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SANTA MARIA VALLEY WATER CONSERVATION DISTRICT

P. O. BOX 364 -:- PHONE (805) 925-5212
SANTA MARIA, CALIFORNIA 93456

November 14, 1994

To All Parties Interested in the Proposed Joint Groundwater Management Plan:

This letter will remind you that the next meeting of the ad hoc group for the formulation of the groundwater management plan for the Santa Maria Valley will be held on Thursday, November 17, 1994, at 3:00 P.M.

The meeting will be held in the second floor conference room of Bonita Packing, rather than the Public Works Conference Room of the City of Santa Maria. The Bonita Packing conference room is larger than the city's conference room and should better accommodate the larger number of people attending the meetings. Several persons suggested a larger meeting place after the November 3, 1994 meeting. We are grateful to Bonita Packing for making their conference room available.

The Bonita Packing office building is located at 1850 West Stowell Road in Santa Maria. The office building is located on West Stowell Road between Blosser Road and Black Road. It is located on the left side of Stowell Road. Those coming from Santa Barbara should exit the freeway at Stowell Road (near Costco and Home Base) and proceed west on Stowell Road to the Bonita Packing office.

Enclosed to each of you are copies of the minutes of the November 3, 1994 meeting, again prepared by Pam Cosby of Santa Barbara County Water Agency. We are again indebted to Pam for her work in preparing these minutes.

The November 17th meeting will be devoted to continuing the discussion of facilitating conjunctive use operations and mitigation of conditions of overdraft. The discussion of these subjects was not completed at the November 3rd meeting. The City of Santa Maria did not have an opportunity to present its comments on conjunctive use.

As shown by the enclosed minutes, it seems logical that any extra time at the November 17th meeting should be devoted to beginning the discussion of groundwater monitoring. This is a most important subject and one of particular interest to the farmers in the valley. In addition to the suggestions contained on the last page of the minutes, Brian McCord, of Pacific Engineering, is prepared to make a brief presentation on how to calculate overdraft. These materials were developed by Brian in his academic work for a Masters degree in hydrogeology. The materials are part of his thesis for his Masters degree. Measuring and determining the amount of an overdraft is obviously crucial to any groundwater management plan. It is also of particular interest to the agricultural community.

Enclosed to each of you are copies of Brian's November 13, 1994 letter and the materials referred to therein. These materials should be of use to you in understanding Brian's presentation, whether made on November 17th or at some later time.

Yours very truly,

Maurice F. Twitchell

Maurice F. Twitchell,
Secretary

MFT:gn
Encls.

SANTA MARIA VALLEY GROUNDWATER MANAGEMENT PLAN
MEETING MINUTES
November 3, 1994
DRAFT

I. OPENING

The group agreed to talk about two groundwater plan elements:

E. Mitigation of conditions of overdraft
H. Facilitating conjunctive use operations

II. FOX CANYON GROUNDWATER MANAGEMENT AGENCY WORKSHOP

Pam Cosby with the Santa Barbara County Water Agency reported that she had contacted Sam McIntyre, the large agricultural growers' representative on the Fox Canyon Groundwater Management Agency (FCGMA) Board. Mr. McIntyre has agreed to come to a joint meeting of the Santa Maria, Santa Ynez and Buellton groundwater committees to talk about his Fox Canyon groundwater management experience from an agricultural perspective. Several other Fox Canyon board members or affected pumpers may also be available for the workshop. The Santa Maria Groundwater Committee members agreed that they would like to hear Sam McIntyre's presentation. The workshop date was tentatively set for Wednesday, December 7 from 1 to 4 p.m.. Pam Cosby will work with Maurice Twitchell to find a large meeting room. The time and place will be finalized before the next Santa Maria meeting. Santa Maria participants can submit questions for the panelists to Pam Cosby at 568-3545 prior to the workshop.

III. MITIGATION OF CONDITIONS OF OVERDRAFT

Rob Almy of the Santa Barbara County Water Agency began his presentation with an overview of the Santa Maria Basin hydrogeology. He said that he would focus on options to mitigate the groundwater overdraft rather than defining the overdraft amount. Rob divided the possible mitigation methods into two types: Supply Side and Demand Side Options. Most of the methods and hydrogeological issues are discussed in the County Water Agency's report entitled, "Santa Maria Valley Water Resources Report."

A. SUPPLY SIDE OPTIONS

1. Injection/Percolation of Supplemental Water

Supplemental water such as State Water Project (SWP) water or water from another water basin could be percolated into the groundwater basin through infiltration ponds or injected into new or existing unused wells. No one has developed a master plan for injecting supplemental water

Post-It™ brand fax transmittal memo 7671	# of pages ▸ 8
To Maurice Twitchell	From Pam Cosby
Co. SMVWCD	Co. SBCWA
Dept. PLEASE REVIEW	Phone # 568-3545
Fax # 925-1635	Fax # 568-3434

yet. One good possibility would be locating injection wells near identified pumping troughs to mitigate localized overdraft problems.

2. Watershed Management

This option consists of increasing available stormwater runoff by managing the watershed. For instance, the U. S. Forest Service's controlled burn program is designed to minimize excessive debris accumulation and to increase available runoff. Watershed management would increase runoff in the Santa Ynez basin, but the geometry of the Sisquoc and Cuyama basins limit the probable benefits of a watershed management program there.

3. Enhanced Recharged

Enhanced recharge opportunities fall into four basic types:

- o Recharge related to development (Flood Retention/Percolation Basins)
- o Mining reclamation
- o Flood flow diversion
- o Existing stream channel

Each type was described in greater detail. As land is developed, the increase in impervious area increases storm runoff. The County, cities, airport and County Flood Control are actively involved in controlling excessive runoff created by development, collecting it in retention basins and increasing infiltration to the groundwater basin.

An example of a mining reclamation program is one proposed by Coast Rock as part of its 50-year mining plan. Converting abandoned sand and gravel mining pits to recharge basins would reduce reclamation costs and, depending on design, increase groundwater recharge. Two possible drawbacks to ongoing or expanded mining are undermining of the bridge supports on the Santa Maria River or impacts on the surrounding land uses.

Several projects have been proposed to divert flood flows for temporary storage and later releasing them for spreading and basin recharge during low flow periods. One proposal is to divert Sisquoc River water to a new reservoir on or near the Cuyama River. Most of these options are likely to have a high cost per acre foot since the Santa Maria River's alluvial formations are already an efficient infiltration basin.

The final category of enhanced recharge projects is modifying the existing river channel by installing inflatable dams or contouring the river to slow or divert flood flows. Any specific proposed option should be evaluated for its feasibility and cost per acre foot.

4. Sewage Effluent

Treated effluent from the Santa Maria and Laguna wastewater treatment plants is currently percolated through infiltration ponds to the groundwater basin. The location of the Santa Maria infiltration ponds appears to help maintain water pressure in the downstream confined groundwater aquifer and allow reuse of the water by downstream agricultural pumpers. It also helps to prevent seawater intrusion that could be induced by pumping in the confined zone and in areas to the east. The Laguna infiltration ponds are above the confined aquifer, so most of the runoff may eventually spill to the ocean without benefitting local groundwater basin users. Insufficient geological information is available to establish whether or not there is hydrologic continuity between the Orcutt "Sand Hills" material and the main aquifers, so a monitoring program should be started to understand this important issue. If the aquifers are separate, options to capture the potential benefits from the Laguna discharge include relocating the infiltration ponds to a more strategic location or reusing the treated effluent directly.

5. Groundwater Desalination

Because of its high cost, groundwater or seawater desalination is normally only used as an emergency or backup supply for urban users. This high cost and the imminent availability of State Water Project (SWP) water suggest that this option may be left to future generations when the total water demand may be even higher than today.

6. Surface Water Reservoir

As part of the Santa Barbara County Plan, the County, U. S. Bureau of Reclamation, the Flood Control District and others have been involved in a review of potential surface water reservoir sites. The Round Corral dam site on the Sisquoc River is the most mentioned option. The resulting reservoir would have a maximum safe yield of 8,000 AF/year. A permitting reconnaissance may be more important than the geological reconnaissance since the environmental issues may be the most difficult part of completing a new surface reservoir in California today.

7. Conjunctive Use

Conjunctive use would involve bringing in supplemental water and either: 1) injecting the surplus supplemental water during wet years and withdrawing it during drought years, or 2) using supplemental water when it is available and reserving the groundwater for the drought years when the supplemental water is not available. This process is similar to maintaining a checking account. No one will object to adding water to the groundwater "bank account", but there will probably be concerns regarding the timing, amount and rate of the withdrawals. Given the high cost of surface water reservoirs, storing water within underground aquifers is increasingly the preferred option. This issue will be dealt with in greater detail by the municipalities as part of the next agenda item.

8. Cloud Seeding

Rob did not discuss the cloud seeding option in detail since he considers this County program part of the existing water supply baseline. Cloud seeding does increase the available recharge to the Santa Maria basin.

B. DEMAND SIDE OPTIONS

1. Urban Conservation

A review of the County's annual water conservation survey indicates that the water purveyors in the Santa Maria basin, the Cities of Santa Maria and Guadalupe, and California Cities Water Company, have implemented most of the urban water conservation Best Management Practices. The ones not implemented are costly or they would provide benefits that are difficult to quantify. In Santa Maria where the wastewater effluent recharges the groundwater basin, there would be less benefit from increased conservation than in Orcutt where most of the infiltrated wastewater effluent may flow to the ocean before it is used again.

2. Agricultural Conservation

The Resource Conservation District's mobile lab has been an important resource to improve agricultural water irrigation efficiency. Efficiency rates of 80 percent are an achievable goal. The primary water supply benefits are reducing excessive evapotranspiration and salt concentration. The primary driving force to implement agricultural consevation will be the associated savings in energy and fertilizer costs.

C. QUESTIONS TO INVESTIGATE

1. The participants agreed that more groundwater data and monitoring are needed to understand the amount of interconnection between the shallow, deep and confined aquifers, how much groundwater is lost to the ocean, and if the existing multiple completion wells are affecting the yield and water quality of any aquifer.

2. The effectiveness of directly using tertiary treated sewage and the associated water and cost savings from reduced groundwater pumping should be compared against the cost and effectiveness of percolating secondary treated sewage to recharge the groundwater and then pumping the groundwater again.

3. How could in-basin water transfers be used to increase use of the higher quality groundwater in the basin's east end? Would it be cost effective? What pairs of willing participants could find mutual benefits? Fox Canyon pumpers have handled this by selling groundwater storage credits.

4. How important will agricultural water conservation be to achieving/maintaining balanced pumping of the groundwater basin?

IV. FACILITATING CONJUNCTIVE USE OPERATIONS

A. CALIFORNIA CITIES - ROGER BRETT

Roger Brett began the conjunctive use discussion with an explanation of California Cities' current approach to conjunctive use. A supplemental water source, which could be water from the State Water Project, local sources or the Central Valley, is combined with the groundwater basin supply. As shown in the attached handout (Attachment A), a purveyor needs: a source, a conveyance system, a recharge facility, available groundwater storage capacity, extraction capacity, and institutional assurances and protections that the injected supplemental water will still be there when the purveyor is ready to retrieve it. The state water code lists storage as a beneficial use, providing purveyors with a legal framework for a water storage program. Nevertheless, working out advance agreements so that the conjunctive use program operates according to a plan mutually agreeable to all basin pumpers can help avoid lawsuits.

Roger used the following example to demonstrate how conjunctive use of supplemental and groundwater supplies can increase the effective yield of SWP supplies without increasing the long term groundwater draft.

CONJUNCTIVE USE AND NET YIELD

	W/ BANKING		W/O BANKING	
YEAR	SWP IMPORT	GROUNDWTR PUMPING	SWP IMPORT	GROUNDWTR PUMPING
1	500 AF	0 AF	500 AF	0 AF
2	500	0	500	0
3	1500	-1000	500	0
4	0	500	0	500
5	0	500	0	500
6	500	0	500	0
7	500	0	500	0
TOTAL YIELD	3500 AF	0 AF	2500 AF	1000 AF

In this example, the SWP is able to provide full deliveries in 5 of 7 years. In the two years that SWP water is not available, groundwater is pumped to replace the missing water. The difference in the groundwater banking scenario is that surplus SWP water is injected into the groundwater basin during a wet year. This injected water is then available for pumping during the next two drought years for a net groundwater demand over 7 years of 0 acre feet compared to the net groundwater demand of 1000 AF without banking. Groundwater banking also increases the SWP yield from 2500 to 3500 AF.

Peter Adams asked what impacts banking supplemental water would have on reducing natural recharge and increasing the groundwater discharge to the ocean. Which water would be discharged--local groundwater or the injected supplemental water? Roger Brett and others explained that the groundwater basin would be monitored to estimate the ocean discharge. Any increase could be charged first to the stored supplemental water and then to local groundwater. In order to evaluate whether or not natural recharge would be affected, it will be necessary to know more about the basin's storage capacity. In many basins groundwater can be increased significantly without exceeding the basin's storage capacity.

A. CALIFORNIA CITIES - TOM STETSON

Tom Stetson of Stetson Engineering has been involved in managing California groundwater since 1957. On behalf of California Cities, Mr. Stetson described several groundwater basin management programs in which he has been involved.

1. Santa Ynez River

When Tom Stetson became the Santa Ynez River Water Conservation District Engineer in 1967, the Cachuma Operating Agreement required Cachuma releases whenever there was no flow in the river immediately below the Cachuma reservoir. Quite often additional runoff in the lower Santa Ynez River was so high that the releases only served to increase the ocean discharge. To minimize water losses to the ocean, the Cachuma operating agreement was modified to tabulate water flows separately above and below the Narrows. Essentially this was a conjunctive use agreement.

2. Orange County Water District

The Orange County Water District (OCWD) imports lots of water from the Metropolitan Water District (MWD) and uses it to recharge the groundwater with spreading facilities on the Santa Ana River. They do not limit groundwater pumping, since they can adjust their groundwater recharge to offset any excessive pumping. Each pumper is charged a flat rate for each acre foot pumped. (Editor's Note: The current rate (FY 94-95) is $88/AF for domestic pumpers and $44/AF for agricultural pumpers. Source: OCWD)

3. Basin Adjudications

In the San Gabriel Basin, where Mr. Stetson is the water master, most of the imported MWD water is spread for groundwater recharge rather than used directly. The agreement sets higher pumping rates for pumpers who exceed their adjudicated groundwater rights. The storage agreement with MWD also requires their recharge program to operate between specified minimum and maximum water table limits. The purpose is to avoid wasting groundwater through discharges from the basin or rejected recharge. Any wasted groundwater discharge or recharge would be charged against MWD's stored water, but the operating limits have prevented rejected recharge during all the years of operation.

The Chino Basin, which is home to many dairy farms, has an estimated storage capacity of 147,000 AF and was adjudicated in 1978. The baseline overlying users' allotment of 75,000 AF was set based on historical agricultural pumping rates. Non-agricultural overlying users were allocated 12,000 AF, and the remaining basin capacity and recharge were allocated to basin groundwater appropriators.

The pumpers in the Mojave Basin are currently negotiating a stipulated settlement; however, if all the pumpers do not agree to the stipulated agreement, the case will probably go to trial.

As part of a new innovative project, MWD has contracted with the Semitropic Water Service District, an irrigation purveyor in Kern County, to spread SWP water during wet years and then pump out the stored water and send it on to MWD during drought years. MWD owns the facilities, which will handle a maximum storage of 300,000 to 350,000 AF; Semitropic is responsible for facility construction and operation. MWD is also arranging a banking agreement in Arizona for excess Colorado River water.

The Coachella Valley County Water District and Desert Water Agency both have SWP allocations but no pipeline connection to the SWP facilities. They have an agreement with MWD to take Colorado River water in exchange for their SWP water. In addition, MWD plans to bank up to 600,000 AF in the Coachella basin. Since the basin is already so overdrafted, there should be no problem with potential losses.

These example groundwater basin experiences demonstrate the variety of ways that local pumpers can negotiate among themselves and develop a feasible groundwater management plan that protects groundwater users. The basin plans and agreements can set conditions for where supplemental water is stored, how much can be stored, and how much can be pumped out again at what rate. There are also potential energy savings and water quality improvements for local pumpers when the injected water raises the water table. Another key criteria for a good groundwater management plan is disallowing net out of basin groundwater transfers. This means that only imported water banked in the groundwater basin can be exported. Furthermore, any imported water stored in a groundwater basin should be reduced to account for evaporation losses in a spreading ground, increased groundwater basin outflow, rejected local recharge or other similar factors affecting total basin storage.

The participants discussed the issue of monitoring potential subsurface outflow increases caused by groundwater banking. The easiest way to estimate basin outflow is to first develop a good cross-section of the groundwater basin, identify aquifer permeability and plot a baseline water table slope. Once this background data is available, a strategically placed monitoring well(s) can be used to calculate changes in the water table gradient and basin outflow rate. Alternatively, ocean outflow can be controlled by creating a pumping trough or groundwater mound to contain the stored groundwater.

V. NEXT MEETING

The next meeting will be held on November 17, 1994 from 3 to 6 p.m. at the City of Santa Maria Public Works conference room at 810 West Church Street. The meeting agenda will include:

1. Presentation by City of Santa Maria on their conjunctive use plan (Groundwater Management Plan Element H from draft plan. Continued from November 3 meeting.)

2. Groundwater Monitoring (Groundwater Management Plan Element G from draft plan.) Part of this agenda item will be to identify:

    a. What types of data need to be monitored, (e.g., water table, water quality, pumping?, aquifer permeability, basin outflow, etc.)?

    b. What data is currently available?

    c. What new data must be collected?

    d. Are existing wells available to provide all the needed data or will new monitoring wells be required? Where? What type?

    e. Who will conduct the monitoring program and report the findings?

    f. How will the monitoring program be funded?

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November 11, 1994

Maurice Twitchell
Attorney at Law
Santa Maria Valley Water Conservation District
215 North Lincoln
Santa Maria, CA 93454

SUBJECT: Groundwater Basin Management Calculations

Dear Mr. Twitchell:

Enclosed are some materials for distribution prior to the next meeting of the Ad Hoc Groundwater Management Committee. The material outlines the methods for obtaining, manipulating and interpreting data for hydrologic basin analysis. I have presented this material, in a more specific format for the Sisquoc storage unit, to the Groundwater Resources Association and at an American Association of Petroleum Geologists convention. The talk is about twenty minutes long. It will be formatted to include the entire Santa Maria Basin and inform the participants on how the present overdraft and perennial yield estimates were calculated.

If you have any questions or comments, please contact me at (805) 928-7363.

Sincerely,

PACIFIC ENGINEERING ASSOCIATES, INC.,

Brian M. McCord, R.G., R.E.A.
Registered Geologist #6012

HYDROGEOLOGIC BASIN ANALYSIS

Overdraft and Perennial Yield Estimates

GROUNDWATER STORAGE METHOD

1. Determine Volume of Storage
2. Measure Standing Water Levels
3. Calculate Storage Increase/Decrease

HYDROLOGIC EQUATION

1. Determine Inflow Element Quantities
   - A. Precipitation
   - B. Stream Recharge
   - C. Artificial Recharge (Recycled Water, Return Flow, etc)
   - D. Underflow
2. Determine Outflow Element Quantities
   - A. Underflow
   - B. Evapotranspiration
   - C. Pumping
   - D. Surface Flow
3. Subtract Inflow from Outflow

COMPUTER MODELLING

1. Calibration
2. Validation

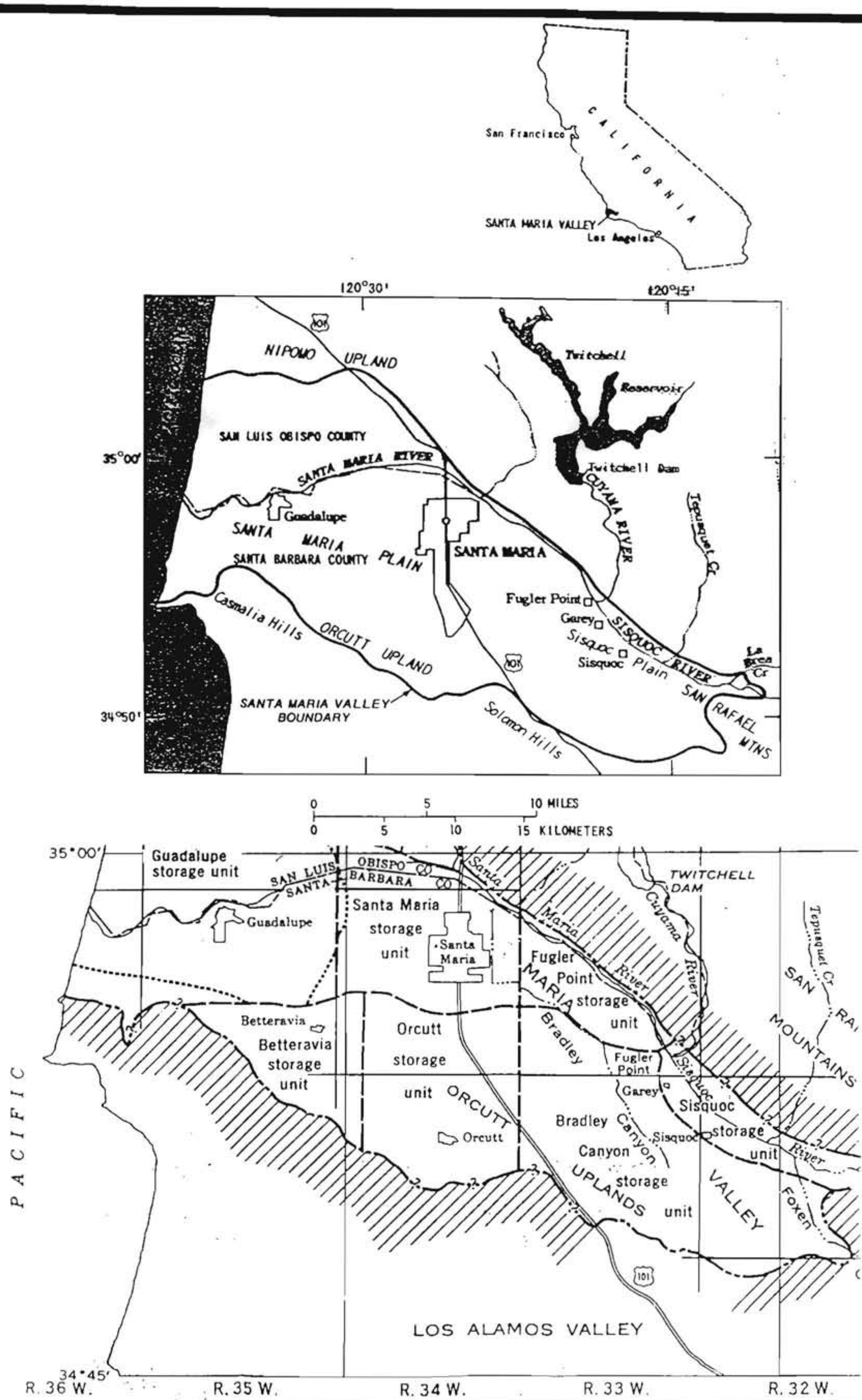


Figure 1 Location Of Sisquoc Storage Unit
After Miller and Evensen (1966)

