• wl's
• gradients to FCWD from upslope
• FI wl's

BAY DELTA WATER RIGHT HEARINGS, PHASE 5

REBUTTAL TESTIMONY OF STEVEN DEVEREL

San Joaquin River Exchange Contractors Water Authority, Exhibit 5(a)

My name is Steve Deverel. I submit this testimony for Phase 5 of the Bay Delta Hearings of the State Water Resources Control Board. My education and work experience is summarized in the attachment to this Testimony.

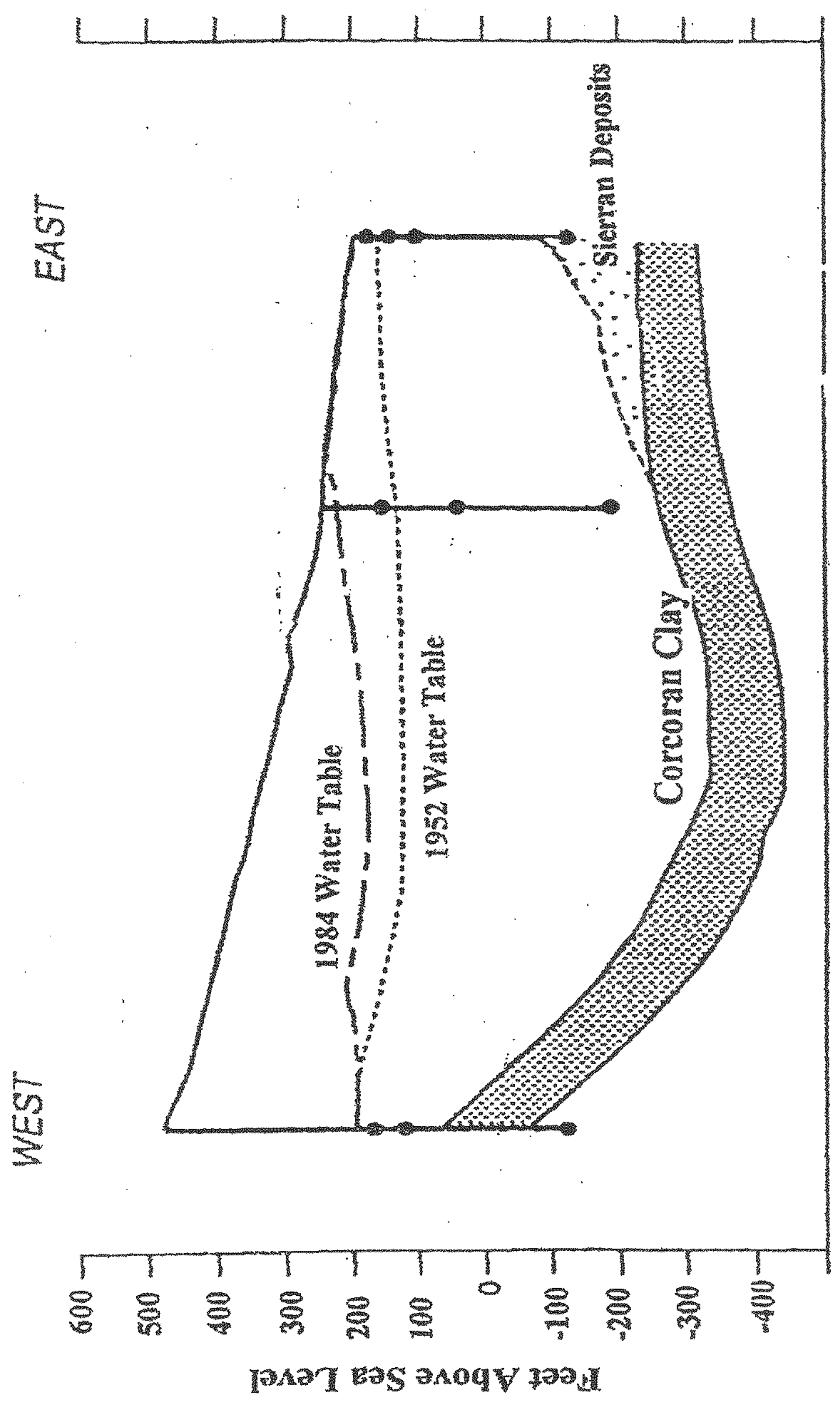
1. Is Mr. Hildebrand correct in stating that the ultimate and only real solution to the agricultural drainage problem in the western San Joaquin Valley is the construction of drains that convey saline drainage water out of the valley?

Yes. As Mr. Hildebrand testifies (Hildebrand testimony, Phase 5, pg. 5), it is true that for farming to continue in the western San Joaquin Valley in its present form, which includes many salt-sensitive crops, there needs to be an outlet for salt. Otherwise, lands will eventually become saline and non-productive.

In the western San Joaquin Valley, the salts come from the dissolution of soil minerals and the application of irrigation water. The salts dissolved from soil minerals are stored in the groundwater and continue to flow out the drains. These soil minerals are the primary source of selenium. Because of the lack of a drainage system when irrigation began upon these lands, there is now a large reservoir of salts stored in the shallow groundwater, these salts will continue to flow out to the drainage systems for decades into the future, even if there is little irrigation in certain areas. Emphasis on the application of new salts through irrigation water is therefore, in my opinion, less productive in approaching a solution then focusing on the concentrated salts in shallow and deep groundwater.

2. If a drain is not built, what will happen?

To answer this question, I need to explain a little bit about the groundwater hydraulics in western Valley. Because there is more water applied than can be used by the crop to leach salts from the soil, there is a constant increase in groundwater storage. This means that the water table is slowly and steadily rising, increasing the need for drainage and increasing the flow to existing drainage systems. This is illustrated by the following Exhibits.



From Dubrosvky and others, 1993, <u>in</u> Regional Groundwater Quality (Alley, edtior)

HYDROFOCUS

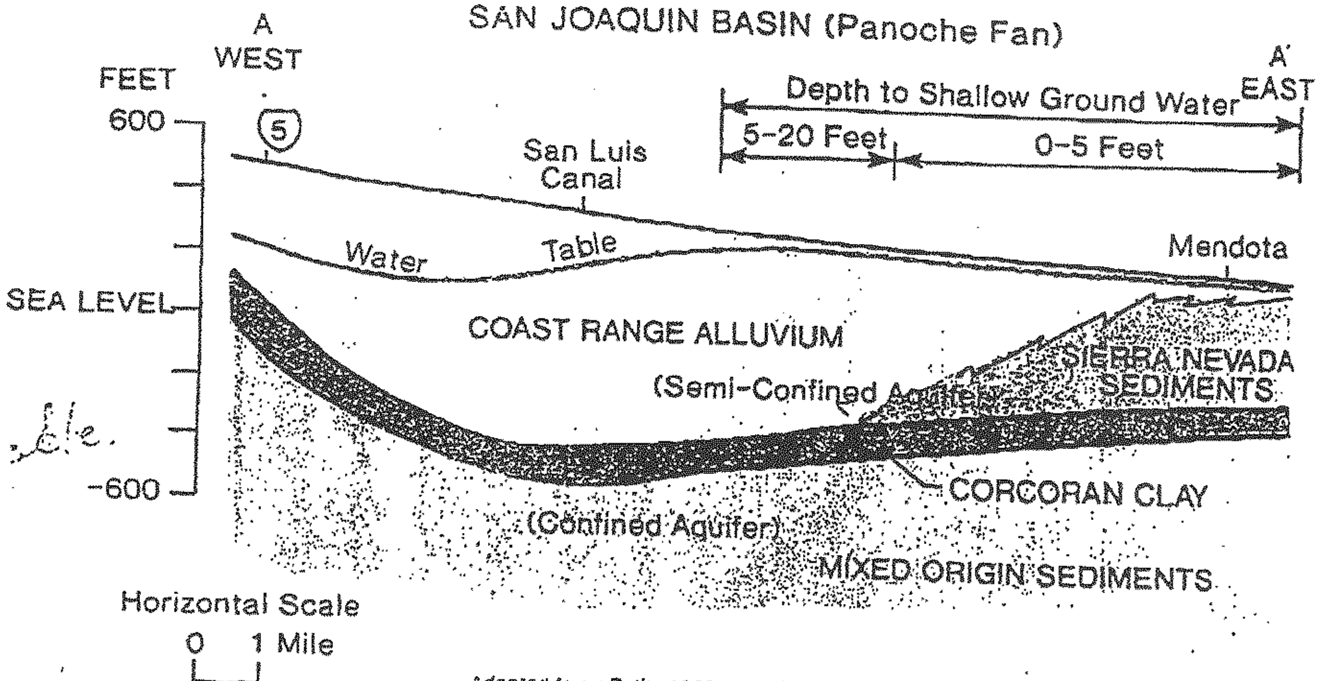
San Joaquin River Exchange Contractors Water Authority
Exhibit 5(b)

1 [Exchange Contractors Exhibit 5(b)]

Figure 4

GENERALIZED GEOHYDROLOGICAL CROSS-SECTIONS IN THE SAN JOAQUIN AND TULARE BASINS

(Locations Shown in Figure 6)



Adapted from: Belitz, 1988 and DWR, 1987.

1 [Exchange Contractors Exhibit 5(c)]

Because the water table continues to rise as it has done in the past, the hydraulic pressure on drainage systems will increase. The reason the water table was lower in 1952 was due to groundwater pumping. As pumping has decreased the water table has risen and will continue to rise. This rise in the water table was predicted by the San Joaquin Valley Drainage Program reports. This water table rise will continue now whether or not there is a drain. The San Joaquin River, if there is to be no Master Drain, will inevitably receive part of this drainage water.

With increasing volumes of drainage and increases in the water table, the need for an out of valley solution will increase.

3. <u>How does water conservation affect drainage, and is it a long-term solution?</u>

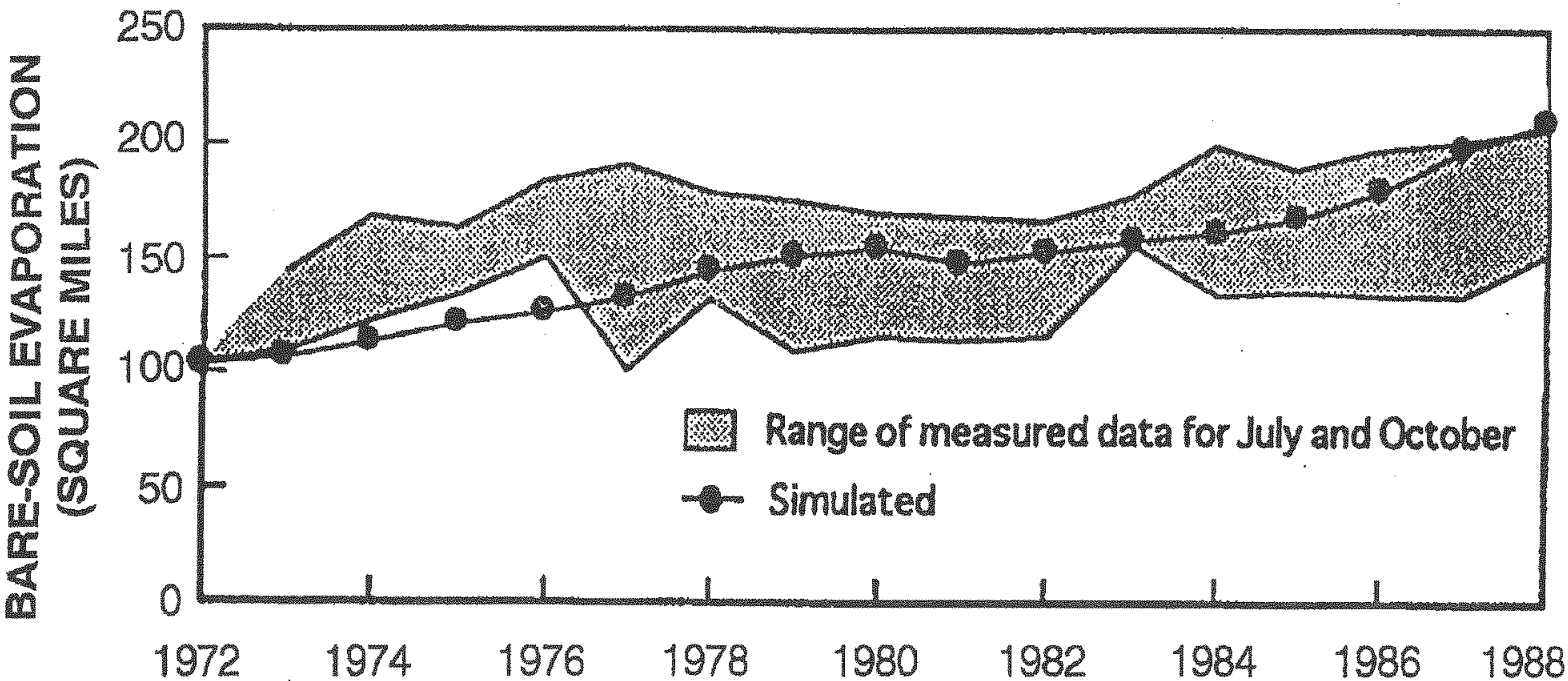
Water conservation in the short term can reduce the drain loads and volumes in certain areas. In other areas of the westside such as the Exchange Contractor's, deep percolation of groundwater is part of a conjunctive use program of groundwater use and as I will describe hereafter, conservation and <u>corporations</u> which interfere with groundwater recharge can compound the salinity problem. Because there is a need for water to move salts out of the root zone build up during crop production, and the underlying groundwater is in some places of poor quality and not fully utilizable, the water table on the westside will continue to slowly rise. Farming irrigated crops requires that some part of the applied water leaches salts from the root zone. Because of this, hydraulic pressure due to additions to the groundwater pressures on lowland areas where there are drainage systems will increase.

Continuing water conservation measures that reduce loads throughout the western Valley will reduce the deep percolation and flow to drains in some areas. However, this results in storage of salts in the subsurface that slowly move downwards and to the northeast. The rate of downward movement of water is about 1 foot per year. Groundwater flows laterally at rates of about 10 to 1000 feet per year.

