April 14, 2008

From: J. Peter Clum, 45638 South Fork Drive, Three Rivers, CA 93271

To: David Bryant, Project Planner, Tulare County Resource Management Agency (RMA), 5961 South Mooney Boulevard, Visalia, CA 93277

Subj: Comments on the Tulare County General Plan 2030 Update Draft Environmental Impact Report (DEIR)

Encl: (1) My Written Comments on DEIR Submitted Feb 26, 2008 at the Joint Hearing of the Tulare County Board of Supervisors and the Tulare County Planning Commission

(2) My Additional Written Comments on DEIR Submitted Same Date and Hearing

(3) My ltr w/out Enclosures dtd Mar 13, 2008 to David Bryant, Project Planner Tulare County RMA

(4) Carole Clum's Fact Checking on Tables 4-4 and 4-5 of Draft EIR and Discussion Thereof dtd Feb 26, 2008

(5) Climate Change Impacts on the Central Valley

(6) Modeling Tools to Estimate Climate Change Emissions Impacts of Projects/Plans

(7) "Climate Change and the California Environmental Quality Act" by Dave Owen

(8) Additional Online Resources/Environmental Gateway Pages

(9) "Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America" by Richard

Seager et al, pages 1181 to 1184, May 25, 2007 Science (Originally Published in Science Express)

(10) Executive Summary of Article Contained in Enclosure (9)

(11) "Drying of the West" by Robert Kunzig, pages 90-113, Feb 2008, National Geographic

(12) Board of Supervisors, County of Tulare ltr to Assemblyman Maze dtd Sep 25, 2007

(13) Sources of Data on Groundwater Impacts That Have Been Attributed to Irrigated Agriculture

(14) Sources of Data on Surface Water Impacts That Have Been Attributed to Irrigated Agriculture

(15) Internal ltr dtd Jan 15, 2008, of California Regional Water Quality Control Board Central Valley Region

(16) "Temporal Trends in Concentrations of DBCP and Nitrate in Groundwater in the Eastern San Joaquin Valley, California, USA," Hydrogeology Journal

(17) "Assessing the Vulnerability of Public-Supply Wells to Contamination from Urban, Agricultural, and Natural Sources," USGS Fact Sheet 2005-3022, April 2005

(18) Summary of Constituents Above Drinking Water Standards, GAMA Domestic Well Assessment Project, Tulare County, dtd Dec 12, 2006

(19) Tulare County Applications Pertaining to Groundwater Contamination Submitted to the California Department of Health

(20) Water Quality Comments on General Plan Submitted Feb 22, 2007, by Tulare County Environmental Health Depart, Health and Human Services Agency to Tulare County RMA, pages 246 to 250, Public Comment Matrix, Tulare County General Plan

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(21) Agenda For Subcommittee on Nitrates Nitrate Investigation Workshop of Jan 17, 2008

These comments address air quality, water supply and water quality and are in addition to my comments earlier submitted, enclosures (1 and 2). Enclosure (1) highlighted specific deficiencies in the DEIR. Enclosure (2) requested a report prepared by Mr. Keller of Keller, Wegley and Associates. To date, this request has been responded to only in part. As a result, another request, enclosure (3), was hand-delivered to RMA on March 13, 2008.

An environmental impact report "must include detail sufficient to enable those who did not participate in its preparation to understand and to consider meaningfully (emphasis added) the issues raised by the proposed project." Laurel Heights Improvement Assn. v. Regents of University of California (1988) 47 Cal.3d 376, 405. "[A]n Failure to comply with the information disclosure requirements constitutes a prejudicial abuse of discretion when the omission of relevant information has precluded informed decision making and informed public participation, regardless of whether a different outcome would have resulted if the public agency had complied with the disclosure requirements." Bakersfield Citizens for Local Control v. City of Bakersfield (5th Dist. 2004) 124 Cal.App.4th

1184, 1198. Environmental Impact reports serve an important public informational purpose. "An EIR is an educational tool not just for the decision maker, but for the public as well." Association of Irritated Residents v. County of Madera (5th Dist. 2003) 107 Cal.App.4th 1383, 1392.

The information presented in the DEIR pertaining to air quality, water supply and water quality is inadequate and fails to meet the above standards. As a result, meaningful assessment of the true scope of serious adverse environmental impacts is thwarted. Bakersfield Citizens for Local Control v. City of Bakersfield (5th Dist 2004) 124 Cal.App.4th 1184, 1220.

Air Quality

The people of Tulare County encounter on a regular basis some of the worst air quality in the United States. At times we experience the worst air quality. The incidence of asthma is abysmal. Should not there be some discussion of this and analysis of air pollution data juxtaposed the trade offs on health effects and the cost of treating the same? The DEIR is lacking in this regard. It has no detailed discussion of our air quality's effects on health and the economy. Instead, we have some passing references, comments and one table (Goals and Policies Report: AQ-3 on page 9-6, AQ 4-5 on page 9-7; Background Report: page 5-55 last line, page 6-4 end of first paragraph, page 6-5 Table 6-1; DEIR page ES-42, page ES-48, page 4-49 upper half, pages 4-57 and 4-58, page 8-15). Page 9-7 of the Goals and Policies Report contains policy AQ-4.5 "Public Awareness,

[t]he County shall promote public awareness of the seriousness and extent of the existing pollution problem." This policy seems like a prudent measure given our bad air. But, unfortunately, there is no implementation measure (see pages 9-8 and 9-9 Goals and Policies Report). Nor is there any refence to this policy in the DEIR executive summary. For whatever reason, policy AQ-45 Public Awareness does not appear on page ES-42 of the DEIR, which page corresponds to the pertinent goals and policies on pages 9-6 to 9-7 of the Goals and Policies Report. Table 6-1, page 6-5 of the Background Report, contains the most extensive reference to health effects appearing in the DEIR. However, the reference to Table 6-1 contained in the text on page 6-4 says nothing about health effects and states only "[a] summary of the state and federal ambient air quality standards is shown in Table 6-1." Page 4-49 of the DEIR, under the section captioned "standards of significance" starting on page 4-47 appears to expressly delay health risk assessment until specific projects are considered under the General Plan Update.

CEQA Guidelines § 15126.2(a) requires an EIR to discuss "health and safety problems caused by the physical changes" that the General Plan Update will precipitate. The DEIR contains no meaningful discussion of the anticipated adverse impact on air quality and increases in specific respiratory conditions and illnesses. An EIR requires more than raw data and statement of facts. It requires meaningful analysis which serves to inform the public and government officials of the environmental consequences of decisions before they are made and which would provide decision makers with sufficient information to make intelligent decisions.

Water Supply

The DEIR fails to provide a proper baseline and, more importantly, contains inadequate information to inform the public and for intelligent decision making. The water resources section of the DEIR has many broad statements and generalities about existing conditions. Correct, quantitative information is missing as it pertains to existing baseline conditions. There is incomplete and inaccurate data in Table 4-5, page 4-107 of the DEIR, which purports to show the ability of 21 unincorporated communities to meet population growth demands of the General Plan Update buildout to 2030. See enclosure (4). The water resources section refers to data and tables from the California Water Plan Update 1998 (Department of Water Resources Bulletin 160-98). The California Water Plan Update 2005 (Department of Water Resources Bulletin 160-05) was released in December 2005. While the reports are formatted differently, the 2005 edition has significantly more discussion about global climate change and the consequences thereof for our water supply. Bulletin 160-05, pages 3.15 and 3.16, pages 4.32 to 4.36, Volume 1. The 1998 water plan contains only a brief mention thereof and the statement "if global warming occurs," page 3-11, Volume 1, Bulletin 160-98. Since the release of Bulletin 160-05, the science has advanced. Yet, the Background Report and the DEIR water resources analysis ignore completely the anticipated consequences but yet to be determined full severity of global climate change. Table 10-1, "California Water Supplies with Existing Facilities and Programs Thousand Acre Feet" presented on page 10-6 of the Background Report is drawn from Bulletin 160-98 and of uncertain present reliability. Page 10-1 of the Background Report indicates "[t]he information contained in this section was obtained from various sources, including the 2001 (emphasis added) Tulare County General Plan Background Report. Additional information is based on printed reports by the State Department of Water Resources, including the State Water Plan ...." 2001 is hardly current information. Review of Chapter 10 of the Background Report makes clear the Water Plan relied on was the 1998 version, not 2005. Concern with the reliability of water supply increases with each year. The DEIR should have provided the most current information for the baseline as of April 2006 (Notice of Preparation issued April 25, 2006) and thorough discussion of anticipated changes throughout the buildout of the General Plan. It fails to do this. However, even given these inadequacies, the water resources section of the DEIR forecasts substantial uncertainty, at best, about the adequacy of surface water and groundwater to meet the projected growth. Pages 4-127 through 130, page 8-12 and page 8-20 DEIR. Page C-27, first version, issued January 25, 2008 "correctory information" and page C-27, second version, issued February 26, 2008 "correctory information #2." (Both C-27's are pages of Appendix C of the Background Report. The Background Report is Appendix B, separate volume, of the DEIR.

A more accurate presentation of existing conditions and information pertaining to presently occurring and forecasted to occur environmental changes of major impact on our water supply reliability throughout the General Plan buildout period should have and could have been included. The DEIR avoids addressing the magnitude of oncoming water supply problems and fully disclosing the uncertainty associated with water development and delivery. To fulfill its informational disclosure requirements, the DEIR should have included discussion of the following additional information:

(1) As recognized in the California Water Plan Update 2005, Bulletin 160-05, page 434, Volume I "[c]omputer modeling of global climate change scenarios predict significant future reductions in the Sierra snowpack. A reduced snowpack will reduce the total water storage for the state". Also noted on the same page and depicted in Figure 4-9 is that "[h]istorical records reveal long-term changes in the pattern of April-July runoff," i.e. linear regression.

(2) Since publication of Bulletin 160-05, more has become clear concerning the expected adverse effects of global climate change. The modeling is better and the science further advanced. See enclosures (5 through 11).

(3) Page 3.12, Volume 1, Bulletin 160-05 notes "[w]ater managers today use hydrologic records of the past century to estimate how climate conditions would affect water availability and water needs." Unfortunately, as we are slowly beginning to recognize, the last one hundred years in the Southwest were by far the wettest in the last millenium. We are returning to the normal, much drier conditions which may well last hundreds of years. This phenomenon is, at least in part, separate from that resulting from global climate change, which may add an extra dimension. See "Requiem for a River" by Tim Folger, pages 24-35, ONEARTH, Spring 2008, published quarterly by the Natural Resources Defense Council and "Drying of the West" contained

in enclosure (11). The baseline California water managers have been using is dramatically skewed in the wrong direction toward more water rather than what is apparently is our normal condition of less water. If we do not make the appropriate adjustments, the "impending water crisis facing Tulare County and all of California" addressed by the Board of Supervisors, County of Tulare in enclosure (12) could prove catastrophic to our population, economy and environment. Using the current historical records to document single and multiple dry years water supply is no longer a reliable or prudent practice in water supply assessment.

(4) As noted by all five Tulare County Supervisors in a letter to Assemblyman Bill Maze [enclosure (12)], there is an impending water crisis facing Tulare County and all of California" ... which "will only worsen in the coming years." The letter states the San Joaquin River restoration "will force a reduction in water to Friant users at an average of 19% and a maximum of 23%." The letter further indicates the delta smelt decision will reduce "water supplies to Northern, Central, and Southern California ... by 14-35%". The letter concludes "the current water situation in Tulare County is in dire need of assistance. ... Our citizens will be left with a minimum supply of drinking water, and our farmers will not be able to irrigate their crops. Something must be done about this dangerous situation." If the situation was dangerous in 2007, what will it be in 2010, 2020, and 2030?

(5) There is no comprehensive information regarding the County's

groundwater resources, pages 4-129 and 130, DEIR. The Kings, Kaweah, Tule, and Tulare Lake Basin are all in critical overdraft. "A basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts." ... "Overdraft is the condition of a groundwater basin in which the amount of water withdrawn by pumping over the long term exceeds the amount of water that recharges the basin. Overdraft is characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. Overdraft can lead to increased extraction costs, land subsidence, water quality degradation, and environmental impacts," pages 3.13 and 14, Volume 1, Bulletin 160-05. It has been estimated that the Tulare Lake Hydrologic Region accounts for 56% of the State's overdraft condition, California Water Plan Update 1998, Table 3-15, page 3-50, Volume 1, Bulletin 160-98. The Kings, Kaweah and Tule Basins account for about 70% of the Tulare Lake Hydrologic Region overdraft, pages 8-45 and 46, Volume 2, Bulletin 160-98. Unless the lead agency knows approximately how much water exists in the affected basin, the agency cannot possibly know what level of additional withdrawals would involve significant impacts. "Groundwater pumping, a major source of supply in the Tulare Lake [hydrologic] region continues to increase in response to growing urban and agricultural demands. If groundwater extraction continues to be used to offset anticipated but unmet surface water imports, it will have negative consequences. One such effect of long-term groundwater overdraft is land subsidence, which also results in a reduction of aquifer storage space. This has already caused some damage to canals, utilities, pipelines, and roads in the region." Page 8.8, Volume 3, Bulletin 160-05. As noted earlier, the water resources section of the Background Report has been in preparation since at least as early as 2001. Page 10-1, Background Report. Impact WR-3, page ES-72 of the DEIR, states "[the] General Plan Update would have the potential, in the long-term, to deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table. This sterile, unmodified recitation of a checklist item from Appendix G, CEQA Guidelines understates the impact. We are already in a critical overdraft condition, in long-term regression of groundwater levels, and by most reasonable predictions entering a much drier era with declining surface water deliveries. The environmental alarm bells have been ringing, loud and clear and few are listening. One of the policies listed on page ES-72 of the DEIR is WR-1.7 Collection of Additional Groundwater Information. See also pages 11-4, 6, 7, and 8, Goals and Policies Report; and pages 4-128 to 134, DEIR. Page 11-4, Goals and Policies Report states under policy WR-1.7, [t]he County shall support additional studies focused on furthering the understanding of individual groundwater source areas and basins. [New Policy]. Should not we have been doing this at full speed since 2001?

"will conduct studies" is more appropriate language.

"The courts have done their part by suggesting, if not holding, that the proper forum for making tough decisions regarding water supply and land use planning is the General Plan EIR. The courts have also cautioned local agencies to fully disclose the uncertainty associated with water development and delivery in California, and to provide substantial evidence the actual water supplies will be available to serve new development. Finally, the courts have instructed that special care must be taken to learn everything reasonable possible about stressed groundwater resources before committing to a project that relies on such water." Page 786, Guide to CEQA by Michael H. Remy, Tina A. Thomas, James G. Moose and Whitman F. Manley (2006 11th edition Solano Press). The present DEIR falls far short of the informational obligation.

continued on page 13

Water Quality

My comments about this issue supplement those noted in enclosure (1). Inexplicably, the DEIR's assessment of the impact of the General Plan Update buildout on water quality is that it will be less than significant with no mitigation required (Impact WR-4, pages ES-72 to 74 and 4-135, DEIR). Groundwater is the major source of drinking water in Tulare County. The two major threats to groundwater in California are overdraft and contamination. Although groundwater contamination is discussed in general, undetailed terms in the Background Report and DEIR (pages 7-15 to 7-36, 10-11 to 10-13, and Appendix C of the Background Report; pages 4-103 to 4-134 DEIR), there is no in-depth quantitative consideration of this known, serious problem or its correlation to health. In fact, the DEIR contains absolutely no information on or discussion of the health effects of groundwater contamination. The DEIR's assessment of less than significant impact on water quality with no mitigation required is made despite:

(1) the DEIR's general discussion of the inadequacy of groundwater to support growth and of groundwater contamination problems

(2) the conditions and hydrologic changes noted in my comments and enclosures in the preceding section on water supply

(3) the DEIR's assessment that groundwater depletion, substantial interference with groundwater recharge resulting in a net deficit in aquifer volume or of lowering of local groundwater table was a significant but unavoidable impact (Impact WR-3, pages ES-72 and 4-128 to 134, DEIR)

(4) the critical overdraft condition of the Kings, Kaweah and Tule Basins (page 4-129, DEIR; page 3.13, Volume I, Bulletin

160-05; page 3-50, Volume 1, Bulletin 160-98; pages 8-45 to 46, Volume 2, Bulletin 160-98)

(5) that "[u]ncertainty and limitations of surface water deliveries from the Delta are exacerbating groundwater overdraft (in the Tulare Lake Hydrologic Region) because groundwater is used to replace much of the shortfall in surface water supplies." (page 3.23 Volume 1, Bulletin 160-05)

(6) that groundwater "[o]verdraft can lead to ... water quality degradation..." (page 3.14, Volume 1, Bulletin 160-05)

(7) that "[a]gricultural runoff and drainage are also the main sources of nitrate, pesticide, and selenium that endanger groundwater and surface water beneficial uses. The basin (Tulare Lake Hydrological Region) also has a relatively large concentration of dairies that contribute microbes, salinity, and nutrients to both surface and groundwater. Nitrate has contaminated more than 400 square miles of groundwater in the Tulare Lake Basin. In addition, oil field waste has impacted water quality." (page 8.9, Volume 3, Bulletin 160-05)

(8) the lack of comprehensive information regarding the County's groundwater resources (pages 4-129 and 130, DEIR)

(9) the numerous articles and studies addressing groundwater contamination [enclosures (13 to 17)]

(10) the results of the State Water Resources Control Board's (SWRCB) Groundwater Ambient Monitoring and Assessment Program (GAMA) in Tulare County finding that 75 of the 181 private domestic wells tested in the County had nitrate levels over the maximum contaminant level (MCL)

[enclosure (18) dated 12/12/06]

(11) the preapplications for funding, enclosure (19), prepared by RMA and Tulare County Environmental Health Department and processed via the Tulare County Water Commission and the Tulare County Board of Supervisors in July 2007 to address groundwater contamination from nitrates and other contaminants which note "Tulare County has many public water systems with unsafe drinking water"; "[with] decreasing surface water deliveries to the area groundwater water quality and quantity will continue to decline"; "Tulare County has many public water systems with nitrate levels over the Maximum Contaminant Level (MCL) of 45 ppm. Approximately 20% of Tulare County's small public drinking water systems are una le to mee the nitrate MCL on a regular basis, and another 20% are over half the nitrate MCL. The number of systems affected and the levels continue to increase;" "[the County has extensive groundwater quality issues primarily related to the contaminants nitrate, arsenic, DBCP and uranium. It is estimated that contamination issues will be exacerbated by land use practices and from overdraft, drought, and the loss of Friant-Kern water due to the San Joaquin River settlement."

(12) enclosures (20 and 21) also would indicate that RMA as lead agency was well aware of groundwater water quality problems

The DEIR's treatment of water quality has resulted in a faulty baseline and a failure to comply with the information disclosure requirement of CEQA by omitting relevant information which precludes informed public participation and intelligent decision making. It almost seems as if there has been deliberate avoidance of groundwater water quality issues. There has been no compliance with CEQA Guidelines § 15126.2 (a) which requires an EIR to discuss "health and safety problems caused by the physical changes" that the General Plan Update buildout would precipitate. There is not word one about the correlation of adverse groundwater quality impacts to resulting adverse health impacts. The DEIR's role "as an environmental 'alarm bell' whose purpose is to alert the public and its responsible officials to environmental changes before they have reached ecological points of no return," County of Inyo v. Yorty (1973) 32 Cal. App. 3d 795, 810, has not been fulfilled.

/s/ Peter Olson

February 26, 2008

Written Comments submitted by J. Peter Clum,
45638 South Fork Drive, Three Rivers, CA
on the Tulare County General Plan 2030 Update
Draft Environmental Impact Report (DEIR)

Most people would agree with the objectives of the General Plan Update. Perhaps they need to specifically address air and water quality, but generally there is a basis for consensus. That's the good news. The rest is largely bad news because more often than not the policies and implementation measures are general, vague, weak, unenforceable or nonexistent. We simply will not be able to obtain the Update's objectives with these policies and implementation measures.

Further, the baseline set of environmental conditions are incomplete and confusing. There appears almost to have been a conscious effort to avoid meaningful thresholds of significance, feasible mitigation measures, and a reasonable range of alternatives. Mitigation measures are frequently either absent, unenforceable, or deferred without performance standards or criteria to gauge their accomplishment or timeframe therefor. All to often, the determination of an impact is significant but unavoidable when in fact there are existing mitigation measures to lessen the significant impacts. For example, see the public comments contained in the Public Comment Matrix, Tulare County General Plan.

Compounding the problem is that the DEIR fails to provide

Enclosure (i)

a reasonable range of alternatives which offer substantial environmental advantages to the General Plan Update. The purpose of alternatives is to reduce or avoid significant environmental harm while achieving all or most of the objectives. Other than the no project alternative, the alternatives have been preordained to offer little essential or pratical difference.

Let me give you a few examples of what I am talking about:

(1) Page ES-43 to 44 of the DEIR sets forth new policy AQ-4.6, PM-10 and PM 2.5 Reduction Measures for Dairy and Feedlot Operations. The second to last paragraph provides manure water shall either be injected subsurface or placed on the surface in thin layers. The last time I heard, we had significant groundwater contamination issues. How will this new policy help water quality? What is the mitigation measure for this potentially significant impact on water quality? There is none and that's because the DEIRs assessment of the General Plan Update on water quality is less than significant. Pages ES-72 to 74, DEIR. Which is interesting in that the Yokohl Ranch NOP specifically identifies water quality as a potentially significant impact, pages 32 to 34. I note that page 8-5, DEIR, states "[a]s part of the analysis, the following General Plan Amendments (GPAs) and General Plan Initiatives (GPIs) are taken into consideration for the cumulative impacts discussion and analysis." Yokohl Ranch is a specified GPI.

(2) Urban and wildland fire hazards are judged to be less than significant, page ES-64, DEIR, despite the fact the General Plan Update would allow substantial development in the area of greatest concern - the urban wildland interface. Didn't we learn anything from the terrible 2007 California fires? In any case, the Yokohl Ranch NOP, page 1, recognizes this impact as potentially significant.

(3) The DEIR judges hydrology issues other than flooding due to increase in impervious surfaces as less than significant. For example, impact PFS-4 and 5 on pages ES-80 to 82 are judged as less than significant. Quite the opposite conclusion is reached in the Yokohl Ranch NOP, pages 32 to 34.

[signature]

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February 26, 2008

Written Comments submitted by J. Peter Clum,
45638 South Fork Drive, Three Rivers, CA,
on the Tulare County General Plan 2030 Update
Draft Environmental Impact Report (DEIR)

On February 7, 2008, I hand delivered a written request for a report prepared by Mr. Keller of Keller, Wegley and Associates titled "Water Resources General Plan Update County of Tulare." Enclosure (1) sets forth the particulars as well as prior verbal requests for this report.

On page 4-105 of the DEIR, Mr. Keller's report is characterized as a major document which is included in the General Plan Update and which "provides an overview of the water resources in the County. The overview includes the status of each of the major sources of water and any anticipated change in status over the planning horizon covered by the updated General Plan. Issues addressed include groundwater quality, groundwater overdraft and the reliability of identified surface water sources." The report was supposed to have been included with one of the separate volume appendices (Appendix B) to the DEIR formally Released by the January 14, 2008, Notice of Availability. By "Correctory" dated January 25, 2008, the Resource Management Agency, Tulare County (RMA) stated the report had been "inadvertently omitted" and forwarded it as Appendix C of the Background Report. However,

enclosure(2)

2

I soon learned that items were missing from the report, specifically annotated community maps and eight figures. Further, I noticed that contrary to what normally would be expected of a formal report from an engineering firm, it did not appear under the firm's letterhead or bear a signature. Rather, it appears in the same typed format as the rest of the Background Report other than on the bottom left of each page it bears the notation "Revised July 2007" rather than "December 2007" and on the upper left it has the notation "Draft".

Page 4-105 of the DEIR states that in addition to Mr. Keller's report being included in the Background Report, it is incorporated by reference pursuant to section 15150 of the CEQA Guidelines. I note section 15150 provides that when a document is incorporated by reference it "shall be made available to the public for inspection at a public place or public building" and "[a]t a minimum, the incorporated documents shall be made available to the public in an office of the lead agency in the county where the project would be carried out or in one or more public buildings such as county offices or public libraries if the lead agency does not have an office in the county." That means Mr. Keller's report should have been available at RMA on Mooney Boulevard commencing January 14, 2008, the date of the Notice of Availability of the DEIR. It was not and has not been available for public inspection. When I hand delivered my written request to RMA on Feb. 7, RMA was unable to provide me with the annotated community maps, figures, or Mr. Keller's report.

Information disclosure is a fundamental concept of the CEQA process. Yet, what has been characterized as a major report pertaining to the Water Resources portion of the DEIR is not available. It should have been available on January 14 with the release of the Notice of Availability. The report's absence and RMA's inability to produce it in the considerable lapsed time since January 14 is a clear cut noncompliance with required CEQA procedure rendering the Notice of Availability defective and void ab initio. Case law supports the proposition that the comment period does not commence until all the documents are made available to the public. Common sense and basic fairness dictate the same result. How can one review and comment on what is required to have been provided when it has not been? Other pertinent code or guidelines sections are Public Resources Code 21005, 21061 and CEQA Guidelines 15147.

I note that County Counsel's reply (Enclosure (2)) dated February 19, 2008, to my written request for Mr. Keller's report indicates "the Agency's goal as to when the amended packet will be available is on or about February 26, 2008." That's 43 days after it was required to have been available on January 14. How can an agency issue a Notice of Availability of a DEIR when a major report thereof is not available? This unfortunate scenario raises other questions such as: where is the report; why cannot it be quickly reprinted; and what was actually relied on in preparing the Water Resources portion of the DEIR?

Finally, I note that while the initial absence of Mr. Keller's report was characterized as being "inadvertently omitted," conversations I had with RMA staff on February 4 and 7, 2008, indicate there had been discussions about the omitted materials and whether to include them in the January 25, 2008 "Correctory". Specifically, during my February 4 telephone conversation with Mr. Waters of RMA, in which I inquired about the missing materials, he told me he recalled some conversation between he thought Mr. Bryant and Mr. Finney about whether to include them. Further, during my meeting with Mr. Przybylski on February 7, when I delivered my written request, he spontaneously stated Mr. Finney did not make the decision to not include the documents.

J. Peter Clum

J. Peter Clum

Enclosures: (1) My ltr dtd Feb 7, 2008 to David Bryant, Tulare Cty, RMA

(2) County Counsel's ltr dtd Feb 19, 2008 to me

February 7, 2008

From: J. Peter Clum, 45638 South Fork Drive
Three Rivers, CA 93271 (559) 561-4661

To: David Bryant, Project Planner, Tulare County Resource Management Agency, Government Plaza, 5961 South Mooney Boulevard Visalia, CA 93272

Subj: Request for Documents Missing from the Draft Environmental Impact Report General Plan 2030 Update and for Restarting the Commencement Date of the 60 Day Public Review Period

Ref: (a) Your ltr of Jan 25, 2008, County of Tulare General Plan 2030 Update Goals and Policy Report and Background Report Correctory Information

(b) Phoncon Peter Clum and Jason Waters, Tulare County RMA of Feb 4, 2008

(c) Phonmsg Peter Clum to Jason Waters, Tulare County RMA of Feb 5, 2008

(d) Phoncon Carole Clum and Dennis Keller of Feb 4, 2008

1. While reviewing reference (a), which provided a number of pages inadvertently omitted from the General Plan 2030 Update Goals and Policy Report and Background Report, I discovered pages were still missing from the report (Appendix C of the "Correctory") which was supposed to have been included in the Background Report (Appendix B of the DEIR). Specifically, Appendix C of the Background Report is a report prepared by Mr. Keller of Keller, Wegley and Associates,

titled "Water Resources General Plan Update County of Tulare" and is still missing: (1) figures 4-1 through 4-8 referred to in the report, and (2) the individual community maps referred to in the last paragraph on page 27 (page C-27) with "the box being checked" or not. While a number of community maps were provided with the "Correctory," the maps were misarranged in the "Correctory"; so it is not exactly clear whether they are the ones referred to in Mr. Keller's report. In any case, the maps contain no box with or without a check mark.

2. By references (b) and (c), I requested copies of these missing pages. They are not on the County's website or in the hard copy report. I have received no response to my request. The public is entitled to these documents. On page 4-105 DEIR, the second paragraph under "Domestic Water Service Overview" specifically states Mr. Keller's report "Water Resources General Plan Update County of Tulare" is included in the Background Report. The next paragraph refers to Mr. Keller's report as "a matter of public record or is generally available to the public ...." This is not a correct statement. By reference (d), my wife Carole Clum requested a full copy of the report. Mr. Keller declined to do so, stating he was under contract to the County. As noted, the report is missing from the Background Report.

3. Accordingly, I request an unedited and complete copy of Mr. Keller's Report. Additionally, I request that the 60 day public review period be restarted on the date you make this document available to the public. Case law supports the proposition that the

comment period does not begin to run until the lead agency provides the public with complete copies of the documents. Ultramar, Inc. v. South Coast Air Quality Management Dist. (2d Dist. 1993) 17 Cal. App. 4th 689, 700 (21 Cal. Rptr. 2d 608). See page 348, and note 53 on page 992 Guide to the California Environmental Quality Act by Michael H. Remy, Tina A. Thomas, James G. Moose and Whitman F. Manley (2006 11th edition Solano Press).

[signature]
J. Peter Clum

Copy to: (1) Supervisor Allen Ishida, District 1, Tulare County
(2) County Counsel, Tulare County

Rec'd 20Feb'08

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☐ 11200 Avenue 368, Room 102, Visalia CA 93291 — Telephone: (559) 713-3230 — Fax: (559) 713-3240

February 19, 2008

J. Peter Clum
45638 South Fork Drive
Three Rivers, CA 93271

Re: RMA No. 08-026 - Public Records Act Request from J. Peter Clum

Dear Mr. Clum:

Our office represents the Tulare County Resource Agency (Agency) in this matter. We are treating your request for records as a Public Records Act Request pursuant to California Government Code § 6250 et seq. Please be advised that nothing in this response should be considered as a waiver of the right of the Department to assert any and all claims of exemptions or privileges to the inspection of the whole or any part of the record. This letter is in response to your letter dated February 7, 2008.

The Agency is going to issue an amended correctory packet. It is anticipated that the packet will contain the documents you have requested or corrected documents. At this time the Agency's goal as to when the amended packet will be available is on or about February 26, 2008. Please contact David Bryant (559) 733-6291 in order to pay the copying fee and arrange to receive a copy of the packet.

If you have any questions, please telephone me at (559) 733-6263.

Very truly yours,
KATHLEEN BALES-LANGE
County Counsel

By *Linda Weirick*
Linda Weirick
Paralegal

Enclosure (2)

March 13, 2008

From: J. Peter Clum, 45638 South Fork Drive
Three Rivers, CA 93271 (559) 561-4661

To: David Bryant, Project Planner, Tulare County Resource Management Agency, Government Plaza, 5961 South Mooney Boulevard, Visalia, CA 93272

Subj: Request Pursuant to §15150(b) CEQA Guidelines to Inspect the Original of the Report Titled Water Resources General Plan Update County of Tulare Prepared by Keller, Wegley and Associates

Encl: (1) My ltr of Feb 7, 2008 to David Bryant, Tulare Cty RMA
(2) Cty Counsel's ltr of Feb 19, 2008 to me
(3) Cty of Tulare General Plan 2030 Update Background Report Correctory Information #2 of Feb 26, 2008
(4) My Written Comments Submitted Feb 26, 2008 to the Joint Public Hearing of the Tulare Cty Board of Supervisors and the Planning Commission
(5) Cty of Tulare General Plan 2030 Update Goals and Policy Report and Background Report Correctory Information of Jan 25, 2008

By enclosure (1), I requested: (1) certain missing documents, (2) an unedited and complete copy of a report prepared by Keller, Wegley and Associates titled "Water Resources General Plan Update County of Tulare, and (3) restarting the public review period for the Draft Environmental Impact Report

enclosure (3)

General Plan 2030 Update (DEIR). Enclosure (2) advised that an amended correctory packet was expected to be available on or about February 26, 2008 and that it would contain the documents I had requested or corrected documents.

On February 26, 2008, I was handed enclosure (3) prior to the commencement of the combined public hearing of the Tulare County Board of Supervisors and the Planning Commission. During the hearing, I submitted enclosure (4).

Enclosure (3) extended the public review period for the DEIR and provided the missing figures 4-1 through 4-8 and retyped pages C-25 through C-27, which eliminated without explanation, any reference to the individual community maps with or without a box checked. Such reference was contained in the original page C-27 contained in enclosure (5).

I consider enclosure (3) to be an incomplete response to my request of February 7. While it did provide the missing figures, it did not respond to my request for the individual community maps with or without a checked box and for an unedited and complete copy of the report prepared by Keller, Wegley and Associates. I question the timing of the change to page C-27 eliminating reference to the individual community maps with or without a checked box. This change was made only after my request for the individual community maps. These maps are available. I was shown them by Mr. Przyblski during my meeting with him on February 7 at RMA. Only, they did not have on them the boxes with or without checkmarks referred to by Mr. Keller in the original page C-27 contained in enclosure (5). Why was the change made? No explanation or analysis is provided. If Mr. Keller had earlier forgotten to make the notations on the individual community maps which he referred to in the original page C-27, why not go ahead and make them as opposed to eliminating reference to the community maps? The public is left to speculate as to the reason and/or motivation. This somewhat less than transparent course of events hardly meets the information disclosure envisioned by the California Environmental Quality Act.

Further, I find it hard to believe there is no stand alone report prepared by Keller, Wegley and Associates but rather only the typed version appearing in the general plan format as Appendix C of the Background Report. [See third paragraph of enclosure (4).] Nowhere on Appendix C is it indicated to be a report prepared by Keller, Wegley and Associates. Page 4-105 of the DEIR specifically states this report is incorporated by reference and cites § 15150 CEQA Guidelines. Paragraph (b) requires, at a minimum, that a document incorporated by reference be available at RMA for inspection. I want to inspect the original report and compare it with the formatted draft appearing as Appendix C of the Background Report. If there is no original report, I want to know how Appendix C was prepared and who assembled it. In closing, I note my belief that the public comment period does not commence until the lead agency provides the public with complete copies of DEIR documents.

J Peter Clum

Copy to: (1) Supervisor Allen Ishida, District 1, Tulare County
(2) County Counsel, Tulare County

Carole Clum's Factchecking on Tables 4-4 and 4-5 in Draft EIR

Table 4-4 General Plan Population Estimates by Unincorporated Communities

Table 4-5 Summary of Domestic Water Supply Conditions for Unincorporated Communities in Tulare County

Compiled on February 26, 2008

Including Comments on Ability of Each Community to Serve Projected Growth of Updated General Plan for 2030 Buildout

Carole Clum
45638 S. Fork Drive
Three Rivers, CA 93271-9610

Carole G. Clum
February 26, 2008

Enclosure (4)

Alpaugh JPA 949-8199

person interviewed: Martha Howard
date: Feb 22, 2008
total population: 1000
how many water connections: 325
can you hook up any more homes: can serve 20 more
wells: 2, both have arsenic contamination

infrastructure pipes new
water tank new

meters: yes Read but not charging yet by volume flat rate

peak usage: at maximum capacity

water quality high in arsenic, no nitrates

grants: at top of the list for grant to treat arsenic
will use absorbtion method
Boyle Engineering

sewers: septic only

problems: Alpaugh's water system is 70 years old

Comments: This is an impoverished community with arsenic in water supply, old water system at maximum capacity during peak demand
SIGNIFICANT CONCERNS

Cutler PUD 528-3859

person interviewed: Superintendent Junior

date: Jan 31, 2008

total population: 6300 in 2000 census

# of PUD water connections: 1200

can you serve any more homes: very few undeveloped lots
will annex more land

wells: 2 wells
lost 2 wells due to nitrate contamination

infrastructure pipes
water tank

meters: only on a few commercial accounts
will slowly install meters on domestic accounts in future

peak usage: at maximum capacity
rationing landscape watering all year, odd and even day

water quality: nitrates

grants: engineers will apply for any grant they qualify for
want to drill another well. Will be blending water
well will cost $500,000

Sewers: at capacity now
moratorium on sewers since 2006

Comments: This is a poor community with nitrate contamination, almost no capacity to serve more connections, at maximum capacity during peak demand, at capacity for wastewater treatment
SIGNIFICANT CONCERNS

Ducor CSD 559 361-0450

person interviewed: Melanie, bookkeeper, and Pete Garza, manager 333-1

date: Feb. 22, 2008

total population: 300

CSD water connections: 146

Can you serve any more homes: not many $2500 to hook up

wells: 2 wells. (1 well doesn't produce many gallons)
sometimes sulfur smell, sometimes bacteria

infrastructure: pipes – need new pipes
well – need new well

meters: yes. Not read. Flat rate charged

peak usage: pumps run longer, costs run higher
in dry years wells pump less water

water quality: okay (except for occasional sulfur smell and bacteria)

grants: applying for grants for well, piping, meters, tank

Sewers: no sewage treatment plant. All on septic systems

problems: infrastructure

Comments: This community has only 2 wells (1 doesn't produce much water, ~~sometimes~~ bacteria in water, little capacity to serve more with water, no sewage treatment plant, needs new well and new pipes.

SIGNIFICANT CONCERNS

Earlimart PUD 661 849 2663

person interviewed: Rachel Garcia
date: Jan. 31, 2008
total population: 8000
# of PUD water connections: 1600
can you serve any more? at capacity now
annexing 2 parcels 300 houses
each lot will pay $8600 to hook up to water and sewer (This will pay for infrastructure
wells: 3 wells, Well # 4 has choliform bacteria, not using this well. Will drill 5th well.
infrastructure: pipes
tank only have pressure tank, no storage tank
meters: just started using meters
peak usage: low water pressure on west side in summer
grants: none
sewers: at 100% capacity for sewage
485 sewer connections
comments: Impoverished farm town can not serve more water connections, at 100% sewage treatment, one well out of 4 has coliform bacteria, low water pressure on west side of town during peak demand.

SIGNIFICANT CONCERNS

GOSHEN CSD sewers only 651-0323

water comes from CALWATER 624-165 in Visalia

person interviewed: Maria Garcia

date: Jan 31, 2008

total population: 2394 as of 2002

wastewater treatment: not a lot of capacity

planning to expand - new development of 300 homes will treat its own wastewater

Sewer connections: 947 commercial and industrial

760 residential

grants: applying for grant money from state for wastewater treatment enlargement

peak usage: odd and even days for watering landscaping all year

CALWATER supplies Goshen with water, cross connected to entire city of Visalia. As long as Visalia has water, Goshen has water

person interviewed: Jerry Neal 624-1650 operations center

date Jan. 31, 2008

water connections in Goshen entire city from Rd 64 east to Church Street

peak usage no problem. We have over 80 wells. Drill 2 new wells a year, each costing $1 million

potential growth no problem

water quality nitrates We filter it out from well in Patterson tract. MCL - keep lowering levels of contaminants allowable

DBCPs 3 or 4 wells have contamination. We drill wells 320-350' deep, seal upper and middle levels to avoid contamination

meters: charge 50¢ per 100 cubic feet

Comments: Goshen has adequate clean water but almost at capacity for wastewater treatment.

ADEQUATE WITH CONCERNS

Ivanhoe PUD 798-0512

person interviewed: Carol Fina
date: Jan. 31, 2008
total population 5000-6000 people within PUD
# of water connections to PUD 1112
can you serve any more homes: only 15 undeveloped lots, will not expand PUD
wells: 7 wells, 1 contaminated with nitrates

infrastructure: pipes 50 years old, breaking

meters: since 1989. charge 22¢ a cubic foot

peak usage: when PSI falls below 35, switch on backup well

water quality: good

grants: applying for grant for new well from State Reserve Fu-

sewers: when it rains a lot, ponds start to fill up. To keep them from running over, we switch on the clarjester which digests sludge and makes it dry. Irrigate with remaining water and spread it on pasture.

comments: Can serve projected growth if grant is received to drill new well and sewage ponds are expanded or clarjester is run more often. Also pipes are old and breaking. Money will need to be found to repair water pipes.
ADEQUATE WITH CONCERNS

Lemon Cove PUD 597-2504

person interviewed: Bill Pensar, board member
date: January 21, 2008
total population: less than 200
# of connections 41
can you serve more: 40
wells: 1 well searching for clean groundwater
3 wells with too much nitrate contamination, dormant or abandoned
infrastructure: new since 1992

meters: yes. read quarterly. Charge by cubic foot
Standby charge

peak usage: lots of water

water quality: nitrates above drinking water standards

grants: apply for many grants

sewers: at 3/4 capacity, 60 connections

comments: Almost all the land surrounding this small town is in the Williamson Act and can't easily be developed. Population has fallen since 2000 census. Nitrates above drinking water standards. Wastewater treatment at 3/4 capacity. This is a modest town.

SIGNIFICANT CONCERNS

London CSD 591-5142 Mon-Fri 10-4

person interviewed: Carolyn Thomas

date: Jan 31, 2008

total population: 2100

# of water connections 448

wells 3, good

infrastructure: pipes need to be replaced - need new well

meters:

peak usage: Water pressure goes down. We encourage people not to waste water.

water quality: good

grants: applying for grant to drill well

Comments: This small modest town has infrastructure problem including pipes that need to be replaced, a new well to be drilled and low water pressure at peak demand.

SIGNIFICANT CONCERNS

OROSI PUD 528-4262 M-F 8-12 1-10

person interviewed: Elaine Vidana, office manager

date: Jan. 31, 2008

total population: 7318 in 2000 census

how many water connections: 1700

can you serve any more homes:

wells: 4 active, drilling 5th well

abandoned wells on north side of town due to nitrate contamination

infrastructure pipes - replacing water mains, have the money

water tank - need another 750,000 gallon tank, have mo[ney]

meters: had them 4-5 years, pay 76¢ per thousand gallon

peak usage: water pressure low

sewers: replacing sewer lines, 40 years old, seeping water, have the money

moratorium on sewer connections

grants: applying for grant now via Dennis Keller

Comments: This town has a moratorium on sewer connections. This town has raised money to replace pipes, water tank and sewer lines which were leaking, applying grant for new wastewater treatment plant.

ADEQUATE WITH CONCERNS

Pixley PUD   757-3878   11

person interviewed: Randy Masters, manager 799-3196

Jan. 31, 2008

total population: 2584

# of water connections: 800

can you serve any more homes:

wells: 1 good well

3 wells, out of compliance with arsenic standa[rd]

infrastructure: pipes — distribution system old, small lines need to be upgraded

tank — elevated tank

meters: half of homes are metered flat rate $20, charged so much per gallon over 30,000 gallons a month

peak usage: haven't gotten to capacity

water quality arsenic problems

grants: applying for grants from USDA, state, and federal

engineer is Michael Taylor, Provost and Richard

Sewers: at capacity

got some grant money for bigger wastewater treatment plant, borrowed rest of money from USDA

Comments: This town has serious arsenic contamination problems and at capacity for wastewater treatment

SIGNIFICANT CONCERNS

Plainview MWC   special district
a group of individuals

person interviewed: Lindsay utilities district which sends out water bills 562-5982

date: Feb. 25, 2008

total population:

total water hook ups: 168

can you serve any more homes:

wells:

infrastructure: new pipes

meters: yes

peak usage

water quality: their domestic wells had nitrates
Now they get water from Lindsay

Sewers: septic only

Comments: This is a very small community with nitrate contamination problems.

