Mr Carl Austin presentation to IWVWD 6/13/88 — Personal Copy

THE HYDROLOGY OF INDIAN WELLS VALLEY

1. In this presentation I will present a summary of my personal views of the geology and hydrology of this region, I will explain to you why and how as a professional geologist I have arrived at those opinions and I will present how various geologic scenarios would affect our hydrology.

The first thing I will do is present some definitions and general concepts so that hopefully what I say to you will mean the same thing to you as the listener as it means to me as the speaker.

Study Boundary:

The fundamental problem in any hydrology study is to set the boundary of the study. Are you studying the "Regional Ground-water Flow System", a particular "Ground-water Basin" or a "Ground-water Flow System Cell?" These are each different and to collect data pertinent to one and then use it to interpret the other will only lead to confusion. Furthermore it is of critical importance that the choice of study boundary and of initial assumptions not create a self-fullfilling prophesy or drive subsequent studies into too narrow or limited a choice of models to use.

The very first and most significant decision one must make is whether our area is an isolated basin or a part of a widespread hydrologic system of some sort. The reason this is critical is that if you assume we are an isolated basin, by definition we no longer need to look for, examine, or plan to utilize any currently unused potentially large groundwater resource and our future is indeed limited.

The text "Hydrology" edited by Oscar E. Meinzer (1942, Dover Reprint pg 305) provides a clear cut enunciation of our choices and the attendant problems with these choices. I would like to quote him for you with respect to alluvial filled valleys:

> "The container is the bedrock basin that underlies and surrounds the valley. These basins are of two general types—(1) the "closed basin", in which the alluvial fill is for practical purposes completely enclosed by impermeable bedrock bottom and sides continuous with the surrounding hills or mountains; (2) the "open basin" in which the bedrock is leaky or the alluvial fill has one or more areas of direct contact with similar formations outside of the valley that are sufficiently permeable to transmit goundwater. THE OPEN-BASIN TYPE PRESENTS DIFFICULTIES THAT ARE IN SOME VALLEYS INSURMOUNTABLE."

Both types of basins are widely encountered worldwide in the study of hydrology and you should never arbitrarily assume you have one type or the other. Meinzer's text then goes on to state how problems typically arise in hydrology studies. The text states:

> "The ground-water hydrologist endeavors to ascertain the permanent quantitative ground-water yield of the entire basin, of which one element is the consumptive use. For reliable results the method used requires an analysis of all elements of inflow and outflow, both surface and subsurface, as well as ground storage. GROSS ERROR IN THE FINAL RESULTS CAN EASILY ARISE BY THE OMISSION OF HIDDEN ELEMENTS WHOSE IMPORTANCE IS NOT FULLY REALIZED, OR BY THE OMISSION OF MEASUREMENTS FOR WHICH FUNDS ARE NOT AVAILABLE."

This statement is truly a definition of our problems and contentious in this valley. I repeat:

> "For reliable results----requires an analysis of ALL elements of inflow and outflow, both surface and subsurface....."
>
> "Gross error... can easily arise by the omission of hidden elements whose importance is not fully realized or by the omission of measurements for which funds are not available."

Flow Systems:

Let us now define the three types of flow systems we must deal with. By definition, using Pub No. 4, Technical Report Series H.W., Center for Water Research, Desert Institute (funded by University of Nevada and USDOI Office of Water Resource Research):

"Regional Ground-Water Flow System: A regional system is loosely defined as a large ground-water flow system which encompasses one or more topographic basins. A regional system may include within its boundaries several ground-water basins; interbasin flow is common and important with respect to total volume of water transferred within the system boundaries; lengths of flow paths are relatively great when compared to lengths of flow paths of "local" ground-water flow systems."

It is my professional opinion that in order to understand the hydrology of the Indian Wells Valley we must study the basin as a part of a regional flow system, NOT as an isolated entity. Only then can we hope to understand and identify the recharge and discharge patterns that are present, largely as hidden subsurface features.

Rather than arbitrarily exclude any hidden elements from the hydrology model of our Regional Ground Water Flow System I prefer to first make a general model. Only then do I try to assign probabilities and values to the various elements potentially active. Figure 1 is the fundamental flow pattern for the Regional Ground Water Flow System of which the Indian Wells Valley is one part.

Figure one presents the various elements that comprise our regional groundwater flow system. Our problem is to eventually be able to assign actual values to each of these elements, to determine their magnitude and importance and to decide if some of them present us with untapped opportunities for additional producible water. As one example we must decide if there is enough high-quality leakage at some location to warrant trying to capture some of it. None of these elements should be rejected because of a lack of money or because they do not fit some preferred philosophic or political position. All should be carefully evaluated as our long term future would appear to lie with some of them.

The next definition we should clearly fix in our minds is that of:

"GROUNDWATER BASIN: A groundwater basin is usually only part of a groundwater system, and is used in a practical sense in that it is a region of a groundwater flow system where appreciable quantities of groundwater can be encountered and developed by man. More than one groundwater flow system may be involved in a groundwater basin. Within the Great Basin Physiographic Province groundwater basins are commonly the alluvial basins, whereas the entire flow system may involve more than one alluvial basin and also extensive regions of adjacent indurated rocks ____ #.

Please note that the idea of an extensive region of indurated rocks as part of a groundwater basin is part of the fundamental definition used by hydrologists in the great basin. You should clearly understand that it is highly probable that the "basin" is only a part of the system we should be interested in and that the area around the commonly recognized alluvial basin may ultimately be more producible than the basin itself.

The third definition from the reference I gave is:

#Groundwater Flow System Cell: A flow system cell within large regional systems.... The flow system cell, then, is a local system which contributes some flow to a regional flow system.#

The concept of Groundwater Flow System Cells is very important to us. The work being done for the EKCRCD by the University of Utah is extremely valuable as it enables us for the first time to begin to identify the individual flow system cells within the local basin. If one ignores these cells, whose presence now seems to be well established, then there is no way to directly interpret data from well to well. In many instances adjacent wells in different cells will have different chemistry representing different ages of water and different origins. It is the presence of these diverse cells that makes most past attempts to interpret local well data or to model the valley so unreliable.