4. <u>Mr. Hildebrand stated that water conservation and reduction of agricultural return flows on South Delta Water Agency lands generally does not result in reduced salt loading to the Delta and the San Joaquin River. Is this principle correct?</u>

The available data indicates that processes that reduce the amount of drainflow and agricultural return flows generally reduce the salt load to the receiving water. An important process that results in reduced drainage loads is water conservation. Empirically this is true because as flows decrease due to conservation measures or changing hydrologic conditions, loads are decreased. Therefore, anything that decreases the volume of return flow will decrease the salt loads. The following graphs for drainage from areas that contribute drainage water to the San Joaquin River in the Delta are illustrate the relation between loads and flows.

INCREASING NEED FOR DRAINAGE IN THE WESTERN SAN JOAQUIN VALLEY

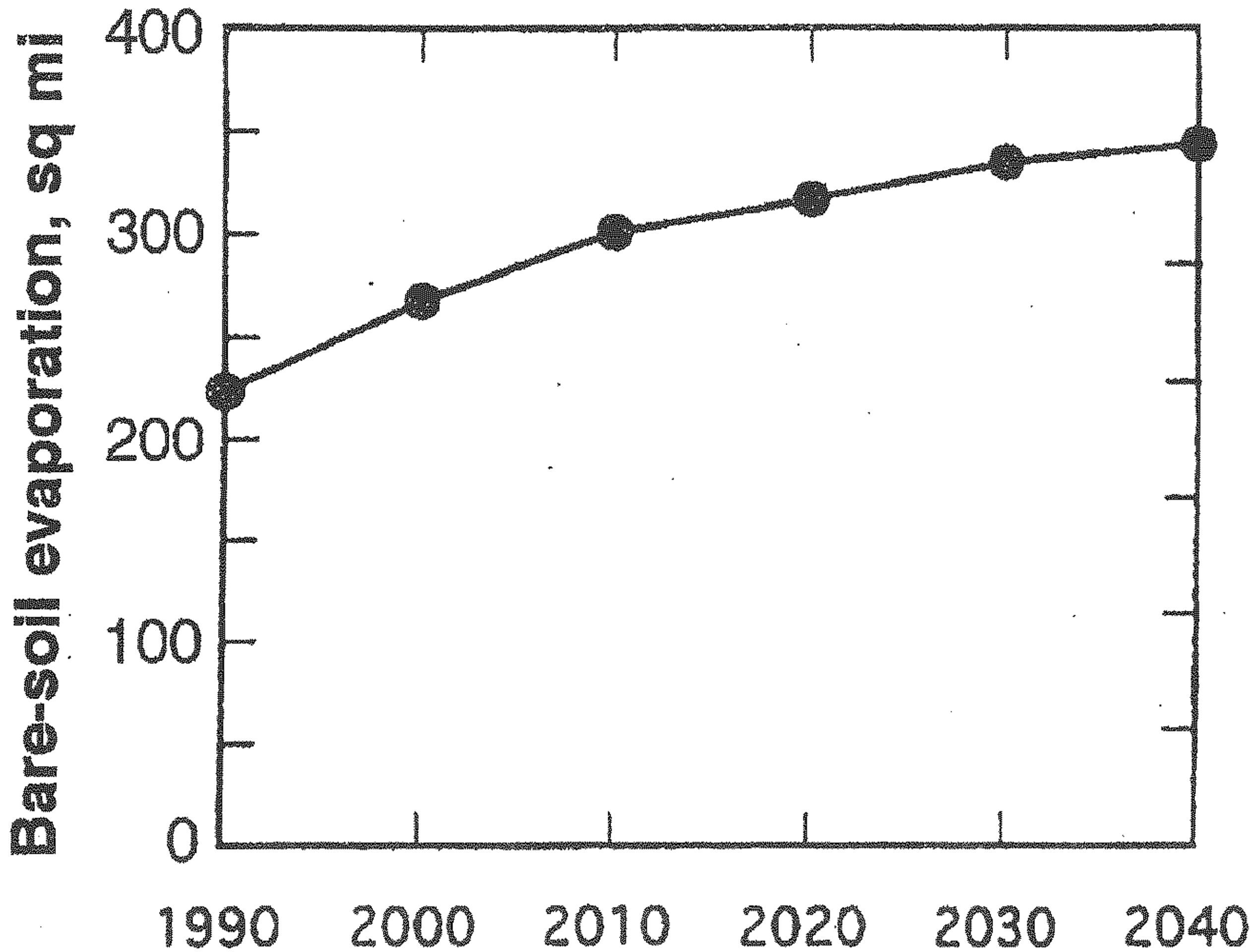


San Joaquin River Exchange Contractors Water Authority
Exhibit 5(d)

HYDROFOCUS

3

INCREASING FUTURE NEED FOR DRAINAGE



From Belitz and Phillips, 1995, Water Resources Research

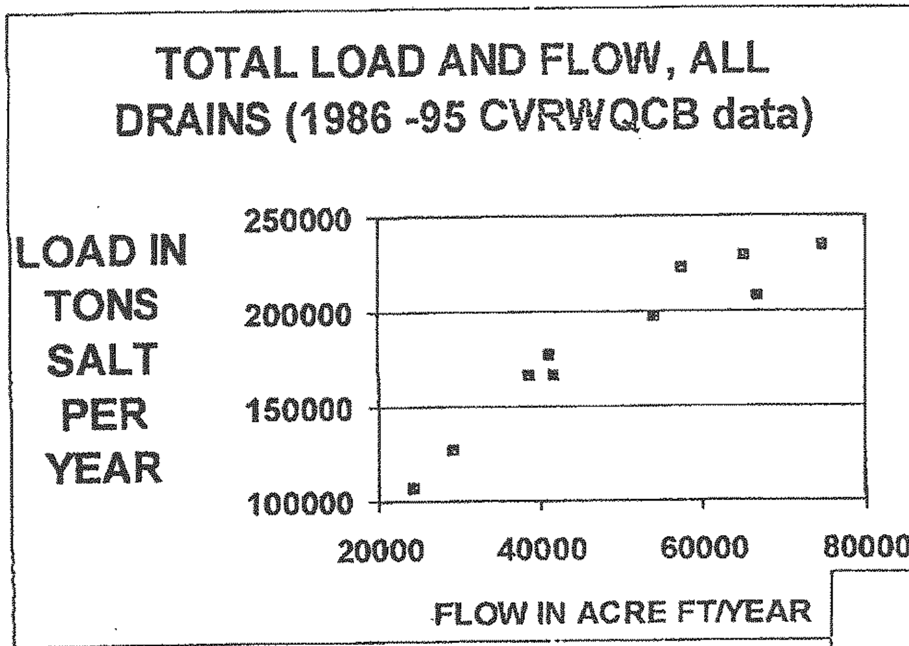
San Joaquin River Exchange Contractors Water Authority
Exhibit 5(e)

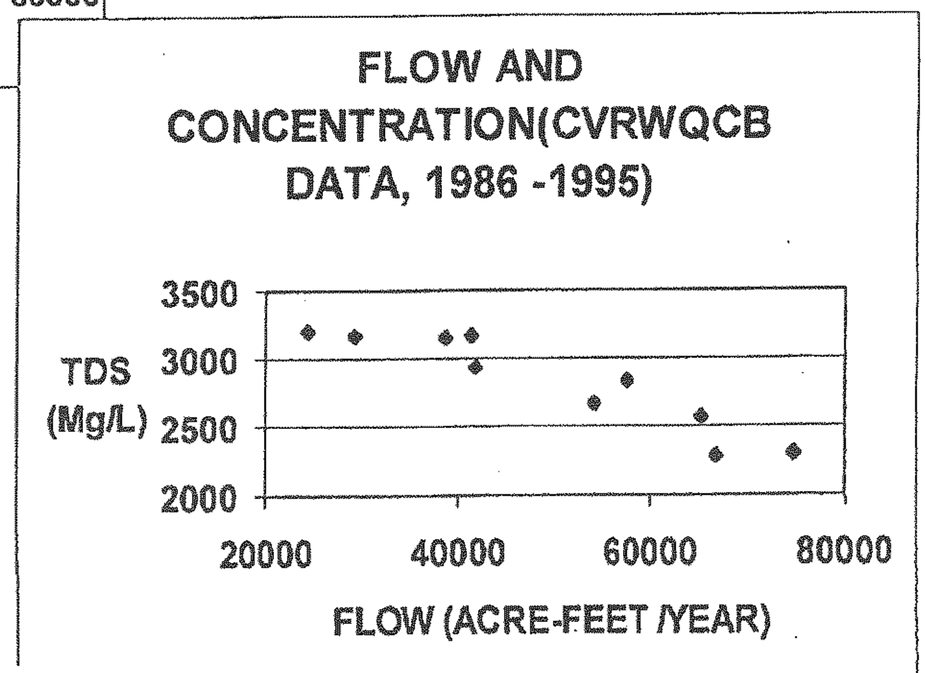
HYDROFOCUS INC.

[Exchange Contractors Exhibit 5(f)]

San Joaquin River Exchange Contractors Water Authority

FLOWS AND LOADS, GRASSLANDS AREA

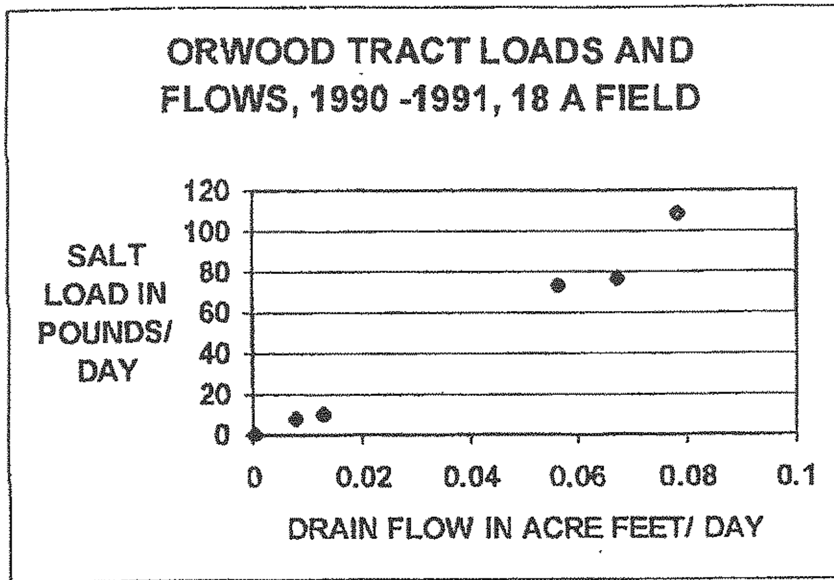


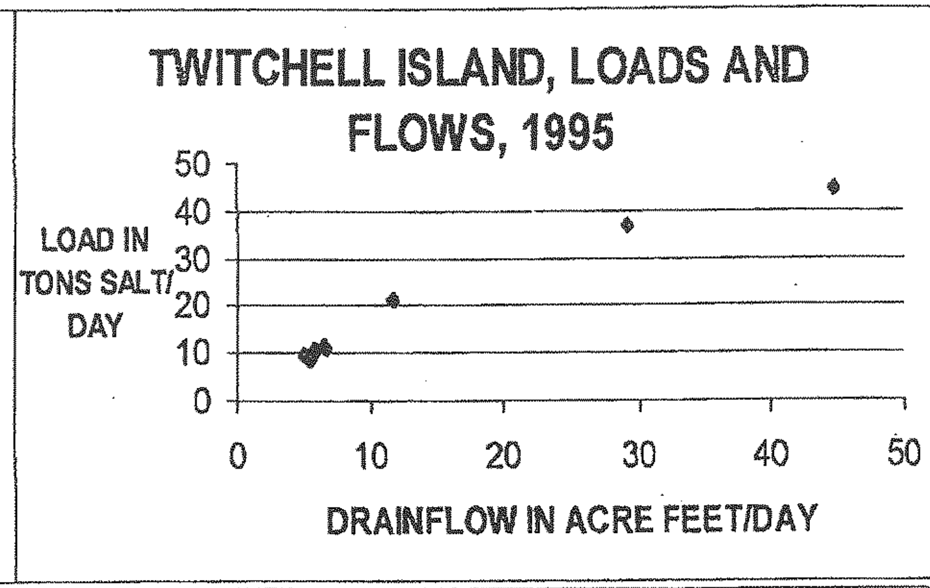


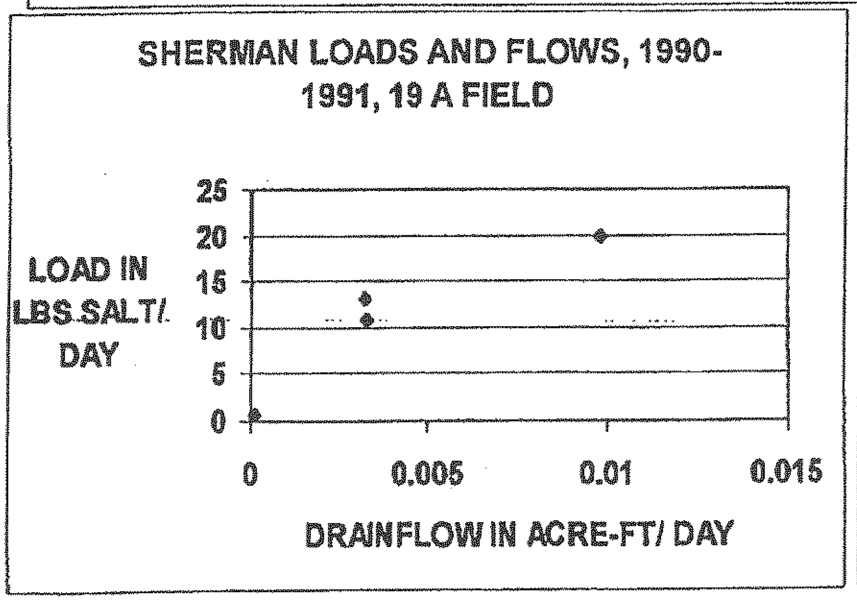
San Joaquin River Exchange Contractors Water Authority
Exhibit 5(f)