SIGNIFICANT CONCERNS

Poplar CSD 784-7009

person interviewed: Mike Clark, board president, cell 559-359-9918
date: Jan 31, 2008 and Feb 22, 2008
total population: 2500 in 2001
water connections: 596
wells: 3 wells, (2 good, 1 has nitrates)
at 80' deep there is standing water
real good water supply
infrastructure: pipes - 1972
tank - 1972
pump - new

meters: yes. Don't read them. Flat rate

peak usage: unlimited water

water quality: good

grants: none

sewers: 1994
640 hook ups
71% of capacity

major expansion planned
2000 homes to be built
They will pay to be connected to water and sewage and they will pay for expansion of wastewater treatment plant

Comments: This small town has some nitrate contamination proble[ms]
raring to build. No growth for 37 years. All land around community is zoned AE20. Can't wait to develop.

ADEQUATE

Richgrove CSD 1-661-725-5632
Mon, Wed, Fri 8-12
Friday only 1-5

person interviewed: Maria Pimentel

date: Feb. 22, 2008

total population: 2723

# of water connections: 532

can you serve more: NO

wells: 2

infrastructure:

meters: working on getting meters

peak usage: at capacity

water quality:

grants: applying for grant from state for new well

sewers: at capacity

Comments: This town cannot serve any more water connections. During peak demand they reach capacity. Waste water treatment plant is at capacity. Applying for grant to drill new well.

SIGNIFICANT CONCERNS

Springville PUD

person interviewed: Nancy Bruce, board member, 539-3351
date: Jan. 22, 2008 and March 23, 2008
total population: 1500
# of water connections: 389
can you serve more: Don't know
wells: None. SPUD uses Tule River water.
infrastructure: Some very old water pipes laid in 1920's
Don't know where the pipes are. Mapping them now. Can't afford to replace them.
meters: Yes.
peak usage: During peak demand, SPUD reaches the limits of its water rights to the Tule River.
water quality: good
grants: Applying for grants to replace old water pipes and improve wastewater treatment
sewers: Sewer moratorium for last 28 years.
No place to grow wastewater treatment plant.
(375 sewer connections) Want to buy $500,000 ultraviolet light to zap all organisms in wastewater except cryptosporidium. SPUD's permit allows them to treat 100,000 gallons of effluent a day.
Comments: 50% of all private wells in Springville are contaminated with radon or nitrates.
This community has severe constraints on growth.
SIGNIFICANT CONCERNS

Strathmore PUD 559 568 1613

person interviewed: Adele Sanchez

date: Feb. 6, 2008

total population:

# of water connections: 487 to 700 dwellings (some share)

can you hook up more homes: yes. Just approved 41 homes + new school

wells: 5 wells, all high in nitrates
blending water with Friant-Kern canal water. Using only one well.
If water from canal is lost, they will install nitration filtration system.

infrastructure: recently replaced 2/3 of water lines

meters: yes. 4.64 per 1000 gallons

peak usage: at capacity. Have to shut down. Ask customers to conserve.

water quality – Nitrates above standards until blending

grants: applied for several grants for nitrate filtration system
problem with disposing of heavily salt laden water

Sewers: old treatment facility
sewer lines need to be replaced
copper in wastewater – hazardous waste
clients pay progressive fee

LSID Lindsay Strathmore Irrigation District supplies water to part of Strathmore PUD.

Comments: All five wells contaminated with nitrates
Blending well water with FRIANT-KERN canal water.
During peak demand at capacity. Wastewater treatment plant old.
Sewer lines need to be replaced. SIGNIFICANT CONCERNS

person interviewed: Karen Kerwood
date: Jan. 31, 2008
total population: 3200
water connections: domestic treated in town 714
surface water untreated 500

wells: no. using water from Friant-Kern canal

infrastructure: established 1915, aging facilities constantly updated

meters: 900 irrigation meters for lawns and agriculture

peak usage: when near capacity, stop taking water orders from farmers

water quality: not an issue for irrigation

grants: applying for state grant for expansion of treated water

sewers: Terra Bella sewer maintenance district is maintained by Tulare County

Comments: Groundwater around Terra Bella is contaminated with nitrates. This small irrigation district does NOT receive its water supply from groundwater but from Friant-Kern canal. It is vulnerable to 30% l[illegible]s of water due to restoration of San Joaquin River. During peak demand it reaches capacity.
SIGNIFICANT CONCERNS

Three Rivers CSD

person interviewed: Randy Pares

date: Jan 21, 2008

total population: 2700

# of CSD water connections: 75 in Alta Acres subdivision

can you serve more homes: only 5 undeveloped lots

wells: 1 well

1 river well recently rebuilt for use during peak demand

infrastructure: all pipes need to be replaced. All homes assessed.

meters: yes. Read bimonthly. Standard rate. For every gallon over they pay tiered rates

peak usage: exceeded maximum capacity until River well rebuilt in 2007

water quality: good

grants: got a loan for $2 million for rehabilitation of water pipes. grant for $.5 million

sewers: septic only

comments: There are 35 small private, volunteer run water systems in Three Rivers. Most serve a very small number of homeowners, one motel, one school, one RV park. The great majority of private wells serve one home. These homes are on 1-5 acres or more. There is no capacity for the growth projected by the General Plan Update. Some wells are contaminated with radon, nitrates, fecal coliform, or arsenic. There is not reliable groundwater.

SIGNIFICANT CONCERNS.

Tipton CSD 752-4182
Mon-Thurs 8-3

person interviewed: Johnny Price, maintenance man, cell- 280-4217

date: Feb. 25, 2008

total population: 1792 in year 2000

# of water connections: 594 commercial and residential

wells: 2 wells, third well shut down due to contamination by oil and nitrates

water quality good

can you serve more? approximately 20-40 more connections

grants: no

meters: don't read meters, flat rate

peak usage: okay, as long as both wells are working

sewers: not maxed out yet, 3/4 capacity

infrastructure: need to drill another well

Comments: This small town could grow as long as both wells work or don't become contaminated. Sewer capacity is at 3/4 capacity. They need to drill another well

ADEQUATE WITH CONCERNS

TRAVER - Tito Balling 559-935-2300

person interviewed: employee of Tito Balling
date: Feb 8, 2008
total population:
water connections: 180
can you serve more: yes
wells: 3, all good. Third well was needed for water pressure problems at school

infrastructure: pipes old, need to be replaced

meters: not metered

peak usage:

grants: applying for grant for meters

sewer: operated by Tulare County "can't serve" order

comments: many people have their own wells.
impoverished community
The old water pipes need to be replaced.
The water system is under "can't serve" order

SIGNIFICANT CONCERNS

Woodville PUD 686-9649

person interviewed: Ralph Guitierez 901-6097 manager

date: Jan 31, 2008, Feb 22, 2008

total population: 1678 according to 2000 census

water connections: 400

can you serve more: 5-10 houses

wells: 2 good wells, 1 well not used because of sand

sometimes only draw 5 gallons a minute

~~sometimes water is salty~~

infrastructure: would need another well if there were a new subdivision

meters: yes. read once a month. Minimum monthly charge plus 50¢ per 100 cubic feet

average water + sewer fee is $50 a month

peak usage: no problem

water quality: good

grants: applying for state money for new sludge beds

sewers: connection fee $7400 for water & sewer

Comments: This small town would need another good well if it were to expand water connections. PUD is applying for state grant money for new sludge beds. Old wells sometimes suck air, draw only 5 gallons a minute or draw up salty water. Only capacity for 5-10 more water connections

SIGNIFICANT CONCERNS

Water Resources Element

There is no factual basis for the County's capacity to accommodate the General Plan Update's population growth projections.

In the Water Resources element of the DEIR on page 4-106, Table 4-4 General Plan Population Estimates by Unincorporated Community there are 21 communities listed with their domestic water service provider, existing population, and projected range of General Plan Population Estimates. Take Three Rivers, for example, the existing population estimate of 2300 people is from 2003 which is five years out of date. The projected population increase for 2030 is from 920 to 1397 people. The domestic water service provider is listed as CSD and mutual water companies. According to Randy Pares, general manager of CSD on January 21, 2008, CSD controls 75 water connections in Alta Acres where there are only 5 unbuilt lots. The South Kaweah Mutual Water Company, according to Lew Nelson, manager, on January 25, 2008, services 220 water connections in Cherokee Oaks subdivision. There are only 20 unbuilt lots. There are no plans to extend the system. Deer Meadows Mutual Water Company in Cherokee Oaks subdivision, according to Ken Elias, board member on January 23, 2008, has 41 connections and arsenic in its water. There are a total of 35 small, privately owned, volunteer run water systems/companies in Three Rivers. Except for the three largest water companies, there are no water meters. The large majority charge flat rates. Many water companies serve one hotel, or one RV park, or the elementary school, or four or five homes. Most of the approximately

1900 water wells in Three Rivers are private wells serving one household. The water companies have various problems; old water pipes, only one well, arsenic above Federal drinking water standards, reach capacity at times of peak water use, have insufficient water pressure for fire flow, have a moratorium on developing new lots, need an expensive new water storage tank ($35,000), and have applied for grants and loans.

According to Tom Marshall, a 15 year member of the Sequoia Foothills Chamber of Commerce, on January 23, 2008, there are 321 motel rooms, bed and breakfast rooms, and RV spaces. During the summer and especially during the holiday weekends of Memorial Day, 4th of July, and Labor Day, they are fully occupied, reaching peak water use. The consultant who gathered data on these service providers did not ask about peak demand on water and how close that came to capacity or the cost of expenditures to drill another well or upgrade infrastructure. Most of the people who live in Three Rivers are outside CSD and all the other mutual water companies. None of the private wells have been evaluated. There has been no study of water quality or quantity in Three Rivers. Drilling a well here is like playing roulette. Some don't produce enough water. Others have unacceptable levels of radon or arsenic. Wells are being drilled deeper of necessity. The only way 900-1400 more people could be accommodated in Three Rivers by 2030 is by a new large development, not on 5 acre ranchettes.

Again, according to Ken Elias, board member of Deer Meadow Estates Water Company in Cherokee Oaks, on January 21, 2008, there is one well that produces 60 gallons a minute and a second inactive well that produces only 3-4 gallons a minute. The water company is considering reactivating this well. There are 27 connections to this water system. The water table for well #1 dropped 30 feet during an earthquake in the 1990's. There is enough water during peak demand. There are expensive repairs upcoming, a sediment ram.

According to Ray Murray, manager of the Sierra King Water Company in Three Rivers on Mineral King Road on January 22, 2008, the water company is a homeowner's association which just deals with water supply. There are 41 connections. Recently they drilled a well which had an unacceptable level of radon. They drilled a third well which has good water but is not on line yet. There is a moratorium on building on the remaining 41 lots. They are not 100% metered. Funding is a real problem. The water system has problems with pressure, not enough for firefighting flow. Because of a pinhole in the storage tank, they need to buy a new one. It will cost $35,000.

And yet, in Table 4-5, Summary of Domestic Water Supply, Conditions for Unincorporated Communities in Tulare County, Three Rivers is listed as having adequate facilities to serve projected General Plan Population Growth with Concerns, meaning Three Rivers either has the capacity to serve projected growth or is likely to solve capacity issues within the time horizon of the General Plan Update. How was this conclusion reached?

The people of Three Rivers believe their road to economic prosperity is attracting more tourism. Businesses in Three Rivers fail at an alarming rate because outsiders visit almost entirely between Memorial Day weekend and Labor Day weekend.

Springville is a more egregious example of "blue sky" analysis. Springville (SPUD) is listed as the domestic service provider in Table 4-4. It gets its water supply from Tule River water rights, not groundwater. According to Nancy Bruce, board member of SPUD on January 22, 2008 during peak demand (four consecutive days at 107° F or above), SPUD reaches its capacity of water rights. There has been a moratorium on sewer connections in SPUD for 28 years. SPUD is in non compliance for effluent treatment. SPUD is unable to expand its wastewater treatment facility due to a lack of available land. And yet, Table 4-5 lists Springville as "More than Adequate", meaning "facility appears capable of serving growth beyond buildout of the General Plan." That's unwarranted optimism and a prediction not based on fact.

Lemon Cove, a community of allegedly 251 people in 2003, has shrunk to less than 200 people on January 21, 2008. The County projects Lemon Cove to grow to 377 to 433 people despite the the fact that Lemon Cove is landlocked by citrus groves in the Williamson Act; its wastewater treatment plant is at 3/4 capacity; it is bisected by Highway 198; and it is assaulted by the noise, dust, vibration, and fumes of heavy diesel trucks hauling crushed granite from the Lemon Cove Granite Pit through town. It is not your ideal town. The Lemon Cove SD has 41 water connections and 60 sewer connections, according to Bill Pensar, board member of Lemon Cove SD, on January 23, 2008. The County does say Lemon Cove has "Significant Concerns", meaning "the provider lacks capacity to serve projected growth and is likely to experience significant difficulties in expanding the system to meet projected demand." They got that right.

I quote from the DEIR, page 4-129

" Impact Analysis

Implementation of the General Plan Update would result in an increased demand on groundwater supplies for urban and rural uses within the unincorporated areas of the County. Due to the lack of comprehensive information regarding the County's groundwater resources, it is uncertain if groundwater supplies would be sufficient to meet the future demand of rural private domestic, small municipal and agricultural wells. This uncertainty combined with the current regulatory approach could result in insufficient groundwater supplies in unincorporated areas of the County. Growth associated with the General Plan Update would require additional groundwater pumping for designated urban development areas of the County where surface water is not available.

In some of the unincorporated urban development areas, there are concerns that adequate water supplies cannot be achieved through sustainable groundwater management, that is, without creating declining groundwater levels, and adversely affecting existing wells. Such concerns are heightened by the fact that most of these areas are presently dependent upon groundwater supplies."

The above impact analysis was based on inadequate, inaccurate data. So, the true impact is most likely worse, creating greater impact on groundwater and existing wells.

Only one small CSD, PUD, ID or JPA in each community was consulted in 2003 in order to analyze each community's ability to meet projected growth. In the case of Three Rivers, the Three Rivers CSD serves 75 water connections. There are approximately 1900 wells in Three Rivers, predominantly one well serving one household. This inadequate analysis was based on less than 5% of the people served by wells in Three Rivers. For a more accurate analysis see Enclosure 10.

In the Background Report under Public Services and Utilities on page 7-35 under "Can't Serve" Special Districts, there are 15 communities listed as under temporary cease and desist orders for water or sewer hook ups as of April 7, 2007.

According to the Background Report, pages 7-41 through 7-43, some of the unincorporated urban areas within Tulare County lack sanitary sewer infrastructure and are served by individual or community septic systems. These are Allensworth, Alpaugh, Alpine Village - Sequoia Crest, Ducor, East Tulare Villa, Lindcove, Monson, Plainview, Ponderosa, Three Rivers, Waukena, West Goshen and others. Other unincorporated communities within Tulare County have sanitary infrastructure in place, however, in many cases the facilities are several years old and are in need of rehabilitation and/or reconstruction to meet current standards. According to Table 7-2, Summary of Sanitary Service Providers on page 7-43, eleven communities have primary or advanced primary treatment level. The other 15 have secondary treatment level of wastewater. None treat wastewater to tertiary level.

This DEIR did not disclose the extent of groundwater contamination in Tulare County. This draft EIR ignores the extent of water problems in unincorporated communities and assumes a solution to the problem of water supply will be reached in order to fulfill growth projections within the time horizon of the General Plan. Decision makers must, under the law, be presented with sufficient facts to evaluate the pros and cons of supplying the amount of water that the projected growth will need.

The DEIR does not disclose the cost of remediation or identify any source of funding for remediation measures for many of the water companies needing new wells, pipes, storage tanks or water treatment facilities to eliminate contamination by nitrates, arsenic, oil, DBCP, perchlorate, radon. Almost all the water companies are applying for grants and/or loans. There is not enough state or federal money to meet all the needs. It is extremely expensive to remove some

CLIMATE CHANGE IMPACTS ON THE CENTRAL VALLEY

These facts were taken from **Our Changing Climate: Assessing the Risks to California**
California General Commission. 2006 Biennial Report. California Climate Change Center

We recommend that you download your own copy of this excellent publication at:
www.climatechange.ca.gov/biennial_reports/2006report/index.html

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How much warming California will experience depends on economic and human population growth, how fast humans shift away from fossil fuel-intensive industries and towards clean and resource-efficient technologies, and which climate model is used to project changes.

The *Our Changing Climate* publication defines 3 possible warming scenarios for California:

- **Lower warming range:** projected temperature rises between 3 and 5.5°F.
- **Medium warming range:** projected temperature rises between 5.5 and 8°F.
- **Higher warming range:** projected temperature rises between 8 and 10.5°F

Public Health

- **Poor air quality made worse:** If temperatures rise to the medium warming range, there will be 75 to 85% more days with weather conducive to ozone formation in the San Joaquin Valley, relative to today's conditions. This is more than twice the increase expected if temperature rises are kept in the lower warming range.

- **More severe heat:** By 2100, if temperatures rise to the higher warming range, there could be up to 100 more days per year with temperatures above 95°F in Sacramento, compared to a current average of 18 such days. This is almost twice the increase projected if temperatures remain within or below the lower warming range. By mid century, extreme heat events in Sacramento could cause two to three times more heat-related deaths than occur today.

Water Resources

- **Decreasing Sierra Nevada snow pack:** If heat-trapping emissions continue unabated, Sierra Nevada spring snowpack will be reduced by as much as 70 to 90%. Decreasing snowmelt and spring stream flows coupled with increasing demand for water could lead to increasing water shortages. By the end of the century, if temperatures rise to the medium warming range and precipitation decreases, late spring stream flow could decline by up to 30%. Agricultural areas could be hard hit, with California farmers losing as much as 25% of their water supply.

- **Saltwater influx:** An influx of saltwater would degrade California's estuaries, wetlands, and groundwater aquifers. Saltwater intrusion would threaten the quality and reliability of the major state fresh water supply, which is pumped from the southern edge of the Sacramento/San Joaquin River Delta.

- **Reduction in hydropower:** Toward the end of the century annual electricity demand could increase by as much as 20% if temperatures rise into the higher warming range. At the same time, diminished snowmelt flowing through dams will decrease the potential for hydropower production. If temperatures rise to the medium warming range and precipitation decreases by 10 to 20%, hydropower production may be reduced by up to 30%.

enclosure(5)

- **Floods:** Continued sea level rise will further increase the vulnerability of levees, which protect freshwater supplies and islands in the San Francisco Bay Delta as well as fragile marine estuaries and wetlands. In the Central Valley, where urbanization and limited river channel capacity already exacerbate rising flood risks, flood damage and flood control costs could amount to several billion dollars.

Changing Landscapes

- **Increasing wildfire.** If temperatures rise into the medium warming range, the risk of large wildfires in California could increase by as much as 55%, almost twice the increase expected if temperatures stay in the lower warming range. In contrast, a hotter, drier climate could promote up to 90% more northern California fires by the end of the century by drying out and increasing the flammability of forest vegetation.

- **Shifting vegetation.** Continued global warming will intensify pressures on the state's natural ecosystems and biological diversity. For example, in northern California, warmer temperatures are expected to shift dominant forest species from Douglas and White Fir to madrone and oaks. In inland regions, increases in fire frequency are expected to promote expansion of grasslands into current shrub and woodland areas.

Agriculture:

- just the medium temp. > will reduce water available to farmers by 25% as a result of evaporation

Agriculture remains the economic base of the Central Valley, the most productive agricultural region in the country and a critical part of the state's economy and the nation's food supply. Agriculture provides 20% of the jobs in the Central Valley. The unique combination of climate, soils, and water in the Central Valley is a major factor in its agricultural productivity.[1]

- **Decreased fruit and nut production:** Rising temperatures could increase fruit development rates and decrease fruit size. A minimum number of chill hours (hours with temperatures below 45°F) are required for proper bud setting. Chill hours are already diminishing in many areas of the state, and if temperatures rise to the medium warming range, the number of chill hours in the entire Central Valley is expected to approach a critical threshold for some fruit trees including almonds, apples and walnuts.

- **Decreased milk production:** California's $3 billion dairy industry supplies nearly one-fifth of the nation's milk products. High temperatures can stress dairy cows, reducing milk production at temperatures as low as 77°F, and substantially dropping production at temperatures above 90°F. Toward the end of the century, if temperatures rise to the higher warming range, milk production is expected to decrease by up to 20%. This is more than twice the reduction expected if temperatures stay within or below the lower warming range.

- **Expanding ranges of agricultural weeds:** Noxious and invasive weeds currently infest more than 20 million acres of California farmland, costing hundreds of millions of dollars annually in control measures and lost productivity. Continued climate change is expected to cause range expansion in many species while range contractions are less likely in rapidly evolving, established populations. Should range contractions occur, it is likely that new or different weed species will fill the emerging gaps.

- **Increasing threats from pests and pathogens:** Continued climate change is likely to alter the abundance and types of many pests, lengthen pests' breeding season, and increase pathogen growth rates. For example, the pink bollworm, a common pest of cotton crops, and the glassy-winged sharpshooter, which transmits Pierce's disease, are currently problems only in southern parts of the state. If temperatures rise, the range of both would likely expand northward into the Central Valley, which could lead to substantial economic and ecological consequences for the state.

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[1] Great Valley Center. *The State of the Great Central Valley of California: Assessing the Region Via Indicators - The Economy*. 2005.

Modeling Tools to Estimate Climate Change Emissions Impacts of Projects/Plans

Tool	Availability	Scope Local/Regional	Scope Transp/Buildings	Data Input Requirements	Data Output
URBEMIS	• Download • Public domain (free)	• Local project level	• Transportation • Some building (area source) outputs • Construction	• Land use information • Construction, area source, and transportation assumption	• VMT per day (Convert to CO2 and methane) • Mitigation impacts
Clean Air and Climate Protection (CACP) Software	• Download • Available to public agencies (free)	• Local project level	• Buildings • Communities • Governments	• Energy usage • Waste generation and disposal • Transportation usage	• eCO2 (tons per year)
Sustainable Communities Model	• Custom model	• Regional scalable	• Transportation • Master planned communities	• Location and site specific information • Transportation assumptions • On-site energy usage	• eCO2 (tons per year)
I-PLACE'S	• Web based • Small access fee • Full model now available in eight CA counties	• Regional scalable to site level	• Transportation • Buildings • Infrastructure (wastewater, street lights, etc.)	• Parcel level land use data (can work with less data) • Project-level data for alternative comparisons.	• CO2 (any quantity over any time) • Provides for immediate comparison of alternatives
EMFAC	• Download • Public domain (free)	• Statewide • Regional (air basin level)	• Transportation emission factors	• Used with travel demand and other models to calculate CO2 impacts of projects	• CO2 and methane (grams per mile) emission factors
Climate Action Registry reporting On-line Tool (CARROT)	• Web-based • Available to Registry members	• Regional, scalable to entity and facility level	• General • Specific protocol for some sectors	• Uses input such as fuel and electricity use, VMT to estimate emissions of each GHG	• Each GHG and eCO2 (tons per year)

VMT = Vehicle miles traveled.
Criteria pollutants = Nitrogen oxides (NOx), reactive organic gases (ROG), Carbon dioxide (CO) sulfur dioxide (SO2), particulate matter (PM)
eCO2= Carbon dioxide equivalent emissions

Note: This is not meant to be a definitive list of modeling tools to estimate climate change emissions. Other tools may be available.

Enclosure (6)

www.CA – i/g.org/climatececa

Description of Modeling Tools

URBEMIS. The Urban Emissions Model (URBEMIS) is currently being used extensively during the CEQA process by local air districts and consultants to determine criteria pollutant impacts of local projects. URBEMIS uses ITE Trip Generation Rate Manual and the Air Resources Board's (ARB) motor vehicle model (EMFAC) for transportation calculations. Area source outputs include natural gas use, landscaping equipment, and fireplaces. It also estimates construction impacts and impacts of mitigation options. An updated version with CO2 outputs may be available soon. In the interim, CO2 factors (pounds per mile) provided by ARB could be used to convert VMT per day into CO2 per day. Web site: http://www.urbemis.com

Clear Air and Climate Protection (CACP) Software. This tool is available to state and local governments and members of ICLEI, NACAA, NASEO and NARUC to determine greenhouse gas and criteria pollutant emissions from government operation and communities as a whole. The user must input aggregate information about energy (usage), waste (quantity and type generated, disposal method, and methane recovery rate) and transportation (VMT) for community analyses. More detailed, site-specific information is necessary to calculate emissions from governmental operations. CACP uses emission factors from EPA, DOE, and DOT to translate the energy, waste and transportation inputs into greenhouse gas (in carbon dioxide equivalents) and criteria air pollutant emissions. If associated energy, waste and transportation reduction are provided, the model can also calculate emission reductions and money saved from policy alternatives. Web site: http://cacpsoftware.org

Sustainable Communities Model (SCM). This model quantifies total eCO2 emissions allowing communities the ability to optimize planning decisions that result in the greatest environmental benefit for the least cost. SCM has been used by a number of master planned communities, but it could also be used for neighborhoods and smaller developments. Total eCO2 emissions are based on emissions from energy usage, water consumption and transportation. SCM uses published data sets for data input such as ARB's EMFAC for transportation calculation. The model provides a comparison of various scenarios to provide environmental performance, economic performance, and cost benefit analysis.
Web site: http://www.ctg-net.com/energetics/News/News_SCM.html

I-PLACE'S is an internet-accessed land use and transportation model designed specifically for regional and local governments to help understand how their growth and development decisions can contribute to improved sustainability. It estimates CO2, criteria pollutant and energy impacts on a neighborhood or regional level for existing, long-term baseline and alternative land use plans. I-PLACE'S is currently being used in San Diego, San Luis Obispo, and other six-county Sacramento region to assist both the public participation process and technical analyses efforts for regional planning. The data input requirements are extensive and require a fiscal commitment from local government. The benefits include a tool that can provide immediate outputs to compare various alternatives during public meetings, as well as provide access for local development project CEQA analyses. Possible future modifications could include a stand-alone tool that would allow project-level analyses of land uses (buildings) without extensive regional data input requirements. Web site: http://www.energy.ca.gov/places/ ; http://places.energy.ca.gov/places

EMFAC. The Air Resources Board's Emissions Factors (EMFAC) model is used to calculate emission rates from all motor vehicles (passenger cars to heavy-duty trucks) in California. The model includes emission factors for CO2, methane, and criteria pollutants. The emission factors are combined with data on vehicle activity (miles traveled and average speeds) to assess emission impacts. California local governments use EMFAC in concert with their travel demand models to assess impacts of transportation plans. The URBEMIS model described above uses EMFAC to calculate the transportation emission impacts of local projects. Web site: http://www.arb.ca.gov./msel/onroad/onroad.htm

Climate Action Registry Report On-Line Tool (CARROT). The California Climate Action Registry uses the Climate Action Registry On-Line Tool (CARROT) for registry members to report greenhouse gas emissions. It calculates GHG emissions from energy, fuel use, and travel estimates made by the user. While use of the tool is only available to members, the Registry makes its protocols available to the public. The general reporting protocol is available at http://www.claimateregistry.org.docs/PROTOCOLS/GRP%2OV2.1.pdf. Specific reporting protocols are also available for reporting by cement, forestry, and power/utility sectors and are being developed for additional sectors. Website: http://www.cliamteregistry.org/CARROT/.

Appendix A

CLIMATE CHANGE AND THE CALIFORNIA ENVIRONMENTAL QUALITY ACT

Dave Owen, Attorney at Law

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INTRODUCTION

Anthropogenically-induced climate change[1] is probably the largest environmental threat facing California. Already it is impacting the state's environment, and scientists predict that if unchecked, it will cut water supplies, intensify heat waves, accelerate coastal erosion, degrade air quality, increase wildfires, and reduce wildlife habitat-among other impacts.[2] Similarly major environmental effects will occur worldwide.[3] Those impacts threaten major ecological and economic costs,[4] and while climate change will affect almost all people, the burdens for low-income or otherwise vulnerable communities will be particularly heavy.[5] For all of these reasons, climate change is a problem California must address.

This paper describes one legal method for assessing and limiting California's contributions to climate change. The California Environmental Quality Act (CEQA)[6] requires government agencies to identify and, if feasible, mitigate or avoid the significant adverse environmental impacts of projects they propose or approve.[7] As discussed below in more detail, many government-sponsored or government-approved projects add to the greenhouse gas (GHG) emissions that cause climate

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1 This memorandum refers to anthropogenic climate change, which encompasses both warming temperatures and changed storm and precipitation patterns, rather than using the narrower term "global warming." In most popular discussions, however, the terms are used interchangeably and refer to the same phenomenon.

2 CALIFORNIA CLIMATE CHANGE CENTER, OUR CHANGING CLIMATE: ASSESSING THE RISKS TO CALIFORNIA 2 (2006) (hereinafter "OUR CHANGING CLIMATE"); CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY, CLIMATE ACTION TEAM REPORT TO GOVERNOR SCHWARZENEGGER AND THE LEGISLATURE (2006).

3 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS SUMMARY FOR POLICYMAKERS 12 (2007) (hereinafter IPCC, THE PHYSICAL SCIENCE BASIS) (describing some of the expected changes); INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: CLIMATE CHANGE IMPACTS, ADAPTATION AND VULNERABILITY (2007) (hereinafter IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY); *Mass. v. EPA*, 127 S. Ct. 1438, 1455 (2007) ("The harms associated with climate change are serious and well recognized.").

4 IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2; *see* Cal. Health and Safety Code § 38501(a), (b); Anthony C. Fisher et al., *The Most Expensive Thing We Can Do Is Nothing: An Open Letter From California Economists*, August, 2006 ("California's economy is vulnerable to climate change impacts, including changes in water availability, agricultural productivity, electricity demand, health stresses, environmental hazards, and sea level.").

5 REDEFINING PROGRESS, CLIMATE CHANGE IN CALIFORNIA: HEALTH, ECONOMIC AND EQUITY IMPACTS (2006); IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2, at 19 (observing that factors like poverty can limit adaptive capacity).

6 Cal. Public Resources Code §§ 21000-21177.

7 *See* Cal. Public Resources Code § 21002. CEQA applies not only to government-sponsored projects, but also to private projects that require discretionary approvals from government agencies. *Friends of Mammoth v. Board of Supervisors*, 8 Cal.3d 247 (1972).

change, and climate change already is causing significant adverse environmental impacts, and will continue to do so. Feasible methods exist, however, for fully mitigating or avoiding those agencies' contributions to climate change. CEQA therefore requires state or local agencies to identify their projects' potential contributions to climate change, and to adopt feasible measures to mitigate or avoid such contributions.

BACKGROUND

I. Climate Change Overview

Carbon dioxide (CO_2) creates what scientists call a "greenhouse effect."[8] While it lets light energy into the earth's atmosphere, it reduces the amount of reflected heat released.[9] Other gases create similar effects, and some, like methane, have greenhouse properties substantially more intense than carbon dioxide.[10] Consequently, scientists long ago predicted that if atmospheric levels of carbon dioxide and other greenhouse gases (GHGs) rose above natural background levels, the earth's climate would become unnaturally warm.

Those predictions have proven accurate. Primarily because of fossil fuel combustion, atmospheric carbon dioxide levels have risen dramatically in recent decades, and are continuing to rise.[11] Global average temperatures also have been increasing for several decades, and while warming earlier in the twentieth century was probably due to non-anthropogenic forcing, human activity all but certainly caused the more recent rise.[12] There is no real scientific doubt that anthropogenic emissions will warm our climate even more if they continue unabated into the future.[13] The projected changes are substantial, with the Intergovernmental Panel on Climate Change predicting worldwide average temperature increases ranging from 1.1 to 6.4 degrees Fahrenheit - with the lower figure assuming efforts to minimize GHG emissions-by the end of the 21st century.[14]

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8 *See* James E. Hansen, et al., *Climate Impact of Increasing Atmospheric Carbon Dioxide*, 213 SCIENCE 957-66 (1981).

9 *See* PEW CENTER FOR GLOBAL CLIMATE CHANGE, THE CAUSES OF GLOBAL CLIMATE CHANGE (2006).

10 *See* THE CALIFORNIA CLIMATE CHANGE CENTER AT UC BERKELEY, MANAGING GREENHOUSE GAS EMISSIONS IN CALIFORNIA I-7 (2006) (hereinafter "MANAGING GREENHOUSE GAS EMISSIONS") (describing the impacts of other GHGs).

11 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 2 ("Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed preindustrial values...").

12 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3 (explaining the causes of climate change); PEW CENTER FOR GLOBAL CLIMATE CHANGE, *supra* note 9, at 1, 2-5 ("During the twentieth century, the earth's surface warmed by about 1.4°F.... Recent decades have seen record-high average global surface temperatures."); *Mass. v. EPA*, 127 S. Ct. 1438, 1446 (2007) ("Respected scientists believe the two trends are related.").

13 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3; Naomi Oreskes, *Beyond the Ivory Tower: The Scientific Consensus on Climate Change*, 306 SCIENCE 1686 (2004) ("Politicians, economists, journalists, and others may have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect."); DAN CAYAN ET AL. (CALIFORNIA CLIMATE CHANGE CENTER), CLIMATE SCENARIOS FOR CALIFORNIA 3 (2006) ("the winter and spring warming that has occurred in the California region over the last few decades is very unlikely to have been caused only be natural climate variations").

14 IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 11.

Temperature increases of that magnitude will cause many major environmental changes, most of them undesirable.[15] Sea levels will continue to rise, permanently flooding low-lying coastal areas and drastically increasing coastal regions' vulnerability to Hurricane Katrina-like storms.[16] Extreme weather events, including droughts and floods, will almost certainly occur more frequently.[17] In combination with the loss of glaciers and summer snowpacks in mountain regions, those droughts will increase water shortages, disrupting both natural systems and human economies.[18] Rising temperatures will shift climate zones to higher latitudes or farther uphill, extinguishing species that are unable to migrate, while facilitating the movement of others-crop pests and disease vectors, for example-that most people would prefer not to face.[19] Rising temperatures also will "very likely"[20] increase the frequency of extreme heat events.[21] Not all of the changes will be negative, but in general, a combination of changing environmental norms and increased variability will have substantial adverse impacts.[22]

Because changes already are occurring, total prevention of anthropogenic climate change no longer is possible.[23] Climate change and the resulting negative impacts are not all-or-nothing phenomena, however; they can occur to greater or lesser degrees, and the damage therefore still may be limited.[24] Taking steps to limit GHG emissions, thus minimizing climate change and its secondary effects, therefore is extremely important, and incremental solutions that slow or reduce climate change offer far greater environmental benefits than no solutions at all.[25]

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15 *See* IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2.

16 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 11 (projecting sea level rises. The IPCC's projections do not include the potential effects of changing ice flow in Greenland or Antarctica); IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2, at 9.

17 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 12 ("It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent.... It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense.... There is less confidence in projections of a global decrease in numbers of tropical cyclones.") (emphasis in original).

18 IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2, at 7-8.

19 IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2, at 8 ("Approximately 20-30% of animal and plant species assessed so far are likely to be at increased risk of extinction if increases in global temperatures exceed 1.5 to 2.5°C."), 9.

20 The IPCC assigns precise numeric values to terms like "very likely;" a "very likely" event is an event that in the judgment of the IPCC authors has at least a 90% probability of occurrence. IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 4 n.6.

21 *See id.* at 12.

22 *See* IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2 (describing both positive and negative impacts; the set of negative impacts is much larger).

23 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 4-9; AMY LYND LUERS AND SUSANNE C. MOSER, PREPARING FOR THE IMPACTS OF CLIMATE CHANGE IN CALIFORNIA: OPPORTUNITIES AND CONSTRAINTS FOR ADAPTATION 3 (2006) ("climate change is demonstrably underway"); *id.* at 5 (table summarizing observed trends), 6; CLIMATE SCENARIOS FOR CALIFORNIA, *supra* note 13, at 1-2 (describing observed trends).

24 *See* CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY, *supra* note 2, at 38 (table showing degrees of impact).

25 *See generally Mass. v. EPA*, 127 S. Ct. 1438, 1457 (2007) (explaining the significance of incremental steps: "Agencies □ do not generally resolve massive problems in one fell regulatory swoop. They instead whittle away at them over time") (internal citation omitted).

II. Climate Change and California

While it derives from the aggregate effects of many local sources, climate change is a global problem. Unlike many localized pollution problems, the location of greenhouse gas emissions matters little. A ton of CO_2 emitted in California is no more or less harmful to California than a ton of CO_2 emitted in Shanghai.[26] The secondary environmental effects are similarly global; while some locations will feel climate change's impacts more than others, few areas are likely to be unaffected.[27] Because the sources of climate change are dispersed throughout the world - no one country contributes a majority share of global GHG emissions - comprehensive solutions will likely require international cooperation.[28] Nevertheless, some areas in particular will contribute substantially to climate change, in some areas the effects will be especially pronounced, and some areas can achieve multiple benefits from climate change prevention. California fits within each of those categories. It bears a large share of responsibility for the significant environmental impacts of climate change, but it is capable of taking substantial steps to help resolve the problem, and will benefit in multiple ways from doing so.

A. California's Contributions to Climate Change

California is a major contributor to global climate change. If it were an independent nation, California would rank (depending upon the metric used) as the tenth- to sixteenth-highest GHG-emitting nation in the world.[29] Indonesia, with a population of nearly 250 million people (California has under 40,000,000),[30] emits similar GHG amounts, and California's emissions are on a par with those of France.[31] California's emissions exceed-by a wide margin-those of any other state except Texas.[32] And California's emissions have been growing. "From 1990 to 2004," according to the California Energy Commission, "total gross GHG emissions rose 14.3%."[33]

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26 *See* CALIFORNIA ENERGY COMMISSION, INVENTORY OF CALIFORNIA GREENHOUSE GAS EMISSIONS AND SINKS iii (2006) (hereinafter "INVENTORY") ("GHGs affect the entire planet, not just the location where they are emitted") (this report is labeled "draft staff report," but it represents the most current inventory, and this paper therefore relies upon it); IPCC, CLIMATE CHANGE 2001: THE PHYSICAL SCIENCE BASIS § 6.1.2, available at *http://www.grida.no/climate/ipcc_tar/wg1/215.htm* (explaining several of the primary GHGs, including carbon dioxide and methane, are "well-mixed gases," meaning that their long lifespan ensures homogenous mixing throughout the atmosphere).

27 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 12; IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2 (describing worldwide and regional impacts).

28 *See* INVENTORY, *supra* note 26, at 20 (2006) (showing worldwide emissions).

29 The differences in emissions among the 10th through 19th-ranked nations are slight, and different reports rank California differently. Compare *id.* at i, 20 (ranking California sixteenth; this report, while publicly available, is labeled a "draft staff report") with MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at I-6 ("Only nine nations have greater total emissions than the state."). The CEC's report's ranking of California's is also affected by its treatment of Texas, which emits more GHGs than California, as a nation. *See* INVENTORY, *supra* note 26, at 20.

30 *See quickfacts.census.gov/qfd/states/06000.html.*

31 INVENTORY, *supra* note 26, at 20.

32 *Id.* at i, 14.

33 *Id.* at 8 ("California's GHG emissions are large and growing… they are expected to continue to increase in the future under 'business-as-usual' unless California implements programs to reduce emissions").

Those emissions derive from a variety of sources. Transportation produces approximately 41% of California's total GHG emissions, with gasoline engines contributing the lion's share.[34] Electricity generation also contributes heavily, and out-of-state power, which more commonly derives from coal, disproportionately produces carbon dioxide emissions.[35] Industrial operations also contribute a large share, as do agriculture and forestry practices.[36] Fossil fuel combustion creates most of California's GHG emissions, but agricultural and landfill methane emissions and industrial releases of nitrous oxide and "high global warming potential" gases also add to the total output.[37] Some agricultural activities and natural processes partly compensate for those emissions by removing GHGs from the atmosphere, but in the aggregate California's contributions far outweigh its sinks.[38]

B. Climate Change's Effects Upon California

As a large and growing number of state-sponsored studies have concluded, California also will be harmed substantially by climate change. Those harms are not unique; other areas will face similar threats, and in some places-particularly low-lying nations, regions already more vulnerable to drought or flooding, or poorer and less stable countries where adaptation will likely prove more difficult - the consequences will be even more severe.[39] The difficulties facing California thus exemplify the worldwide threats posed by climate change, and are by no means outlying worst-case scenarios. But even if California alone were threatened, the likely adverse impacts still would be significant, and California's self-interest alone ought to prompt a vigorous response.

Temperatures already are rising, and the state is likely to experience a significant additional rise in average temperatures, particularly in its inland areas.[40] Those increases threaten a long list of adverse consequences.[41] Air quality, which already is poor in much of California, will get worse.[42] Some precipitation that now falls as snow will in the future be rain, increasing winter flooding and reducing snowpacks and water supplies in summer, when California needs water

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34 *Id.* at ii, 9-10; see MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at I-7, I-10.

35 INVENTORY, *supra* note 26 at ii-iii, 10, 11-12. INVENTORY, *supra* note 26 at ii-iii, 10, 11-12.

36 *Id.* at ii, 10-11; *see* MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at I-7.

37 INVENTORY, *supra* note 26, at 6. The emitted amounts of these other GHGs are much smaller than the amount of CO_2 emitted, but these gases have far more powerful heat-trapping effects. *See* MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at I-7 (describing the greenhouse potential of sulfur hexafluoride).

38 *See* MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at I-10. A "sink" is a process, like forest growth, that removes carbon dioxide from the atmosphere.

39 *See* IPCC, IMPACTS, ADAPTATION, AND VULNERABILITY, *supra* note 2.

40 OUR CHANGING CLIMATE, *supra* note 2, at 2 ("The latest projections, based on state-of-the-art climate models, indicate that if global heat-trapping emissions proceed at a medium to high rate, temperatures in California are expected to rise 4.7 to 10.5 degrees Fahrenheit by the end of the century.").

41 *Id.* ("These temperature increases would have widespread consequences including substantial loss of snowpack, increased risk of large wildfires, and reductions in the quality and quantity of certain agricultural products."); *see* Katherine Hayhoe et al., *Emissions Pathways, Climate Change, and Impacts on California*, 101 PNAS 12422, 12425-26 (2004); Cal. Health & Safety Code § 38501(a).

42 OUR CHANGING CLIMATE, *supra* note 2, at 5. The report states:

> High temperatures are expected to increase the frequency, duration, and intensity of conditions conducive to air pollution formation. For example, if temperatures rise to the medium warming range, there will be a 75 to 85 percent more days with weather conducive to ozone formation in Los Angeles and the San Joaquin Valley, relative to today's conditions.

most badly.[43] Pests and pathogens will migrate to new regions, damaging the state's agricultural economy and threatening human health.[44] Forest fires will occur more frequently.[45] Rising temperatures will degrade many terrestrial and aquatic ecosystems. Heat waves will become more frequent, and extreme temperatures will be higher.[46] Rising sea levels also will affect California, increasing flooding on the coast and in the Sacramento-San Joaquin Delta, accelerating erosion, and leaving coastal construction increasingly vulnerable to storm damage.[47] Those changes in turn will create major consequences not only for the state's environmental quality, but also for its economy; many of the state's most important industries are likely to be harmed.[48]

Those environmental problems would strike a state already struggling to cope with existing conditions. According to the California Climate Change Center,[49] "[t]he state's vital resources and natural landscapes are already under stress due to California's rapidly growing population, which is expected to grow from 35 million today to 55 million by 2050."[50] Californians currently experience the nation's worst air quality, with much of the state's population living in areas that violate federal and state air quality standards.[51] Water allocation is chronically contentious. The state's forests face elevated fire risk. Other natural ecosystems are similarly strained, with dozens of plant and animal species threatened or endangered even under existing conditions. Even without rising sea levels, key areas of coastal California and the Sacramento-San Joaquin Bay-Delta already are vulnerable to flooding. All of those environmental problems create institutional, economic, and political strains in addition to environmental and health costs; in California, litigious natural resource battles already are ubiquitous.