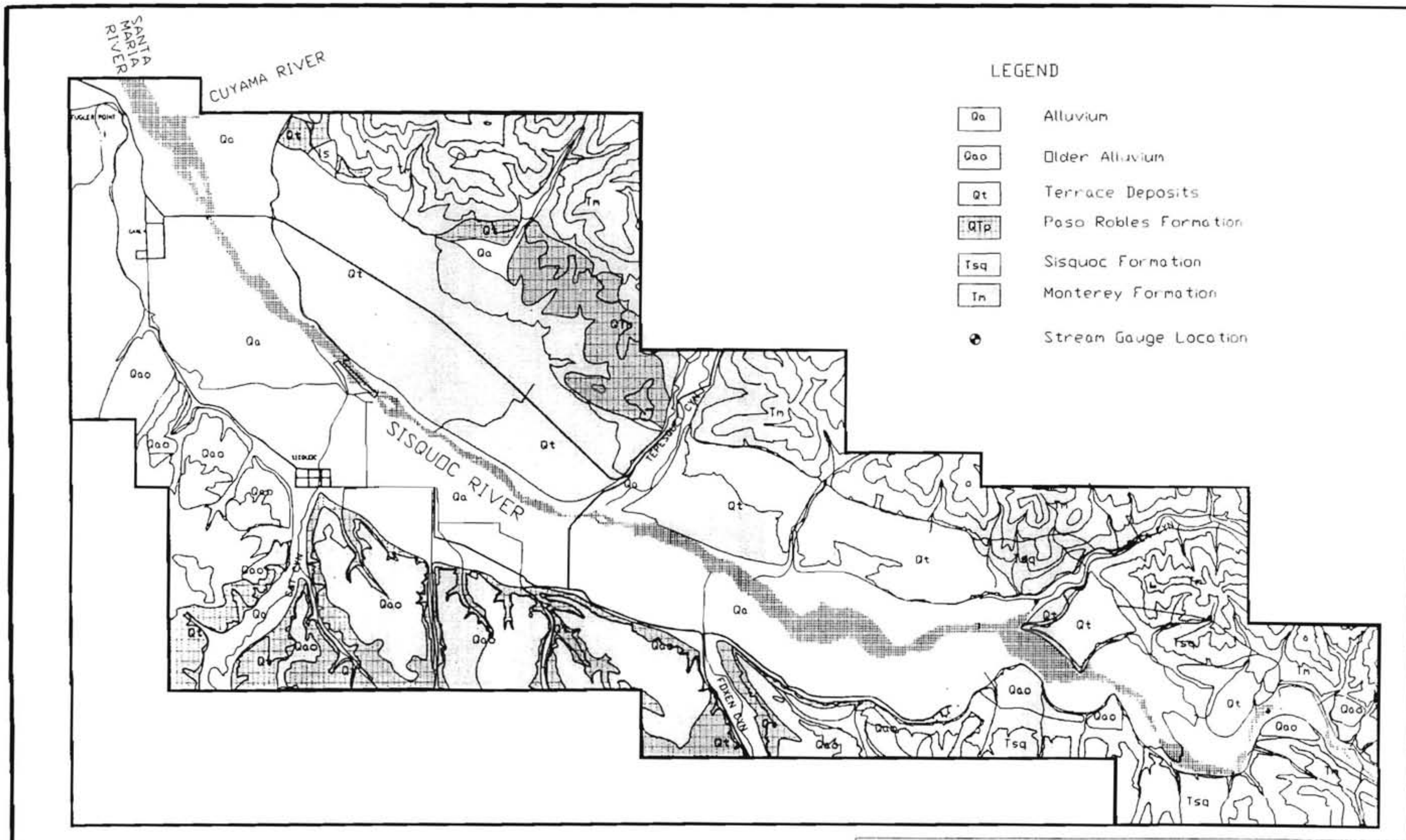


Figure 3 Geology of the Sisquoc Storage Unit

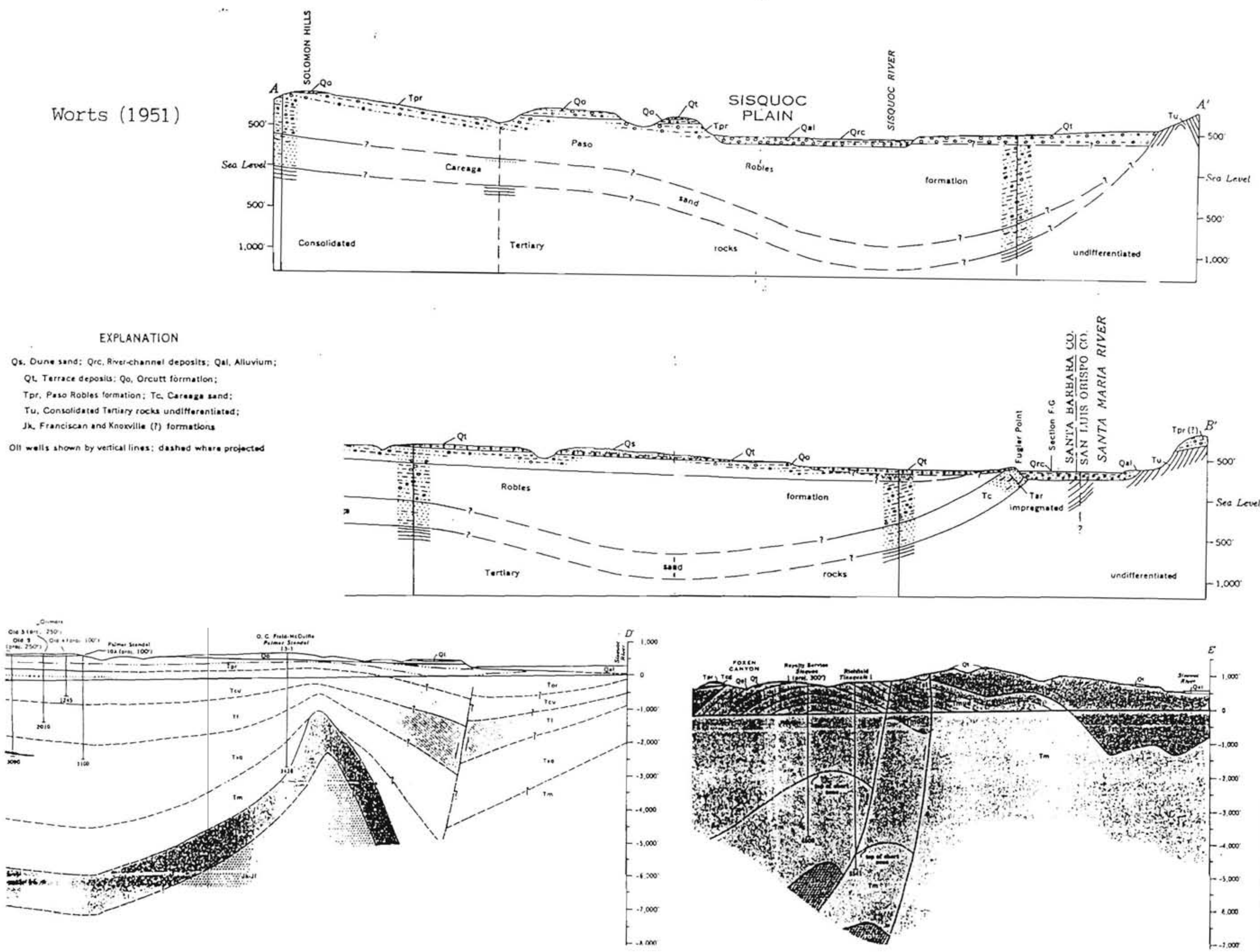
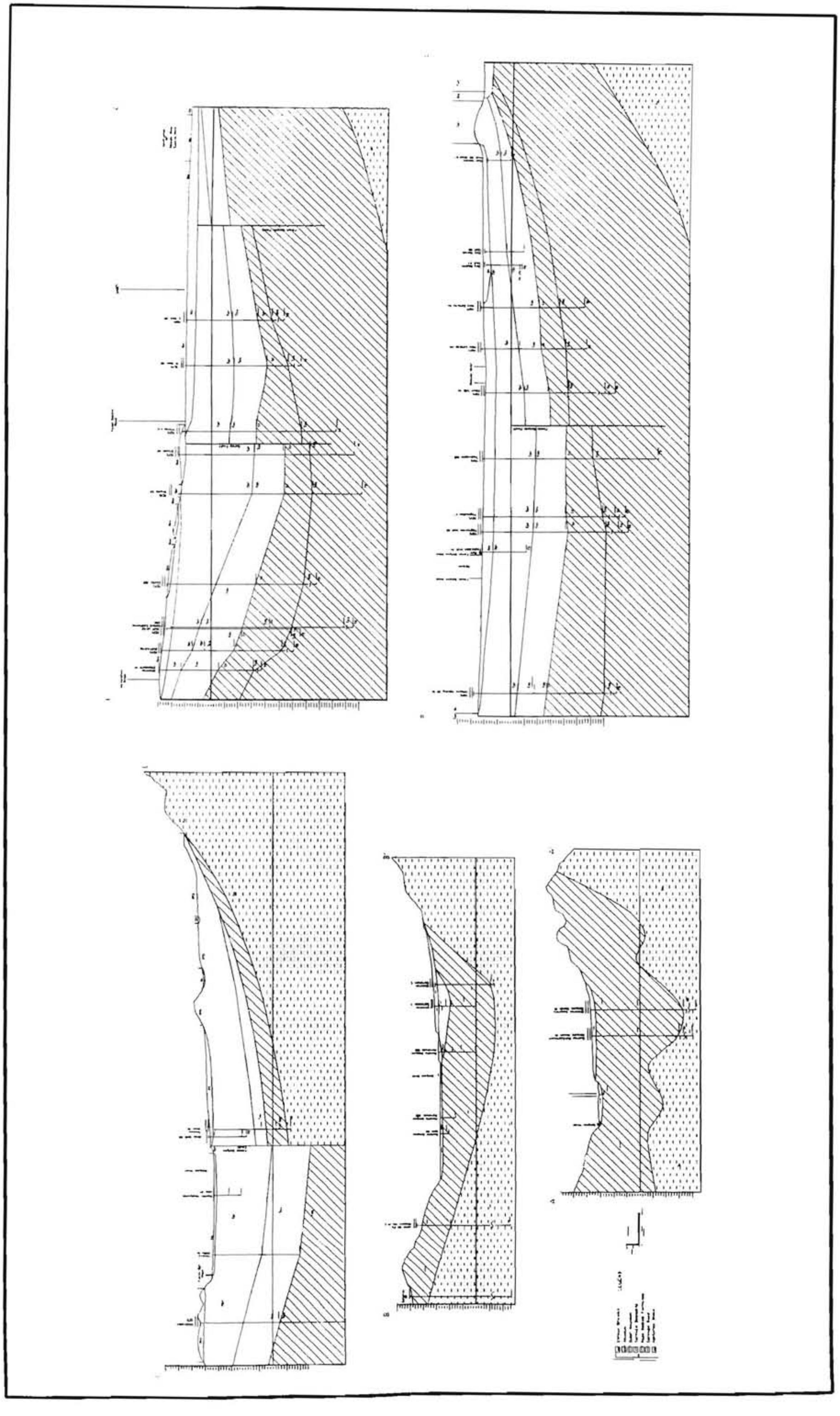


Figure 5 Geologic Cross Sections From Worts (1951) and Woodring and Bramlette (1950)



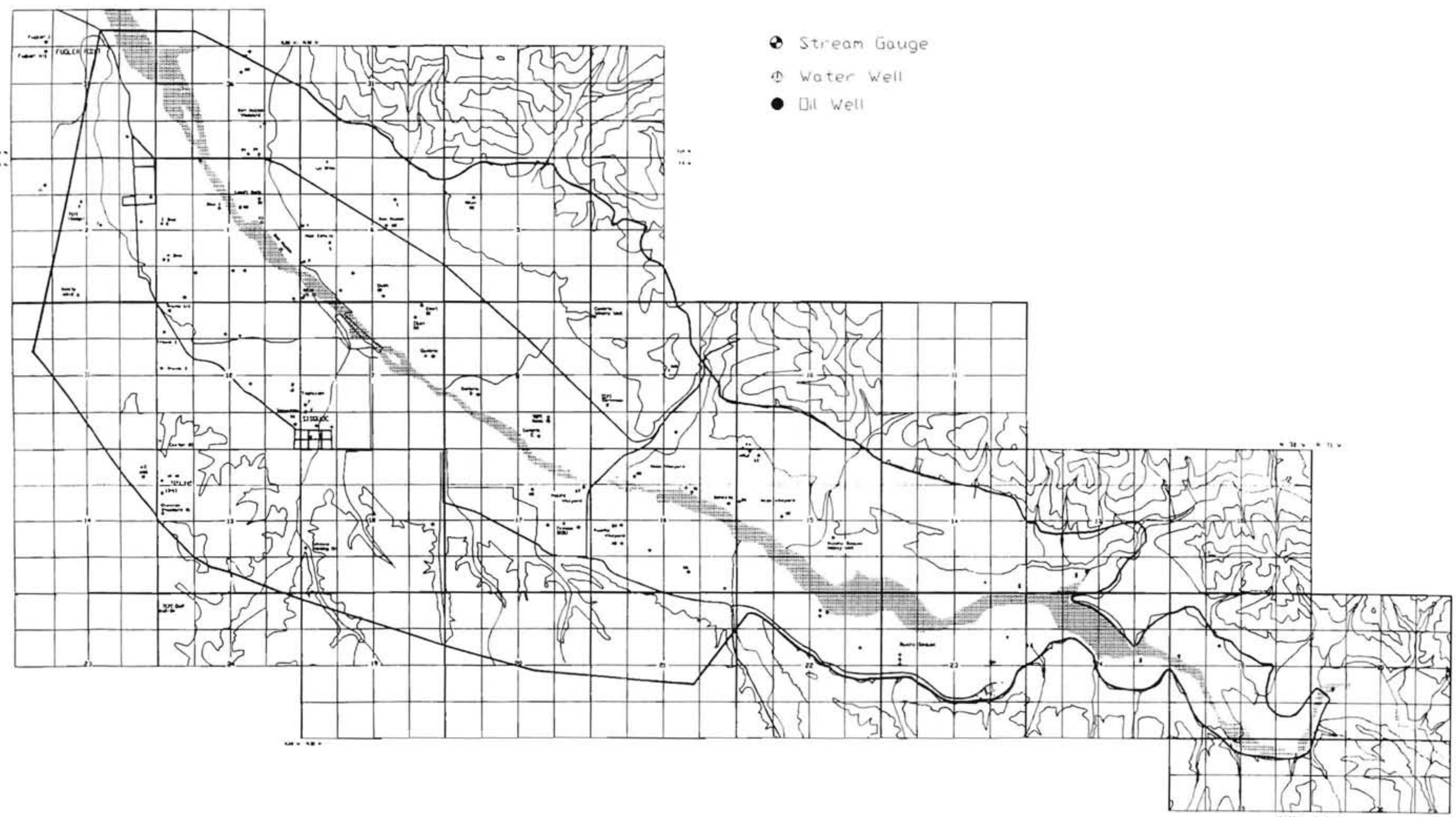
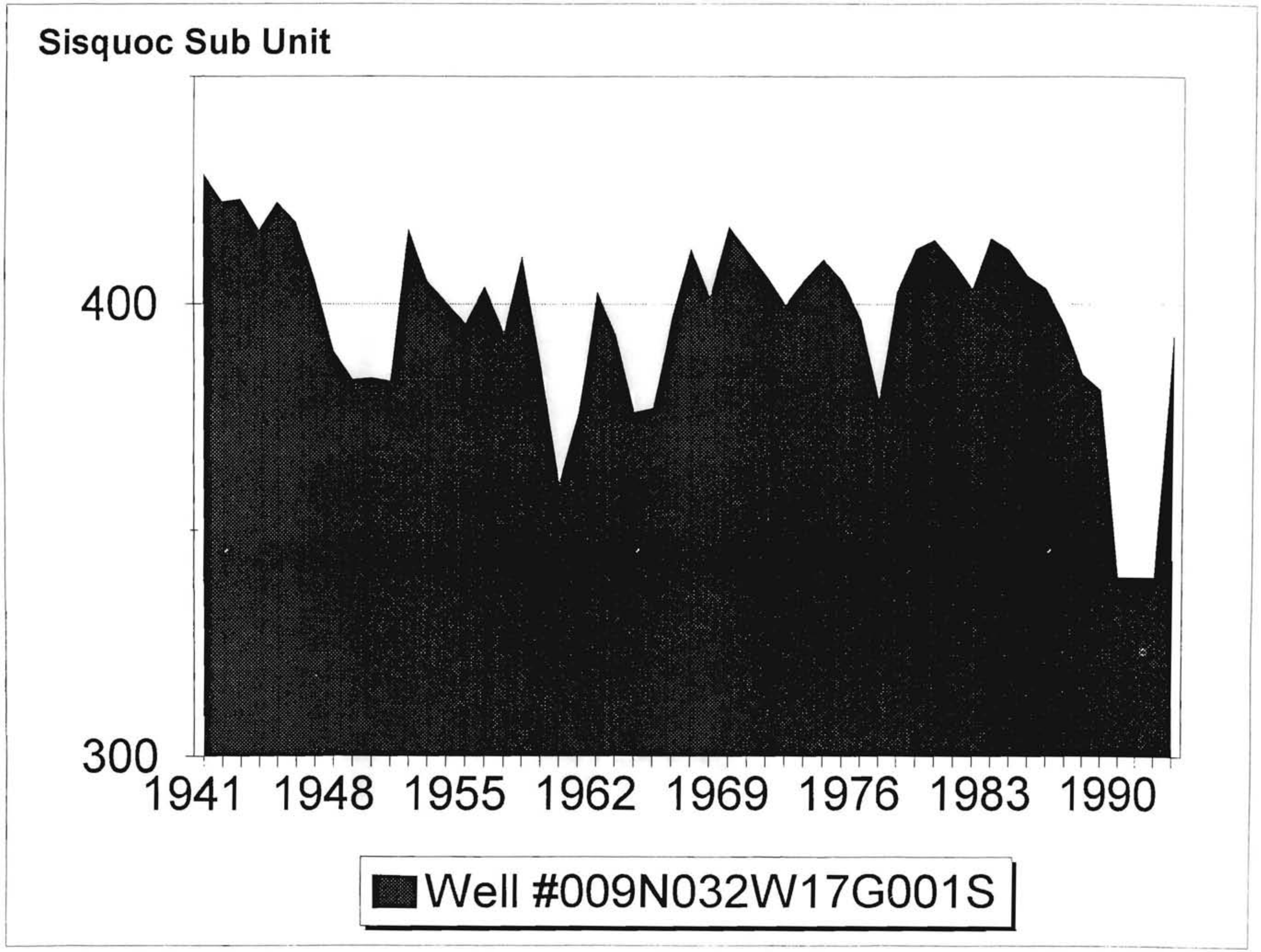
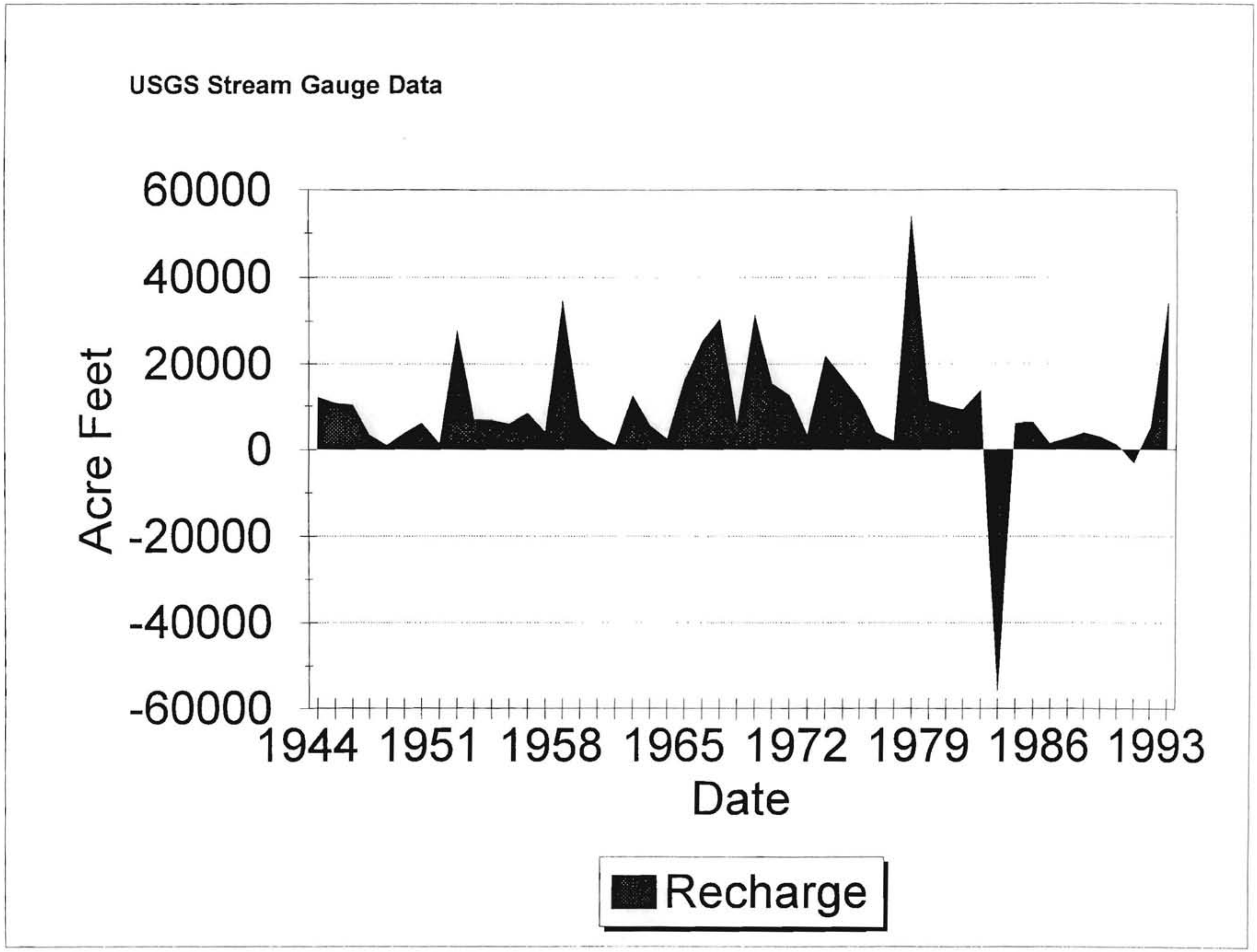


Figure 13 Sisquoc Storage Unit Boundry


Sisquoc Sub Unit
400
300
1941
1948
1955
1962
1969
1976
1983
1990
Well #009N032W17G001S



USGS Stream Gauge Data
60000
40000
20000
0
-20000
-40000
-60000
Acre Feet
1944
1951
1958
1965
1972
1979
1986
1993
Date
Recharge

MOBILE LABORATORY FOR IRRIGATION SYSTEM EVALUATIONS

For Presentation at

Irrigation Association's 1993

International Exposition and Technical Conference

San Diego, California

October 31 - November 3

due to inadequate application of water.

To help alleviate this condition, County Resource Conservation Districts (RCDs)[2] and the USDA Soil Conservation Service (SCS) have offered irrigation system evaluations at no fee to the cooperators[3]. The service included a detailed analysis of the irrigation system's hydraulic performance and an evaluation of irrigation management practices. The primary constituency for the service was commercial agriculture in Santa Barbara and San Luis Obispo Counties. Within the project area, there are approximately 1900 farms irrigating nearly 155,000 acres. Other large water users such as public parks and recreation areas, with significant acres of irrigated turf, were secondary clientele. This report summarizes the results of 300 evaluations performed over 5 years.

The objectives of the project were to conserve water and energy; to improve fertilizer use efficiency, water quality, and crop yield; and to reduce production costs through the application of best irrigation management practices.

Background:

Santa Barbara and San Luis Obispo counties are located along the Central Coast of California and are characterized by a wide range of climatic conditions due to topography and variation in distance from the moderating influence of the Pacific Ocean. These factors influence both rainfall and temperature. Much of the western portions of the counties are at a relatively low elevation and have a mediterranean climate; while much of the east half of the counties are more mountainous or have inland valleys that assume a more continental climatic character. Temperatures range from July high temperatures of around 75 ° F in the coastal valleys to high readings of over 100 ° F in the inland valleys on the east side of the San Rafael Mountains. These variations in temperature results in widely differing growing conditions. In the coastal areas, freezes are relatively rare and high value commercial crops are grown year around. In general, the climate is arid. Most of the rainfall occurs during the winter months and ranges from over 40 inches in some mountain areas to a low of around 5 inches in the Cuyama Valley (UCCE, 1965).

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[2] Cachuma and Lompoc Resource Conservation Districts in Santa Barbara County and the Coastal San Luis Resource Conservation District in San Luis Obispo County.

[3] The project was financially supported at various times by other agencies: County of Santa Barbara, California State Water Quality Control Board, California Department of Water Resources, and County of San Luis Obispo.

SUMMARY AND CONCLUSIONS

The factors affecting distribution uniformity DU were most often related to the maintenance of the irrigation systems. For sprinkler systems, the two most common observations were: worn nozzles and nozzles of mixed diameters. These are inexpensive problems to remedy; thus, nozzle replacement is often a cost-effective solutions to improving irrigation system performance. For micro systems, the most frequent problems observed were: emitter plugging, excessive pressure variation, and miscellaneous maintenance induced conditions. Plugging problems were associated with insufficient filtration, inadequate chemical treatment of the irrigation water, and infrequent flushing. Excessive pressure variation was often caused by improper operation or removal of system components (ie. regulating valves).

Irrigation efficiency was also diminished by improper irrigation scheduling. Growers were often uncertain of the evapotranspiration requirements of the crops and frequently unaware of the precise application rate of their irrigation systems. Calendar methods of planning irrigations were common, often not changing to correspond to changes in day length, temperature, or crop growth stage. For drip irrigation systems, irrigation duration was often too long, causing over irrigation and the percolation of water and nutrients. This was often combined with insufficient frequency of irrigation, resulting in crop water stress and reduced yield. Improvements in management (scheduling) are more difficult to quantify, however, many growers indicated in the follow-up interview that they altered their irrigation practices based on the recommendations of the evaluation. Also increasing numbers of growers are showing an interest in using the CIMIS network. A few growers used tensiometers, and several consultants offered neutron probe services. In general, however, significant water conservation would occur given improvement in irrigation scheduling methods and practices.

Based on the observations of this project, the primary factors that impacted the performance of pressurized irrigation system were: insufficient attention to system maintenance, poor irrigation scheduling, and improper retro-fitting or altering system components from the original design. In most cases, the original irrigation design met minimum engineering standards (USDA, 1990abc and ASAE, 1992).

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SANTA MARIA VALLEY
WATER CONSERVATION DISTRICT

P. O. BOX 364 -:- PHONE (805) 925-5212
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October 3, 1994

To all parties interested in the joint groundwater management plan:

This letter will remind you that the next meeting of the ad hoc group for the formulation of a groundwater management plan for the Santa Maria Valley will be held on Thursday, October 6, 1994, at 2:00 P.M., at the City of Santa Maria Public Works Conference Room at 810 West Church Street.

Enclosed are the following documents that have been submitted since the last meeting:

1. Letter proposal of Pacific Engineering dated September 8, 1994.

2. Pages 1 through 4 and page 12 of a paper sponsored by the Cachuma, Lompoc and San Luis Obispo Resource Conservation Districts for presentation at the Irrigation Association's 1993 International Exposition and Technical Conference in San Diego.

Yours very truly,

Maurice F. Twitchell,
Secretary

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September 8, 1994

Maurice Twitchell
Santa Maria Valley Water Conservation District
215 North Lincoln
Santa Maria, CA 93454

SUBJECT: Groundwater Basin Management Advisory Position (PE40601)

Dear Mr. Twitchell:

During the meeting yesterday it became apparent that a variety of debatable subjects, most notably overdraft, have and will continue to exacerbate the formation and development of the basin plan. Due to the time frame available, it would be advantageous to implement strategies to streamline these debates and ensure that additional debates do not arise at a later date. One suggestion would be to place Pacific Engineering in an advisory position to critically evaluate technical aspects of the plan and recommend modifications or referral for additional study.

This procedure would be advantageous for the following reasons: 1) Pacific Engineering has the experience within this basin and water resources to critically evaluate, structure and present the data in a manner that everyone can understand and the SMVWCD would not be paying someone to learn the process all over; 2) Pacific Engineering has performed independent studies in the valley on water resources and water quality; 3) Pacific Engineering is familiar with the regulatory and authority agencies acting within this valley or have the ability to act within this valley; 4) Pacific Engineering is an independent contractor without political ties and would be more likely to present data without inherent suspicion; 5) Pacific Engineering would review data collected by basin plan participants, saving time and money; 6) Pacific Engineering can identify current debates and future subjects which may cause time and action limiting arguments and; 7) Pacific Engineering would integrate the Basin Management Plan with work performed by other agencies that have not been represented thus far.

The Santa Maria Valley Water Conservation District's idea of creating the Groundwater Management Plan within the agencies involved is highly commendable and appropriate. However, to streamline the debates and allow the process to move ahead, a knowledgeable advisory consultant may be invaluable. The groundwater management plan group would continue to develop the groundwater management plan. Pacific Engineering would perform work on a time and materials basis at the discretion of the SMVWCD and present proposed costs for each task.

If you have any questions or comments, please contact us at (805) 928-7363.