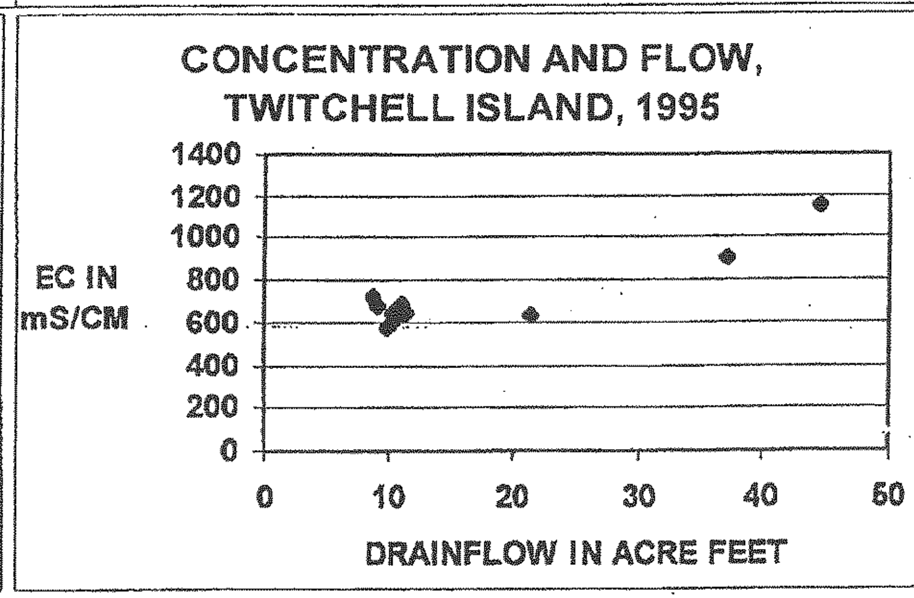
HYDROFOCUS INC

SALT LOADING AND FLOWS IN THE DELTA









From Deverel and Rojstaczer, 1996, Water Resources Research and USGS files

From DWR-MWQI Annual Report, 1997 and Templin and Cherry, USGS, WRI, 1997

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San Joaquin River Exchange Contractors Water Authority
Exhibit 5(g)

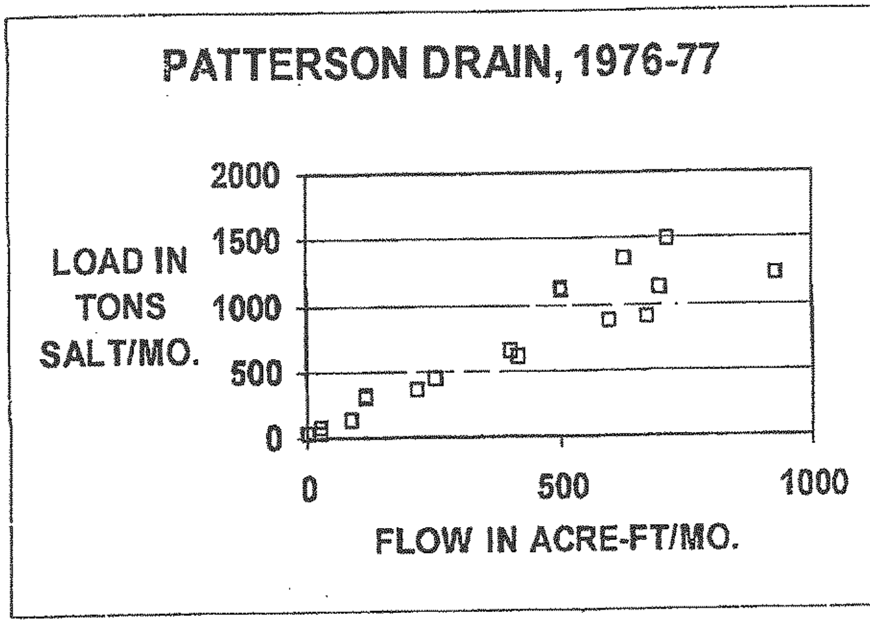
[Exchange Contractors Exhibit 5(g)]

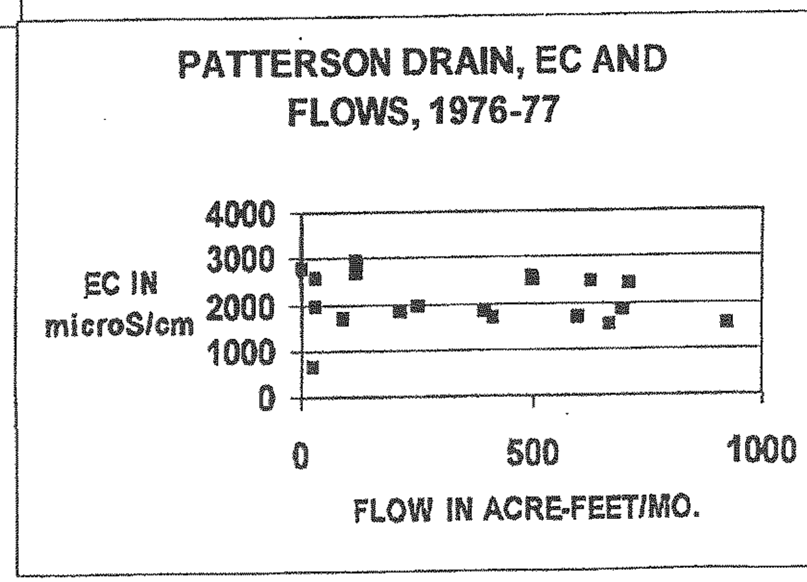
- Ques. 4

[Exchange Contractors Exhibit 5(h)]

San Joaquin River Exchange Contractors Water Authority

PATTERSON DRAIN, LOADS, FLOWS AND ELECTRICAL CON-DUCTIVITY





From CVWQCB, Irrigation Return Flow Monitoring, April, 1979

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For the Patterson and Grasslands areas, the concentration generally increases with decrease in volume of drainage water. However, the increase in concentration is not large enough to offset the decrease in load caused by the decrease in flow. On Twichell and other Delta locations, concentrations can increase with increasing flows.

5. <u>What are the processes that results in the load-flow relationship in which loads increase with increasing flows?</u>

The primary process is shallow groundwater flowing to the subsurface drains. Applied water is concentrated in the root zone and percolates to the groundwater where it can take several decades to move to the drainage outlets. Also, there are subsurface sources of salts in the San Joaquin Valley and Delta that can contribute to the salt load. Because there is often a groundwater source of saline water, the concentration in the drainage outlet is often higher than one would expect from the evapoconcentration of the applied water upon the same parcel of land.[Exchange Contractors Exhibit 5(i), 5(j), 5(k), 5(l), 5(m), 5(n)]

Drainage flows are influenced by saline subsurface flows in the Delta and the San Joaquin Valley. Indicators of saline subsurface flows include chemical indicators such as specific elements that originated in the groundwater or from the leaching of salt during the first decade of irrigation. The saline subsurface water flows steadily to the drainage systems and contributes substantially to the salt load. Because there are large volumes of saline subsurface water that flows to drain laterals and ditches, the dilution that occurs because of additional irrigation volumes does not greatly affect the concentration of the drainage effluent. Therefore the volume increase as the result of additional recharge increases the salt load.

6. <u>What Is the salt loading to the San Joaquin River and Delta Channels below Vernalis and in the Delta?</u>

The available data for salt loading to the Delta comes from three sources. These sources have widely varying methods of analyses, but each indicates that there are substantial benefits to be gained in attempting to manage salt discharges from South Delta and Central Delta lands. The USGS recently published a report on drainflows in the Delta. This, in combination with data collected by the DWR Municipal Water Quality Program can be used to develop loads for the Delta agriculture uses. The input files for the Delta Simulation Model also contain estimates for the drainloads.

I calculated the salt loading to the Delta channels for South Delta Water Agency based on the USGS data and the MWQI data for 1995. In 1995, it appears that the drainage from SDWA was about 0.63 acre-feet per acre based on data reported in the USGS 1997 report. However, the reported drainage volumes in the USGS report included less than one-half of the drainage pumps. At this rate, the salt loading from SDWA was about 141,000 tons in 1995.

Q5

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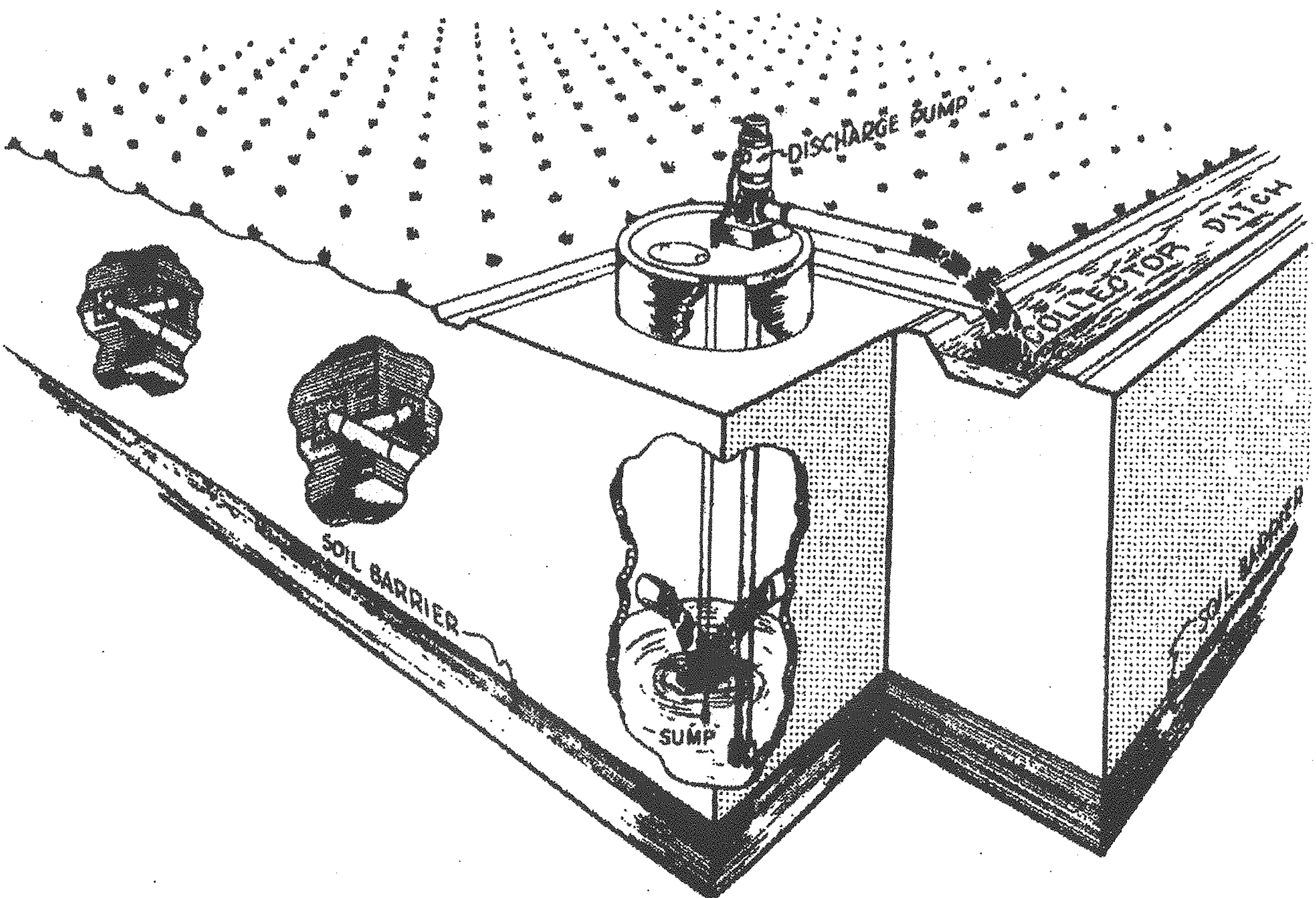
Solutions for Land and Water Resources



San Joaquin River Exchange Contractors Water Authority
Exhibit 5(i)

(8)

INFLUENCES ON DRAIN LOADS

- **The geometry of the drainage system and the distribution of the salt concentrations in the groundwater influence how loads will change with increasing flows.**
- **Deep drain laterals always have larger flows than shallow drain laterals because of larger hydraulic gradients.**
- **In this case, loads and concentrations in drain laterals increase with increasing application rates and recharge, because the changes in hydraulic conditions cause more higher salinity groundwater that is adjacent to the laterals to move to drain laterals.**

INFLUENCES ON DRAIN LOADS

- The average salt concentrations in the shallow groundwater immediately adjacent and below the drain lateral was 6,340 mg/L. The deeper groundwater was less saline (5,600 mg/L).

- The increasing hydraulic gradients cause increasing volumes of the higher salinity water to move towards the drain laterals, thus increasing the loads and concentrations.

INFLUENCES ON DRAIN LOADS

- In general, drain loads increase with increasing flow (i.e. increasing application and recharge rates) because either the decrease in the concentration caused by dilution is not sufficient to offset the increasing load caused by increasing flows and/or hydraulic changes caused by increasing application rates cause higher salinity groundwater to move towards drain laterals.