#Recharge Area: A recharge area is a region of the earth's surface where there is a net flux of water to the zone of regional saturation. This does not necessarily imply that no groundwater discharge occurs; rather it implies that more enters the zone of regional saturation than leaves. In many areas...believed to be recharge areas, there is local groundwater discharge from such features as springs, seeps, streams and phreatophytes. Such discharge has been referred to as "rejected recharge.#

What constitutes the recharge area for the Indian Wells Valley groundwater basin is certainly one of the local controversies. Making the situation more complex and making broad brush simplistic flow and reservoir models even less realistic is that there is good evidence that different flow system cells within the "basin" have different recharge areas and involve identifiably different chemistry, recharge times, transit times and static periods. Past studies that have assumed the "basin" to be one flow system cell have lead to hopeless confusion when attempting to make sense out of data from diverse wells. After all, when one considers the complex chemistry and flow patterns of this valley it is obvious that it will not be uncommon for nearby wells to be in totally different cells.

#Discharge Area: A discharge area is a region of the earth's surface where there is a net flux of ground water from the zone of regional saturation. In a manner similar to recharge areas, recharge to the saturated zone may occur, but on a long term basis, the net flux of water is from the groundwater system.#

There has been very little meaningful study of the overall discharge pattern for our regional system or for the local basins (IWV and Rose Valley) and virtually no study of the discharge patterns of discrete flow cells. Because it is obvious and is located on the surface where everyone can see it, the discharge associated with the playa has received considerable interest but most of the hydrologists who have written reports on our local area have had little experience with fluid flow in fractured and indurated rock, hence the potential for such flows has been largely ignored. Actually, of the numerous published papers on this area, 5 of the papers, those of Spane; Friedman, Smith and Matsuo; Berman; Fourneir and Thompson; and Austin, Moore and Bishop have dealt with various aspects of subsurface and bedrock flow patterns in our local area and the idea that such flow is of local interest is not new or novel.

Pluvial Period: This is a relative term referring to intervals of geologic time, when because of climatic variations, more moisture was available in the Great Basin. The geologic record in the Great Basin indicates several intervals of time when hydrologic conditions were markedly influenced by increased availability of water, probably related to greater precipitation and reduced rates of evaporation.

Most of you have seen maps of the chain of Pleistocene "Ice Age" lakes that have been well popularized for our area, and this has led to public comments, duly reported in the press, about how we are pumping fossil "ice age" water. If you are a fan of John D. Macdonald's Travis McGee books, he popularized the idea of the risk of pumping fossil water in his book "A Purple Place for Dying." Unfortunately, things are not so simple. Which so called ice age would you like to argue about? Our basin and especially our Regional Groundwater Flow System has apparently been subjected to at least 14 identifiable pluvial events and it is obvious there are probably a lot more still waiting to be recognized and published on. Each one of these pluvial events should have resulted in the flushing out and refilling of anywhere from a few to most of our groundwater flow cells. However it is still reasonable to expect some cells to have stayed stagnant during any given pluvial event. It may sound dramatic to talk about "the last great ice age" but the 14 pluvial events we know of that have affected us include significant events much younger than the so called "last ice age". The pluvials that are known for our area are:

	YEARS BEFORE PRESENT
Matthes	0-600
Unnamed	1000
Recess Peak	2,000-6,000
Unnamed	6,000-7,000
Hilgard	11,000
Tioga	20,000
Tenaya	26,000
Mono Basin	87,000
Donner Lake	250,000
Casa Diablo	400,000
Sherwin	750,000
McGee	1,500,000
Deadman	3,000,000

The next time someone proposes that we are pumping "fossil water" ask them which pluvial, which flow cell and in particular how do they know the age of the water. I have been in two recent meetings in this valley where attendees have quoted vague stable isotope studies as proving the age of the water in this basin. Ignoring the complex flow cell geometry we have, the stable isotope studies being mentioned by these people are incapable of providing any age data at all; they only indicate possible source. Regarding local pluvial events, it is interesting to note that one canyon that is a tributary to Indian Wells Valley appears to have a rather prominent lateral morraine in it rather clearly suggesting that at some time or other not too long ago our basin was directly fed in part by local glacier melt. In fact this canyon appears to have involved some interesting morrainal damming and probably created an impressive local flood when the morraine was breached.

"Regional Saturation: Regional saturation implies continuous saturation in earth materials over broad areas where voids and permeability exist."

This does not mean there is a uniform or flat surface to the water table and it in no way implies the valley is a stack of flat layers, but taken as a whole, Indian Wells and Rose Valley are saturated and the Sierran granitics and metamorphics are impressively saturated. There is also some strong indications the Coso and the Argus Ranges are saturated at modest depths as well.

"Local Saturation": This term is used for "perched water" or groundwater where there is evidence for the absence of hydraulic continuity with nearby bodies of groundwater."

When I moved on base in early 1961 the main talk then was how long the perched saline waters would last that occur just south of the base. That area had numerous wells that were too salty to drink when they were first drilled, long before our present controversy started. I should also note, these little saline cells are interspersed with cells of quite good water, which after all these years are still good. This interesting and complex area, fed in part by geothermal leakage, probably from the "Haystack" area, should never be used to explain or illustrate anything involving the main valley flow cells. Other perched waters are known. One of these zones fed shallow hand dug wells out on Brown Road according to early verbal reports, yielding water at less than 50 feet.

Historical Studies:

Given this general background, let us next briefly examine the historical studies on the hydrology of this area, for such a review will enable you to see what might be relevant, what might be too simplistic, and how championing some individual or agency's past notions way lead to perpetual controversy.

U.S.G.S. Water Supply Paper 578: The U.S.G.S. published a paper by David G. Thompson in 1929. Thompson's study approached the regional concept, but he did not move outside of the topographic basins per se. Thompson concluded that recharge to Indian Wells Valley came from the adjacent hills, from Rose Valley and from Coso Basin. The numbers Thompson used appear to be derived from altitude and area considerations, i.e. probable recharge. Thompson concluded:

> "... it is probable that the total run-off from the mountain areas of all three basins does not exceed 50,000 acre-feet a year."

