

THE HYDRODYNAMICS GROUP
Studies in mass & energy transport in the earth

REVISED COMMENTS

CADIZ GROUNDWATER STORAGE PROJECT
CADIZ AND FENNER VALLEYS
SAN BERNARDINO COUNTY, CALIFORNIA

PREPARED FOR: WESTERN ENVIRONMENTAL LAW CENTER
TAOS, NEW MEXICO

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TABLE OF CONTENTS

Overview	2
Introduction	3
The Geographic/Geologic Setting	4
Infeasibility of Monitoring and Control	9
A Five Year Pilot Project	12
A Sustainable Project	13
Conclusion and Recommendation	14
References	15
Figures	

OVERVIEW

I have prepared this supplemental comment in an effort to both clarify and elaborate on points made in my earlier report on the proposed Cadiz Water Project. This comment specifically responds 1) to assertions made by the project proponents, 2) to measures that are reportedly being considered by the Agencies responsible for reviewing the project as means of addressing, or avoiding, the concerns raised in my earlier report, and 3) the critiques of other technical reviewers.

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For example, it has been suggested the inefficacy of the monitoring system that I addressed in my earlier report can be remedied by 1) better placement of the observation wells, 2) by lowering the threshold at which a response would be triggered, and/or 3) or by adjusting the models that are to be used to predict the future response of the groundwater system. While this approach sounds superficially appealing, as I explain below, it does not address the fundamental problem that the recharge is undetermined. It does not address the fact that early warning signals will be subtle, and will be obscured by the operations of recharge and pumping, and by natural fluctuations in water levels. Monitoring for response and control has little chance of being effective.

In addition there is reportedly a proposal to treat the first five years of project life as a pilot project, or trial period, to observe how the groundwater system is responding to project operations. The idea is that magnitude of future extractions of native groundwater would be based upon the aquifer response during the five-year pilot period. As explained below this suggestion, while superficially appealing, is also fraught with problems and as a practical matter probably unworkable.

In this revised comment I conclude:

1. The magnitude of the recharge is an order of magnitude smaller than that suggested by the proponents of the project. The weight of evidence indicates it is approximately 5,000 acre-feet annually (ac-ft/yr) rather than 50,000 ac-ft/yr as the proponents suggest.
2. Monitoring for the purpose of avoiding undesired impacts and controlling the project is unlikely to work because the early warning signals of impending problems are both subtle and small, and will be obscured by the signals associated with the operations along with natural water level fluctuations. The threshold levels of what constitutes an early warning signal of adverse impacts are left unspecified by the project. The remedial measures to stop adverse consequences are also left unspecified.
3. The major uncertainty in assessing the long-term life of the project is the magnitude of the recharge. A pilot project, or trial period, must stress the aquifer sufficiently so as to give an indication of the impact of the long-term pumping of large quantities of native groundwater. The pumping in order to be definitive must be approximately an order of magnitude larger than the current Cadiz Company pumping for agriculture—currently the pumping is approximately 5,000 ac-ft/yr. Pumping 50,000 ac-ft/yr of native groundwater in the first five years of the project is in conflict with the practical consideration that surplus

water from the Colorado River may only be available during the first decade or so of project.

4. A *sustainable* Cadiz project is one in which the pumping of native groundwater is restricted to the current rate of pumping by the Cadiz Company for agriculture—approximately 5,000 ac-ft/yr. In a sustainable project the current agriculture pumping would be acquired by the project. ***I recommend a sustainable project in which the pumping of native groundwater is restricted to an average of 5,000 ac-ft/yr.***

INTRODUCTION

Before embarking on the analysis, a brief recap of the principal features of the Cadiz Water Project is in order.

The Cadiz Valley Groundwater Storage Project is proposed to serve three functions: 1) store water from the Colorado River Aqueduct during periods when water is available, 2) pump the water stored, and 3) pump a significant quantity of indigenous native groundwater from the Cadiz and Fenner Valleys when Colorado River water is deficient.

The project facilities consist of a pipeline (approximately 35 miles long) through Cadiz Valley from the Colorado River Aqueduct, at least one pumping station for the pipeline, recharge ponds, and a well field. The recharge ponds are used to infiltrate Colorado River water into the underlying alluvial aquifer where it is stored. The well field is used both to pump out stored water as well as the native groundwater in the area. The facilities are designed to recharge as much 145,000 acre-feet of water per year (ac-ft/yr). Similarly the well field is designed to pump 145,000 ac-ft/yr of groundwater.

The project is proposed both to store water and pump groundwater. The proposal is to extract more groundwater than that which is stored. One scenario of development indicates the project will extract 1,700,000 acre-feet of groundwater in excess of the amount stored during a 50-year period. Under this scenario 1,100,000 acre-feet of Colorado River water will be stored during the 50-year period; however, the total groundwater extracted will be 2,800,000 acre-feet during the period.