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43 *Id.* at 6-7; Hayhoe et al., *supra* note 41, at 12425-26; DEPT. OF WATER RESOURCES, *supra* note 11, at 2-6, 2-22 to 2-31, 4-1 ("Planning and design of the Central Valley Project □ and State Water Project has, for the most part, assumed an unchanging climate… and a changing climate may threaten to destabilize the infrastructure and operations dependent on that assumption."); CALIFORNIA DEPARTMENT OF WATER RESOURCES, CALIFORNIA WATER PLAN UPDATE 2005 4-32 to 4-36 (2006) ("Predictions include increased temperature, reductions to Sierra snowpack, earlier snowmelt, and a rise in sea level, although the extent and timing of the changes remain uncertain. The changes could have major implications for water supply, flood management, and ecosystem health.").

44 OUR CHANGING CLIMATE, *supra* note 2, at 9.

45 *Id.* at 10-11.

46 OUR CHANGING CLIMATE, *supra* note 2, at 5; *see* REDEFINING PROGRESS, *supra* note 5, at 19-26; Hayhoe et al., *supra* note 41, at 12424-45.

47 DEPT. OF WATER RESOURCES, *supra* note 11, at 2-31 to 2-52.

48 *See* Cal. Health & Safety Code § 38501(b) ("Global warming will have detrimental effects on some of California's largest industries, including agriculture, wine, tourism, skiing, recreational and commercial fishing, and forestry.")

49 The California Climate Change Center is an academic research unit based primarily at the University of California's Berkeley and San Diego campuses. Several of its reports have been sponsored by California state agencies. *See* OUR CHANGING CLIMATE, *supra* note 2, at 2.

50 OUR CHANGING CLIMATE, *supra* note 2, at 2; see AMY LYND LUERS AND SUSANNE C. MOSER, PREPARING FOR THE IMPACTS OF CLIMATE CHANGE IN CALIFORNIA: OPPORTUNITIES AND CONSTRAINTS FOR ADAPTATION v (2006).

51 OUR CHANGING CLIMATE, *supra* note 2, at 5.

While most Californians will be affected, the impacts of climate change are likely to be particularly harsh for the state's poorest and most vulnerable people, many of whom are people of color.[52] In part, those disproportionate impacts will arise because adjusting to environmental change generally requires money and insurance, and poorer people lack the former and are less likely to own the latter.[53] Geography will also exacerbate distributional disparities. Some of the earliest and largest temperature changes are expected in California's Central Valley,[54] which contains some of California's poorest areas, and poverty could increase as climate change disrupts the region's agricultural economy.[55] The Central Valley is already one of California's hottest regions, and that heat contributes to some of the nation's worst air quality problems.[56] Consequently, some of the harshest impacts will fall upon California's most vulnerable people.

Climate change and its secondary environmental impacts thus pose significant threats to California. With consequences likely to strike across much of California's landscape and throughout many sectors of California's economy, and with harsh potential impacts upon those Californians already vulnerable to economic and environmental risk, climate change presents a large and urgent threat.

C. California's Role in Climate Change Solutions

While California presently is a major contributor to climate change, it also can be a major contributor to, and beneficiary of, climate change solutions.

California has a longstanding tradition of pushing the frontiers of environmental protection. California's pioneering regulation of automobile emissions led to national adoption of more protective standards, and California's innovations in energy efficiency have created improvements well beyond the state's borders. California now can play that role again. No other state has been as proactive in responding to climate change,[57] and California's innovative measures will likely provide examples and lessons for regulatory approaches worldwide. California has begun to embrace that leadership role; the state legislature recently passed the Global Warming Solutions Act of 2006 (more commonly known, and referred to herein, as AB 32), which declares:

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52 *See* REDEFINING PROGRESS, *supra* note 5.

53 *See id.* at 16-19, 36-37, 57-58, 63-64.

54 *Id.* at 9-10; *see* Hayhoe et al., *supra* note 41, at 12424 (showing maps of projected temperature increases).

55 *See* REDEFINING PROGRESS, *supra* note 5, at 3-4, 41-50 ("agriculture... is a significant source of employment for low-income groups and people of color. Shocks experienced by the industry could disproportionately affect these communities."); OUR CHANGING CLIMATE, *supra* note 2, at 8-9 (describing impacts to agriculture); Hayhoe et al., *supra* note 41, at 12426-27 (describing impacts to dairy and wine grape production).

56 *See* REDEFINING PROGRESS, *supra* note 5, at 19-26 (describing disparities in vulnerability to heat waves), 26-35 (describing threats posed by increasing ozone (smog) pollution); Hayhoe et al., *supra* note 41 at 12425 ("Individuals most likely to be affected (by increases in extreme heat) include elderly, children, the economically disadvantaged, and those who are already ill.").

57 *See infra* Part III.

[t]he program established by this division will continue this tradition of environmental leadership by placing California at the forefront of national and international efforts to reduce emissions of greenhouse gases... action taken by California to reduce emissions of greenhouse gases will have far-reaching effects by encouraging other states, the federal government, and other countries to act.[58]

Notwithstanding common arguments that responding to climate change will require society-wide economic sacrifices, California's responses actually could boost the state economy. According to the California Legislature, "[b]y exercising its global leadership role, California will also position its economy, technology centers, financial institutions, and businesses to benefit from national and international efforts to reduce emissions of greenhouse gases."[59] Governor Schwarzenegger has acknowledged those potential benefits, asserting that "technologies that reduce greenhouse gas emissions are increasingly in demand in the worldwide marketplace, and California companies investing in these technologies are well-positioned to profit from this demand, thereby boosting California's economy, creating more jobs and providing increased tax revenue."[60] California's Environmental Protection Agency similarly has concluded that implementing climate change prevention strategies could "increase jobs and income by an additional 83,000 and $4 billion, respectively."[61] Independent studies back those predictions; according to a recent California Climate Change Center report:

[g]lobally, increasing GHG emissions are assumed to be essential to a growing economy. This is not true in California. The state can take an historic step by demonstrating that reducing emissions of GHG can accelerate economic growth and bring new jobs.... California can gain a competitive advantage by acting early in the new technologies and industries that will come into existence worldwide around the common goal of reducing GHG emissions.[62]

III. Existing Regulatory Responses to Climate Change

Despite the threats posed by climate change, and despite the potential benefits of preventive regulation, the state and federal governments have taken only preliminary steps to limit the greenhouse gas emissions that drive global warming.

Federal action has been almost totally absent. The United States has neither ratified the Kyoto Protocol nor proposed any substitute international regulatory structure. Congress has not

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58 Cal. Health and Safety Code § 38501(d); *see* Executive Dept., State of California, Executive Order S-3-05 (June 1, 2005) (touting California's "leadership role in reducing greenhouse gas emissions").

59 Cal. Health & Safety Code § 38501(e).

60 Executive Order S-3-05, *supra* note 58.

61 CAL. ENVTL. PROT. AGENCY, *supra* note 2, at 65.

62 MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at E-6.

passed any legislation addressing climate change. EPA long declined to address carbon dioxide emissions, insisting, until corrected by the United States Supreme Court, that it had neither the obligation nor even the power to do so.[63] Although the Bush Administration now acknowledges the reality of anthropogenically-caused climate change, it has placed its faith almost entirely in voluntary responses.[64]

Unlike the federal government, California's leaders have recognized climate change as a problem requiring a vigorous response, but the state's response still is in its nascent stages. The Governor and the California Legislature have taken several major steps, including the passage of legislation setting automotive emissions standards for greenhouse gases.[65] In 2005, Governor Schwarzenegger pointedly declared the debate over climate change to be "over," and issued an executive order targeting ambitious reductions in the state's carbon emissions.[66] In accordance with Schwarzenegger Administration policy, many of California's administrative agencies are studying ways in which those agencies may respond to climate change.[67] The state attorney general's office has repeatedly attempted to compel responses to climate change, most notably by joining lawsuits seeking to impose nuisance liability on the electric power and automotive industries, to compel EPA to regulate automotive GHG emissions, and to force consideration of higher federal fuel economy standards.[68] Those efforts build upon earlier achievements. Because of past energy shortages and stringent air quality protections, California has implemented many measures designed to improve energy efficiency. Partly because of those measures, Californians' per capita GHG emissions now are lower than those of most Americans, even though their aggregate emissions are high and growing.[69]

Adding significantly to those achievements, in 2006 the California Legislature passed and Governor Schwarzenegger signed into law AB 32, also known as the California Global Warming

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63 *See Mass. v. EPA*, 127 S. Ct. 1438 (2007).

64 *See* MANAGING GREENHOUSE GAS EMISSIONS, *supra* note 10, at ES-4 ("While helpful, there is no evidence that voluntary measures provide sufficient incentives to attain the Governor's targets.").

65 *See* Cal Health & Safety Code § 43018.5. The automotive industry almost immediately challenged that legislation. *See Cent. Valley Chrysler-Jeep Inc. v. Witherspoon*, 2005 U.S. Dist. LEXIS 26536 (E.D. Cal. 2005) (allowing environmental groups to intervene in the automakers' lawsuit).

66 *See* Bill Blakemore, *Schwarzenator v. Bush: Global Warming Debate Heats Up*, ABC NEWS, August 30, 2006, at *http://abcnews.go.com/US/GlobalWarming/story?id=2374968&page=1*; Executive Order S-3-05, *supra* note 58. The order states, in part: "the following greenhouse gas emission reduction targets are hereby established for California: by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; by 2050, reduce GHG emissions to 80% below 1990 levels...."

67 *E.g.*, DEPT. OF WATER RESOURCES, *supra* note 11.

68 *Conn. v. Am. Elec. Power Co.*, 406 F. Supp. 2d 265 (S.D.N.Y. 2005) (dismissing the nuisance case); *Mass. v. EPA*, 127 S. Ct. 1438 (2007); Nick Bunkley, *California Sues 6 Automakers Over Global Warming*, NEW YORK TIMES, September 21, 2006.

69 *See* INVENTORY, *supra* note 26 at i, 12 ("California's ability to slow the rate of growth of GHG emissions is largely due to the success of its energy efficiency and renewable energy programs and a commitment to clean air and clean energy.... Although California's total GHG emissions are larger than every state but Texas, California has relatively low carbon emission intensity. In 2001, California ranked fourth lowest of the 50 states in carbon dioxide emissions per capita from fossil fuel consumption and fifth lowest of the 50 states in carbon dioxide emissions per unit of gross state product.").

Solutions Act of 2006, a landmark statute designed to cap California's greenhouse gas emissions.[70] AB 32 requires the California Air Resources Board (CARB) to cap statewide emissions at 1990 levels.[71] It empowers CARB to use a variety of regulatory mechanisms to achieve compliance with that cap by 2020, if not sooner.[72] AB 32 also requires establishment of a monitoring and enforcement system for tracking and regulating GHG emissions, and empowers CARB to take immediate steps to limit high-emitting sources.[73] The Legislature left most other details to the agency's discretion; while CARB must avoid environmental injustice in implementing its measures, its program will take shape primarily through rulemaking processes.[74]

Passing AB 32 was a major step. No other state has a law like it, and the federal government has until recently shown no inclination toward passing anything nearly so ambitious. Nevertheless, its passage is only a start. Even if fully achieved, AB 32's emission reductions, while important, won't eliminate California's contribution to the overall problem. Full implementation of the statute would reduce emissions only by approximately 25%, but many experts estimate that an 80 to 90% reduction ultimately will be necessary to fully eliminate anthropogenic climate change.[75] Nor should full implementation automatically be assumed. The regulatory program developed by CARB also may have gaps, which other laws and regulatory approaches can help fill.[76] And AB 32 places heavy responsibility upon CARB. If CARB is unable to meet its responsibilities, other statutory mechanisms may be necessary to spur change. AB 32 does not purport to occupy the regulatory field,[77] and both the need and the opportunity for other regulatory approaches therefore remain.

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70 California Climate Change Solutions Act of 2006, A.B. 32, 2005-06 Sess., codified at Cal. Health & Safety Code §§ 38500-99.

71 *Id.* §§ 38550-38551.

72 *Id.* §§ 38560-38565.

73 *Id.* § 38530.

74 *See id.* §§ 38560-38574

75 *See* MANAGING GREENHOUSE GAS EMISSIONS, supra note 10, at I-4; Executive Order S-3-05, supra note 58; Thomas Wigley, The Kyoto Protocol: CO_2, CH_4, and Climate Implications, 25 GEOPHYSICAL RESEARCH LETTERS 2285 (1998) (concluding that compliance with the Kyoto Protocol's modest targets would fall well short of removing the human footprint from the global climate).

76 For example, AB 32 implies that CARB should focus primarily on a subset of sources, see Cal. Health & Safety Code §§ 38530(b)(1), and for reasons of practicality and administrative efficiency the agency is likely to follow that directive. That means, however, that many smaller or more diffuse sources may escape regulation under AB 32, at least immediately and perhaps indefinitely, even though the aggregate effect of those smaller sources could be quite large.

77 Cal. Health and Safety Code §§ 38592(a) ("All state agencies shall consider and implement strategies to reduce their greenhouse gas emissions."), 38592(b) ("Nothing in this division shall relieve any person, entity, or public agency of compliance with other applicable federal, state, or local laws or regulations, including state air and water quality requirements, and other requirements for protecting public health or the environment."), 38598 ("Nothing in this division shall limit the existing authority of a state entity to adopt and implement greenhouse gas emissions reduction measures. ☐ Nothing in this division shall relieve any state entity of its legal obligations to comply with existing law or regulation.").

CEQA provides such a complementary approach. Though CEQA's substantive and procedural requirements have yet to be fully applied to projects contributing to climate change, the Act's core provisions require state and local public agencies to avoid or mitigate the significant adverse climate change impacts of any project they sponsor or approve. Multiple methods-many affordable, and some capable of creating significant collateral benefits-of avoiding or mitigating GHG emissions already are available.[78] And those mandates are readily enforceable; both government agencies and community groups have long-established traditions of using CEQA to create effective environmental change.[79]

I. The Requirements of CEQA

CEQA mandates that state and local agencies "[d]evelop and maintain a high quality environment now and in the future, and take all action necessary to protect, rehabilitate, and enhance the environmental quality of the state;" "take all coordinated actions necessary to prevent [critical environmental] thresholds being reached;" and "[e]nsure that the long-term protection of the environment, consistent with the provision of a decent home and suitable living environment for every Californian, shall be the guiding criterion in public decisions."[80]

Those broad purposes have informed legal principles. "In enacting CEQA," the California Supreme Court has written, "the Legislature declared its intention that all public agencies responsible for regulating activities affecting the environment give prime consideration to preventing environmental damage when carrying out their duties."[81] The state's high court has repeatedly directed that "CEQA is to be interpreted 'to afford the fullest possible protection to the environment within the reasonable scope of the statutory language.'"[82]

CEQA fulfills those protective purposes primarily through a few basic requirements. Any time a state or local public agency makes a discretionary decision[83] to approve or carry out a project with potentially significant environmental impacts-even if the project will be implemented by private parties[84]-the agency must consider and disclose the potential environmental consequences of

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78 *See supra Part I.C.*

79 *See PLANNING AND CONSERVATION LEAGUE, EVERYDAY HEROES PROTECT THE AIR WE BREATHE, THE WATER WE DRINK, AND THE NATURAL AREAS WE PRIZE: THIRTY-FIVE YEARS OF THE CALIFORNIA ENVIRONMENTAL QUALITY ACT (2005) at http://www.pcl.org/pcl_files/full_report.pdf.*

80 Cal. Pub. Res. Code §§ 21000(d), 21001(a), (d).

81 Mountain Lion Foundation v. Fish and Game Commission, 16 Cal.4th 105, 112 (1997); see City of Marina v. Board of Trustees of the California State University, 39 Cal.4th 341, 348 (2006).

82 Mountain Lion Foundation, 16 Cal.4th at 112 (quoting Friends of Mammoth v. Board of Supervisors, 8 Cal. 3d 247, 259 (1972)); Laurel Heights Improvement Ass'n v. Regents of the Univ. of Cal., 47 Cal.3d 376, 390 (1988).

83 See Cal. Pub. Res. Code § 21080(a); Friends of Westwood v. City of Los Angeles, 191 Cal. App. 3d 259, 267 (1987) (holding that the existence of any discretion in an approval process triggers CEQA's applicability).

84 See Friends of Mammoth, 8 Cal.3d 247 (holding that CEQA applies to private projects receiving governmental approvals).

its decision.[85] It also must identify, discuss, and, if feasible, adopt measures capable of avoiding or reducing a proposed project's significant adverse environmental impacts.[86] The discussion below explains these requirements in more detail.

A. Disclosure of Significant Adverse Environmental Impacts

If a proposed project[87] may cause significant adverse impacts upon the environment, CEQA requires the lead agency[88] either to: (a) adopt or require project changes that will avoid or fully mitigate potentially significant impacts; or (b) prepare an "environmental impact report" (EIR) before approving or carrying out the project.[89] The EIR, if prepared, must identify and discuss the project's potentially significant adverse environmental impacts. That discussion should inform both decision-makers and the public of the environmental consequences of the agency's proposed action, allowing assessment of whether the project really is worth its potential environmental cost.[90]

CEQA defines "significant impacts" broadly and inclusively. Its definition includes-and agencies therefore must discuss-not only the direct environmental consequences of implementing the project, but also indirect effects that may follow from the project's direct physical consequences.[91] That discussion need not address speculative effects,[92] but where an indirect consequence is foreseeable, the existence of a causal chain between project and impact-even an attenuated one-does not excuse the agency from discussing that impact in an EIR.[93]

A lead agency also must address significant "cumulative" environmental impacts-that is, contributions, even if small, to larger environmental problems. CEQA defines a "significant effect on the environment" as including

> possible effects of a project (that) are individually limited but cumulatively considerable. As used in this paragraph, 'cumulatively considerable' means that the incremental effects

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85 CEQA does set forth certain classes of projects that are categorically exempt from statutory requirements. *E.g.*, Cal. Pub. Res. Code §§ 21080(b), 21080.14 (creating an exemption for "affordable housing projects in urbanized areas").

86 *Sierra Club v. State Bd. of Forestry*, 7 Cal.4th 1215, 1233 (1994).

87 *See* 14 Cal. Code Regs. § 15002(b) (explaining the types of actions to which CEQA applies).

88 CEQA defines a "lead agency" as "the public agency which has the principal responsibility for carrying out or approving a project which may have a significant effect upon the environment." Cal. Pub. Resources Code § 21067.

89 *See Friends of Davis v. City of Davis*, 83 Cal. App. 4th 1004, 1016-67 (2000) ("An EIR is required whenever it can be 'fairly argued on the basis of substantial evidence that the project may have significant environmental impact.'") (citations omitted); 14 Cal. Code Regs. §§ 15064, 15065(b)(1).

90 *See Sierra Club*, 7 Cal. 4th at 1229 (describing an EIR as "an environmental alarm bell" and a "document of accountability").

91 *See* 14 Cal. Code Regs. § 15064(d)(2); *see also* 14 Cal. Code Regs. § 15358.

92 *See Planning & Conservation League v. Department of Water Resources*, 83 Cal. App. 4th 892, 919 (2000) ("We need not venture into speculation. But CEQA does compel reasonable forecasting.").

93 *See* 14 Cal. Code Regs. § 15064(d)(2).

of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.[94]

The presence of such cumulatively significant effects can trigger the obligation to prepare an EIR, for an agency must prepare an EIR if its "project has possible environmental effects that are individually limited but cumulatively considerable."[95] The EIR then must disclose those cumulative impacts; agencies are obligated to "discuss cumulative impacts of a project when the project's incremental effect is cumulatively considerable."[96]

Judicial decisions have carefully enforced those requirements. California's courts have emphasized the importance of cumulative impacts analyses, cautioning that "[o]ne of the most important environmental lessons is that environmental damage often occurs incrementally from a variety of small sources. These sources appear insignificant when considered individually, but assume threatening dimensions when considered collectively with other sources with which they interact."[97] The courts therefore have required agencies to treat as significant projects' contributions to larger environmental problems, even where the individual project contribution would seem small in isolation.[98] They also have rejected a *de minimis* exemption from that general rule, reasoning that such an exemption would contravene the core purposes of a cumulative impacts analysis.[99] Some debate remains about where exactly the lower bound of a cumulatively significant contribution lies; though the rejection of a *de minimis* exception indicates that even tiny contributions

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94 Public Resources Code § 21083(b)(2). The CEQA Guidelines similarly state that "'[c]umulative impacts' refer to two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts." 14 Cal. Code Regs. § 15355. "While Section 21083 governs the situations in which an agency must prepare an EIR, its provisions have also been applied to the contents of an EIR once it is determined an EIR must be prepared." *Los Angeles Unified School Dist.*, 58 Cal. App. 4th at 1024 n.6 (citing *Laurel Heights Improvement Ass'n*, 47 Cal.3d at 394).

95 14 Cal. Code Regs. § 15065 (a)(3).

96 *Id.* § 15130(a); *see Los Angeles Unified School Dist.*, 58 Cal. App. 4th at 1024-26 (1997); *San Franciscans for Reasonable Growth v. City & County of San Francisco*, 151 Cal. App. 3d 61, 73 (1984) ("Part of [CEQA's] vital informational function is performed by a cumulative impact analysis.").

97 *Communities for a Better Environment v. California Resources Agency*, 103 Cal. App. 4th 98, 114 (2002); *see Bakersfield Citizens for Local Control v. City of Bakersfield*, 124 Cal. App. 4th 1184, 1214 (2005) (quoting *Communities for a Better Environment*); Los Angeles Unified School Dist, 58 Cal. App. 4th at 1025; *San Joaquin Raptor/Wildlife Rescue Ctr. v. County of Stanislaus*, 27 Cal. App. 4th 713, 739 (1996); *Las Virgenes Homeowners Federation, Inc. v. County of Los Angeles*, 177 Cal. App. 3d 300, 306 (1986); *Whitman v. Board of Supervisors*, 88 Cal. App. 3d 397, 408 (1979).

98 *E.g.*, *Kings County Farm Bureau v. City of Hanford*, 221 Cal. App. 3d 692, 718-24 (1990) (rejecting an EIR that failed to consider whether project emissions, in combination with emissions from other sources throughout the San Joaquin Valley, would create a significant impact); *Los Angeles Unified School Dist.*, 58 Cal.App.4th at 1025 ("the relevant issue to be addressed in the EIR on the plan is not the relative amount of traffic noise resulting from the project when compared to existing traffic noise, but whether any additional amount of traffic noise should be considered significant in light of the serious nature of the traffic noise problem already existing around the schools").

99 *Communities for a Better Environment*, 103 Cal. App. 4th at 116-21 (following *Kings County*, which it described as "[t]he seminal decision," and *Los Angeles Unified School District*).

often matter, commentators have argued against a "one-molecule" standard for air pollution.[100] But past decisions leave little doubt that CEQA's full suite of obligations can be triggered even by a seemingly small contribution to a larger problem.

CEQA's definition of significant impacts also extends to impacts occurring outside California. While CEQA governs only decisions made and conduct occurring within California, nothing in its definition of significant impact excludes impacts outside state lines. Instead, "CEQA requires a public agency to mitigate or avoid its projects' significant effects not just on the agency's own property but 'on the environment,' with 'environment' defined for these purposes as 'the physical conditions which exist within the area which will be affected by a proposed project.'"[101] That functional definition invokes no political boundaries; if an area is affected, it is part of the relevant physical environment, regardless of the governmental authority exercising local jurisdiction.

CEQA, its implementing regulations, and judicial decisions thus compel agencies to disclose, in an EIR, their projects' contributions to any significant environmental problem, even if those contributions are indirect, even if project-specific contributions, if viewed in isolation, would seem small, and even if those impacts will occur partly outside California.

B. Identification of Alternatives and Mitigation Measures

In addition to requiring identification of significant environmental impacts, CEQA also requires agencies to discuss ways in which those impacts can be avoided or reduced. Agencies must "systematically identif[y]... feasible alternatives or feasible mitigation measures which will avoid or substantially lessen [a project's] significant effects."[102] That discussion of alternatives and mitigation measures forms the "core" of an EIR.[103]

CEQA's alternatives requirement compels agencies to consider whether different versions of the project, or even different projects, could accomplish most project purposes while reducing environmental costs.[104] Courts have repeatedly stated that agencies "must describe all reasonable alternatives to the project including those capable of reducing or eliminating environmental effects."[105] No universally-applicable list sets forth the alternatives agencies must consider-the scope of the analysis instead is governed by project-specific circumstances, the standards set forth in the statute and the CEQA Guidelines, and a "rule of reason"[106]-but agencies often

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100 *See, e.g.*, MICHAEL H. REMY ET AL., GUIDE TO THE CALIFORNIA ENVIRONMENTAL QUALITY

101 *American Canyon Community United for Responsible Growth v. City of American Canyon*, 145 Cal. App. 4th 1062, 1082 (2006) (italics removed; *quoting* Cal. Pub. Res. Code § 21002.1(b) and *City of Marina v. Board of Trustees of California State University*, 39 Cal. 4th 341, 359-60 (2006)); 14 Cal. Code Regs. § 15360.

102 Cal. Pub. Res. Code § 21002; *see* Cal. Pub. Resources Code § 21061 (stating that an EIR must "list ways in which the significant effects of such a project might be minimized" and "indicate alternatives to such a project.").

103 *Citizens of Goleta Valley v. Board of Supervisors*, 52 Cal.3d 553, 564 (1990).

104 *See* 14 Cal. Code Regs. § 15126.6.

105 *County of Inyo v. City of Los Angeles*, 71 Cal. App. 3d 185, 203 (1977); *see Wildlife Alive v. Chickering*, 18 Cal.3d 190, 197 (1976); *Laurel Heights Improvement Assoc. v. Regents of Univ. of Calif.*, 47 Cal. 3d 376, 400 (1988); 14 Cal. Code Regs. § 15126.6.

106 *See* 14 Cal. Code Regs. § 15126.6; *Citizens of Goleta Valley*, 52 Cal.3d at 565.

consider building in alternative locations,[107] using different infrastructure to accomplish project purposes,[108] or scaling back a project's scope.[109]

CEQA also "requires that an EIR indicate the ways in which a project's significant effects can be mitigated, by setting forth 'mitigation measures proposed to minimize significant effects on the environment.'"[110] The CEQA Guidelines describe several categories of mitigation measures, including "avoiding the impact altogether by not taking a certain action or parts of an action;" restoring the environment impacted by the action; altering project operations to minimize the impact; or "[c]ompensating for the impact by replacing or providing substitute resources or environments."[111] They also specify that "where relevant," EIRs must describe measures capable of reducing "inefficient and unnecessary consumption of energy."[112]

C. Adoption, if Feasible, of Alternatives or Mitigation Measures Capable of Avoiding Significant Environmental Impacts

While discussion of impacts and alternatives is central to CEQA compliance, the statute requires more than just disclosure. CEQA also includes a "substantive mandate that public agencies refrain from approving projects for which there are feasible alternatives or mitigation measures."[113] "[N]o public agency shall approve or carry out a project" if "one or more significant effects on the environment [] would occur if the project is approved or carried out," unless the public agency determines either: (a) that the impacts will be mitigated to a less-than-significant level; or (b) that full mitigation is infeasible, but project benefits still justify proceeding.[114] The CEQA Guidelines repeat that mandate, stating that the "basic purposes of CEQA" include

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107 *E.g., Citizens of Goleta Valley*, 52 Cal.3d at 570-75 (concluding that evaluation of a single off-site alternative was adequate); *San Bernardino Valley Audubon Society, Inc. v. County of San Bernardino*, 155 Cal.App.3d 738, 751 (1984) (rejecting an EIR that considered too narrow a range of site alternatives).

108 *E.g., County of Inyo*, 71 Cal. App. 3d 185, 203 (1977) (rejecting an EIR for a water-delivery project that failed to consider conservation as an alternative to increased pumping); *Kings County Farm Bureau v. City of Hanford*, 221 Cal. App. 3d 692, 730-37 (1990) (rejecting an EIR that considered a natural gas-burning alternative to a coal-fired power plant, but did not provide enough quantitative data to facilitate an effective comparative analysis).

109 *E.g., Village of Laguna Beach v. Board of Supervisors*, 134 Cal. App. 3d 1022, 1028-32 (1982) (upholding an EIR that considered a range of sizes for a proposed residential development).

110 *Save Our Peninsula Committee v. Monterey County Bd. of Supervisors*, 87 Cal. App. 4th 99, 139 (2001) (citing Cal. Public Resources Code §§ 21100, 21002.1, and 21061); see 14 Cal. Code Regs. § 15002(a)(2) (stating that one of CEQA's "basic purposes" is to "[i]dentify ways that environmental damage can be avoided or significantly reduced").

111 14 Cal. Code Regs. § 15370. At the margins, the difference between an alternative and a mitigation measure may be fuzzy, but generally speaking, mitigation measures involve revisions within the same project, while alternatives involve fundamentally different versions of the project. *See Laurel Heights*, 47 Cal.3d at 403 ("alternatives are a type of mitigation").

112 14 Cal. Code Regs. § 15126.4.

113 *Mountain Lion Foundation v. Fish and Game Commission*, 16 Cal.4th 105, 134 (1997); see *Sierra Club v. State Bd. of Forestry*, 7 Cal.4th 1215, 1233 (1994) ("CEQA compels government first to identify the [significant] environmental effects of projects, and then to mitigate those adverse effects through the imposition of feasible mitigation measures or through the selection of feasible alternatives."); *Sierra Club v. Gilroy City Council*, 222 Cal.App.3d 30, 41 (1990) (CEQA "requires public agencies to deny approval of a project with significant adverse effects when feasible alternatives or feasible mitigation measures can substantially lessen such effects.")

114 Cal. Pub. Res. Code § 21081.

"[p]revent[ing] significant, avoidable damage to the environment by requiring changes in projects through the use of alternatives or mitigation measures when the governmental agency finds the changes to be feasible."[115] Thus, if mitigation or avoidance of a project's significant adverse impacts is feasible, an agency cannot approve the project without adoption of those mitigation or avoidance measures.

Those provisions require mitigation of cumulatively significant impacts. A cumulatively significant impact is, by definition, a significant project impact,[116] and CEQA requires mitigation, if feasible, of all significant impacts.[117] That does not mean agencies must fully resolve environmental problems that their projects only partially cause; instead, an agency may satisfy its CEQA obligations by mitigating its proportional contribution.[118] The agency also may accomplish its share of mitigation in a variety of ways, including participation in regional mitigation programs.[119] But an agency cannot simply ignore its project's share of a larger impact. If a project's contribution is incrementally important yet can be avoided or mitigated, the project cannot proceed without such mitigation.

CEQA thus creates both powerful incentives and clear mandates for agencies to refrain from contributing to larger environmental problems. Such contributions can trigger the obligation to prepare an EIR, and agencies wishing to avoid that obligation must fully mitigate their projects' potential contributions. If the agency does not adopt such mitigation measures at the outset, its EIR must disclose potential contributions to that larger problem, and those disclosures may raise questions about the wisdom of proceeding with the project. Finally, if a project's contributions to a significant impact can feasibly be avoided or mitigated, the agency cannot proceed without such avoidance or mitigation measures in place.

II. Applying CEQA's Requirements to Climate Change

The core CEQA provisions described above constrain state or local public agencies' contributions to climate change. Many public projects directly or indirectly cause GHG emissions,[120] and all of those projects collectively add major contributions to significant environmental impacts.[121] But multiple methods exist for feasibly mitigating or avoiding those projects' contributions to climate change.[122] Consequently, and as explained in more detail below, CEQA requires that

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115 14 Cal. Code Regs. §§ 15002(a)(3), (h), 15021..

116 *See* 14 Cal. Code Regs. § 15065(a)(3) (stating that "a lead agency shall find that a project may have a significant impact on the environment" if the project "has possible environmental effects that are individually limited but cumulatively considerable.").

117 Cal. Pub. Res. Code 21081.

118 14 Cal. Code Regs. § 15130(a)(3) ("An EIR may determine that a project's contribution to a significant cumulative impact will be rendered less than cumulatively considerable and thus is not significant. A project's contribution is less than cumulatively considerable if the project is required to implement or fund its fair share of a mitigation measure or measures designed to alleviate the cumulative impact."); 14 Cal. Code Regs. § 15064(h)(2) (same).

119 *Save Our Peninsula Committee*, 7 Cal. App. 4th at 139-40. The *Save Our Peninsula* court also warned, however, that "a commitment to pay fees without any evidence that mitigation will actually occur is inadequate." *Id.* at 140; *City of Marina*, 39 Cal.4th at 365.

120 *See infra* Part II.A.

121 *See infra* Part II.B.

California state and local agencies refrain from approving projects that contribute to climate change or implement full mitigation.

A. Climate Change Contributions and State and Local Government Projects

The threshold trigger for CEQA is a discretionary state or local government action with potential environmental consequences, and government-implemented or approved projects that lead, directly or indirectly, to GHG emissions clearly cross that threshold.[123] In fact, much of California's GHG emissions derive at least partly from discretionary government decisions.

A listing of all public agency projects contributing to climate change would fill a book, but a partial sampling illustrates the extent to which GHG emissions intertwine with discretionary government action. Public agencies build transportation systems,[124] control land use planning and consequent automobile use, and regulate the location of new residential, commercial, industrial, agricultural, and power-generating facilities.[125] Timber harvests, which release some of the carbon previously stored in forests and reduce their sequestration potential, are regulated by California's Board of Forestry.[126] Methane-generating agricultural or industrial practices, like construction of major dairies, typically are subject to local land use authority, and require authorization from local governments. Government decisions also affect power demand; every subdivision, industrial project, or water project[127] that public agencies approve necessitates electricity. Public agencies also are major power consumers. The single largest power user in the state is California's State Water Project, which utilizes an extraordinary amount of energy every year delivering water to users in southern California.[128] Perhaps the most telling statistics are the numbers of project decisions issued by California agencies. In an average year, those agencies file thousands of documents notifying the public that a CEQA process has been completed, and many, if not most, of those projects may in some way affect GHG emissions.[129]

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122 *See infra* Parts II.C, II.D.

123 *See Friends of Mammoth v. Board of Supervisors*, 8 Cal. 3d 247 (1972)

124 *See, e.g.*, California Department of Transportation, About Caltrans, at *http://www.dot.ca.gov/aboutcaltrans.htm* (last checked September 15, 2007) (describing Caltrans' role in building state transportation infrastructure).

125 *See, e.g.*, *Kings County Farm Bureau v. City of Hanford*, 221 Cal. App. 3d 692 (1990) (considering the environmental consequences of constructing a new power plant); California Energy Commission, *Welcome to the California Energy Commission*, at *http://www.energy.ca.gov/commission/index.html* (explaining the CEC's role, which includes "[l]icensing thermal power plants 50 megawatts or larger").

126 *See Big Creek Lumber Co. v. County of Santa Cruz*, 38 Cal. 4th 1139, 1146-47 (2006). That state regulatory power does not extend to the national forest system's extensive holdings within California.

127 *See* NATURAL RESOURCES DEFENSE COUNCIL AND PACIFIC INSTITUTE, ENERGY DOWN THE DRAIN: THE HIDDEN COSTS OF CALIFORNIA'S WATER SUPPLY (2004) ("According to the Association of California Water Agencies, water agencies account for 7 percent of California's energy consumption and 5 percent of summer peak demand.").

128 *See* ENERGY DOWN THE DRAIN, *supra* note 127, at 2 ("The California Energy Commission reports that SWP energy use accounts for 2 to 3 percent of all electricity consumed in California.").

129 *See* Office of Planning and Research, *Environmental Document Filings with the State Clearinghouse, 1999 through 2005, at http://www.opr.ca.gov/clearinghouse/PDFs/1999-2005_All_Document_Filings.pdf.*

B. GHG-Emitting Projects and Significant Environmental Impacts

Not all discretionary public agency decisions trigger CEQA's requirements; instead, the second major trigger for CEQA's information-disclosure and mitigation obligations is a potentially significant environmental impact.[130] Projects causing increased GHG emissions create that potential. Each project's individual contribution exacerbates climate change and leaves California further from achieving the state's declared emissions-reduction goals, and the collective result of those contributions, in combination with other emissions worldwide, is a classic example-perhaps the quintessential example-of the oft-repeated CEQA maxim "that environmental damage often occurs incrementally from a variety of small sources."[131]

Individual GHG-emitting projects clearly contribute to climate change. While no individual project can claim more than a relatively small share of responsibility for the overall consequences, every GHG-emitting project does increase the problem; there is no inconsequential time or location for GHG emissions to occur.[132] Although those individual contributions might seem inconsequential if isolated and unique, CEQA precludes agencies from dismissing them as *de minimis*. The California courts have specifically rejected a *de minimis* exemption to CEQA's cumulative impact requirements, instead cautioning that "the greater the existing environmental problems are, the lower the threshold should be for treating a project's contribution to cumulative impacts as significant."[133] While emissions of conventional air pollutants may be treated as insignificant where those emissions comply with applicable plans for attaining regional air quality goals,[134] no such plans presently exist for greenhouse gases, and California has established no safe threshold for greenhouse gas emissions.[135] Instead, California's

130 14 Cal. Code Regs. § 15130(b)(5). Subsection 15130(e), however, states that for certain types of projects, an EIR need not address impacts previously addressed in a prior EIR.

131 *Communities for a Better Environment v. California Resources Agency*, 103 Cal. App. 4th 98, 114 (2002); *see id.* at 120 (observing that to exempt small contributions to big problems "contravenes the very concept of cumulative impacts").

132 *See supra* note 26; *see also Mass. v. EPA*, 127 S. Ct. 1438, 1457-58 (2007) (rejecting EPA's argument that its contributions to climate change are insufficient to confer standing).

133 *See Communities for a Better Environment*, 103 Cal. App 4th at 116-21.

134 *See* 14 Cal. Code Regs. § 15064(h)(3).

135 In a recent white paper discussing methods for addressing climate change in CEQA review, the Association of Environmental Planners suggests that "[i]t can easily be argued that proposed projects that implement all appropriate actions listed in the emissions reductions strategies relevant to the proposed project would have a less than significant impact to global climate change;" the planners argue against a no-net-emissions increase approach. MICHAEL HENDRIX ET AL., RECOMMENDATIONS BY THE ASSOCIATION OF ENVIRONMENTAL PLANNERS (AEP) ON HOW TO ANALYZE GREENHOUSE GAS EMISSIONS AND GLOBAL CLIMATE CHANGE IN CEQA DOCUMENTS 9-10 (2007) (referring to recommended actions in CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY, *supra* note 2). The California EPA report does contain many useful ideas for reducing projects' GHG emissions, and is a useful resource for agencies or activists seeking ways to reduce carbon footprints. But the planners' proposed approach cannot pass legal muster, for the California EPA report provides a set of possible, and often partially-formed or vaguely described, approaches to emissions reductions, not specific design or performance standards against which performance might feasibly be measured. In addition, the report does not assert, and could not assert, that implementing all of its proposed measures will reduce California's levels to insignificant levels; instead, it projects that those emissions could be reduced to levels consistent with the Governor's 2020 targets, yet experts project that far greater reductions are necessary. *See supra* note 73 and accompanying text.

acknowledged and urgent need for drastic reductions in GHG emissions vitiates any argument that an incremental increase, unless tiny enough to be essentially immeasurable,[136] is insignificant. Even seemingly small increases are fundamentally inconsistent with the need, repeatedly acknowledged by both the Legislature and the Governor, to cut emissions; and by pushing California further from its stated goals, every increase necessitates increased cuts in other GHG-emitting activities.[137]

The aggregate environmental effects of greenhouse gas emissions clearly are significant. Greenhouse gases pose an extraordinary environmental threat, with the potential to harm multiple ecosystems, badly damage resource-dependant economies, and diminish the health and safety of millions of people in California and elsewhere.[138] The California Legislature and Governor have repeatedly acknowledged the severity of the danger, describing climate change as "a serious threat to the economic well-being, public health, natural resources, and the environment of California."[139] And while California may face particularly acute threats, its likely burdens are by no means unique.[140] Both within and outside California's borders, climate change will create highly significant environmental impacts.[141]

CEQA decisions addressing analogous environmental threats support treating contributions to GHG emissions as significant impacts. In *Kings County Farm Bureau v. City of Hanford*, a seminal cumulative impacts case, the respondent city had approved a power plant project that would emit ozone precursors.[142] That plant's contributions would have had little effect in isolation, and represented only a small percentage of regional emissions, and the project proponent argued that those emissions therefore could not be significant.[143] The court disagreed. Noting that the small contribution would affect an area already suffering from excess air pollution, the court required the city to assess whether, given that regional context, the project's increased emissions would contribute to a significant environmental impact.[144] "The relevant question to

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136 *Communities for a Better Environment*, 103 Cal. App 4th at 120 ("the 'one-[additional]-molecule' rule is not the law") (brackets in original; quoting REMY ET AL., *supra* note 100, at 476-78). Neither *Kings County Farm Bureau* nor *Communities for a Better Environment* explains how exactly an agency should draw the line between a project contributing one molecule to a larger problem - which contribution presumably would not constitute a significant impact - and a project contributing a cumulatively considerable amount. However, *Communities for a Better Environment's* rejection of a *de minimis* exception, along with the basic CEQA principle that the act should be interpreted to maximize environmental protection, suggests that the threshold is extremely low, particularly where the emission exacerbates non-compliance with emissions-reduction goals and the ultimate problem is vast.

137 Executive Order S-3-05, *supra* note 58; Cal. Health and Safety Code §§ 38592(a)

138 *See* OUR CHANGING CLIMATE, *supra* note 2.

139 Cal. Health and Safety Code § 38501.

140 *See* IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3, at 12-13.

141 *Id.*

142 *Kings County Farm Bureau v. Hanford*, 221 Cal. App. 3d 692, 718-24 (1990).

143 *Id.* at 718 ("The DEIR concludes the project's contributions to ozone levels in the area would be immeasurable and, therefore, insignificant because the plant would emit relatively minor amounts of precursors compared to the total volume of precursors emitted in Kings County."); *id.* at 719.

144 *Id.* at 722 ("We find the analysis used in the EIR and urged by GWF avoids analyzing the severity of the problem and allows the approval of projects which, when taken in isolation, appear insignificant, but when viewed together, appear startling.... the standard for a cumulative impacts analysis is defined by the use of the term 'collectively significant'").

be addressed in the EIR," it held, "is not the relative amount of precursors emitted by the project when compared with preexisting emissions, but whether any additional amount of precursor emissions should be considered significant in light of the serious nature of the ozone problems in this air basin."[145] That reasoning is similarly applicable to climate change. Much as regional air quality problems derive from the small contributions of a large number of sources-none of which in isolation would seem important, and most of which would seem small in comparison to the overall scope of the problem-climate change derives from the individually minor contributions of thousands of projects and actions worldwide, all of which collectively create major consequences.

In addition to being legally mandated, discussing contributions to climate change should prove manageable. Attributing ultimate environmental outcomes solely to a specific project's emissions generally will be impossible, but the basic premise of a cumulative impacts analysis is that collective, not individual, effects matter,[146] and describing individual emissions and collective effects is a straightforward task. Ample guidance already exists for projecting an individual project's GHG emissions.[147] Likewise, ample and reliable documentation of collective effects already exists.[148] Numerous studies, both from California state agencies and from international scientific bodies, describe the anticipated consequences of global GHG emissions, and those studies can easily be quoted or summarized in CEQA-required reports.[149]

C. GHG Emissions and Avoidance or Mitigation

Because government projects and decisions measurably contribute to the GHG emissions that drive climate change, and because those emissions' cumulative environmental impacts are significant, any CEQA study must also discuss ways to avoid or mitigate the project's contributions to those impacts. Unless those measures are infeasible, no CEQA-regulated project may be

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145 *Id.* at 718.