Sincerely,

PACIFIC ENGINEERING ASSOCIATES, INC.,

Brian M. McCord, R.G., R.E.A.
Registered Geologist #6012

Clay S. Bradfield, P.E., R.E.A.,
R.C.E. #47085

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RICHARD E. ADAM, DIV. 5
OWEN S. RICE, DIV. 6
JAMES SHARER, DIV. 7

SANTA MARIA VALLEY WATER CONSERVATION DISTRICT

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August 30, 1994

Reese Riddiough, Dwayne Chisam
and Paul Karp, Public Works
Department, City of Santa Maria
Maynard Silva, City of Guadalupe
Doug Jones, Nipomo Community
Service District
Michael Stoker, Supervisor,
Santa Barbara County
Timothy J. Staffel, Supervisor,
Santa Barbara County
Tom Urbanske
Rob Almy, Matt Naftaly and
Jon Ahlroth, Santa Barbara County
Water Agency
Floyd Wicks, Southern California
Water Company
Donald K. Saddoris, Southern
California Water Company
Roger Brett, California Cities
Water Company
Gail Johnson, Woodland Park
Mutual Water Company
Istar Holliday, Laguna Negra
Mutual Water Company
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Warren Bendixen, The University of
California Cooperative Extension
Brian McCord and Clay Bradfield,
Pacific Engineering
Bob Royster, Santa Maria Valley
Economic Development Association
Dick Hulme
Herb Gerfen, Skyway Engineering, Inc.
Clint Milne, Engineer, San Luis
Obispo County
Rolf Ohlemutz, Kennedy Jenks
Consultants

Board of Directors, Santa Maria
Valley Water Conservation District

To Parties Interested in the Groundwater Management Plan:

Enclosed are the following materials for consideration at the adhoc group for the formulation of the groundwater management plan to be held September 7, 1994 at 2:00 P.M. at the City of Santa Maria Public Works Department Conference Room at 810 West Church Street in Santa Maria:

1. "Status of Basin Report" prepared by Dwayne Chisam of the City of Santa Maria and Roger Brett of California Cities Water Company, to be utilized as a starting point for the September 7th meeting.

2. Materials obtained by Rob Almy of Santa Barbara County Water Agency consisting of Synopsis of AB 3030, draft of Department of Water Resources Bulletin 118-3030, Water Resources Checklist prepared by the Department of Water Resources and AB 3030 Ground Water Management Manual prepared by the Association of California Water Agencies. I believe these materials were presented to the Santa Ynez River Water Conservation District by Carl Hauge of Department of Water Resources.

3. Copy of Santa Ynez River Enhancement Plan dated July 15, 1994 (also obtained by Rob Almy).

4. Copy of two articles entitled The Tragedy of the Commons, by Professor Garrett Hardin, and The Dynamics of Social Dilemmas, by Glance and Huberman, submitted by Rob Almy as general interest to members of the group.

Yours very truly,

Maurice F. Twitchell,
Secretary

MFT:gn
Encls.

STATUS OF BASIN REPORT
Santa Maria Valley Water Conservation District
Ground Water Management Group
September 7, 1994

(PLEASE NOTE: This status report has been assembled by the sub-committee with an inclination to furnish conservative, generic, and innocuous data that may have a better potential to survive "consensus building" sessions within the general membership of this management group.)

BASIN BOUNDARIES: NIPOMO SUB-UNIT HAS BEEN DEFINED BY LAWRANCE, FISK AND MCFARLAND (MAP ATTACHED)

This map is furnished as a starting point only. No producers close to the boundaries will be prevented from participating, nor required to participate, in this ground water management group.

POPULATION PROJECTIONS: GROWTH INDUCEMENT SECTION OF SWP EIR

Santa Barbara County Growth Inducement Potential of State Water Importation, Pamela Gene Cosby, 3/15/91, Table 3.

Santa Maria Annexation Sphere of Influence Study, City of Santa Maria, 1993.

AGRICULTURAL USAGE: CROP PATTERN/USAGE/RETURN FLOW CREDIT ESTIMATES

It is recommended that the Agriculture members of this ground water management group furnish this data.

SEAWATER INTRUSION

Unlikely, as none has been reported, but if this phenomenon occurs in the future, it is within the purview of this group to address/correct.

OVERDRAFT OF BASIN: 30,000 ACRE FEET/YEAR

City of Santa Maria, Long Term Water Management Plan, February, 1991, p.18 (30,026 acre feet/year)

It is recommended that focus of this group be directed towards developing as many projects as possible to provide supplemental water to the basin, rather than deliberating the precise quantity of the overdraft.

ORCUTT SUB-BASIN OVERDRAFT: 18,000 ACRE FEET/YEAR

City of Santa Maria, Long Term Water Management Plan, February, 1991, p.19 (18,570 acre feet/year)

STORAGE CAPABILITY (10 FEET ABOVE SEA LEVEL, TO TOP OF SATURATED ZONE): 1,000,000 ACRE FEET

Santa Maria Valley Water Resources Report, County of Santa Barbara, 1994, p.39 (1,105,000 million acre feet, with a total capacity of 3,072,000 acre feet)

EXISTING GROUND WATER LEVELS: NO MANIFESTED PROBLEMS

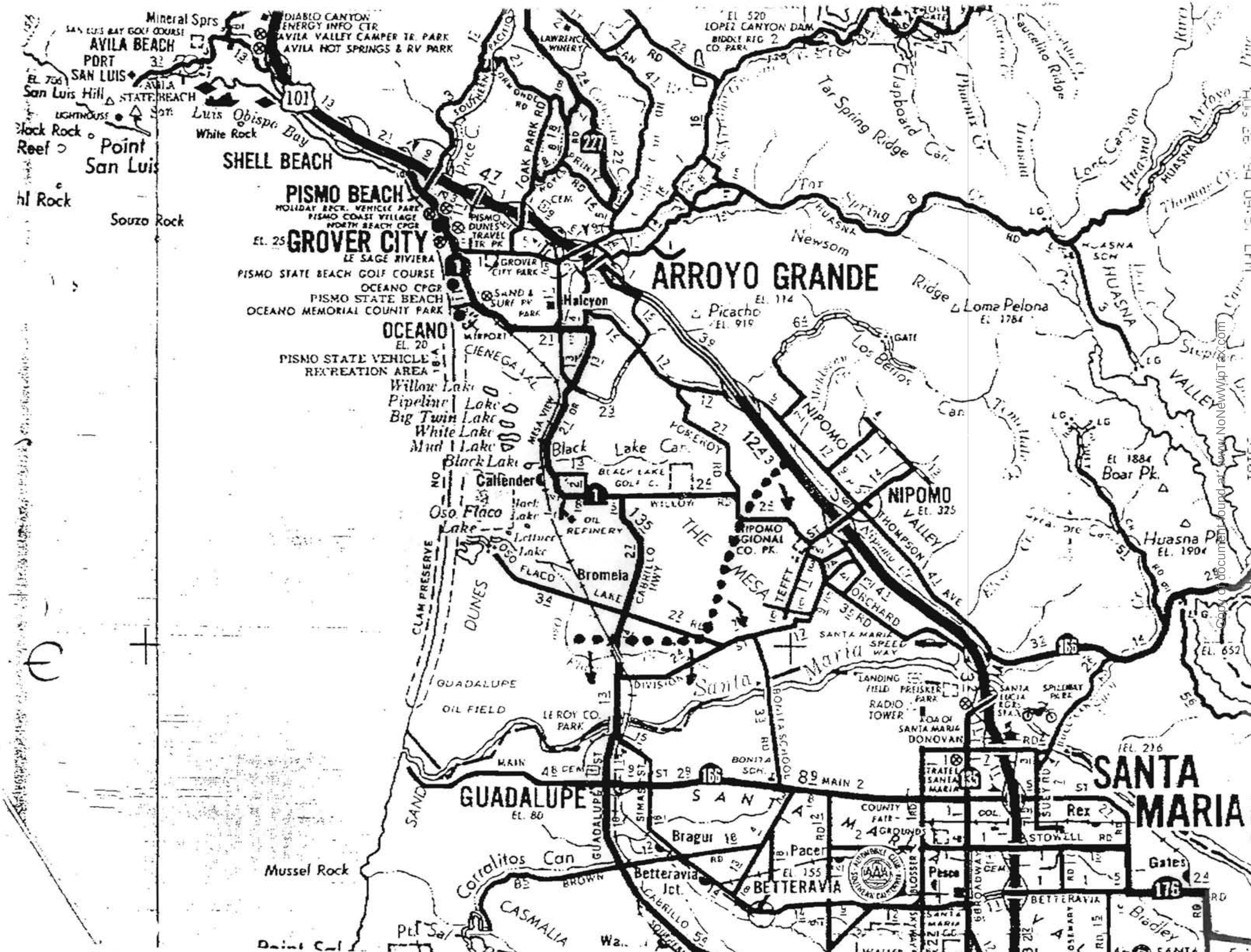
No current problems have been reported within the County of Santa Barbara, or within the Nipomo Mesa Area. If rising water or artisan water problems are encountered in the future, this issue will be revisited.

CONTAMINATION PROBLEMS: 10 SITES IN GUADALUPE (Oil)
1 SITES IN ORCUTT (Oil)

The above problems, as reported to the County Environmental Health Department, deal with oil-related water pollution and are currently being monitored.

To minimize future concerns, it is very likely that a "well abandonment program" will be recommended to be administered by this group.

att: LFM map of Nipomo sub-unit boundary


Mineral Sprs
DIABLO CANYON ENERGY INFO CTR
AVILA VALLEY CAMPER TR. PARK
AVILA HOT SPRINGS & RV PARK
SAN LUIS BAY GOLF COURSE
AVILA BEACH
PORT SAN LUIS
San Luis Hill
AVILA STATE BEACH
LIGHTHOUSE
San Luis Obispo Bay
White Rock
Black Rock
Reef
Point San Luis
SHELL BEACH
PISMO BEACH
HOLIDAY RECR. VEHICLE PARK
PISMO COAST VILLAGE
NORTH BEACH CPGR
PISMO DUNES TRAVEL TR PK
Souzo Rock
EL. 25
GROVER CITY
LE SAGE RIVIERA
PISMO STATE BEACH GOLF COURSE
GROVER CITY PARK
OCEANO CPGR
PISMO STATE BEACH
OCEANO MEMORIAL COUNTY PARK
SAND & SURF PK PARK
Halcyon
OCEANO
EL. 20
AIRPORT
PISMO STATE VEHICLE RECREATION AREA
Willow Lake
Pipeline Lake
Big Twin Lake
White Lake
Mud Lake
Black Lake
Callender
Oso Flaco Lake
Black Lake Can
BLACK LAKE GOLF C.
WILLOW RD
OIL REFINERY
Bromela
OSO FLACO LAKE
CABRILLO HWY
THE MESA
CLAM PRESERVE
DUNES
GUADALUPE OIL FIELD
LE ROY CO. PARK
DIVISION
Santa Maria
MAIN
GUADALUPE
EL. 80
SANTA MARIA
Mussel Rock
Corralitos Can
BROWN
CASMALIA
Betteravia Jct.
Bragur
Pacer
BETTERAVIA
EL. 155
LAWRENCE WINERY
LOPEZ CANYON DAM
EL. 520
BIDDLE REG. CO. PARK
Tar Spring Ridge
Clapboard Can.
Phoenix Cr.
Caracillo Ridge
Long Canyon
Huasna
HUASNA
Thomas Cr.
Tar Spring
Newsom Ridge
ARROYO GRANDE
EL. 114
Picacho
EL. 919
Loma Pelona
EL. 1784
Los Berros Can.
HUASNA SCH
VALLEY
NIPOMO
EL. 325
THOMPSON AVE
NIPOMO REGIONAL CO. PK.
TEFFT ST
ORCHARD RD
Boar Pk.
EL. 1884
Huasna Pk.
EL. 1904
SANTA MARIA SPEED WAY
LANDING FIELD
PREISKER PARK
RADIO TOWER
KOA OF SANTA MARIA
DONOVAN RD
SANTA LUCIA RCRS STA
SPILLWAY PARK
EL. 652
EL. 216
SANTA MARIA
Rex
COL.
STOWELL RD
SUEY RD
COUNTY FAIR GROUNDS
BROADWAY
BLOSSER
Pesca
CEM
Gates
BETTERAVIA
Bradley
TRAVEL SANTA MARIA
BONITA SCH.
BONITA SCHOOL RD
SIMAS ST
MAIN 2
WALLER PARK
SANTA MARIA C.C.
ROSEMARY
101
166
176
135
227
1

LFM

LAWRANCE, FISK & McFARLAND, INC.
CONSULTING ENGINEERS • SANTA BARBARA • BREA

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FAX NO. (805) 564-8575

LFM JOB NO. 94081

JOB NAME SMVGWB

DATE AUGUST 26, 1994

PAGE 1 OF 2

TO: CAL CITIES WATER (FAX 805/734-3240)

ATTN: ROGER BRETT

SUBJECT: NORTHERN LIMIT OF SANTA MARIA GROUNDWATER BASIN ON OR NEAR THE NIPOMO MESA
(ATT: LOCATION MAP ARROYO GRANDE, SANTA MARIA & VICINITY, SHOWING APPROXIMATE N. LIMIT)

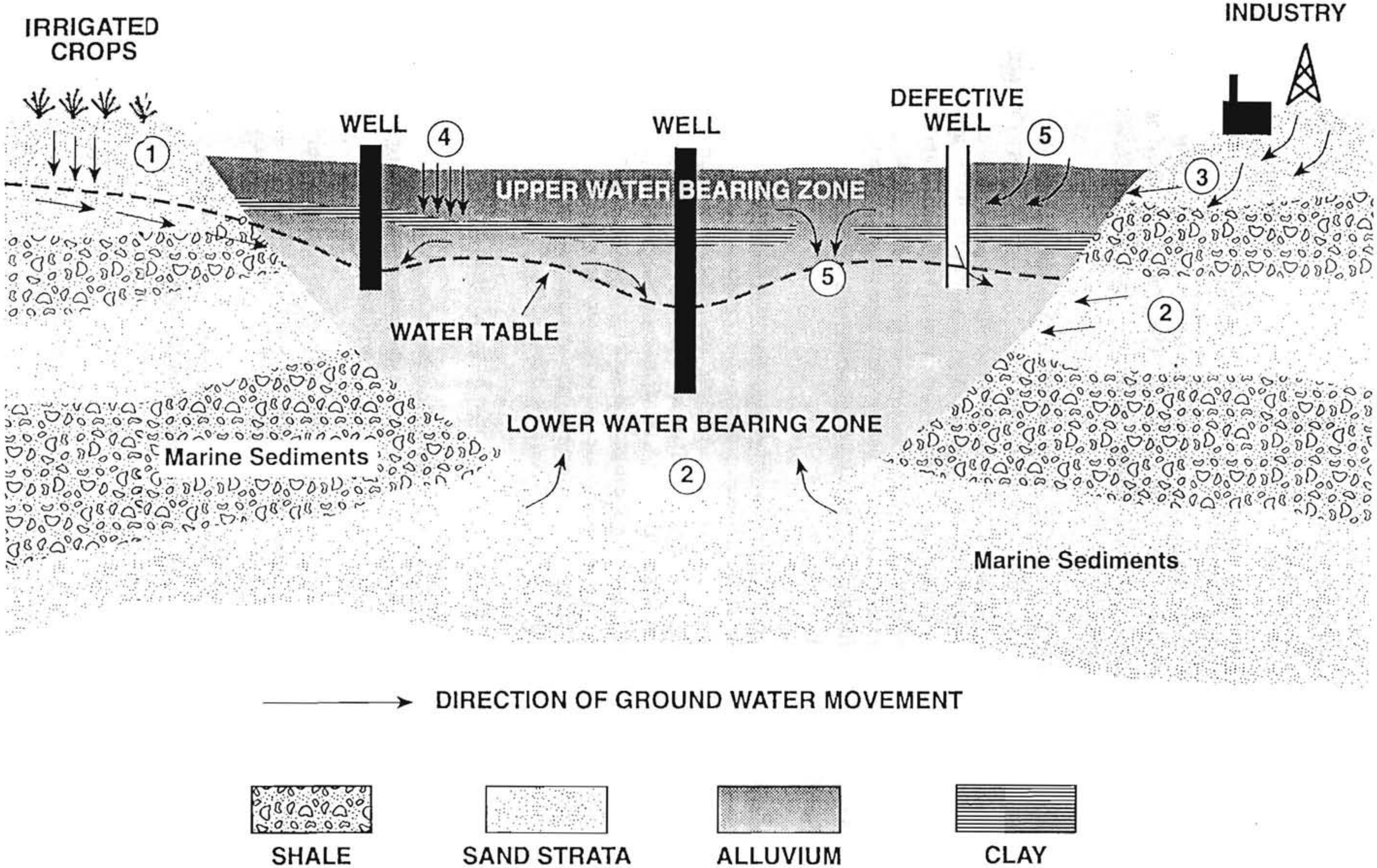
COMMENTS: 1. ~~THE HEAVY CIRCLES REPRESENT THE~~ APPROXIMATE NORTHERN LIMIT OF THE SMGWB AND ARROWS INDICATE FLOW FROM THE MESA TO SANTA MARIA RIVER AREA.
2. I HOPE THIS RESPONDS PROPERLY TO YOUR REQUEST.

Please call if you do not receive all pages or if there is a problem with this transmission.

Thank you.

Charles H. Lawrance

cc by FAX: Hatch & Parent, Scott Slater, Esq
Nipomo CSD, Doug Jones



Schematic Section Across an Alluvium-Filled Ground Water Basin Underlain and Flanked by Less Permeable Sediments of Marine Origin

AB 3030 Sec. 10753.7 (l)

The Review Of Land Use Plans And Coordination With Land Use Planning Agencies To Assess Activities Which Create A Reasonable Risk Of Ground Water Contamination

An important component of developing a ground water management plan is the review of land use plans for the surrounding area or basin, and coordinating efforts with regional, sub-regional, and local land use planning agencies. In California, the majority of land use decisions are made by city and county government agencies. Undoubtedly, land activities and how they are managed can affect both ground water quality and quantity. The threat that a certain land use may pose to a ground water resource is a function of the ground water aquifer properties, management practices associated with the individual land use, and actual use of surrounding land (cumulative impact of all activities). As an example, hydrologic conditions may dictate that in certain areas, the aquifer is more vulnerable to pollution. This may be due to the permeability of the underlying soils and/or a shallower depth to the water table. To assure protection of ground water quality in the basin, this type of information may be taken into consideration when making land use decisions regarding zoning.

Examples of common land uses with a potential to adversely impact ground water supplies include large scale unsewered residential development, and industrial development without proper control measures or management practices. Cumulative impacts to a basin and relative land development density should also be evaluated. The use of shallow drainage wells to dispose of surface run off from streets, highways, parking lots, and agricultural areas, if determined to be of concern for the area, can also be addressed in the management plan. In this instance, the risk of a major roadway accident or spill, or the potential for the well being used as an illegal disposal site for hazardous substances, could be factored into the planning process.

A key aspect of ground water management is maintaining quantity or supply. Land use planning decisions that lead to covering up large portions of land with impervious surfaces can increase storm water runoff. This can lead to excessive down cutting and erosion in stream channels and flooding in the lower part of the watershed. The amount of natural recharge to the ground water basin can be significantly reduced. Land use decisions such as maintaining green space in areas of high recharge and encouraging the use of pervious materials will have a net benefit to the ground water basin.

The process of developing a ground water management plan can allow for information exchange between several parties, including agricultural and industrial water users, citizens, and resource, regulatory and planning agencies. The ground water management plan ultimately assists local planners, and local planners assist in the process of developing a comprehensive plan which can be realistically implemented resulting in effective protection and management of the ground water resource.

For more information on this topic, please contact:

State

San Francisco Bay Regional Water Quality Control Board, Dyan Whyte 510/286-1324

ACKNOWLEDGEMENTS

The following persons contributed to this report:

William R. Mills Jr.	Orange County Water District
James Goodrich	San Gabriel Basin Water Quality Authority
Dyan Whyte	San Francisco Bay Regional Water Quality Control Board
Carl Hauge	Department of Water Resources, State of California
Ken Harris	State Water Resources Control Board, State of California
Doris Betuel	U.S. Environmental Protection Agency, Region 9
Tony Lewis	U.S. Environmental Protection Agency, Region 9
Susan Whichard	U.S. Environmental Protection Agency, Region 9
Mark Leyes	Orange County Water District
Dana Wisehart	Association of California Water Agencies

March 1994

SYNOPSIS OF AB 3030
(SWC Sec. 10750 et seq.)
Procedures and Technical Components

AB 3030 (Water Code Sections 10750 - 10767)

I. Purpose of AB 3030

A. Local agency

B. Management area and agency power

1. May exercise many of the powers of a Water Replenishment District (SWC §60220 AND §60300)

C. Procedures

1. Publish notice of public hearing
2. Conduct a hearing on whether to adopt a ground water management plan
3. May adopt a resolution of intention to adopt a ground water management plan
4. Must publish notice
5. Must prepare a ground water management plan within 2 years
6. If not, return to step 1
7. Hold a 2d hearing after the plan is prepared
8. Consider protests
9. A majority protest consists of more than 50% of the assessed value of the land within the agency
10. If a majority protest exists, the plan shall not be adopted
11. No new plan for the same area may be considered for 1 year
12. If there is no majority protest, the ground water management plan may be adopted within 35 days after the 2d public hearing

D. Rules and regulations

E. Finances

F. Proposed fees

G. Coordination with other agencies

II. Water Code Section 10753.7 states that a ground water management plan may include components relating to all of the following:

A. The control of saline water intrusion

B. Identification and management of wellhead protection areas and recharge areas

C. Regulation of the migration of contaminated ground water

D. The administration of a well abandonment and well destruction program

E. Mitigation of conditions of overdraft

F. Replenishment of ground water extracted by water producers

G. Monitoring of ground water levels and storage

H. Facilitating conjunctive use operations

I. Identification of well construction policies

J. The construction and operation by the local agency of ground water contamination cleanup, recharge, storage, conservation, water recycling and extraction projects

K. The development of relationships with state and federal regulatory agencies

L. The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of ground water contamination

III. Additional powers granted under SWC Part 4 starting with §60220 and Part 6 starting with §60300 include levying assessments, conducting technical studies, protecting ground water supplies, taking action outside the district to protect ground water, water replenishment assessments, and water measuring devices

IV. Section 3 requires DWR to publish a bulletin no later than 1 January 1998 that reports on the ground water management plans that have been adopted by local agencies.

V. Benefits of ground water management

A. The basin is managed efficiently as a ground water reservoir.
B. Water supply is maximized.
C. Long term water supply is assured
D. Costs, benefits and water shortages are shared equitably

Carl Hauge, Department of Water Resources (916) 327-8861, 12 Aug 94

DRAFT

DEPARTMENT OF WATER RESOURCES BULLETIN 118-3030: Status of Ground Water Management Plans Adopted and Implemented Pursuant to AB 3030

Section 3, Chapter 947, Statutes of 1993: The Department of Water Resources shall, on or before January 1, 1998, prepare and publish, in a bulletin of the department published pursuant to Section 130 of the Water Code, a report on the status of ground water management plans adopted and implemented pursuant to Part 2.75 (commencing with Section 10750) of Division 6 of the Water Code.

Table of Contents

I. Name of local agency

II. County

III. Name, number and description of ground water basin
   - A. Size.
   - B. Major stream.
   - C. Water bearing material (s).

IV. Does the agency include the entire ground water basin?
   - A. If not, how many other agencies are partially or wholly within the same basin?
   - B. Map showing agency boundaries and ground water basin boundaries.

V. What section of the State Water Code has been used to form the ground water management plan?

VI. Status of Ground Water Management Plan
   - A. If formed pursuant to SWC Section 10750 et seq:
     1. Adopted a resolution of intention to develop a ground water management plan. Date.
     2. Entered into Memorandum of Understanding, Joint Powers Agreement, or other agreement with 1 or more local water service entities to develop a ground water management plan.
     3. Ground water plan adopted. Date.
     4. Ground water plan voted down. Date.
     5. Date when new resolution of intention to develop a ground water management plan can be adopted.
   - B. If formed pursuant to another Section of the SWC, please list Section number and activities included in the plan.

VII. Contents of plan:
   - A. Control of saline water intrusion.
   - B. Identification and management of wellhead protection areas and recharge areas.
   - C. Regulation of the migration of contaminated ground water.
   - D. Administration of a well abandonment and well destruction program.
   - E. Mitigation of conditions of overdraft.

F. Replenishment of ground water extracted by water producers.
G. Monitoring of ground water levels and storage.
H. Facilitating conjunctive use operations.
I. Identification of well construction policies.
J. Construction and operation by the local agency of ground water contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
K. Development of relationships with state and federal regulatory agencies.
L. Review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of ground water contamination.
M. Other.

VIII. Rules and regulations adopted to implement and enforce the ground water management plan
A. Limitation on extraction and/or water purchasing requirements.
B. Other.

IX. Fees and assessments proposed
A. Date voted on.
B. Passed/failed.
C. Amount of fee.

X. Purpose of the fee
A. Ground water extraction.
B. Replenishment water.
C. Administrative and operating costs.
D. Construction costs for capital facilities.

XI. Time schedule for implementing the plan's objectives. Identify phases.

XII. Hydrogeologic characteristics of the basin.
A. Well yields in gpm: Maximum and average
B. Depth zone in feet
C. Storage capacity in acre feet
D. Usable storage capacity in acre feet
E. Extraction in acre feet per year
F. Perennial yield in acre feet per year
G. Overdraft in acre feet per year
H. Estimated pump lift in feet
I. Number of wells monitored: Water level and quality

XIII. Degree of knowledge
XIV. Most recent study
XV. Problems
XVI. Cost
XVII. Management and status of basin

Carl Hauge, Department of Water Resources
(916) 327-8861, 10 Aug 94

GROUND WATER MANAGEMENT IN CALIFORNIA

Conclusions

1. Goals of ground water basin management have been clearly defined:

    a. Protection of natural recharge and use of intentional recharge.

    b. Planned variation of amount and location of extraction over time.

    c. Use of ground water storage conjunctively with surface water from local and imported sources, including recycled water.

    d. Protection and planned maintenance of ground water quality.

2. There is no single, institutional, financial, legal, or technical program for managing ground water in different parts of California.

3. Ground water management plans must match the institutional and technical framework that exists in a specific area. For this reason, management plans may not be identical from basin to basin or sub-basin to sub-basin.