The argument put forward in the Draft EIR/EIS is that the 1,700,000 acre-feet of indigenous groundwater pumped is somewhat less than the cumulative recharge to the aquifers in the area during the 50-year period of project operation, and therefore will have no adverse impacts on the groundwater system. The Draft EIR/EIS indicates that the annual recharge is in the range of 40,000 to 50,000 acre-feet per year. It is on this basis that the report suggests little or no adverse impact on the groundwater system. It is the analysis of the impacts of pumping the native groundwater that creates great concern.

In my earlier report (Bredehoeft, 2000) I indicated that:

1. the estimate of annual recharge used in the Draft EIR/EIS is an order of magnitude too high—it is probably only 5,000-6,000 ac-ft/yr;

2. using a more realistic recharge rate there will be adverse impacts to the groundwater system and the environment; and
3. once development has proceeded for a period of several decades simply stopping the pumping of native groundwater, as implied in the Supplemental EIR/EIR, will not halt the adverse environmental impacts—in other words, the groundwater system once perturbed has sufficient persistence that adverse impacts will persist well beyond 100 years, even though the project is stopped after 50 year or earlier.

In this comment I wish to elaborate on some of the points made earlier. In order that the document stands by itself I am restating some of my earlier arguments.

THE GEOGRAPHIC/GEOLOGICAL SETTING

The Cadiz and Fenner Valleys are typical valleys within the Great Basin geographical province. The valleys are situated between mountain ranges. The mountain ranges are composed of older bedrock that ranges in age from PreCambrian through Mesozoic. The mountain ranges were uplifted by the basin and range tectonics of the region. The valleys are underlain by alluvial material that was eroded from the mountain ranges. Often the alluvial valley fill is quite thick, commonly in the more open parts of the valleys several thousand feet thick. The alluvial deposits beneath the valleys are good aquifers.

The valleys and surrounding mountain ranges are often closed topographic basins; the closed topographic basins form closed watersheds. Precipitation that falls in the watershed remains in the watershed. The discharge of water from these closed watersheds occurs either as evaporation or as plant transpiration. This is a desert; the precipitation ranges from a low of the 3 to 4 inches per year in Cadiz Valley to a high of 11 to 12 inches in the higher parts of the Granite Mountains west of Fenner Valley.

Commonly a playa forms in the lowest parts of the valleys in the area. These playas are ephemeral lakes. During periods of unusually high rainfall the runoff from the surrounding area is sufficient that the playas become lakes for a period; however, these events are infrequent. Most times runoff from the surrounding mountains is insufficient to reach the playa. Typically the runoff from winter snowfall and from summer thunderstorms 1) evaporates, 2) is held in the shallow soil where the plants transpire the moisture, or 3) infiltrates to the underlying groundwater table (the *water table*).

Freshwater is supplied to the playas either as surface runoff in infrequent runoff events, or by underlying groundwater flow. The water evaporates from the playa; as it evaporates it leaves behind dissolved salts. The salts buildup naturally over time in the groundwater associated with the playas. There is highly saline groundwater underlying both Bristol Lake Playa and Cadiz Lake Playa; under Bristol Lake the groundwater is 7 times higher in dissolved salt than seawater. There are commercial salt works associated with both these playas.

The Hydrology of Valleys in the Basin and Range

Under natural conditions the alluvial aquifers that underlie the valleys are full of groundwater. These systems have existed for geologic time. There were periods of higher rainfall in the area during the Pliocene ice ages. Under natural (virgin) conditions before any development the recharge to the aquifers is balanced by the discharge from the aquifers, or:

$$\text{Recharge} = \text{Discharge} \quad (\text{under virgin conditions})$$

As suggested above, the discharge from the aquifers occurs in many of the closed valleys in the Basin and Range as either evaporation from the playa, or by transpiration from plants in the lower parts of the valleys that draw their water from the water table. (Plants that draw water from the water table are referred to as *phreatophytes*.) Common plants that draw groundwater from the water table are creosote bush, giant sage, and rabbit brush. Very few of these plants are present in Cadiz Valley; groundwater in this area is thought to discharge, before development, as evaporation from the local playas.

Pumping groundwater in one of these valleys constitutes an additional withdrawal from a system that was in a natural state of balance under virgin conditions. In order for such a groundwater system to reach a new equilibrium (a state of indefinite *sustainability*) two things must occur: 1) the pumping must increase the recharge, and/or 2) the pumping must decrease the discharge. Usually groundwater pumping has no impact on the recharge; recharge is determined by climatic conditions—precipitation, etc. On the other hand the pumping can decrease the discharge. For example, in Cadiz Valley pumping groundwater can lower the water table beneath Bristol Lake playa and either reduce or eliminate groundwater discharge as evaporation there.

In the parlance of the hydrogeologist, pumping can capture groundwater discharge. *In order for a groundwater system to be indefinitely sustainable the pumping must be balanced by an equal capture of discharge.* If the pumping exceeds the total amount of the natural discharge from the system the system cannot be brought into a new balanced state; in other words one will be mining groundwater—such a system is not indefinitely sustainable.

One rarely hears the discussion of groundwater sustainability put in terms of the capture of virgin discharge. The usual statement is that *pumping must not exceed the recharge (in order for the system to be sustainable)*. In the discussion above I made the point that the virgin rate of discharge in these systems equals the virgin rate of recharge. The statement *pumping must not exceed recharge* is a round about way of saying that the pumping must not exceed the virgin discharge—the presumption is that all the virgin discharge can be captured by the pumping.