What he did was estimate:	Acre Ft/Yr
Runoff into Indian Wells Valley	27,000
Runoff from Rose Valley	10,000
Runoff from Coso Basin	12,000
	49,000

At this time Lee had also estimated the evaporation on the playa as about 32,000 acre feet per year, which leaves one with a probable 17,000 acre feet per year of bedrock under flow out of the Indian Wells Valley, although Thompson did not discuss this at all. It is worth noting that if you use the modern U.S.G.S. reduction of Lee's 32,000 to 11,000 or so, then you are by definition proposing an increase in the bedrock water loss of the order of 21,000 acre feet per year, and if you still use Thompson's recharge numbers you are proposing a total underflow of 38,000 acre feet per year. The point is that if you reduce your estimate of the playa discharge you need not arbitrarily reduce the basin recharge. Instead you should look for additional subsurface discharge areas, and some of those might well prove to be prolific producers if properly explored.

Kunkle and Chase, U.S.G.S. Open File: The next paper to provide ammunition in the fray to come was the mid-valley underflow study by Kunkle and Chase, published in 1969. This paper made the assumption that the flow across the valley was simple lateral flow, they did not worry about cells or water chemistry, and the flow pattern they proposed would include no water entering the valley from Coso Basin, none from the Argus, and should include none from Rose Valley in all probability. The author's concluded in their text that the mid-valley underflow was 18,000 acre feet per year.

If Kunkel and Chase's numbers were right (and when one considers the magnitude of the simplifying assumptions they made, any validity to their numbers is more likely fortuitous than the product of science), then you could argue:

Mid-Valley Underflow	18,000 Acr ft/yr
Coso Basin (per Thompson)	12,000 Acr ft/yr
Rose Valley (per Thompson)	10,000 Acr ft/yr
Total Minimum Recharge	40,000 Acr ft/yr

However Kunkel and Chase achieved their numbers, they stayed fairly consistent with Thompson's 1929 conclusions regarding recharge.

It is in Kunkel and Chase's text in 1969 that we first encounter the U.S.G.S. recalculation of the prior work by Lee regarding playa discharge. Persons, some identified, some not, recalculated Lee's 32,000 acre foot per year playa discharge number and reduced it to 11,000 acre feet per year. Now then, some subsequent authors have assumed that this new low value proves the recharge is drastically less than Thompson presented. It is just as logical if not more so to assume the subsurface discharge was simply greater than originally thought. Kunkel and Chase went on and calculated a perennial yield, i.e. the safe total pumping rate for the Indian Wells Valley by taking the U.S.G.S. recalculation of Lee, minus 1000, adding to this an arbitrarily chosen 15,000-1,000 and then dividing the sum by two to give an average of these two numbers of 12,000 acre feet per year. Looked at in the cold light of reason, this perennial yield number would appear to have no technical basis whatsoever.

Bloyd and Robson

In 1971 the ground water controversy took a quantum leap with the publication of a report entitled "Mathematical Ground Water Model of Indian Wells Valley, California". This came out as an open file U.S.G.S. report. Everyone involved in the local water controversy should take a long hard careful look at this paper and what it says.

A very widely mis-used and misunderstood statement made by the authors was:

> "A mathematical model of Indian Wells Valley groudwater basin was developed and verified."

This statement has been widely interpreted by the public to mean the model is technically valid. It means no such thing. It merely means the model is internally consistent, in effect if you were to put 5.237 lbs of garbage into the model you will get 5.237 pounds of garbage out. It means nothing more.

Without getting into the internal politics of that time between the U.S.G.S. groundwater office and the people at Menlo Park, anyone who reads the Bloyd and Robson paper runs into some serious inconsistencies that cast significant doubt on the utility of this paper.

On page 12 of their paper Bloyd and Robson state:

> "Although Kunkel and Chase (1969) estimated total steady-state recharge to the deep aquifer, additional work was required to properly distribute this recharge over the model area. A simple altitude area relation was used to apportion recharge to the various parts of the valley."

In any event, Bloyd and Robson go on to explain how they apportioned the recharge value they attribute to Kunkel and Chase, based on total land areas above 5000 feet elevation in the desert ranges and on total land areas above 4500 feet elevation in the Sierra that are within the topographic basin. Now the first problem is that Kunkel and Chase at no place in their text devise, derive or use the recharge number of 9850 acre ft/year that Bloyd and Robson attribute to then.

What Kunkel and Chase did say was:

Pg. 2 "The perennial yield . . . . is approximately 12,000 acre feet per year."

> You should carefully remember that this was derived from an average of two very strange numbers - the recalculated number of Lee minus 1,000 added to an arbitrarily chosen 15,000 minus 1,000, with the sum then divided by 2.

and again in their section called "ground-water recharge" Kunkel & Chase said on page 73:

> "These quantities discussed in the previous section were estimated to be 11,000 and 15,000 acre feet"

I would remind you though, the 11,000 was originally 31,600 to be exact and the 15,000 was 18,000 in the body of the text by Kunkle and Chase. For some unexplained reason Bloyd and Robson assumed the recharge of the Indian Wells Valley to be 9850 acre feet, not the 49,000 acre feet of Thompson who at least tried to study the whole valley.

Ignoring the fact that Bloyd and Robson apparently plucked their 9,850 acre feet per year out of thin air, let us see what they did with it.

Let us make a chart of the areas of recharge defined by the U.S.G.S., the recharge the U.S.G.S. claims for each area, and then let us see what the areas are above 5,000 feet elevation (slightly different than Bloyd and Robson's 4,500 feet for the Sierra portion but erring on the conservative side) and see what recharge Bloyd and Robson think we are getting per square mile of recharge area.