4. If there is no ground water management plan in your area, you should start planning immediately with the data that are available. Don't wait for other studies to be started or finished.

5. Many existing water service agencies already have some regulatory authority relating to ground water.

6. AB 3030 provides clear procedures for developing a ground water management plan, but it does not eliminate previously existing institutional problems. Consensus-building that leads to resolution of such problems remains the responsibility of water managers.

7. Efficient management of the ground water reservoir maximizes water supply, assures a long-term supply, and spreads costs, benefits, and water shortages equitably.

Carl Hauge, Department of Water Resources, (916) 327-8861, 21 Jul 94

California Department of Water Resources
2 February 1993

WATER RESOURCES CHECKLIST--

SUBJECTS TO CONSIDER IN WATERSHED AND BASIN STUDIES FOR

WATER MANAGEMENT PLANS

Includes surface water, ground water, and recycled water.

This checklist can be used when planning and undertaking studies of watersheds and ground water basins. The checklist includes all subjects that could be considered relevant in studies of water resources to ensure effective and efficient water management.

Some of the subjects on the check list may not be relevant in some areas of the state and therefore may not require the same degree of study as in other areas. All of the subjects are included on the checklist to allow water managers to decide whether to include all subjects in their study or to exclude some subjects because consideration of those subjects may not be necessary in that watershed and basin.

The checklist is organized into 5 phases for ease in contracting with government agencies or private vendors to complete the work, and to allow management decisions as portions of the work are completed. At the end of any one of the first 3 phases you may decide to change the scope of the following phase before beginning the work, or you may decide to go no further with the project.

Phase 1

I. Identify management goals

II. Water Management Plan (Local Water Purveyors' plans)
   - A. Conservation practices
   - B. Conjunctive use
   - C. Plans for future phase 2 and phase 3 activities

III. Institutional Issues
   - A. Water Rights
   - B. Water Quality
   - C. Water management jurisdiction
      - 1. Statutory authority
      - 2. Boundaries

IV. "Process" Issues
   A. Interagency Coordination
   B. Planning Process
   C. Staffing
   D. Funding

V. Data Availability
   A. Surface water
   B. Ground water
   C. Water.quality
   D. Precipitation
   E. Geology
   F. Land use
   G. Land ownership
   H. Habitat designation

Phase 2

VI. Previous studies
   A. Surface water
   B. Ground water
   C. Water quality
   D. Protection of recharge areas
   E. Health
   F. Sewage treatment
   G. Waste water discharge
   H. Solid waste disposal
   I. Environmental projects
   J. Wetlands
   K. Habitat restoration
   L. Desalination

VII. Regional Water Budget (surface and ground water)
   A. Basin boundaries
   B. Precipitation
   C. Surface water runoff
   D. Ground water recharge
   E. Ground water outflow
   F. Evapotranspiration
   G. Inflow - outflow = change in storage

VIII. Hydrogeology
    A. Well inventory
        1. Drillers logs
            a. Construction information
            b. Lithology
        2. Canvass (field reconnaissance)
        3. Other sources
            a. Local agencies
            b. State, federal agencies
    B. Historical ground water data
        1. Ground water levels
        2. Ground water quality
        3. Change in ground water levels or quality
    C. Regional hydrogeology
        1. Recharge areas
            a. Recharge characteristics
                (1) Distribution
                (2) Quality
            b. Land use
            c. Hydraulic continuity between recharge and discharge areas
        2. Discharge areas
        4. Aquifer geometry
        5. Aquifer characteristics
            a. Transmissivity (T)
            b. Storativity (S)

IX. Water demands
    A. Present
        1. Population
        2. Land use
        3. Water demand

    B. Projected
        1. Assumptions
        2. Land use
        3. Population
        4. Water demand

X. Existing surface water delivery, drainage, and sewage systems
    A. Locations
    B. Capacities

XI. Water Quality
  A. Surface
  B. Ground water
    1. Protection of recharge areas
      a. Land use zoning
      b. Well Head Protection Areas (WHPAs)

  C. Sources of contamination
    1. Non-point sources
      a. Fertilizer
      b. Sewer leakage
      c. Other
    2. Point sources
      a. Industrial
      b. Sewage Treatment Plants
      c. Mining
      d. Others

XII. Recycled water
  A. Sources
    1. Amount
    2. Wheeling capability
  B. Facilities
    1. Treatment plants
    2. Pipelines
    3. Storage
      a. Surface
        (1) Location
        (2) Capacity
      b. Ground water recharge
        (1) Location
        (2) Capacity
  C. Potential uses
    1. Ground water recharge
    2 Landscape irrigation
    3 Industrial
    1. Agricultural
    2. Recreation
    3. Firefighting
    4. Construction
    5. Dual plumbing systems
      a. Toilets/urinals in high rises
      b. Cooling plants/towers

XIII. Environmental Impacts

A. Enhancement
1. Stream flow augmentation
2. Habitat restoration
3. Aesthetics
4. Other

B. Damage
1. Causes
2. Extent
3. Mitigation

XIV. Economics of water management and conjunctive use

A. Benefits
1. Water demands (see item VIII)
2. Direct and indirect impacts
   a. Income
   b. Employment
3. Environmental value
4. Mitigation of damages

B. Costs
1. Project scale
2. Regional/local comparisons
3. Project timing
   a. Integration with local activities
   b. Local project assistance
4. Environmental damage
   a. Foregone value
   b. Mitigation costs

C. Net project benefits

XV. Other study issues

A. GIS capability

B. Staffing or expertise in the following fields
1. Ground water
2. Surface water
3. Urban/agricultural water demand economics
4. Environment/ecology
5. Social impacts
6. Water recycling
7. Public participation and workshops
8. CEQA/NEPA documentation

Phase 3

Selection and design of a surface water allocation model and a ground water model. This phase can begin while phase 2 is underway. While conceptual and/or computer models are being developed they are useful in helping to increase the understanding of surface water and ground water flow in the basin and in helping to evaluate data collection programs for effectiveness at assessing the resource.

Phase 4

Selection of the preferred water management alternative(s)

A. Surface water
B. Recycled water
   1. Test program to prove the suitability of the recycled water for recharge
C. Ground water
   1. Conjunctive use
   2. Recharge
      a. In-channel
      b. Off-stream spreading basins
      c. Injection wells
      d. In-lieu use of surface water
   3. Identification of recharge sites that are available for a reasonable price
   4. Test programs to certify that available recharge sites have adequate:
      a. Infiltration rates
      b. Hydraulic continuity with discharge areas

Phase 5

Implementation of a water management program that will increase the amount of water available through more efficient use of all water supplies, including surface water, ground water, and recycled water.

AB 3030
GROUND WATER MANAGEMENT MANUAL

ELEMENTS OF A GROUND WATER MANAGEMENT PLAN

Produced by:

Ground Water Committee
Association of California Water Agencies

MARCH 1994

AB 3030
THE GROUND WATER MANAGEMENT ACT

GROUND WATER MANAGEMENT PLAN ELEMENTS

AB 3030, the Ground Water Management Act, authored by California State Assemblyman Jim Costa (D-Fresno) and signed into law in 1992, lists 12 components that may be included in a ground water management plan. Each component would play some role in evaluating or operating a ground water basin so that ground water can be managed to maximize the total water supply while protecting ground water quality.

Department of Water Resources' Bulletin 118-80 (pg. 9) defines ground water basin management as including planned use of the ground water basin yield, storage space, transmission capability, and water in storage. Ground water basin management includes:

(1) protection of natural recharge and use of intentional recharge;

(2) planned variation in amount and location of pumping over time;

(3) use of ground water storage conjunctively with surface water from local and imported sources; and,

(4) protection and planned maintenance of ground water quality.

The 12 components listed in Section 10753.7 of the Ground Water Management Act (AB 3030) form a basic list of data collection and operation of facilities that may be undertaken by an agency operating under this act.

Data collection will provide information to evaluate the water resources in the basin within the boundaries of the district. The construction of facilities will allow operation of the basin to protect ground water quality and to maximize the water supply by means of recharge of surface water and extraction of ground water at appropriate times and locations.

Specific comments about each of the 12 items listed in Section 10753.7 are included in the discussion that follows. For specific information about any issue, contact the Association of California Water Agencies, the California State Water Resources Control Board, the U.S. Environmental Protection Agency, or the California Department of Water Resources. Names and telephone numbers of appropriate experts are listed at the end of each discussion.

GROUNDWATER MANAGEMENT PLAN ELEMENTS AS SET FORTH IN AB 3030

10753.7 A groundwater management plan may include components relating to all of the following:

a) The control of saline water intrusion.

b) Identification and management of wellhead protection areas and recharge areas.

c) Regulation of the migration of contaminated groundwater.

d) The administration of a well abandonment and well destruction program.

e) Mitigation of conditions of overdraft.

f) Replenishment of groundwater extracted by water producers.

g) Monitoring of groundwater levels and storage.

h) Facilitating conjunctive use operations.

i) Identification of well construction policies.

j) The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.

k) The development of relationships with state and federal regulatory agencies.

l) The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

The Control of Saline Water Intrusion

Saline water can slowly degrade a ground water basin and ultimately render all or part of a basin unusable. Several sources can contribute to increased salinity in ground water. In addition to sea water intrusion, saline degradation of ground water can be caused by use and re-use of the water supply; lateral or upward migration of saline water; downward seepage of sewage and industrial wastes; downward seepage of mineralized surface water from streams, lakes, and lagoons; and interzonal or interaquifer migration of saline water (see illustration).

1. Increase in salt content dissolved from earth materials:
   Salts present in soil, sediment and rocks are dissolved by water that flows through those materials, increasing the salt content of that ground water.
   Control:
   This is a natural process and can not be prevented.

2. Lateral or upward migration of saline water:
   High quality ground water in an aquifer can be degraded if a ground water gradient is created that induces lower quality water to flow either laterally or vertically into the aquifer. This can occur through natural or manmade pathways. In some areas this may occur naturally when confining layers in the aquifer system are deposited in discontinuous lenses. The most common manmade pathway is a well. If wells are not built according to adequate standards, the ground water gradient may induce movement of lower quality water to flow into an aquifer with high quality water.
   Control:
   When the problem is naturally occurring, the method of control is to change the gradient so that the lower quality water does not flow into the aquifer containing high quality water. This can be accomplished by reduction of extraction from the aquifer, recharging the aquifer with good quality water, or by importing surface water to use in lieu of ground water. When the problem is caused by wells, enforcement of adequate well standards in well construction, renovation, and destruction can prevent such interzonal movement of lower quality ground water. Every ground water management plan should include provisions to ensure that wells in the basin do not become conduits for contamination of the aquifer.

3. Downward seepage of sewage, agricultural, or industrial waste:
   Sewage, agricultural and industrial waste that is disposed of indiscriminately will seep downward and eventually enter the aquifer and contaminate the ground water. By law such discharges must be permitted by the Regional Water Quality Control Boards under waste discharge permits. Discharges that occurred in the past, however, are revealing themselves today.
   Control:
   The first step in control is to be sure that such discharges are no longer taking place. Such steps include more rigorous enforcement of waste discharge permits on all industrial and agricultural operations, and a better understanding of the relationship between land use, discharge of pollutants, and ground water contamination.

4. Downward seepage of mineralized surface water:
Mineralized surface water from streams, lakes and lagoons can enter the aquifer and contaminate ground water.
Control:
If the mineralization is human-caused, better discharge control should be implemented. If the mineralization is natural, management options may include treatment, diversion, or replacement of the water.

5. Interzonal or interaquifér migration of saline water:
If wells are not built according to adequate standards, the ground water gradient may induce movement of lower quality water to flow into an aquifer with high quality water. In some areas this may occur because confining layers in the aquifer system were deposited in discontinuous lenses.
Control:
Enforcement of adequate well standards in well construction, renovation, and destruction can prevent interzonal movement of lower quality ground water through well borings. Every ground water management plan should include provisions to ensure that wells in the basin do not become conduits for contamination of the aquifer.

If discontinuous confining or perching layers in the aquifer provide openings through the clay layer that act as conduits for interzonal contamination, ground water managers should consider managing the basin to maintain interaquifer gradients that prevent or minimize such contamination."

6. Sea water intrusion (not shown in illustration):
Sea water intrudes inland into coastal aquifers when the head in the aquifer is reduced by ground water extraction inland (up-gradient) of the coast.
Control:
Three methods are available to control sea water intrusion. First, extraction of ground water up gradient can be reduced. In California, where the population is continuously increasing, this has proven to be unworkable. Second (and most common), a sea water intrusion barrier can be built that injects water into the aquifer. The barrier consists of fresh water at a higher head than the sea water so that the sea water can not flow inland into the aquifer. Some of the fresh water injected into the barrier flows seaward while some of the injected water flows inland and may be extracted by wells that are perforated in the aquifer. Third, a sea water intrusion barrier can be built that extracts water along the coast which lowers the ground water levels along the coast below sea level and below the level of nearby fresh ground water. The mix of fresh water and sea water is then pumped back to the ocean.

For more information on this topic, please contact:
State
Department of Water Resources, Carl Hauge 916/327-8861

Key to Illustration

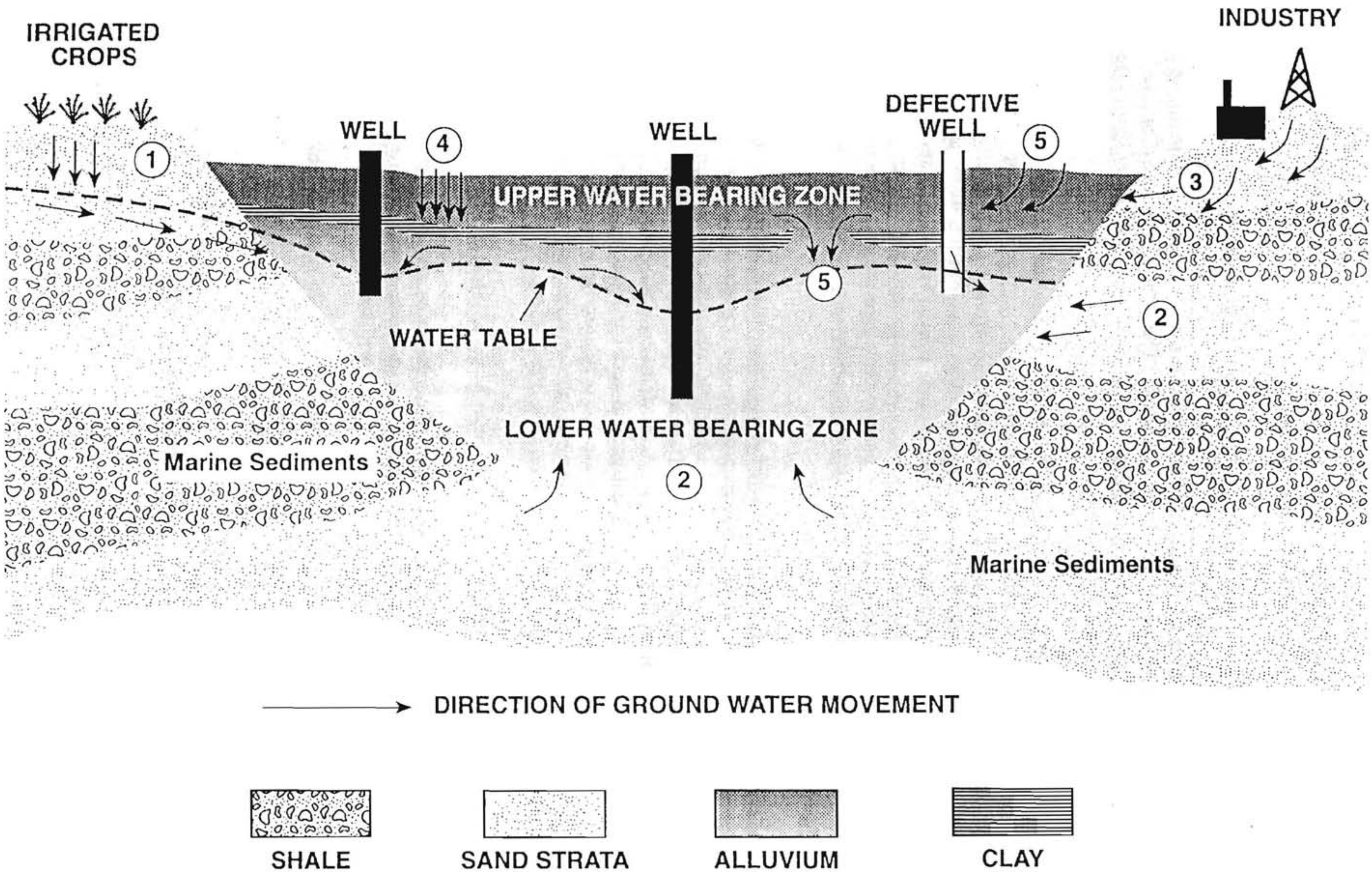
1. **Degradation of Ground Water Through Use and Re-use**
   Example: Irrigation water applied to crops is increased in salinity through evaporation. The seepage, unconsumed by vegetation, returns to the ground water and is further degraded en route by leaching salts from the soil.

2. **Degradation of Ground Water Through Lateral or Upward Migration of Saline Waters**
   Example: The sand strata illustrated were deposited in the ocean and were subsequently elevated to their present positions. Sea water contained within these sediments since their deposition migrates to the alluvium under influence of the hydraulic gradient created by pumping of the wells. Prior to exploitation of ground water such migration was generally negligible.

3. **Degradation of Ground Water Through Downward Seepage of Sewage and Industrial Wastes**
   Example: Sewage and industrial waste seeping from cesspools or permeable sumps ultimately migrates to the ground water supply.

4. **Degradation Through Downward Seepage of Mineralized Surface Waters From Streams, Lakes and Lagoons**
   Example: Mineralized surface water migrates to the ground water supply.

5. **Degradation Through Interzonal Migration of Saline Waters**
   Example: Degraded water with the upper water-bearing zone enters the lower productive water-bearing zone through an opening in the clay layer that separates the two zones or through defective, improperly constructed or abandoned wells.



Schematic Section Across an Alluvium-Filled Ground Water Basin Underlain and Flanked by Less Permeable Sediments of Marine Origin

Identification and Management of Wellhead Protection Areas and Recharge Areas

The federal Wellhead Protection Program was established by Section 1428 of the Safe Drinking Water Act Amendments of 1986. The purpose of the program is to protect ground water sources of public drinking water supplies from contamination, thereby eliminating the need for costly treatment to meet drinking water standards. The program is based on the concept that the development and application of land-use controls (usually applied at the local level in California) and other preventative measures can protect ground water.

A Wellhead Protection Area (WHPA), as defined by the 1986 Amendments is, "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield". The WHPA may also be the recharge area that provides the water to a well or wellfield. Unlike surface watersheds that can be easily determined from topography, WHPAs can vary in size and shape depending on geology, pumping rates, and well construction. There are several different methods which can be used to delineate the lateral boundaries of a WHPA. These include simple fixed radius techniques, analytical equations, numerical modeling, and geologic mapping.

Under the Act, states are required to develop an EPA-approved Wellhead Protection Program. To date, California has no formal state-mandated program, but instead relies on local agencies to plan and implement programs. For this reason, AB 3030 was enacted. A number of local governments, including Santa Clara Valley Water District, Descanso Community Water District, West San Bernardino County Water District, and Monterey County Water Management District, are in various stages of developing local ground water management programs that include WHPAs. Wellhead Protection Programs are not regulatory by nature, nor do they address specific sources. They are designed to focus on the management of the resource rather than control a limited set of activities or contamination sources.

A complete Wellhead Protection Program should consist of seven elements:

1. Form a committee of participants and determine the roles of various state agencies, local governments, and public water suppliers. The committees should prepare a summary and purpose describing how the WHP goal will be achieved;

2. Delineation of Wellhead Protection Areas (WHPAs) based on reasonably available hydrogeologic information on ground water flow, recharge and discharge, and other information deemed necessary to adequately determine the wellhead protection area;

3. Identification of potential sources of contaminants within each WHPA. Current, past, and future land uses should be considered when developing the contamination source inventory;

4. Development of management approaches to protect the ground water from contaminants, including technical assistance, financial assistance, implementation of control measures, education, training, and demonstration projects;

5. Development of a contingency plan to provide alternate drinking water supplies in case a well or wellfield becomes contaminated;

6. Development of a plan to prevent new well drilling from contaminating or spreading the contamination of ground water; and,

7. Development of a public participation program so that local citizens can be involved throughout the planning process.

For more information on this topic, please contact:

State

Department of Water Resources
For California ground water information, call:
Carl Hauge at 916/327-8861

Federal

U.S. Environmental Protection Agency
For specific WHP information, call:
Sunny Kuegle at 415/744-1830 or
Susan Whichard at 415/744-1924

To obtain a listing of WHP documents, call 800/ 426-4791.

For California ground water information, call:
Tony Lewis at 415/744-1913 or
Susan Whichard at 415/744-1924

U.S. Geological Survey, Water Resources Division, Sacramento
For California ground water information.

AB 3030 Sec. 10753.7 (c)

Regulating Contaminant Migration In Ground Water

Ground water contamination originates from a number of sources or activities, such as leaking tanks discharging petroleum products or solvents, or the application of pesticides and fertilizers. Effective control and clean-up of contaminated ground water requires a coordinated effort between all regulatory agencies involved, source control, understanding of the hydrogeology, and delineation of the contamination.

Agencies with a role to play in mitigating ground water contamination generally include the Regional Water Quality Control Board (Regional Water Board), Department of Toxic Substances Control, U.S. Environmental Protection Agency, and now the ground water management agency (GMA). Each agency has a unique set of regulatory authorities and expertise to contribute. The degree to which they participate depends on the nature and magnitude of the problem. What ever role the GMA decides to play, it should insure its actions are in concert with those of the other involved agencies.

Typically, source control is the identification of current and past users of hazardous materials, and verification of the proper storage and disposal of these materials. In many cases the Regional Water Board conducts this activity. If, during the verification process, evidence of any uncontrolled discharge or spill of these materials is found, then the Regional Water Board can order investigation of the extent of contamination and its subsequent cleanup. Usually, these activities are conducted on a site basis and generally do not consider regional identification and control of contamination. The GMA should remain in close contact with the Regional Water Board during the source investigations and site cleanups.

In the event that the source(s) of contamination is not found, the GMA can have a role in finding, containing, and removing the contamination, usually on a regional scale. Controlling the migration of contamination requires an understanding of the hydrogeology of the basin and delineating the lateral and vertical extent of the contaminant plume(s). Technical information for many basins is available from a number of sources such as the United States Geological Survey and Department of Water Resources. The most common tool for delineating the boundaries of a plume is the monitoring well. Monitoring wells can tap one aquifer or many, depending on the design and need. Very often, monitoring wells used for contaminant control are made part of a larger data collection effort for the GMA (for example, a series of wells to monitor water levels throughout the basin).

Once the location of contamination is verified, the GMA can choose to monitor its migration, contain it from moving further into clean aquifers, or remove it from the aquifer. Containment is often an interim step to protect downgradient aquifers and drinking water supplies and/or to provide time to complete investigations and construct a more comprehensive long-term treatment system.

Complete removal of some contaminants, such as solvents and nitrates, is often difficult, if not impossible. The level of effort undertaken by the GMA to deal with the contamination depends on several factors, including available funds, risk to drinking water supplies and public health, the extent and concentration of contamination, the ability to use the ground water that is removed and treated, and state and federally mandated clean-up levels.

For more information on this topic, please contact:
Local
San Gabriel Basin Water Quality Authority
Jim Goodrich 818/859-7777

State
Regional Water Quality Control Board for your area.
Department of Toxic Substances Control District Office for your area.

Federal
U.S. Environmental Protection Agency, Region 9

AB 3030 Sec. 10753.7 (d)

The Administration Of A Well Abandonment And Well Destruction Program

All wells should be properly destroyed or decommissioned if they are not to be used in the future. Wells that are abandoned or improperly destroyed can pollute ground water to the point where it is unusable or requires expensive treatment. There are three general means by which this occurs: 1) pollutants enter the well from the surface, 2) the well establishes vertical communication and allows poor quality ground water and pollutants to move from one aquifer to another, and (3) the well is used for illegal waste disposal . Ground water contamination is not the only threat to public health due to abandoned wells. These wells also pose a serious physical hazard to humans and animals. A survey of wells in Fresno County found about 10% of abandoned wells were not properly destroyed.

Property owners or lessees who do not properly destroy an abandoned well on their land may be guilty of a misdemeanor (under Section 24400 of the Health and Safety Code). Wells do not have to be destroyed if future use is anticipated, but they must be properly capped and maintained, as specified in the Code. Criminal penalties do not apply unless the well presents a public health hazard or a probable preferential pathway for the movement of pollutants, contaminants, or poor quality water. In any case, the owner can be assessed clean-up costs if the well causes a ground water contamination problem.

Sections 13700 through 13806 of the California Water Code require proper destruction of wells. Minimum standards for the destruction of wells are specified in Department of Water Resources Bulletins 74-81 and 74-90. These standards apply to all water wells, cathodic protection wells, and monitoring wells. The only significant exception is oil, gas, and geothermal wells, which are regulated by the Department of Conservation. If a local agency does not have its own well standards ordinance, it must enforce the State's Model Well Ordinance (State Water Resources Control Board Resolution No. 89-98). Local agency requirements may exceed State standards.

For more information on this topic, please contact:

<u>State</u>

State Water Resources Control Board
Ken Harris 916/657-0876

For copies of DWR Bulletins call 916/653-1097.

Mitigation Of Groundwater Overdraft

Uncontrolled overdraft, long-term depletion of storage or groundwater mining in a ground water basin can cause several problems, including subsidence, degradation of ground water quality, and increased cost in pumping. In addition, if the storage in a ground water basin is depleted and not replaced naturally or by an artificial recharge program, this source of supply cannot be counted upon when surface water sources are limited, as in a prolonged drought. A Ground Water Management Plan under AB 3030 would provide a tool to assist in developing methods to control and manage ground water overdraft.

Mitigation of ground water overdraft can occur through the cessation or regulation of extractions and/or the increase of recharge to offset over extraction. This could take the form of restrictions through strict regulations of amounts extracted. Another form would be the use of financial incentives to control the amounts extracted, i.e. significant surcharges on quantities extracted in excess of a prescribed limit.