Nevada Groundwater Law

The Cadiz and Fenner Valleys are comparable to the closed Basin and Range Valleys in Nevada; they are dissimilar to much of the rest of California. For this reason it is worth looking at how Nevada treats groundwater in similar valleys.

Nevada recognized in the early 1900s that the water supply for many of the valleys within the state would have to come totally from groundwater. The Nevada decision was to attempt to make that the groundwater supply within these valleys sustainable. The discharge in many of the valleys in Nevada is similar to Cadiz Valley where the groundwater discharge is by evaporation from the playas and from plants that tap the water table—the phreatophytic plants mentioned above. Nevada was willing to let the groundwater pumping capture both the evaporation and the groundwater that went to support the phreatophytic plants. This thinking led to the Nevada doctrine *that groundwater pumping must not exceed the recharge*.

As an aside, it has been difficult for the water managers in Nevada to administer this doctrine in places of heavy urbanization such as Las Vegas, even though Nevada law codified the doctrine.

Nevada has systematically surveyed the entire state in an effort to investigate the recharge in each of its many valleys. Many of the techniques of estimating recharge in the Basin and Range Province have stemmed from efforts in Nevada. One of the widely used methods of estimating recharge is the Maxey/Eakin Method. This is an empirical procedure devised by Burke Maxey and Tom Eakin (1949) working for the U.S. Geological Survey (USGS) in cooperation with the state of Nevada.

Even though the Maxey/Eakin Method is more than 50 years old it is still in widespread use. Its applicability has been evaluated in recent years. Avon and Durbin (1994) published an evaluation of the method in which they showed that it gave good estimates of recharge for valleys in the Basin and Range. The Maxey/Eakin Method, along with other methods, indicates a much lower rate of recharge for Cadiz and Fenner Valleys than the method that was used in the Draft EIR/EIS. The method used in the Draft EIR/EIS continues to serve as the basis for overly optimistic projections of the quantity of native groundwater that can be extracted on a sustained basis from the Cadiz-Fenner groundwater system.

As discussed above, whether a groundwater system can be brought into a state of indefinite sustainability depends upon whether the system can ultimately capture sufficient natural discharge to balance the pumping. I indicated that under virgin conditions, before development, in these systems the recharge is balanced by an equal amount of discharge. If a proposed development is much larger than the amount of potential discharge that can be captured the system will never be brought into a new equilibrium—one will be continuing to mine groundwater. In other words one will be draining the groundwater system.

Let's state these ideas in another way. Remember the virgin recharge equals the virgin

discharge. If the proposed development is much larger than the recharge (or in other words the virgin discharge since it is equal) one can never capture sufficient natural discharge to bring the system to a new balance. Therefore, one hears the common statement the *development must not exceed the recharge if the development is to be sustainable*.

The estimate of recharge becomes critical in any analysis of how a groundwater system will perform. If the estimate of recharge is in error then predictions of system performance will also be in error. Thus, one cannot make accurate predictions of future performance without a good estimate of the natural recharge. One cannot make a defensible judgment about the impacts of withdrawing native groundwater without a good estimate of recharge. I wish to examine the various estimates of recharge for the Fenner and Cadiz Valleys that were referenced in my earlier report.

Summary of the Recharge Estimates

Table 1 summarizes the various estimates of recharge to the Fenner/Cadiz Valleys.

Table 1. A summary of the recharge estimates.

Methodology/Author	Estimate (ac-ft/yr)
1. Watershed Runoff Model—MWD & BLM (1999) GeoScience Groundwater Model	20,000-70,000 50,000
2. Maxey/Eakin Method USGS (2000) Durbin (2000)	2,550-11,200 5,000
3. Fenner Gap Groundwater Flow Friewald (1984—USGS) LaMoreaux (1995) USGS (2000)	270 3,700 2,600-4,300
4. Chloride Method (correctly applied) USGS (2000) Durbin (2000)	1,700-9,000 2,000
5. Drawdown Associated with Cadiz Co. pumping Boyle Engineering (1996)	4,000

Looking at Table 1, the only investigator that estimated the recharge as high as 50,000 acre-feet per year was GeoScience in their work reported in the Draft EIR/EIS Report. This estimate was commissioned by the Cadiz Company and done in support of the project. The other eight estimates performed using a variety of proven methods indicated that the annual recharge is less than approximately 10,000 ac-ft/yr. While there is a range in the estimates the most probable value for the annual recharge is 5,000 acre-feet per year—an order of magnitude lower than that used in the Draft EIR/EIS.

The Boyle Engineering (1996) report indicated that Cadiz Company was pumping

approximately 4,000 ac-ft/yr for irrigation in 1996. Boyle noted small, continued declines in the groundwater levels of approximately 1 foot per year; they suggested that the recharge was less than the 4,000 ac-ft/yr pumped in 1996. The Cadiz agricultural pumping has, or will capture the natural discharge that is thought to have occurred as evaporation from the dry lakes under virgin conditions. The pumping for irrigation, now approximately 5,000 ac-ft/yr, appears to have had little, or no significant adverse impacts to date. The Cadiz Company has approval from San Bernardino County to continue their pumping for irrigation.