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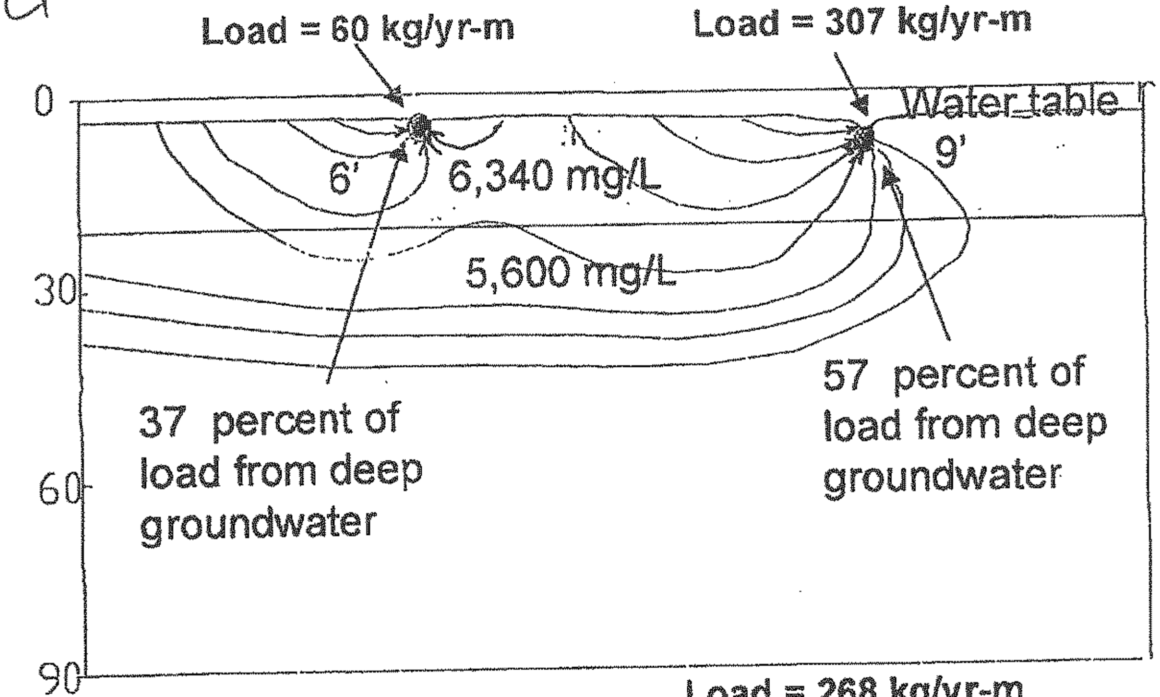
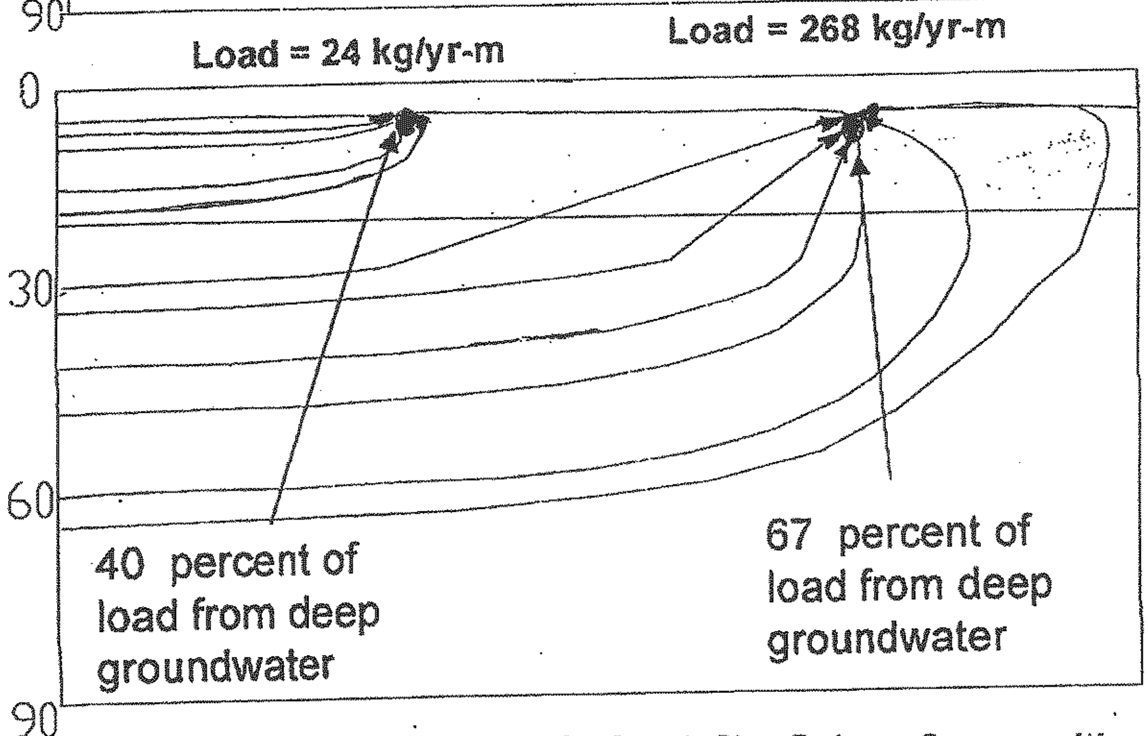
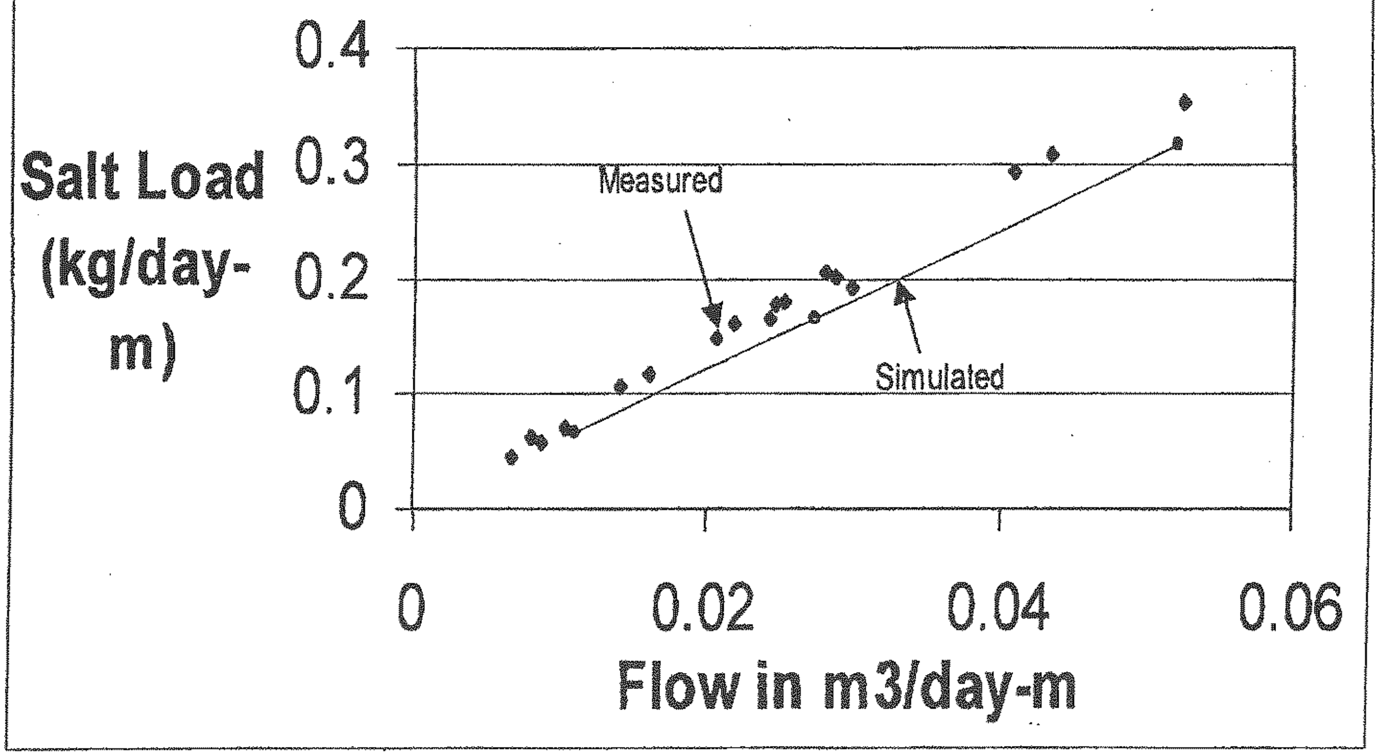


- Recharge = 0.5 ft/yr
- Upward flow of deeper ground-water is responsible for 37 and 57 of the salt load in the drain laterals.
- Concentric flow paths push more higher salinity groundwater towards drain laterals.
- Concentrations are 6,040 and 5,900 mg/L for the 6 and 9 foot laterals reflecting proportions of different sources of water.



- Zero recharge
- Upward flow of deeper ground water is responsible for 40 and 67 percent of the salt load in the drain laterals
- Salinity of deeper groundwater is less than groundwater ad-jacent to and immediately below laterals.
- Concentrations in drainflow are 5,980 and 5,830 mg/L, for 6 and 9 foot laterals.

Q5



Measured and Simulated Flows and Load, 26 A Field Near Firebaugh

This is in close agreement with the average load from SDWA estimated in the Delta Stimulation Model for 1922 through 1994 of 126,000 tons per year (see Exhibit 5(o)). However, the model-input data indicates that salt loads from SDWA were 271,000 tons in 1994. The exhibit below shows the annual agricultural return loads in the South Delta Water Agency. In 1995, if water diversions were 450,000 acre feet per year (SDWA -USBR,1980), about 191,600 tons of salt were diverted from Delta channels onto SDWA lands.

In the Central Delta, the quality of the drainage water is generally better than in the South Delta areas. In 1995 and 1996, the salinity of the drainage water was about twice the channel water or about 588 mg/l as per the MWQI report. Data for 1995 from the USGS Delta Drainage Report indicates that drainage in the Central Delta is probably about 2.3 acre feet per acre. This results in a salt loading of about 1 ton of salt per acre.

These estimates are not generally useful for the exactitude but to provide an estimate of what the salt loading is in the Delta. This and the data that shows a positive relation between flows and loads for the Delta demonstrate that reducing salt loading to the channels through reducing drainflows should be examined more closely, and that there are opportunities for reducing salt loads through conservation.

7. <u>What Does the Data Say about Sources of Salts in the Delta?</u>

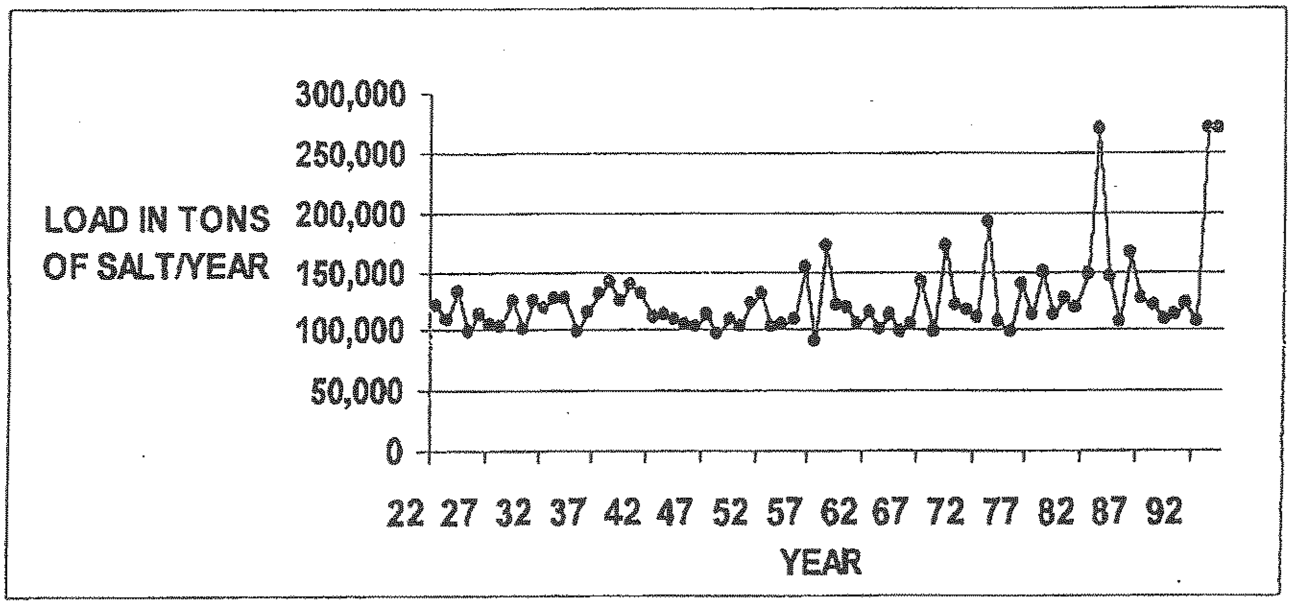
There are four sources of salts in agricultural return flows from irrigation in the Delta; (1) groundwater, (2) concentration of salts during crop growth, (3) oxidation of peat soils, and (4) dissolution of soil salts. The contribution of these four sources varies spatially.