U.S.G.S. RECHARGE AREA	U.S.G.S. RECHARGE	SQUARE MILES OVER 5,000 FT	ACRE FEET PER YEAR PER SQUARE MILE OVER 5,000 FT
Bird Spring, Horse, Sage & Little Dixie	2040	32	64
Freeman	430	12	36
Indian Wells & Short	400	10	40
Grapevine	1620	4	405
Sand	495	9	55
Nine Mile & No Name	775	10	78
Dead Foot & Five Mile	475	10	48
Rose Valley	45	45 Sierran) 16 Desert)61	0.7
Coso Wash	1000	61	16
Petroglyph	590	22	27
Renegade	230	28	8
Mtn Spring	930	13	72
Unamed Wash	60	3	20
Wilson & Deadman	350	21	16
Burro	8	0	0
El Paso Pks & Laurel Mountain	400	0	0

I teach the hydrology class at Cerro Coso College periodically and this chart is one every student of mine gets to make. The reason is to teach them to critically review what is published and to identify and evaluate the assumptions people make and not just blindly accept them because they are in the literature.

A simple in-consistency is that Bloyd and Robson claimed to apportion recharge based on land areas over 5,000 feet in elevation for the desert side. Since there is no such land feeding Burro Canyon or the El Pasó Pks and Laurel Mountain areas, they plainly made those numbers up. The incredible whopper in this chart is Rose Valley. Here we have a tributary to Indian Wells Valley with 61 square miles of recharge area, essentially twice the Bird Spring, Horse, Sage, Little Dixie recharge area, and these two U.S.G.S. authors only credit Rose Valley with contributing 45 acre feet of recharge to Indian Wells Valley. This is really and truly strange. Rose Valley water either goes east subsurface, or goes south subsurface or evaporates off Little Lake. Now Little Lake is a chloride lake, it is not simply Sierran or Rose Valley groundwater and it is actually fed in part by geothermal leakage and hot springs. That's not new data. That was published in the 1870's. The glorious question is where does the Rose Valley water go? The 45 square miles of Sierran recharge area above 5,000 feet in elevation and that is adjacent to Rose Valley is in a higher and wetter zone than most of that along side Indian Wells Valley, so Rose Valley should get recharge that is at the very least equal to Indian Wells Valley from Freeman through Nine Mile (i.e. 45 square miles). That water can not just magically disappear. It has to go somewhere.

Consider Grapevine. If Grapevine really does make 1620 acre feet per year, then Sand Canyon which has 2 times the recharge area, had better make 3645 acre feet per year and Rose Valley should be making 6176 acre feet per year from the Sierra and 1145 acre feet per year from the desert side. If you do not believe this, then you must justify your inconsistencies. Did the U.S.G.S. authors credit Grapevine with such a high recharge value just because of past development in that canyon?

What I am trying to show you is that the numbers Bloyd and Robson used in the so-called model they developed are a highly inconsistent apportionment of a recharge number that appears to have been plucked out of thin air. It has been my opinion for a number of years that anyone who reads the paper by Bloyd and Robson with an open mind and attempts to figure out how they arrived at the numbers and conclusions they present, will conclude their paper is patent nonsense. It is nonsense that has caused an immense amount of alarm and pointless controversy in this valley.

A paper was prepared under contract to NWC that was published in 1978 as NWC TP 6025 which gives a very illuminating map of regional ground water flow patterns. This paper, by Frank Spane of Hydrosearch concluded that the deep regional flow pattern in Indian Wells Valley is out of the Sierra into our local basin and out of our local basin as an underflow through the Argus Range into northern Searles Valley and that Rose Valley drains subsurface into this basin as well.

A final paper I should comment on is that by St. Amand which appeared as NWC TP 6404 in 1984. On page 7 St. Amand states: "The valley is a closed container." When one looks at water chemistry and temperature data alone this is an unsupportable assumption. St. Amand also chose his own assumptions for the purpose of reducing the U.S.G.S. midvalley underflow number of Kunkel and Chase even further, ignoring the fact that Kunkel and Chase made no attempt to study actual flow cell patterns in the valley. With respect to Rose Valley, St. Amand assumes the recharge to Rose Valley is (Pg 54) 800 acre feet per year, a number that is impossible to reconcile with the extensive recharge area of this valley or for that matter with the water chemistry of Rose Valley. Indeed, if you were to believe the 61 square miles of recharge area in Rose Valley results in only 800 acre feet per year of recharge, then you would have to believe that Indian Wells Valley with 235 square miles of recharge area (over 5000 feet) is actually getting only 3081 acre feet per year. Conversely if Indian Wells Valley gets the 9,850 acre feet per year recharge assumed by Bloyd & Robson, then Rose Valley must get 2556 acre feet per year. You should not use widely different constants for these two adjacent valleys. In any event, you never will arrive at St. Amand's 800 acre foot number. St. Amands paper is largely a complex rehash of the assumptions, and estimates of various U.S.G.S. authors. The critical assumptions used by St. Amand are that the basin is for all practical purposes water tight and that the evaporation on the playa, whatever it might actually turn out to be or have been, is a valid measure of the recharge to the basin. There are no compelling geologic reasons to consider either of these assumptions valid at this time.

This is as good a place as any to point out that a widely quoted falacy is that the valley has a shallow aquifer and a deep aquifer. There are scattered local confined zones, but there is no evidence that the basin as a whole, with its multitude of flow cells and complex folding of its sediments has any recognizable division into broad horizontal layers of different kinds of waters.

With this as a beginning, albeit a rather lengthy and detailed beginning, let us take a look at the idea the basin is in serious overdraft. To do this we should review the use of pumping data. Then I will finish up by showing something about the recharge and discharge patterns for our area of interest.

Are we in overdraft and if so by how much is certainly a question of interest to all of us. Indeed what is an overdraft? An overdraft is when your pumping is so large that the total of all losses, surface and subsurface, exceeds the total of all recharges, surface and subsurface.

Let us stop and carefully think about this - the only evidence offered and indeed the only idea in support of the overdraft concept is the assumption that the playa evaporation is a measure of the total recharge. The idea we are in overdraft comes solely from this assumption - that the playa evaporation, as calculated or assumed by various people, is a valid measure of the recharge. If this assumption is wrong, then there is no, I repeat NO evidence whatsoever of an overdraft situation.