Controlling ground water overdraft may be accomplished through active replenishment of the basin. Surface water may be acquired by the ground water management agency and used to recharge the basin supplies. Some enhancement of natural replenishment may be appropriate, or a more intensive system of spreading grounds, off-stream recharge basins, and/or injection wells could be employed to introduce the recharge water into the basin.

Managing ground water overdraft may also be accomplished through conjunctive use. The establishment of a conjunctive use program would use surface water to recharge the basin in times of surplus, and rely more on ground water pumping in times of shortage of surface water. The use of surface water "in-lieu" of ground water, and the ability to extract ground water to replace limited or depleted surface water supplies, necessitates redundant systems and a certain investment in infrastructure to maximize the efficiency of this type of program.

For more information on this topic, please contact:

Local
Orange County Water District
William R. Mills Jr. 714/378-3200

State
Department of Water Resources
Carl Hauge 916/327-8861

AB 3030 Sec. 10753.7 (f)

Replenishment Of Ground Water Extracted By Producers

The replenishment of ground water extracted by producers is an important management technique of a ground water agency because it can increase the yield of the basin.

Replenishment of ground water can be achieved through recharge of either natural water supplies or water acquired from outside the basin by the ground water management agency. Maximizing the use of naturally occurring supplies can be accomplished through effective management of those resources. A ground water management agency may develop facilities to retain rainfall and runoff, and to capture surplus flows in natural streams or rivers, in order to have supplies to replenish the ground water basin.

An assessment of local geology is necessary to determine the areas or sites where surface water may be most efficiently percolated into the ground water basin. A careful examination should be performed of surplus quarry sites or abandoned excavations, which may have the requisite geologic characteristics and provide for a minimal cost opportunity for establishing recharge facilities.

A ground water management agency may also acquire water supplies, through purchase or diversion, to replenish a ground water basin. This method may require the securing of water rights to a supply. If the ground water management agency is unable to use naturally occurring stream beds for the delivery of surface water, the construction of facilities, such as canals or pipelines, may be necessary to deliver the water to other facilities used to replenish the basin.

Replenishment of a ground water basin may be in the following ways: 1) through natural percolation of surface water through the soil to the basin, 2) the delivery of surface water to spreading grounds or basins which are maintained to allow maximum percolation into the ground water; or 3) through injection of surface water into the ground water basin through injection wells.

The ground water management agency may have the need for funds to purchase surface water, construct facilities to deliver surface water, or purchase, construct or maintain replenishment facilities. A Replenishment Assessment (RA) is often levied by ground water management agencies to fund the purchase of replenishment water and to finance facilities for replenishment. A tiered assessment may be considered in which a lower RA rate is used for water pumped below the safe yield and a higher RA rate used to offset the additional burdens on the resource caused by overdraft.

For more information on this topic, please contact:

Local	State
Orange County Water District	Department of Water Resources
William R. Mills Jr. 714/378-3200	Carl Hauge 916/327-8861

AB 3030 Sec. 10753.7 (g)

Monitoring Of Ground Water Levels And Storage

The purpose of a ground water level monitoring program is to provide information that will allow computation of the change of ground water in storage. The information needed includes spring and fall ground water levels, the hydraulic properties of the aquifer(s) (such as permeability and specific yield), and the land area covered by the basin.

An adequate monitoring well network includes wells that are representative of the vertical and lateral dimensions of the aquifer(s). Establishing the network of monitoring wells requires that each well be designed to tap individual aquifers in the basin.

Data collected from each monitoring well should be entered into a computer data base. These data can then be used to create hydrographs, ground water elevation contour maps, and ground water change contour maps that will provide the tools to evaluate ground water levels and determine changes in ground water in storage.

While AB 3030 does not mention monitoring of ground water quality, monitoring for water quality should be included in any ground water management plan. Water quality and water quantity can not be separated. Changes in ground water quality can only be detected by comparison with earlier ground water quality data.

For more information on this topic, please call:
<u>State</u>
Department of Water Resources
Carl Hauge 916/327-8861

AB 3030 Sec. 10753.7 (h)

Facilitating Conjunctive Use Operations

Conjunctive operation of a ground water basin is defined in DWR Bulletin 118-80 as:

> "Operation of a ground water basin in coordination with a surface water reservoir system. The basin is intentionally recharged in years of above average precipitation so ground water can be extracted in years of below average precipitation when surface water supplies are below normal."

Another way to describe conjunctive operation of a ground water basin is that the ground water reservoir is managed in a manner that is similar to a surface water reservoir. Such management includes reduction of storage in the reservoir when water demand is high.

A conjunctive use program requires:

- a source of surface water in years of high precipitation;
- conveyance facilities to import or export water;
- recharge facilities;
- usable storage capacity in the aquifer;
- extraction facilities; and,
- distribution facilities for surface water and ground water.

A conjunctive use program can vary from a limited program to a comprehensive, intensively managed program that coordinates surface water use and delivery, and ground water use and extraction. A limited program makes use of surplus surface water only when it happens to be available, whereas the comprehensive program includes contractual commitments to purchase surface water for recharge, metered extraction, and control of points and amounts of extraction to minimize pump lift and minimize or correct ground water quality problems. In addition, there may be many programs that fall between the two extremes.

Conjunctive operations must also consider several potential undesirable results, including lost phreatophyte vegetation and wetland habitat, adverse effects on third parties, land subsidence, and degradation of water quality in the aquifer.

Loss of phreatophytes may occur when ground water levels are lowered and less water is available for wetlands. Third party effects might include lowering of ground water levels below the bottom of a well, or raising ground water levels so that local flooding occurs. Subsidence caused by extraction of ground water can damage canals, wells, buildings, tanks, bridges, and other surface facilities that would require costly repair. Ground water quality can be degraded if ground water gradients induce movement of lower quality water into the aquifer.

Conjunctive operations are employed in many areas of southern California, San Joaquin Valley, and Santa Clara Valley. Conjunctive operations will expand because of the need for more water and the expense of new surface water facilities. In general, conjunctive operations promise to be less costly than traditional surface water projects, increasing the efficiency of water supply systems and causing fewer negative environmental impacts than new surface water reservoirs.

For more information on this topic, please contact:

State
Department of Water Resources
Carl Hauge 916/327-8861

AB 3030 Sec. 10753.7 (i)

Identification Of Well Construction Policies

Improperly constructed wells can result in poor yields, but more importantly may result in contaminated ground water by establishing a pathway for pollutants entering a well for drainage from the surface, allow communication between aquifers of varying quality, or the unauthorized disposal of waste into the well.

Well construction policies should be identified which ensure that well drillers comply with local ordinances and State law. A county permit is required for drilling, deepening, modifying, or repairing a well. Whoever performs the work must have an active C-57 Contractor's license. In most cases, an inspection is required prior to sealing the well.

Sections 13700 through 13806 of the California Water Code requires proper construction of wells. Minimum standards for the construction of wells are specified in Department of Water Resources Bulletins 74-81 and 74-90. These standards apply to all water wells, cathodic protection wells, and monitoring wells. The only significant exception is oil, gas, and geothermal wells, which are regulated by the Department of Conservation. If a local agency does not have its own well standards ordinance, it must enforce the State's Model Well Ordinance (State Water Resources Control Board Resolution No. 89-98). Local agency requirements may exceed State standards.

For more information on this topic, please contact:
State
State Water Resources Control Board
Ken Harris 916/657-0876

For copies of DWR Bulletins call 916/653-1097

Construction and Operation of Ground Water Management Facilities

Effectively managing a ground water basin requires the planning and construction of projects that protect the quality of ground water and assures that the quantity of ground water in storage is managed to meet long-term demands. Where conjunctive use is practiced, water distribution facilities must be planned to deliver both ground water and surface water, depending on the hydrologic conditions in the region or state. Following are examples of facilities which aid in efficient management of ground water resources.

Ground Water Contamination Cleanup Projects
Contamination of ground water not only results in unusable water supply, but also poses a hazard for ground water supplies within the same basin caused by the migration of the contamination. In some cases, it may cause a decrease in operational storage and yield of the basin. Projects within the basin to cleanup contaminated ground water protect the entire basin from further contamination, and are also capable of producing water.

Ground Water Recharge Facilities
An agency may find it necessary to acquire, establish or construct ground water recharge facilities to quickly replace ground water extracted by producers. These facilities, which can increase the operational yield of the basin, may include: stream beds or spreading grounds, percolation basins, injection wells, and surface water delivery systems.

Water Recycling Projects
Demand management can be achieved by the replacement of irrigation supplies with non-potable, recycled water. Water recycling projects can relieve demands on the ground water basin by lowering the demand for ground water supplies for irrigation of landscaping, some agriculture and some industrial uses. Although water recycling projects are capital and O&M intensive, they do provide a reliable source of water.

Ground Water Extraction Projects
Conjunctive use programs deliver surface water in-lieu of ground water during surpluses, in exchange for increased extraction of ground water during dry periods. The trade off may result in users being asked to expand the capacity of their ground water extraction facilities. Ground water extraction projects may also be required by the shifting of extractions from one part of the basin to another as a result of contamination, hydrologic conditions, or recharge efforts. An agency may also construct extraction projects in order to entice the users to switch the source of their ground water.

For more information on this topic, please contact:

Local	State
Orange County Water District	Department of Water Resources
William R. Mills Jr. 714/378-3200	Carl Hauge 916/327-8861

AB 3030 Sec. 10753.7 (k)

The Development of Relationships With State and Federal Regulatory Agencies

The formation of a ground water management district involves the development of relationships and communication strategies with a variety of state and federal regulatory agencies. Working effectively with each of these agencies requires a local ground water management district to understand the role of these players in regulating and managing ground water resources.

Ground water planning, as defined in AB 3030, is a state led activity. The State Water Resources Control Board (State Water Board), as the lead state water agency responsible for maintaining water quality standards, provides the framework and direction for California's ground water protection efforts. Through its Regional Water Quality Control Boards, the State Water Board initiates state-wide planning and protection programs. Local communities should consider work with the State Water Board and Regional Boards in actually designing and implementing their ground water protection programs.

National policy direction and consistency in ground water protection efforts is provided by the Environmental Protection Agency (EPA). EPA provides both national guidance in state-led comprehensive ground water protection plans and a portion of the resources needed to carry out those planning efforts. While states are provided the flexibility to design programs that make sense on a regional and local basis, EPA guidelines ensure that all ground water protection plans and programs are preventive in nature, comprehensive in scope and consistent in maintaining a high level of protection across the nation.

For more information on these agencies and their roles and responsibilities, please contact:

State
State Water Resources Control Board
Ken Harris 916/657-0876

Federal
U.S. Environmental Protection Agency
Tony Lewis 415/744-1913

AB 3030 Sec. 10753.7 (l)

The Review Of Land Use Plans And Coordination With Land Use Planning Agencies To Assess Activities Which Create A Reasonable Risk Of Ground Water Contamination

An important component of developing a ground water management plan is the review of land use plans for the surrounding area or basin, and coordinating efforts with regional, sub-regional, and local land use planning agencies. In California, the majority of land use decisions are made by city and county government agencies. Undoubtedly, land activities and how they are managed can affect both ground water quality and quantity. The threat that a certain land use may pose to a ground water resource is a function of the ground water aquifer properties, management practices associated with the individual land use, and actual use of surrounding land (cumulative impact of all activities). As an example, hydrologic conditions may dictate that in certain areas, the aquifer is more vulnerable to pollution. This may be due to the permeability of the underlying soils and/or a shallower depth to the water table. To assure protection of ground water quality in the basin, this type of information may be taken into consideration when making land use decisions regarding zoning.

Examples of common land uses with a potential to adversely impact ground water supplies include large scale unsewered residential development, and industrial development without proper control measures or management practices. Cumulative impacts to a basin and relative land development density should also be evaluated. The use of shallow drainage wells to dispose of surface run off from streets, highways, parking lots, and agricultural areas, if determined to be of concern for the area, can also be addressed in the management plan. In this instance, the risk of a major roadway accident or spill, or the potential for the well being used as an illegal disposal site for hazardous substances, could be factored into the planning process.

A key aspect of ground water management is maintaining quantity or supply. Land use planning decisions that lead to covering up large portions of land with impervious surfaces can increase storm water runoff. This can lead to excessive down cutting and erosion in stream channels and flooding in the lower part of the watershed. The amount of natural recharge to the ground water basin can be significantly reduced. Land use decisions such as maintaining green space in areas of high recharge and encouraging the use of pervious materials will have a net benefit to the ground water basin.

The process of developing a ground water management plan can allow for information exchange between several parties, including agricultural and industrial water users, citizens, and resource, regulatory and planning agencies. The ground water management plan ultimately assists local planners, and local planners assist in the process of developing a comprehensive plan which can be realistically implemented resulting in effective protection and management of the ground water resource.

For more information on this topic, please contact:

State

San Francisco Bay Regional Water Quality Control Board, Dyan Whyte 510/286-1324

STEPS TO APPLY AB 3030

1) Local Agency holds noticed public hearing on Resolution of Intention to draft a Groundwater Management Plan.

2) After hearing, local Agency drafts Resolution of Intention to adopt a Groundwater Management Plan.

3) Publish Resolution of Intention.

4) Prepare a draft Groundwater Management Plan (within two years).

5) After draft Groundwater Management Plan is completed, Local Agency holds second noticed public hearing.

6) Land owners affected by Plan may file protests to the Plan.

7) If majority protest occurs (**representing more than 50% of assessed valuation of the land only, excluding structures**), the Ground Water Management Plan shall <u>not</u> be adopted.

8) Otherwise, Plan may be adopted.

9) A Local Agency may fix and collect fees and assessments for groundwater management costs associated with the implementation of the Groundwater Management Plan, **if such authority is approved by a majority of votes cast in a popular election**.

ACKNOWLEDGEMENTS

The following persons contributed to this report:

William R. Mills Jr.	Orange County Water District
James Goodrich	San Gabriel Basin Water Quality Authority
Dyan Whyte	San Francisco Bay Regional Water Quality Control Board
Carl Hauge	Department of Water Resources, State of California
Ken Harris	State Water Resources Control Board, State of California
Doris Betuel	U.S. Environmental Protection Agency, Region 9
Tony Lewis	U.S. Environmental Protection Agency, Region 9
Susan Whichard	U.S. Environmental Protection Agency, Region 9
Mark Leyes	Orange County Water District
Dana Wisehart	Association of California Water Agencies

March 1994

SANTA MARIA VALLEY
WATER CONSERVATION DISTRICT

P. O. BOX 364 -:- PHONE (805) 925-5212
SANTA MARIA, CALIFORNIA 93456

February 2, 1995

To All Parties Interested in the Proposed Joint Groundwater Management Plan:

The next meeting of the ad hoc group for the formulation of a joint groundwater management plan for the Santa Maria Valley will be held on Thursday, February 9, 1995, at 2:00 P.M., at the Bonita Packing conference room, 1850 West Stowell Road, in Santa Maria.

The Bonita Packing office building is located south of West Stowell Road between Blosser Road and Black Road.

At the January, 1995 meeting, it was agreed that the Santa Barbara County Water Agency would put together a preliminary draft of a proposed groundwater management plan from materials previously presented to the committee and from the minutes of prior meetings.

Enclosed to each of you is the draft prepared by Santa Barbara County Water Agency. Darcy Ashton of the water agency staff, and Rob Almy, agency manager, did most, if not all, of the work on this draft.

It was emphasized at the January meeting that the enclosed draft is a working document, one that should be extensively amended, corrected or modified. This document is only a starting point and is in no way a proposal. Darcy and Rob will not be upset if anyone suggests that their work can be improved. They will be pleased.

It was also suggested and agreed at the January meeting that the February meeting would be devoted to discussing the draft with a view of improving it. Therefore, please be prepared to offer constructive criticism, proposed modifications and additions to the enclosed draft, both as to the structure and details of the proposed plan.

Also enclosed to each of you for your file is a copy of the minutes of the minutes and attendance sheet for the January 12, 1995 meeting.

Yours very truly,

Maurice F. Twitchell,
Secretary

MFT:gn
Encls.

JOINT GROUNDWATER MANAGEMENT PLAN FOR THE SANTA MARIA VALLEY GROUNDWATER BASIN

I.
INTRODUCTION

A. General.
This groundwater management plan is adopted by ________ and SANTA MARIA VALLEY WATER CONSERVATION DISTRICT pursuant to authority of the Groundwater Management Act of 1992 (Water Code Sections 10750, et seq.) for the purpose of assuring long term reliability and quality of the groundwater in the Santa Maria Valley groundwater basin.

B. Purpose.
The objective of the plan is to ensure that sufficient water resources are available to satisfy the present and projected beneficial uses of water within the plan area. The plan is designed to protect groundwater quality within the basin and to balance long-term average annual replenishment with extractions and other losses to the basin as may be consistent with the public interest. (Source: Slater handout/16 AUG 94)

C. References.
The sources of information for this plan are the Santa Maria Valley Water Resources Report, Santa Barbara County Water Agency. April 1994; information presented in a series of public meetings (Appendix A); and additional studies as specified in this plan.

II.
GOALS FOR THE BASIN

NOT ADDRESSED

III.
CONDITION OF THE BASIN

A. Monitoring network and results

The Santa Barbara County Water Agency, City of Santa Maria and California Cities Water monitor water levels in the Santa Maria groundwater basin through monitoring wells or active agricultural or municipal wells. This information is published annually in USGS groundwater reports. These wells are listed in Appendix B.
(Source: Santa Maria Water Resources Report)

B. Estimated storage

The total volume of water in saturated deposits within the Santa Maria Groundwater basin has been estimated to be about 100 million acre feet. The total usable groundwater stored in the basin was estimated to be 1.5 million acre feet.
(Source: Santa Maria Water Resources Report)

C. Historical variations in groundwater level

Data collected indicates that groundwater levels have declined significantly since 1918. Groundwater levels in 1991 suggest total storage was about 1.1 million AF lower than those initially recorded in 1918. Groundwater levels in 1984 were significantly higher due to an exceptionally wet period beginning in 1978, then declined dramatically in the subsequent 1985 - 1991 dry period. Most groundwater levels recorded in 1991 and 1992 were the lowest in recorded history.
(Source: Santa Maria Water Resources Report)

D. Historical variations in groundwater pumpage

Currently, municipal and industrial use accounts for roughly one quarter of the total water used in the valley. Municipal and industrial water use is clearly related to population, and population in the Santa Maria Valley nearly doubled between 1970 and 1990. The expected increase in water use may be somewhat offset by a projected decrease in per capita demand due to increased water efficiency. Per capita M & I water use declined by approximately 12.5% during the 1980's, and it has been assumed that future efficiency would remain at 10% below 1970 (baseline) per capita use. However, per capita rates could drop further as additional urban and agricultural best management practices are implemented.

Agricultural water use varies by crop requirements, soil characteristics, precipitation, temperatures and irrigation efficiency. In 1944, irrigated lands totalled about 35,000 acres with an estimated groundwater pumpage of 71,000 AF. After World War II (1945 to 1958), irrigation pumpage jumped upward to levels estimated by the USGS as varying between a low of 93,000 AFY in 1951 to a high of 139,000 AFY in 1958, and averaging almost 109,000 AFY. The estimate for 1990 agricultural pumpage, using Department of Water Resources cropped acreage estimates and University of California Cooperative Extension, Farm Advisor water duty factors, is 130,619 AF.

(Source: Santa Maria Water Resources Report)

E. Known contamination problems, federal/state response

Within the Santa Maria groundwater basin there has been some groundwater contamination. The City of Santa Maria has shut down one well because of PCB contamination; two more are out of service due to high nitrate concentrations (above the 45 ppm limit). Much of the existing

M & I GROUNDWATER PUMPAGE, ACRE FEET/YEAR
1983 – 1993

Cal. Year	AGENCY:	City of Santa Maria	Cal Cities Water	City of Guadalupe
1983		8903	5714	733
1984		10299	7079	961
1985		10605	7276	908
1986		11033	7625	800
1987		11191	7616	757
1988		11849	8678	823
1989		12464	8860	828
1990		12052	8691	724
1991		11476	8210	NR
1992		12116	8381	NR
1993		11984	8174	NR

NR = No record

From the Santa Barbara County Water Agency, January 1995

Source: Santa Maria Water Resources Report

Table III – 4

IRRIGATION WATER USE IN SANTA MARIA VALLEY CIRCA 1990							
IRRIGATED CROP	Santa Maria DAU Cropped acres	Applied Water (ft/crop)	Applied Water (ac ft)	South SL Obispo DAU cropped ac.	Applied Water (ft/crop)	Applied Water (ac ft)	Total Applied Water SM Valley (ac ft)
Grain	1690	0.5	845	220	0.5	110	955
Corn	1050	1.8	1890	40	1.5	60	1950
Other Field	2430	1.8	4374	300	1.5	450	4824
Alfalfa	890	3.0	2670	110	2.6	286	2956
Pasture	2840	3.0	8520	230	2.8	644	9164
Tomatoes	0	1.7	0	80	1.5	120	120
Other Truck	41260	1.7	70142	18800	1.6	30080	100222
Deciduous	10	1.7	17	0	1.2	0	17
Citrus & Subtropical	70	1.7	119	1110	1.2	1332	1451
Vineyards	4360	2.0	8720	200	1.2	240	8960
TOTALS	54600		97297	21090		33322	130619

NOTES: The above applied water estimates are derived by using California Department of Water Resources (DWR) preliminary 1990 cropped acreages combined with the University of California Cooperative Extension (Farm Advisor) unit water duty factors for crops grown in the Santa Maria Valley area.

"Other Truck" is assumed to be Broccoli, Cabbage, Cauliflower, Carrots, Celery, Lettuce, Potatoes, and Strawberries as per the Crops listed under "Vegetables" in the Farm Advisors "IRRIGATION WATER USE TABLE" (see Appendix C).

The Santa Maria value for Cauliflower (or the Sisquoc value for Broccoli) from the Farm Advisor Table was used to reflect the average "Other Truck" crop unit duty factor for the Santa Barbara County part of Santa Maria Valley. For the San Luis Obispo part of Santa Maria Valley the "Other Truck" average crop unit duty factor is reduced by one tenth foot (1.7 to 1.6 feet) as most of these plantings are in the Oso Flaco alluvial wing of the ground water basin.

The Sisquoc Range unit duty value (2 ft/yr) for grapes was used to reflect vineyard use in the Santa Barbara County part of Santa Maria Valley, while the lower Santa Maria and Lompoc Range value (1.2 ft/yr) was used for vinyards in the San Luis Obispo part of the valley.

Note that the preliminary 1990 total applied ag water estimated by DWR (172,528 ac ft, as seen in Appendix C) is 41909 ac ft higher than the above estimate of 130,619 ac ft due to the larger unit duty factors used by DWR.

TABLE VI-1
SANTA MARIA GROUND WATER BASIN
ESTIMATED STORAGE ABOVE SEA LEVEL

		AF in Storage (x 1,000)					
STORAGE UNIT	SURFACE AREA (AC)	1918[b]	1950[b]	1959[b]	1977[c]	1984[c]	1991[c]
Guadalupe[a]	25,000	235	171	145	125	165	131
Nipomo	10,500	250	160	140	136	167	134
Betteravia	6,100	82	65	47	34	53	37
Santa Maria	17,400	540	292	265	190	392	180
Fugler Point	5,500	230	153	170	151	214	138
Orcutt	16,200	460	277	290	151	231	161
Bradley Cny.	22,000	1,020	992	900	931	1,010	923
Sisquoc	4,200	255	252	250	270	302	263
TOTAL	106,900	3,072	2,362	2,207	1,988	2,534	1,967

a) Ground water in storage from 10 ft. above sea level to top of saturated zone

b) From USGS Water Supply Paper 1819-A, Pg. A7

c) From Santa Maria Ground Water Basin Budget Status, Jon Ahlroth, SBCWA 1992

source: Santa Maria Water Resources Report nitrate contamination has apparently been caused by agricultural fertilization; however, technological improvements in nitrogen application rate and residuals monitoring have allowed farmers to cut back significantly on their contribution to nitrate levels. Many large-scale farming operations have built their own monitoring laboratories. The Cachuma Resource Conservation District hopes to add nitrate monitoring to their irrigation efficiency evaluation services (Mobile Lab) when they can secure sufficient funding. Septic systems and wastewater treatment plants could be other point source contributors to nitrate levels.

Currently, wells located along the coast near the mouth of the Santa Maria River do not indicate the presence of sea water intrusion. However, the Santa Maria aquifer extends offshore and it is possible that encroachment is occurring further to the west below the Pacific ocean. Both the prevailing groundwater gradient (east to west) and the indications of underflow out, support the conclusion that encroachment is not taking place.

(Source: Minutes 20 OCT 94)

IV.
FUTURE DEMANDS ON THE BASIN

A. Potential changes in water usage
NOT ADDRESSED

B. Potential changes in land use
NOT ADDRESSED

C. Environmental concerns
NOT ADDRESSED

D. Impacts on the basin
NOT ADDRESSED

V.
ELEMENTS OF THE GROUNDWATER MANAGEMENT PLAN

A. Control of saline water intrusions

Background:

Sea water intrusion is presently monitored by monitoring wells near the Pacific Ocean maintained by the United States Geological Survey. These wells, and other evidence, indicate there is presently no sea water intrusion. The freshwater aquifer extends an unknown distance beneath the Pacific Ocean. If intrusion is occurring, it is most likely in this zone.

Management Strategies:

Periodically review existing monitoring wells and adequacy of monitoring plan. If appropriate, formulate additional monitoring or remedial action upon changed conditions or development of additional monitoring techniques. Particular attention should be paid to the need for additional monitoring wells either north or south of the existing wells.
(Source: Minutes 17 NOV 94)

B. Identification and management of well head protection areas and recharge areas.

Background:

The main recharge area for the Santa Maria groundwater basin has been identified as the portion of the Santa Maria Valley east of Black Road and north of the Orcutt uplands. Well head protection areas are set by state and county water well construction standards. The main source of recharge is the Santa Maria River, which is naturally maintained by periodic flows and scouring. Twitchell Reservoir is an integral part of the water supply, capturing flood flows and providing a supplemental source of groundwater recharge. Water conserved in the reservoir (up to 135,615 AF) is released down the Santa Maria River where it percolates into the groundwater basin. No well head protection areas exist or appear warranted at this time.

(Source: Santa Maria Water Resources Report)

Management Strategies:

If state and county standards and enforcement appear to be or become inadequate, propose remedial measures to the governing authority, or adopt appropriate regulations not prohibited or preempted by law.