146 *See id.* at 722; see also *National Steel Corp. v. Gorsuch*, 700 F.2d 314, 323-24 (6th Cir. 1983) (observing, in a case addressing conventional air pollutants' contributions to non-attainment of air quality standards, that "[t]he fact that there is insufficient technical knowledge to determine the precise degree to which each source contributes to nonattainment does not require that the EPA be prohibited from acting with regard to all sources.") In accordance with those principles, a legally adequate discussion of a project's potential climate change contributions could simply discuss (1) the project's projected GHG emissions; (2) the predicted environmental consequences of those emissions in combination with other similar emission worldwide (a discussion that could be largely adopted from reports issued by the IPCC, the California Climate Change Center, and others); and (3) ways of avoiding or mitigating those project-specific emissions. Describing exactly how much sea level rise or how many storms would be attributable to the specific project would be neither feasible nor useful, and CEQA does not require such discussion.

147 *See* U.S. Envtl. Prot. Agency, State Inventory Guidance, at *http://www.epa.gov/climatechange/emissions/state_guidance.html* (describing various resources for estimating GHG emissions) (last checked February 20, 2007); U.S. Envtl. Prot. Agency, Personal Emissions Calculator, at *http://www.epa.gov/climatechange/emissions/ind_calculator.html* (providing on-line calculator for individual impacts) (last checked September 15, 2007); *see also Planning and Conservation League v. Dept. of Water Resources*, 83 Cal. App. 4th 892, 919 (2000) ("CEQA does compel reasonable forecasting"). Compliance demonstrations for the Clean Air Act are based largely on emissions budgets that state and local agencies develop by predicting the likely emissions from individual projects. *See* 42 U.S.C. § 7502(c)(4).

148 Compare 14 Cal. Code Regs. §§ 15144-45 (stating that agencies need not "foresee[] the unforeseeable or address matters "too speculative for evaluation"). As described in detail in the numerous reports cited herein, the connections between GHG emissions and climate change are no longer unforeseeable or speculative.

149 *See*, e.g., OUR CHANGING CLIMATE, *supra* note 2; IPCC, THE PHYSICAL SCIENCE BASIS, *supra* note 3; CAL. ENVTL. PROT. AGENCY, *supra* note 2.

approved without such avoidance or mitigation measures.[150] For many CEQA-regulated projects, measures feasibly capable of reducing or eliminating GHG emissions likely exist, and those measures may be both affordable and capable of generating collateral environmental and economic benefits.

1. Project Alternatives

For many proposed projects, functionally similar alternatives can vastly reduce GHG emissions. Renewable power sources, for example, provide alternatives to constructing fossil fuel power plants. Constructing transit systems often provides a lower-emissions alternative to constructing new roads. Rather than building new water delivery projects, which tend to consume huge amounts of energy, project proponents could implement water use efficiency programs, either within their own supply areas or in areas sharing common water sources.[151] Instead of breaking new ground and building new housing in undeveloped areas, local governments could limit their land use approvals to infill development projects, which tend to require substantially less energy-intensive infrastructure and result in fewer indirect GHG emissions.[152] Such alternatives won't always be feasible-some projects may unavoidably need to be located in a particular place-and often environmentally-beneficial alternatives will still create some GHG emissions, but alternatives capable of substantially reducing GHG emissions will fairly often be available.

2. On-Site Mitigation

Even if no alternative is capable of avoiding a project's emissions, on-site measures often are capable of substantially mitigating greenhouse gas emissions. For example, developers can use green-building technology and renewable power systems, and build housing with ready transit access and internal or nearby options for grocery shopping and recreation, reducing their projects' energy footprint.[153] A variety of measures, ranging from reliance on recycled water for outdoor irrigation to utilization of water-conserving technologies and tiered pricing, can significantly reduce the amount of energy required to transport, distribute, heat, and dispose of water.[154] Highways, if necessary, can include HOV lanes. Dairy farms and landfills can be

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[150] If mitigation is not available, and significant impacts remain, the lead agency must provide a statement explaining why "overriding... benefits" justify proceeding with the project. *See* Cal. Pub. Res. Code § 21081(b).

[151] *See, e.g.*, ENERGY DOWN THE DRAIN, *supra* note 127, at 34 (describing the costs and benefits of alternative methods of boosting San Diego's water supplies).

[152] Many air pollution control districts already publish guidelines for development patterns that minimize emissions of other pollutants, and the same principles can help minimize GHG emissions. *See, e.g.*, San Luis Obispo County Air Pollution Control District, Residential Design Considerations, available at *http://www.slocleanair.org/business/pdf/residential%20flyer.pdf* (last checked September 15, 2007); SOLANO TRANSPORTATION AUTH. ET AL., TRANSPORTATION AND LAND USE TOOLKIT (2003), available at *http://www.ysaqmd.org/planning-info.php*.

[153] *See* San Luis Obispo County Air Pollution Control District, *supra* note 152; SOLANO TRANSPORTATION AUTH. ET AL., *supra* note 152.

[154] *See* ENERGY DOWN THE DRAIN, *supra* note 127 (describing measures capable of reducing water use, and explaining their benefits).

constructed with methane-recovery technologies.[155] These examples provide only a partial sampling, and as efforts toward GHG management intensify, an increasing variety of mitigation measures will likely become available.

3. Off-Site Mitigation

Sometimes neither project alternatives nor on-site mitigation measures will be capable of fully avoiding GHG emissions.[156] But even for those projects, off-site mitigation should allow projects to avoid contributing to GHG emissions. The primary available method is generally known as emissions trading.

The concept behind emissions trading is fairly straightforward. To compensate for increased emissions resulting from its project, a project proponent can either reduce its own emissions elsewhere; pay some other entity to commensurately reduce emissions; or undertake or fund actions that will permanently sequester an equivalent amount of carbon.[157] For example, a municipality approving a housing development that unavoidably will contribute tons of carbon each year might implement a city-wide energy efficiency program creating equivalent reductions in carbon emissions. The compensation need not be exactly in kind; for example, the emissions deriving from a new transportation project might be offset by funding the conversion of abandoned agricultural land to a permanent forest.[158]

If well-designed and transparent, emissions trades can fulfill CEQA's mitigation requirements. Using offsets-purchasing conservation easements as partial mitigation for conversion of farmlands or habitat, for example, or constructing new wetlands to compensate for wetlands destroyed-already is a common mitigation practice, and agencies often mitigate project impacts by contributing fees to regional mitigation programs.[159] Likewise, in some areas with deficient air quality new projects must offset emissions by purchasing reduction credits from existing sources.[160] Such approaches have legal limitations; a "commitment to pay fees without any evidence that mitigation will actually occur is inadequate" under CEQA, and fictitious or non-verifiable offsets therefore cannot constitute

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155 *See* United States Environmental Protection Agency, Methane, at *http://www.epa.gov/methane/projections.html* (last checked September 15, 2007).

156 Even projects widely viewed as otherwise socially and environmentally desirable-installing infill or low income housing, for example, or operating water-recycling facilities, or developing transit systems-still create GHG emissions, unless those projects are able to purchase their energy from sustainable sources. On-site mitigation measures can and should be used to reduce those emissions, but rarely will those measures eliminate emissions entirely.

157 *See* The Climate Trust, About Offsets, at *http://www.climatetrust.org/about_offsets.php* (last checked September 15, 2007).

158 *See, e.g., id.*

159 *See* 14 Cal. Code Regs. § 15130(a)(3) (allowing this practice).

160 *E.g.*, Berkeley Keep Jets over the Bay Com. v. Board of Port Commissioners, 91 Cal. App. 4th 1344, 1365 (2001) (referring to this technique); Kings County Farm Bureau v. City of Hanford, 221 Cal. App. 3d 692, 713 (1990) (same).

proper mitigation.[161] But so long as the reality of reductions or sequestration is rigorously verifiable, emissions trades should pass legal muster. Emissions trades also can facilitate mitigation that otherwise would not occur. While CEQA lead agencies sometimes may plausibly assert that off-site alternatives or on-site measures simply aren't capable of fully mitigating a project's emissions, purchasing offsets generally will be feasible; such offsets already are available.[162] Similarly, while project proponents might often argue that projects' climate change contributions are too small to justify full-scale environmental review or to necessitate alternatives or on-site mitigation methods, trading creates a correspondingly non-intrusive method for mitigating minor emissions. If a project's emissions contributions really are small, so too will be the cost of offsets, and *de minimis* arguments should provide no policy rationale for avoiding the mitigation measures that established CEQA rules require.[163] Trades thus can facilitate emissions reductions that agencies otherwise might not implement.

CONCLUSION

In coming years, local, state, and national governments will likely take many steps to regulate GHG emissions and reduce climate change. Those actions are indispensable; if we are to address this challenge, we have no choice but to develop new legal regimes and regulatory approaches. But the mandates of existing law also can help. The core principles of CEQA already require California's public agencies to evaluate and take steps toward addressing climate change. Compliance with those mandates can move the state-and, potentially, the nation and the world-toward resolving one of the most pressing environmental problems of our era.

This legal memo will be published in the Columbia Journal of Environmental Law in 2008.

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161 *City of Marina v. Board of Trustees of California State University*, 39 Cal. 4th 341, 365 (2006). For a critique of offsets, and an explanation of the transparency and verifiability problems poorly-designed offset programs can present, see TONY DUTZIK AND ROB SARGENT, STOPPING GLOBAL WARMING BEGINS AT HOME: THE CASE AGAINST THE USE OF OFFSETS IN A REGIONAL POWER SECTOR CAP-AND-TRADE PROGRAM 9-11 (2004). *See also* Fiona Harvey and Stephen Fidler, *Industry Caught in Carbon 'Smokescreen,'* FINANCIAL TIMES, April 25, 2007, at *http://www.ft.com/cms/s/48e334ce-f355-11db-9845-000b5df10621.html.*

162 *See, e.g.*, The Climate Trust, at *http://www.climatetrust.org/index.php* (last checked September 15, 2007); The Climate Exchange, *The Carbon Counter*, at *www.carboncounter.org*; A New Approach to Global Warming, THE ECONOMIST, Oct. 17, 2002 (describing the Chicago Climate Exchange); Jeff Goodell, Capital Pollution Solution?, NEW YORK TIMES, July 30, 2006 (discussing the Chicago Climate Exchange, and also describing the reservations of some of its critics).

163 *See Communities for a Better Environment v. California Resources Agency*, 103 Cal. App. 4th 98, 116-21 (2002) (rejecting a *de minimis* exception to CEQA's cumulative impacts requirements). Offsets thus could allow agencies pursuing low-emissions projects to avoid the expense of preparing an EIR. Rather than arguing, probably unsuccessfully, that their emissions are insignificant, those agencies could offset their contribution and thus proceed under a mitigated negative declaration.

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Additional online resources/environmental gateway pages:

Planning and Conservation League: *http://www.pcl.org/*

Planning and Conservation League Foundation: *http://www.pclfoundation.org/*

National Wildlife Federation: *http://www.nwf.org/*

National Environmental Trust: *http://www.net.org/*

U.S. Fish and Wildlife Service: *http://www.fws.gov/*

National Environmental Policy Act (NEPA): *http://www.law.indiana.edu/envdec/a.html*

California Resources Agency: *http://resources.ca.gov/*

California Department of Fish and Game: *http://www.dfg.ca.gov/*

California Natural Diversity Database: *http:/www.dfg.ca.gov/bdb/html/cnddb.html*

Information Center for the Environment (UC Davis): *http://ice.ucdavis.edu/*

CEQAnet database: *http://www.ceqanet.ca.gov/*

Intergovernmental Panel on Climate Change: *http://www.ipcc.ch/*

U.S. EPA Climate Change: *http://www.epa.gov/climatechange/*

Pew Center on Global Climate Change: *http://www.pewclimate.org/*

California Climate Change Portal: *http://www.climatechange.ca.gov/index.html*

California Climate Action Team and Climate Change Initiative:
http://www.climatechange.ca.gov/climate_action_team/index.html

California Air Resources Climate Change: *http://www.arb.ca.gov/cc/cc.htm*

California Air Resources Board Climate Change Program for Mobile Sources:
http://www.arb.ca.gov/cc/ccms/ccms.htm

California Energy Commission Climate Change Proceedings:
http://www.energy.ca.gov/global_climate_change/

California Climate Action Registry: *http://www.climateregistry.org/Default.aspx?refreshed=true*

Our Changing Climate: Assessing the Risks to California - Summary Report
California Climate Change Center:
http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF

Progress on Incorporating Climate Change into Management of California's Water Resources
California Department of Water Resources:
http://baydeltaoffice.water.ca.gov/climatechange/DWRClimateChangeJuly06.pdf
Inventory of California Greenhouse Gas Emissions and Sinks 1990-2004 California Energy Commission:
http://www.climatechange.ca.gov/policies/greenhouse_gas_inventory/index.html

Technical Support Document for Staff Proposal Regarding Reduction of Greenhouse Gas Emissions from Motor Vehicles - Climate Change Overview (2004) California Air Resources Board:

http://www.arb.ca.gov/cc/factsheets/support_ccoverview.pdf

Guidebook for Implementation of Senate Bill 610 and Senate Bill 221 of 2001:
http://www.owue.water.ca.gov/Guidebook.pdf

CEQA net database: *http://www.ceqanet.ca.gov/*

Publications about CEQA

Guide to the California Environmental Quality Act
By Tina A. Thomas, James G. Moose, and Whitman F. Manley
(2006 [Eleventh] edition Solano Press) Single soft bound volume.
This is a very complete review of CEQA and includes a listing of the major CEQA cases, and useful index to topics covered in this book. The 2006 edition costs $85 plus tax, shipping and handlings. To order call Solano Press at (800) 931-9373. Solano press is also on the Internet at:0 *http://www.solano.com* email address: *spbooks@solano.com.*

Practice Under the California Environmental Quality Act
By Stephen Kostka and Michael Zischke 2-volume loose leaf.
This is also a very complete review of CEQA and includes the statute, Guidelines, and an index. Because it is loose leaf within a hard-shell three ring binder, it is updated regularly. (The last updated version costs $263.00 plus shipping and handling.) To order, call CEB at (800) 232-3444. Order online: *www.ceb.com.*

The California Environmental Quality Act - On the Front Line of California's Fight Against Global Warming
By Siegel, Vespa & Nowicki (Center for Biological Diversity, September 2007)
To download this report go to:
http://www.biologicaldiversity.org/swcbd/programs/policy/energy/CBD-CEQA-white-paper-10-03-07.pdf

Other Publications Referred to in Guide

An Inconvenient Truth - The Planetary Emergency of Global Warming and What We Can Do About It
By Al Gore (2006, RODALE).

Everyday Heroes Protect the Air We Breath, the Water We Drink, and the Natural Areas We Prize; Thirty Five Years of the California Environmental Quality Act
By PCL, PCL Foundation and California League of Conservation Voters
Everyday Heroes is a compilation of over 75 California Environmental Quality Act success stories written by a number of California's environmental leaders. You can download this report visiting: *http://www.pcl.org/projects/everydayheroes.html* or purchase a hard copy visiting: *http://www.pclfoundation.org/general/publications.html.*

Sciencexpress Report

Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America

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How anthropogenic climate change will impact hydroclimate in the arid regions of Southwestern North America has implications for the allocation of water resources and the course of regional development. Here we show that there is a broad consensus amongst climate models that this region will dry significantly in the 21st century and that the transition to a more arid climate should already be underway. If these models are correct, the levels of aridity of the recent multiyear drought, or the Dust Bowl and 1950s droughts, will, within the coming years to decades, become the new climatology of the American Southwest.

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reported that the average of all the participating models showed a general decrease in rainfall in the subtropics during the 21st century although there was also considerable disagreement amongst the models (*1*). Subtropical drying accompanying rising CO_2 is also found in the models participating in the second Coupled Model Intercomparison Project (*2*). Here we examine future subtropical drying by analyzing the time history of precipitation in 19 climate models participating in the Fourth Assessment Report (AR4) of the IPCC (*3*). The future climate projections followed the A1B emissions scenario (*4*) in which CO_2 emissions increase until about 2050 and decrease modestly thereafter leading to a CO_2 concentration of 720 ppm in 2100. We also analyzed the simulations by these models of the 1860–2000 period in which the models were forced by the known history of trace gases and, with some variation amongst the models, estimated changes of solar irradiance, volcanic and anthropogenic aerosols and land use. These simulations provide initial conditions for the 21st century climate projections. For each model, climatologies were computed over the 1950–2000 period by averaging over all the simulations available for each model. All climate changes shown are departures from this climatology.

We define an area (shown as a box on Fig. 4) called 'The Southwest' including all land between 125°W and 95°W and 25°N and 40°N that incorporates the southwestern United States and parts of northern Mexico . Fig. 1 shows the modeled history and future of the annual mean precipitation minus evaporation (*P–E*) averaged over this region for the period common to all the models, 1900–2098. The median, 25th and 75th percentiles of the model *P–E* distribution and the median of *P* and *E* are shown. For cases in which there were multiple simulations with a single model these were averaged together before computing the distribution. *P–E* equals the moisture convergence by the atmospheric flow and, over land, the amount of water that goes into runoff.

In the multi-model ensemble mean there is a transition to a sustained drier climate that begins in the late 20th and early 21st centuries. In the ensemble mean both *P* and *E* decrease but the former by a larger amount. *P–E* primarily reduces in winter when *P* reduces and *E* is unchanged or modestly increased while in summer both *P* and *E* decrease (not shown). The annual mean reduction in *P* for this region, calculated from rain gauge data within the Global Historical Climatology Network, was 0.09 mm/day between 1932 and 1939 (the Dust Bowl drought) and 0.13 mm/day between 1948 and 1957 (the 1950s Southwest drought). The ensemble median reduction in *P* that drives the reduction in *P–E* reaches 0.1 mm/day in mid-century and one quarter of the models reach this in the early part of the current century.

Figure 2 shows for the 19 models the annual mean *P–E* difference between 20 year periods in the 21st century and the model's 1950–2000 climatology. Almost all models have a drying trend in the American Southwest and consistently so throughout the century. Only one of the 19 models has a trend to a wetter climate. Of the total of 49 individual projections conducted with the 19 models, even as early as the 2021 to 2040 period, only 3 show a shift to a wetter climate. Examples of modeled history and future precipitation for single simulations of four individual models are shown in Fig. 3 and provide an idea of potential trajectories towards the more arid climate.

Figure 4 shows (contours, all panels) a map of the change in *P–E* for the decades between 2021 and 2040 minus the

enclosure (9)

1950–2000 period for one of the IPCC models: the Geophysical Fluid Dynamics Laboratory climate model CM2.1 (5). In general, large regions of the relatively dry subtropics dry further while wetter higher latitude regions become wetter still. In addition to the American Southwest, the Southern Europe-Mediterranean-Middle East region also experiences a severe drying. This pattern of subtropical drying and moistening at higher latitudes is a robust feature of current projections with different models of future climate (6).

The change (δ) in $P-E$ (in m/s) is balanced by a change in atmospheric moisture convergence, viz.:

$$\rho_w g\delta(P-E) = -\delta\left(\int_0^{p_s} \nabla\cdot(\overline{\underline{u}q})dp + \int_0^{p_s} \nabla\cdot(\overline{\underline{u}'q'})dp\right) \quad (1)$$

Overbars indicate monthly means and primes departures from the monthly mean, ρ_w is the density of water. The change in moisture convergence can be divided into contributions from the 'mean flow' and from 'eddies'. In the former the atmospheric flow $(\overline{\underline{u}})$ and the moisture $(\overline{q})$ are averaged over a month before computing the moisture transport, while the latter is primarily associated with the highly variable wind ($\underline{u}'$) and moisture (q') fields within storm systems. The moisture convergence is integrated over pressure (p) from the top of the atmosphere ($p = 0$) to the surface (p_s). The mean wind and humidity fields in Eq. 1 can be taken to be their climatological fields. (The rectification of interannual variability in the monthly mean flow and moisture fields is found to be negligible.) Changes in the mean flow contribution can, in turn, be approximated by one part associated with the 1950–2000 climatological circulation $(\overline{\underline{u}}_P)$ operating on the increase in climatological atmospheric humidity ($\delta\overline{q}$, a consequence of atmospheric warming) and another part due to the change in circulation climatology $(\delta\overline{\underline{u}})$ operating on the 1950–2000 atmospheric humidity climatology $(\overline{q}_P)$. The nonlinear term involving changes in both the mean flow and moisture field is found to be relatively small (not shown). Hence Eq. 1 can be approximated by:

$$\rho_w g\delta(P-E) \sim -\int_0^{p_s} \nabla\cdot(\overline{q}_P\delta\overline{\underline{u}} + \overline{\underline{u}}_P\delta\overline{q})dp - \delta\int_0^{p_s} \nabla\cdot(\overline{\underline{u}'q'})dp \quad (2)$$

We therefore think in terms of a three-fold decomposition of $P-E$, as displayed in Fig. 4 (colors) for the GFDL CM2.1 model: a contribution from the change in mean circulation, a contribution from the change in mean humidity, and a contribution from eddies.

The mean flow convergence term involving only changes in humidity (Fig. 4B) causes increasing $P-E$ in regions of low level mean mass convergence and decreasing $P-E$ in regions of low level mean mass divergence, generally intensifying the existing pattern of $P-E$ (6). This term helps explain much of the reduction in $P-E$ over the subtropical oceans where there is strong evaporation, atmospheric moisture divergence and low precipitation (6). Over land areas, in general, there is no infinite surface water source and $P-E$ has to be positive and sustained by atmospheric moisture convergence. Over the American Southwest, in the current climate, it is the time varying flow that sustains most of the positive $P-E$ while the mean flow diverges moisture away. Here, the 'humidity contribution' leads to reduced $P-E$ as the moisture divergence by the mean flow increases with rising humidity. Over the Mediterranean region there is mean moisture divergence and again rising humidity leads to increased mean moisture divergence and reduced $P-E$.

Over the ocean the contribution of humidity changes to changes in $P-E$ can be closely approximated by assuming that the relative humidity remains fixed at its 1950–2000 values (6). Over almost all land areas, and especially over those that have reduced $P-E$, the relative humidity decreases in the early 21st century. This is because, unlike over the ocean, evaporation cannot keep pace with the rising saturation humidity of the warming atmosphere. Over land the humidity contribution to the change in $P-E$ is distinct from that associated with fixed relative humidity.

Decreases in $P-E$ can also be sustained by changes in atmospheric circulation that alter the mean moisture convergence even in the absence of changes in humidity (Fig. 4A). This 'mean circulation contribution' leads to reduced $P-E$ at the northern edge of the subtropics (e.g. the Mediterranean region, the Pacific and Atlantic around 30°N and parts of southwestern North America). The change in moisture convergence by the transient eddies (Fig. 4C) dries southern Europe and the subtropical Atlantic and moistens the higher latitude Atlantic but does not have a coherent and large impact over North America.

A significant portion of the mean circulation contribution, especially in winter, can be accounted for by the change in zonal mean flow alone (not shown), indicating that changes in the Hadley Cell and the extratropical mean meridional circulation are important. In summary, increases in humidity and mean moisture divergence, changes in atmospheric circulation and intensification of eddy moisture divergence, cause drying in the subtropics, including over western North America and the Mediterranean region. For the Southwest region, the annual mean $P-E$ reduces by 0.086 mm/day which is largely accounted for by an increase in the mean flow moisture divergence. Changes in the circulation alone contribute 0.095 mm/day of drying and changes in the humidity alone contribute 0.032 mm/day. This is modestly offset by an increased transient eddy moisture convergence of 0.019 mm/day.(7).

Within models the poleward edge of the Hadley Cell and the mid-latitude westerlies move poleward during the 21st century (*8–10*). The descending branch of the Hadley Cell causes aridity and hence the subtropical dry zones expand poleward. In models, a poleward circulation shift can be forced by rising tropical SSTs in the Indo-Pacific region (*11*) and by uniform surface warming (*12*). The latter results are relevant because the spatial pattern of surface warming in the AR4 models is quite uniform away from the poles. One explanation (*13, 14*) is that rising tropospheric static stability, an established consequence of moist thermodynamics, stabilizes the subtropical jet streams at the poleward flank of the Hadley Cell to baroclinic instability. Consequently the Hadley Cell extends poleward, increasing the vertical wind shear at its edge, to a new latitude where the shear successfully compensates for the suppression of baroclinic instability by rising static stability.

While increasing stability is likely to be a significant component of the final explanation, a fully satisfying theory for the poleward shift of the zonal mean atmospheric circulation in a warming world must account for the complex interplay between the mean circulation (Hadley Cell and the mid-latitude Ferrell Cell) and the transient eddies (*13*, *14*) that will determine where precipitation will increase and decrease in the future. However not all of the subtropical drying in the Southwest and Mediterranean region can be accounted for by zonally symmetric processes and a full explanation will require attention to moisture transport within localized storm tracks and stationary waves.

The six severe, multiyear, droughts that have struck western North America in the instrumental record have all been attributed, using climate models, to variations of sea surface temperatures (SSTs) in the tropics, particularly persistent La Niña-like SSTs in the tropical Pacific Ocean (*15–19*). The future climate of intensified aridity in the Southwest is caused by different processes since the models vary in their tropical SST response to anthropogenic forcing. Instead it is caused by rising humidity that causes increased moisture divergence and changes in atmospheric circulation cells that include a poleward expansion of the subtropical dry zones. The drying of subtropical land areas that, according to the models is imminent or already underway, is unlike any climate state we have seen in the instrumental record. It is also distinct from the multidecadal megadroughts that afflicted the American Southwest during Medieval times (*20-22*) which have also been attributed to changes in tropical SSTs (*18, 23*). The most severe future droughts will still occur during persistent La Niña events but they will be worse than any since the Medieval period because the La Niña conditions will be perturbing a base state that is drier than any experienced recently (*25*).

References and Notes

1. U. Cubasch et al., in *Climate Change 2001 - The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (Eds. Houghton, J.T. et al.) (Cambridge University Press, 2001), pp. 525–582.
2. M. R. Allen and W. J. Ingram, *Nature* **419**, 224 (2002).
3. Details of the models analyzed can be found at http://www-pcmdi.llnl.gov/ipcc/model_documentation/ipcc_model_documentation.php and the data at https://esg.llnl.gov:8443/index.jsp.
4. N. Nakicenovic, R. Swart (Eds.), *Special Report on Emissions Scenarios* (Cambridge University Press, New York, 2000).
5. T. L. Delworth et al., *J. Climate* **19**, 643 (2006).
6. I. M. Held, B. J. Soden, *J. Climate* **19**, 5686 (2006).
7. The model P–E is not fully accounted for by the computed moisture flow convergence by the sum of the components of the mean flow and transient eddies (the imbalance is 0.022 mm/day). Calculations were performed with daily data on the model grid using closely matching numerics but errors can be introduced by not using sub-daily data and by neglect of moisture diffusion, potentially large over mountains) which was not archived. The data is available at http:/kage.ldeo.columbia.edu/SOURCES/.LDEO/.ClimateGroup/.GFDL.
8. J. H. Yin, *Geophys. Res. Lett.* doi:10.1029/2005GL023684 (2005).
9. P. J. Kushner, I. M. Held and T. L. Delworth, *J. Climate* **14**, 2238 (2001).
10. L. Bengtsson, K. I. Hodges and E. Roeckner, *J. Climate* **19**, 3518-3543.
11. N.-C. Lau. A. Leetmaa and M. J. Nath, *J. Climate* **19**, 3607 (2006).
12. S. Lee, *J. Atmos. Sci.* **56**, 1353 (1999).
13. T. Schneider, *Ann. Rev. Earth Plan. Sci.* **34**, 655 (2006).
14. C. C. Walker and T. Schneider, *J. Atmos. Sci.* **63**, 3333.
15. 13. S. D. Schubert, M. J. Suarez, P. J. Region, R. D. Koster, J. T. Bacmeister, *Science* **303**, 1855 (204).
16. S. D. Schubert, M. J. Suarez, P. J. Region, R. D. Koster, J. T. Bacmeister, *J. Climate* **17**, 485 (2004).
17. R. Seager, Y. Kushnir, C. Herweijer, N. Naik, J. Velez. *J. Climate* **18**, 4068 (2005).
18. C. Herweijer, R. Seager and E. R. Cook, *The Holocene* **16**, 159 (2006)
19. H.-P. Huang, R. Seager and Y. Kushnir, *Clim. Dyn.* **24**, 721 (2005).
20. S. Stine, *Nature* **369**, 546 (1994).
21. E. R. Cook, C. A. Woodhouse, M. Eakin, D. M. Meko and D. W. Stahle, *Science* **306**, 1015(2004).
22. C. Herweijer, R. Seager, E. R. Cook and J. Emile-Geay, *J. Climate* **20**, 1353.

23. E. R. Cook, R. Seager, M. A. Cane, D. W. Stahle, *Earth Sci. Rev.* **81**, 93 (2007).
24. This work was supported at LDEO by NOAA grants NA03OAR4320179, NA06OAR4310151, NA03OAR4320179 and NA03OAR4320179, and NSF grants ATM05-01878 and ATM03-47009. We thank R. Dole, W. Robinson, and M. Wallace for useful conversations

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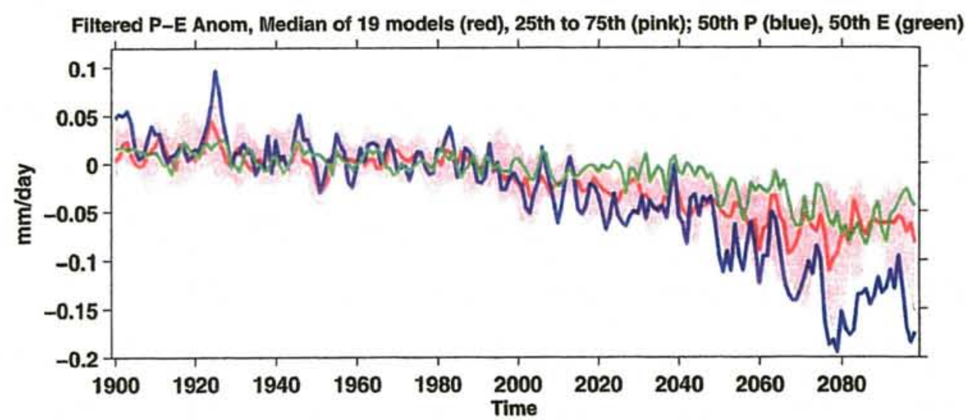
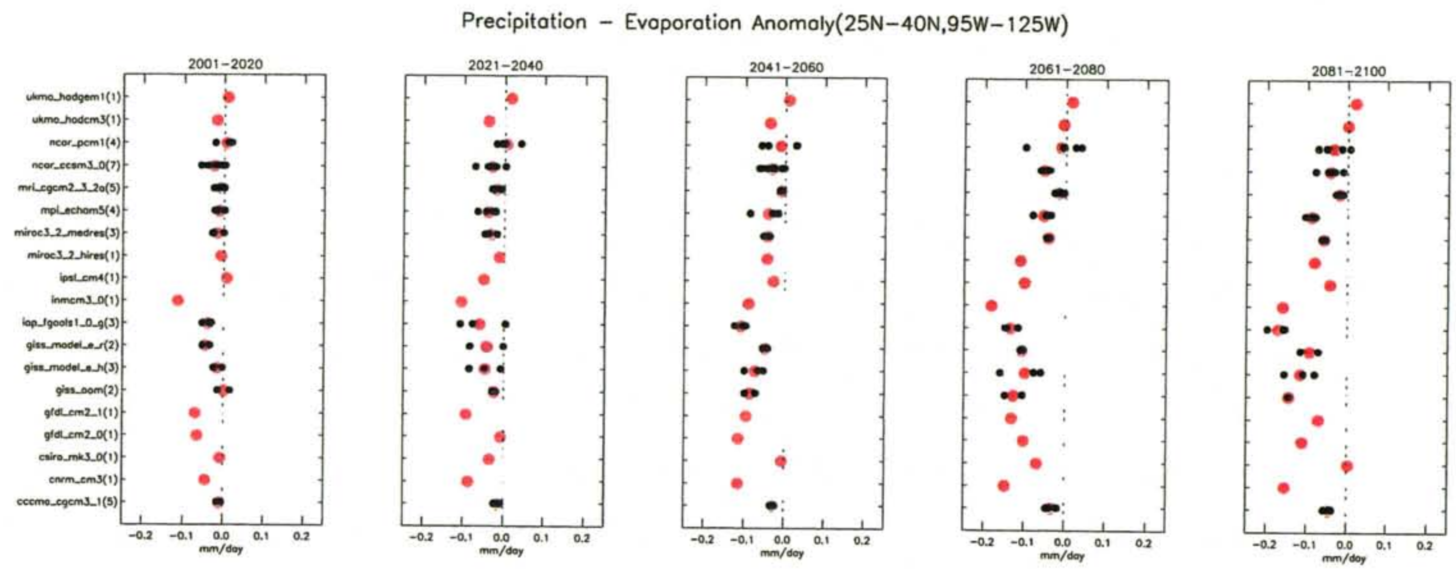
Fig. 1: Modeled changes in annual mean precipitation minus evaporation over the American Southwest (125°W–95°W, 25°N–40°N, land areas only) averaged over ensemble members for each of the 19 models. The historical period used known and estimated climate forcings and the projections used the SResA1B emissions scenario. Shown are the median (red line) and 25th and 75th percentiles (pink shading) of the *P–E* distribution amongst the 19 models, and the ensemble medians of *P* (blue line) and *E* (green line) for the period common to all models (1900 to 2098). Anomalies for each model are relative to that model's climatology for 1950–2000. Results have been six year low pass Butterworth filtered to emphasize low frequency variability that is of most consequence for water resources. Units are in mm/day. The model ensemble mean *P–E* in this region is around 0.3 mm/day.

Fig. 2: The change in annual mean *P–E* over the American Southwest (125°W–95°W, 25°N–40°N, land areas only) for 19 models relative to model climatologies for 1950-2000. Results are averaged over twenty year segments of the current century. The number of ensemble members for the projections are listed by the model name at left. Black dots represent ensemble members, where available, and red dots represent the ensemble mean for each model. Units are in mm/day.

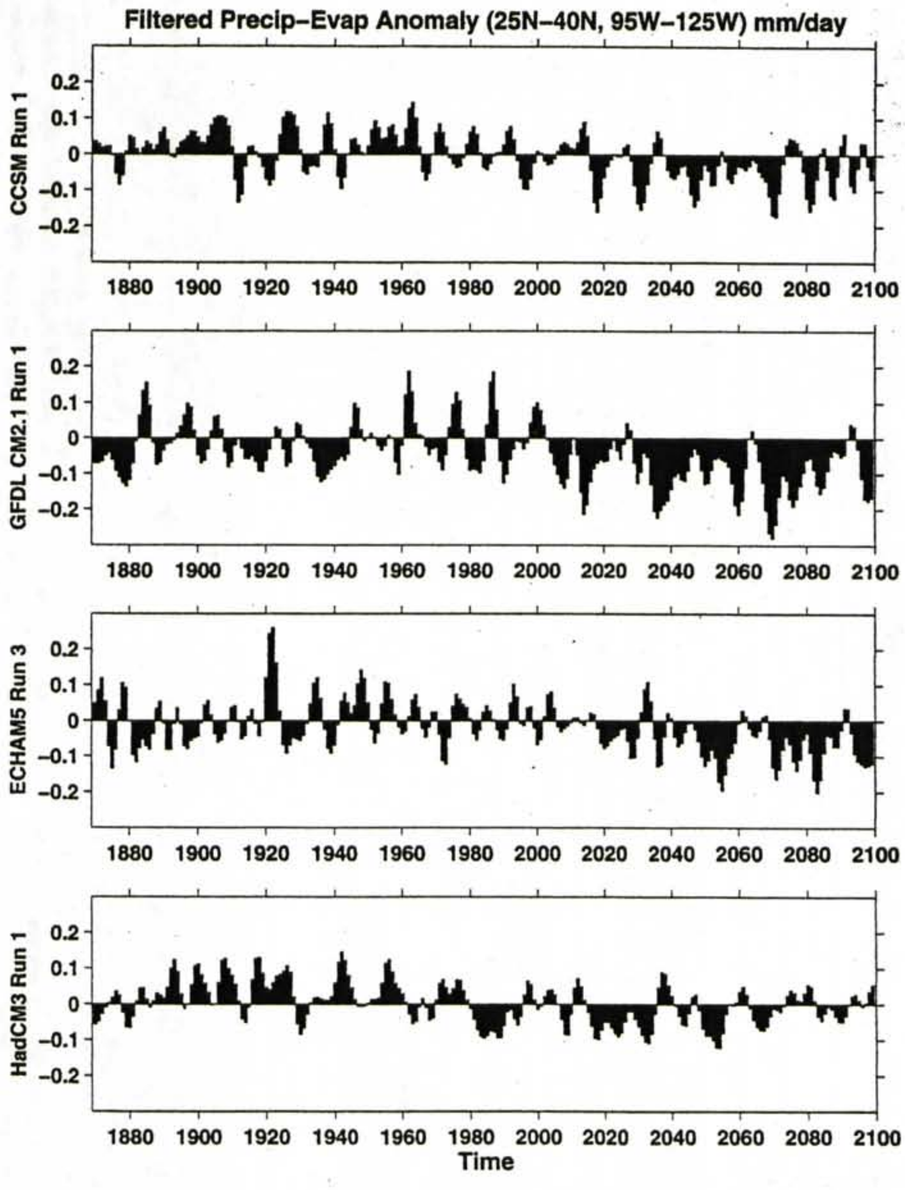
Fig. 3: The change in annual mean *P–E* over the American Southwest (125°W–95°W, 25°N–40°N, land areas only) for four coupled models relative to model ensemble mean climatologies for 1950–2000. The results are from individual simulations of the 1860 to 2000 period forced by known and estimated climate forcings and individual projections of future climate using the SResA1B scenarios of climate forcings. Since the modeled anomalies have not been averaged together here these time series provide an idea of plausible evolutions of Southwest climate towards a more arid state. The models are the National Center for Atmospheric Research Community Climate System Model, Geophysical Fluid Dynamics Laboratory model CM2.1, Max Planck Institut Für Meteorologie model ECHAM5 and Hadley Centre for Climate Change model HadCM3. All time series are for annual mean data and a six year low pass Butterworth filter has been applied. Units are in mm/day.

Fig. 4: The change in annual means of *P–E* for 2021–2040 minus 1950–2000 (all panels, contours) and contributions to the change in vertically integrated moisture convergence (colors, negative values imply increased moisture divergence) by the mean flow due to changes in the flow (top), the specific humidity (middle) and the transient eddy moisture convergence (bottom), all for the GFDL CM2.1 model. The box shows the area we define as the "Southwest."


Filtered P–E Anom, Median of 19 models (red), 25th to 75th (pink); 50th P (blue), 50th E (green)
mm/day
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
Time

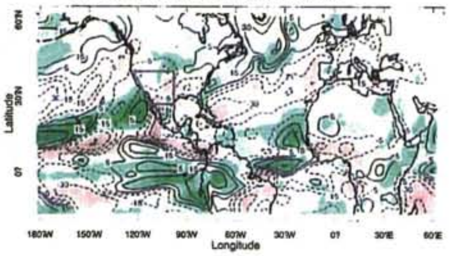


Precipitation - Evaporation Anomaly(25N-40N,95W-125W)
2001-2020
2021-2040
2041-2060
2061-2080
2081-2100
ukmo_hadgem1(1)
ukmo_hadcm3(1)
ncar_pcm1(4)
ncar_ccsm3_0(7)
mri_cgcm2_3_2a(5)
mpi_echam5(4)
miroc3_2_medres(3)
miroc3_2_hires(1)
ipsl_cm4(1)
inmcm3_0(1)
iap_fgoals1_0_g(3)
giss_model_e_r(2)
giss_model_e_h(3)
giss_aom(2)
gfdl_cm2_1(1)
gfdl_cm2_0(1)
csiro_mk3_0(1)
cnrm_cm3(1)
cccma_cgcm3_1(5)
-0.2
-0.1
0.0
0.1
0.2
mm/day

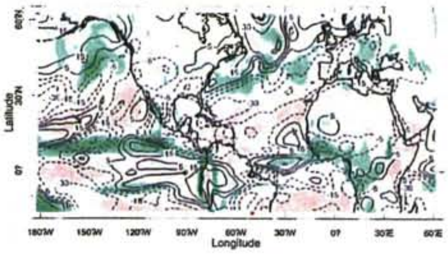

Filtered Precip-Evap Anomaly (25N-40N, 95W-125W) mm/day
CCSM Run 1
GFDL CM2.1 Run 1
ECHAM5 Run 3
HadCM3 Run 1
0.2
0.1
0
-0.1
-0.2
1880 1900 1920 1940 1960 1980 2000 2020 2040 2060 2080 2100
Time

Contributions to Change in Moisture Convergence (2021-2040) - (1950-2000)

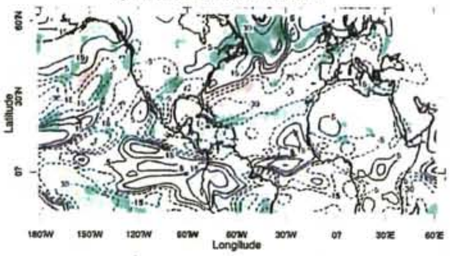
a) Mean Circulation Contribution



b) Q Contribution to Mean



c) Transient Contribution



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An imminent transition to a more arid climate in southwestern North America

Richard Seager
Lamont-Doherty Earth Observatory of Columbia University

Low water at Lake Powell (April 2003. Farley Canyon), photo by Eric Nyre, Canoe Colorado.

Take home lessons:

1. **Southwestern North America and other subtropical regions are going to become increasingly arid as a consequence of rising greenhouse gases.**
2. **The transition to a drier climate should already be underway and will become well established in the coming years to decades, akin to permanent drought conditions.**
3. **This is a robust result in climate model projections that has its source in well represented changes in the atmospheric hydrological cycle related to both rising humidity in a warmer atmosphere and poleward shifts of atmospheric circulation features.**

Projections of anthropogenic climate change conducted by nineteen different climate modeling groups around the world, using different climate models, show widespread agreement that Southwestern North America - and the subtropics in general - are on a trajectory to a climate even more arid than now. According to the models, human-induced aridification becomes marked early in the current century. In the Southwest the levels of aridity seen in the 1950s multiyear drought, or the 1930s Dust Bowl, become the new climatology by mid-century: a perpetual drought. *A PDF of the complete article (Seager et.al, 2007) can be downloaded from Science Express.*

Mechanisms of Southwest and subtropical drying

Drying of the Southwest and the subtropics are caused by large scale changes in the atmospheric branch of the hydrological cycle. There are two aspects of this:

1. The subtropics are already dry because the mean flow of the atmosphere moves moisture out of these regions whereas the deep tropics and the higher latitudes are wet because the atmosphere converges moisture into those regions. As air warms it can hold more moisture and this existing pattern of the divergence and convergence of water vapor by the atmospheric flow intensifies. This makes dry areas drier and wet areas wetter.
2. As the planet warms, the Hadley Cell, which links together rising air near the Equator and descending air in the subtropics, expands poleward. Descending air suppresses precipitation by drying the lower atmosphere so this process expands the subtropical dry zones. At the same time, and related to this, the rain-bearing mid-latitude storm tracks also shift poleward. Both changes in atmospheric circulation, which are not fully understood, cause the poleward flanks of the subtropics to dry.

Besides Southwestern North America other land regions to be hit hard by subtropical drying include southern Europe, North Africa and the Middle East as well as parts of South America.