Upward flow of groundwater to drainage ditches in the Delta is common and deeper groundwater can be more saline than shallow groundwater. [Exchange Contractors Exhibit 5(p), 5(q)]

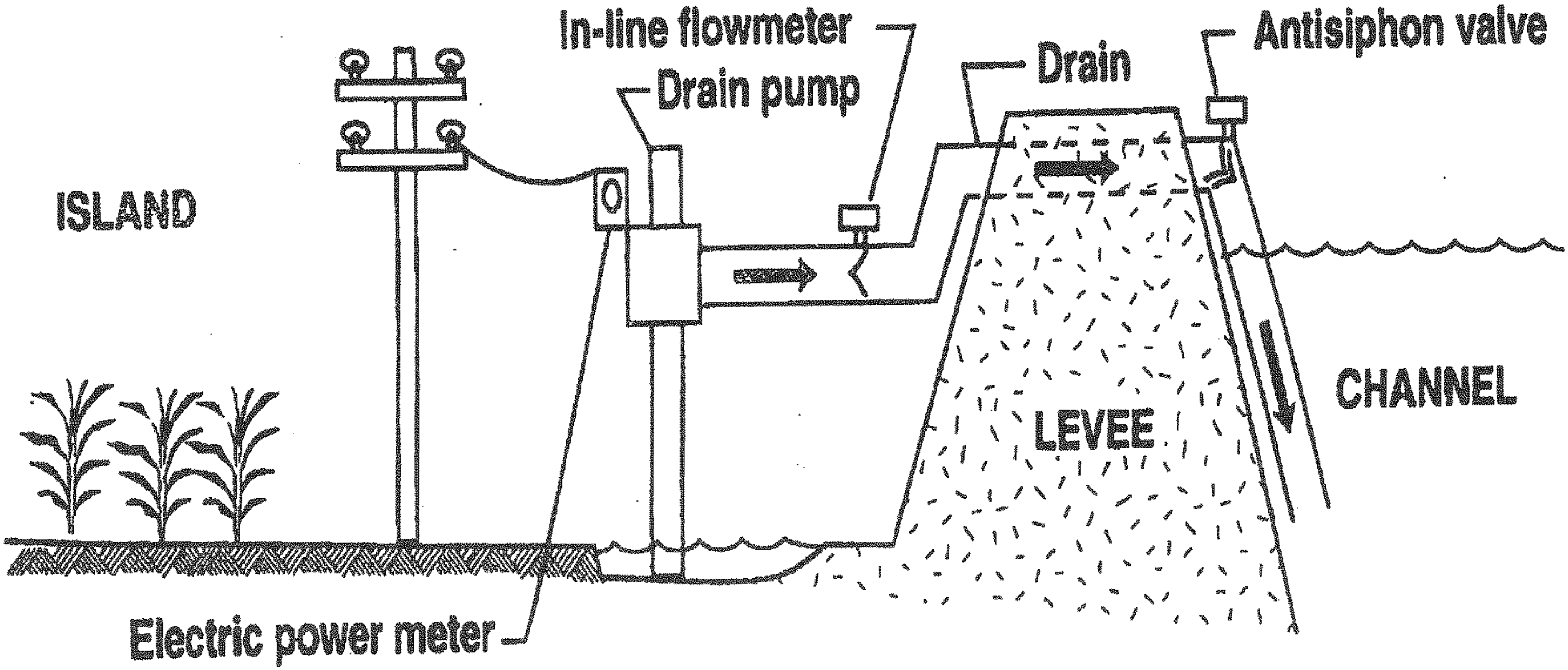
Peat soils are prevalent in the Delta. These soils are disappearing and result in decreasing land-surface elevations on Delta Islands which are between and 5 and 25 feet below sea level. The historic rates of subsidence varied between .5 to 4 inches per year but the rates have slowed in recent years. The present-day rates of subsidence in the central Delta are estimated to be about 1 inch per year. The disappearance of the peat soils and the lowering of the land surface results in seepage and hydraulic pressures on the Delta land and they need to be drained. The lowering of the land surface results in a need for lowering the elevation of the drainage ditches that collect subsurface drainage water and this results in water seepage onto the Islands. Also, when the peat oxidizes, salts are left behind. University of California researchers estimated based on laboratory experiments that peat oxidation could release 100 to 1000 pounds of salt per acre per year.

Question 6.

ESTIMATED ANNUAL SALT LOAD FROM SOUTH DELTA WATER AGENCY



DRAINAGE RETURN



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San Joaquin River Exchange Contractors Water Authority
Exhibit 5(p)

GROUNDWATER FLOW AND QUALITY ON BOULDIN ISLAND

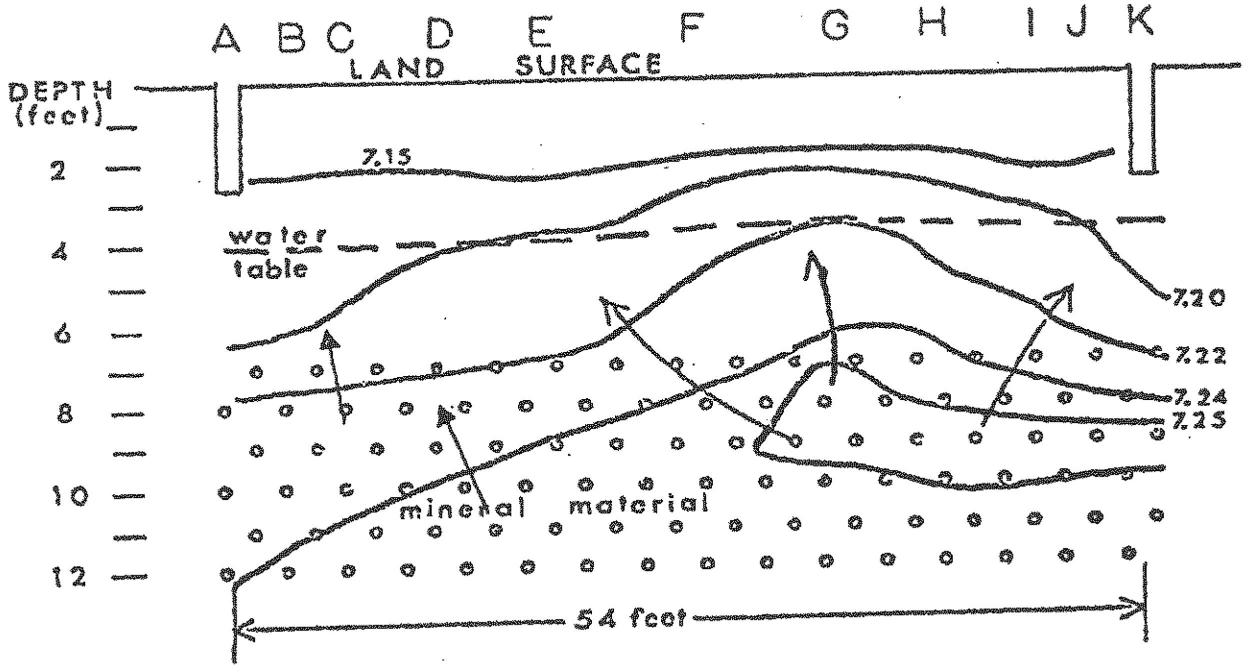
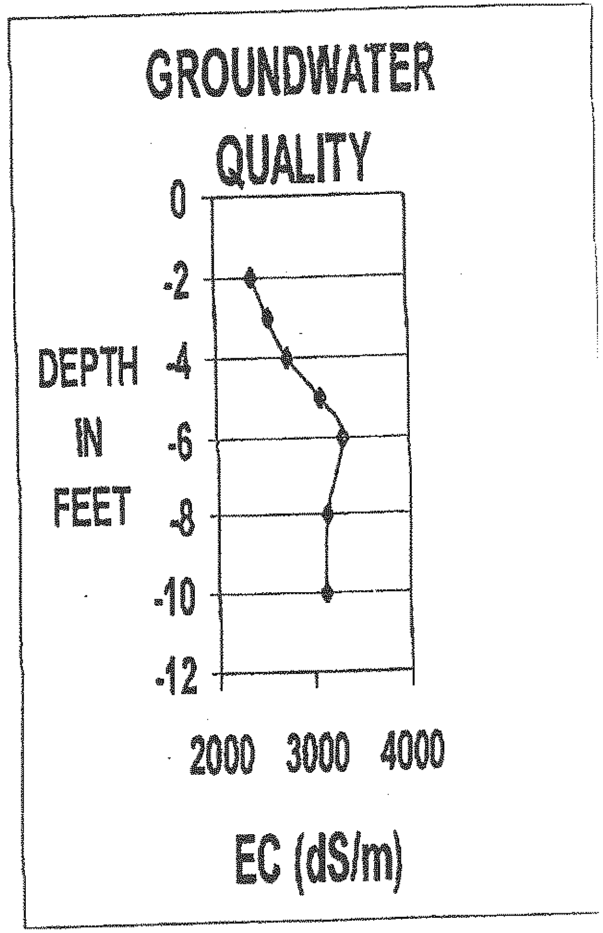


FIGURE 5. LINES OF EQUAL HYDRAULIC HEAD (METERS) PRIOR TO IRRIGATION- BOULDIN ISLAND.



From Hanson and Carlton, 1979, Progress report for Delta Salinity Study, UC Davis, Department of Land, Air and Water Resources

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In the South Delta area, the third source is the areas where there has been dissolution of soil salts as indicated by the presence of selenium. An example of this is in the New Jerusalem Collector Drain near Vernalis that discharges to the San Joaquin River. The average concentration of salts in samples collected from this collector drain in the 1980's was about 1,700 mg/L. The selenium concentration averaged about 5 ppb.

8. Mr. Hildebrand testified to no apparent benefit from conserving water in the irrigation of lands of the South Delta Water Agency on the San Joaquin River or from the Delta channels. Mr. McGahan seemed to be testifying that conservation of water and reuse of drainage water was a key part of salinity management in the Grassland Farmers project area. How does water conservation of irrigation water fit into reducing salinity concentrations and loads and improving the beneficial uses of San Joaquin River water in the area upstream of the Delta and in the South Delta area itself?

Answer: The available data indicates that anything that reduces the volume of the drainage water will reduce the load of salts in the drainage water in the Delta and the western San Joaquin Valley. Therefore conservation should in most cases reduce the instantaneous salt load to the receiving waters. The long-term salt loading to the river can be affected by movement of salt to the river in the groundwater. However, this is a very slow process because groundwater moves at generally slow rates. Generally, decreasing loads of salts in drainage water discharging to receiving waters will cause the concentrations in the receiving waters to decrease. It is important to evaluate the timing of the release of drainage water relative to the beneficial use and meeting water quality standards.

The flow to drains and residence time in groundwater of drainage water influences how changing water management practices will change the salt load in the drainage water. Because it often takes groundwater several years to several decades to flow to drainage ditches and laterals, the effects of changing the concentration of the salinity of the irrigation water takes a long time to show up in the drainage water. However, the hydraulic effects are immediate. In other words, if one applies less water this immediately translates to less drainflow. This drainflow/irrigation relation is somewhat befuddled in the Delta by the fact that some growers are pumping agricultural return flows from the other growers. Further evaluation of the effects of water conservation on drain loads and flows should be part of changing water management practices to reduce the salinity of Delta channel waters and will probably yield beneficial results.

Mr. Hildebrand, in attempting to be brief, and emphasizing that without a drain to the ocean it is inevitable that salt will reach the San Joaquin River, may be misunderstood. Timing of the salt discharge is important in all areas, and there is not perfect dilution of drain discharge. Just as the above graphs in Exhibit 5(f), (g) and (h) show, the more drainage water pumped from Delta and San Joaquin Valley lands, the more salt load discharge to the river or channel. In the Delta, not all of this salt is from current San Joaquin River sources. The water from one farmer's drain may without much dilution at all be picked up and put on another's farm land by an adjacent pump. There are also displacements in time. Salt applied with irrigation water may not be drained out for substantial periods, the receiving water quality may be higher in TDS at that time, and the compounding effect of high load drainage water and higher TDS receiving water may be greater.

Knowledge of the salt impacts of practices in the South Delta and management is likely to yield improvements in protecting beneficial uses. The Tidal Barriers Program is one element of a salinity management program. Changing water management practices in the South Delta Water Agency service area can be an extension of this program.

9. <u>Various witnesses talked about conservation. Isn't it just as simple as saying that everyone should conserve and use less water in irrigating their crops both from the San Joaquin River in the South Delta and on the westside of the San Joaquin Valley? Can't we extend this to idling certain farmlands and not irrigating them?</u>

<u>Answer:</u> Under the Exchange Contractors and other areas in the western San Joaquin Valley there is groundwater which is recharged from overlying application and is generally of good quality. The quality of this groundwater could be decimated over time by reducing applied water. If surface water is not available, the landowners will pump groundwater, increasing the rate at which the poor saline groundwater will flow laterally to the northeast and downward. (See Exchange Contractors Exhibit 5(g))

Reduction in surface water application in the Grassland Bypass area allows greater management flexibility, but it if goes too far groundwater will probably be applied to permit farming. This groundwater is of lower quality than surface water. Delivering less water to the western San Joaquin Valley, including the Grasslands Bypass areas, may result in the pumping of groundwater which in many places is of acceptable quality for irrigation. This will increase the downwards and probably lateral movement to the northeast of poor quality groundwater which is within 100 feet of land surface. Over time this will degrade the quality of the groundwater. The quality of this groundwater is already lower than surface water and may limit the growing of some crops.

Pumping groundwater would seem to solve the problem of rising water levels but it is a short-term solution. It will cause water levels to decline and reduce drainage loads. However, increased groundwater pumping will increase the rate of downward movement causing shallow saline groundwater to eventually reach well screens and decrease the quality of the groundwater. This process will probably take 50 to 100 years or more. However, poor quality water could move down well boreholes to deeper depths at a much faster rate.

Finally, various questioners asked about the ultimate water conservation by taking land out of production as a means of improving salinity in the San Joaquin River. There are some lands which, through irrigation, contribute substantial loads of salinity including selenium on their drainage water. Not irrigating those lands will reduce these contributions. (See Exchange Contractors Exhibit 5(h))

Key points with regard to land retirement in the western San Joaquin Valley and its effects on water quality:

1) Results of groundwater flow modeling by USGS indicated that retiring land will reduce but not eliminate the need for drainage and it will reduce drainflow only in areas where the land is retired. It will have little effect on the drainflow from adjacent lands, and it may not stop drainage which appears on or under the idled lands.

2) Retiring lands will not necessarily result in zero drainflow for those lands. Because of the influence of upslope hydraulic pressures, drainflow may continue, depending on the location of the drainage system.

3) If the drainage system of idled land is plugged, the water table can rise in the retired land and may result in increased concentrations in the shallow groundwater because of the evapoconcentration effects. These shallow waters can extend to surrounding areas.

4) The poor quality water underlying retired lands will continue to move downward and laterally in the groundwater system.

10. <u>What is in your view the proper interrelationship between the testimony of Mr. McGahan in regard to management efforts and the results of those efforts within the grassland farmer's or bypass area, the testimony of the City of Stockton requesting TMDL's be established up the San Joaquin River and the testimony of the South Delta Water Agency?</u>

Waiting for the Bureau of Reclamation to lead us to a new technological solution or to completion of the San Luis Drain has not worked. This Board, if it is unwilling to insist that a condition of holding the Bureau water rights is that it provide drainage facilities out of the valley to the lands served on the Westside of the San Joaquin River, some of which lands are within or adjacent to the South Delta Water Agency, must focus upon management efforts to reduce the impacts.