C. Regulation of the migration of contaminated groundwater

Background:

Contamination of groundwater and migration of contaminated groundwater is presently regulated by county, state and federal authority. The USGS currently monitors water quality in certain wells in the groundwater basin and publishes the data annually.

Management Strategies:

Monitor the effectiveness of such regulation and, if appropriate, propose modification of standards, enforcement or monitoring appropriate for the Santa Maria groundwater basin.

Evaluate effectiveness of existing monitoring programs, specifically focussing the effect of sewage effluent disposal, solid waste disposal and agricultural chemicals upon groundwater quality within the Santa Maria groundwater basin. If appropriate, propose modifications to monitoring programs or disposal procedures that are found to be beneficial or necessary for the Santa Maria groundwater basin.

D. Administration of well abandonment and well destruction program.

Background:

Well abandonment and well destruction are regulated by Santa Barbara County Environmental Health Services.

Management Strategies:

Evaluate the effectiveness of regulations and implementation and, if appropriate, propose modifications of standards, enforcement or monitoring found to be appropriate for the Santa Maria Groundwater basin. Continue to monitor effectiveness of program.

E. Mitigation of conditions of overdraft

Background:

The condition of overdraft in the basin is a controversial issue. Long term dewatering of some areas has occurred, however, the various estimates of dewatering are small compared to the total volume in storage and observed wet/dry cycle fluctuations. This issue needs to be better understood in order to protect the availability of water and protect/improve water quality. Past estimates of the overdraft ranged from 12,000 AFY (USGS, 1945) to 20,000 AFY (SBCWA, 1994).

Management Strategies:

The level and effects of groundwater overdraft in the Santa Maria groundwater basin will be determined by further studies conducted through this groundwater management plan. After the degree of overdraft is determined and its adverse impacts assessed, appropriate methods of mitigating this overdraft will be implemented.

Possible mitigation methods for conditions of overdraft fall into two categories: supply side options and demand side options discussed below.

a. SUPPLY SIDE OPTIONS

1. Injection/Percolation of Supplemental Water

Supplemental water such as State Water Project (SWP) water or water imported from outside the basin can be percolated into the groundwater basin through infiltration ponds or injected into new or existing unused wells. Alternatively, this supplemental water may supplant some existing pumping i the basin.

Further Study: A master plan for injecting or other use of supplemental water should be developed for the Santa Maria groundwater basin; one possibility is to locate injection wells near identified pumping troughs to mitigate localized overdraft problems and to control migration of injected water for water quality reasons.

2. Watershed Management

This option consists of increasing available stormwater runoff by managing the watershed. Controlled burn programs can be designed to minimize excessive debris accumulation and to increase available runoff.

Further Study: The Sisquoc and Cuyama watersheds should be analyzed to determine the typical runoff percentage increases that would result from a controlled burn program. To the extent opportunities to expand vegetation management in a way to demonstrably increase runoff, benefitting entities should pursue such measures.

3. Enhanced Recharge

Any specific proposed option for enhanced recharge will be evaluated for its feasibility and cost per acre foot. Enhanced recharge opportunities fall into four basic types:

o **Recharge related to development (Flood Retention/Percolation Basins):** As land is developed, the increase in impervious area increases storm runoff. The County, cities, airport and County Flood Control are actively involved in controlling excessive runoff created by development, collecting it in retention basins and increasing infiltration to the groundwater basin. Special recharge zones may also be adopted to require developers to offset lost recharge acreage with retention/infiltration ponds or other improvements. Particular attention should be paid to the location of ponds to maximize recharge to main basin aquifer zones.

o **Mining reclamation:** Converting abandoned sand and gravel mining pits to recharge basins can reduce reclamation costs and, depending on design, increase groundwater recharge.

Further Study: Studies should be done to determine whether increased recharge through mining reclamation can be accomplished without undermining of bridge supports on the Santa Maria River or causing other adverse impacts to surrounding land uses.

o **Flood flow diversion:** Flood flows can be diverted for temporary storage and subsequent release for spreading and basin recharge during low flow periods. One option is to divert Sisquoc River water to a new reservoir on or near the Cuyama River.

Further Study: Options for flood flow diversion should be evaluated for cost per acre foot relative to existing natural recharge, as Santa Maria River's alluvial formations are already an efficient infiltration basin.

- **Modification of Existing stream channel**: Existing river channels can be modified by installing inflatable dams or contouring the river to slow or divert flood flows.

4. Sewage Effluent

Treated effluent from the Santa Maria and Laguna wastewater treatment plants is currently percolated through infiltration ponds to the groundwater basin. The location of the Santa Maria infiltration ponds appears to help maintain water pressure in the down-gradient confined groundwater aquifer and maintain pumping levels for downstream agricultural pumpers. It also helps to prevent seawater intrusion that could be induced if declining water levels in the confined zone and in areas to the east were to occur.

Further Study: The Laguna infiltration ponds and spray disposal areas are above a perching zone, so most of the runoff may eventually spill to the ocean without benefitting or contaminating local groundwater basin users. Geological information should be gathered through a monitoring program to establish whether or not there is hydrologic continuity between the Orcutt "Sand Hills" material and the main aquifers. If the aquifers are separate, options to capture the potential benefits from the treated Laguna discharge include relocating the infiltration ponds to a more strategic location or reusing the treated effluent directly to replace water pumped from the ground.

The effectiveness of directly using tertiary treated sewage and the associated water and cost savings from reduced groundwater pumping should be compared against the cost and effectiveness of percolating secondary treated sewage.

5. Groundwater/Seawater Desalination

Currently, the high cost of desalination, environmental constraints and the imminent availability of State Water Project (SWP) water make this option economically infeasible. However, such an option may be considered in the future if water demand, water quality regulatory requirements and costs make it economically feasible.

6. Surface Water Reservoir

The Round Corral dam site on the Sisquoc River was identified in the U. S. Bureau of Reclamation's 1945 Santa Barbara County-wide "Comprehensive Basin Plan" as a potential surface reservoir site. The resulting reservoir would have a maximum safe yield of 8,000 AF/year.

Further Study: A permitting reconnaissance is necessary before considering this option as the environmental regulations developed after 1945 have changed the economic and permitting feasibility of building a surface reservoir in the state.

7. Conjunctive Use

Conjunctive use involves bringing in supplemental water and either injecting the surplus supplemental water during wet years and withdrawing it during drought years, or using supplemental water when it is available and reserving the groundwater for the drought years when the supplemental water is not available. See Section H below for information on facilitating conjunctive use projects.

8. Cloud Seeding

The current cloud seeding program increases the available water within the Santa Maria basin. Therefore, the County's cloudseeding program is considered part of the existing water supply baseline. The program currently balances water supply augmentation and public safety (flooding) concerns. No increased operational opportunities exist at the current time.

9. Twitchell Reservoir Operational Modifications

Additional storage potential could be created in Twitchell Reservoir by surcharging above the spillway. Under normal circumstances, the Army Corps of Engineers and USBR regulations do not allow surcharging of the flood control pool for water conservation purposes prior to March 15 during any given year. However, operations could be modified to allow surcharge of the flood control pool based on the likelihood of the occurrence of flooding. Operated in this manner, the yield of the project could increase significantly.

b. DEMAND SIDE OPTIONS

1. Urban Conservation

Water purveyors in the Santa Maria basin, the Cities of Santa Maria and Guadalupe, and California Cities Water Company, have implemented many of the statewide urban water efficiency Best Management Practices (BMPs). The BMPs currently not implemented are considered economically infeasible, or provide benefits that cannot be quantified at this time. However, as water prices increase and more information is made available on the economic impact of additional BMPs, more practices may become feasible. In Santa Maria, where the wastewater effluent recharges the groundwater basin, there would be less benefit from increased conservation than in Orcutt where most of the infiltrated wastewater effluent may flow to the ocean before it is used again. However, increased water efficiency would have water quality benefits in both Santa Maria and Orcutt.

2. Agricultural Conservation

The Cachuma Resource Conservation District's mobile lab provides analysis and technical assistance locally to increase agricultural water irrigation efficiency. Efficiency rates of 80 percent are an achievable goal. The primary water supply benefits are reducing excessive evapotranspiration and salt concentration. The primary driving force to implement agricultural conservation will be the associated savings in energy and fertilizer costs. The cities and agencies involved in this plan could provide financial support to the mobile lab and publicize its services to local growers.

Further Study: Information needs to be gathered concerning the impact of agricultural water conservation on the level of return flows into the groundwater basin.

(Source: Minutes 03 NOV 94)

F. Replenishment of groundwater extracted by water purveyors
NOT ADDRESSED

G. Monitoring of groundwater levels in storage

An expanded groundwater monitoring program is needed to improve understanding of the Santa Maria Valley groundwater dynamics. This program requires adding more wells to the County's current well monitoring program. Key issues to be monitored and evaluated include:

- Seawater intrusion potential
- Annual basin outflow to the ocean
- Basin geology and groundwater flow patterns and rates
- Groundwater recharge sources and quantities
- Water table fluctuations seasonally and annually
- Water quality trends
- Sources of water quality degradation
- Groundwater pumping estimates (gross and net)
- Opportunities for groundwater banking
- Basin safe yield
- The likely groundwater table fluctuations within the long term safe yield for wet and drought years
- How basin could be managed to optimize the basin safe yield
- Best locations for groundwater recharge, available storage capacity and new wells from an overall basin management perspective
- More groundwater data and monitoring are needed to understand the amount of interconnection between the shallow, deep and confined aquifers, and if the existing multiple completion wells are affecting the yield and water quality of any aquifer.

The enhanced groundwater monitoring program could begin with a detailed study. The basic steps would be:

1. Based on goals for basin, define what additional data is required.
2. Add strategically placed existing wells to current well monitoring program.
3. Determine whether existing wells could be added to the monitoring program or whether dedicated monitoring wells are needed in certain areas of the basin
4. Drill additional monitoring wells in key locations and/or to monitor groundwater at specific depths.
5. Collect data at regular intervals. This may involve monitoring some wells monthly for two years then annually thereafter.
6. Analyze basin groundwater data and answer questions identified (see Appendix C) in AB3030 plan.
7. Finalize strategy and programs to bring basin into balance.
8. Continue monitoring program.
9. Verify that the trends expected from the detailed study are what actually occur.
10. Monitor the success or inadequacy of programs and actions to bring the groundwater basin production and recharge into balance.
11. Revise basin management projects and actions as needed to meet continuing basin management goals.

(Source: Cosby Scoping Memo, 20 DEC 94)

H. Facilitating conjunctive use operations.

Conjunctive use can involve bringing in supplemental water and either: 1) injecting the surplus supplemental water during wet years and withdrawing it during drought years, or 2) using supplemental water when it is available and reserving the groundwater for the drought years when the supplemental water is not available. Any increases in ocean discharge due to banking of supplemental water could be charged to the beneficiary or "owner" of the stored supplemental water. Estimates of subsurface inflow and outflow are made using studies of the geologic composition of the basin and the gradient of the aquifer. The cross sectional area of the aquifer is known and the ability of the aquifer to transmit water is used to determine the flow at different storage volumes. For the Santa Maria groundwater basin, the groundwater underflow loss to the Pacific Ocean has been estimated to be significant (as high as 16,000 AFY in 1918 with a very full basin).

Further Study: Guidelines must be developed regarding the timing, amount and rate of the withdrawals. More information is needed on the basin's storage capacity in order to determine if there is any adverse impact of water banking on natural recharge.

Other issues to be studied include whether in-basin water transfers could be used to increase use of the higher quality groundwater in the basin's east end, the cost effectiveness of this measure, and the possible pairs of willing participants which could benefit from these transactions.

(Source: Minutes 03 NOV 94; Santa Maria Valley Water Resources Report)

I. Identification of well construction policies

Background:

Well construction policies are regulated by the state and the County Environmental Health Services.

Management Strategies:

Monitor the effectiveness of regulations and, if appropriate, propose modifications of standards, enforcement or monitoring found to be appropriate for the Santa Maria groundwater basin.

(Source: Minutes 20 OCT 94)

J. The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling and extraction projects.

NOT ADDRESSED

K. The development of relationships with state and federal regulatory agencies.

The MOU process allows cooperation with any interested state/federal agencies. The Department of Water Resources imports State Water Project water. The U.S. Bureau of Reclamation owns but SMWCD operates Twitchell Dam.

L. The review of land use plans and coordination with land use planning agencies to assess activities that create a reasonable risk of groundwater contamination.

NOT ADDRESSED

VI.
BASIN MANAGEMENT COMMITTEE

A. Representation, responsibilities and funding.

The Santa Maria Valley Groundwater Management Plan will be administered through a Memorandum of Understanding (MOU) between the Santa Maria Valley Water Conservation

District, the City of Santa Maria, the City of Guadalupe, California Cities Water, agricultural interests and the Santa Barbara County Water Agency. Committees will be established to make decisions regarding necessary studies and projects. Decisions on individual signatory participation in and funding of each project will be made on a case by case basis.

Further study: Discussion and direction regarding the administration and cost of the monitoring program are needed.
(Source: Minutes 12 JAN 95)

B. Annual status report and review.

NOT ADDRESSED

C. Procedure for amendment of plan.

NOT ADDRESSED

VII.
FUTURE PROJECTS

A. Identification of potential recharge projects.

1. Enhanced Recharge of Laguna Sanitation Effluent

The Laguna Sanitation District currently discharges about 2400 AF of effluent a year. This effluent is spray irrigated on land underlaid by a perched zone, so the effluent provides little, if any, benefit towards recharging the Santa Maria Valley groundwater basin. There is the possibility of providing additional treatment and thereby allowing direct recharge of the Laguna effluent.

The Regional Water Quality Control Board classifies groundwater recharge into four categories:

1. Surface spreading - Organics Removed
2. Surface spreading - Reclaimed water (Tertiary Treatment)
3. Surface spreading - Oxidized and disinfected
4. Direct recharge by injection - Organics removal

There are also requirements that the reclaimed water be no more than 20 percent of the total recharge to the groundwater and that the recharged water travel a minimum distance between the infiltration and extraction sites.

There are two constituents of Laguna effluent that will be of primary concern to the Regional Board: TDS (including chloride levels) and nitrates. The nitrates could be handled by nitrification in a biofilter (such as artificial wetlands) and subsequent de-nitrification although the existing treatment plant may handle this process adequately.

There are four basic options for addressing TDS levels:

1. Reduce TDS in Source Water. This would require California Cities to switch to its higher cost but lower TDS wells.

2. Ban Residential Water Softeners. State law forbids residential water softener bans. A current lawsuit by one of Southern California's major water districts may take the issue of conflicting state laws (water softeners versus discharge standards) to the California Supreme Court, but this lawsuit may take years to resolve.

3. Partial Demineralization. To reduce the TDS below the 1000 ppm limit would require treating a fraction of the wastewater effluent (probably 25 to 30 percent) by reverse osmosis or ion exchange and blending back the two effluent streams before final discharge. This would be the most expensive option.

4. Dilution. This alternative would involve blending the wastewater effluent with the runoff from the Orcutt surface runoff recharge system designed by Flood Control or with the runoff in one of the local creeks. This would be the easiest alternative, but the unreliability of runoff water could cause problems. Even though the Regional Board allows dischargers to measure the 20 percent mix requirement on an annual basis, the widely variable runoff quantities from year to year may make it difficult to consistently meet the dilution requirement.

The feasibility study for using the Laguna Sanitation District effluent to enhance groundwater recharge will consider alternatives 1, 3 and 4. Participants may include representatives from the Laguna Sanitation District, County Flood Control District, California Cities Water Company, the Water Conservation District and AB 3030 committee.

B. Supplemental sources of water

State Water Project: The Coastal Branch project and Mission Hills extension, which will bring State Water Project water into the Santa Maria Valley, is targeted for completion in mid-1996. Currently, the Cities of Santa Maria and Guadalupe are scheduled to receive 16,200 AFY and 500 AFY of State Water, respectively. The Southern California Water Company currently has the option to receive 500 AFY of water. The amount of water actually received by each entity depends upon the availability of project water.

Additional water may be available for purchase from other Coastal Branch contractors, particularly during early years of operation. This could be the basis of a groundwater banking scheme or be a means of improving water quality on a short term (5 - 10 year) basis.

Source: Santa Maria Water Resources Report

C. Seasonal storage projects

NOT ADDRESSED

VIII.
IMPLEMENTATION OF PLAN

A. Action Plan

NOT ADDRESSED

B. Schedule

NOT ADDRESSED

PROPOSED APPENDICES

Appendix A: Minutes of Santa Maria Valley Groundwater Plan Meetings

Appendix B: List of monitoring wells (County, City of Santa Maria, California Cities Water)

Appendix C: Glossary of hydrologic terms

APPENDIX C

Definitions of Terms

ACRE-FOOT - The quantity of water required to cover one acre to a depth of one foot; equal to 43,560 cubic feet, or approximately 325,851 gallons.

APPLIED WATER DEMAND - The quantity of water that would be delivered for urban or agricultural applications if no conservation measures were in place.

ARTIFICIAL RECHARGE - The addition of water to a ground water reservoir by human activity, such as irrigation or induced infiltration form streams, wells, or recharge basins. See also GROUND WATER RECHARGE, RECHARGE BASIN.

BRACKISH WATER - Water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

CONJUNCTIVE USE - The operation of a ground water basin in coordination with a surface water storage and conveyance system. The purpose is to recharge to the basin during years of above-average water supply to provide storage that can be withdrawn during drier years when surface water supplies are below normal.

CONSERVATION - As used in this report, urban water conservation includes reductions realized from voluntary, more efficient, water use practices promoted through public education and from State-mandated requirements to install water-conserving fixtures in newly constructed and renovated buildings. Agricultural water conservation, as used in this report, means reducing the amount of water applied in irrigation through measures that increase irrigation efficiency. See NET WATER CONSERVATION.

CRITICAL DRY PERIOD - A series of water-deficient years, usually an historical period, in which a full reservoir storage system at the beginning is drawn down (without any spill) to minimum storage at the end.

CRITICAL DRY YEAR - A dry year in which the full commitments for a dependable water supply cannot be met and deficiencies are imposed on water deliveries.

CWA - Santa Barbara **C**ounty **W**ater **A**gency (or successor agency).

DESALTING - A process that converts sea water or brackish water to fresh water or an otherwise more usable condition through removal of dissolved solids. Also called "desalination."

DWR - California **D**epartment of **W**ater **R**esources (or successor agency).

FIRM YIELD - The maximum annual supply of a given water development that is expected to be available on demand, with the understanding that lower yields will occur in accordance with a predetermined schedule or probability.

GROUND WATER - Water that occurs beneath the land surface and completely fills all pore spaces of the alluvium or rock formation in which it is located.

GROUND WATER BASIN - A ground water reservoir, together with all the overlying land surface and underlying aquifers that contribute water to the reservoir.

GROUND WATER MINING - The withdrawal of water from an aquifer greatly in excess of replenishment; if continued, the underground supply will eventually be exhausted or the water table will drop below economically feasible pumping lifts.

GROUND WATER OVERDRAFT - The condition of a ground water basin in which the amount of water withdrawn by pumping exceeds the amount of water that replenishes the basin over a period of years.

GROUND WATER RECHARGE - Increases in ground water by natural conditions or by human activity. See also ARTIFICIAL RECHARGE.

GROUND WATER STORAGE CAPACITY - The space contained in a given volume of deposits. Under optimum use conditions, the usable ground water storage capacity is the volume of water that can, within specified economic limitations, be alternately extracted and replaced in the reservoir.

GROUND WATER TABLE - The upper surface of the zone of saturation (all pores of subsoil filled with water), except where the surface is formed by an impermeable body.

M&I - Municipal and Industrial (water use); generally urban uses for human activities.

mg/ℓ - Abbreviation for "milligrams per liter," the mass (milligrams) of any substance dissolved in a standard volume (liter) of water. Nearly the same as parts per million (ppm).

NET WATER CONSERVATION - The difference between the amount of applied water conserved and the amount by which this conservation reduces usable return flows.

NET WATER DEMAND - The applied water demand less water saved through conservation efforts (= net applied water = actual water used).

OVERDRAFT - Withdrawal of groundwater in excess of a basin's perennial yield; also see "PROLONGED OVERDRAFT."

P&D - Santa Barbara County Planning and Development Department (or successor agency); prior to February 1994, named the Resource Management Department (RMD).

PERCHED GROUNDWATER - Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone.

PERCOLATION - The downward movement of water through the soil or alluvium to the ground water table.

PERENNIAL YIELD - "The rate at which water can be withdrawn perennially under specified operating conditions without producing an undesired result" (Todd, 1980). An undesired result is an adverse situation such as: (1) a reduction of the yield of a water source; (2) development of uneconomic pumping lifts; (3) degradation of water quality; (4) interference with prior water rights; or (5) subsidence. Perennial yield is an estimate of the long-term average annual amount of water which can be withdrawn without inducing a long-term progressive drop in water level. The term "safe yield" is sometimes used in place of perennial yield, although the concepts behind the terms are not identical: the older concept of "safe yield" generally implies a fixed quantity equivalent to a basin's average annual natural recharge, while the "perennial yield" of a basin or system can vary over time with different operational factors and management goals.

PROLONGED OVERDRAFT - Net extractions in excess of a basin's perennial yield, averaged over a period of ten or more years. (Also see footnote to Goal 1 in main text.)

ppm - Abbreviation for "parts per million," a measure of a substance's concentration in a solution or other mixture. Nearly the same as milligrams per liter (mg/ℓ).

RECHARGE BASIN - A surface facility, often a large pond, used to increase the infiltration of water into a ground water basin.

RECLAIMED WATER - Urban waste water that becomes suitable for a specific beneficial use as a result of treatment.

RETURN FLOW - The portion of withdrawn water that is not consumed by evapo-transpiration and returns instead to its source or to another body of water.

REUSE - The additional use of once-used water.

RMD - Santa Barbara County **R**esource **M**anagement **D**epartment; reorganized and renamed as the Planning and Development Department (P&D) in February 1994.

RWQCB - California **R**egional **W**ater **Q**uality **C**ontrol **B**oard (or successor agency).

SAFE YIELD (GROUND WATER) - The maximum quantity of water that can be withdrawn from a ground water basin over a long period of time without developing a condition of overdraft. Sometimes referred to as sustained yield.

SALINITY - Generally, the concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids), electrical conductivity, or osmotic pressure.

Where sea water is the major source of salt, salinity is often used to refer to the concentration of chlorides in the water. See also TDS.

SBCFCWCD - Santa Barbara County Flood Control and Water Conservation District (or successor agency).

SERIOUS OVERDRAFT - Prolonged overdraft which results or, in the reasonably foreseeable future (generally within ten years) would result, in measurable, unmitigated adverse environmental or economic impacts, either long-term or permanent. Such impacts include but are not limited to seawater intrusion, other substantial quality degradation, land surface subsidence, substantial effects on riparian or other environmentally sensitive habitats, or unreasonable interference with the beneficial use of a basin's resources. (Also see Policy 3.5 *et seq.* in main text.)

SPREADING WATER - Discharging native or imported water to a permeable area for the purpose of allowing it to percolate to the saturated zone. Spreading, artificial recharge, and replenishment all refer to operations used to place water in the groundwater basin.

STORAGE CAPACITY - The volume of space below the land surface that can be used to store groundwater. Total Storage Capacity is the total volume of space that could be used to store groundwater. Available Storage Capacity is that volume of storage capacity that does not presently contain groundwater and is therefore available to store recharged water.

SWP - State Water Project.

SWRCB - California State Water Resources Control Board (or successor agency).

TDS - Total Dissolved Solids, a quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter (mg/ℓ) or in parts per million (ppm). See also Salinity.

USGS - United States Geological Survey (or successor agency).

WATER RECLAMATION - The treatment of water of impaired quality, including brackish water and sea water, to produce a water suitable for the intended use.

WATER RIGHT - A legally established entitlement to take possession of water in a water supply and to divert that water for beneficial use.

SANTA MARIA VALLEY GROUNDWATER MANAGEMENT PLAN
MEETING MINUTES
January 12, 1995

The meeting was convened by Maurice Twitchell at 2:00 pm in the Bonita Packing conference room. The discussion focused on the structure of the groundwater management plan.

1. ORGANIZATION/STAFFING: ALTERNATIVES

Rob Almy, Santa Barbara County Water Agency, described some alternatives for a decision making structure for the groundwater management plan:

a) Joint Powers Agreement (JPA) - formed by government agencies
b) Memorandum of Understanding (MOU) between government agencies
c) Invite one agency with broad geographic jurisdiction to implement management plan, i.e. Santa Maria Valley Water Conservation District or Santa Barbara County Flood Control/Water Agency

Staffing of the managing organization could consist of appointed staff from participating agencies.

Q: What is the difference between a JPA and an MOU?
A JPA creates a new government agency which has a specific jurisdiction and may have actual governmental powers. An MOU is made between existing organizations which already have the powers necessary to implement the plan or agreement. An MOU tends to be less restrictive and easier to get out of than a JPA. An MOU does not create a new agency, it just delineates how existing agencies will operate cooperatively towards a common goal.

After some discussion, the group expressed an overall preference for operating under an MOU. Basic principles of the MOU desired by the group include:
No forced agreements
Group to work together
Participation in specific projects is voluntary
Agencies can act independently if project does no harm to another

2. ADMINISTRATION OF MOU

The question was raised concerning staffing for implementing the management plan. Several options were suggested:

a) Wait until a plan is adopted and then decide the level of staffing on a project by project basis.

b) Appoint committees to study specific issues

c) Initially, county staff might continue to provide technical and administrative support. These options are not mutually exclusive.

3. DEVELOPMENT OF MOU

Once participants agree on a management plan, the elements of the MOU can be defined. Maurice Twitchell suggested this outline for steps to develop the MOU.

1. Agree on further studies to determine the volume and area extent of overdraft or other problems in the basin. (To be used as a basis for management objectives.)

2. Identify ways to reduce overdraft, using supply or demand side solutions. Investigate economic feasibility of various overdraft solutions.

3. Investigate water quality issues.

Basic principles of the MOU would be that the group would work together and there would be no forced agreements. The MOU would be between the District, two cities, two counties and other agencies such as Nipomo CSD, with agricultural interests maintaining veto power on demand-side measures.

4. DISCUSSION

Scott Slater clarified that the purpose of the MOU is to address governance of the groundwater management plan, i.e. how the players will inter-relate. The question of who will manage the plan should be separated from the implementation of the projects. Creating a dispute resolution system is also an imperative to the success of the management plan; this can be done through the MOU.