Apart from the GeoScience report there has been one other minority voice among the technical reviewers of the Cadiz Project. Lee Davisson, a scientist at Lawrence Livermore Laboratory, wrote a short letter that endorses the quantity of recharge indicated by GeoScience. The Davisson letter suggested that his support for the GeoScience estimate was based upon isotopic studies of the native groundwater. It is difficult to assess the Davisson suggestion since his letter is brief; it does not contain the usual scientific information—his method of analysis, his assumptions, his data, or his results.

The Supplemental EIR/EIS did not address the issue of how large is the recharge to the local groundwater system. It sidestepped the issue of the recharge by proposing a monitoring and control scheme. The idea is that the project operations would be carefully monitored and modified to control adverse impacts as they were observed. This proposal has two fatal flaws:

1. The future impacts of the project cannot be projected at all accurately without an up-front estimate of the recharge.
2. By the time an adverse impact is detected by the monitoring the groundwater system will be sufficiently perturbed that even completely stopping the pumping of native groundwater will not ameliorate the impacts.

The bottom line is that if a large quantity of native groundwater is mined from the Fenner-Cadiz system it will cause water levels to drop below the dry lakebeds. This in turn will result in an increase in dust from the two associated playas. An increase in dust from a similar dry lakebed in Owens Valley has been a difficult and expensive problem to attempt to ameliorate. In addition, saline water will move out from beneath the playas and invade parts of the aquifer that currently contain freshwater. Springs in the nearby mountains may be caused to dry up.

The connection between the springs in the nearby mountains and the pumping in the valley is undetermined. The proponents of the project argue there is no connection. However, there is insufficient understanding or empirical data to know what will happen to the springs. If the springs do dry up as a result of the local pumping it will have a severe impact on a local herd of Desert Bighorn Sheep.

The Cadiz Company does not seem to be concerned about these impacts. Once a large public investment is made in the project, the pressure will mount to continue the project including the mining of native groundwater.

INFEASIBILITY OF MONITORING & CONTROL

The Cadiz project entails a substantial investment of public funds to build the facilities—pipeline, pumping station, recharge basin, and well field. Monitoring the groundwater system by observing water levels and water quality might reveal that the project operation is creating adverse environmental impacts. However, the early warning signs will be subtle, at best. The signals will be obscured by effects of the project operations, both storage and pumping, and other natural water-level fluctuations

The Supplemental EIR/EIS—Monitoring and Control

A number of individuals, in commenting on the Draft EIR/EIS suggested that the recharge indicated the Draft Report was much too large—approximately an order of magnitude too large. The Supplemental Draft EIR/EIS did not address this issue directly; a different tack was taken. The Supplemental Report proposed extensive monitoring with the idea that adjustments could be made to the project operation that would ameliorate adverse impacts.

The idea put forward in the Supplemental EIR/EIS is that early signs of adverse impacts will trigger modifications in the project operations. Exactly how the operations will be changed is not specified. Nor is it specified what constitutes an early warning sign of an adverse impact—what is the signal that triggers a modification of the project. The trigger signals that indicate adverse impacts are also left unspecified.

The problem with this idea is that once the project has operated for several decades the groundwater system will be sufficiently perturbed that stopping the pumping of native groundwater by the project will not stop the adverse impacts. Entirely stopping the pumping of native groundwater is probably the most drastic corrective action that can be taken. Clear signs of an overdraft of native groundwater will not occur until the project has operated for some time. In the early stages of operation it will be easy to discount early warning signs of adverse impacts as the result of project operations (storing water and pumping stored water) or natural groundwater fluctuations

Once the groundwater system is perturbed, that perturbation will work its way through the system at a rate dictated by the response time of the groundwater system. It is much like a freight train put into motion; once it has started moving it will be difficult, if not impossible, to stop the system from responding.

The traditional method of analyzing the impact of stopping pumping in a groundwater system is:

1. to analyze the aquifer as if the pumping is continued; and
2. to superimpose a recharge well of opposite but equal magnitude at the site of the pumping well.

This has the effect that the impacts of the pumping continue to migrate through the aquifer even though the pumping has ceased. It takes some time for the impact of the

superimposed recharge well to catch up with the impact of the pumping. The rule of thumb is that the impact of the pumping after it is stopped persists for a time approximately equal to the time of pumping. For example if one pumps for a year and then stops, the impact of the pumping will persist for approximately another year—it takes a year for the aquifer to recover. Therein lies the difficulty for monitoring; adverse impacts persist within the system even after pumping ceases.