Generally overdraft is said in one breath and in the next breath people tell how their well is going down. Of course their well is going down. Every well that is pumped should go down for years, until eventually years later the drawdown for that well or the combined drawdown for a cluster of wells finally reaches equilibrium. Some wells are now beginning to do this in some parts of the valley. They are going down more and more slowly. Individual wells going down has absolutely no bearing on whether or not the valley is in overdraft. Let us consider how and why a well goes down.

Pumping Depressions: the fact that the pumping level in a well gets lower with time does not mean the basin is in overdraft. It simply proves that water runs downhill, and if a well is to produce water, it must make a depression so more water will run in - AND - that depression will grow and flatten with time until eventually, many, many years later, stability is achieved. If several wells are close together, their depressions will interact and get deeper faster.

An open minded look at the multitude of wells in this valley shows that although some are at or close to stability, i.e. the declines are getting less with time most are still noticeably going down. Taking water well levels in one well or in a group of wells can be remarkably misleading - even if you weight the tape and read it right. Consider these three examples:

Case 1: In July of 1982, fearing the effects of hay field pumping Mr. Well Owner A measures his well and gets a depth of 150 feet to water. Then in October 83, expecting things to be at their worst, Mr. Well Owner A is pleasantly surprised to find no change has occurred at all, the depth to water is still 150 feet. Wondering what the fuss is about he measures his well each spring in '84, '85 and '86 and gets 150 feet to water each time. Becoming alarmed over the controversy he goes out in the middle of the pumping season and measures--- 150 feet to water. He concludes the controversy is nonsense.

Case 2: Well Owner B decides he should be concerned and measures his well near the end of the hay season - it is at 152 feet. Fearing he may be being pumped dry, he measures it again in July of the next year, and gets 152 feet. Hearing a talk on the importance of being consistent he decides to measure the well each spring. In April 84 it is 151 feet to water, in April 85 it is

150 feet to water. In March 86 it is only 149 feet and in March 87 he gets 147 feet to water. He's excited. His well is coming up. It is not going down.

Case 3: Well Owner C measures his well in March '82, '83, '84, April 85 and May 86 and then in Sep 87 (extrapolated). He concludes his well is going dry FAST, having dropped 13 feet in 5 years.

Each of these 3 examples uses real data from a real well. In case 1 the well owner will conclude nothing is happening and the groundwater hullabaloo is all nonsense. In case 2 the well owner will conclude that not only is nothing wrong, things are obviously getting better. In case 3 the well owner is sure his well will be dry in a few years and he is in a panic. Not only are these real data from a real well, all of this data is from the same well. Everyone should clearly understand that by choosing the data from a well, somewhat maliciously, you can prove anything you want to in this valley. Furthermore, by taking the data completely honestly and in all innocence - especially by using widely spaced sampling times, people with adjacent wells will probably get widely diverse results and if you deal with wells located in different flow cells, your water level data will be truly un-interpretable.

As to how long it takes a well to recover if you stop pumping, it depends on the shape of the drawdown curve. If the curve is deep and narrow or if the well is quite young, the recovery in some such wells in this valley is very fast for most of the drawdown. If the well field has been exercised for a long time so the field is widely and flatly pulled down, the head that is driving the recovery is very slight and recovery to early conditions will be very slow. In any case the final recovery of the last few feet in most wells will often take a long time, measured in years. This would be true even if the well were the only well in the entire basin. The fact that water levels decline in a well being pumped is not a cause for alarm. It just proves water runs downhill.

A big problem with water level measurements is the lack of a good record at most wells as to what the original conditions were. Where were the measurements taken from? How much fluid did the driller dump into the hole to make a little local mound of water? Was there a small perched water table? These problems all give you discrepancies measured in terms of feet. How recently was the pump on is a critical factor that is often ignored. There are very few water level records in this valley that are worth the paper they are written on. Another problem is that people irresponsibly spread all sorts of unsupportable tales regarding water levels. To illustrate:

> Not too long ago I put in a new well on my ranch. A few weeks later a neighbors pump burned out. One of the people who came to help the neighbor pull his pump came over and chewed out one of my kids, telling him his old man's big new well was responsible for a drop in the water table that had burned out the neighbors pump and that he should be held liable for the damages. Well I went down and offered him a flashlight so he could look down the casing and see for himself that I had no pump in the hole. He apologized. He apologized several times but he will never undo the nasty rumors he started by telling tales without bothering to get any data. I see this type of thing happening over and over here in the valley.

For example, at a meeting of the Indian Wells Valley board of directors about 10 or 12 years ago, a prominent member of the audience got up and claimed that irrigation of the hay fields in Rose Valley had caused up to 70 feet of decline in some of the wells there and Rose Valley was running out of water. The owner of these wells, Phil Hennis was also in the audience unknown to the self styled expert. Phil then got up and explained that each well in question was either unchanged or had come up slightly in the past year and that to his knowledge the self-styled expert had never been on his ranch and had never measured any of his wells. The self-styled expert then got up and without another word stalked out of the meeting and slammed the door. But the mistaken notions stated in that meeting persist to this day.

The point is -- when you are told a well is up or down or has turned saline or something - find out who took the actual data, find out what they actually measured, find out when was it done, and get these facts written down.

As a final anecdote regarding water well levels, not too long ago I had an employee go out and measure the depth to water in a particular well. As I recall he came back and told me that the water level had dropped severely and was standing at 350 feet. Since the well was only drilled to 300 feet I found this a little remarkable. What had happened was the sounding line had gotten hung up on a projection on the casing. A very sheepish employee came back after the second time to inform me the water level had not gone down at all. Hydrology systems generally change very slowly - be a skeptic over major anomalies.

Let us talk about recharge and discharge patterns next. When I became interested in the hydrology of this valley, one of the things I felt it would be useful to do was to look at similar valleys with a similar geology and see what investigators found in those situations, thinking such analogies might be useful guides for us. Here is an example of such a comparison.