In the absence of a facility that conveys salts out of the valley, the question becomes how to equitably share the water among all stake holders during years in which it is scarce. In years when there is excess water, the quality is good enough for all stakeholders. In dry and critically dry years, there is not enough good quality water to meet all beneficial uses.

It is clear that a large part of the problem is the salt load from the western San Joaquin

Valley. It is not just the lands where there are drainage systems that influence this salt load, there are regional hydraulic influences and it requires a regional solution.

The imposition of TMDL's without a regional solution in place to meet the TMDL's will not solve the problem of not enough good quality water for all beneficial uses. The ideal solution must be precise, i.e., it must lead towards meeting the quality objectives without unduly penalizing dischargers. Thus there is a need for a regional solution that reflects the best understanding of the factors affecting drain flow and loads and how they influence the salt concentrations and loads in the river.

In the absence of a salt outlet, a regional solution will consist of six components to meet TMDL's in the short-term that reflect the current salinity objectives:

1. Land retirement
2. Reduction in surface water deliveries
3. Groundwater pumping
4. Water conservation
5. Management of the timing of discharges
6. Real-time monitoring of San Joaquin River water quality

As we have seen, the cause of the drainage problem is due to increasing groundwater levels throughout the region. Groundwater levels will continue to increase in the future leading to an increasing need for drainage and larger drainage volumes and loads. This trend can only be stopped and reversed by reversing the trend of increasing water levels in the western Valley. This can be accomplished through a combination of water conservation, land retirement and groundwater pumping. There are consequences associated with each one of these management options.

Water conservation reduces the volume of deep percolation which reduces the amount of groundwater rise. However, there will always be a need for leaching of salts from the root zone which requires water over and above that required for crop consumption. Also, irrigation can never be 100 percent efficient. These two facts lead to deep percolation which contributes to increasing groundwater levels. The bottom line is that even with water conservation, there is more water applied than leaves the system through groundwater pumping, groundwater flow to drains, etc., and water is being added to the groundwater which causes water levels to rise.

Pumping groundwater would seem to solve the problem of rising water levels but it is a short-term solution. It will cause water levels to decline and reduce drainage loads. However, increased groundwater pumping will increase the rate of downward movement causing shallow saline groundwater to eventually reach well screens and decrease the quality of the groundwater. This process will probably take 50 years or more.

Land retirement can also help in some cases but it only reduces the drainage loads from fields that are taken out of production. It can reduce the rise of the water table if large parcels of land are retired and the water is removed from the region. What lands are removed from production will influence how the water levels will change.

In the short-term, real-time monitoring of the river flow and quality and timing of discharges to meet the assimilative capacity and water conservation measures can probably result in meeting or coming close to meeting the standards in the river. However, in the long-term, water levels in the valley will continue to rise and drain flows and loads will increase, making it increasingly difficult to meet the water quality standards in the river. In the long-term, without an outlet for salts, the most probable way to address the problem will be land retirement, although groundwater pumping may play some role. With both of these, highly saline groundwater will continue to move to drains and/or pumping wells. The exact scenario of what and how much land is retired will influence the movement of groundwater and drainflow. Without an outlet, the saline water remains in the western Valley where it can continue to move and affect beneficial uses of surface water and groundwater.

11. In the cross examination by Westlands Water District and Direct Examination of the Regional Board personnel there was reference to evidence as to whether any substantial portion of the saline water entering the San Joaquin River, either as surface water or accretion, originated in the Westlands Water District. In the testimony of Mr. Delamore of the Bureau of Reclamation there was reference to the uncertainties in regard to how irrigation of acreage upslope of downslope acreage, and the idling of parcels located in either area, affects drainage and San Joaquin River Water quality. There have been numerous references to the Rainbow Report.

Could you please answer in brief fashion a few selected questions in regard to this system in which salinity is moved and transferred from one area to another, and what your work tells you is likely to develop if there is no Master Drain?

1. Is there a groundwater divide, as Mr. Johnson has described it, and if so when did it exist, and does it have any significance in understanding how shallow drainage water moves downslope toward the San Joaquin River?

Answer: It was identified using data from 1984. It has not been studied in any detail since that time and may have moved. The mound probably has some relationship to the leakage from the California Aqueduct. It also has some relationship to filling of the aquifer which has occurred as a result of abundant deliveries of surface Water to Westlands and other San Luis Contractors in the 1960's and 1970's and early 1980's, deliveries from the Delta Mendota Canal in the 1950's, and relaxation of pumping of groundwater in the San Luis Unit and Delta Mendota Canal Service Area.

It tells us the likelihood of direction of flow of a particle of Water in the saturated zone, but it tells us nothing about the direction of flow of a particle of saline Water reaching a strata, clay lens or shallow Water barrier above the saturated zone. The migration time of a particle of Water that in fact arrived in the saturated material which is dense and which particles do move slowly would be very gradual toward the West or East depending upon the mound location and the area the particle descended to.

Along the whole frontage of the San Luis Unit with the Exchange Contractors there are sand and gravel lenses located at shallow depths and there are shallow clay layers. There is a hydraulic gradient to the East in these shallow geologic features, and there are calculations which have been done by myself and experiments and calculations by Mr. Kenneth Schmidt, a groundwater hydrologist working for the Firebaugh Canal Water District.

In 1988, Mr. Schmidt installed and monitored shallow groundwater wells along the boundary between Westlands Water District in the Firebaugh Canal Water District. He calculated that approximately 1000 acre feet of Water per annum of poor-quality Water with an acreage salinity of 3,700 mg./lt. and with selenium in the range of 6 to 142 ppb could be calculated to flow in these shallow lenses and above these shallow clay layers.

I have personally done calculations preparatory to the subsequent phases of the Trial to be conducted by Judge Wanger when the appeals to the Ninth Circuit are completed which confirms this observation along the whole boundary of the San Luis Unit lands and Firebaugh Canal Water District and CCID.

I have also been asked if I could quantify the load of salinity and selenium that enters along this boundary by downslope migration compared to the drainage load leaving Firebaugh Canal Water District as an example. Downslope migration does not explain all of the load but a part of it is from this shallow downslope flow, in the range of 20 to 40%. We will talk about the load that cannot be explained by these shallow migrating waters in a moment.

2. <u>Does the groundwater Ridge or Mound also tend to distract attention from the pressure effect of the ridge and mound and the saturated ground Water levels upon the salinity flows to the San Joaquin River in the downslope areas?</u>

The ground Water ridge may take the eye of the beholder off of the other significant effect of groundwater elevations in the upslope area. Elevations of groundwater in saturated areas in upslope areas are higher than elevation in lower areas. Although a particular particle of Water will take many years to migrate, in saturated soils pressure is very quickly transmitted to areas of lesser pressure. That is what is happening here. Pressure transmitted from high areas to low areas as an example will cause poor quality Water to show up in surface drain and be counted as load. A particle of poor quality Water may have originated from farming the downslope areas or migrated in the shallow geological features from upslope, but the pressure causes it to rise into the tile drainage and surface drain and flow out.

3. <u>Have pressure gradients changed over time in this area because of groundwater elevation changes and irrigation? If so, how did they change?</u>

<u>Answer:</u> Briefly, under pre-development conditions, groundwater flowed from the Coast Ranges to the valley axis and discharged in sloughs, wetlands and the San Joaquin River. The Exchange Contractors had to provide some drainage to allow agriculture in the form of ditches and there was some groundwater pumping the late 1800's and early 1900's.

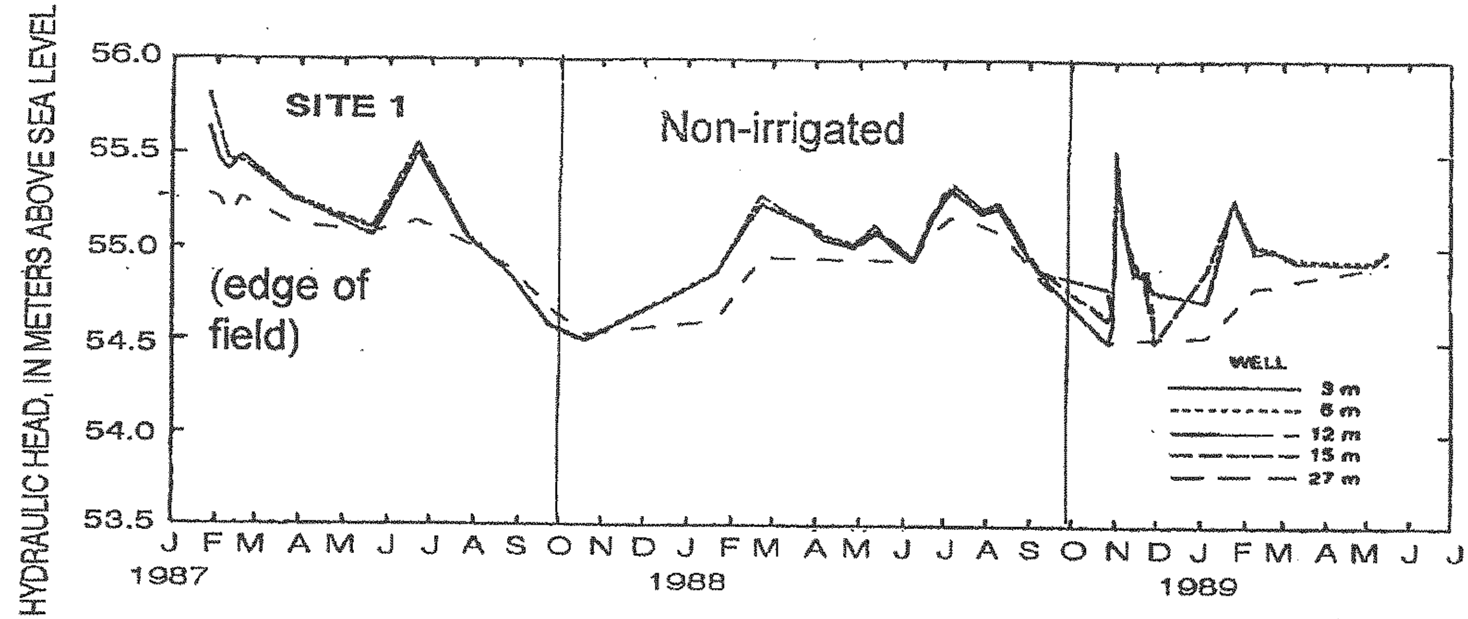
Pumping in the western Valley increased rapidly after World War I and reached a peak in the 1950's and 1960's prior to delivery of DMC and SLC water. This caused lowering of the water levels in confined zone and lowering of the water table in many areas of the western Valley. The upslope pressures on areas in the trough of the valley from upslope areas were probably non-existent during this time.

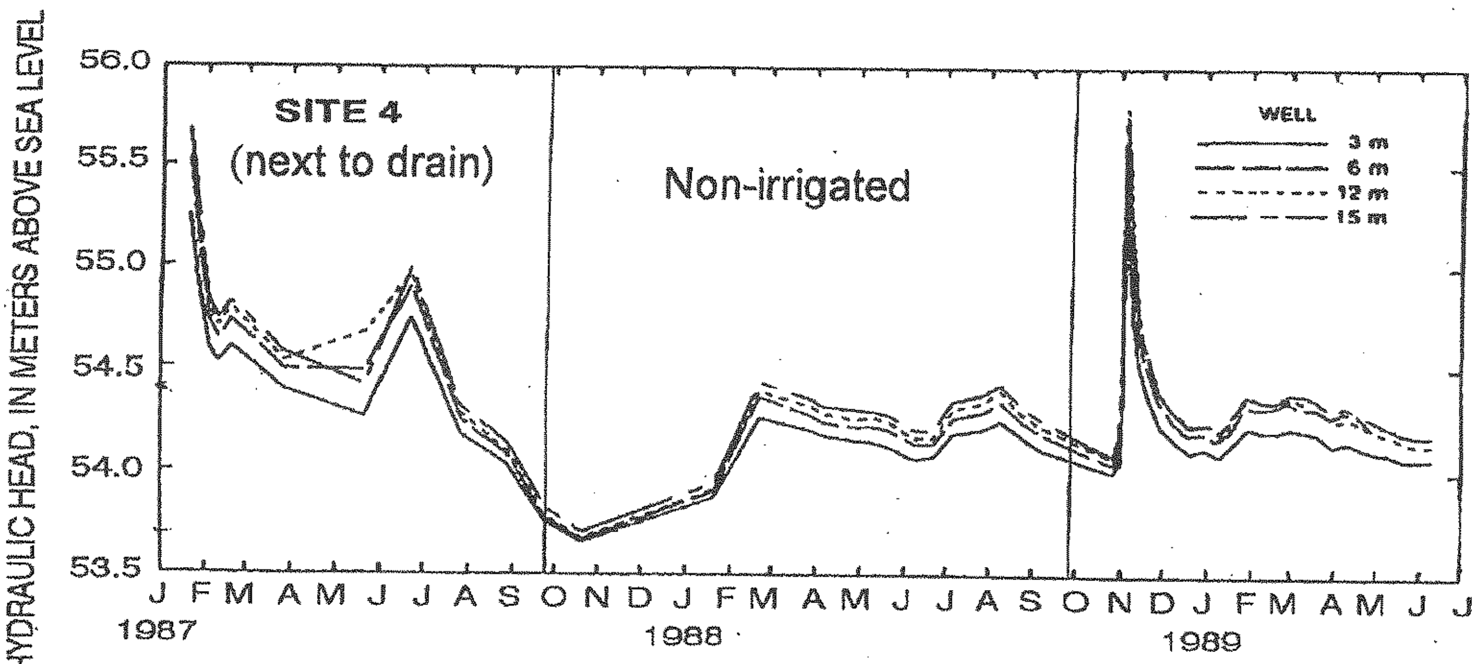
Pumping decreased substantially during the 1950's and 1960's as surface water was delivered and groundwater water levels rose. This rise in the groundwater levels continues to occur and has caused increases in pressures in downslope areas which have contributed to drainage flows.