Future drying: historical droughts and Medieval megadroughts

The dynamical causes of imminent subtropical drying appear distinct from the causes of historical North American droughts such as occurred in the 1950s and during the 1930s Dust Bowl. Climate modeling has led to those being related to small, naturally occurring, changes in tropical Pacific (and, to a lesser extent, tropical Atlantic) sea surface temperature that also drive a change in atmospheric circulation that places anomalous

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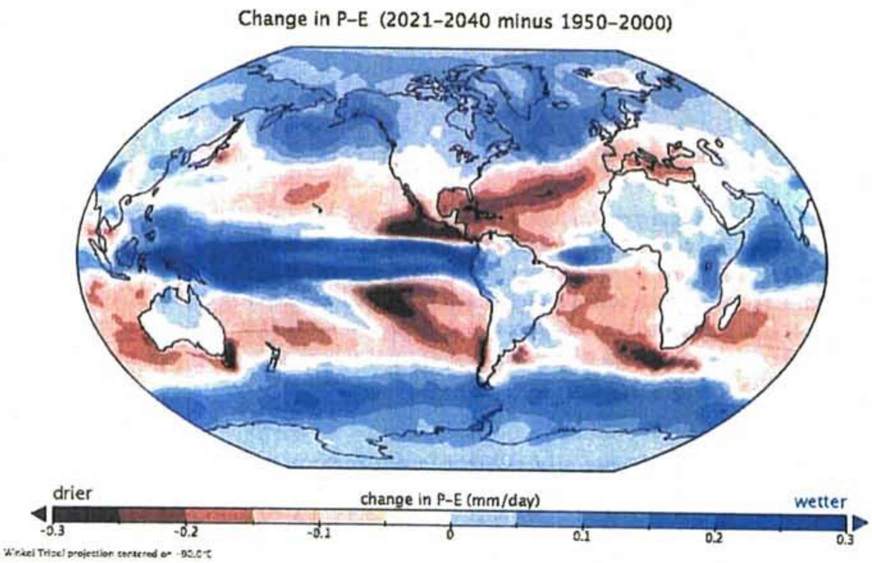
descent over Southwestern North America. See our Drought Research homepage and the page on the Causes and consequences of the nineteenth century droughts in North America.

The succession of 'megadroughts' - droughts like the Dust Bowl but which lasted for decades at a time - that occurred in the West in Medieval times have also been linked to equally persistent La Nina-like conditions in the tropical Pacific. However it is thought that the Sun was relatively strong at this time and volcanism weak which both would have resulted in positive radiative forcing of the climate system akin to rising greenhouse gases today. The differences and similarities of future drying with the Medieval megadroughts, and their global atmosphere-ocean contexts, needs to be determined. See our page on the North American Medieval megadroughts.

In contrast to historical droughts, future drying is not linked to any particular pattern of change in sea surface temperature but seems to be the result of an overall surface warming driven by rising greenhouse gases. Evidence for this is that subtropical drying occurs in atmosphere models alone when they are subjected to uniform increases in surface temperature.

Will this really happen and what are the implications?

Imminent drying of the Southwest and subtropics in the models is such a robust result because it does not depend on poorly understood and highly parameterized parts of the model (such as cloud physics) but instead arises as a response of the large scale atmospheric dynamics - which we think is quite well represented in models - to a warming world. Similarly there is little reason to think that the models are wrong to have this response even if the dynamics involved need to be fully worked out.



Change in precipitation (P) minus surface evaporation (E) for the 2021-2040 period minus the average over 1950-2000. Results are averaged over simulations with 19 different climate models. P-E is the net flux of water at the surface that, over land, sustains soil moisture, groundwater and river runoff. Figure by N. Naik.

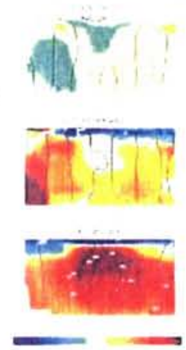
Drying of arid lands in the southwestern United States and northern Mexico will have important consequences for water resources, regional development and cross border relations and migration. According to the models the drying should already be underway and, over the length of time it takes to plan significant changes in water resource engineering and allocation (years to a few decades), will become well established.

How could we tell if this is happening?

(click on figure to enlarge)

The historical droughts were forced by natural variability of the tropical atmosphere-ocean system: persistent La Nina-like events in the tropical Pacific with a warm subtropical North Atlantic sometime playing a supporting role. Future drying is caused by overall warming. The aspect of the atmospheric circulation common to both is poleward shifted jet streams and mid-latitude storm tracks. But there are important differences that may allow identification of whether any drought that occurs is a naturally occurring one - and can be expected to end - or is anthropogenic - and can be expected to continue. For example droughts associated with persistent

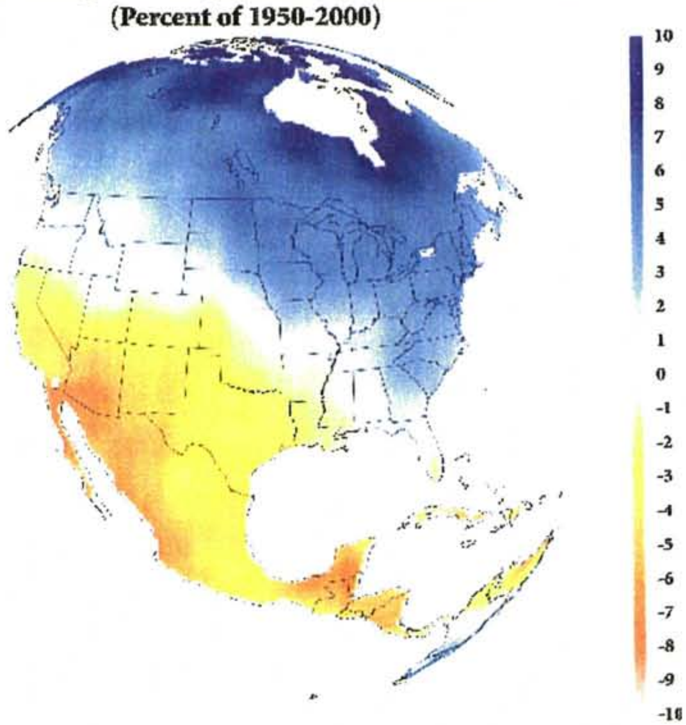
La Nina events involve increased heat uptake in the eastern and central equatorial Pacific Ocean and, hence, a cool tropical troposphere. The atmospheric dynamical response to this induces warming in the mid-latitudes. In contrast anthropogenic droughts will go along with warming almost everywhere and a maximum warming in the upper tropical troposphere. The tropical and subtropical zonal mean zonal winds are, necessarily, also distinct for natural and anthropogenic droughts. These differences may allow identification of onset of anthropogenic drying. Why La Nina events and global warming both induce subtropical drying is an active topic of research in atmospheric dynamics. Click on the thumbnail on the right for a relevant figure.



See also the GFDL Climate Modeling Research Highlight (volume 1, n5): *Will the wet get wetter and the dry drier?*

This work was performed as a collaboration of the scientists at Lamont-Doherty Earth Observatory (R. Seager, M.F. Ting, Y. Kushnir, H.-P. Huang, J. Velez, C. Li, N. Naik) NOAA Geophysical Fluid Dynamics Laboratory (I.M. Held, G. Vecchi, N.-C. Lau, A. Leetmaa) the National Center for Atmospheric Research (J. Lu) and Tel-Aviv University (N. Harnik).

Projected Change in Precipitation 1950-2000 to 2021-2040
(Percent of 1950-2000)



Projected change in precipitation for the 2021-2040 period minus the average over 1950-2000 as a percent of the 1950-2000 precipitation. Results are averaged over simulations with 19 different climate models. Figure by G. Vecchi.

References:

- R. Seager, M.F. Ting, I.M. Held, Y. Kushnir, J. Lu, G. Vecchi, H.-P. Huang, N. Harnik, A. Leetmaa, N.-C. Lau, C. Li, J. Velez, N. Naik, 2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. *Science*, Vol. 316. no. 5828, pp. 1181 - 1184 DOI: 10.1126/science.1139601. PDF

News Articles:

- "Denial in the Desert" by Mike Davis. *The Nation*, Tuesday, April 3, 2007.
- "Return of the dust bowl? Climate change set to make the arid southwest even drier" by Daemon Fairless. *news@nature.com*, Thursday, April 5, 2007.
- "Study Sees Drought Trend in U.S. Southwest". *NPR* , Friday, April 6, 2007,The Day to Day Program.
- "Southwest May Get Even Hotter. Drier" *Washington Post* , Friday, April 6, 2007; Page A03,
- And too many others to mention, see the Google news search for Friday Afternoon, April 6, 2006.

Opinions expressed are those of the authors and not necessarily those of their institutions.

Maintained by: Naomi Naik, Lamont-Doherty Earth Observatory of Columbia University

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enclosure (11)

County of Tulare

Administration Bldg.
2800 West Burrel
Visalia, CA 93291

TEL: (559) 733-6271
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September 25, 2007

Assemblyman Bill Maze
5959 S. Mooney Blvd.
Visalia, CA 93277

Dear Assemblyman Maze:

There is an impending water crisis facing Tulare County and all of California. This is an ongoing problem, and the situation will only worsen in the coming years.

In September of 2006, the Friant Water Users Authority reached an agreement that will restore water flows down the San Joaquin River to help sustain a salmon fishery. This will force a reduction in water to Friant users at an average of 19% and a maximum of 23%. Friant contractors include the City of Lindsay, the City of Orange Cove, and the community of Strathmore, among others. The City of Fresno receives 40% of its water from the Friant system.

In August 2007, Judge Oliver Wanger reached a decision to reduce pumping in the Sacramento-San Joaquin Delta to save an endangered fish; the Delta Smelt. As a result, water supplies to Northern, Central, and Southern California will be reduced by 14-35%. An estimated 25 million people statewide use water from the Delta. The Central Valley, the Bay Area and Los Angeles will be affected by this ruling.

The decreased supply of surface water will lead to more pumping from the underground aquifers. We are currently in an overdraft situation, and the two recent lawsuits will further exacerbate this problem. Pumping additional water can lead to higher levels of contaminants in our residents' drinking water.

As you can see, the current water situation in Tulare County is in dire need of assistance. Losing water will affect agriculture and people. Our citizens will be left with a minimal supply of drinking water, and our farmers will not be able to irrigate their crops. Something must be done about this dangerous situation.

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We urge you to support the Governor's plans for additional water storage and to impress upon your urban colleagues the need to endorse his plan. It is time to take action on this issue of great importance.

Sincerely,

Allen Ishida, Chairman
Tulare County Board of Supervisors

Connie Conway, Vice-Chairman
Tulare County Board of Supervisors

Phil Cox, District Three
Tulare County Board of Supervisors

J. Steven Worthley, District Four
Tulare County Board of Supervisors

Mike Ennis, District Five
Tulare County Board of Supervisors

CC: Tulare County Legislative Delegation

SOURCES OF DATA ON GROUNDWATER IMPACTS THAT HAVE BEEN ATTRIBUTED TO IRRIGATED AGRICULTURE

Barrow, K.R., Shelton, J.L., and Dubrovsky, N.M., OCCURRENCE OF NITRATE AND PESTICIDES IN GROUND WATER BENEATH THREE AGRICULTURAL LAND-USE SETTINGS IN THE EASTERN SAN JOAQUIN VALLEY, CALIFORNIA, 1993–1995 U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 97-4284 NATIONAL WATER-QUALITY ASSESSMENT PROGRAM.
http://ca.water.usgs.gov/sanj/pub/usgs/wrir97-4284/wrir97-4284.pdf

Burow, K.R., Pashin, S.Y., Dubrovsky, N.M., Vanbrocklin, D., *and* Fog, G.E., Evaluation of Processes Affecting 1,2-Dibromo-3-Chloropropane (DBCP) Concentrations in Ground Water in the Eastern San Joaquin Valley, California: Analysis of Chemical Data and Ground- Water Flow and Transport Simulations Prepared in cooperation with the UNIVERSITY OF CALIFORNIA, DAVIS, U.S. Geological Survey Water-Resources Investigations Report 99-4059.
http://ca.water.usgs.gov/sanj/pub/usgs/wrir99-4059/wrir99-4059.pdf

Shallow Ground-Water Quality Beneath Rice Areas in the Sacramento Valley, California, 1997 U.S. Geological Survey Water-Resources Investigations Report 01-4000, 33 p. Available on-line.

http://water.usgs.gov/pubs/wri/wri014125/wrir01-4125.pdf Ground-Water Quality in the Southeastern Sacramento Valley Aquifer, California, 1996 U.S. Geological Survey Water-Resources Investigations Report 01-4125, 24 p.

Quality-Control Results for Ground-Water and Surface-Water Data, Sacramento River Basin, California, National Waer-Quality Assessment; 1996-1998 U.S. Geological Survey Water Resources Investigations Report 02-4201, 46 p. Available on-line only: Download a 916 KB pdf here.

Organophosphorus pesticide occurrence and distribution in surface and ground water of the United States, 1992-97 by *Evelyn H. Hopkins, Daniel J. Hippe, Elizabeth A. Frick, and Gary R. Buell* U.S. Geological Survey Open-File Report 00-187, CD-ROM Organophosphorus in SW & GW

Distribution of Major Herbicides in Ground Water of the United States
By Jack E. Barbash, Gail P. Thelin, Dana W. Kolpin, *and* Robert J. Gilliom U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 98-4245 Sacramento, California, 1999 Major Herbicides in Ground Water

The Quality of Our Nation's Waters Nutrients and Pesticides U.S. Geological Survey Circular 1225
The Quality of Our Nation's Waters: Nutrients and Pesticides *Circular 1225 (8-6-99)*

Occurrence of Pesticides in Shallow Ground Water of the United States: Initial Results from the National Water-Quality Assessment Program *by* Dana W. Kolpin, Jack E. Barbash, and Robert J. Gilliom, Adapted from original article published in the Environmental Science & Technology, v 32, 1998_Pesticides in Shallow Ground Water: Initial Results

Pesticides in Ground Water: Summary Statistics; Preliminary Results from Cycle I of the National Water Quality Assessment Program (NAWQA), 1992-2001 *PROVISIONAL DATA -- SUBJECT TO REVISION By* Dana W. Kolpin and Jeffrey D. Martin, March 25, 2003 Pesticides in Ground Water, 1992-2001 (3/25/03)

enclosure (3)

Data Series 107 Data on dissolved pesticides and volatile organic compounds in surface and ground waters in the San Joaquin-Tulare basins, water years 1992-1995

Scientific Investigations Report 2005-5032 Occurrence and distribution of volatile organic compounds and pesticides in ground water in relation to hydrogeologic characteristics and land use

EH 02-10 (PDF, 226 kb)
Prather, T., F. Liu, N. O'Connell, M. Freeman, K. Hembree. 1999. Mitigating movement of simzaine into ground water in citrus grapes.

EH 86-06 (PDF, 491 kb)
Gonzales, D. and D.J. Weaver. 1986. Monitoring concentration of aldicarb and its breakdown products in irrigation water runoff and soil from agricultural fields in Kern County, 1985.

Spurlock, F., K. Burow, and N. Dubrovsky. 2000. Chlorofluorocarbon Dating of Herbicide-Containing Well Waters in Fresno and Tulare Counties, California. **Article** J. Environ. Qual. 29:474-483. Reprinted with the permission of the American Agronomy Society.(PDF, 3 mb)

Troiano, J., C. Garretson, C. Krauter, J. Brownell, and J. Hutson. 1993. Influence of Amount and Method of Irrigation Water Application on Leaching of Atrazine. **Article** J. Environ. Qual. 22: 290-298. (PDF, 680 kb). Reprinted with the permission of the American Agronomy Society.

Kinsey, W.B., Johnson, M.V., and Gronberg, J.M., 1998, Data on Dissolved Pesticides and Volatile Organic Compounds in Surface and Ground Waters in the San Joaquin – Tulare Basins, California, Water Years 1992-1995: U.S. Geological Survey Data Series 107, 372 p.
http://pubs.usgs.gov/ds/2005/107/

California GAMA Program: A Contamination Vulnerability Assessment for the Bakersfield Area
Jean E. Moran, G. Bryant Hudson, Gail F. Eaton, and Roald Leif
Lawrence Livermore National Laboratory, L-231, P.O. Box 808, Livermore, CA 94550
http://www.waterboards.ca.gov/gama/docs/cas_llnl_bakersfield.pdf

Dawson, B.J., Ground-Water Quality in the Southeastern Sacramento Valley Aquifer, California, 1996: U.S. Geological Survey, Water-Resources Investigations Report 01-4125,
http://pubs.usgs.gov/wri/wri014125/wrir01-4125.pdf

Boxall, A.B.A., Kolpin, D.W., Halling-Súrensen, B., and Tolls, J., 2003,
Are Veterinary Medicines Causing Environmental Risks? Environmental Science and Technology, v, 37, no. 15, p. 265A-304A.

Dawson, B.J, Shallow Ground-Water Quality Beneath Rice Areas in the Sacramento Valley, California, 1997 U.S. GEOLOGICAL SURVEY Water Resources Investigation Report 01-4000 NATIONAL WATER-QUALITY ASSESMENT PROGRAM Sacramento, California 2001
http://ca.water.usgs.gov/archive/reports/wrir014000/

Sutton, J.D., et. al., Water Quality and Agriculture Status, Conditions, and Trends, July 1997 NRCS Working Paper #16 http://www.nrcs.usda.gov/TECHNICAL/land/pubs/WP16.pdf

Spurlock, F., Burow, K., and Dubrovsky, N., Chlorofluorocarbon Dating of Herbicide-Containing Well Waters in Fresno and Tulare Counties, California, Reprinted from t he Journal of Environmental Quality Volume 2 9,no.2, Mar.-Apr.2 000.
http://www.cdpr.ca.gov/docs/empm/pubs/ehapref/chlordat.pdf

Troiano, J., Marade, J., and Spurlock, F., Empirical Modeling of Spatial Vulnerability Applied to a Norflurazon Retrospective Well Study in California, Published in J. Environ. Qual. 28:397-403 (1999). http://www.cdpr.ca.gov/docs/empm/pubs/ehapref/norstdy.pdf

Zhang, M., Geng, S., Ustin, S.L., Tanji, K.K., 1996, Pesticide Occurrence in Groundwater in Tulare County, California, in *Environmental Monitoring and Assessment*, Vol 45, 1997, p. 101-127. http://www.cstars.ucdavis.edu/papers/html/zhangetal1997b/

Spurlock, F., K. Burow, and N. Dubrovsky. 2000. Chlorofluorocarbon Dating of Herbicide-Containing Well Waters in Fresno and Tulare Counties, California. **Article** J. Environ. Qual. 29:474-483. Reprinted with the permission of the American Agronomy Society.(PDF, 3 mb)

Harter, T., Davis, H., Mathews, M.C., and Meyer, R.D., Shallow groundwater quality on dairy farms with irrigated forage crops: Department of Land, Air, and Water Resources, University of California, One Shields Avenue, Davis, CA 95616-8628, USA **PII: S0169-7722(01)00189-9**

Harter, T., et.al., 2005, Deep Vadose Zone Hydrology Demonstrates Fate of Nitrate in Eastern San Joaquin Valley, California Agriculrture, Vol. 59, Number 2, pp. 124-132. http://calag.ucop.edu/0502AMJ/pdfs/VadoseZone.pdf

Pesticide and Groundwater Quality By Dr. Jay Gan in University of California, Riverside Cooperative Extension Pesticide Wise A Quarterly Publication of the Department of Environmental Sciences http://www.pw.ucr.edu/textfiles/PesticideWiseWinter2002.htm
Lower Merced River and Mustang Creek Watersheds Selected for a National Water-Quality Study

http://jeq.scijournals.org/cgi/content/abstract/30/2/448 Summary of Well Water Sampling in California to Detect Pesticide Residues Resulting from Nonpoint-Source Applications, April 21, 2000 by John Troiano, Don Weaver, Joe Marade, Frank Spurlock, Mark Pepple, Craig Nordmark and Donna Bartkowiak, *Journal of Environmental Quality* 30:448-459 (2001).

http://www.ers.usda.gov/publications/arei/eib16/Chapter2/2.2/ Agricultural Resources and Environmental Indicators, 2006 Edition *By* Keith Wiebe and Noel Gollehon, Editors USDA Economic Information Bulletin No. (EIB-16) , July 2006

Harter, T., Davis, H., Mathews, M.C., Meyer, R.D., 2001, Nonpoint Source Pollution from Animal Farming in Semi-Arid Regions: Spatio-Temporal Variability and Groundwater Monitoring Strategies, Proceedings, 3rd Intl. Conf. on Future Groundwater Resources at Risk Lisbon, Portugal, 25-27 June 2001.
http://groundwater.ucdavis.edu/Publications/Harter_201_FGR2001.pdf

Harter, T., Davis, H., Mathews, M.C., Meyer, R.D., 2001, Shallow groundwater quality on dairy farms with irrigated forage crops Department of Land, Air, and Water Resources, University of California, USA, Journal of Contaminant Hydrology 55 (2002) 287– 315.
http://groundwater.ucdavis.edu/Publications/Harter_201_JoCH2002.pdf

Harter, T., Davis, H., Mathews, M.C., Meyer, R.D., 2001, Effects of Dairy Manure Nutrient Management on Shallow Groundwater Nitrate: A Case Study Written for presentation at the 2001 ASAE Annual International Meeting Sponsored by ASAE Sacramento Convention Center Sacramento, California, USA July 30-August 1, 2001
http://groundwater.ucdavis.edu/Publications/Harter_201_ASAE2001_UCCE_Case_Study_paper.pdf

Nitrate Contamination in California Groundwater: An Integrated Approach to Basin Assessment and Resource Protection, Lawrence Livermore National Laboratory 10 December 2002 LLNL Nitrate Working Group Brad Esser, Bryant Hudson, Jean Moran *Chemistry & Material Science Directorate* Harry Beller, Tina Carlsen, Brendan Dooher, Paula Krauter, Walt Mcnab, Vic Madrid, Dave Rice, Matthew Verce *Environmental Protection Department* Nina Rosenberg *Earth and Energy Directorate*. http://www.waterboards.ca.gov/gama/docs/llnl_nitrate_wp_ucrl-151454.pdf

Colangelo, D.J., and Brand M.H., Nitrate Leaching beneath a Containerized Nursery Crop Receiving Trickle or Overhead Irrigation,Department of Plant Science, U-67, Univ. of Connecticut, 1376 Storrs Rd., Storrs, CT 06269-4067 Received for publication August 31, 2000. *Journal of Environmental Quality* 30:1564-1574 (2001) http://intl-jeq.scijournals.org/cgi/content/abstract/30/5/1564

Prichard, T., Troiano, J., and Canevari, M., Alfalfa Herbicide Pollution Pathways and Mitigation Practices (2002). U.C. Davis http://ucce.ucdavis.edu/files/filelibrary/2019/1682.pdf

P ickel, C.H., Hawkens, S., E. Pehrson, E., and Oconnell, N.V., 1990, HERBICIDE USE IN CITRUS PRODUCTIONAND GROUND WATER CONTAMINATION **IN TULARE COUNTY, California Dept. of Food and Agriculture, April, 1990, PM 90-1. http://www.cdpr.ca.gov/docs/pmap/pubs/pm9001.pdf**

Clayton, M. **2005 Status Report Pesticide Contamination Prevention Act,** California Environmental Protection Agency, Department of Pesticide Regulation Environmental Monitoring Branch, Environmental Hazards Assessment Program
EH05-07 http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0507.pdf

Prichard, T., Schwankl, L., Canevari, M., and Troiano, J.,
Develop Holding Pond Mitigation Practices to Prevent Herbicide Movement to the Ground Water. Final Report for DPR Contract 02-0171C Submitted to The California Department of Pesticide Regulation In Fulfillment of U.S. EPA, Region 9 Funding Supplied by Contract E-00915503-1 Submitted September 6, 2004 http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0403.pdf

Update of Ground Water Protection Areas. http://www.cdpr.ca.gov/docs/gwp/eh0305update.pdf

A Technical Advisor's Manual, Managing Agricultural Irrigation Drainage Water, *A guide for developing Integrated On-Farm Drainage Management Systems,* 2005, Developed for the State Water Resources Control Board by the Westside Resource Conservation District in conjunction with the Center for Irrigation Technology, California State University, Fresno http://www.sjd.water.ca.gov/drainage/tech_manual/index.cfm

R.C. Jamieson, R.J. Gordon, K.E. Sharples, G.W. Stratton and A. Madani, Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: A review Volume 44 2002 CANADIAN BIOSYSTEMS ENGINEERING
http://www.engr.usask.ca/societies/csae/protectedpapers/c0121.pdf

National Management Measures for the Control of Nonpoint Pollution From Agriculture, U.S. Environmental Protection Agency Office of Water (4503T) 1200 Pennsylvania Avenue, NW Washington, D.C. 20460 EPA-841-B-03-004, July 2003 http://www.epa.gov/nps/agmm/index.html

Abstracts

Munday, C., and Domagalski, J.L., 2002, Quality-Control Results for Ground-Water and Surface-Water Data, Sacramento River Basin, California, National Water-Quality Assessment, 1996-1998: U.S. Geological Survey Water-Resources Investigations Report 02-4201, 40p.

Barbash, J.E., Thelin, G.P., Kolpin, D.W., and Gilliom, R.J., 1999, Distribution of Major Herbicides in Ground Water of the United States: U.S. Geological Survey, Water-Resources Investigations Report 98-42454

Burow, K.R., Panshin, S.Y., Dubrovsky, N.M., VanBrocklin, David, and Fogg, G.E., 1999, Evaluation of processes affecting 1,2-Dibromo-3-Chloropropane (DBCP) concentrations in ground water in the eastern San Joaquin Valley, California: Analysis of chemical data and ground-water flow and transport simulations: U.S. Geological Survey Water-Resources Investigations Report 99-4059, 57 p.

Barrow, K.R., Shelton, J.L., and Dubrovsky, N.M., 1998, Occurrence of nitrate and pesticides in ground water beneath three agricultural land-use settings in the eastern San Joaquin Valley, California, 1993-1995: U.S. Geological Survey Water-Resources Investigations Reports 97-4284, 51 p. http://ca.water.usgs.gov/sanj/pub/usgs/wrir98-4040a/wrir98-4040a.pdf

Burow, K.R., Stork, S.V., and Dubrovsky, N.M., 1998, Nitrate and pesticides in ground water in the eastern San Joaquin Valley, California: Occurrence and trends: U.S. Geological Survey Water-Resources Investigations Report 98-4040, 33 p.

SOURCES OF DATA ON SURFACE WATER IMPACTS THAT HAVE BEEN ATTRIBUTED TO IRRIGATED AGRICULTURE

Domagalski, J.L., 1993, Pesticides detected in the San Joaquin River Basin, California -- Results of an intensive fixed-station sampling design developed for the National Water Quality Assessment Program (abs.): EOS, Transactions of the American Geophysical Union, Spring Meeting Supplement, v. 74, no. 16, p. 129.

Domagalski, J.L., 1997, Pesticides in surface and ground water of the San Joaquin-Tulare Basins, California: Analysis of Available Data, 1966 through 1992: U.S. Geological Survey Water-Supply Paper 2468, 74 p.

Domagalski, J.L., 1995, Nonpoint sources of pesticides in the San Joaquin River, California -- Input from winter storms, 1992-93: U.S. Geological Survey Open-File Report 95-165, 15 p.

Domagalski, J.L., Dubrovsky, N.M., and Kratzer, C.R., 1997, Pesticides in the San Joaquin River, California: Inputs from dormant sprayed orchards: Journal of Environmental Quality, v. 26, p. 454-465.

Dubrovsky, N.M., and Domagalski, J.L., 1993, Pesticides detected in the San Joaquin River basin, California: Analysis of existing data and design of monitoring network (abs.): EOS, Transactions of the American Geophysical Union, Spring Meeting Suplement, v. 74, no. 16, p. 134-135.

Dubrovsky, N.M., Domagalski, J.L., Gronberg, J.M., Kratzer, C.R., Kuivila, K.M., and Panshin, S.Y., 1997, Pesticide occurence as a function of landuse, application, and hydrology, San Joaquin River, California: Society of Environmental Toxicology and Chemistry, SETAC 17th Annual

Gronberg, J.M., Dubrovsky, N.M., Kratzer, C.R., Domagalski, J.L., Brown, L.R., *and* Burow, K.R., ENVIRONMENTAL SETTING OF THE SAN JOAQUIN–TULARE BASINS, CALIFORNIA National Water-Quality Assessment Program, U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 97-4205. http://ca.water.usgs.gov/sanj/pub/usgs/wrir97-4205/wrir97-4205.pdf

Kratzer, C.R., 1997, Transport of diazinon in the San Joaquin River Basin, California: U.S. Geological Survey Open-File Report 97-411, 22 p.

Kratzer, C.R., 1998, Transport of sediment-bound organochlorine pesticides to the San Joaquin River, California: U.S. Geological Survey Open-File Report 97-655, 30 p.

Kratzer, C.R., 1998, Pesticides in storm runoff from agricultural and urban areas in the Tuolumne River Basin in the vicinity of Modesto, California: U.S. Geological Survey Water-Resources Investigations Reports 98-4017, 17 p.

Panshin, S.Y., Dubrovsky, N.M., Gronberg, J.M., and Domagalski, J.L., 1998, Occurrence and distribution of dissolved pesticides in the San Joaquin Basin, California, U.S. Geological Survey Water-Resources Investigations 98-4032, 88 p.

http://pubs.er.usgs.gov/usgspubs/citfor/ofr/ofr95110?currow=0 Dissolved Pesticide Data for the San Joaquin River at Vrnalis and the Sacramento River at Sacramento, California, 1991-94 U.S. Geological Survey Open-File Report 95-110, 27 pages.

enclosure (4)

http://ca.water.usgs.gov/sac_nawqa/wri004203.pdf Water Quality Assessment of the Sacramento River Basin, California--Environmental Setting and Study Design U.S. Geological Survey Water-Resources Investigations Report 97-4254

Pesticides in Surface Water Measured at Select Sites in the Sacramento River Basin, California, 1996-1998. U.S. Geological Survey Water-Resources Investigations Report 00-4203, 24 p. Available on-line: Download a 3.0 MB pdf here.

http://pubs.water.usgs.gov/circ1215 Water Quality in the Sacramento River Basin, California,1994–98 *By* Joseph L. Domagalski, Donna L. Knifong, Peter D. Dileanis, Larry R. Brown, Jason T. May, Valerie Connor, *and* Charles N. Alpers U.S. GEOLOGICAL SURVEY CIRCULAR 1215

Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998. Available on-line at: http://ca.water.usgs.gov/sac_nawqa/waterindex.html.

Water-Quality Assessment of the Sacramento River Basin, California--Water Quality of Fixed Sites, 1996-1998. U.S. Geological Survey Water-Resources Investigations Report 00-4247, 60 p. Available on-line: Download pdf.

Domagalski, J.L., and Munday, C., Evaluation of Diazinon and Chlorpyrifos Concentrations and Loads, and Other Pesticide Concentrations, at Selected Sites in the San Joaquin Valley, California, April to August, 2001 Prepared in cooperation with the CALIFORNIA DEPARTMENT OF PESTICIDE REGULATION Sacramento, California 2003 Water-Resources Investigations Report 03-4088 U.S. GEOLOGICAL SURVEY 6438-13
http://pubs.usgs.gov/wri/wri034088/pdf/wri03_4088.pdf

Quality-Control Results for Ground-Water and Surface-Water Data, Sacramento River Basin, California, National Waer-Quality Assessment; 1996-1998 U.S. Geological Survey Water Resources Investigations Report 02-4201, 46 p. Available on-line only: Download a 916 KB pdf here.

Organic Carbon Trends, Loads, and Yields to the Sacramento-San Joaquin Delta, California, Water Years 1980 to 2000 Available on-line: Download a 15.2 MB pdf, and associated data tables, here.

Organophosphorus pesticide occurrence and distribution in surface and ground water of the United States, 1992-97 by *Evelyn H. Hopkins, Daniel J. Hippe, Elizabeth A. Frick, and Gary R. Buell* U.S. Geological Survey Open-File Report 00-187, CD-ROM Organophosphorus in SW & GW

The Quality of Our Nation's Waters Nutrients and Pesticides U.S. Geological Survey Circular 1225, *(8-6-99)*
The Quality of Our Nation's Waters: Nutrients and Pesticides

Pesticides in Streams of the United States--Initial Results from the National Water-Quality Assessment Program *By* Steven J. Larson, Robert J. Gilliom, *and* Paul D. Capel U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 98-4222 Sacramento, California, 1999 Pesticides in Streams of the U.S. - Initial Results

Pesticides in Streams: Summary Statistics; Preliminary Results from Cycle I of the National Water Quality Assessment Program (NAWQA), 1992-2001 *PROVISIONAL DATA -- SUBJECT TO REVISION By* Jeffrey D. Martin, Charles G. Crawford, and Steven J. Larson, February 19, 2003 Pesticides in Streams, 1992-2001 (2/19/03)

Organochlorine Pesticides and PCBs in Bed Sediment and Whole Fish from United States Rivers and Streams: Summary Statistics; Preliminary Results from Cycle I of the National Water Quality Assessment Program (NAWQA), 1992-2001 ***PROVISIONAL DATA -- SUBJECT TO REVISION*** *By* Lisa H. Nowell and Charles G. Crawford, April 10, 2003 Organochlorine Pesticides and PCBs in Bed Sediment and Fish, 1992-2001 (4/10/03)

Data Series 197 Seasonal changes in concentrations of dissolved pesticides and organic carbon in the Sacramento-San Joaquin delta, 1994-1996

Data Series 120 Kinsey, W.B., Johnson, M.V., and Gronberg, J. M., Concentrations of organic contaminants detected during managed flow conditions, San Joaquin River and Old River, 2001

Data Series 107 Data on dissolved pesticides and volatile organic compounds in surface and ground waters in the San Joaquin-Tulare basins, water years 1992-1995

Scientific Investigations Report 2006-5152 Environmental setting of the lower Merced River basin

Scientific Investigations Report 2005-5220 Analysis of pesticides in surface water and sediment from Yolo Bypass 2004-2005

Water-Data Report CA-05 Water Reources Data, California, Water Year 2005

EH 05-01 (PDF, 949 kb)
Bacey, J. 2005. Biological Assessment of Urban and Agricultural Streams in the California Central Valley (Fall 2002 through Spring 2004).

EH 04-01 (PDF, 636 kb)
Bacey, J., K. Starner, and F. Spurlock. 2004 The occurrence and concentration of esfenvalerate and permethrin in water and sediment in the Sacramento and San Joaquin watersheds.

EH 03-03 (PDF, 3.8 mb)
Starner, K. , F. Spurlock, S. Gill , K. Goh , H. Feng , J. Hsu, P. Lee , D. Tran , and J. White. 2003. Monitoring Surface Waters of the San Joaquin River Basin for Selected Summer-Use Pesticides, 2002.

EH 02-11 (PDF, 36 kb)
O'Connell, N. and F. Liu. 2002. Simazine runoff losses from a cover croppped citrus orchard.

EH 01-01 (PDF, 16 mb)
Spurlock, F.2002. Analysis of diazinon and chlorpyrifos surface water monitoring and acute toxicity bioassay data, 1991- 2001.

EH 00-09 (PDF, 1.6 mb)
Ross, L.J., R. Stein, J. Hsu, J. White, and K. Hefner. 2000. Insecticide concentrations in the San Joaquin River Watershed, California .

EH 99-01 (PDF, 6.1 mb)
Ross, L. J., R. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and mass loading of insecticides in the San Joaquin River, California, Spring 1991 and 1992.

EH 98-02 (PDF, 1.5 mb)
Executive Summary (PDF, 378 kb), Bennett, K. P., C. E. Nordmark, J. Schuette, H. Feng, J. Hernandez, and P. Lee. 1998. Occurence of aquatic toxicity and dormant spray pesticide detections in the San Joaquin River Watershed, Winter 1996-97.

EH 97-06 (PDF, 4.3 mb)
Executive Summary (PDF file, 35 kb), Ganapathy C., C. Nordmark, K. Bennett, and A. Bradley. 1997. Temporal distribution of insecticide residues in four California rivers.

EH 97-03 (PDF, 3 mb)
Executive Summary (HTML), Ross, L. J., K. D. Bennett, K. D. Kim, K. Hefner, and J. Hernandez. 1997. Reducing dormant spray runoff from orchards. Protocol 141 (HTML).

EH 97-02 (HTML) Spurlock, F., C. Garretson, and J. Troiano. 1997. Runoff from citrus orchard middles: Comparison of three herbicides and effect of organosilicon surfactant. Protocol 149 (HTML).

EH 95-11 (PDF, 2 mb)
Executive Summary (HTML), Wofford, P.L., and P. Lee. 1995. Results of monitoring for the herbicide MCPA in surface water of the Sacramento River Basin.

EH 94-03 (PDF, 3.8 mb)
Linde, C.D. 1994. Physico-chemical properties and environmental fate of pesticides.

EH 92-03 (PDF, 2 mb)
Kollman, W.S., P.L. Wofford, and J. White. 1992. Dissipation of methyl parathion from flooded commercial rice fields.

EH 90-04 (PDF, 3 mb)
Executive Summary (PDF, 239 kb), Nicosia, S., N. Carr, D.A. Gonzales, and M.K. Orr. 1990. Off-field movement and dissipation of soil-incorporated carbofuran from three commercial rice fields, and potential discharge in agricultural runoff water.

EH 86-06 (PDF, 491 kb)
Gonzales, D. and D.J. Weaver. 1986. Monitoring concentration of aldicarb and its breakdown products in irrigation water runoff and soil from agricultural fields in Kern County, 1985.

EH 85-06 (HTML)
Mischke, T., K. Brunetti, V. Acosta, D. Weaver, and M. Brown. 1985. Agricultural sources of DDT residues in California's environment.

Study Memo Gill, S. 2006. Results for Study 235: Constructed Vegetated Ditches as a Management Practice in Irrigated Alfalfa (PDF 113 kb)
Study 235 Maps, Graphs, Results Tables (PDF 682 kb)

Study Memo Guo, L., Kelley, K., Gill, S. and Sava, 2005. A Partition of Pesticide Loads in Major Subbasins in the Sacramento River Watershed-Preliminary Results of Study 227
(PDF 396 kb)

Study Memo Kelley, K. and Starner, K. 2004. Preliminary Results for Study 219: Monitoring Surface Waters and Sediments of the Salinas and San Joaquin River Basins for Organophosphate and Pyrethroid Pesticides
(PDF 1.43 mb)

Study Memo Bacey, J. 2004. Preliminary Results of Study #210: Biological Assessment in the Sacramento and San Joaquin Watersheds (Fall 2002 through Spring 2004) (PDF, 1.2 mb)

Study Memo Spurlock, F. 2004. Analysis of Recent Chlorpyrifos Use and Surface Water Monitoring Data. (PDF, 599 kb)

Study Memo Gill, S. and F. Spurlock. 2004. Preliminary Results for Study 215: Monitoring Esfenvalerate Runoff from a Dormant Spray Application in a Glenn County Prune Orchard. Revised April 17, 2006. (PDF, 328 kb)

Study Memo Bacey, J., K. Starner, and F. Spurlock. 2003. Preliminary Results of Study #214: Monitoring the Occurrence and Concentration of Esfenvalerate and Permethrin Pyrethroids. (PDF, 476 kb)

Study Memo Guo, L. and K. Starner. 2003. Monitoring Results of Oryzalin in San Joaquin River Basin During 2000-2001 Winter Storm Season (Study #202). (PDF, kb)

Study Memo Bacey, J. 2002. Preliminary Results of Pesticide Residue Analysis Acute and Chronic Toxicity Testing of Surface Water Monitored in the San Joaquin River Watershed, Winter 2000-2001. (PDF, 460 kb)

Study Memo Bacey, J. 2002. Preliminary Results of Study 205: Monitoring the Occurrence and Typical Concentration of Esfenvalerate and Permethrin Pyrethroids in the Sacramento and San Joaquin Watersheds, Winter 2002. (PDF, 897 kb)

Study Memo Jones, D. 2000. Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the San Joaquin River Watershed, Winter 1999-2000. (PDF, 288 kb)

Study Memo Guo, L. and F. Spurlock 2000. Recommendation for the Priority Surface Water Monitoring Studies on Selected Pesticides. (PDF, 470 kb)

Study Memo Nordmark, C. 1999. Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1998-99. (PDF, 3.8 mb).

Study Memo Rodriguez, B., Singhasemanon, N., Barry, T. and Troiano, J. 1996. Summary of Results for a Study to Monitor Diuron in a Tailwater Recovery System in Yolo County, California. (PDF, 950 kb).

Study Memo Bennett, K. P. 1995. DBCP and Bentazon Monitoring Results - Solano County. (PDF, 243 kb).

Juanita Bacey and Frank Spurlock. 2006. Biological Assessment of Urban and Agricultural Streams in the California Central Valley. Environmental Monitoring and Assessment: Publisher Springer Netherlands ISSN 0167-6369 (Print) 1573-2959 (Online) DOI 10.1007/s10661-006-9438-8. October 28, 2006 (online date).
http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0501.pdf

ERIN L. AMWEG, DONALD P. WESTON, and NICOLE M. UREDA, *USE AND TOXICITY OF PYRETHROID PESTICIDES IN THE CENTRAL VALLEY, CALIFORNIA, USA*, Environmental Toxicology and Chemistry, Vol. 24, No. 4, pp. 966–972, 2005.
http://www.allenpress.com/pdf/entc_24_414_966_972.pdf

Ross, L.J., Stein, R., Hsu, J., White, J., and Hefner K., DIST.RIBUTION AND MASS LOADING OF INSECTICIDES IN THE SAN JOAQUIN RIVER, CALIFORNIA Winter 199 1-92 and 1992-93, STATE OF CALIFORNIA, Environmental Protection Agency, Department of Pesticide Regulation Environmental Monitoring and Pest Management Branch, Environmental Hazards Assessment Program EH 96-02 http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh9602.pdf

BRUNS, J., Foe, C., RASMUSSEN, R., MCGRAW, M., BAY PROTECTION PROGRAM TOXIC HOT SPOT CLEANUP PLANS FOR DIAZINON IN ORCHARD DORMANT SPRAY DIAZINON AND CHLORPYRIFOS IN URBAN STORMWATER CHLORPYRIFOS IN IRRIGATION RETURN FLOW *December 2002,* CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY REGIONAL WATER QUALITY CONTROL BOARD, CENTRAL VALLEY REGION. http://www.swrcb.ca.gov/rwqcb5/available_documents/bay_protection/diaz_chlorpyr_plans.pdf

Troiano, J. and C. Garretson. 1998. Movement of Simazine in Runoff Water from Citrus Orchard Row Middles as Affected by Mechanical Incorporation. **Article** J. Environ. Qual. 27: 488-494. (PDF, 102 kb). Reprinted with the permission of the American Agronomy Society.

Nicosia, S., N. Carr, D.A. Gonzales, and M.K. Orr. 1991. Off-field movement and dissipation of soil-incorporated carbofuran from three commercial rice fields. J. Environ.Qual. 20(3): 532-539. http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh9004.pdf

Pesticide Monitoring of Surface Waters in the Northern District Memorandum Report, April 1990 (PDF: 2.61MB)
The purpose of this investigation was to determine the extent of pesticide monitoring of surface waters in Northern California, and to determine additional monitoring requirements. The study area includes the 13 counties of Northern District and those monitoring stations within Sutter and Yolo Counties that are located on the Sacramento River and its major drainages.