The problem of recovery of the system is compounded if a large quantity of groundwater is mined. I made the point above that a number of investigators suggested that the recharge to the aquifer in the area is probably 5,000 acre-feet annually (ac-ft/yr). This estimate is an order of magnitude lower than the estimate presented in the Draft EIR/EIS for the Cadiz Project; the project estimate was 50,000 to 60,000 ac-ft/yr. Let's assume for the sake of argument that the project is operated based upon the higher estimate of 50,000 ac-ft/yr. Let's further assume that in 10 years of operation:

pumping indigenous groundwater	10 years @ 50,000 ac-ft/yr	500,000 ac-ft
recharge	10 years @ 5,000 ac-ft/yr	50,000 ac-ft
overdraft (groundwater mined)		450,000 ac-ft

Even if we stopped pumping indigenous groundwater after 10 years of operation we have created an overdraft that will take at least 90 years to refill at a recharge rate of 5,000 ac-ft/yr. This is without any other natural discharge from the system. Of course there will be continued natural discharge or other extractions that the project operators will not be able to control. By extension, if the project extracts groundwater at the proposed rate for two or three decades as seems likely, an overdraft will be created that takes more than a century or two to replenish.

If one is sufficiently alert there will be subtle early warning signs of trouble ahead. However, the early warning will be sufficiently obscure as to not halt the mining of native groundwater. As suggested above, once the project has operated for several decades it will be impossible to halt the adverse impacts even if the pumping of native groundwater is stopped. Let me try to illustrate my point further with results from the earlier modeling.

Water Levels in Selected Observation Wells

Using a groundwater flow model I projected the drawdown at several observation wells to illustrate the point about the difficulty associated with monitoring and control of the Cadiz Project. In order to do the modeling one has to assume some schedule of project operations. My assumed schedule of recharge and pumping is shown in Figure 1. Figure 2 is a map showing selected hypothetical observation well locations. Figure 3 shows the model-projected hydrographs for the three hypothetical well locations.

Consider for example the drawdown in Fenner Valley as observed in the observation well near Danby—see Figures 2 and 3. This well has almost no drawdown in 40 years of project operation. The drawdown is approximately 3 feet in 50 years, but this is only the beginning. The drawdown is 10 feet in 100 years, 50 years after the project was shut

down, and the drawdown at Danby is continuing to decline. At 100 years the drawdown is continuing to migrate up Fenner Valley to the north even though the pumping was totally stopped 50 years earlier.

The monitoring situation is a bit clearer beneath Bristol Lake—see Figure 3. There is no decline in the water table beneath the center of the lake out to 20 years. By 30 years the drawdown is approximately 7 feet and by 50 years it is approximately 12 feet. Again this is only the beginning, the drawdown goes to 20 feet in 80 years and remains at 20 feet to 100 years. Even though the project was stopped after year 50, there is no recovery in water levels beneath the lake in 100 years.

Water Quality in Observation Well SCE 5

I ran a groundwater transport model to simulate the movement of the brine beneath Bristol Lake. Observation well SCE 5 is situated approximately halfway from the proposed project and Bristol Lake playa—see Figure 2. The total dissolved solids, as observed in this observation well, are plotted in Figure 4. Notice that the dissolved solids start to increase slightly in year 30. By year 45 it increases to 1,000 milligrams per liter (mg/l); by year 50 the concentration is 1,300 mg/l. This water is still useable; but again this is only the beginning. The concentration increases to more than 7,500 mg/l by 100 years, and it is still increasing—again the project was halted 50 years earlier.

The point shown especially by the brine movement is that we would have to halt the pumping of native groundwater very early on in order for there not to be a significant degradation in water quality at this location. I selected only one location to make my point, but this is not an isolated location; the degradation in water quality between Bristol Lake and the project will be widespread and continuing out to at least 100 years. The groundwater flow into the cone of depression will still be significant at 100 years. The groundwater flow from the region of Bristol Lake will bring with it brine from beneath the lake. The outward flow of brine will render the groundwater unusable without costly treatment. The modeling suggests an area more than 10 square miles will be impacted.

To make my point that adverse impacts persist I stopped the project after 50 years of operation. To the reader this may suggest a worst-case scenario analysis. However, as suggested above the same point can be made after a much shorter period. As indicated above after a one-year period of pumping at any rate (for example 5,000 ac-ft/yr), pumping impacts will exist in the system for approximately another year; after a decade they will persist for approximately another decade; and so forth. The magnitude of the drawdown created is a direct function of the pumping rate; for example, the drawdown from pumping at 50,000 ac-ft/yr is ten times larger than drawdown from pumping at 5,000 ac-ft/yr. However, the rate at which the impacts migrate outward from the well through the groundwater system are the same for both pumping rates.

Modeling as an Integral Part of Monitoring

Modeling is one of the tools that hydrogeologists use to assess impacts of development—in this case recharge and withdrawal. Models have the ability to project the impacts into

the future. The procedure in using a model is to fit the model output to empirical data. This procedure is referred to as *calibration*, or in the petroleum industry *history matching*. Once the model fits the observed data it is referred to as calibrated. The calibrated model is then used to make predictions of the future response of the system.