INDIAN WELLS VALLEY	THE ANALOGUE
a. Dry desert	a. Dry desert, a little more summer thunderstorms.
b. No perennial streams flowing in.	b. No perennial streams flowing in.
c. Adjacent tributary valleys.	c. Adjacent tributary valleys.
d. Traversed by a major canal.	d. Traversed by a major canal.
e. Scattered alfalfa farms.	e. Scattered alfalfa farms.
f. One large and one small town.	f. One large and one small town
g. Bordered by granite mountains.	g. Bordered by granite mount-ains.
h. Bordered by a geothermal system under development.	h. Bordered by a geothermal system under development.
i. Area of valley equals 1152 square miles.	i. Area of valley equals 1160 square miles.

The people who studied the hydrology of this analogue valley found the following recharge:

a.	Subsurface inflow from tributary valleys.	1,700 Acre ft/yr
b.	Subsurface inflow in a large wash.	2,200 Acre ft/yr
c.	Losses from stream channels.	5,000 Acre ft/yr
d.	Losses from major ~~channels~~. canals	8,500 Acre ft/yr
e.	Infiltration from farms.	22,700 Acre ft/yr
f.	Infiltration from lawns and gardens in town.	100 Acre ft/yr
g.	Infiltration from precipitation on the valley floor.	2,000 Acre ft/yr
h.	Subsurface inflow from bedrock in mountains.	16,000 Acre ft/yr
	Total Recharge Rounded	58,000 Acre ft/yr

If you look at this list, you will note some striking analogies to our area, plus the fact that much of this recharge is originating from outside the basin from which the water is produced. The authors of the hydrology paper on the Milford, Utah area chosen as an analogue were skilled and respected hydrologists of the U.S. Geological Survey. The two hydrologists were Mower and Cordova. The paper they wrote appeared in Utah Geological Association Publication 3, 1973 edited by Lehi Hintze of Bringham Young University and James A. Whelan of the University of Utah. There are several points in this paper on a valley that is quite similar to ours that should cause you to consider very carefully what might be happening in our valley:

Infiltration from farms - alfalfa farming pours water back into the groundwater system.

Losses from major canals - the LADWP aqueduct should be leaking a large amount of water into our valley.

Subsurface inflow from bedrock in mountains - our adjacent Sierra Nevada clearly gets better recharge than the Mineral Range in Utah which contributes so prolifically to the Milford Valley area that was studied.

Other people in similar situations have sought and identified major sources of recharge (and discharge) to exploit. Would we not be remiss if we failed to do so in our situation?

Let us then return to our Regional Ground Water Flow System and see what we can tell about our area. Let us then look at each of the recharge and discharge elements in turn. To place my discussion in context with respect to prior studies I have prepared the following series of figures for you showing how various authors have dealt with the possible elements of our Regional Ground-Water Flow System.

Using our generalized model, we note that Thompson of the U.S.G.S. in his water supply paper considered at most the presence and quantitative aspects of only 4 of the readily identifiable 25 elements of our regional ground water flow system.

Kunkel and Chase are difficult to fit into this model as they failed to consider the flow-cell pattern of the basin at all. In reality, they considered only the consumptive elements and they concluded that the playa evaporation was indicative of the recharge. Inherent in their study is a series of major assumptions as to whether the underlying materials are clay, silt, sand and gravel. Data on this for our valley is obtainable in only the crudest fashion from so-called driller's logs and is available from only a small portion of the valley. I have sat water well drilling in this valley and seen the drillers, albeit in good faith, write up meaningless logs.

Bloyd and Robson in their paper derive a set of runoff/recharge figures from their assumed playa evaporation, which of course ignores any recharge needed to account for subsurface discharge.

Spane in his NWC TP, although not presenting quantified data, gives the flow patterns that appear to be most complete. For all practical purposes, Spane recognized the presence of all of the flow patterns, but because of the nature of his map, he was not concerned with consumptive uses or with the results of aqueduct leakage. His is the most complete study of our valley in terms of the general concepts presented.

St. Amand, by considering Indian Wells Valley a closed container and by relying on the work of Bloyd and Robson limited his study to the flow elements of Bloyd and Robson as noted previously.

The remainder of this presentation will be a discussion of the various elements of our Ground-Water Flow System of a Regional nature, as I understand them.

Sierran "Runoff"

When we evaluate the recharge potential of the Sierra Nevada it is very important to us to decide whether or not our recharge system includes the fractured granitics west of the topographic divide. I believe we obtain significant recharge from west of the crest and that certain geologic features within the Sierran bedrock are attractive potential major water sources. I believe this for several reasons.

1. Throughout much of the world and in particular in the western states, mining in fractured granitic rocks has been plagued unto desperation by water flows in such rocks. My experience in fractured granitics includes mines, shafts, tunnels and addits in the Sierra, in our valley, and various mines scattered throughout the western U.S. as well as underground installations in granitic rocks in many countries.

2. I have located wells and drilled for water successfully in the granitic rocks of our area.

3. I am the project leader for a drilling program that at present is producing 5700 acre feet per year of water from fractured granitic rocks in our area and that expects by early 1990 to be producing some 30,000 acre feet per year of water from fractured granitic rocks.

4. I can not help but note that people in other areas of the U.S. where water is being sought are looking at granitic rock aquifers. For example, people in the Salt River area near the city of Phoenix are seeking additional water in previously untested granitic masses and have recently announced the finding of a major potential aquifer in granite bedrock in the form of a thrust fault. This is a type of geologic situation that I believe we may be in a position to exploit in our own area to our long term advantage.

5. I have long noted the general lack of surface runoff in the high rainfall and snow fall areas between the Sierra Crest and the South Fork of the Kern River, in particular from just west of 9-Mile to north of Tunawee. Believing this to indicate a possible major recharge to the hydrologic systems of our area, including the Coso hydrologic system, I tasked the U.S.G.S. to study the stable isotope chemistry of the Coso steam wells. The U.S.G.S. in an open file report concluded that the recharge to Coso comes from as far west as the South Fork of the Kern River. This conclusion has been independently verified by Geothermex, the consultants for Credit Suisse who are funding a part of the Coso geothermal project. The identical geometry applies to this valley and we too should be getting significant recharge from the Sierra west of the topographic divide.

6. When one looks at the hydraulic gradients present in the Sierra adjacent to our valley and Rose Valley, the probability of significant flow beneath the crest and into our area of potential exploitation becomes a near certainty. Gradients exceed 300 feet per mile, more than adequate for major flows eastward.