Domagalski, J.L., Knifong, D.L., Dileanis, P.D., Brown, L.R., May, J.T., Conner, V., and Alpers, C.N., 2000, Water Quality in the Sacramento River Basin California, 1994-98: U.S. Geological Survey Circular 1215, 36 p. http://pubs.usgs.gov/circ/circ1215/#pdf

Dubrovsky, N.M., Kratzer, C.R., Brown, L.R., Gronberg, J.M., and Burow, K.R. 1998, Water Quality in the San Joaquin – Tulare Basins California 1992-95: U.S. Geological Survey Circular 1159, 38 p. http://pubs.usgs.gov/circ/circ1159/circ1159.pdf

Kinsey, W.B., Johnson, M.V., and Gronberg, J.M., 1998, Data on Dissolved Pesticides and Volatile Organic Compounds in Surface and Ground Waters in the San Joaquin – Tulare Basins, California, Water Years 1992-1995: U.S. Geological Survey Data Series 107, 372 p. http://pubs.usgs.gov/ds/2005/107/

Orlando, J.L., and Kuivila, K.M., 2005, Concentrations of Organic Contaminants Detected during Managed Flow Conditions, San Joaquin River and Old River, California, 2001: US Geological Survey Data Series 120, 19 p. http://pubs.usgs.gov/ds/2005/120/

Smalling, K.L., Orlando, J.L., and Kuivila, K.M., 2005, Analysis of Pesticides in Surface Water and Sediment from Yolo Bypass, California, 2004–2005: US Geological Survey Scientific Investigations Report 2005-5220, 30 p. http://pubs.usgs.gov/sir/2005/5220/

Leland, H.V., and Fend, S.V., 1998 Benthic invertebrate distributions in the San Joaquin River, California, in relation to physical and chemical factors Can. J. Fish. Aquat. Sci./J. can. sci. halieut. aquat. 55(5): 1051-1067 (1998) http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?_handler_=HandleInitialGet&journal=cjfas&volume=55&calyLang=eng&articleFile=f97-316.pdf

Battaglin, W.A., and Goolsby, D.A., 1995, Spatial data in Geographic Information System format on agricultural chemical use, land use, and cropping practices in the United States: U.S. Geological Survey Open-File Report 94-4176, 87 p.

Boxall, A.B.A., Kolpin, D.W., Halling-Súrensen, B., and Tolls, J., 2003,
Are Veterinary Medicines Causing Environmental Risks? Environmental Science and Technology, v, 37, no. 15, p. 265A-304A.

Sutton, J.D., et. al., Water Quality and Agriculture Status, Conditions, and Trends, July 1997 NRCS Working Paper #16 http://www.nrcs.usda.gov/TECHNICAL/land/pubs/WP16.pdf

Juanita Bacey and Frank Spurlock. 2006. Biological Assessment of Urban and Agricultural Streams in the California Central Valley. Environmental Monitoring and Assessment. Publisher Springer Netherlands ISSN 0167-6369 (Print) 1573-2959 (Online) DOI 10.1007/s10661-006-9438-8. October 28, 2006 (online date).
http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0501.pdf

Starner,K., F. Spurlock, S. Gill, K. Goh, H. Feng, J. Hsu, P. Lee, D. Tran, J. White. 2005. Pesticide residues in surface water from irrigation-season monitoring in the San Joaquin Valley, California, USA. Bull. Environ. Contam. Toxicol. 74(5): 920-927.

Bacey,J., F. Spurlock, K. Starner, H. Feng, J. Hsu, J. White, and D.M. Tran. 2005. Residues and Toxicity of Esfenvalerate and Permethrin in Water and Sediment, in Tributaries of the Sacramento and San Joaquin Rivers, California. Bull. Environ. Contam. Toxicol. 74(5): 864-871

Guo, L., C. Nordmark, F. Spurlock, B. Johnson, L.Y. Li, M. Lee, K.S. Goh. 2004. Characterizing Dependence of Pesticide Load in Surface Water on Precipitation and Pesticide Use for the Sacramento River Watershed. Environ. Sci. Technol. 38: 3842-3852.
http://pubs.acs.org/journals/esthag/toc_current.html

Pest Management Strategic Plan California Fresh Market Tomato Production,Prepared for the United States Department of Agriculture and the Environmental Protection Agency By the California Tomato Commission and the California Minor Crops Council June, 2003EPORT GROUND WATER QUALITY http://www.ipmcenters.org/pmsp/pdf/CATomato.pdf

http://www.ers.usda.gov/publications/arei/eib16/Chapter2/2.2/ Agricultural Resources and Environmental Indicators, 2006 Edition *By* Keith Wiebe and Noel Gollehon, Editors USDA Economic Information Bulletin No. (EIB-16) , July 2006

Starner, K., Spurlock, F., Gill, S., Goh, K., Feng, H., Hsu, J., Lee, P., Tran, D., and White, J., Perstcide Residues in Surface Water form Irrigation-Season Monitoring in the San Joaquin Valley, California, USA., 2005, Bull. Environ. Contam. Toxicol. (2005) 74: pp. 920-927.

Schulz, R., Field Studies on Exposure, Effects, and Risk Mitigation of Aquatic Nonpoint-Source Insecticide Pollution Published in J. Environ. Qual. 33:419-448 (2004). http://intl-jeq.scijournals.org/cgi/content/abstract/33/2/419

Harter, T., Davis, H., Mathews, M.C., Meyer, R.D., 2001, Nonpoint Source Pollution from Animal Farming in Semi-Arid Regions: Spatio-Temporal Variability and Groundwater Monitoring Strategies, Proceedings, 3rd Intl. Conf. on Future Groundwater Resources at Risk Lisbon, Portugal, 25-27 June 2001.
http://groundwater.ucdavis.edu/Publications/Harter_201_FGR2001.pdf

G. Fred Lee, F.G., and Jones-Lee, A., 2002, Report TP 02-07
Issues in Developing a Nonpoint Source Water Quality Monitoring Program for Evaluation of the Water Quality - Beneficial Use Impacts of Stormwater Runoff and Discharges from Irrigated Agriculture in the Central Valley, CA, California Water Institute California State University, Fresno Fresno, California for the State Water Resources Control Board and the Central Valley Regional Water Quality Control Board Sacramento, California December 2002.
http://www.gfredlee.com/Agwaivemonitoring-dec.pdf

Prichard, T., Troiano, J., and Canevari, M., Alfalfa Herbicide Pollution Pathways and Mitigation Practices (2002). U.C. Davis http://ucce.ucdavis.edu/files/filelibrary/2019/1682.pdf

Rachael Freeman Long, Mary Nett, Daniel H. Putnam, Guomin Shan, Jerry Schmierer, and Barbara Reed (2002) "Insecticide choice for alfalfa may protect water quality", California Agriculture: Vol. 56: No. 5, Page 163.
http://repositories.cdlib.org/cgi/viewcontent.cgi?article=3172&context=anrcs/californiaagriculture

Kratzer, C.R., *and* Shelton, J.L., 1998, Water Quality Assessment of the San Joaquin–Tulare Basins, California: Analysis of Available Data on Nutrients and Suspended Sediment in Surface Water, 1972–1990, U.S. Geological Survey professional paper ; 1587.
http://ca.water.usgs.gov/sanj/pub/usgs/pp1587/pp1587.pdf

Siemering, Geoff. 2005. Aquatics Herbicides: Overview of Usage, Fate and Transport, Potential Environmental Risk, and Future Recommendations for the Sacramento-San Joaquin Delta and Central Valley White Paper for the Interagency Ecological Program. SFEI Contribution 414. San Francisco Estuary Institute, Oakland, CA.
http://science.calwater.ca.gov/pdf/workshops/POD/CDFG_POD_Aquatic_Herbicides_White_Paper.pdf

Bacey, J., DEVELOPMENT AND SELECTION OF BIOASSESSMENT REFERENCE SITES IN THE SAN JOAQUIN VALLEY USING BENTHIC MACROINVERTEBRATE DATA January 2007 CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY Environmental Monitoring Branch California Department of Pesticide Regulation 1001 I Street Sacramento, California 95812 Report No. EH06-02
http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0702.pdf

Clayton, M. **2005 Status Report Pesticide Contamination Prevention Act,** California Environmental Protection Agency, Department of Pesticide Regulation Environmental Monitoring Branch, Environmental Hazards Assessment Program
EH05-07 http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0507.pdf

Newhart, K. 2002. **Rice pesticide use and surface water monitoring 2002**, Report to the California Regional Water Quality Control Board, December 31, 2002, California Environmental Protection Agency, Department of Pesticide Regulation, Environmental Monitoring Branch, Environmental Hazards Assessment Program, 1001 I Street, Sacramento, California 95814-3510
EH02-09 http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh0209/eh0209.pdf

A Technical Advisor's Manual, Managing Agricultural Irrigation Drainage Water, *A guide for developing Integrated On-Farm Drainage Management Systems,* 2005, Developed for the State Water Resources Control Board by the Westside Resource Conservation District in conjunction with the Center for Irrigation Technology, California State University, Fresno
http://www.sjd.water.ca.gov/drainage/tech_manual/index.cfm

R.C. Jamieson, R.J. Gordon, K.E. Sharples, G.W. Stratton and A. Madani, Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: A review Volume 44 2002 CANADIAN BIOSYSTEMS ENGINEERING
http://www.engr.usask.ca/societies/csae/protectedpapers/c0121.pdf

National Management Measures for the Control of Nonpoint Pollution From Agriculture, U.S. Environmental Protection Agency Office of Water (4503T) 1200 Pennsylvania Avenue, NW Washington, D.C. 20460 EPA-841-B-03-004, July 2003 http://www.epa.gov/nps/agmm/index.html

Final programmatic EIS/EIR Water Quality Program Plan for the CALFED Bay-Delta Program, 2000. http://calwater.ca.gov/CALFEDDocuments/Final_EIS_EIR.shtml

Abstracts

Brown, L.R., 1997, Concentrations of Chlorinated Organic Compounds in Biota and Bed Sediment in Streams of the San Joaquin Valley, California: Archives of Environmental Contamination and Toxicology, v.33, no. 4, p. 357-368

Domagalski, J.L, 2000, Pesticides in Surface Water Measured at Select Sites in the Sacramento River Basin, California, 1996-1998: U.S. Geological Survey, Water-Resources Investigations Report 00-4203, 29 p.

Domagalski, J.L., 1995, Nonpoint sources of pesticides in the San Joaquin River, California -- Input from winter storms, 1992-93: U.S. Geological Survey Open-File Report 95-165, 15 p.

Domagalski, J.L., 1996, Occurrence of dicofol in the San Joaquin River, California: Bulletin of Environmental Contamination and Toxicology, v. 57, p. 284-291.

Domagalski, J.L., 1997, Results of a prototype surface water network design for pesticides developed for the San Joaquin River Basin, California: Journal of Hydrology, v. 192, p33-50.

Domagalski, J.L., and Dubrovsky, N.M., 1994, Inputs of the dormant orchard pesticide, diazinon, to the San Joaquin River, California, in Sorenson, S.K., ed., Proceedings abstracts of the American Water Resources Association's symposium on the National Water Quality Assesssment (NAWQA) Program -- November 7-9, 1994, Chicago, Illinois: U.S. Geological Survey Open-File Report 94-397, p. 8.

Domagalski, J.L., Dubrovsky, N.M., and Kratzer, C.R., 1995, Inputs of the dormant-spray pesticide, diazinon, to the San Joaquin River, California, February 1993: U.S. Geological Survey Fact Sheet FS-133-95, 2 p.

Domagalski, J.L., Dubrovsky, N.M., and Kratzer, C.R., 1997, Pesticides in the San Joaquin River, California: Inputs from dormant sprayed orchards: Journal of Environmental Quality, v. 26, p. 454-465.

Kratzer, C.R., 1994, An assessment of the increasing nitrate trend in the lower San Joaquin River, California, in Sorenson, S.K., ed., Proceedings abstracts of the American Water Resources Association's symposium on the National Water Quality Assessment (NAWQA) Program -- November 7-9, 1994, Chicago, Illinois: U.S. Geological Survey Open- File Report 94-397, p. 5.

Panshin, S.Y., Domagalski, J.L., and Dubrovsky, N.M., 1994, Pesticide concentrations in surface water as a function of agricultural land use in five small watersheds, western San Joaquin Valley, California (abs.): EOS, Transactions of the American Geophysical Union, v. 75, no. 44, Supplement, p. 246.

Panshin, S.Y., Kratzer, C.R., Gronberg, J.M., Dubrovsky, N.M., Domagalski, J.L., 1995, Diazinon concentrations in surface water of the lower San Joaquin Basin, California (abs.): Society of Environmental Toxicology and Chemistry abstract book, Second SETAC World Congress (16th annual meeting), Global Environmental Protection: Science, Politics, and Common Sense, Vancouver, British Columbia, Canada, p. 157.

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TO: Joe Karkoski
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Control Engineer
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FROM: Polly Lowry
Senior Engineering Geologist
Irrigated Land/Non-15

DATE: 15 January 2008

SIGNATURE: ____________________

SUBJECT: ***FEBRUARY 2006 DRAFT IRRIGATED LANDS EXISTING CONDITIONS REPORT***

I have reviewed Chapter 4 (Groundwater Quality) of the February 2006 *Draft Irrigated Lands Existing Conditions Report*. In general, it would be helpful to add an introduction to this Chapter that emphasizes the importance of and need to protect groundwater quality and that provides information that would be useful in developing a long-term regulatory program that will protect groundwater quality. Some of the introductory sections of each of the groundwater basins could be transferred to this introduction. Some suggestions for the Chapter 4 Introduction, Sacramento and San Joaquin Valley Groundwater Basins sections, and the long-term regulatory program follow.

CHAPTER 4 INTRODUCTION

Importance of Groundwater

For purposes of discussing the importance of groundwater in the Region, the Chapter Introduction could include very brief discussions of the following:

1. The importance of groundwater in the Central Valley Region.

   The extent of the groundwater basins and agriculture and the use of groundwater for agriculture uses as well as urban uses in the Region are significant and have been quantified in the Department of Water Resources Bulletin 118 available at http://www.groundwater.water.ca.gov/bulletin118/. Additional information on this can be found in United States Geological Survey (USGS) Scientific Investigation Report 2007-5179 available at http://pubs.usgs.gov/sir/2007/5179.

2. The connection of groundwater and surface water.

   The connection between groundwater and surface water is important in the development of any program designed to protect water rẽsources since the movement of water from one hydrologic system to another can also move pollutants between the two systems. Discussions of the importance of the interconnection between groundwater and surface water can be found in *Why Protecting Land Helps Protect Water* available at http://www.tpl.org/tier3_print.cfm?folder_id=1885&content_item_id=21897&mod_type=1

enclosure (15)

and the California Department of Water Resources Bulletin 118 (*California's Groundwater*) available at http://www.groundwater.water.ca.gov/bulletin118/.

Groundwater systems are part of the entire hydrologic system and consist of recharge, discharge, and storage (aquifers) areas. Groundwater systems can be connected to surface water in each of these areas. It would be useful to include a conceptual model of a hydrologic system showing groundwater recharge, discharge, and storage areas. Some examples of recharge and discharge areas that could be included are:

- Recharge areas:
  - Infiltration of precipitation
  - Inflow from streams, rivers
  - Irrigation water leaching below a crop's root zone
  - Surface water pumped into an injection well to artificially store water in an aquifer
  - Agricultural return flows recirculated back to cropland

- Discharge areas:
  - Groundwater discharging to surface water along a stream
  - Groundwater pumping (discharging) from an aquifer to irrigate cropland running off the cropland as tailwater into a nearby stream or river
  - Shallow groundwater discharging to surface water via subsurface drains

An example conceptual model can be found at http://in.water.usgs.gov/NAWQAWHMI/act_sugar.php.

A discussion of groundwater in the California hydrologic cycle can be found in University of California's Division of Agriculture and Natural Resources (ANR) Publication 8083 (Basic Concepts of Groundwater Hydrology) available at http://anrcatalog.ucdavis.edu/pdf/8083.pdf.

The differences in the movement of surface water and groundwater are also important in the effects and solutions to pollution. Most important is that groundwater does not typically flow to a single outlet and groundwater movement occurs on a different time scale than surface water pollution. A discussion of this can be found in University of California's Division of Agriculture and Natural Resources (ANR) Publication 8084 (Groundwater Quality and Groundwater Pollution) available at http://groundwater.ucdavis.edu/Publications/Harter_FWQFS_8084.pdf.

Useful Information To Consider In Development of a Long-Term Regulatory Program
How agriculture impacts groundwater quality and the vulnerability of groundwater to pollution from agricultural practices will be important considerations when developing a long-term regulatory program for irrigated lands. The Chapter 4 Introduction should include a brief discussion of these issues as suggested below.

1. How agriculture impacts groundwater quality.
   To provide an understanding of how agriculture impacts groundwater quality in the Region, it would be helpful to include a discussion of the following:

- The methods of impact (irrigation resulting in leaching of imported, naturally occurring, or concentrated pollutants; tillage: drainage; chemical use; application of animal waste)
- The common pollutants in groundwater related to agriculture and their characteristics

Information on this can be found in the following:

- USGS Fact Sheet 2004-3098 (*Studies by the U.S. Geological Survey on Sources, Transport, and Fate of Agricultural Chemicals*, September 2004) available at http://pubs.usgs.gov/fs/2004/3098/pdf/fs2004-3098.pdf.
- Irrigated Agriculture Technical Advisory Committee Report available at http://www.swrcb.ca.gov/nps/docs/tacrpts/tac_irriag.doc.
- University of California's Division of Agriculture and Natural Resources (ANR) Publication 8055 (*Nonpoint Sources of Pollution in Irrigated Agriculture*) available at http://anrcatalog.ucdavis.edu/pdf/8055.pdf.
- University of California Sustainable Agriculture Research and Education Program Components Newsletter Spring 1990 (*California Agriculture and Groundwater Quality*) available at http://www.sarep.ucdavis.edu/newsltr/components/v1n2/sa-3.htm.

2. The importance of groundwater vulnerability to pollution.

Several agencies have recognized the importance of identifying the vulnerability of groundwater to pollution as a result of agricultural practices and use this information to prioritize where and what solutions are needed. A brief discussion of the Department of Pesticide Regulation's (DPR's) Groundwater Protection Program, the California Department of Food and Agriculture's (CDFA's) Fertilizer Research and Education Program (FREP), the California Department of Health Services Drinking Water Source Assessment Program, and the State Water Resources Control Board Groundwater Ambient Monitoring and Assessment (GAMA) Program would be helpful.

The discussion could include the factors used to evaluate groundwater vulnerability, what potential pollutants are evaluated, how the information is used, and where additional information on these programs can be found (DPR's Groundwater Protection Program at http://www.cdpr.ca.gov/docs/emon/grndwtr/index.htm, CDFA's FREP at http://www.cdfa.ca.gov/is/fflders/criteria.html, CDHS's DWSAP at http://www.cdph.ca.gov/certlic/drinkingwater/Pages/DWSAP.aspx, and the State Water Resources Control Board GAMA Program at http://www.waterboards.ca.gov/gama/index.html).

A brief discussion of the drainage problems along the west side of the San Joaquin Valley should also be included in this section. The San Joaquin Valley Drainage Program has identified areas along the west side of the San Joaquin Valley between the Sacramento-San Joaquin Delta and the Tehachapi Mountains to the south that are vulnerable to drainage problems caused by irrigation of cropland where the underlying groundwater is shallow and there are marine sediments derived from the Coast Ranges that naturally contain elevated levels of salts and trace elements. Irrigation of these areas has leached the salts and trace elements from the sediments to groundwater. A shallow clay layer underlying these areas obstructs vertical movement of the irrigation water. Because of the poor drainage, the groundwater table rises to within a few feet of the surface and subsurface drainage is required to remove this water from the crop's root zone. The San Joaquin Valley Drainage Implementation Program (SJVDIP) was established in 1991 to implement recommendations of the San Joaquin Valley Drainage Program to address the drainage problems on the west side of the San Joaquin Valley. Information on these drainage problem areas is available at http://www.sjd.water.ca.gov/drainage/index.cfm and information on the SJVDIP is available at http://www.owue.water.ca.gov/statedrain/index.cfm.

Other Topics from the Sacramento River and San Joaquin Valley Groundwater Basin Introductory Sections

The Chapter 4 Introduction could also include some of the common topics that are included in the introductory sections for Sacramento River and San Joaquin Valley Groundwater Basins. These topics could then be removed from each of the Groundwater Basin discussions. These topics include the following.

1. Organization and Elements and General Sources of Information for both groundwater basins. This information is available under the separate introductory sections for the Sacramento River and San Joaquin Valley Groundwater Basin and would best be combined into the introduction to Chapter 4.

2. Constituents of Concern in Groundwater related to agriculture. Table 4 in the General Concepts and Processes Affecting Groundwater Quality in the Sacramento River Basin is also applicable to the San Joaquin Valley Groundwater Basin and could be included in the Chapter 4 Introduction.

SACRAMENTO RIVER AND SAN JOAQUIN VALLEY GROUNDWATER BASIN SECTIONS
Introductory Sections

The introductory section for each of the groundwater basins should be consistent. Assuming the Chapter 4 Introduction includes the recommendations above, the remaining topics in the introductory sections for each groundwater basin should include:

1. Overview of Agricultural Chemical Impacts to Groundwater
   This information for the Sacramento River Basin is currently under the heading General Concepts and Processes Affecting Groundwater Quality in the introductory section to the Sacramento River Basin. This heading (not the information under the heading) should be revised to Overview of Agricultural Chemical Impacts to Groundwater to be consistent with the San Joaquin Valley Groundwater Basin.

2. Groundwater Movement and Solute Transport
   The section on Groundwater Movement and Solute Transport in the Sacramento River Basin introductory section discusses results of a GAMA study on the susceptibility of groundwater in the Chico area to contamination (The report should provide a reference for this discussion). It is not mentioned that the GAMA program has also completed similar studies in the Fresno, Stanislaus, Sacramento, and Kern County areas and is also

working on a similar study in the San Joaquin County area. It would be appropriate to discuss the GAMA study results for the Sacramento County area or at least refer to the study in the Sacramento River Basin introductory section.

It would also be appropriate to include a section on Groundwater Movement and Solute Transport in the San Joaquin Valley Groundwater Basin introductory section where the results of the GAMA studies in the Fresno, Stanislaus, and Kern County areas could be summarized. A table similar to Table 4-3 (Summary of Groundwater Quality Issues for the Groundwater Basins) in the introductory section of the Sacramento River Basin under the subheading Groundwater Quality Summary would be very useful in the San Joaquin Valley Groundwater introductory section as well.

3. General Management Practices
Management Measures are discussed for each groundwater subbasin in the Sacramento River Basin. Management Measures are not discussed for the subbasins in the San Joaquin Valley Groundwater Basin although the introductory section for the San Joaquin Valley Groundwater Basin includes a discussion of General Management Practices. A consistent approach should be used for both groundwater basins. Since most of the subbasins for the Sacramento River Basin indicate that management measures were not identified and management measures for subbasins that have the same crops were the same, it would be appropriate to summarize management practices specific to certain crop types grown in the Sacramento River Basin under the heading General Management Practices in the introductory section of the Sacramento River Basin.

The discussions of groundwater level and groundwater quality monitoring by government agencies and Groundwater Management Plans that are included in the Sacramento River Subbasin discussions are not appropriate under the heading Management Measures. Such information is useful but would be more appropriate in the section on Pertinent Ordinances or Regulations.

4. Assessment of Data Adequacy
Each Sacramento River Subbasin includes a discussion of the Assessment of Data Adequacy and Need for Added Data. There is no discussion of data adequacy for each groundwater subbasin in the San Joaquin Valley Groundwater Basin although the introductory section for the San Joaquin Valley Groundwater Basin includes a discussion of Assessment of Data Adequacy. A consistent approach should be used for both groundwater basins. Since for most of the subbasins in the Sacramento River Basin "Data from DWR provide somewhat limited picture of groundwater quality…in that there is not extensive areal coverage for groundwater quality" it would be appropriate to summarize this in the introductory section to the Sacramento River Basin and remove the Assessment of Data Adequacy and Need for Added Data from the subbasin discussions. Also, the following should be removed from the Sacramento River Basin under the heading Assessment of Data Adequacy: (1) the discussion of the Need for Added Data since the purpose of the Existing Conditions Report does not include identifying where more data is needed, and (2) groundwater quality issues for each subbasin should be moved to the Water Quality section of each subbasin.

Other useful information (available in California Department of Water Resources Bulletin 118) that could be included in the introductory section for each groundwater basin includes:

- General hydrogeology (general groundwater flow direction, Coast Range sediments on west side and Sierra Nevada sediments on east side – additional information is available in *A Management Plan for Agricultural Subsurface Drainage and Related problems on the Westside San Joaquin Valley, Final Report of the San Joaquin Valley Drainage Program*, September 1990 available at http://www.owue.water.ca.gov/docs/RainbowReportIntro.pdf).
- Groundwater development

Subbasin Sections

The Sacramento River Subbasin and San Joaquin Valley Groundwater Subbasin discussions should follow the same format. The following differences were noted.

1. Management Measures
   For the Sacramento River Subbasins, this information should be moved to the introductory section to the Sacramento River Basin under the heading General Management Practices as noted on page 5 above.

2. Assessment of Data Adequacy and Need for Added Data
   For the Sacramento River Subbasins, this information should be moved to the introductory section to the Sacramento River Basin under the heading Assessment of Data Adequacy as noted on page 5 above.

3. Water Quality
   The Water Quality discussions for the Sacramento River Subbasins only include general water quality information on inorganics from DWR Bulletin 118, while the Water Quality discussions for the San Joaquin Valley Groundwater Subbasins includes the general water quality information from DWR Bulletin 118 (Inorganic Constituents) and information on pesticides from the Department of Pesticide Regulation (DPR). Pesticides in the Sacramento River Basin counties are discussed in the introductory section of the Sacramento River Basin. A consistent approach should be used for both groundwater basins. Some consistency could be provided without having to add additional information to the Water Quality section of the Sacramento River Basin by including a table similar to Table 4-2 (Pesticide Detections in Wells for Counties in the Sacramento River Basin (1985-2003)) in the San Joaquin Valley Groundwater Basin introductory section with the appropriate counties listed.

4. The introductory section and the subbasin sections for the Sacramento River Basin use the word "we" in describing what is included or discussed in the report. The word "we" does not occur in the San Joaquin Valley Groundwater Basin or Subbasin discussion. Use of the word "we" is not appropriate in the report and should be removed.

LONG-TERM PROGRAM CONCERNS

Dairies

The current waiver program for discharges from irrigated lands does not cover discharges from irrigated lands that receive liquid waste from sources such as dairy operations and food processors and requires that owners and/or operators of facilities that receive such liquid waste must obtain waste discharge requirements or a separate conditional waiver. Under Waste Discharge Requirements General Order No. R5-2007-035 for Existing Milk Cow Dairies (General Order), owners and/or operators of existing dairies that apply dairy waste (liquid or solid) to land that is under their control are required to develop and implement a nutrient management plan and monitor discharges of storm water and tailwater (when irrigation has occurred less than 60 days after application of manure and/or wastewater) to surface water. Dairy owners/operators who transfer their wastewater to a third party for the third party's use are only required to have a written agreement with the third party. While the third party agrees to use the wastewater at agronomic rates and prevent runoff of wastewater to surface water in the written agreement, the third parties are not currently directly regulated under either the General Order or the Irrigated Lands Waiver Program.

If third parties are put under waste discharge requirements, it would likely discourage them from receiving dairy wastewater and would likely require significant staff resources since such transfers of waste can fluctuate significantly within short periods of time. It may be appropriate to consider allowing these lands to be covered under the long-term irrigated lands program with the requirement that a nutrient management plan be developed and implemented for any such land. This requirement could also be applied to third parties that receive solid waste from dairies, who are now covered under the irrigated lands waiver program.

Water Quality Protection Measures

The long-term regulatory program should be an integrated approach with the goal of protecting both surface water and groundwater quality. Any required management measures to protect surface water should not have a negative impact on groundwater quality, and vice versa.

RECOMMENDED NEXT STEPS

The most efficient way to revise Chapter 4 would be a stepwise approach. The first revisions should include the following (see the discussion above and the outline below).

1. Draft the Chapter 4 Introduction.

2. Revise the introductory section to the San Joaquin Valley Groundwater Basin (this section needs more additional information than the Sacramento River Basin introductory section).

3. Revise the first subbasin of both the Sacramento River Basin and the San Joaquin Valley Groundwater Basin.

Once these revisions are completed, then the introductory section of the Sacramento River Basin and the remaining subbasin discussions can be completed.

The following outline for a revised Chapter 4 should be used as guide to complete Chapter 4.

Chapter 4 Introduction
Importance of Groundwater
Useful Information to Consider in Development of a Long-Term Regulatory Program
How Agriculture Impacts Groundwater Quality
Importance of Groundwater Vulnerability to Pollution
Organization and Elements
General Sources of Information
Constituents of Concern in Groundwater Related to Agriculture

Sacramento River Basin
Introduction
Overview of Agricultural Chemical Impacts to Groundwater - *This is under the heading General Concepts and Processes Affecting Groundwater Quality in the Sacramento River Basin in the 2006 Draft Existing Conditions Report*
Groundwater Movement and Solute Transport – *add discussion of GAMA study in Sacramento County area*
Groundwater Quality Summary
General Management Practices
Assessment of Data Adequacy
General Hydrogeology
Groundwater Development

Subbasins (Individual)
General Basin Parameters
Acreage, Physiography, and Water-Bearing Units
Major Sources of Recharge
Land Use
Coalitions, Water Districts, Major Urban Areas
Pertinent Ordinances or Regulations – *include any Groundwater Management Plans or groundwater level or groundwater quality monitoring by government agencies as noted under Management Measures in the 2006 Draft Existing Conditions Report*
Water Quality – *move water quality discussions covered under the heading Assessment of Data Adequacy and Need for Added Data in the 2006 Draft Existing Conditions Report to this section*
Inorganics
Pesticides
Other
Discharge Pathways and Sources of Contaminants - *The subheadings Dissolved Solids, Nitrate, Boron, and Pesticides should be moved to the Water Quality section.*

San Joaquin Valley Groundwater Basin
Introduction
Overview of Agricultural Chemical Impacts to Groundwater - *Include a table similar to Table 4-2 (Pesticide Detections in Wells for Counties in the Sacramento River Basin (1985-2003)) with the appropriate counties listed*

Groundwater Movement and Solute Transport – *add discussion of GAMA studies in Fresno, Kern, and Stanislaus County areas*

Groundwater Quality Summary – *add a table similar to Table 4-3 (Summary of Groundwater Issues for the Groundwater Basins)*

General Management Practices

Assessment of Data Adequacy

General Hydrogeology

Groundwater Development

Subbasins (Individual)

General Basin Parameters

- Acreage, Physiography, and Water-Bearing Units
- Major Sources of Recharge
- Land Use
- Coalitions, Water Districts, Major Urban Areas
- Pertinent Ordinances or Regulations

Water Quality

- Inorganics
- Pesticides
- Other

Discharge Pathways and Sources of Contaminants

Temporal trends in concentrations of DBCP and nitrate in groundwater in the eastern San Joaquin Valley, California, USA

K. R. Burow · N. M. Dubrovsky · J. L. Shelton

Abstract Temporal monitoring of the pesticide 1,2-dibromo-3-chloropropane (DBCP) and nitrate and indicators of mean groundwater age were used to evaluate the transport and fate of agricultural chemicals in groundwater and to predict the long-term effects in the regional aquifer system in the eastern San Joaquin Valley, California. Twenty monitoring wells were installed on a transect along an approximate groundwater flow path. Concentrations of DBCP and nitrate in the wells were compared to concentrations in regional areal monitoring networks. DBCP persists at concentrations above the US Environmental Protection Agency's maximum contaminant level (MCL) at depths of nearly 40 m below the water table, more than 25 years after it was banned. Nitrate concentrations above the MCL reached depths of more than 20 m below the water table. Because of the intensive pumping and irrigation recharge, vertical flow paths are dominant. High concentrations (above MCLs) in the shallow part of the regional aquifer system will likely move deeper in the system, affecting both domestic and public-supply wells. The large fraction of old water (unaffected by agricultural chemicals) in deep monitoring wells suggests that it could take decades for concentrations to reach MCLs in deep, long-screened public-supply wells, however.

Résumé Les suivis en temps du pesticide 1,2-dibromo-3-chloropropane (DBCP), des nitrates et des indicateurs de l'âge moyen des eaux souterraines ont été utilisés dans le but d'estimer le transport et le devenir des produits agrochimiques dans les eaux souterraines, et de prédire leurs effets à long terme dans le système aquifère régional de la San Joaquin Valley orientale, en Californie. Vingt piézomètres ont été implantés en alignement, approximativement selon une ligne de flux souterrain. Les concentrations en DBCP et nitrates mesurées dans les piézomètres ont été comparées aux concentrations dans les réseaux de surveillance du secteur. Le DBCP dépasse continuellement la valeur limite fixée par l'US Environmental Protection Agency, à des profondeurs proches de 40 m sous le niveau piézométrique, et plus de 25 ans après son interdiction. Les concentrations en nitrates supérieures aux limites se retrouvent à des profondeurs supérieures à 20 m sous le niveau piézométrique. Les écoulements verticaux sont prépondérants, du fait des pompages intensifs et de la réalimentation par irrigation. Les concentrations élevées (supérieures aux limites) présentes dans la tranche la plus superficielle de l'aquifère sont susceptibles de migrer plus en profondeur dans le système, et d'affecter les puits privés et ceux destinés à l'alimentation en eau potable. Cependant, la large proportion d'eau ancienne (non affectée par les produits agrochimiques) dans les piézomètres profonds suggère que les limites de concentration ne seront pas dépassées avant longtemps dans les puits d'alimentation en potable, qui sont profonds et présentent des hauteurs crépinées conséquentes.

Resumen La monitorización temporal del plaguicida 1,2-dibromo-3cloropropano (DBCP) y de los nitratos así como indicadores de la media de edad del agua subterránea han sido utilizados para evaluar el transporte y el destino de los compuestos químicos en el agua subterránea y para predecir los efectos a largo plazo en el sistema acuífero regional situado al este del Valle de San Joaquín, California. Se instalaron veinte pozos de control en un transecto situado aproximadamente siguiendo la línea de flujo del agua subterránea. Las concentraciones de DBCP y nitratos en los pozos se compararon con las concentraciones en la red de control regional. DBCP persiste con concentraciones por encima de los niveles máximos contaminantes (MCL) de la Agencia de Protección Medioambiental de Estados Unidos a profundidades cercanas a los 40 fm por debajo del nivel piezométrico, más de 25 años después de haber sido prohibido. Las concentraciones de nitratos por encima de MCL alcanzaron profundidades de más de 20 m por debajo del nivel piezométrico. Debido al bombeo intensivo y los retornos de riego, las líneas de flujo verticales son dominantes. Las altas concentraciones (por encima de MCLs) situadas en la parte superficial del sistema acuífero regional probablemente se moverán más profundamente en el sistema,

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enclosure (16)

afectando a los pozos domésticos y a los pozos de abastecimiento. No obstante, la alta proporción de aguas antiguas (no afectadas por compuestos químicos de origen agrícola) en los pozos de control profundos sugiere que pueden pasar décadas para que se alcancen concentraciones que alcancen MCLs en profundidad, en los pozos de abastecimiento totalmente ranurados.

Keywords Agriculture · Contamination · San Joaquin Valley · Groundwater monitoring · Groundwater age

Introduction

Widespread occurrence of 1,2-dibromo-3-chloropropane (DBCP) and nitrate at concentrations of concern affects both rural and public drinking-water supplies in the eastern San Joaquin Valley, California. DBCP, a soil fumigant used to control nematodes, was applied to crops nationwide beginning in the 1950s. In 1977, agricultural use of DBCP was suspended in California in response to concern about the potential hazardous effects of DBCP on human health; however, DBCP persists in groundwater in this region at concentrations above the US Environmental Protection Agency (USEPA) maximum contaminant level (MCL) of 0.2 μg/L, posing a threat to drinking-water supplies more than 25 years after it was banned from use (California State Water Resources Control Board 2002a). Similarly, nitrate occurrence in groundwater is an issue of concern, in part, because nitrate concentrations persist in oxic groundwater and have increased over time in many areas (Nightingale 1970; Schmidt 1972; Madison and Brunett 1985; Lowry 1987; Anton et al. 1988; Almasri and Kaluarachchi 2004). Nitrate has been widely detected in groundwater in the eastern San Joaquin Valley. Nitrate concentrations exceeded the USEPA MCL of 10 mg/L (as nitrogen) in 24% of domestic wells sampled during 1993–1995 (Dubrovsky et al. 1998), and the Central Valley is one of the top three regions in the state in regards to the number of public drinking-water wells exceeding the USEPA MCL for nitrate (California State Water Resources Control Board 2002b). Nitrate concentrations in groundwater in the eastern San Joaquin Valley are expected to persist over the long term, owing to continued anthropogenic nitrogen inputs and generally oxic geochemical conditions.

Many studies have addressed issues of DBCP and nitrate occurrence and sources in the eastern San Joaquin Valley aquifer (Schmidt 1972; Miller and Smith 1976; Nightingale and Bianchi 1974; Schmidt 1986, 1987; Burow et al. 1998a; Harter et al. 1998; Loague et al. 1998a,b; Loague and Abrams 1999) and some studies have analyzed data on temporal trends in concentration (Nightingale 1970; Schmidt 1972; California State University Fresno Foundation 1994; Kloos 1996; Burow et al. 1998b; Burow et al. 1999); however, long-term monitoring data are scarce, and few wells have been sampled over time spans long enough to assess the potential for long-term degradation of the groundwater resource. Predicting the long-term fate of agricultural chemicals in groundwater in this region is difficult owing to intensive groundwater pumping, mixing sources of recharge water, and complex flow paths through heterogeneous alluvial fan sediments. Coupling chemical concentrations with groundwater age indicators can aid in understanding groundwater-flow systems and identifying trends in groundwater quality (Cook and Böhlke 1999; Lindsey et al. 2003; MacDonald et al. 2003; Broers and van der Grift 2004; Puckett and Hughes 2005). Understanding the behavior of nonpoint source agricultural constituents such as DBCP and nitrate, is fundamental to predicting the long-term effects of anthropogenic practices on the quality of groundwater in the eastern San Joaquin Valley. Analysis of these constituents can assist in characterizing dominant aquifer processes controlling the fate and transport of a wide range of possible chemicals of concern in the subsurface.

To assess temporal trends in groundwater quality in the study area and determine the possible long-term effects of agricultural management practices on groundwater quality in this region, DBCP and nitrate concentrations in groundwater were analyzed in samples collected from monitoring wells in 1994–1995 and in 2003. The monitoring wells were installed at multiple depths along a transect, representing a range of groundwater ages. The groundwater ages, determined from CFC concentrations, were used to estimate the concentration of DBCP and nitrate in recharge through time. Simulated age distributions for each monitoring well, derived from a groundwater flow and transport model developed for the study site (Weissmann et al. 2002b), were evaluated in relation to DBCP concentrations and compared to previous estimates of the in-situ half-life of DBCP in the aquifer (Burow et al. 1999). Spatial and temporal patterns of nitrate concentrations were also evaluated and compared to nitrogen fertilizer applications. Simulated age distributions (Weissmann et al. 2002b) were used to adjust fertilizer application curves to further interpret apparent changes in nitrate concentration over time. Results of the analysis at the study site were compared to data from regional areal well networks to extrapolate the findings to a larger spatial scale.

Study area

Hydrogeology of Fresno study area

The study area is west of the foothills of the Sierra Nevada and east of the San Joaquin Valley trough on the upper part of the Kings River alluvial fan (Fig. 1). The alluvial sediments consist primarily of interlayered lenses of gravel, sand, silt, and clay deposited by the Kings River in aggradation sequences linked to Pleistocene glacial episodes (Burow et al. 1997; Weissmann et al. 2002a). These sediments were derived from source materials in the Sierra Nevada that consist primarily of granitic rocks, with lesser amounts of metasedimentary and metavolcanic rocks (Page and LeBlanc 1969; Cehrs et al. 1980).

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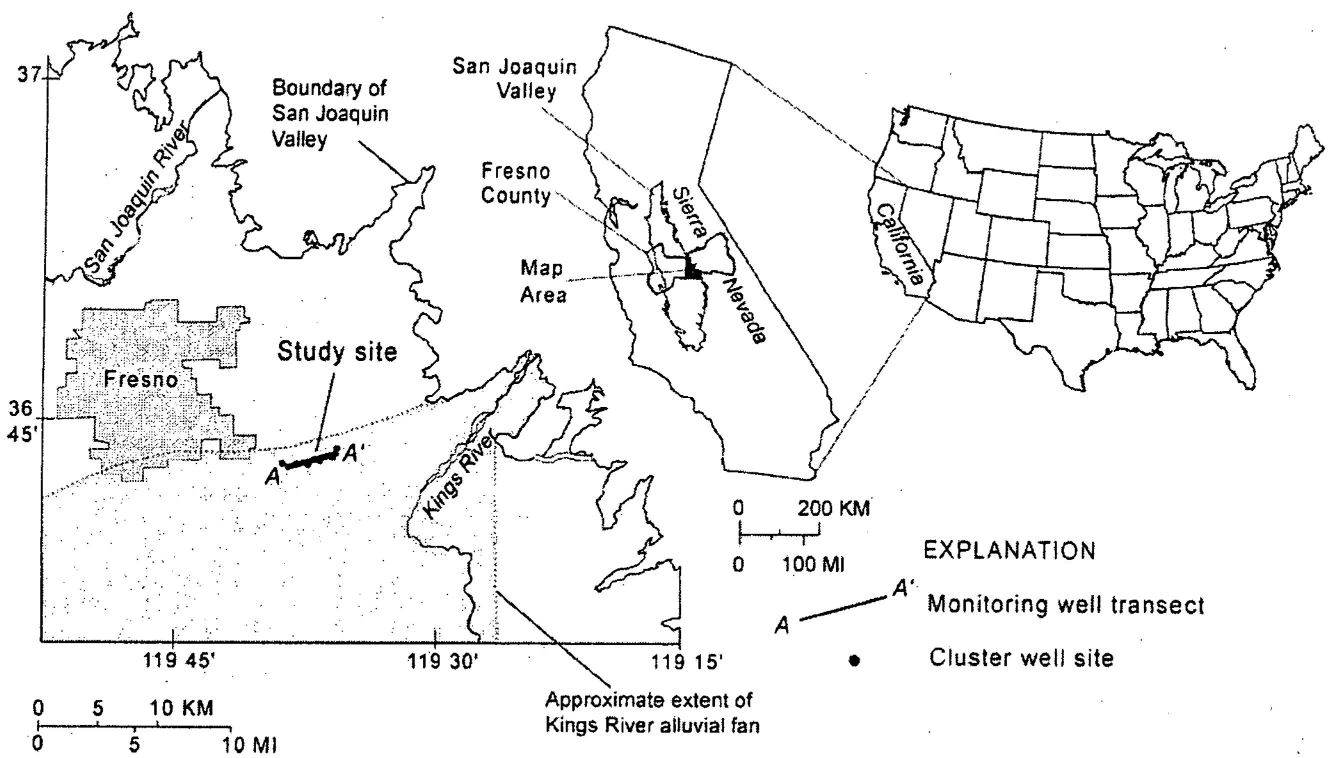

Fig. 1 Study site near Fresno in the eastern San Joaquin Valley, California

The aquifer in the study area is unconfined. Locally, water-bearing layers of sand and gravel are confined by clay layers, but at the regional scale, the sand layers are interconnected (Page and LeBlanc 1969). The transmissivity of the aquifer sediments ranges from about 650 to 2,000 m^2/day (Page and LeBlanc 1969); the hydraulic conductivity of the individual hydrogeologic facies units ranges over several orders of magnitude (Burow et al. 1999).

Regional movement of groundwater is southwest, toward the axis of the San Joaquin Valley; however, because of the intensive pumping and irrigation recharge, the dominant flow paths in the aquifer system are vertically downward. The horizontal gradient along the transect is about 0.002, whereas vertical gradients between monitoring wells varied from 0.0003 to 0.1, due to local confining clay layers or pumping of nearby irrigation wells (Burow et al. 1999). Groundwater in the study area is recharged by artificial recharge from canal seepage and infiltration of excess irrigation water; by natural recharge from precipitation, rivers, and streams; and by subsurface inflow from adjacent areas. Pumping is the primary mechanism of groundwater withdrawal in the study area, although some groundwater flows downgradient to adjacent areas or discharges into the San Joaquin and Kings Rivers (Muir 1977).