Models are routinely calibrated based upon limited data sets. A steady-state model can be calibrated using either a high or a low estimate of recharge. Usually the aquifer permeability is adjusted to compensate for the high or low estimate of recharge. It will take a period of sustained high pumping from the aquifer before the impact of the recharge rate will be felt and a better estimate of the recharge provided by the modeling or other analyses. The bottom line is that the long-term behavior of the aquifer cannot be accurately estimated without a good upfront estimate of recharge.

During calibration what constitutes a good fit to the observed data is a matter of judgment on the part of the modeler. Compounding the calibration is the fact that the data is never sufficient to provide a unique model. The modeler adjusts the model parameters until an adequate fit to the observations is achieved. However, the non-uniqueness arises from the fact that another set of different model parameters could provide a similar fit to the observations. In colloquial terms, there are too many knobs to adjust in the model to be sure that the model is unique. Even so, once the model is calibrated it is used to make predictions of aquifer response.

This leads to the fact that analysis of the future response using models, or other analytical tools, has an inherent uncertainty associated with the prediction. The question is: in a situation where one is controlling one's actions based upon model predictions that are uncertain, *how seriously will the model results be taken?* This question becomes more important as the investment in the project increases.

Model uncertainty is likely to be used as an excuse for not taking warning signs predicted by the model seriously. This is especially likely in a project like Cadiz where a very substantial initial investment is made in the project before the model begins predicting problems. The likelihood of discounting the early warning signs of a model prediction are even greater where the decision to take remedial action is controlled by parties having a direct financial stake in the production of native groundwater.

A FIVE-YEAR PILOT PROJECT

It has been suggested that concerns associated with the long-term impact of pumping native groundwater can be resolved by using the first five years of the project as a pilot project or trial period. Such a pilot project might give an indication of the potential long-term impacts of pumping groundwater; however, five years is a short period to reveal how the long-term pumping of large quantities of native groundwater will impact the system. In order to be at all definitive the pumping rate must be much larger than the current Cadiz Company pumping for agriculture. There is an additional practical problem; water for storage from the Colorado River is probably only available during the

first decade of project operation. This consideration will probably preclude pumping large quantities of native groundwater during the first five years.

The major uncertainty in pumping native groundwater by the Cadiz Project is the recharge—is it 50,000 or some larger figure, or is it 5,000 ac-ft/yr? A five-year project in which a large amount of indigenous groundwater is pumped may provide an indication of whether the proposed pumping is sustainable. The Cadiz Company is reportedly currently pumping approximately 5,000 ac-ft/yr and has been doing so for more than a decade. The impacts of the current pumping appear to be acceptable

At issue is what happens if the pumping of indigenous groundwater is increased dramatically—up to the 50,000 ac-ft/yr of the projected recharge in the Draft EIR/EIS. Unless the pumping in the pilot project is much larger than the current level of pumping by the Cadiz Company, the pilot project will be inconclusive at best, and possibly misleading. The pilot project pumping needs to approach the larger estimate of annual recharge to be meaningful

A pilot project that calls for pumping so large a level of native groundwater is inconsistent with the proposal to store large amounts of Colorado River water in the first decade of the project when it is anticipated surplus water will be available from the Colorado River. Beyond 2015 surplus water from the Colorado River may be quite limited.

A SUSTAINABLE PROJECT

Many of the objections to the Cadiz Project are based upon the analysis that the project as proposed will mine a large quantity of indigenous groundwater. Given our current understanding of the groundwater system in the area, only a project that pumped a smaller quantity of local groundwater while storing Colorado River water could be sustainable indefinitely.

As suggested above, the recharge to the Cadiz/Fenner valley aquifers is probably of the order of 5,000 ac-ft/yr. This is approximately equal to the quantity of groundwater being pumped for irrigation by the Cadiz Company. The current agricultural pumping has, or will capture the natural discharge that probably occurred as evaporation from the dry lakes under virgin conditions. The agricultural pumping been going on for more than decade and appears to have little, or no significant adverse impacts.

A Cadiz Project in which the quantity of groundwater pumped currently for irrigation is acquired by the project, and not exceeded, is probably sustainable. This would be pumping by the project instead of for agriculture—the irrigation by the Cadiz Company would cease.

Accordingly, I recommend a sustainable Cadiz Project in which the total pumping of native groundwater from the Cadiz/Fenner Valleys be restricted to an average of 5,000 ac-ft/yr.

CONCLUSIONS AND RECOMMENDATION

From my analysis I reached the following conclusions:

1. Valley aquifers is of the order of 5,000 ac-ft/yr, not 50,000 ac-ft/yr as suggested in the Draft EIR/EIS.
2. Water table groundwater systems respond slowly to perturbations. Impacts occur at long times into the future. This poses a challenge for monitoring and control. The delayed reaction of the groundwater system combined with the fact that the subtle indications of overdraft tend to be masked or easily confused with fluctuations due to other causes will profoundly undermine the early warning system that has been proposed. The weight of evidence indicates that the recharge to the Cadiz/Fenner for the project. Furthermore, trigger levels of what constitutes an early warning sign of adverse consequences have not been specified. One is left with only verbal assurances that careful monitoring will inform the project staff when bad consequences are anticipated. What triggers a response and what the response will be is left unspecified.
3. Models are useful tools in the monitoring. They can be used to assess long-term impacts. However, future predictions made using models carry a degree of uncertainty inherent in the analysis. Given 1) the fact that a model analysis indicates an unwanted future adverse impact, and 2) the uncertainty inherent in the analysis, the question arises *will such an analysis be sufficiently persuasive to modify or halt the mining of native groundwater—especially given the project investment?*
4. A five-year pilot project is a short time in which to collect sufficient data to evaluate the long-term viability of the project. The major uncertainty is the magnitude of the recharge. The Cadiz Company currently pumps approximately 5,000 ac-ft/yr without apparent adverse impacts. In order to assess the recharge issue the pumping must be much larger than the current Cadiz Company pumping. To be definitive the five-year pilot period must involve pumping an order of magnitude greater than the current pumping; even at the higher pumping rate the results may not be definitive. To assess the recharge the pilot project must entail mostly pumping indigenous groundwater during its five-year life. This appears to be in conflict with the availability of surplus water for storage from the Colorado River.
5. The Cadiz Project could probably be sustainable if one limited the magnitude of pumping of native groundwater to approximately the current rate of pumping by the Cadiz Company—5,000 ac-ft/yr. In a sustainable mode the project would acquire the irrigation pumping of the Cadiz Company—irrigation in the area would cease. This rate of pumping of native groundwater is equal to 250,000 ac-ft over the 50-year life of the project. *It is my recommendation that the project be made sustainable with the pumping of native groundwater restricted to an average rate of 5,000 ac-ft/yr.*

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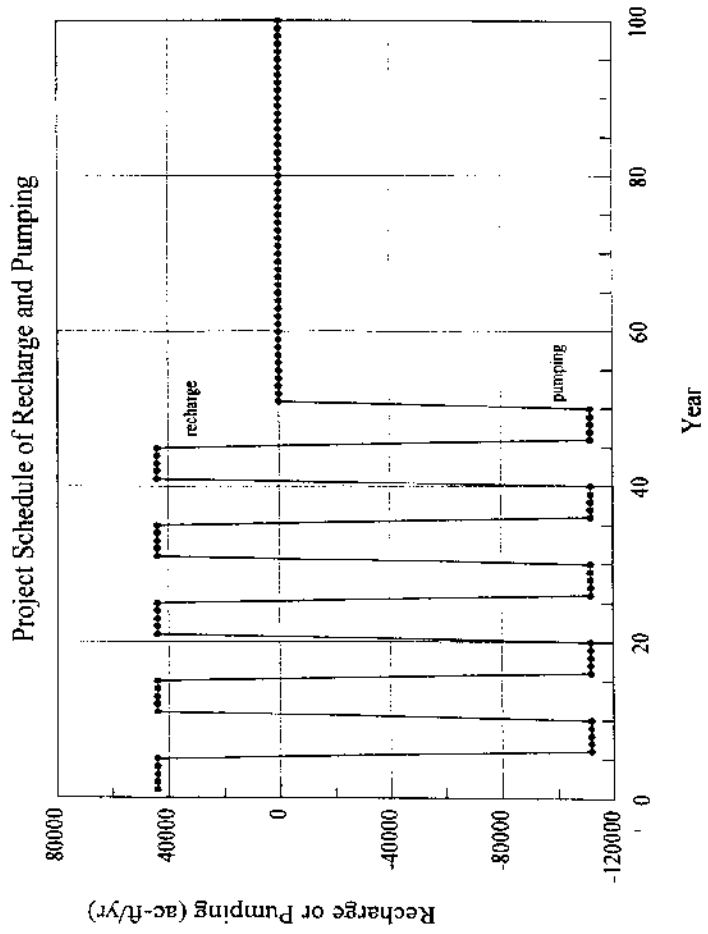


Figure 1. Hypothetical schedule of pumping and recharge.