7. The Sierra Nevada is highly fractured. Contrary to uninformed popular belief it is not just the scattered large fractures that offer a major recharge potential, but the storage and flow potential of myriad micro-fractures are also very significant. These micro-fractured areas are seen as areas of subdued terrain as opposed to prominent blocky ridges. However, for the relatively small amounts of water we are trying to account for, a number of prominent large fractures will provide ready access for our basin to large areas of storage and recharge.

The structural geology of the Sierra Nevada is certainly important to us. If it is highly shattered along side of us, it will be a more prolific water storage unit and a more easily producible water source. If thrust faulted by older thrusts as many believe, these faults which dip gently west, some to rise in mid range, can serve as superb water collectors and aquifers. These types of thrusts have been mapped in our general area by Silver (Jawbone to Tehachipi), Hewett (near Tehachipi) and in our area by Austin for the EKCRCD, by Austin for LADWP and for private parties, and by Erskine for CECI. The reader should be aware that interpretations that the Sierra Nevada adjacent to this valley and to Rose Valley is a system of rootless granitic sills overlying marine sediments and that it is a complex thrust and tectonic denudation system including thrust faulting out over our basin is not some thing casually dreamed up by myself or by Ward Austin. That the Sierra is a complex compressional feature was published on by such great geologists as Baily Willis and Andy Lawson in the mid-1930's and noted by Mayo in the 1940's - I was required to familiarize myself with their work when I studied the geology of this area years ago under Dr. Armand Eardley - but what really raised my enthusiasm for this type of interpretation was my opportunity to learn that AMOCO in the early 1980's came to a similar conclusion as these earlier authors and that very extensive thrusting has been mapped in the Antelope Valley. If you wish to delve deeper into the structural geology of the Sierra as it affects the recharge and storage of our basin, you should obtain and carefully review the data of AMOCO, the studies by the consultants to the EKCRCD, the studies by the consultants to LADWP and to California Energy Company, as well as the recent work by the U.S.G.S. that discussed the rootless nature of the Sierra Nevada. Seeing as how the mineral developers active in this area have spent over $20,000,000 on the study of our geology and are developing drill hole data at the rate of $1/4 million per day, we would all be remiss to not carefully learn as much of what these people have learned as they are willing to show us.

It is not my role to convince you in a short talk that the Sierra Nevada in our area is a complex thrust system with great lystral faults and the like. I am perfectly aware of the local dissenting view and I am also very aware of the inability of what some might call the popular view to explain what we are seeing in the field in this area today.

If in fact the Sierra Nevada is stacked up thrust sheets, and some of the intensly shattered granitics extend out over valley fill next to this basin as various modern investigators have concluded, and similar structures involve Rose Valley as well, you would do well to carefully ponder what this means in terms of groundwater recharge, groundwater storage and in particular the produceability of Sierran derived ground waters.

To me the evidence for Sierran thrusting is strong enough so that with two geologists from Cal Energy I co-authored a paper on an overthrust model for this area in 1987. The Naval Weapons Center has published this paper, which was granted the best paper award at the Energy Minerals Section of the 1987 AAPG national meeting. Since preparing this paper, even more convincing data has been obtained that supports a thrusting model.

When someone comes before you to debate the structure of the Sierra, ask them to please explain such things as the data recovered from the NURE drill hole in Rose Valley. This hole showed no Sierran fanglomerates below a depth of 840 feet. Instead the hole went to 3400 feet in what looks suspiciously like marine sediments AND there could have been NO nearby mountains. Where were the mountains? A thrust model combined with lystral faults and slumping off of the east edge of the thrust sheet answers a great many questions we see in the field, far more than Gilbert's antiquated graben and horst model of 1872 that is still considered the popular model by some people.

The presence of thrusting and lystral faulting in the Sierra, regardless of the age of motion, (and in the Argus and Coso's as well) has created great potential aquifers. Let us try to identify them, and if they are there exploit them to our mutual benefit. Others are doing so in other basins - are we any less capable or must we founder in dogmatic bickering.

In addition to the granitic rocks of our region, our hydrology is involved with metamorphic roof pendant rocks. These rocks not only disrupt the granitics, leading to more intense fracturing and extensive faulting but the roof pendant rocks themselves provide great conduits into and out of our basin, especially to the south.

I believe that if people would carefully read a text such as "Naturally Fractured Reservoirs" and then apply the concepts presented to our geology as it actually exists they too would expect flow both into and out of our basin, not only in great open breccia zones, of which there are two very prominent ones that run from this basin north-westerly across the Sierra, but in broad zones of intense micro fracturing that are seen only as easily erodible areas of subdued topography. We are only just beginning to understand the lystral fault blocks that are a part of the margins and subsurface of Rose Valley, Indian Wells Valley and Searles Valley. As we learn how to incorporate these features into our models our search for added ground water should be even more effective.

<u>COSO BASIN RUN-Off</u>: I believe, based on structural geology and demonstrable flow patterns and water chemistry, that Thompson over estimated the recharge from Coso

Basin and that the chemistry of this recharge is not favorable. I also note that none of the published investigators - Thompson, Bloyd and Robson, and St. Amand recognized or understood the geology of the Coso geothermal system and its impact on the hydrology of the southern Coso mountains and the central Argus Range. This is not to imply criticism of these authors. It simply means they did not have adequate data and their papers are out of date.

GEOTHERMAL LEAKAGE: Along with other NWC geoscientists I some years ago published on the fact that there is geothermal fluid leaking into the main portion of Indian Wells Valley, derived from a reservoir at depth within the valley area. Indeed, the evidence suggests at least three areas of such leakage that are completely independent of the Coso geothermal system. Some people may not like it, but the groundwater hydrology of the Indian Wells Valley is intimately affected by active geothermal systems that provide exceptionally good water in some areas and very poor water in other flow cells, and that cause thermal upwellings bringing water of various qualities up to drillable depths in various parts of the valley.

