTY, CALIFORNIA.

These subbasins may contain isolated or partially isolated hydrogeologic systems. Solid lines represent prominent, continuous bounding highs. Dashed lines represent low areas along these boundaries where communication between subbasins is more likely.

NOTE - This map is derived solely from a structural interpretation. Other sources of hydrogeologic data such as gradients, geochemical analyses, etc. will help determine the role of these individual subbasins in the hydrogeology of the southern San Joaquin Valley.

WORKSHOP REQUEST

17. Please provide a copy of the water supply agreement BVWSD.

RESPONSE

The Applicant will provide a copy of the water supply agreement prior to the CEC's issuance of the Final Staff Assessment.

WORKSHOP REQUEST

18. Please provide a copy of the MODFLOW and MODPATH modeling files.

RESPONSE

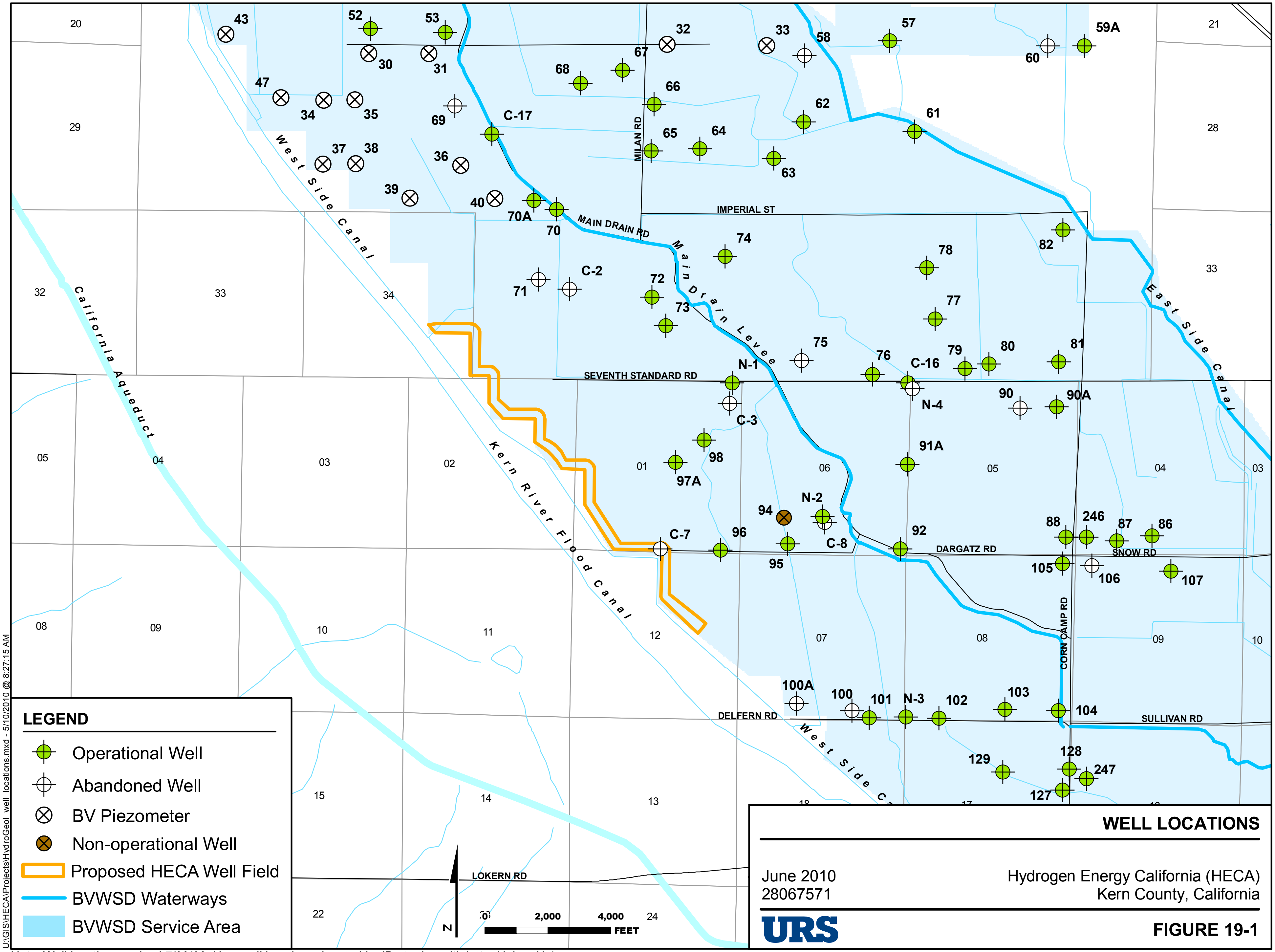
The requested modeling files are being submitted under confidential cover.

WORKSHOP REQUEST

19. Please provide a map with well locations in the proposed Buena Vista Water Storage District Brackish Groundwater Remediation Program Well Field.

RESPONSE

Attached Figure 19-1 presents the requested information.



Note: Well locations revised 7/30/08. New well locations denoted by ID starting with letter N, i.e., N-1.

U:\GIS\HECA\Projects\HydroGeol_well_locations.mxd - 5/10/2010 @ 8:27:15 AM

WORKSHOP REQUEST

20. Please provide the well specifications for the wells included in the field data acquisition program. Include well depth in feet below ground surface, top and bottom screened interval, well type, and recent years' water levels. Please also include the Department of Water Resources (DWR) Well Completion logs.

RESPONSE

On April 29, 2010, the Applicant docketed the Draft Hydrogeologic Data Acquisition Report (March 2010) and its Addendum (April 2010). This Report and its Addendum contain well construction information, Department of Water Resources (DWR) logs, and water level information. Summaries of well specifications are presented in the Report Addendum's Revised Table 3, DWR logs are presented in the Report's Appendix A, and recent water level data is provided in the Report's Appendix C.

Applicant has been informed by the CEC that they have received the DWR well completion logs from DWR.