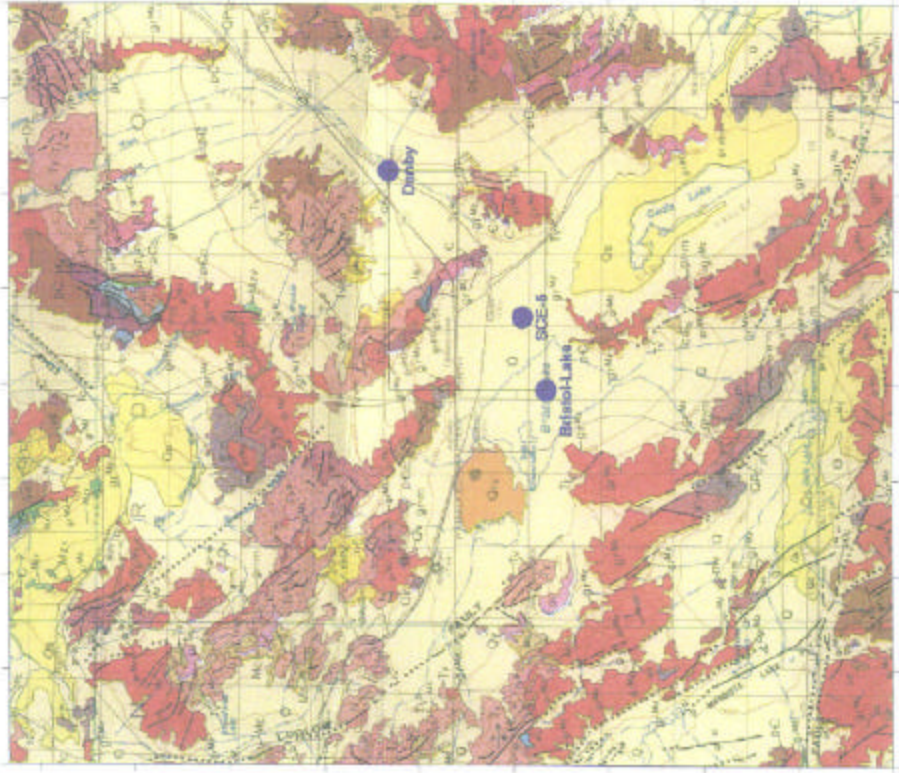


Figure 2
Location map of three
hypothetical observation wells.

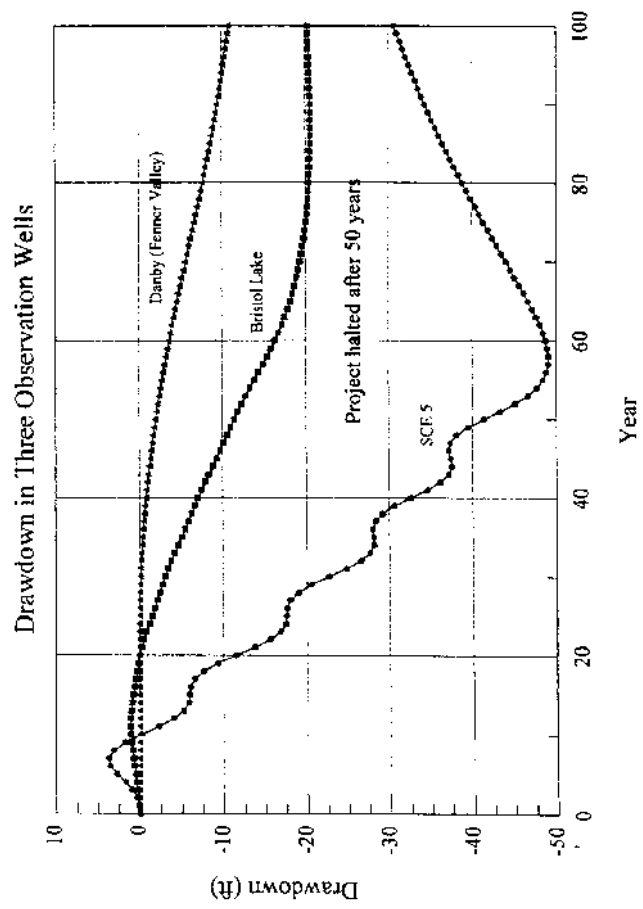


Figure 3. Computed drawdown in three hypothetical observation wells.

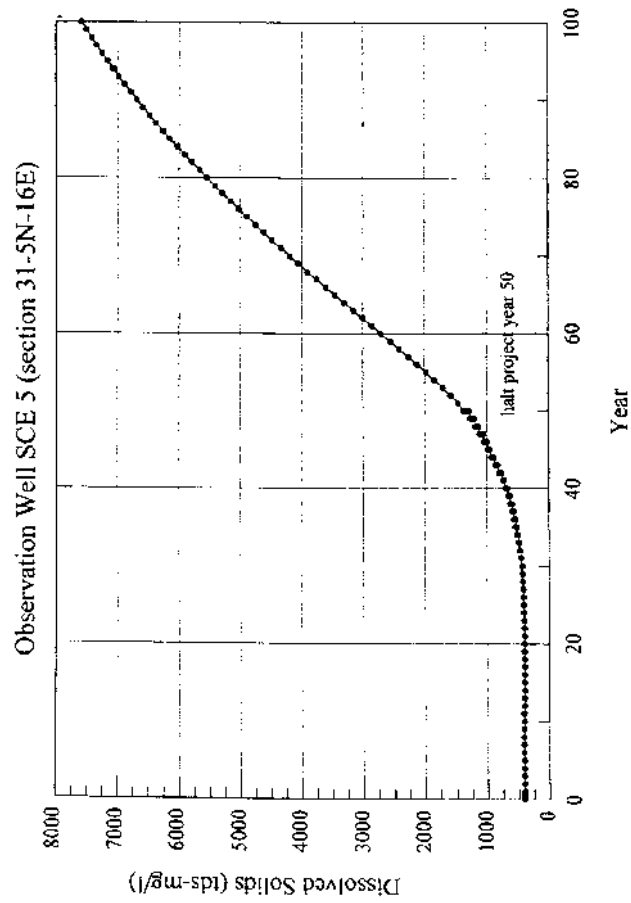


Figure 4. Computed plot of TDS in observation well SCE 5.