Groundwater development in the study area began in about 1880. Groundwater withdrawals increased slowly until the 1940s and 1950s when groundwater pumping for irrigation increased sharply (Bertoldi et al. 1991). Beginning in the early 1950s, water from the San Joaquin River, which has low nitrate and DBCP concentrations, was diverted into canals to distribute surface water to farms in the study area. In 2000, about 14 m^3/day of water was used in this region; more than 90% of the water is used for irrigation (Hutson et al. 2004). The relative proportion of surface water and groundwater used for irrigation varies spatially and temporally. Fields adjacent to the irrigation canals likely receive more surface water than fields at greater distances. During wet years, surface-water supplies may be available during the irrigation season, but during dry years, many farmers rely solely on groundwater for irrigation. Although the source of water to specific locations varies from year to year, about 50% of the total urban and agricultural water use is supplied by groundwater (Fred Stumpf, California Department of Water Resources, unpublished data, 1988; Hutson et al. 2004).

Land use and sources of DBCP and nitrate

Agriculture is the predominant land use in the San Joaquin Valley. In the eastern San Joaquin Valley, vineyards occupy about 19% of the more than 1.1 million ha of agricultural land. In eastern Fresno County near the monitoring well transect, grapes have been grown since the late 1800s and the area of harvested grapes has increased steadily from about 570 km^2 in 1958 to more than 900 km^2 in the late 1990s (Fresno County Agricultural Commissioner, unpublished data, 2005). The acreage of vineyards near the monitoring well transect has remained relatively constant during the last several decades (Fig. 2); however, some individual fields were converted from vineyards to other crops (primarily orchards) between 1987 and 2000 (California Department of Water Resources 1971, 2001).

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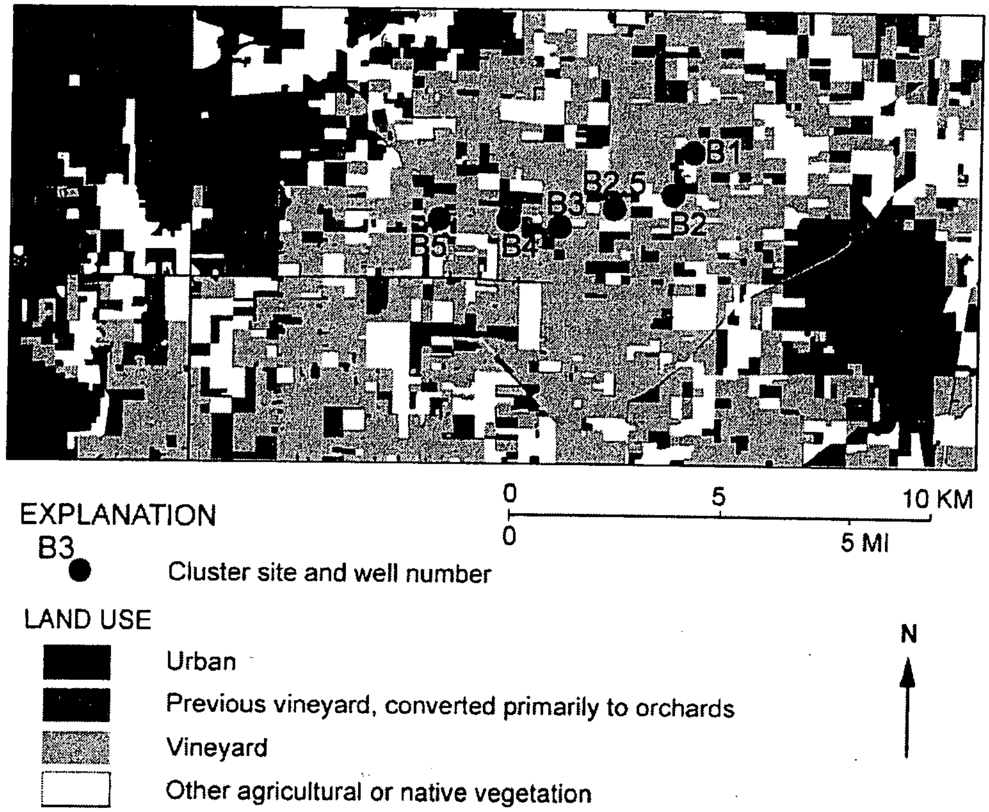

Fig. 2 Land use in the vicinity of the monitoring well transect

Application of DBCP to crops is not well documented, although partial reporting of applications to the California Department of Pesticide Regulation indicates that DBCP was used primarily on vineyards and orchards beginning in the 1950s; the most intensive use was between about 1960 and 1977 (California Department of Food and Agriculture 1973; Domagalski 1997). DBCP was used intermittently to treat nematode problems that occurred especially in older, well-established crops; at many locations it was used only once (California State University Fresno Foundation 1994). In 1977, agricultural use of DBCP was suspended in California in response to concern about the potential hazardous effects of DBCP on human health (California State Water Resources Control Board 2002a).

The persistence of DBCP was documented in laboratory studies, which indicated a half-life ranging from 6.1 years (Deeley et al. 1991) to more than 140 years (Burlinson et al. 1982). The term half-life is a radioactive decay rate that is often used to represent organic chemical transformation. Half-life is used here to represent the time required for the concentration of DBCP to decrease to one-half of the original value, and was determined in laboratory studies by curve-fitting the kinetic data. Several of the chemical and physical properties of DBCP facilitate its transport to groundwater and its continued presence in the aquifer near Fresno. DBCP has a relatively low vapor pressure, 0.8 torr at 21°C, and a moderate water solubility, 700–1,230 mg/L at 20°C (Burlinson et al. 1982; US Environmental Protection Agency 1985). Using subsurface sediments from the Fresno area, Deeley et al. (1991) determined that DBCP is weakly sorbed (K_D, sorption coefficient, ranged from 0.06 to 0.07 l/kg), owing to the predominantly low organic content of soils in this area. Laboratory experiments by Castro and Belser (1968) indicate that DBCP could undergo biological transformation in soils, but DBCP is resistant to biological transformation in well-oxygenated groundwater (Bloom and Alexander 1990) such as the groundwater in the Fresno area. An apparent half-life for DBCP determined from a contaminant transport modeling study (Burow et al. 1999) is consistent with the 6.1-year half-life determined by Deeley et al. (1991). Results from Burow et al. (1999) indicate that chemical transformation of DBCP to 2-bromoallyl alcohol (BAA) is not a dominant process, however, and the mechanism for decreases in concentrations observed in the Fresno region was not determined. Apparent decreases in DBCP concentrations may be due to unknown transformation processes or the result of physical processes such as hydrodynamic dispersion and pumping and reapplication of irrigation water (Burow et al. 1999).

Nitrate occurs naturally in groundwater; however, in agricultural areas, elevated concentrations of nitrate (above background levels) occur as the result of farming operations where nitrogen fertilizers or manure are applied (Nightingale 1972; Owens et al. 1992), confined animal feeding operations, and rural septic systems. In the study

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area, confined animal feeding operations were not present, and background concentrations of nitrate are expected to be less than 3 mg/L (Schmidt 1972). Septic inputs were expected to be small, relative to the contribution from the surrounding crops, although locally they could affect concentrations in water from individual wells. In contrast to DBCP use in the area, nitrogen fertilizer use has generally increased since the 1950s (Alexander and Smith 1990; Battaglin and Goolsby 1994; Ruddy et al. 2006). Nitrogen fertilizers were applied more consistently (spatially and temporally) than DBCP and continued to be applied after DBCP use was banned.

Methods

Twenty monitoring wells were installed in 1994–1995 at depths ranging from 21.3 to 81.7 m below land surface at six cluster sites along a 5.9-km transect southeast of Fresno (Figs. 2 and 3). The length of the screened interval of each well is about 1.5 m (Burow et al. 1997, 1999). The monitoring well transect generally was aligned in the direction of regional groundwater flow in the study area.

Groundwater samples were collected during 1994–1995 and 2003 and analyzed for DBCP and nitrate concentrations. Groundwater samples were also collected and analyzed for CFCs and SF_6 concentrations to estimate mean groundwater ages along the transect. Concentrations of nitrate plus nitrite are hereafter referred to as nitrate because nitrite was only detected in three samples and accounted for less than 3% of the total nitrate plus nitrite in those samples.

Groundwater samples were collected using protocols developed by the USGS National Water-Quality Assessment (NAWQA) program (Koterba et al. 1995) and are further described in Burow et al. (1999). Analyses of DBCP and nitrate were completed at the USGS National Water-Quality Laboratory (NWQL) in Arvada, Colorado. DBCP samples were collected by filling 40-ml vials with unfiltered water and analyzed by liquid/liquid extraction followed by gas chromatography/electron-capture detection (GC/ECD; Fishman 1993). The detection limit for DBCP using this method was 0.03 μg/L. Nitrate samples were filtered using a 0.45-μm pleated capsule filter and analyzed using standard methods of analysis (Fishman and Friedman 1985). Following collection of the samples described above, a submersible, positive-displacement piston pump with 0.6-cm diameter aluminum tubing was used to collect samples for analysis of CFC concentrations using methods described by Busenberg and Plummer (1992). The samples were analyzed for dichlorodifluoromethane (CFC-12), trichlorofluoromethane (CFC-11), and trichlorotrifluoromethane (CFC-113) by the USGS labo-

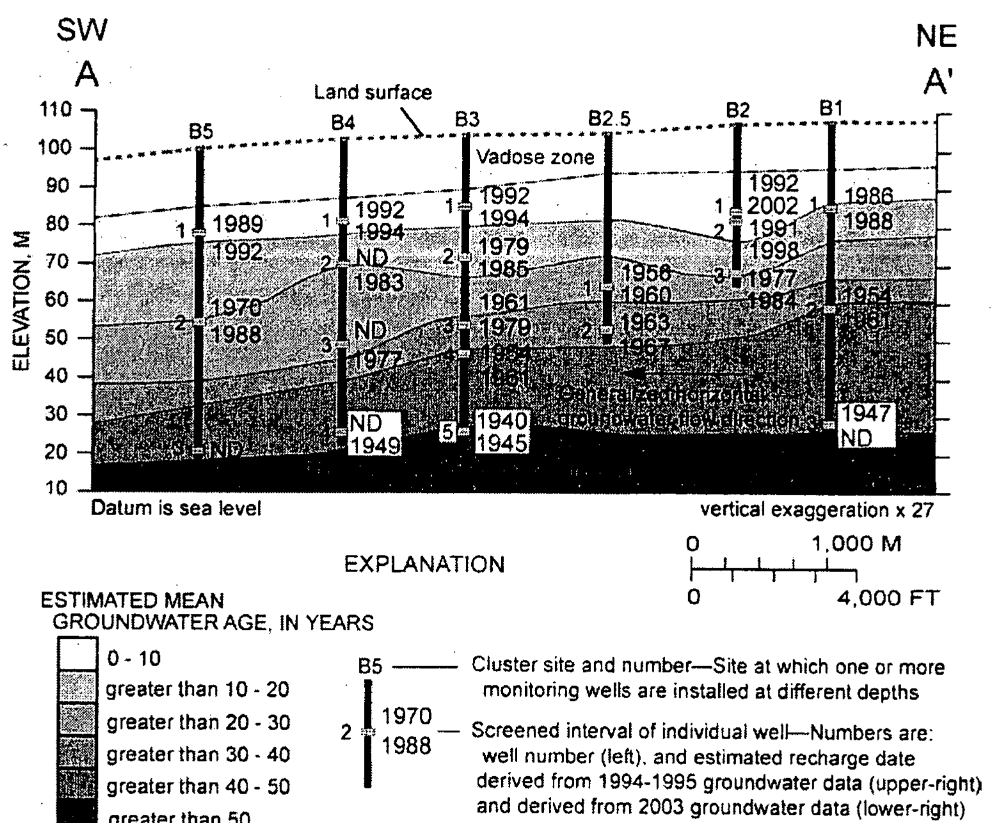

Fig. 3 Monitoring well transect showing estimated groundwater recharge dates determined from chlorofluorocarbon (CFC) concentrations in groundwater samples collected from wells during 1994–1995 and 2003 (refer to Fig. 1 for transect location)

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ratory in Reston, Virginia, using a purge-and-trap GC/ECD procedure (Busenberg and Plummer 1992). Samples were collected for dissolved gases (N_2, Ar, CO_2, CH_4, and O_2) and sulfur hexafluoride (SF_6) also. The dissolved gas samples were analyzed by gas chromatography after extraction in headspaces of glass samplers (Busenberg et al. 1998), and SF_6 was determined by methods described in Busenberg and Plummer (2000).

Results and analysis

Groundwater age

Mean groundwater ages (the mean age of groundwater reaching the wells) were estimated along the monitoring well transect using CFC concentrations in samples collected in 1994–1995 (Burow et al. 1999) and in 2003 (Table 1). CFC concentrations were the primary age tracers used in this analysis; SF_6 concentrations were used primarily to corroborate the CFC-determined ages.

In the study area, CFC-based mean groundwater age increased with depth (Fig. 3). Groundwater in the shallow aquifer depth zone, less than or equal to 10 m below the water table, was generally less than 15 years old, whereas groundwater in the deep aquifer depth zone, more than 60 m below the water table, was generally more than 45 years old (Table 1). In most samples, concentrations of two or more tracers were evaluated and compared to simple analytical models of groundwater age (e.g., Cook and Böhlke 1999) using the TRACERMODEL software (Böhlke 2005). The groundwater age interpreted from concentrations of the various tracers were generally concordant, indicating a lack of significant mixing between young (1940s or younger) and old, pre-tracer-aged groundwater. The mean groundwater ages determined from CFC concentrations were based primarily on a piston-flow model (Plummer and Busenberg 2004), where the ages of groundwater samples from different depths are nearly uniform. Some samples indicated local contamination problems and other samples had concentrations consistent with the early (1940s) or late (after 1990s) part of the input curve, which resulted in a greater uncertainty in interpreted mean ages. Additional factors considered in the interpretation of mean age included comparison to concentrations of other solutes, knowledge of specific site history, and fitting of a conceptual model for position of the well in the flow system.

Mean groundwater ages determined from groundwater flow and transport simulations (Weissmann et al. 2002b) were older than the CFC-based mean ages-about 25 years in the shallow aquifer depth zone and more than 100 years in the intermediate (10–60 m below the water table) and the deep depth zones. Simulated CFC concentrations were similar to observed concentrations, however (Weissmann et al. 2002b). The mean ages determined from the simulations were older than CFC-based mean ages because the simulated mean ages account for the full distribution of ages of water reaching the well screens, including water that is older than the introduction of the age-dating tracers into the environment. As noted by Kazemi et al. (2006), it is difficult to accurately represent complex groundwater-flow systems with simple analytical models; however, the simulated age distributions resembled a piston-flow type curve in the shallow part of the system, and resembled an exponential-piston-flow- or dispersion-type curve with depth as the proportion of old, pre-tracer-aged groundwater increased. Conceptually, the piston-flow part of the age distribution curves likely represents the young fraction of water traveling through preferential flow paths, whereas the exponential part of the age distribution curves represent older water traveling along slower flow paths or diffusing from fine-grained sediments. Because the CFC concentrations indicated a lack of significant mixing, the CFC-based mean ages reflect the mean age of the young, piston-flow fraction of water reaching the wells.

Change in DBCP concentrations

DBCP concentrations in 2003 persisted at concentrations above the USEPA MCL at 7 of the 20 wells along the monitoring well transect (Table 1), at depths of nearly 40 m below the water table. DBCP concentrations increased in 6 of the 20 wells between 1994–1995 and 2003 but decreased in 8 other wells. DBCP was not detected in either 1994–1995 or 2003 in the remaining six wells, likely reflecting variability in application patterns and the effects of heterogeneity on transport in the subsurface. The largest changes in concentration were decreases in the high concentrations at site B2 (Table 1) in the shallow and intermediate depths of the aquifer, suggesting that high-DBCP water was replaced by recharge with low-DBCP water at this site (Fig. 4). DBCP concentrations varied greatly near the water table. DBCP was not detected in either 1994–1995 or 2003 at shallow aquifer depths at sites B3 and B4. DBCP was also not detected in the deepest wells at sites B3, B4, and B5 (Fig. 4). DBCP concentrations increased at intermediate aquifer depths at sites B2.5, B3, and B4, and although the concentrations were low, the largest percentage change in concentrations between 1994–1995 and 2003 was at wells with increases in low concentrations (Table 1). The largest percentage change in concentration occurred at B1-3, the deepest well along the transect where DBCP was detected. DBCP concentrations also increased in the intermediate and shallow depth wells at site B1, indicating that high concentrations of DBCP have moved laterally and downward within the aquifer adjacent to site B1.

Persistence of DBCP and initial concentrations

Using the change in concentration of DBCP and estimated groundwater recharge dates derived from CFC concentrations in groundwater samples collected in 1994–1995 and 2003, an in-situ half-life estimate for DBCP in groundwater was calculated. The DBCP half-life was calculated using a first-order decay equation (Domenico and Schwartz 1998),

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Table 1 Mean groundwater age determined from chlorofluorocarbon (CFC) concentrations, and 1,2-dibromo-3-chloropropane (DBCP) and nitrate concentrations in groundwater samples in 1994–1995 and 2003 in the eastern San Joaquin Valley, California

Well (Figs. 2 and 3)	Depth below land surface to midpoint of screened interval (m)	Depth below water table (m)	Depth zone[a]	Mean age for 1994–95 samples (years)	Mean age for 2003 samples (years)	DBCP in 1994–1995 (μg/L)[b]	DBCP in 2003 (μg/L)[b]	Difference in DBCP concentration (percent)	Nitrate in 1994–1995 (mg/L)[c]	Nitrate in 2003 (mg/L)[c]	Difference in nitrate concentration (%)
B1-1	22.4	7.2	Shallow	8	16	2.6	3.1	19	8.6	11	28
B1-2	48.9	33.7	Intermediate	41	43	0.29	0.49	69	2.3	2.4	4
B1-3	79.4	64.2	Deep	48	ND	<0.03	0.18	500	1.4	2.1	50
B2-1	22.4	7.2	Shallow	2	2	2.8	0.17	−94	12	20	67
B2-2	25.2	10.0	Shallow	4	6	3.0	0.44	−85	14	18	29
B2-3	38.9	23.7	Intermediate	18	19	6.4	3.6	−44	11	13	18
B2.5-1	40.4	25.2	Intermediate	39	43	<0.03	0.08	170	1.9	2.2	16
B2.5-2	51.7	36.5	Intermediate	32	37	0.86	0.47	−45	3.3	3.9	18
B3-1	19.0	3.8	Shallow	3	9	<0.03	<0.03	0	6.3	30	380
B3-2	32.2	17.0	Intermediate	16	19	0.3	0.08	−73	11	17	55
B3-3	50.1	34.9	Intermediate	33	24	0.04	0.12	200	5.1	8.6	69
B3-4	57.8	42.6	Intermediate	41	43	0.46	0.17	−63	2.9	3	3
B3-5	78.5	63.3	Deep	55	58	<0.03	<0.03	0	2.3	2	−13
B4-1	21.5	6.3	Shallow	2	9	<0.03	<0.03	0	6	14	130
B4-2	32.8	17.6	Intermediate	ND	20	<0.03	<0.03	0	6.1	8.7	43
B4-3	53.8	38.6	Intermediate	ND	26	0.86	1.1	31	4.1	5.1	24
B4-4	77.3	62.1	Deep	ND	55	<0.03	<0.03	0	2.6	2.6	0
B5-1	22.1	6.9	Shallow	6	12	1.3	0.06	−95	31	40	29
B5-2	45.9	30.7	Intermediate	25	16	2.0	1.7	−12	8.1	10	23
B5-3	79.4	64.2	Deep	ND	ND	<0.03	<0.03	0	5	7.9	58

[a] *Shallow* includes depths of less than or equal to 10 m below the water table, *intermediate* includes depths of more than 10 m to 60 m below the water table, and *deep* includes depths of more than 60 m below the water table

[b] Micrograms per liter

[c] Milligrams per liter

ND no data

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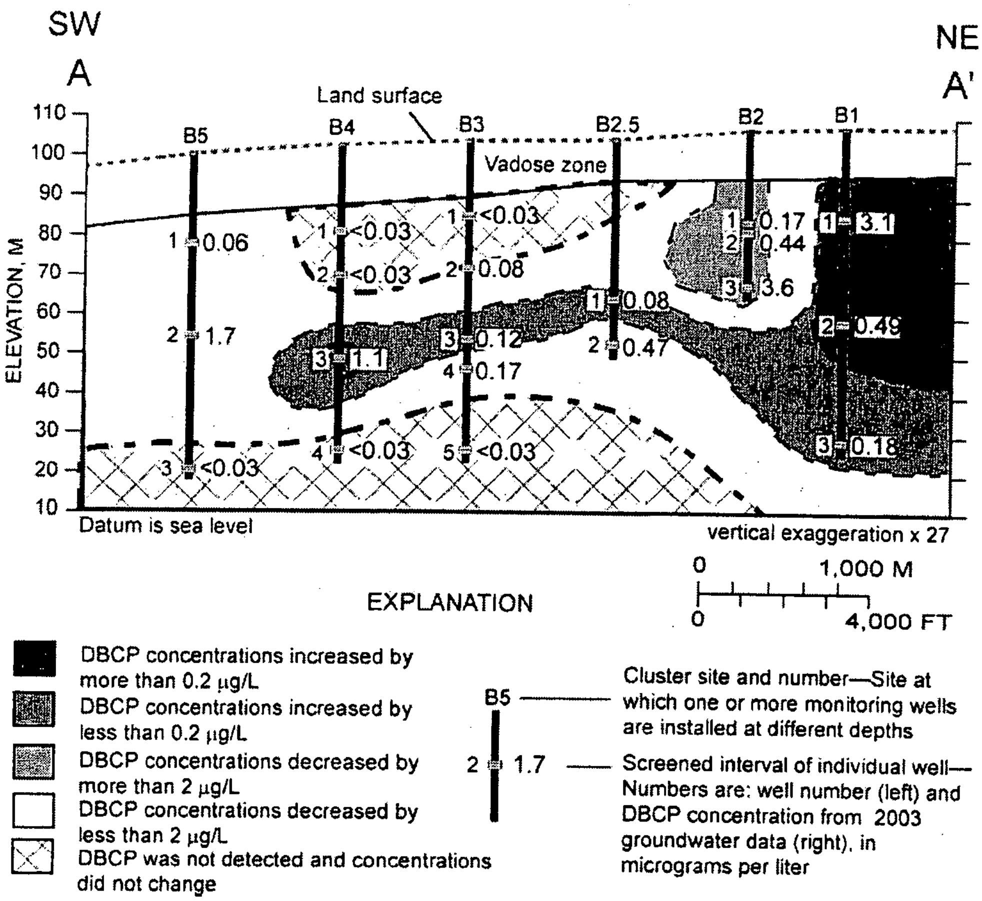

Fig. 4 DBCP concentrations in groundwater samples collected from wells in 2003 and change in DBCP concentrations between 1994–1995 and 2003

$$C_o = C(t)e^{kt}, \qquad (1)$$

and

$$k = \frac{0.693}{t_{1/2}}, \qquad (2)$$

where C_o is the initial DBCP concentration, $C(t)$ is the DBCP concentration at time t, t is the time since beginning of the reaction, k is the rate constant for a first-order reaction, and $t_{1/2}$ is the half-life for the reaction. The difference in concentrations of DBCP between 1994–1995 and 2003 for wells with similar recharge dates in 1994–1995 and 2003 were used in the half-life calculations (Table 2). Samples were paired if the estimated recharge dates were within 1 year. In most cases, there was only one sample from 1994–1995 and one sample from 2003 for each recharge date. Although the first-order reaction rate may not adequately reflect DBCP reaction rates in the aquifer, limited data were available to characterize the decay function, and previous work was limited to the use of a first-order reaction rate (Burow et al. 1999).

Resulting DBCP half-life estimates ranged from 2 to 6 years, with a median of 4 years. An estimated half-life of in this range is consistent with results of earlier work, in which contaminant transport model results suggested that the effective in-situ half-life of DBCP was about 6 years (Burow et al. 1999). Although the results indicated by this analysis compare generally well with previous estimates

Table 2 Calculated 1,2-dibromo-3-chloropropane (DBCP) half-life from changes in DBCP concentration and groundwater age dates for groundwater samples with common recharge dates in the eastern San Joaquin Valley California

Recharge date	DBCP in 1994–1995 (µg/L)[a]	DBCP in 2003 (µg/L)[a]	Calculated DBCP half-life (years)
1960	0.04	0.17	[b]
1977	6.4	1.1	3
1979	0.3	0.12	6
1986	2.6	0.89	5
1989	1.3	3.1	[b]
1992	2.8	0.06	2
Mean	2.2	0.91	4
Median	2.0	0.53	4

[a] Micrograms per liter

[b] Half-life could not be calculated because concentrations increased

Elapsed time between sample dates was 8.5 years

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of the in-situ half-life of DBCP determined through contaminant transport modeling, this approach assumes that DBCP is generally well-distributed throughout the profile and that the mixing of older water does not affect the calculations. A mass-balance approach would likely provide a better estimate of in-situ DBCP half-life; however, the data and analysis requirements to attempt a mass balance in this system were prohibitive.

Estimated initial concentrations of DBCP in recharge through time were calculated, again using the first-order decay Eqs. 1 and 2 and the CFC-based and simulated mean groundwater age estimates. Initial concentrations of DBCP calculated using groundwater recharge dates estimated from CFC concentrations and a half-life of 6 years ranged from less than 1 to 70 μg/L (Table 3). Maximum measured concentrations in production wells sampled during the early 1980s were about 50 μg/L (California Department of Pesticide Regulation 1992, 1993, 1994). For comparison, initial concentrations of DBCP were calculated using the simulated mean groundwater age (Weissmann et al. 2002b). Initial concentrations resulting from the simulated mean age were from 2 to 5 orders of magnitude higher than the estimates from the CFC mean age (Table 3). The initial concentration estimates from the simulation-based mean age were extremely high because the simulated age distributions include water that is older than the introduction of DBCP into the environment, and, thus, the simulated mean age does not represent the mean age of the fraction of water containing DBCP. In 6 of 14 wells where DBCP was detected in 2003 (B2-3, B2.5-1, B2.5-2, B3-3, B3-4, and B4-3), estimated groundwater recharge dates from the simulated mean groundwater ages were before 1950, probably before DBCP was used (California State University Fresno Foundation 1994).

The analysis described above indicates that the mean age determined by CFC concentrations better reflects the age of the water containing DBCP than the simulated mean age because the CFC-based mean ages correspond more closely with the timing of the input of DBCP. Additionally, the uncertainty in the simulated mean ages determined in the transport simulations ranged from 10 to 30 years (Weissmann et al. 2002b), suggesting that the simulated mean ages may be a coarse evaluation of age for interpreting changes in chemical concentrations of less than a few decades. To accurately represent the true mean age and predict long-term concentrations in the aquifer, however, a complete distribution of age is needed that includes the age distributions of both the young and old fractions of water.

Change in nitrate concentrations and relation to nitrogen fertilizer use

Nitrate was detected in samples from all wells along the monitoring well transect. Concentrations in 2003 ranged from about 2 mg/L (as nitrogen) in the deepest monitoring wells to 30 to 40 mg/L in the shallow wells (Table 1). Concentrations above the USEPA MCL reached depths of more than 20 m below the water table. As noted in Burow et al. (1999), and corroborated with dissolved gas data collected in 2003, groundwater along the transect is oxic. Nitrate is expected to be persistent in the aquifer and assumed to be transported conservatively through the system.

Nitrate concentrations increased by more than 1 mg/L between 1994–1995 and 2003 in 12 of 20 wells along the monitoring well transect (Table 1). Increases in nitrate concentrations were the greatest in the shallow part of the aquifer (Fig. 5). Nitrate concentrations in shallow wells at sites B2, B3, B4, and B5 increased by 8–23 mg/L. A plum orchard was in production immediately upgradient from site B3 during the 1990s, and other citrus and nectarine orchards were planted upgradient from site B4 by 2000. Nitrogen fertilizer application rates are typically much higher for orchard crops (158 kg/ha/year) than for grapes (60 kg/ha/year; Rauschkolb and Mikkelsen 1978), although it is not known whether the high nitrate concentrations are due to the differences in crops or whether other sources of nitrate or management practices may have affected concentrations at these sites. Nitrate concentrations increased at a slower rate in wells screened in the intermediate part of the aquifer. Nitrate concentrations generally increased less than 1 mg/L in the deepest wells and remained at concentrations of less than 3.0 mg/L in the intermediate and deep wells at sites B1, B3, and B4.

Nitrate concentrations were compared to nitrogen fertilizer applications to evaluate whether the observed changes in nitrate concentration in recharge through time could be explained by fertilizer use. Using a method outlined by (Böhlke 2002), nitrate concentration in recharge water from nitrogen fertilizer applications were estimated using groundwater recharge dates and data for county-level fertilizer applications. Based on the mean groundwater age from CFC concentrations, a linear groundwater age gradient was characterized, indicating a constant vertical water velocity with depth (Cook and Böhlke 1999). Although the aquifer in the study area is a heterogeneous mixture of alluvial fan sediments, the aquifer receives distributed recharge and lacks extensive confining clays, which is consistent with a generally linear or logarithmic age gradient with depth. The estimated recharge rate, r, was calculated using the equation,

$$r=nZ/\tau, \qquad (3)$$

where n is the effective porosity, Z is the saturated thickness of the aquifer, and τ is the mean age of groundwater in the aquifer (Cook and Böhlke 1999; Böhlke 2002). An effective porosity of 0.3 was calculated, assuming an effective porosity ranging from 0.2 to 0.35 and using the proportion of each of the four hydrogeologic facies identified in the study area (Weissmann and Fogg 1999). A saturated thickness of about 50 m was assumed. A mean age of groundwater of 24 years was calculated by averaging the apparent CFC-based mean ages from 1994–1995 and 2003 concentrations (Table 1). The resulting

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Table 3 Initial 1,2-dibromo-3-chloropropane (DBCP) concentrations in recharge determined from chlorofluorocarbon (CFC) age dates and simulated age distributions in the eastern San Joaquin Valley, California

Well (Figs. 2 and 3)	Estimated recharge date from CFC age dates in 1994–1995 (year)	Estimated recharge date from CFC age dates in 2003 (year)	Initial DBCP concentration from CFC age dates in 1994–1995 using a half-life of 6 years (μg/L)[a]	Initial DBCP concentration from CFC age dates in 2003 using a half-life of 6 years (μg/L)[a]	Simulated mean age[b] (years)	Estimated recharge date from simulated mean age[b] (year)	Simulated fraction of groundwater younger than 50 years[b] (%)	Initial DBCP concentration from simulated mean age using a half-life of 20 years[b] (μg/L)[a]
B1-1	1986	1988	6.6	20	22	1981	100	40
B1-2	1954	1961	33	70	ND	ND	ND	ND
B1-3	1947	ND	ND	ND	ND	ND	ND	ND
B2-1	1992	2002	3.5	0.2	32	1971	70	6.8
B2-2	1991	1998	4.8	0.9	33	1970	70	20
B2-3	1977	1984	51	32	57	1946	60	2,600
B2.5-1	1956	1960	ND	11	81	1922	60	920
B2.5-2	1963	1967	35	32	140	1863	40	5.0E+6
B3-1	1992	1994	ND	ND	18	1985	90	ND
B3-2	1979	1985	1.9	0.7	34	1969	70	4.1
B3-3	1961	1979	1.8	1.9	87	1916	60	2,800
B3-4	1954	1961	52	24	97	1906	40	12,000
B3-5	1940	1945	ND	ND	ND	ND	ND	ND
B4-1	1992	1994	ND	ND	19	1984	100	ND
B4-2	ND	1983	ND	ND	44	1959	70	ND
B4-3	ND	1977	ND	22	100	1903	30	110,000
B4-4	ND	1949	ND	ND	120	1883	<1	ND
B5-1	1989	1992	2.6	0.2	24	1979	70	1.0
B5-2	1970	1988	36	10	52	1951	60	690
B5-3	ND	ND	ND	ND	120	1883	0	ND

[a] Micrograms per liter

[b] Simulations from Weissmann et al. 2002b

ND No data

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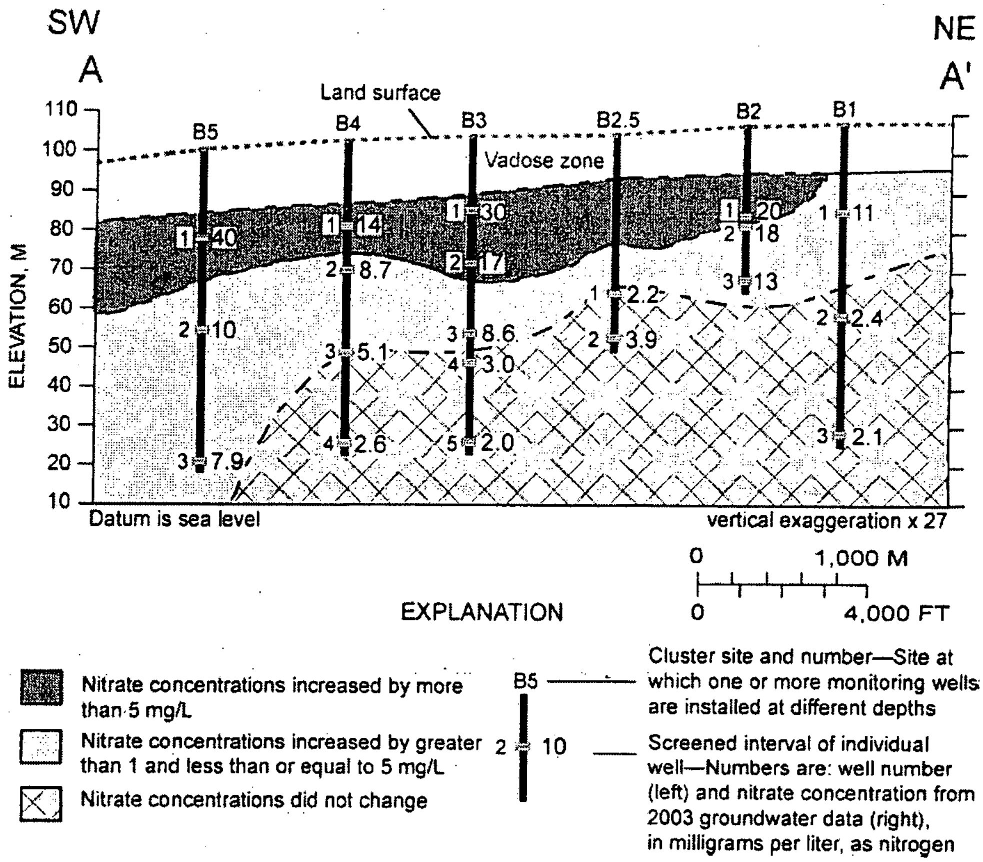

Fig. 5 Nitrate concentrations in groundwater samples collected from wells in 2003 and change in nitrate concentrations between 1994–1995 and 2003

estimated recharge rate was 0.6 m/year. The mean age of groundwater used in the estimate of the recharge rate is based on the CFC mean ages because the elevated nitrate concentrations are likely contained within the piston-flow component of the age distribution, which appears to be adequately represented by the CFC-based ages. The nitrogen application was estimated by dividing the reported application by the area of fertilized land in the county, as determined from annual crop estimates, and assuming that 50% of the nitrogen fertilizer reached the water table.

Estimated initial nitrate concentrations in recharge, represented as observed nitrate concentrations and estimated groundwater recharge dates, generally increased over time (Fig. 6). Estimated nitrogen fertilizer applications also generally increased over time. The axes representing initial nitrate concentration and nitrogen fertilizer application are quantitatively related through the recharge rate such that the application amount on one axis corresponds to the expected concentration in recharge on the other axis (Fig. 6). The estimated nitrogen fertilizer applications were higher than observed nitrate concentrations before about 1980. After this time, the observed nitrate concentrations appear to have increased significantly, whereas the nitrogen fertilizer applications leveled off.

The analysis using nitrogen fertilizer applications may cause the amount of nitrogen expected in the groundwater samples from annual fertilizer applications to be overestimated because the applications do not account for the wide range of ages represented in each groundwater sample: each fertilizer application amount is associated with only 1 year. Therefore, the nitrogen fertilizer applications were corrected using the distribution of groundwater age from simulations of Weissmann et al. (2002b). The estimated fertilizer application was applied to the fraction of water for each year for each well for which an age distribution was simulated. Before about 1970, the resulting age-corrected nitrogen fertilizer applications correspond more closely to the observed nitrate concentrations than the uncorrected applications, but after 1970, the age-corrected applications appear to be much lower than the observed concentrations (Fig. 6). Local variability in management practices may have contributed to the high observed nitrate concentrations in recent years. The highest observed concentrations are at site B5; concentrations of nitrate were 31 mg/L in 1994–1995 and 40 mg/L in 2003. The history of land use at this site includes vineyards and corn in 1986 and vineyards and orchards in 2000; vineyards comprise about 50% of the area around the well. Consistently high nitrate concentrations relative to those at the other sites along the transect may be due to the presence of orchards and/or corn, which typically receive much more nitrogen fertilizer than vineyards. Concentrations of 30 to 40 mg/L were observed in samples from other wells in the eastern San

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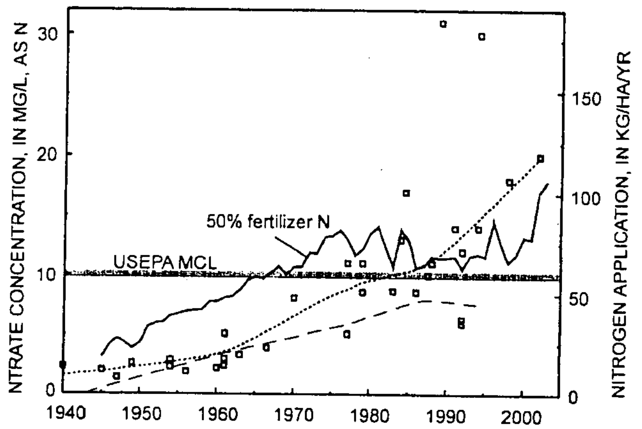

Fig. 6 Estimated initial nitrate concentrations in recharge and nitrogen concentrations estimated from county-level annual nitrogen fertilizer applications. The fertilizer loading curves represent 50% of the nitrogen fertilizer applications divided by the area of fertilized land, dissolved in 0.6 m/year of recharge. Fertilizer loads are also shown corrected for simulated distribution of ages at monitoring wells. *USEPA* US Environmental Protection Agency; *MCL* maximum contaminant level

Joaquin Valley representing groundwater beneath almond orchards and corn, alfalfa, and vegetable crops (Burow et al. 1998a).

The discrepancy between observed nitrate concentrations and nitrogen fertilizer applications may also have been caused by evapoconcentration of nitrate as groundwater containing nitrate was pumped and reapplied as irrigation water (Nightingale and Bianchi 1974). Burow et al. (1999) indicated that recycling of groundwater through groundwater pumping and reapplication of irrigation water was likely a dominant process in the study area. This process is likely to result in increasing concentrations of nitrate even without increasing fertilizer applications. Because of the complexity of the groundwater system in this area, however, it is difficult to separate the effect of the recycling of groundwater from other processes such as the mixing of groundwater and surface water used for irrigation and local variability or changes in management practices over the long term. Surface water supplied for irrigation has low nitrate concentrations and using this water would result in lower nitrate concentrations in recharge than groundwater-derived irrigation water.

Long-term changes in water quality in the regional aquifer

Nitrate concentrations from samples collected from the local network of monitoring wells along the transect were compared to nitrate concentrations in regional areal networks to evaluate whether concentrations observed along the monitoring well transect near Fresno were reflected in regional areal networks in the eastern San Joaquin Valley. Concentrations along the transect were compared to networks of domestic and monitoring wells sampled as part of the NAWQA program (Burow et al. 1998a,b) that represent shallow groundwater conditions throughout the aquifer underlying the eastern San Joaquin Valley, an approximately 16,000 km^2 area. Concentrations along the transect were also compared to concentrations in nearby public-supply wells sampled for regulatory compliance monitoring (Wright et al. 2004). The public-supply wells are typically deep and have long screened intervals.

Nitrate concentrations from wells in the regional areal networks sampled in 2001–2002 were grouped by well type and well depth below the water table to characterize nitrate concentrations in the different parts of the used resource and to extrapolate concentrations areally to other parts of the regional aquifer. In the regional aquifer, domestic wells are generally screened in the shallow part of the aquifer, whereas public-supply wells tend to be screened in the deeper part of the aquifer. Monitoring wells included in the analysis from the regional areal networks are screened near the water table. Similar to conditions observed along the transect, groundwater in the areal networks is typically oxic (Burow et al. 1998a,b). Nitrate is expected to be persistent in the aquifer and assumed to be transported conservatively through groundwater.

Nitrate concentrations are the highest and most variable in the shallow monitoring wells in the areal networks; variability and concentration decrease with depth (Fig. 7). Highly variable concentrations of nitrate at the water table are expected, even with relatively constant fertilizer applications, because of the heterogeneous distribution of sediments and the high variability of nitrate in the moderately thick vadose zone (Harter et al. 1998). The observed decrease in concentration with depth could be due to dispersion and mixing as nitrate moves farther from the source of nitrate in recharge; however, the decrease in

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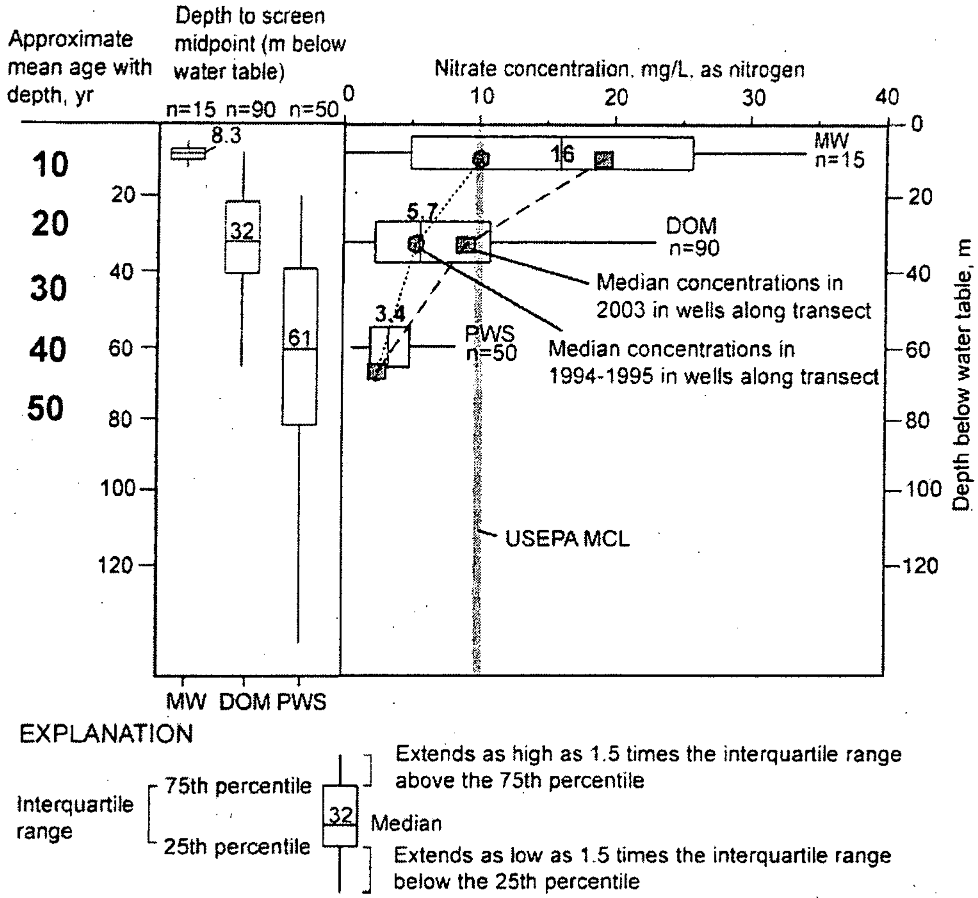

Fig. 7 Relation among nitrate concentration, well type, well screen depth below water table, and groundwater age in the eastern San Joaquin Valley, California. Concentrations in samples from wells along monitoring well transect are grouped by well type. *Boxplots* are concentrations of nitrate sampled in the 2000s from monitoring and domestic well networks (Burow et al. 1998a). Boxplot of concentrations in public-supply wells from Wright et al. (2004). *MW*, monitoring well; *DOM*, domestic well; *PWS*, public-supply well; *n* number of samples; *USEPA*, US Environmental Protection Agency; *MCL*, maximum contaminant level

concentrations with depth is also consistent with an increase in nitrogen fertilizer applications over time (Fig. 6). In the shallow and intermediate depths in the aquifer, concentrations increased between 1994–1995 and 2003 to concentrations similar to those observed at the water table in 1994–1995, indicating that the elevated concentrations at the water table did not attenuate significantly as groundwater moved deeper in the system.