4. <u>Have you and your associates at the USGS done tests to show the current interrelationship between irrigation upon upslope lands and Water appearing in tile drains and in surface drains upon lands located some distance away, downslope?</u>

<u>Answer:</u> Yes. In 1988 and 1989, John Fio and I conducted studies upon certain lands within the Broadview Water District which were not irrigated. Shallow monitoring wells were installed and the results published in 1991. Exhibit 5(r) graphically depicts the results of irrigation upon upslope and surrounding lands shallow groundwater underlying this unirrigated parcel.

HYDRAULIC EFFECTS OF UPGRADIENT IRRIGATION





San Joaquin River Exchange Contractors Water Authority
Exhibit 5(r)

1. The top figurehead of Exhibit 5(r) shows that even though the field (located just west of FCWD in BWD) was not irrigated during the 1988 water year, water levels rose about 0.75 meters, or about 2.5 feet, in the wells installed at the edge of the field due to upslope irrigation.

2. Although the water levels were lower in the wells next to the drain lateral, there was also about 2.5 feet of rise during the irrigation season. Water levels in this well are lower because it is adjacent to the drain lateral which flowed during the entire water year due to the hydraulic effects of upslope activities.

3. The water levels in the wells at the site near the drain change faster than at the site at the edge of the field (e.g. November, 1989) because the drain laterals collect the groundwater and cause water levels to drop.

CONCLUSIONS

1. Management of irrigation practices, recirculation of tile drainage water, and reconfiguration of surface water and tile water recovery systems can reduce loads of salts reaching the San Joaquin River. The individual farmer with tile drainage leaving his property has some but not total control over the load and volume of drain flows.

2. Surface water was delivered to the western San Joaquin Valley to alleviate the problems of groundwater overdraft and to increase the agricultural acreage and water quality for agriculture. The consequences of this action (the increased need for drainage) were apparently not fully considered or if considered, the appropriate actions for mitigating the consequences were not carried to fruition. The government sought to increase agricultural production but left out a key part of the equation which is making sure that there was to be adequate drainage.

3. An operable drain which removes salt from the Valley is the only way the agriculture in its current form which includes raising crops sensitive to salts can continue in the western San Joaquin Valley. Management, monitoring, and reduction of the volumes of drainage flows will help in the short-term. In the long-term, more drastic measures will have to be used.

STEVEN JOHN DEVEREL

QUALIFICATIONS

Over 14 years of problem-solving experience in soil- and water-related issues. Specific areas of expertise and experience include the following.

- Extensive hydrologic knowledge and experience in the Sacramento-San Joaquin Delta and San Joaquin Valley.
- Extensive experience in the analysis of water quality data for surface and ground waters.
- In-depth knowledge of statistical techniques for hydrology and water resources.
- In-depth knowledge of chemical and physical processes affecting flow and transport of chemical constituents in the saturated and unsaturated subsurface.
- Ability to use and develop analytical tools and numerical models for the simulation and analysis of flow and transport in saturated and unsaturated subsurface.
- Ability to present understandable technical results to all audiences orally and in writing.
- Ability to identify client needs and help them solve problems.
- Broad academic background and professional experience

PROFESSIONAL EXPERIENCE

2/1996 to present **Consulting Hydrologist in Private Practice** *Davis, CA*

Consulting assignments include the following.

- Evaluates groundwater flow and solute transport in the San Joaquin Valley.
- Assesses subsidence mitigation strategies for the Sacramento-San Joaquin Delta.
- Evaluates pesticide transport in groundwater at EPA Superfund Site in Davis, CA.
- Evaluates water quality and hydrologic effects of gravel mining near Chico, CA.
- Directs field evaluation of subsidence mitigation strategies in the Sacramento-San Joaquin Delta.
- Quantifies amounts and causes of subsidence in the Sacramento-San Joaquin Delta.
- Develops groundwater management strategies in Yuba county.

1994 to 1996 **Senior Hydrologist** *Hydrologic Consultants, Inc., Davis, CA*

Consulting assignments included the following.

- Evaluated sea water intrusion, nitrate contamination and ground-water flow in the Salinas Valley, CA.
- Evaluated water supply and quality issues in the Santa Ynez Valley, CA, related to the sharing of water resources among competing interests.
- Developed water resources element of City of Lompoc General Plan.
- Advised California Department of Water Resources on issues relating to subsidence in organic soils in the Sacramento-San Joaquin Delta.
- Evaluated ground-water transport of pesticides at EPA Superfund Site in Davis, CA.
- Served as expert witness for litigation involving drainage issues in San Joaquin Valley.
- Evaluated geochemical processes and groundwater flow for gold mining operations in northern Nevada.

1991 to 1994 **Supervisory Hydrologist** *U.S. Geological Survey, Sacramento, CA*

Assistant District Chief for California. Managed and led hydrologic research, investigations and data collection programs throughout California.

- Directly supervised and planned research on the effects of different land- and water-management practices on subsidence and carbon fluxes in the Sacramento-San Joaquin Delta.
- Coordinated interaction among diverse projects and personnel.
- Coordinated with resource management community to develop and maintain projects that advanced relevant understanding of processes affecting water and land resources.
- Communicated research results to the resource management community and other audiences through published reports and oral presentations.
- Developed long range plans for research and data collection activities.
- Responsible for over 100 employees and a budget of over $11 million.

1984 to 1991 **Project Leader** *U.S. Geological Survey, Sacramento, CA*

Led study of physical and chemical processes affecting the mobility and transport of chemical constituents in aqueous and gaseous phases in soils and ground water as affected by irrigated agriculture on the west side of the San Joaquin Valley at regional, subregional and local scales. Led an interdisciplinary team that effectively integrated physical and chemical data and analyses from different scales of observation to:

- define movement of water and solutes to agricultural drainage systems,
- define processes affecting the mobility of trace elements in ground water and soils, and
- assess statistical methods for the analysis of spatially variable chemical data.

Led study of carbon fluxes and subsidence in organic soils in the Sacramento-San Joaquin Delta. Accomplishments included the following.

- Defined processes affecting subsidence.
- Defined carbon fluxes from drained and irrigated organic soils in relation to subsidence and the global carbon balance.
- Developed water and land management strategies that will reduce subsidence.
- Identified influences of changing water management practices on drainage water quality.

1980 to 1984 **Research Associate** *University of California, Davis, CA*

- Developed computer code for the simulation of solute transport and chemical reactions occurring during the soil reclamation process.
- Designed and conducted laboratory and field experiments to study water movement and chemical reactions in soils and ground water in the Sacramento-San Joaquin Delta.
- Completed Ph.D. dissertation on soil and groundwater chemical reactions in the Sacramento-San Joaquin Delta.

ACADEMIC BACKGROUND

Ph.D., June, 1983, Soil and Water Chemistry, University of California at Davis
MS, September, 1980, Soil-Plant-Water Relations, University of California at Davis
BS, December 1979, Agricultural Science and Management, University of California at Davis
BA, June, 1974, Zoology, University of California at Berkeley
Instructor, " Ground-water Solute Transport Concepts", USGS, 1988 -1994
Lecturer and Associate, University of California at Davis, 1988-1992

VOLUNTEER mediator, City of Davis, 1994 to the present

PUBLICATIONS: Authored or coauthored over 30 journal articles and reports .

LANGUAGES: Portuguese spoken, written and read fluently.

PROFESSIONAL AFFILIATIONS: Member American Geophysical Union and International Association of Hydrogeologists

AWARDS AND HONORS

Miller Plant Science Award, University of California at Davis, 1979; U.S. Geological Survey Special Achievement Awards, 1985,1987 ,1990, 1991; Letter of appreciation from Assistant Secretary of the Interior, 1985. Biography in "Who is Who in the West", 1992-1995

PAST AND PRESENT CLIENTS INCLUDE THE FOLLOWING

Alta Irrigation District, Dinuba, CA
Boyle Engineering Corporation
California Department of Water Resources, Sacramento, CA
Frontier Fertilizer Superfund Oversight Group, Davis, CA
Knife River Mining Company, Bismarck, ND
Minassian Law Firm
Reclamation District 1601, Rio Vista, CA
San Joaquin River Exchange Contractors Water Authority
South Yuba Water District

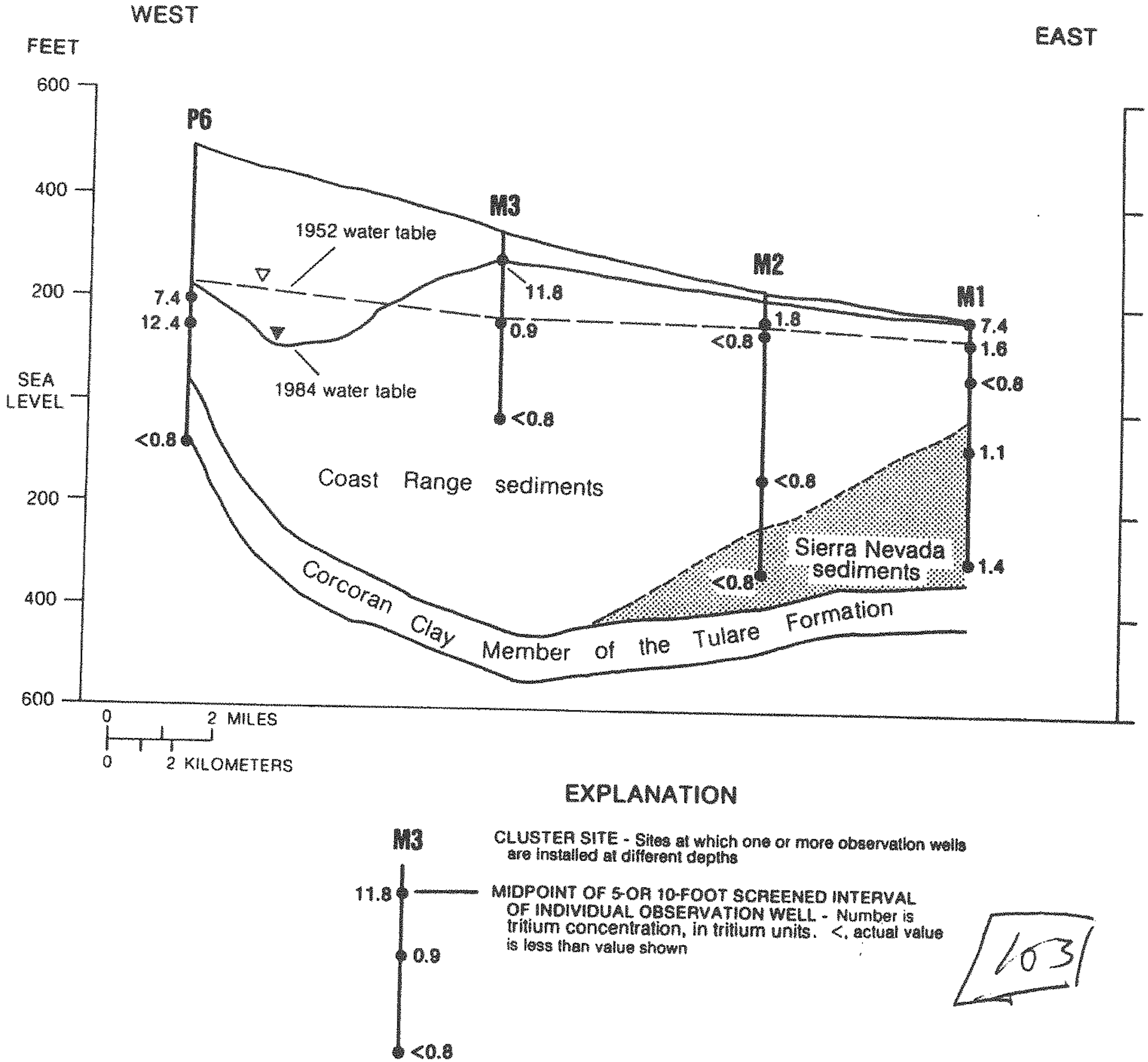


FIGURE 25.— Distribution of tritium in water from observation wells along the P6-M1 geohydrologic section. Section location is shown in figure 21. Water-table altitudes and locations of geologic boundaries are from Belitz (1988). Samples were collected during 1985-87.