Concern was expressed that the Santa Maria Valley Water Conservation District will miss its September deadline for completing its management plan if it is involved in this cooperative plan. In response, most committee members expressed the opinion that there is enough time to first attempt a joint plan. Twitchell recommended that it would be more advantageous to develop one cooperative plan, rather than developing individual plans and then trying to reconcile them.

5. PLAN OUTLINE

It was then decided that the next step is to outline a draft plan. This can be done using the minutes of meetings of this committee which contain the group's discussions of program elements. Rob Almy offered to have Water Agency staff create a draft outline of the groundwater management plan following that procedure. The draft plan will then be circulated to committee members so that they can review it prior to the next meeting. Revisions to the draft will be made at the next committee meeting, before the draft plan is circulated to city councils or boards of directors. The goal is to complete the draft plan and mail it to committee members within 3 - 4 weeks of this meeting.

Several committee members requested a model of an MOU, which Almy agreed to provide. The MOU will outline such elements as:

Process for

- forming committees

- scoping related studies
- selection of which agency will do the work

Deciding:

- who pays/how much
- who manages projects
- how to modify/continue the MOU

6. NEXT MEETING

The next meeting will be on Thursday, February 9, 1995 from 2:00 pm to 5:00 pm at the Bonita Packing conference room.

CORRECTION:
Please note the following correction to the November 17 meeting minutes: In Section III on the Nipomo Mesa Basin, the first two sentences are incorrect and should be deleted. Instead they should read:

> "The County of San Luis Obispo has recently initiated a $350,000 study of the San Luis Obispo component of the Santa Maria groundwater basin, and results are expected in a few years. Susan Ostow gave a copy of the appendix of the South County (San Luis Obispo) EIR, which reviews in detail the water situation in the Nipomo Mesa Basin."

This correction is as per Susan Ostrow of the San Luis Obispo County Planning Commission.

JANUARY 12. 1995

Warren Twiddell	SMVWCD
Richard Quandt	GSVA
Dorothy Laine	CWA
MARVIN C. TEIXEIRA	TEIXEIRA FARMS S.M.
Owen S Rice	SMVWD
Richard E. Adam	SMVWCD.
Robert Almy	SBCWA
Jeanne Sparks	5th District
Darcy Aston	SBCWA
Charles Varni	SM citizen
Mark Moore	"
Jim Mehagh	Newhall LAND
Larry Lerini	Betteravia Farms
Scott Slater	Hatch and Parent
Warren E Beadleston	Univ of California
Maynard Silva	City of Guadalupe
Tom Urbanske	County of Santa Barbara
Doug Jones	NIPOMO CSD
DWAYNE CHISAM	CITY OF SANTA MARIA
HERB GERFEN	SKYWAY ENGINEERING, INC
ROGER BRETT	CANCER CENTER WATER
LON FLETCHER	HAMPTON FARMING / CACHUMA RCD

The Dynamics of Social Dilemmas

Individuals in groups must often choose between acting selfishly or cooperating for the common good. Social models explain how group cooperation arises—and why that behavior can suddenly change

by Natalie S. Glance and Bernardo A. Huberman

Imagine that you and a group of friends are dining at a fine restaurant with an unspoken agreement to divide the check evenly. What do you order? Do you choose the modest chicken entrée or the pricey lamb chops? The house wine or the Cabernet Sauvignon 1983? If you are extravagant, you could enjoy a superlative dinner at a bargain price. But if everyone in the party reasons as you do, the group will end up with a hefty bill to pay. And why should others settle for pasta primavera when someone is having grilled pheasant at their expense?

This lighthearted situation, which we call the Unscrupulous Diner's Dilemma, typifies a class of serious, difficult problems that pervade society. Sociologists, economists and political scientists find that this class of social dilemma is central to a wide range of issues, such as protecting the environment, conserving natural resources, eliciting donations to charity, slowing military arms races and containing the population explosion. All these issues involve goals that demand collective effort and cooperation. The challenge is to induce individuals to contribute to common causes when selfish actions would be more immediately and personally beneficial. Studies of these problems cast light on the nature of interactions among individuals and the emergence of social compacts. Moreover, they explain how personal choices give rise to social phenomena.

Social dilemmas have often been studied using groups of people who are given choices that present a conflict between the general good and the costs to an individual. Such experiments confirmed the hypothesis, first made by the economist Mancur L. Olson in the 1950s, that small groups are more likely to secure voluntary cooperation than are larger ones. They also revealed that repeated iterations of a situation tend to promote cooperative attitudes. The amount of cooperation further increases when communication among the participants is permitted.

More recently, powerful computers have been drafted for simulations of the social behavior of groups. The computer experiments gloss over the complexities of human nature, but we believe they can help elucidate some of the principles that govern interactions involving many participants. For the past three years, we have investigated social cooperation using both analytical techniques and computer simulations. We have tried to look not just at the outcomes of the dilemmas but also at the dynamics of the interactions and the ways in which those outcomes evolve in various groups.

Our mathematical theory of social dilemmas indicates that overall cooperation cannot generally be sustained in groups that exceed a critical size. That size depends on how long individuals expect to remain part of the group

NATALIE S. GLANCE and BERNARDO A. HUBERMAN explore their joint interest in the dynamics of social systems at the Xerox Palo Alto Research Center. For several years, Glance has studied the role of expectations and beliefs in systems of intentional agents. She received her Ph.D. in physics from Stanford University last June. Huberman is a Xerox Research Fellow and has been a visiting professor at the University of Paris and the University of Copenhagen. He received his physics degree from the University of Pennsylvania and has worked in condensed matter physics, statistical mechanics and chaotic dynamics. He is a corecipient of the 1990 Prize of the Conference on Economics and Artificial Intelligence.

as well as on the amount of information available to them. Moreover, both general cooperation and defection can appear suddenly and unexpectedly. These results can serve as aids for interpreting historical trends and as guidelines for constructively reorganizing corporations, trade unions, governments and other group enterprises.

Mathematical theories of social dilemmas have traditionally been formulated within the framework of game theory. The mathematician John von Neumann and the economist Oskar Morgenstern developed that discipline in the mid-1940s to model the behavior of individuals in economic and adversarial situations. An individual's choices are ranked according to some payoff function, which assigns a numerical worth—in dollars or apples or some other commodity—to the consequences of each choice. Within game theory, individuals behave rationally: they choose the action that yields the highest payoff. (Real people may not be consistently rational, but they do behave that way when presented with simple choices and straightforward situations.)

Social dilemmas can readily be mapped into game settings. In general terms, a social dilemma involves a group of people attempting to provide themselves with a common good in the absence of central authority. In the Unscrupulous Diner scenario, for instance,

WHAT SHOULD I ORDER? That is the question for individuals in groups that have agreed to split the bill equally. An individual can get a modest meal and lower everyone's bill or get a sumptuous meal and eat at the others' expense—but thereby increase the chance that others, too, will follow that strategy. The Diner's Dilemma is typical of a class of social problems in which individuals must choose between cooperating with the group or defecting for personal gain.

the common good is achieved by minimizing the amount of the check. The individuals are said to cooperate if they choose a less expensive meal; they defect if they spare no expense (for the group, that is!). Of course, the game is only an idealized mathematical model—how well can one quantify intangibles such as the enjoyment of the meal or guilt over saddling friends with a large bill? Nevertheless, the dynamics of the game are still instructive.

Each individual can choose either to contribute to the common good or to shirk and "free ride" on the sacrifices of others. All individuals share equally in the common good, regardless of their actions. Each person who cooperates therefore increases the common good by a fixed amount but receives back only some fraction of that added value. (The return is diminished by free riders who benefit without contributing.)

When an individual realizes that the costs of cooperating exceed her share of the added benefit, she will rationally choose to defect and become a free rider. Because every individual faces the same choice, all the members of a group will defect. Thus, the individually rational strategy of weighing costs against benefits has an inferior outcome: no common good is produced, and all the members of the group are less well off than they could be.

The situation changes, however, if the players know they will repeat the game with the same group. Each individual must consider the repercussions of a decision to cooperate or defect. The issue of expectations then comes to the fore. Individuals do not simply react to their perceptions of the world; they choose among alternatives based on their plans, goals and beliefs.

Of what do these expectations and beliefs consist? First, an individual has a sense of how long a particular social interaction will last, and that estimate affects her decision. A diner who goes out with a group once is more likely to splurge at the expense of others than is one who goes out with the same friends frequently. We call the expected duration of a game the horizon length. A short horizon reflects a player's belief that the game will end soon, whereas a long one means the player believes the game will repeat far into the future.

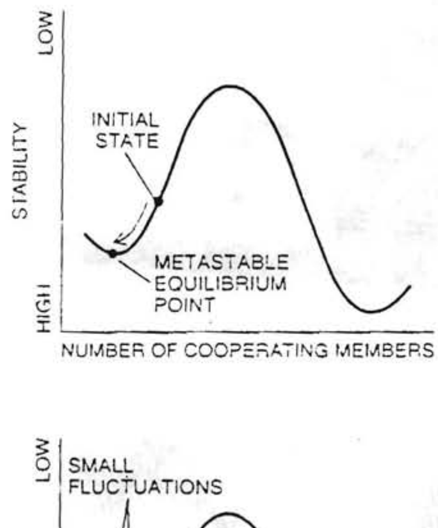
Second, each player has beliefs about how her actions will influence the rest of the group's future behavior. A diner may reject the option of an expensive meal out of fear that it would prompt others to order lavishly at the next gathering. The size of the group bears directly on this thinking. In a large crowd, a player can reasonably expect that the effect of her action, cooperative or not, will be diluted. (Ten dollars more or less on the group's bill matters less when it is divided among 30 diners than among three.) The player will reason that her actions become less influential as the size of the group increases.

For groups beyond some size, overall cooperation becomes unsustainable. The likelihood of bad consequences from an individual's defection becomes so small, whereas the potential gain stays so large, that the disincentive to defect vanishes. As our experiments have determined, this critical size depends on the horizon length: the longer that players expect the game to continue, the more likely they are to cooperate. That conclusion reinforces the commonsense notion that cooperation is most likely in small groups with lengthy interactions.

The smallest possible social group, consisting of only two players, raises the special limiting case widely known as the Prisoner's Dilemma. It is so named because of one common way in which it is framed: a prisoner is given the choice of betraying a fellow prisoner (defecting) and going free or keeping silent (cooperating) and thereby risking a harsh punishment if the other prisoner betrays him. Because the psychology of the interactions is unique, certain strategies that work well for individuals in the Prisoner's Dilemma fail in larger groups. The highly successful one known as tit-for-tat depends on retaliation and forgiveness. A player initially cooperates and thereafter does whatever the other player last did. Tit-for-tat works because it allows each player to recognize that the other's actions are in direct response to her own. In groups of more than two, however, it is impossible for one player to punish or reward another specifically because any modification of her own actions affects the entire group.

In larger groups, an individual caught in a social dilemma forms a strategy for conditional cooperation from a calculation of the expected payoffs: she will cooperate if at least some critical fraction of the group is also cooperating. When enough of the others are cooperating, she expects that her future gains will compensate for present losses. If the number of cooperating individuals falls below that threshold, then her expected losses rule out cooperation, and she will defect. The strategies, expectations and thresholds of the individuals determine whether cooperation within a group is sustainable.

Quite aside from the question of whether a group can achieve cooperation is the equally important matter of how cooperation or defection emerges in a social setting. Imagine that the hypothetical diners, after many consecutive budget-busting meals, decide to split into smaller groups, hoping that



STABILITY FUNCTION explains the dynamics of groups confronting social dilemmas. No matter what a group's initial state may be, it quickly shifts into a state of relative equilibrium, in which either many or few people are cooperating (*top*). Small fluctuations around this equilibrium point are routine (*middle*). Large fluctuations, however, which are rare, can carry the group over a stability barrier. The group will then very rapidly advance to a lower true equilibrium state (*bottom*). In the long run, a group will always settle into the lowest equilibrium state.

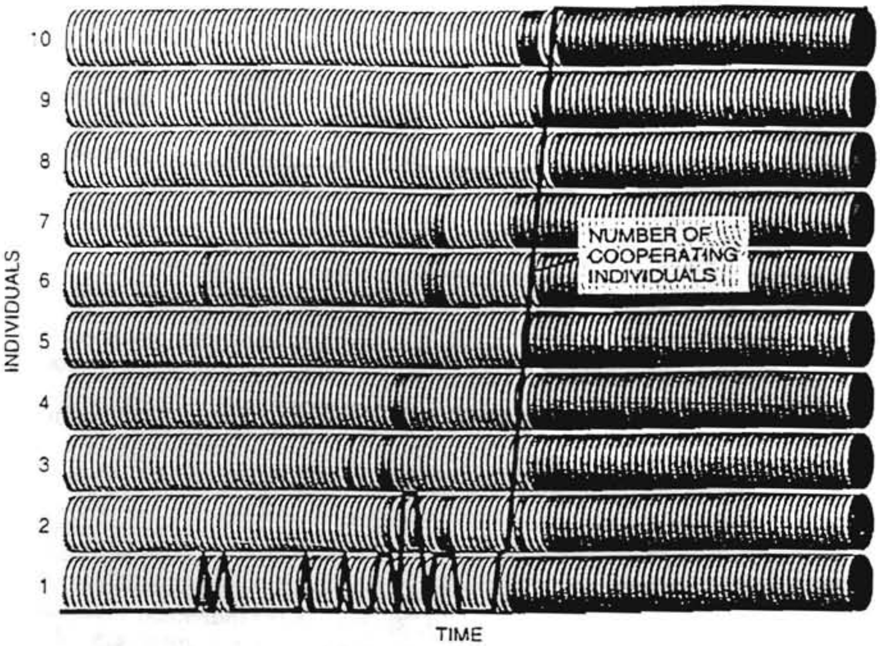
the limited size of the resulting tables will aid cooperation. How long does it take for the small groups of defectors to switch? Is the process smoothly evolutionary or sudden?

To study the evolution of social cooperation, we borrowed methods from statistical thermodynamics. This branch of physics attempts to derive the macroscopic properties of matter from the interactions of its constituent molecules. We adapted the approach to study the aggregate behavior of individuals confronted with social choices.

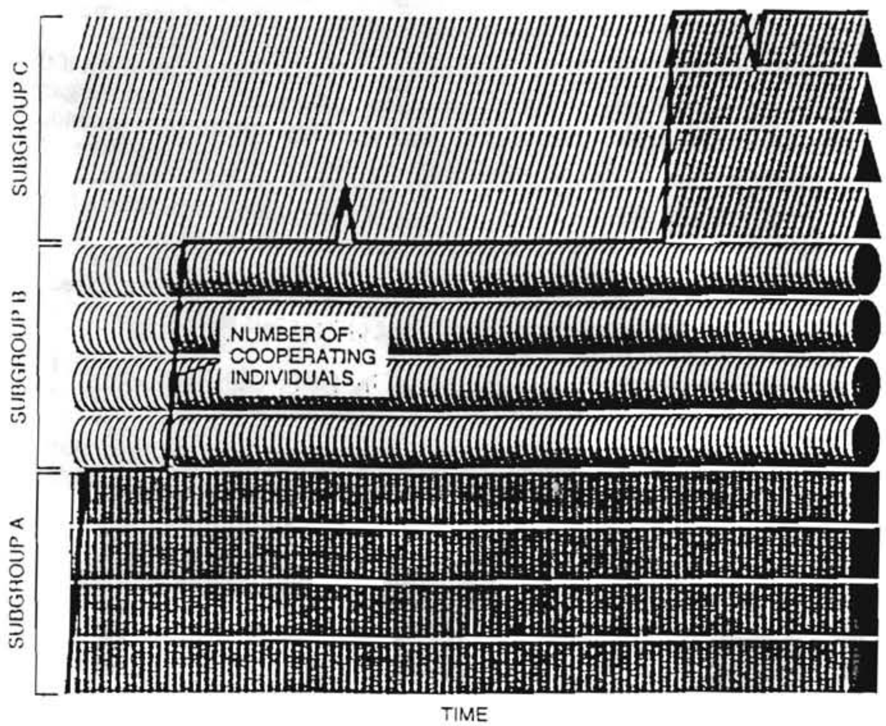
Our method relies on the mathematical construction of a curve called a stability function. This curve describes the relative stability of a group's behavior in terms of the amount of cooperation present. The values of the curve derive from a knowledge of the costs, benefits and individual expectations associated with a given social dilemma. The stability function generally has two minima, or troughs, which represent the most stable states of the group: widespread defection and widespread cooperation. They are separated by a high barrier, which is the least stable state. The relative heights of these features depend on the size of the group and the amount of information available to its members. From this function, one can predict the possible outcomes of the dilemma and how long the group will stay in a particular state.

Like a ball rolling downhill, the group's behavior will always gravitate from its initial state toward the closest trough. Once in a trough, however, the system does not become static. Instead it jiggles back and forth randomly, just as a small ball would be moved by vibrations. These random perturbations are caused by the uncertainty that individuals have about the behavior of others. If an individual misperceives the level of cooperation in the group, she may erroneously defect and thereby briefly move the system away from equilibrium. The more uncertainty there is in the system, the more likely there will be fluctuations around an equilibrium state.

These perturbations are usually small, so in the short run the system stays near one minimum. Over the long run, however, large fluctuations become important. Such fluctuations, caused by many individuals switching from defection to cooperation, or vice versa, can push the group over the barrier between the minima. Consequently, given sufficient time, a group will always end up in the more stable of the two equilibrium states, even if it initially moves into the other, metastable one.



OUTBREAKS OF COOPERATION can be simulated using computer agents that act like individuals. In a homogeneous group of agents that are all initially defectors (*green*), the shift to widespread cooperation (*orange*) is sudden and rapid.



HETEROGENEOUS GROUPS evolve stepwise toward overall cooperation, with each subgroup experiencing a distinct transition on its own.

Huge random fluctuations are extremely rare—on average, they occur over periods proportional to the exponential of the size of the group. Once the transition from the local minimum to the maximum of the function takes place, however, the system slides down to the global minimum very quickly—in a period proportional to the logarithm of the group size. Thus, the theory predicts that although the general behavior of a group in a dilemma stays the same for long periods, when it does change, it does so very fast.

Computer experiments demonstrate those predictions. A society of computational agents, or programs acting like individuals, can be presented with a social dilemma. The agents intermittently and asynchronously reevaluate their options and decide whether to cooperate or to defect. They base their decisions on information, which may be imperfect and delayed, about how many of the others are cooperating. The sum of all the agents' actions reveals the degree of cooperation or defection in the group. The experimenter can compile statistics on the level of cooperation over time.

One typical experiment features a group of 10 agents, all of which are initially defecting. If one agent misjudges how many others are cooperating and switches its behavior, that change might lead the rest of the group to make a similar shift. The group therefore stays at or near its initial metastable state of mutual defection for a long time, until a sudden and abrupt transition carries the group to mutual cooperation.

That abrupt appearance of cooperation in a computer simulation well describes certain real social phenomena, such as the recent upsurge in environmental awareness and activism. In many parts of the U.S. and Europe, voluntary recycling has become a normal part of daily life. A decade ago that was not the case. Recycling poses a social dilemma for the consumer: the environmental benefits are great if most of the population recycles but marginal if only a few do, and the individual's invested effort in bringing bottles and newspapers to the recycling center is the same in either case. Our theory may help explain why the population, after a long period of relative apathy, has so quickly embraced recycling, emissions controls and other environmental protection measures.

REGIONAL RECYCLING PROGRAMS are spreading in accordance with the rules of cooperation in hierarchies. The enjoyment of benefits from recycling in one community spurs neighboring communities to join the effort.

In the hypothetical social dilemmas we have described so far, all the individuals evaluate their payoffs the same way and share the same expectations about the outcomes of their actions. In any real group of humans, however, individuals have largely disparate beliefs. We have therefore looked at how diversity affects the dynamics of social dilemmas.

A heterogeneous group can display two different types of diversity: variation around a common average or segregation into factions. The first involves a simple spread in opinion or concern among individuals who are fundamentally the same. For example, some unscrupulous diners may anticipate and value more future meals than others. If the typical diner looks about 10 meals into the future, then individuals will have horizons that vary but cluster around that average.

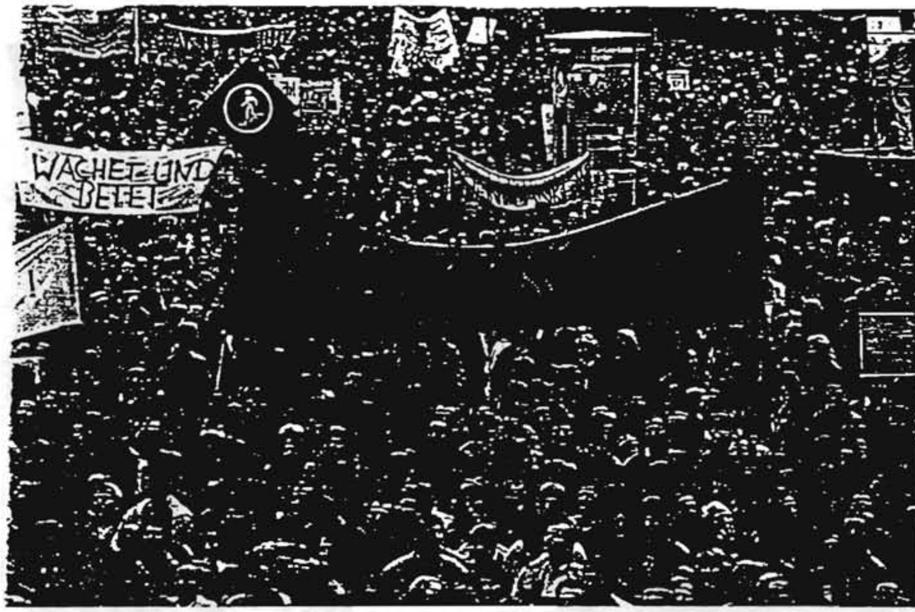
Although models of social dilemmas that include this type of diversity are more complicated than ones for homogeneous groups, their dynamics still follow a clear pattern. Basically the diversity acts as an additional form of uncertainty, instigating fluctuations in the state of the group. If most individuals are defecting, the first to decide to cooperate will probably be the one who has the longest horizon. That decision might then convince others who have longer-than-average horizons to cooperate, too. Those transitions can trigger a cascade of further cooperation, until the whole group is cooperating.

The events that led to the mass protests in Leipzig and Berlin and to the subsequent downfall of the East German government in November 1989 vividly illustrate the impact of such diversity on the resolution of social dilemmas. Earlier that year Mikhail S. Gorbachev, then president of the Soviet Union, stopped backing the Eastern European governments with the force of the Soviet military. His new policy reopened the issue of whether the Eastern European population would still subscribe to the existing social compact. The citizens of Leipzig who desired a change of government faced a dilemma. They could stay home in safety or demonstrate against the government and risk arrest—knowing that as the number of demonstrators rose, the risk declined and the potential for overthrowing the regime increased.

A conservative person would demonstrate against the government only if thousands were already committed; a revolutionary might join at the slightest sign of unrest. That variation in threshold is one form of diversity. People also differed in their estimates of the duration of a demonstration as well as in the amount of risk they were willing to take. Bernhard Prosch and Martin Abraham, two sociologists from Erlangen University who studied the Leipzig demonstrations, claim that the diversity in thresholds was important in triggering the mass demonstrations. They also documented that over just six weeks the number of demonstrators grew from a handful of individuals to more than 500,000.

A second type of diversity within a social group describes differences that do not range around an average value. It is found in groups composed of several distinct factions, each characterized by a distinct set of beliefs. Among the diners, for example, might be a mix of students and professionals. Students on a tight budget have concerns different from those of well-off professionals. On the whole, the variation among the students' preferences would be small as compared with the average differences between the two subgroups.

When a large group containing several factions changes from overall defection to cooperation, it does so through progressive transitions. The subgroup with the greatest tendency to cooperate (for example, the one with the longest horizon in its average expectations or the one with the lowest average costs for cooperation) will usually be the first



PUBLIC DEMONSTRATIONS signaled the end of the old social compact in East Germany. People dissatisfied with the government saw that the risk of arrest declined as more people joined the protests, which fueled the explosive growth of the crowds.

to cross over. The other groups will then follow in turn, probably in the order of their willingness to cooperate.

Relationships among subgroups may powerfully influence the evolution of cooperation, a fact that is notably important in large hierarchical organizations. The weight that an individual in one division gives to the actions of others depends on those persons' placement in the hierarchy. Hierarchies are therefore very different from level groups.

Functional hierarchies often hide in informal settings. Air pollution is a problem that the whole world faces and must solve collectively. Yet each person is usually bothered more by a neighbor burning a compost pile than by someone across town doing the same. The dilution of environmental impact with distance can be represented as a hierarchy of layered interactions between neighborhoods, towns, counties, states, countries and continents. The effect of someone else's actions on your own choices will depend on how many layers distant she is from you.

The effective size of the hierarchy is therefore much smaller than the number of its constituents. Suppose that in its effect on your decisions, the action of your nearby neighbor counts as much as the summed actions of an entire distant neighborhood. Then the effective number of people influencing your decision is much smaller than the total population of your town. We can say that the hierarchy has been rescaled, because the whole is smaller than the sum of its parts.

Computer experiments show how cooperation can spread in large hierarchical organizations. Transitions from defection to cooperation (or the other way around) tend to originate within the smallest units, which usually occupy the lowest level of the hierarchy. Cooperation can then progressively spread to higher levels. The switching trend can even terminate if the cooperative influence of distant units is too attenuated to be felt. In such a case, the organization may contain some branches that cooperate and others that defect for long periods.

These results suggest practical ways to restructure organizations to secure cooperation among members faced with a social dilemma. Corporations benefit, for example, when managers share their knowledge with one another. Yet managers may withhold information they fear their colleagues can use for their own advancement. To volunteer information, a person needs to feel secure that others will, too. Setting up a network of smaller groups of managers could overcome the dilemma by promoting that sense of security. Moreover, restructuring a large corporation into smaller units may encourage the appearance of pockets of collaboration that might spread rapidly.

Conversely, when organizations grow without a major reorganization, the tendency to ride for free grows and lowers efficiency. The act of reorganizing does not guarantee instant improvement: the switch to collective cooperation may still take a long time. That time can be shortened by increasing the benefits for individuals who cooperate and by dispersing the most cooperative managers among small core groups throughout the organization.