LADWP LEAKAGE: LADWP is widely maligned as a divertor of groundwater from us. On the contrary, their aqueduct is a major asset to this valley. LADWP has in the past in meetings estimated the leak rate on the old aqueduct at 10%. If this is true, the 50 miles of the aqueduct that is in the Indian Wells and Rose Valley loses approximately 4000 acre feet per year which serves as recharge in both the Indian Wells and Rose Valleys. From the stand point of canal and aqueduct operation, a 10% leak rate is not unusual and canal systems and unlined or poorly lined tunnels give massive recharge wherever they are built. The aqueduct is a major recharge that no prior studies of the U.S.G.S. or the studies of St. Amand appear to have considered. I have seen no studies that would show how far east this recharge has migrated in the past 3/4 century or so, nor any studies as to which flow cells are being impacted although the pending maps under preparation by the University of Utah for the EKCRCD may give us this data.

I believe our basin definitely leaks into Searles Valley, as a major discharge and I strongly suspect there is major leakage south to the Koehn Lake/Cantil area. The leakage to Searles Valley can clearly be seen in the chemistry of the water in the Leslie Salt Well at the east end of Poison Canyon as an example. In addition, the metamorphosed sediments that extend south out of the Indian Wells Valley should be highly permeable zones that can transport water south.

In simple terms, I view Indian Wells and Rose Valley as an essentially continuous basin, filled with various types of sediments including marine and estuarine materials overlain with locally derived outwash from the present mountain systems. The present Sierra Nevada is a very young feature, shoved against and in some places out over these sediments. The sediments of Indian Wells Valley are folded into a series of anticlines which sharply affects flow cell geometry. Actually, in the subsurface, Indian Wells Valley looks like two adjacent valleys with a thin veneer of Sierran debris covering the complex of sediments below. Because of the thick sands seen in drilling Rose Valley, and reported in a drill hole in southern Owens Valley and because of the similarity of materials seen in drill holes in lower Centennial Flats there is a good possibility all of these areas are inter connected at moderate depths. Although cut by major fractures there is no geologic evidence these basins or any major segments of them are isolated by these fractures.

At our present level of knowledge, I believe it is safe to say we have extensive bedrock derived recharge into both the Indian Wells Valley and Rose Valley and that there is extensive flow from Rose Valley into Indian Wells Valley beneath the surface. I believe that there is far more natural discharge from Indian Wells Valley than is represented by the evaporation on the playa, and that to use the playa evaporation to estimate the recharge is conservative beyond good sense.

When I look at the Sierra and the recharge we should be getting from the entire accessible Sierran recharge zone, I estimate our locally accessible recharge to average at least 30,000 acre feet per year. That we do not see it on the playa is what one would expect, given experience in fractured bedrock systems.

People for years have asked me where to drill new wells and how to obtain more water resources to ensure the growth and stability of our area. I have believed and espoused for years that we should:

1. Carefully determine the fracture system of the Sierra Nevada so as to determine what fault zone aquifers might be accessible to us, so we can exploit them, including the near vertical breciated faults, the zones of micro-fracturing and as we come to recognize and understand them, the various thrust faults and lystral fault systems.

2. Carefully determine the chemistry, including stable isotope chemistry, of the water of Indian Wells Valley so we could determine sources and flow-cell boundaries within the basin, and place well fields in flow cells with a major recharge potential for good quality water.

3. Carefully determine the chemistry of the waters in the Searles Valley and Koehn Lake/Cantil areas so that this data combined with fracture data will enable us to locate significant discharge zones in which useful water is presently being lost, so that we can capture and use this water.

If one wants to intelligently expand the major well fields in this valley, the place to begin is to take the work of the EKCRCD on both fracture patterns and chemistry and try to select flow-cells with good recharge potential, little chance of rapid contamination and a minimum of potential for impact on neighboring well owners. It is unfortunate that a few strident individuals who have attacked the motives of the EKCRCD studies have caused considerable delay in the making available of this invaluable data that could be used right now to help select potential well field areas that not only make sense hydrologically but would be politically defensible as well. Indeed, no matter who does it, we badly need data on water chemistry and flow cell boundaries for continued sensible exploitation within this valley. We need intricate detail for the fracture and fault pattern of the Sierra Nevada and surrounding hills so as to identify the various types of bedrock aquifers present and so we can identify the major recharge and discharge zones that we can ultimately tap for the long term benefit of the valley as a whole.

There is no question in my mind that the water resources of Indian Wells Valley are finite and anyone who believes otherwise is indulging in wishful thinking. The question is how finite? When should we be concerned? Where can we produce more without undue impact on others?

By focusing on the playa discharge as the sole indicator of basin wide recharge, some investigators have fostered the notion of major overdrafts and impending crisis. I firmly believe that the scattered pumping depressions prove absolutely nothing with respect to possible overdraft. They simply prove heavy local pumping by a few big wells and clusters of wells, nothing else.

If we are all to be satisfied with a narrowing future, expensive bandaides and patches, squabbles and litigation then we should continue to ignore the potential for using the structural and chemical data of the type the EKCRCD is now trying to develop, for the purpose of finding major new and producible zones of water. If instead we all take an open minded look at this basin we can determine if we can expand our groundwater resources to ensure a much brighter future, allowing optimal development of our area, and use of our ground water resources to the fullest. The acrimony of the past few years has not helped any of us, and because of this acrimony it is not unreasonable to seek to obtain consultants who have broad experience with Regional Groundwater Flow Systems especially with interbasin transfer of flow and with flow systems involving fractured bedrock. Never lose sight of the fact it is difficult to find something you do not believe exists and we should choose our consultants to find answers, not support positions.

I have given you my general outlook on the hydrology of this region. I would in closing like to urge you to look at all the options for recharge and discharge. - Whether water district board or interested citizen, it is all of our jobs, in my opinion, to explore every reasonable geologic option for the production of water to support our valley. Your job is not to espouse any particular geologic fad, notion or philosophy. If I as a professional geologist with many years of experience with bedrock water flow systems and interbasin water flows can assist in taking the broadest and most potentially productive look at our Regional Groundwater Flow System, I would be a poor citizen indeed if I failed to offer my best professional opinion for consideration.

CARL F. AUSTIN