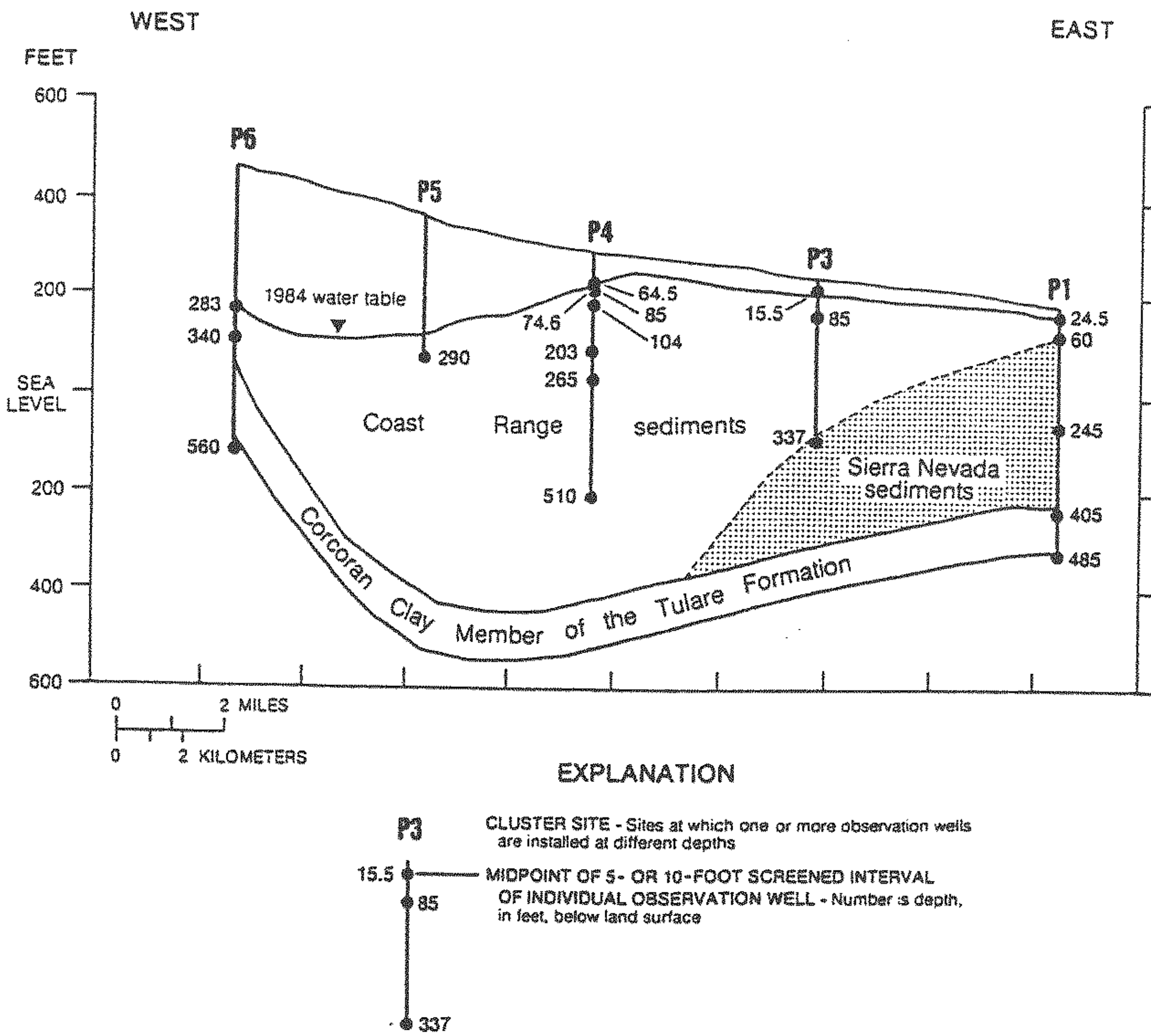


FIGURE 22.— Locations and depths of observation wells at cluster sites along the P6-P1 geohydrologic section. Section location is shown in figure 21. Water-table altitudes and locations of geologic boundaries are from Belitz (1988).

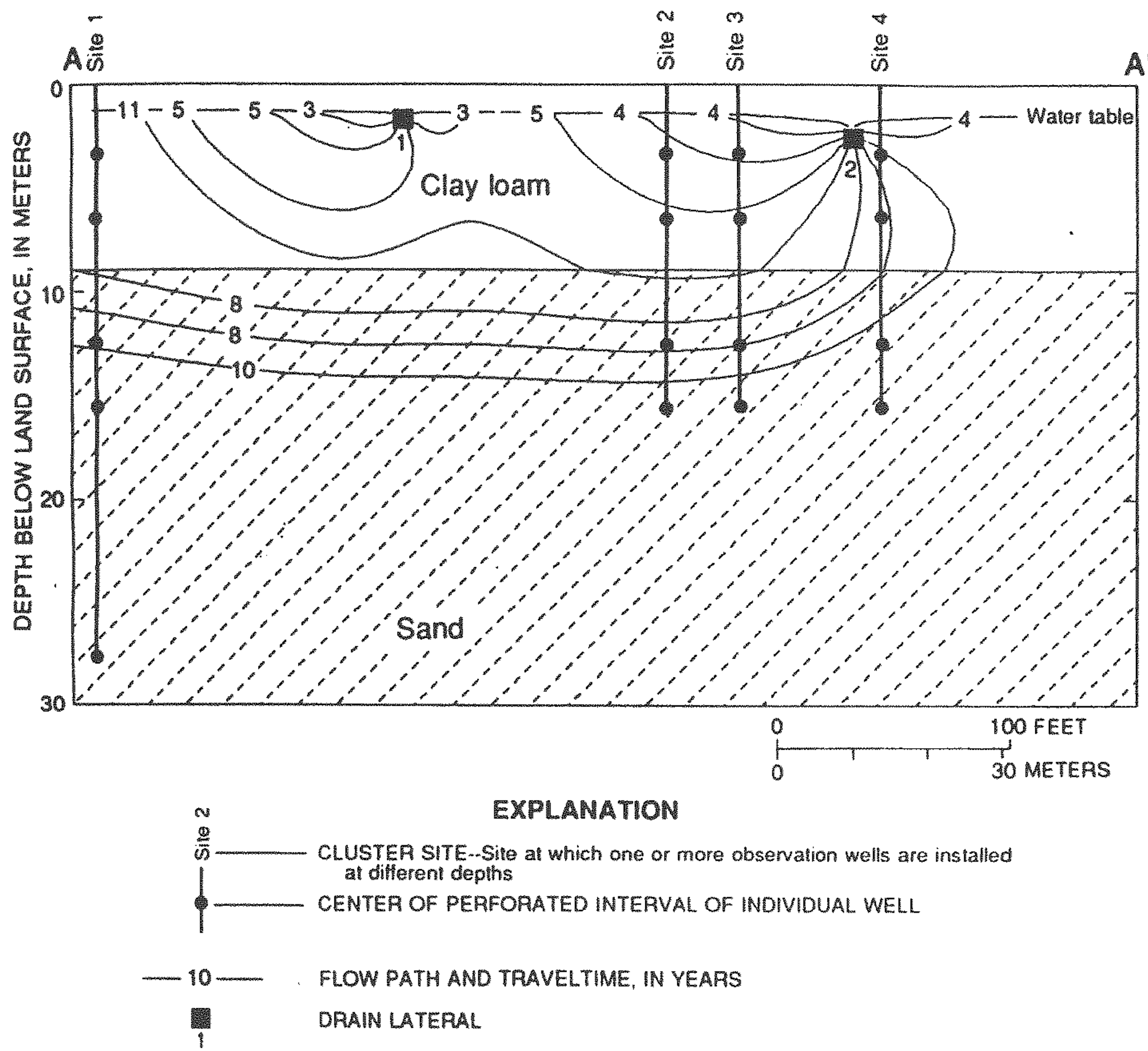


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Figure 9. Simulated ground-water-flow paths and estimated traveltimes for irrigated conditions. Simulated flow for drain lateral 1 is 27 $(m^3/yr)/m$; drain lateral 2 is 63 $(m^3/yr)/m$.

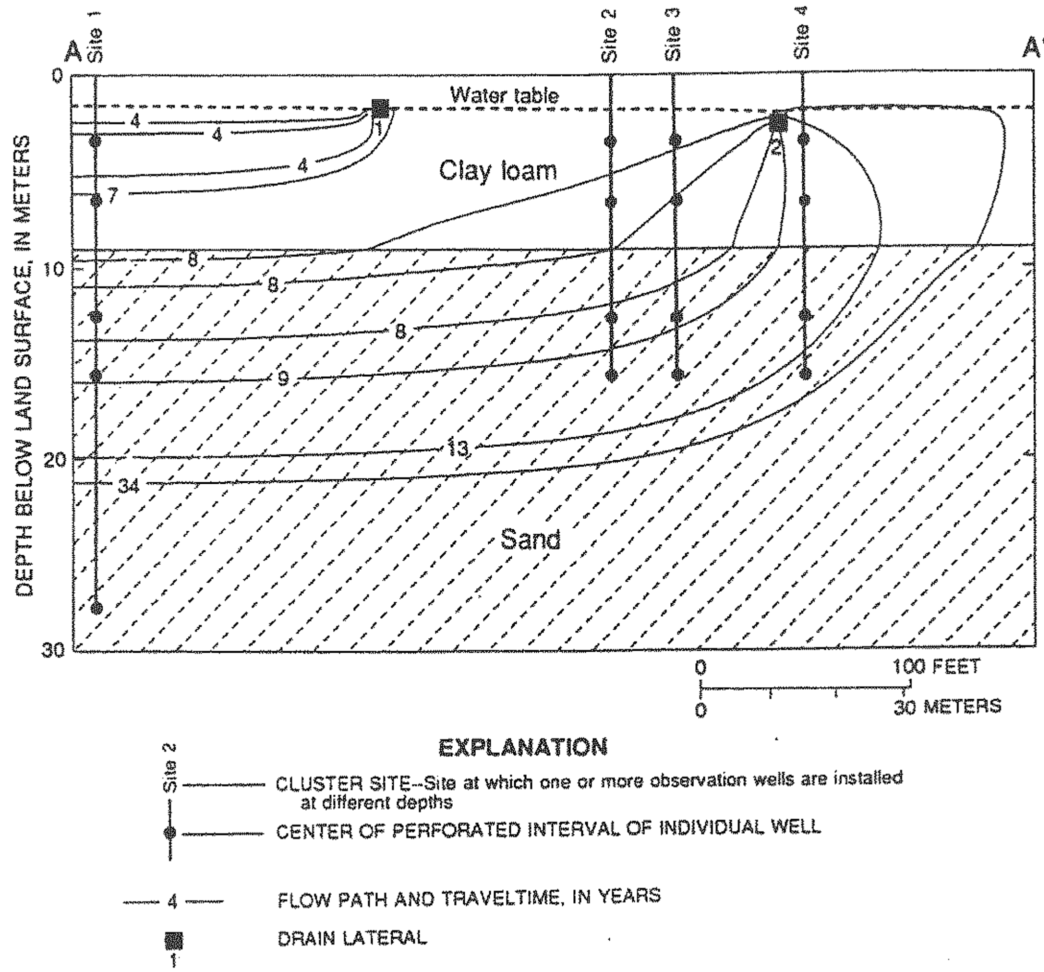

Figure 5. Simulated ground-water-flow paths and estimated traveltimes for nonirrigated conditions. Simulated flow for drain lateral 1 is 4 $(m^3/yr)/m$; drain lateral 2 is 46 $(m^3/yr)/m$.

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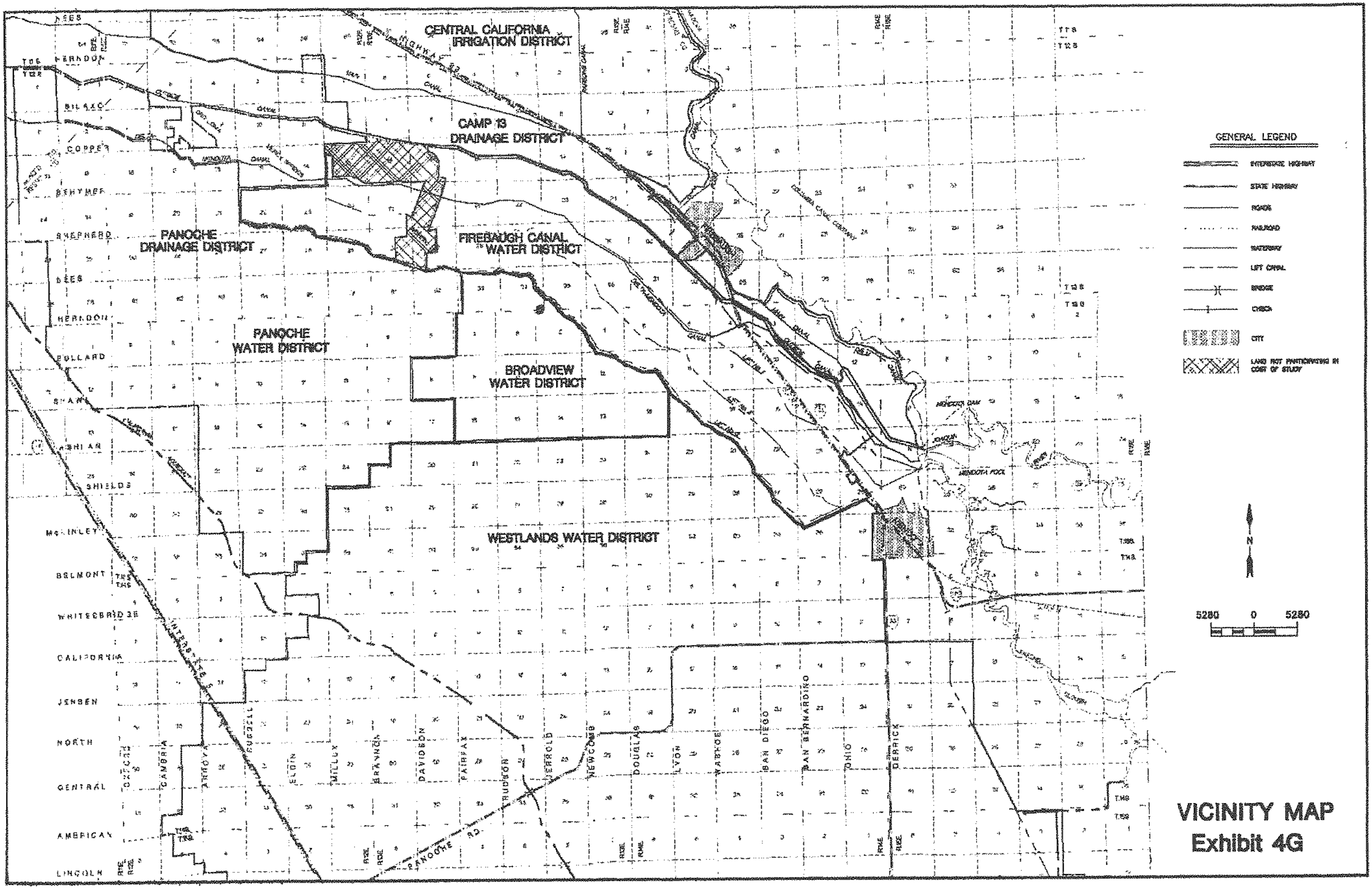
CENTRAL CALIFORNIA
IRRIGATION DISTRICT
CAMP 13
DRAINAGE DISTRICT
PANOCHE
DRAINAGE DISTRICT
FIREBAUGH CANAL
WATER DISTRICT
PANOCHE
WATER DISTRICT
BROADVIEW
WATER DISTRICT
WESTLANDS WATER DISTRICT
GENERAL LEGEND
5280
0
5280
VICINITY MAP
Exhibit 4G