The study of social dilemmas provides insight into a central issue of behavior: how global cooperation among individuals confronted with conflicting choices can be secured. These recent advances show that cooperative behavior can indeed arise spontaneously in social settings, provided that the groups are small and diverse in composition and that their constituents have long outlooks. Even more significantly, when cooperation does appear, it does so suddenly and unpredictably after a long period of stasis.

The world still echoes with the thunderous political and social events marking the past few years. The fall of the Berlin Wall, leading to a unified Germany, and the breakdown of the centralized Soviet Union into many autonomous republics are examples of abrupt global defections from prevailing social compacts. The member countries of the European Union currently face their own social dilemma as they try to secure supranational cooperation. The pressing issue is whether or not those countries can build a beneficial cooperative superstructure while each one remains autonomous. If our predictions are accurate, these restructurings will not proceed smoothly. Rather they will always be punctuated by unexpected outbreaks of cooperation.

FURTHER READING

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The Tragedy of the Commons

The population problem has no technical solution; it requires a fundamental extension in morality.

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From: SCIENCE, Vol 162, pp 1243-1248
13 DEC, 1968

At the end of a thoughtful article on the future of nuclear war, Wiesner and York (*1*) concluded that: "Both sides in the arms race are . . . confronted by the dilemma of steadily increasing military power and steadily decreasing national security. *It is our considered professional judgment that this dilemma has no technical solution.* If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

I would like to focus your attention not on the subject of the article (national security in a nuclear world) but on the kind of conclusion they reached, namely that there is no technical solution to the problem. An implicit and almost universal assumption of discussions published in professional and semipopular scientific journals is that the problem under discussion has a technical solution. A technical solution may be defined as one that requires a change only in the techniques of the natural sciences, demanding little or nothing in the way of change in human values or ideas of morality.

In our day (though not in earlier times) technical solutions are always welcome. Because of previous failures in prophecy, it takes courage to assert that a desired technical solution is not possible. Wiesner and York exhibited this courage; publishing in a science journal, they insisted that the solution to the problem was not to be found in the natural sciences. They cautiously qualified their statement with the phrase, "It is our considered professional judgment. . . ." Whether they were right or not is not the concern of the present article. Rather, the concern here is with the important concept of a class of human problems which can be called "no technical solution problems," and, more specifically, with the identification and discussion of one of these.

It is easy to show that the class is not a null class. Recall the game of tick-tack-toe. Consider the problem, "How can I win the game of tick-tack-toe?" It is well known that I cannot, if I assume (in keeping with the conventions of game theory) that my opponent understands the game perfectly. Put another way, there is no "technical solution" to the problem. I can win only by giving a radical meaning to the word "win." I can hit my opponent over the head; or I can drug him; or I can falsify the records. Every way in which I "win" involves, in some sense, an abandonment of the game, as we intuitively understand it. (I can also, of course, openly abandon the game—refuse to play it. This is what most adults do.)

The class of "No technical solution problems" has members. My thesis is that the "population problem," as conventionally conceived, is a member of this class. How it is conventionally conceived needs some comment. It is fair to say that most people who anguish over the population problem are trying to find a way to avoid the evils of overpopulation without relinquishing any of the privileges they now enjoy. They think that farming the seas or developing new strains of wheat will solve the problem—technologically. I try to show here that the solution they seek cannot be found. The population problem cannot be solved in a technical way, any more than can the problem of winning the game of tick-tack-toe.

What Shall We Maximize?

Population, as Malthus said, naturally tends to grow "geometrically," or, as we would now say, exponentially. In a finite world this means that the per capita share of the world's goods must steadily decrease. Is ours a finite world?

A fair defense can be put forward for the view that the world is infinite; or that we do not know that it is not. But, in terms of the practical problems that we must face in the next few generations with the foreseeable technology, it is clear that we will greatly increase human misery if we do not, during the immediate future, assume that the world available to the terrestrial human population is finite. "Space" is no escape (*2*).

A finite world can support only a finite population; therefore, population growth must eventually equal zero. (The case of perpetual wide fluctuations above and below zero is a trivial variant that need not be discussed.) When this condition is met, what will be the situation of mankind? Specifically, can Bentham's goal of "the greatest good for the greatest number" be realized?

No—for two reasons, each sufficient by itself. The first is a theoretical one. It is not mathematically possible to maximize for two (or more) variables at the same time. This was clearly stated by von Neumann and Morgenstern (*3*), but the principle is implicit in the theory of partial differential equations, dating back at least to D'Alembert (1717–1783).

The second reason springs directly from biological facts. To live, any organism must have a source of energy (for example, food). This energy is utilized for two purposes: mere maintenance and work. For man, maintenance of life requires about 1600 kilocalories a day ("maintenance calories"). Anything that he does over and above merely staying alive will be defined as work, and is supported by "work calories" which he takes in. Work calories are used not only for what we call work in common speech; they are also required for all forms of enjoyment, from swimming and automobile racing to playing music and writing poetry. If our goal is to maximize population it is obvious what we must do: We must make the work calories per person approach as close to zero as possible. No gourmet meals, no vacations, no sports, no music, no literature, no art. . . . I think that everyone will grant, without

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argument or proof, that maximizing population does not maximize goods. Bentham's goal is impossible.

In reaching this conclusion I have made the usual assumption that it is the acquisition of energy that is the problem. The appearance of atomic energy has led some to question this assumption. However, given an infinite source of energy, population growth still produces an inescapable problem. The problem of the acquisition of energy is replaced by the problem of its dissipation, as J. H. Fremlin has so wittily shown (*4*). The arithmetic signs in the analysis are, as it were, reversed; but Bentham's goal is still unobtainable.

The optimum population is, then, less than the maximum. The difficulty of defining the optimum is enormous; so far as I know, no one has seriously tackled this problem. Reaching an acceptable and stable solution will surely require more than one generation of hard analytical work—and much persuasion.

We want the maximum good per person; but what is good? To one person it is wilderness, to another it is ski lodges for thousands. To one it is estuaries to nourish ducks for hunters to shoot; to another it is factory land. Comparing one good with another is, we usually say, impossible because goods are incommensurable. Incommensurables cannot be compared.

Theoretically this may be true; but in real life incommensurables *are* commensurable. Only a criterion of judgment and a system of weighting are needed. In nature the criterion is survival. Is it better for a species to be small and hideable, or large and powerful? Natural selection commensurates the incommensurables. The compromise achieved depends on a natural weighting of the values of the variables.

Man must imitate this process. There is no doubt that in fact he already does, but unconsciously. It is when the hidden decisions are made explicit that the arguments begin. The problem for the years ahead is to work out an acceptable theory of weighting. Synergistic effects, nonlinear variation, and difficulties in discounting the future make the intellectual problem difficult, but not (in principle) insoluble.

Has any cultural group solved this practical problem at the present time, even on an intuitive level? One simple fact proves that none has: there is no prosperous population in the world today that has, and has had for some time, a growth rate of zero. Any people that has intuitively identified its optimum point will soon reach it, after which its growth rate becomes and remains zero.

Of course, a positive growth rate might be taken as evidence that a population is below its optimum. However, by any reasonable standards, the most rapidly growing populations on earth today are (in general) the most miserable. This association (which need not be invariable) casts doubt on the optimistic assumption that the positive growth rate of a population is evidence that it has yet to reach its optimum.

We can make little progress in working toward optimum poulation size until we explicitly exorcize the spirit of Adam Smith in the field of practical demography. In economic affairs, *The Wealth of Nations* (1776) popularized the "invisible hand," the idea that an individual who "intends only his own gain," is, as it were, "led by an invisible hand to promote . . . the public interest" (*5*). Adam Smith did not assert that this was invariably true, and perhaps neither did any of his followers. But he contributed to a dominant tendency of thought that has ever since interfered with positive action based on rational analysis, namely, the tendency to assume that decisions reached individually will, in fact, be the best decisions for an entire society. If this assumption is correct it justifies the continuance of our present policy of laissez-faire in reproduction. If it is correct we can assume that men will control their individual fecundity so as to produce the optimum population. If the assumption is not correct, we need to reexamine our individual freedoms to see which ones are defensible.

Tragedy of Freedom in a Commons

The rebuttal to the invisible hand in population control is to be found in a scenario first sketched in a little-known pamphlet (*6*) in 1833 by a mathematical amateur named William Forster Lloyd (1794–1852). We may well call it "the tragedy of the commons," using the word "tragedy" as the philosopher Whitehead used it (*7*): "The essence of dramatic tragedy is not unhappiness. It resides in the solemnity of the remorseless working of things." He then goes on to say, "This inevitableness of destiny can only be illustrated in terms of human life by incidents which in fact involve unhappiness. For it is only by them that the futility of escape can be made evident in the drama."

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility *to me* of adding one more animal to my herd?" This utility has one negative and one positive component.

1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly -1.

2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another: and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

Some would say that this is a platitude. Would that it were! In a sense, it was learned thousands of years ago, but natural selection favors the forces of psychological denial (*8*). The individual benefits as an individual from his ability to deny the truth even though society as a whole, of which he is a part, suffers.

Education can counteract the natural tendency to do the wrong thing, but the inexorable succession of generations requires that the basis for this knowledge be constantly refreshed.

A simple incident that occurred a few years ago in Leominster, Massachusetts, shows how perishable the knowledge is. During the Christmas shopping season the parking meters downtown were covered with plastic bags that bore tags reading: "Do not open until after Christmas. Free parking courtesy of the mayor and city council." In other words, facing the prospect of an increased demand for already scarce space, the city fathers reinstituted the system of the commons. (Cynically, we suspect that they gained more votes than they lost by this retrogressive act.)

In an approximate way, the logic of the commons has been understood for a long time, perhaps since the discovery of agriculture or the invention of private property in real estate. But it is understood mostly only in special cases which are not sufficiently generalized. Even at this late date, cattlemen leasing national land on the western ranges demonstrate no more than an ambivalent understanding, in constantly pressuring federal authorities to increase the head count to the point where overgrazing produces erosion and weed-dominance. Likewise, the oceans of the world continue to suffer from the survival of the philosophy of the commons. Maritime nations still respond automatically to the shibboleth of the "freedom of the seas." Professing to believe in the "inexhaustible resources of the oceans," they bring species after species of fish and whales closer to extinction (*9*).

The National Parks present another instance of the working out of the tragedy of the commons. At present, they are open to all, without limit. The parks themselves are limited in extent—there is only one Yosemite Valley—whereas population seems to grow without limit. The values that visitors seek in the parks are steadily eroded. Plainly, we must soon cease to treat the parks as commons or they will be of no value to anyone.

What shall we do? We have several options. We might sell them off as private property. We might keep them as public property, but allocate the right to enter them. The allocation might be on the basis of wealth, by the use of an auction system. It might be on the basis of merit, as defined by some agreed-upon standards. It might be by lottery. Or it might be on a first-come, first-served basis, administered to long queues. These, I think, are all the reasonable possibilities. They are all objectionable. But we must choose—or acquiesce in the destruction of the commons that we call our National Parks.

Pollution

In a reverse way, the tragedy of the commons reappears in problems of pollution. Here it is not a question of taking something out of the commons, but of putting something in—sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free-enterprisers.

The tragedy of the commons as a food basket is averted by private property, or something formally like it. But the air and waters surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, by coercive laws or taxing devices that make it cheaper for the polluter to treat his pollutants than to discharge them untreated. We have not progressed as far with the solution of this problem as we have with the first. Indeed, our particular concept of private property, which deters us from exhausting the positive resources of the earth, favors pollution. The owner of a factory on the bank of a stream—whose property extends to the middle of the stream—often has difficulty seeing why it is not his natural right to muddy the waters flowing past his door. The law, always behind the times, requires elaborate stitching and fitting to adapt it to this newly perceived aspect of the commons.

The pollution problem is a consequence of population. It did not much matter how a lonely American frontiersman disposed of his waste. "Flowing water purifies itself every 10 miles," my grandfather used to say, and the myth was near enough to the truth when he was a boy, for there were not too many people. But as population became denser, the natural chemical and biological recycling processes became overloaded, calling for a redefinition of property rights.

How To Legislate Temperance?

Analysis of the pollution problem as a function of population density uncovers a not generally recognized principle of morality, namely: *the morality of an act is a function of the state of the system at the time it is performed* (*10*). Using the commons as a cesspool does not harm the general public under frontier conditions, because there is no public; the same behavior in a metropolis is unbearable. A hundred and fifty years ago a plainsman could kill an American bison, cut out only the tongue for his dinner, and discard the rest of the animal. He was not in any important sense being wasteful. Today, with only a few thousand bison left, we would be appalled at such behavior.

In passing, it is worth noting that the morality of an act cannot be determined from a photograph. One does not know whether a man killing an elephant or setting fire to the grassland is harming others until one knows the total system in which his act appears. "One picture is worth a thousand words," said an ancient Chinese; but it may take 10,000 words to validate it. It is as tempting to ecologists as it is to reformers in general to try to persuade others by way of the photographic shortcut. But the essense of an argument cannot be photographed: it must be presented rationally—in words.

That morality is system-sensitive escaped the attention of most codifiers of ethics in the past. "Thou shalt not . . ." is the form of traditional ethical directives which make no allowance for particular circumstances. The laws of our society follow the pattern of ancient ethics, and therefore are poorly suited to governing a complex, crowded, changeable world. Our epicyclic solution is to augment statutory law with administrative law. Since it is practically impossible to spell out all the conditions under which it is safe to burn trash in the back yard or to run an automobile without smog-control, by law we delegate the details to bureaus. The result is administrative law, which is rightly feared for an ancient reason—*Quis custodiet ipsos custodes?*—"Who shall

watch the watchers themselves?" John Adams said that we must have "a government of laws and not men." Bureau administrators, trying to evaluate the morality of acts in the total system, are singularly liable to corruption, producing a government by men, not laws.

Prohibition is easy to legislate (though not necessarily to enforce); but how do we legislate temperance? Experience indicates that it can be accomplished best through the mediation of administrative law. We limit possibilities unnecessarily if we suppose that the sentiment of *Quis custodiet* denies us the use of administrative law. We should rather retain the phrase as a perpetual reminder of fearful dangers we cannot avoid. The great challenge facing us now is to invent the corrective feedbacks that are needed to keep custodians honest. We must find ways to legitimate the needed authority of both the custodians and the corrective feedbacks.

Freedom To Breed Is Intolerable

The tragedy of the commons is involved in population problems in another way. In a world governed solely by the principle of "dog eat dog"—if indeed there ever was such a world—how many children a family had would not be a matter of public concern. Parents who bred too exuberantly would leave fewer descendants, not more, because they would be unable to care adequately for their children. David Lack and others have found that such a negative feedback demonstrably controls the fecundity of birds (*11*). But men are not birds, and have not acted like them for millenniums, at least.

If each human family were dependent only on its own resources; *if* the children of improvident parents starved to death; *if*, thus, overbreeding brought its own "punishment" to the germ line—*then* there would be no public interest in controlling the breeding of families. But our society is deeply committed to the welfare state (*12*), and hence is confronted with another aspect of the tragedy of the commons.

In a welfare state, how shall we deal with the family, the religion, the race, or the class (or indeed any distinguishable and cohesive group) that adopts overbreeding as a policy to secure its own aggrandizement (*13*)? To couple the concept of freedom to breed with the belief that everyone born has an equal right to the commons is to lock the world into a tragic course of action.

Unfortunately this is just the course of action that is being pursued by the United Nations. In late 1967, some 30 nations agreed to the following (*14*):

> The Universal Declaration of Human Rights describes the family as the natural and fundamental unit of society. It follows that any choice and decision with regard to the size of the family must irrevocably rest with the family itself, and cannot be made by anyone else.

It is painful to have to deny categorically the validity of this right; denying it, one feels as uncomfortable as a resident of Salem, Massachusetts, who denied the reality of witches in the 17th century. At the present time, in liberal quarters, something like a taboo acts to inhibit criticism of the United Nations. There is a feeling that the United Nations is "our last and best hope," that we shouldn't find fault with it; we shouldn't play into the hands of the archconservatives. However, let us not forget what Robert Louis Stevenson said: "The truth that is suppressed by friends is the readiest weapon of the enemy." If we love the truth we must openly deny the validity of the Universal Declaration of Human Rights, even though it is promoted by the United Nations. We should also join with Kingsley Davis (*15*) in attempting to get Planned Parenthood-World Population to see the error of its ways in embracing the same tragic ideal.

Conscience Is Self-Eliminating

It is a mistake to think that we can control the breeding of mankind in the long run by an appeal to conscience. Charles Galton Darwin made this point when he spoke on the centennial of the publication of his grandfather's great book. The argument is straightforward and Darwinian.

People vary. Confronted with appeals to limit breeding, some people will undoubtedly respond to the plea more than others. Those who have more children will produce a larger fraction of the next generation than those with more susceptible consciences. The difference will be accentuated, generation by generation.

In C. G. Darwin's words: "It may well be that it would take hundreds of generations for the progenitive instinct to develop in this way, but if it should do so, nature would have taken her revenge, and the variety *Homo contracipiens* would become extinct and would be replaced by the variety *Homo progenitivus*" (*16*).

The argument assumes that conscience or the desire for children (no matter which) is hereditary—but hereditary only in the most general formal sense. The result will be the same whether the attitude is transmitted through germ cells, or exosomatically, to use A. J. Lotka's term. (If one denies the latter possibility as well as the former, then what's the point of education?) The argument has here been stated in the context of the population problem, but it applies equally well to any instance in which society appeals to an individual exploiting a commons to restrain himself for the general good—by means of his conscience. To make such an appeal is to set up a selective system that works toward the elimination of conscience from the race.

Pathogenic Effects of Conscience

The long-term disadvantage of an appeal to conscience should be enough to condemn it; but has serious short-term disadvantages as well. If we ask a man who is exploiting a commons to desist "in the name of conscience," what are we saying to him? What does he hear?—not only at the moment but also in the wee small hours of the night when, half asleep, he remembers not merely the words we used but also the nonverbal communication cues we gave him unawares? Sooner or later, consciously or subconsciously, he senses that he has received two communications, and that they are contradictory: (i) (intended communication) "If you don't do as we ask, we will openly condemn you for not acting like a responsible citizen"; (ii) (the unintended communication) "If you *do* behave as we ask, we will secretly condemn you for a simpleton who can be shamed into standing aside while the rest of us exploit the commons."

Everyman then is caught in what Bateson has called a "double bind." Bateson and his co-workers have made a plausible case for viewing the double bind as an important causative factor in the genesis of schizophrenia (*17*). The double bind may not always be so damaging, but it always endangers the mental health of anyone to whom it is applied. "A bad conscience," said Nietzsche, "is a kind of illness."

To conjure up a conscience in others

is tempting to anyone who wishes to extend his control beyond the legal limits. Leaders at the highest level succumb to this temptation. Has any President during the past generation failed to call on labor unions to moderate voluntarily their demands for higher wages, or to steel companies to honor voluntary guidelines on prices? I can recall none. The rhetoric used on such occasions is designed to produce feelings of guilt in noncooperators.

For centuries it was assumed without proof that guilt was a valuable, perhaps even an indispensable, ingredient of the civilized life. Now, in this post-Freudian world, we doubt it.

Paul Goodman speaks from the modern point of view when he says: "No good has ever come from feeling guilty, neither intelligence, policy, nor compassion. The guilty do not pay attention to the object but only to themselves, and not even to their own interests, which might make sense, but to their anxieties" (*18*).

One does not have to be a professional psychiatrist to see the consequences of anxiety. We in the Western world are just emerging from a dreadful two-centuries-long Dark Ages of Eros that was sustained partly by prohibition laws, but perhaps more effectively by the anxiety-generating mechanisms of education. Alex Comfort has told the story well in *The Anxiety Makers* (*19*); it is not a pretty one.

Since proof is difficult, we may even concede that the results of anxiety may sometimes, from certain points of view, be desirable. The larger question we should ask is whether, as a matter of policy, we should ever encourage the use of a technique the tendency (if not the intention) of which is psychologically pathogenic. We hear much talk these days of responsible parenthood; the coupled words are incorporated into the titles of some organizations devoted to birth control. Some people have proposed massive propaganda campaigns to instill responsibility into the nation's (or the world's) breeders. But what is the meaning of the word responsibility in this context? Is it not merely a synonym for the word conscience? When we use the word responsibility in the absence of substantial sanctions are we not trying to browbeat a free man in a commons into acting against his own interest? Responsibility is a verbal counterfeit for a substantial *quid pro quo*. It is an attempt to get something for nothing.

If the word *responsibility* is to be used at all, I suggest that it be in the sense Charles Frankel uses it (*20*). "Responsibility," says this philosopher, "is the product of definite social arrangements." Notice that Frankel calls for social arrangements—not propaganda.

Mutual Coercion Mutually Agreed upon

The social arrangements that produce responsibility are arrangements that create coercion, of some sort. Consider bank-robbing. The man who takes money from a bank acts as if the bank were a commons. How do we prevent such action? Certainly not by trying to control his behavior solely by a verbal appeal to his sense of responsibility. Rather than rely on propaganda we follow Frankel's lead and insist that a bank is not a commons; we seek the definite social arrangements that will keep it from becoming a commons. That we thereby infringe on the freedom of would-be robbers we neither deny nor regret.

The morality of bank-robbing is particularly easy to understand because we accept complete prohibition of this activity. We are willing to say "Thou shalt not rob banks," without providing for exceptions. But temperance also can be created by coercion. Taxing is a good coercive device. To keep downtown shoppers temperate in their use of parking space we introduce parking meters for short periods, and traffic fines for longer ones. We need not actually forbid a citizen to park as long as he wants to; we need merely make it increasingly expensive for him to do so. Not prohibition, but carefully biased options are what we offer him. A Madison Avenue man might call this persuasion; I prefer the greater candor of the word coercion.

Coercion is a dirty word to most liberals now, but it need not forever be so. As with the four-letter words, its dirtiness can be cleansed away by exposure to the light, by saying it over and over without apology or embarrassment. To many, the word coercion implies arbitrary decisions of distant and irresponsible bureaucrats; but this is not a necessary part of its meaning. The only kind of coercion I recommend is mutual coercion, mutually agreed upon by the majority of the people affected.

To say that we mutually agree to coercion is not to say that we are required to enjoy it, or even to pretend we enjoy it. Who enjoys taxes? We all grumble about them. But we accept compulsory taxes because we recognize that voluntary taxes would favor the conscienceless. We institute and (grumblingly) support taxes and other coercive devices to escape the horror of the commons.

An alternative to the commons need not be perfectly just to be preferable. With real estate and other material goods, the alternative we have chosen is the institution of private property coupled with legal inheritance. Is this system perfectly just? As a genetically trained biologist I deny that it is. It seems to me that, if there are to be differences in individual inheritance, legal possession should be perfectly correlated with biological inheritance—that those who are biologically more fit to be the custodians of property and power should legally inherit more. But genetic recombination continually makes a mockery of the doctrine of "like father, like son" implicit in our laws of legal inheritance. An idiot can inherit millions, and a trust fund can keep his estate intact. We must admit that our legal system of private property plus inheritance is unjust—but we put up with it because we are not convinced, at the moment, that anyone has invented a better system. The alternative of the commons is too horrifying to contemplate. Injustice is preferable to total ruin.

It is one of the peculiarities of the warfare between reform and the status quo that it is thoughtlessly governed by a double standard. Whenever a reform measure is proposed it is often defeated when its opponents triumphantly discover a flaw in it. As Kingsley Davis has pointed out (*21*), worshippers of the status quo sometimes imply that no reform is possible without unanimous agreement, an implication contrary to historical fact. As nearly as I can make out, automatic rejection of proposed reforms is based on one of two unconscious assumptions: (i) that the status quo is perfect; or (ii) that the choice we face is between reform and no action; if the proposed reform is imperfect, we presumably should take no action at all, while we wait for a perfect proposal.

But we can never do nothing. That which we have done for thousands of years is also action. It also produces evils. Once we are aware that the

status quo is action, we can then compare its discoverable advantages and disadvantages with the predicted advantages and disadvantages of the proposed reform, discounting as best we can for our lack of experience. On the basis of such a comparison, we can make a rational decision which will not involve the unworkable assumption that only perfect systems are tolerable.

Recognition of Necessity

Perhaps the simplest summary of this analysis of man's population problems is this: the commons, if justifiable at all, is justifiable only under conditions of low-population density. As the human population has increased, the commons has had to be abandoned in one aspect after another.

First we abandoned the commons in food gathering, enclosing farm land and restricting pastures and hunting and fishing areas. These restrictions are still not complete throughout the world.

Somewhat later we saw that the commons as a place for waste disposal would also have to be abandoned. Restrictions on the disposal of domestic sewage are widely accepted in the Western world; we are still struggling to close the commons to pollution by automobiles, factories, insecticide sprayers, fertilizing operations, and atomic energy installations.

In a still more embryonic state is our recognition of the evils of the commons in matters of pleasure. There is almost no restriction on the propagation of sound waves in the public medium. The shopping public is assaulted with mindless music, without its consent. Our government is paying out billions of dollars to create supersonic transport which will disturb 50,000 people for every one person who is whisked from coast to coast 3 hours faster. Advertisers muddy the airwaves of radio and television and pollute the view of travelers. We are a long way from outlawing the commons in matters of pleasure. Is this because our Puritan inheritance makes us view pleasure as something of a sin, and pain (that is, the pollution of advertising) as the sign of virtue?

Every new enclosure of the commons involves the infringement of somebody's personal liberty. Infringements made in the distant past are accepted because no contemporary complains of a loss. It is the newly proposed infringements that we vigorously oppose; cries of "rights" and "freedom" fill the air. But what does "freedom" mean? When men mutually agreed to pass laws against robbing, mankind became more free, not less so. Individuals locked into the logic of the commons are free only to bring on universal ruin; once they see the necessity of mutual coercion, they become free to pursue other goals. I believe it was Hegel who said, "Freedom is the recognition of necessity."

The most important aspect of necessity that we must now recognize, is the necessity of abandoning the commons in breeding. No technical solution can rescue us from the misery of overpopulation. Freedom to breed will bring ruin to all. At the moment, to avoid hard decisions many of us are tempted to propagandize for conscience and responsible parenthood. The temptation must be resisted, because an appeal to independently acting consciences selects for the disappearance of all conscience in the long run, and an increase in anxiety in the short.

The only way we can preserve and nurture other and more precious freedoms is by relinquishing the freedom to breed, and that very soon. "Freedom is the recognition of necessity"—and it is the role of education to reveal to all the necessity of abandoning the freedom to breed. Only so, can we put an end to this aspect of the tragedy of the commons.

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