CFC-based mean groundwater age in the monitoring wells along the transect were used to estimate the mean age of groundwater at the depths of the domestic wells; the groundwater in the domestic wells was estimated to be about 20–30 years old. However, mean groundwater age of about 6 years was determined from 18 domestic wells sampled for CFC concentrations in eastern Fresno and Tulare Counties (Spurlock et al. 2000). Despite the apparent differences in groundwater ages, nitrate concentrations observed in the local network of monitoring wells along the transect are within the range of observed concentrations in the areal networks at the same depths. The estimated age of groundwater in domestic wells could be younger than monitoring wells screened at the same depths because of pumping.

Using a similar analysis as described above, CFC-based mean groundwater age at the depths of the public-supply wells are about 30–50 years old. To the extent that the areal networks reflect processes observed in the local network of monitoring wells along the transect and based on chemical data indicating that the aquifer is generally oxic, high nitrate concentrations at the water table in the regional aquifer will likely move deeper in the system without significant attenuation of concentrations over time. However, the proportion of water older than the age-dating tracers increases with depth. The simulated age distributions in the deepest monitoring wells along the transect indicate that groundwater at the depth of the public-supply wells contains from 0 to 40% young water and mean ages are 100 years or more (Weissmann et al. 2002b). Although some young water containing elevated concentrations of nitrate concentrations may reach the deeper wells relatively rapidly along preferential flow paths, the distribution of ages of the old fraction of water reaching the well will control the length of time for concentrations of nitrate to reach levels of concern (MCLs) in the public-supply wells.

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Although DBCP was applied less consistently throughout the eastern San Joaquin Valley, causing detection frequencies to vary more, a similar analysis was done using wells from areal networks representing the almond and vineyard land-use settings (Burow et al. 1998a). DBCP was used most commonly on permanent crops such as orchards and vineyards. In contrast to nitrate concentrations, water along the monitoring well transect having the highest median DBCP concentrations of 0.17 μg/L was in the intermediate depth zone, at a depth comparable to that of the areal domestic well networks (Fig. 8). DBCP was detected in 49% of the domestic wells in the areal network; 33% exceeded the USEPA MCL of 0.2 μg/L. DBCP was detected in less than 50% of the areal domestic network wells, and, therefore, detection frequencies instead of concentrations were used for comparison to concentrations along the monitoring well transect. The median DBCP concentration in the shallow wells along the monitoring well transect, 0.12 μg/L, was lower than the concentration in the intermediate depth zone. Similarly, detection frequencies for the areal networks were lower for the shallow depth wells than the intermediate depth wells. DBCP was detected in 30% of the areal monitoring well networks at shallow depths; 10% exceeded the USEPA MCL. Because overall detection frequencies and concentrations at the water table appear to be about one-half of those at the depth of the domestic wells, and concentrations of DBCP in the shallow monitoring wells along the transect decreased between 1994–1995 and 2003, DBCP concentrations in domestic wells likely will not increase in the future. DBCP was not detected in public-supply wells in Fresno above the detection limit of 0.5 μg/L (Wright et al. 2004); however, small increases in concentration along the monitoring well transect suggest that DBCP detections and concentrations may increase at the depths of the public-supply wells in the future.

Because of the dominantly vertical-downward flow paths in the aquifer system and the lack of significant attenuation mechanisms, high concentrations of DBCP and nitrate are expected to move downward over time, which would result in increasing concentrations in the deeper domestic and public-supply wells in the future. The length of time to reach concentrations of concern will depend on the age mixtures in water in the wells. Further

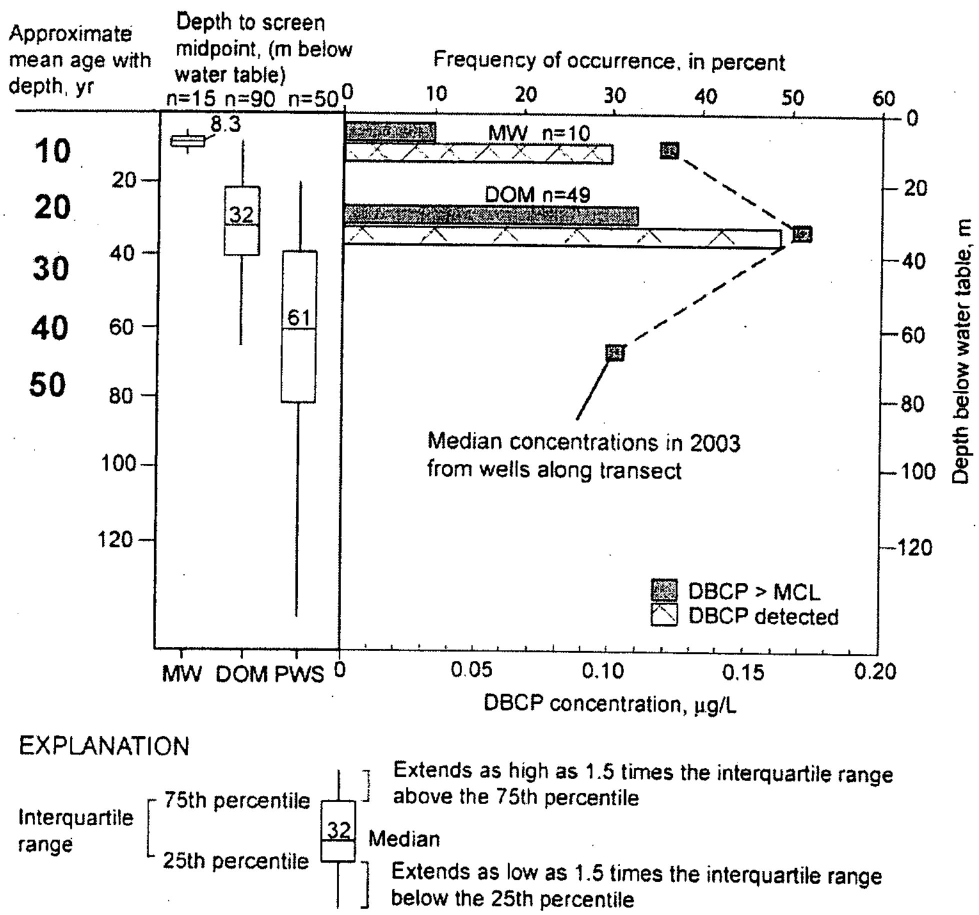

Fig. 8 Relation among DBCP concentration, DBCP detection frequency, well type, well screen depth below water table, and groundwater age in the eastern San Joaquin Valley, California. Concentrations in samples from wells along monitoring well transect are grouped by depth category. *Bar charts* correspond to frequency of detection of DBCP in wells sampled in the 2000s from monitoring and domestic well networks (Burow et al. 1998a) in the eastern San Joaquin Valley. *MW*, monitoring well; *DOM*, domestic well; *PWS*, public-supply well; *n* number of samples; > greater than

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characterization of ages of the older fraction of water in the regional aquifer is needed to better predict future impacts on the aquifer resource.

Conclusions

Mean groundwater ages determined from CFC concentrations along a monitoring well transect in the eastern San Joaquin Valley, California indicate that groundwater less than about 10 m below the water table is generally less than 15 years old, whereas mean ages of water at depths of more than 60 m below the water table are generally more than 45 years old. DBCP concentrations in groundwater persist at concentrations above the USEPA MCL more than 25 years after its use was banned, although high concentrations of DBCP in the shallow and intermediate depths of the aquifer have been replaced by recharge consisting of water with low DBCP concentrations. DBCP concentrations increased in samples from deep wells along the transect as DBCP moved deeper in the aquifer.

Using the changes in concentration of DBCP and the difference in mean groundwater age between samples collected in 1994–1995 and 2003, an estimated half-life of 2–6 years with a median of 4 years was determined. This half-life is in the range of earlier analysis and contaminant transport modeling results indicating a half-life of about 6 years (Burow et al. 1999). Initial concentrations of DBCP calculated assuming first-order decay and using groundwater recharge dates estimated from CFC concentrations and a half-life of 6 years were consistent with historical data on observed maximum concentrations in the aquifer. Calculations of initial concentrations of DBCP using simulated mean groundwater ages at the study site (Weissmann et al. 2002b) were inconsistent with observed concentrations because the simulated mean age accounts for ages of groundwater that are older than the age-dating tracers. Although the full age distributions are needed to interpret overall travel times in the aquifer and predict future impacts, the mean age of the young fraction of water determined using CFC concentrations better reflects the age of the water containing DBCP than the simulated mean age in this analysis of temporal changes in DBCP concentrations.

Nitrate concentrations ranged from about 2 mg/L in the deepest monitoring wells to 30 to 40 mg/L in the shallow wells, with concentrations above the USEPA MCL reaching depths of more than 20 m below the water table. Nitrate concentrations increased from 8 to 23 mg/L in the shallow part of the aquifer between 1994–1995 and 2003. Estimated initial concentrations of nitrate in recharge indicate an overall increase in nitrate concentrations during the last 50 years, which is generally consistent with increases in nitrogen fertilizer applications. Transport simulation results were used to correct estimates of nitrogen fertilizer loads to account for the full groundwater age distribution reaching the well screens (Weissmann et al. 2002b). Elevated nitrate concentrations resulting from pumping groundwater with high nitrate concentrations and reapplying it as irrigation water may explain elevated concentrations in later years.

DBCP and nitrate concentrations along the monitoring well transect were compared to concentrations in areal monitoring networks. Overall, concentrations along the monitoring well transect were similar to concentrations in the areal networks, suggesting that the dominant processes affecting nitrate concentrations may be similar at both local and regional scales. Nitrate concentrations were the highest and most variable in the shallow monitoring wells in the regional areal monitoring networks; the variability in nitrate concentrations and median values decreased with depth. Because of intensive pumping and irrigation recharge, the dominant groundwater flow paths in the aquifer system are vertically downward. High concentrations in the shallow part of the aquifer could be expected to move downward over time, which would result in increasing concentrations in the deeper domestic and public-supply wells in the future as water with high nitrate concentrations moves deeper in the groundwater system. Therefore, to the extent that the areal networks reflect processes observed in the monitoring wells along the transect and based on chemical data supporting that the regional aquifer is generally oxic, it is likely that high nitrate concentrations at the water table in the regional aquifer will move deeper in the system without significant attenuation of concentrations over time, affecting both domestic and public-supply wells in the regional aquifer. In contrast to nitrate concentrations, the highest DBCP concentrations were in intermediate depths in the aquifer. DBCP concentrations in shallow and intermediate depths in the regional aquifer represented by domestic wells will likely not increase in the future; however, increasing detection of low concentrations of DBCP may occur in public-supply wells open to the deepest parts of the aquifer as DBCP moves deeper in the system.

The analysis of spatial and temporal data on agricultural constituents such as DBCP and nitrate and indicators of mean groundwater age, are a useful approach to understanding the movement and fate of agricultural chemicals in the aquifer and in predicting future impacts on the resource. The data indicate that anthropogenically impacted water containing DBCP and nitrate has reached the deepest wells along the transect, at depths that corresponding to the depths of typical public-supply wells open to the regional aquifer. Mean ages determined from CFC concentrations correlate with the age of the anthropogenically impacted water; however, the CFC-based ages did not characterize the distribution of pre-tracer-aged groundwater. The simulated groundwater age distributions in the monitoring wells (Weissmann et al. 2002b) indicate that these wells contain a large fraction of old water, resulting in mean ages of 100 years or more. Assuming that DBCP and nitrate will continue to move deeper in the system, the length of time for concentrations of DBCP and nitrate to reach levels of concern in the public-supply wells in the regional aquifer will depend on the distribution of ages in water from those wells. Further characterization of the distribution of ages in the regional aquifer is needed to better predict future impacts of anthropogenic chemicals on the regional aquifer.

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References

Alexander RB, Smith RA (1990) County-level estimates of nitrogen and phosphorus fertilizer use in the United States, 1945 to 1985. U S Geol Surv Open-File Rep 90–130:12

Almasri MN, Kaluarachchi JJ (2004) Assessment and management of long-term nitrate pollution of ground water in agriculture-dominated watersheds. J Hydrol 295:225–245

Anton EC, Barnickol JL, Schnaible DR (1988) Nitrate in drinking water: report to the legislature. California Water Resources Control Board, Division of Water Quality Report 88–11WQ, California Water Resources Control Board, Sacramento, CA, 148 pp

Battaglin WA, Goolsby DA (1994) Spatial data in geographic information system format on agricultural chemical use, land use, and cropping practices in the United States. US Geol Surv Water-Resour Invest Rep 94-4176

Bertoldi GL, Johnston RH, Evenson KD (1991) Ground water in the Central Valley, California: a summary report. US Geol Surv Prof Pap 1401-A:44

Bloom RA, Alexander M (1990) Microbial transformation of 1,2-dibromo-3-chloropropane (DBCP). J Environ Qual 19:722–726

Böhlke JK (2002) Groundwater recharge and agricultural contamination. Hydrogeol J 10:153–179

Böhlke JK (2005) C. Tracermodell: Excel workbook for calculation and presentation of environmental tracer data for simple groundwater mixtures In: International Atomic Energy Agency guidebook on the use of chlorofluorocarbons in hydrology. International Atomic Energy Agency, Vienna, pp 202–206

Broers HP, van der Grift B (2004) Regional monitoring of temporal changes in groundwater quality. J Hydrol 296:192–220

Burlinson NE, Lee LA, Rosenblatt DH (1982) Kinetics and products of hydrolysis of 1,2-dibromo-3-chloropropane. Environ Sci Technol 16(9):627–632

Burow KR, Weissmann GS, Miller RD, Placzek G (1997) Hydrogeologic facies characterization of an alluvial fan near Fresno, California, using geophysical techniques. US Geol Surv Open-File Rep 97-46:15

Burow KR, Shelton JL, Dubrovsky NM (1998a) Occurrence of nitrate and pesticides in ground water beneath three agricultural land-use settings in the eastern San Joaquin Valley, California. US Geol Surv Water-Resour Invest Rep 97-4284, 51 pp

Burow KR, Stork SV, Dubrovsky NM (1998b) Nitrate and pesticides in ground water in the eastern San Joaquin Valley, California: occurrence and trends. US Geol Surv Water-Resour Invest Rep 98-4040A, 33 pp

Burow KR, Panshin SY, Dubrovsky NM, VanBrocklin D, Fogg GE (1999) Evaluation of processes affecting 1,2-dibromo-3-chloropropane (DBCP) concentrations in ground water in the eastern San Joaquin Valley, California: analysis of chemical data and ground-water flow and transport simulations. US Geol Surv Water-Resour Invest Rep 99-4059, 57 pp

Busenberg E, Plummer LN (1992) Use of chlorofluorocarbons (CCl_3F and CCl_2F_2) as hydrologic tracers and age-dating tools: the alluvium and terrace system of central Oklahoma. Water Resour Res 28(9):2257–2283

Busenberg E, Plummer LN (2000) Dating young groundwater with sulfur hexafluoride: natural and anthropogenic sources of sulfur hexafluoride. Water Resour Res 36(10):3011–3030

Busenberg E, Plummer LN, Bartholomay RC, Wayland JE (1998) Chlorofluorocarbons, sulfur hexafluoride, and dissolved permanent gases in ground water from selected sites in the and near the Idaho National Engineering and Environmental Laboratory, Idaho, 1994–97. US Geol Surv Open-File Rep 98-274:72

California Department of Food and Agriculture (1973) Pesticide use data. Computer tapes available from California Department of Food and Agriculture, Sacramento, CA

California Department of Pesticide Regulation (1992) Sampling for pesticide residues in California well water: 1992 well inventory data base, cumulative report 1986–1992. Seventh Annual Report to the Legislature, State Department of Health Services, Office of Environmental Health Hazard Assessment, and the State Water Resources Control Board Report EH 93-02, California Water Resources Control Board, Sacramento, CA, 222 pp

California Department of Pesticide Regulation (1993) Sampling for pesticide residues in California well water: 192 well inventory data base, 1993 update. Eighth Annual Report to the Legislature, State Department of Health Services, Office of Environmental Health Hazard Assessment, and the State Water Resources Control Board, Report EH 93-06, California Department of Pesticide Regulation, Sacramento, CA,167 pp

California Department of Pesticide Regulation (1994) Sampling for pesticide residues in California well water: 1992 well inventory data base, 1994 update. Ninth Annual Report to the Legislature, California Department of Pesticide Regulation, Sacramento, CA

California Department of Water Resources (1971) Land use in California: an index to surveys conducted by the California Department of Water Resources. Bulletin 176:16

California Department of Water Resources (2001) Land use for Fresno County, California, for 2000 (digital data). California Department of Water Resources, Division of Planning and Local Assistance, Statewide Planning Branch, Land and Water Use, California Department of Pesticide Regulation, Sacramento, CA

California State University Fresno Foundation (1994) Strategy for mitigation of DBCP contamination of Kings ground water basin. Contract report for California State Water Resources Control Board 1-234-250-0, California Water Resources Control Board, Sacramento, CA, variously paged

California State Water Resources Control Board (2002a) DBCP Groundwater Information Sheet, (http://www.waterboards.ca.gov/gama/docs/dbcp_oct2002_rev3.pdf). Cited 14 November 2006

California State Water Resources Control Board (2002b) Nitrate/nitrite groundwater information sheet, (http://www.waterboards.ca.gov/gama/docs/nitrate_oct2002_rev3.pdf). Cited 14 November 2006

Castro CE, Belser NO (1968) Biodehalogenation: reductive dehalogenation of the biocides ethylene dibromide, 1,2-dibromo-3-chloropropane, and 2,3-dibromobutane in soil. Environ Sci Technol 2(3):298–303

Cehrs D, Soenke S, Bianchi WC (1980) A geologic approach to artificial recharge site selection in the Fresno-Clovis area, California. US Dep Agri Tech Bull 1604:73

Cook PG, Böhlke JK (1999) Determining timescales for groundwater flow and solute transport: environmental tracers in subsurface hydrology. Kluwer, Boston, pp 1–30

Deeley GM, Reinhard M, Stearns SM (1991) Transformation and sorption of 1,2-dibromo-3-chloropropane in subsurface samples collected at Fresno, California. J Environ Qual 20(3):547–556

Domagalski JL (1997) Pesticides in surface and ground water of the San Joaquin-Tulare basins, California: analysis of available

DOI 10.1007/s10040-006-0148-7

data, 1966 through 1992. US Geol Surv Water-Supply Pap 2468:74
Domenico PA, Schwartz FW (1998) Physical and chemical hydrogeology, 2nd edn. Wiley, New York, p 506
Dubrovsky NM, Kratzer CR, Brown LR, Gronberg JM, Burow KR (1998) Water quality in the San Joaquin-Tulare Basins, California, 1992–95. US Geol Surv Circ 1159:38
Fishman MJ (1993) Methods of analysis by the US Geological Survey National Water Quality Laboratory: determination of inorganic and organic constituents in water and fluvial sediments. US Geol Surv Open-File Rep 93-125:127
Fishman MJ, Friedman LC (1985) Methods for determination of inorganic and organic substances in water and fluvial sediments. US Geol Surv Open-File Rep 85-495:709
Harter T, Heeren K, Weissmann G, Horwath W, Hopmans J (1998) Non-point source contamination in a heterogeneous, moderately deep vadose zone: the Kearney research site. Groundwater Quality: Remediation and Protection, Proceedings of the International Association of Hydrological Sciences Groundwater Quality Conference, Tubingen, Germany, September 1998, pp 257–263
Hutson SS, Barber NL, Kenny JF, Linsey KS, Lumia DS, Maupin MA (2004) Estimated use of water in the United States in 2000. US Geol Surv Circ 1268:46
Kazemi GA, Lehr JH, Perrochet P (2006) Groundwater age. Wiley, Hoboken, NJ, 325 pp
Kloos H (1996) 1,2 dibromo-3-chloropropane (DBCP) and ethylene dibromide (EDB) in well water in the Fresno/Clovis metropolitan area, California. Arch Environ Health 51(4):291–299
Koterba MT, Wilde FD, Lapham WW (1995) Ground-water data-collection protocols and procedures for the National water-quality assessment program: collection and documentation of water-quality samples and related data. US Geol Surv Open-File Rep 95-399:113
Lindsey BD, Phillips SW, Donnelly CA, Speiran GK, Plummer LN, Böhlke JK, Focazio MJ, Burton WC, Busenberg E (2003) Residence times and nitrate transport in ground water discharging to streams in the Chesapeake Bay Watershed. US Geol Surv Water-Resour Invest Rep 03-4035:39
Loague K, Abrams RH (1999) DBCP contaminated groundwater: hot spots and nonpoint sources. J Environ Qual 28(2):429–446
Loague K, Lloyd D, Nguyen A, Davis SN, Abrams RH (1998a) A case study simulation of DBCP groundwater contamination in Fresno County, California, 1: leaching through the unsaturated subsurface. J Contam Hydrol 29(2):109–136
Loague K, Abrams RH, Davis SN, Nguyen A, Stewart IT (1998b) A case study simulation of DBCP groundwater contamination in Fresno County, California, 2: transport in the saturated subsurface. J Contam Hydrol 29(2):137–163
Lowry P (1987) Hilmar ground water study. California Regional Water Quality Control Board-Central Valley Region files, variously paged, State of California, Central Valley Regional Water Quality Control Board, Sacramento, CA
MacDonald AM, Darling WG, Ball DF, Oster H (2003) Identifying trends in groundwater quality using residence time indicators: an example from the Permian aquifer of Dumfries, Scotland. Hydrogeol J 11:504–517
Madison RJ, Brunett JO (1985) Overview of the occurrence of nitrate in ground water of the United States. In: National Water Summary 1984-hydrologic events, selected water-quality trends, and ground-water resources. US Geol Surv Water-Supply Pap 2275:93–105
Miller RJ, Smith RB (1976) Nitrogen balance in the southern San Joaquin Valley. J Environ Qual 5(3):274–278
Muir KS (1977) Ground water in the Fresno area, California. US Geol Surv Water-Resour Invest Rep 77-59:22
Nightingale HI (1970) Statistical evaluation of salinity and nitrate content and trends beneath urban and agricultural areas: Fresno, California. Ground Water 8(1):22–28
Nightingale HI (1972) Nitrates in soil and ground water beneath irrigated and fertilized crops. Soil Sci 114(4):300–311
Nightingale HI, Bianchi WC (1974) Ground-water quality related to irrigation with imported surface or local ground water. J Environ Qual 3(4):356–361
Owens LB, Edwards WM, Van Keuren RW (1992) Nitrate levels in shallow ground water under pastures receiving ammonium nitrate or slow-release nitrogen fertilizer. J Environ Qual 21:607–613
Page RW, LeBlanc RA (1969) Geology, hydrology, and water quality in the Fresno area, California. USGS, Water Res. OF, 21 plates, 70 pp
Plummer LN, Busenberg E (2004) Chlorofluorocarbons in aquatic environments. In: International Atomic Energy Agency guidebook on the use of chlorofluorocarbons in hydrology, Vienna, International Atomic Energy Agency, Vienna, pp 8–12
Puckett LJ, Hughes WB (2005) Transport and fate of nitrate and pesticides: hydrogeology and riparian zone processes. J Environ Qual 34:2278–2292
Rauschkolb RS, Mikkelsen DS (1978) Survey of fertilizer use in California, 1973. Berkeley, University of California, Division of Agricultural Sciences, Cooperative Extension, US Depart Agric Bull 1887:27
Ruddy BC, Lorenz DL, Mueller DK (2006) County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982–2001. US Geol Surv Sci Invest Rep 2006-5012:17
Schmidt KD (1972) Nitrate in ground water of the Fresno-Clovis metropolitan area. Ground Water 10(1):50–64
Schmidt KD (1986) DBCP in ground water of the Fresno-Dinuba area, California. In: Proceedings of the Agricultural Impacts on Ground Water: National Water Well Association Conference, 11–13 August 1986, NGWA, Westerville, OH, pp 511–529
Schmidt KD (1987) Effect of irrigation on groundwater quality in California. J Irrig Drain Eng 113(1):16–29
Spurlock F, Burow K, Dubrovsky N (2000) Chlorofluorocarbon dating of herbicide-containing well waters in Fresno and Tulare Counties, California. J Environ Qual 29(2):474–483
US Environmental Protection Agency (1985) Drinking water criteria document for 1,2-dibromo-3-chloropropane (DBCP). US Environmental Protection Agency Document ECAO-CIN-410, USEPA, Philadelphia, PA
Weissmann GS, Fogg GE (1999) Multi-scale alluvial fan heterogeneity modeled with transition probability geostatistics in a sequence stratigraphic framework. J Hydrol 226:48–65
Weissmann GS, Mount JF, Fogg GE (2002a) Glacially driven cycles in accumulation space and sequence stratigraphy of a stream-dominated alluvial fan, San Joaquin Valley, California, USA. J Sediment Res 72(2):240–251
Weissmann GS, Zhang Y, LaBolle EM, Fogg GE (2002b) Dispersion of groundwater age in an alluvial aquifer system. Water Resour Res 38(10):16-1 to 16–13
Wright MT, Belitz K, Johnson T (2004) Assessing the susceptibility to contamination of two aquifer systems used for public water supply in the Modesto and Fresno Metropolitan Areas, California, 2001 and 2002. US Geol Surv Sci Invest Rep 2004-5149:35

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Assessing the Vulnerability of Public-Supply Wells to Contamination from Urban, Agricultural, and Natural Sources

By Sandra M. Eberts, Martha L. Erwin, and Pixie A. Hamilton

What are the most important factors controlling contamination of public-supply wells, and how can we do a better job of predicting their vulnerability to contamination?

In 2001, the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program began an intensive study to assess the vulnerability of public-supply wells to contamination from a variety of compounds.

The study builds on previous NAWQA studies from 1991 to 2001 that found low levels of mixtures of contaminants in ground water near the water table in urban areas across the Nation (in about 90 percent of monitoring wells) and, less frequently, in deeper ground water typically developed for public supply (Hamilton and others, 2004). Data from more than 1,000 public-supply wells within major water-supply aquifers are being evaluated in this study, and data from more aquifers and wells are scheduled to be added in 2009 (see map, p. 4).

This NAWQA study is focusing on the transport and chemical breakdown of selected anthropogenic contaminants from urban and agricultural sources, as well as contaminants from natural sources, within that part of the ground-water system contributing water to public-supply wells. Scientists are investigating how the linkage between contaminant sources and public-supply wells is affected by processes that occur below land surface—whereby contaminants are mobilized, dispersed, diluted, volatilized, adsorbed, and (or) degraded. Scientists are also investigating how the operation of public-supply wells can affect their vulnerability to contamination.

Because subsurface processes and management practices differ among aquifers and public-water systems, public-supply wells in different parts of the Nation are not equally vulnerable to contamination, even where similar contaminant sources exist. The study is identifying these important differences, as well as similarities, in a complementary set of aquifer systems, urban settings, and public-water systems.

A national priority, a scientific challenge

About one-third of the U.S. population gets drinking water from public-supply wells. The occurrence of contaminants in these wells is highly variable (U.S. Environmental Protection Agency, 1999). To safeguard public health, we need a better understanding of how these wells can become contaminated.

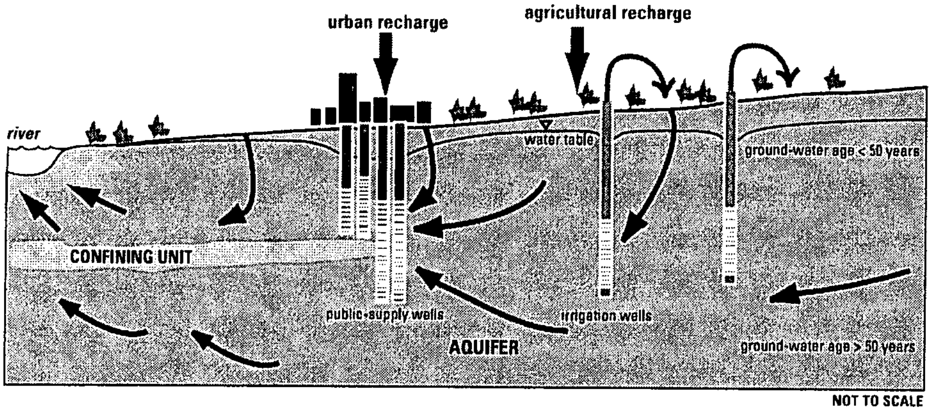
Understanding public-supply well contamination is also an economic issue because cleaning up contaminated ground water is expensive and difficult. Drinking water from public-supply wells must meet U.S. Environmental Protection Agency (USEPA) and (or) State water-quality standards. Vulnerability assessments based on sound science will help decision-makers *predict* which wells are vulnerable to contamination and design strategies to *prevent* future contamination, thereby sustaining the water supply.

Vulnerability assessments, however, are inherently uncertain. Scientists do not fully understand contaminant behavior in the subsurface, and there are limitations in the databases and models used to perform the assessments (National Research Council, 1993). An additional challenge is the need to strike a balance between complex, costly assessments and those that are oversimplified (Focazio and others, 2002). As a result, ground-water vulnerability has been assessed using many different methods (Nolan, 1998); most of the previous assess-

Contaminants assessed in this study

- Anthropogenic contaminants, including nitrate, pesticides and their breakdown products (such as atrazine and deethylatrazine), compounds found in wastewater; and volatile organic compounds (such as MTBE and disinfection by-products)
- Naturally occurring contaminants, including arsenic, uranium, radon, and radium
- Fecal contamination, using indicators such as *E. coli* and total coliform (bacteria) and coliphage (a group of viruses)

enclosure (1)



An aquifer system and public-water system in an urban setting. The water entering the well screens of the public-supply wells is of different ages and from different areas because of their long screened intervals, which commonly make public-supply wells vulnerable to contamination from multiple sources. In this example, sources of contaminants may include those associated with urban and agricultural land-use activities. Aquifer materials may also serve as sources of natural contaminants such as arsenic.

Ground-water vulnerability—the likelihood that contaminants will reach a specified reference location in a ground-water system (the water table, deep within the aquifer, a public-supply well, the interface between ground and surface water) (National Research Council, 1993).

Area contributing recharge—the surface area at the water table or a surface-water body from which water entering the ground-water system eventually flows to the well. Estimates of areas contributing recharge to public-supply wells are made in order to target ground-water protection practices (Franke and others, 1998).

Ground-water age—the time elapsed (ranging from days to millennia) since water reached the water table during recharge. Young ground water tends to be more susceptible to contamination from current sources at the land surface than older ground water (Focazio and others, 2002). Water discharging from a well is usually a mixture of waters of different ages.

Ground-water sustainability—the development and use of ground-water resources in a manner that can be maintained indefinitely without unacceptable consequences (Alley and Leake, 2004). Water quality and water quantity are equally critical for the long-term sustainability of the Nation's water supply (U.S. Geological Survey, 2002).

ments have focused on the transport of contaminants to the water table rather than to public-supply wells.

In the current study, we address the challenges of vulnerability assessments by collecting and analyzing similar data within a variety of settings, including unique data collected using new tools. We are developing a library of site-specific models to help sort out the most important factors to include in vulnerability assessments in different settings at both regional and local scales.

Study results will provide a foundation for assessing the vulnerability of the Nation's public-supply wells to a variety of contaminants, and will help those involved in well siting and water-quality protection anticipate the response of different systems to changes in management practices. The results also will be useful to those involved in planning and implementing State source-water assessment and protection programs, as guided by the USEPA (U.S. Environmental Protection Agency, 1997).

General objectives of the study

- Identify the dominant contaminants and sources of those contaminants in public-supply wells in representative water-supply aquifers across the Nation
- Assess the effects of natural processes (such as degradation) and human activities (such as irrigation) on the occurrence of contaminants in public-supply wells in representative aquifers
- Identify the factors that are most important to incorporate into public-supply well vulnerability assessments in different settings and at different spatial scales
- Develop simple methods and models for screening public-supply wells for vulnerability to contamination in unstudied areas and from newly emerging contaminants
- Increase understanding of the potential effects of water-resource development and management decisions on the quality of water from public-supply wells

Unique characteristics of the study

Sampling at different depths

The screened or open intervals of public-supply wells are commonly from tens to hundreds of feet in length; therefore, water from these wells is generally a mixture of waters of different ages that enter the well at different depths and are associated with different potential sources of contamination. The graphic on this page illustrates a situation where recharge to public-supply wells reflects urban and agricultural land-use activities. Specifically, water recharges the aquifer in the urban area containing urban-related contaminants, such as volatile organic compounds, and enters the well screens above water that has traveled from the more distant agricultural area where recharge water may contain contaminants such as agricultural pesticides.

Using a USGS-developed sampler (Izbicki, 2004), we are collecting samples at multiple depths in pumping public-supply wells to ascertain where and how contaminants from different sources enter the wells. For example, samples collected from public-supply wellheads and analyzed for concentrations of multiple contaminants are being "dated" to determine ground-water age and compared to samples and ages of water entering the wells at various depths (see graph below). This analysis is helping to evaluate the usefulness of ground-water age samples from wellheads for predicting the risk of contamination.

Evaluating multiple settings and scales

Consistent methods are being used to collect and analyze data, and investigations are being conducted at both regional (tens to thousands of square miles) and local scales (less than 10 square miles). We can therefore compare and contrast results and identify the most important processes to include in vulnerability assessments applied at different scales and in a variety of water-supply aquifers. For example, nitrate is detected in ground water in most participating study areas. The distribution and concentration of nitrate between the water table and public-supply wells are controlled predominantly by dilution in some areas and by dispersion or degradation in others. Using models developed for each study area, we are exploring how these differences in subsurface processes affect the response of different aquifer systems to common management practices.

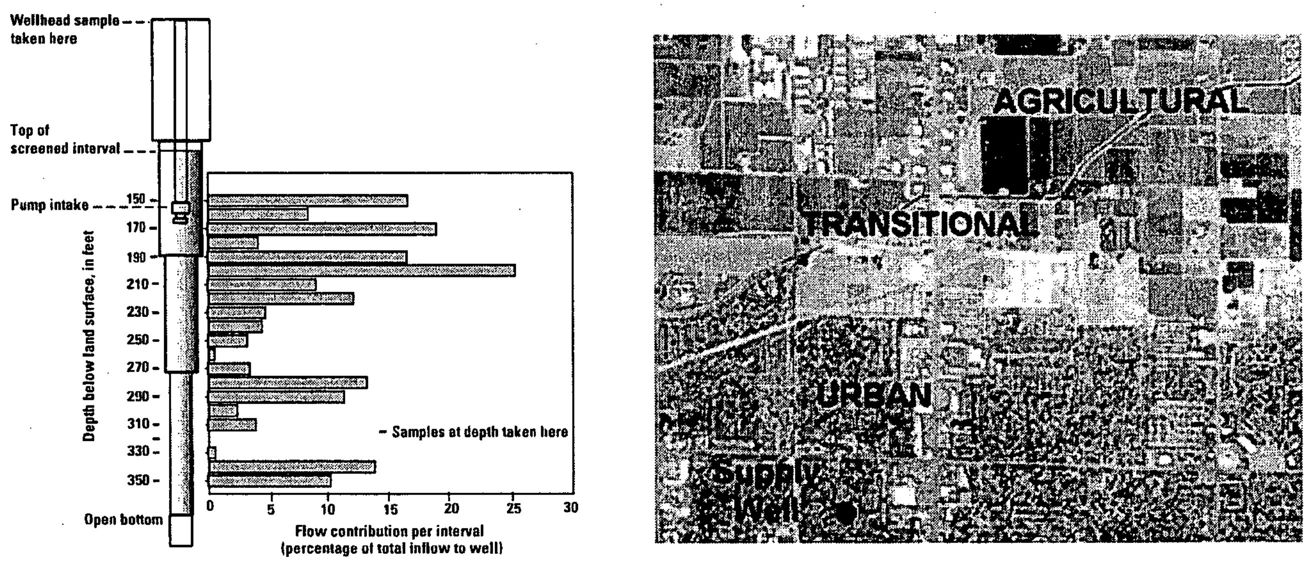
Exploring the consequences of uncertainty

To make informed decisions about activities at a particular location, decision-makers need to know whether the location is contributing recharge to public-supply wells. They also need information about traveltimes between potential contaminant sources and public-supply wells. Because this information cannot be measured directly, decision-makers must rely on estimates that are inherently uncertain (due to limitations in the methods). We are exploring the consequences of this uncertainty, and helping decision-makers understand these consequences, by comparing estimates from traditional and probabilistic modeling approaches with actual water-quality data from public-supply wells.

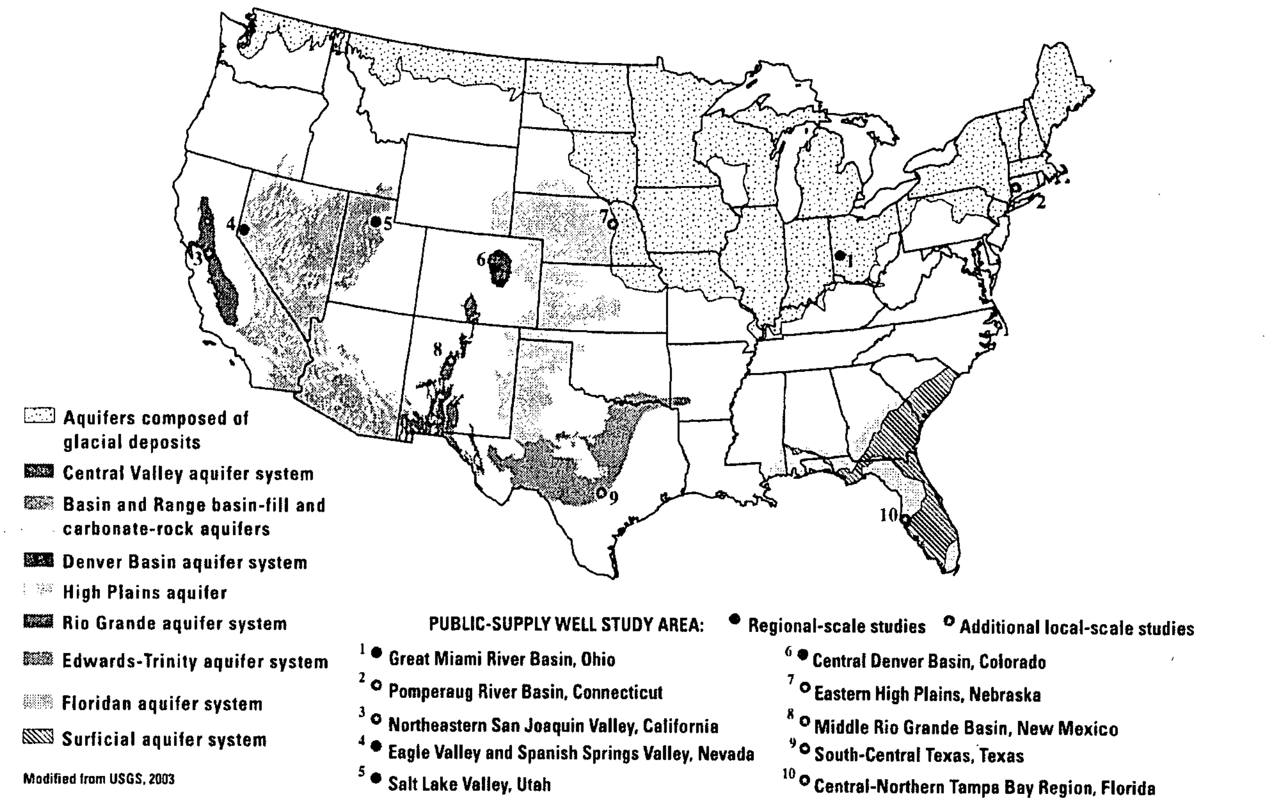
How this information can be used

Study results, models, and other decision-support tools will apply to broad classes of contaminants, including newly identified, emerging contaminants, and will help water managers and scientists:

- Better understand how and why contamination of public-supply wells occurs
- Improve assessments of the vulnerability of ground water and public-supply wells to contamination, even in unmonitored areas
- Choose new sites for water supply and develop and prioritize monitoring programs
- Evaluate various resource-development and management scenarios.



Inflow at different depths within a public-supply well. The aerial photo shows an approximately 63-square-mile area near the well. Water entering the well screen is associated with different potential sources of contaminants because of the different land-use activities in the areas contributing recharge to various intervals along the well screen, as well as the different aquifer materials through which water flows between the recharge areas and the well. The amount of contamination that might be contributed by any given interval is related to the volume of water that flows into the well along the interval and the concentration of any associated contaminants. Depth-dependent samples are a composite of all intervals beneath the sampling point; these samples are being analyzed for chemical quality and ground-water age and then compared to samples collected from the wellhead.



Locations of regional-scale studies of public-supply well vulnerability to contamination from urban, agricultural, and natural sources. Studies began in 2001 in eight States, in Texas and New Mexico in 2005, and are scheduled for Illinois and New Jersey or New York in 2009.

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References

Alley, W.M., and Leake, S.A., 2004, The journey from safe yield to sustainability: Ground Water, v. 42, no. 1, p. 12-16.

Focazio, M.J., Reilly, T.E., Rupert, M.G., and Helsel, D.R., 2002, Assessing ground-water vulnerability to contamination–Providing scientifically defensible information for decision makers: USGS Circular 1224, 33 p.

Franke, O.L., Reilly, T.E., Pollock, D.W., and LaBaugh, J.W., 1998, Estimating areas contributing recharge to wells–Lessons from previous studies: USGS Circular 1174, 14 p.

Hamilton, P.A., Miller, T.L., and Myers, D.N., 2004: Water quality in the Nation's streams and aquifers–Overview of selected findings, 1991-2001: USGS Circular 1265, 20 p.

Izbicki, J.A., 2004, A small-diameter sample pump for collection of depth-dependent samples from production wells under pumping conditions: USGS Fact Sheet 2004-3096, 2 p.

National Research Council, 1993, Ground-water vulnerability assessment–Predicting relative contamination potential under conditions of uncertainty: Washington, D.C., National Academy Press, 204 p.

Nolan, B.T., 1998, Modeling approaches for assessing the risk of nonpoint-source contamination of ground water: USGS Open File Report 98-531, 15 p.

U.S. Environmental Protection Agency, 1997, State source water assessment and protection programs–Final guidance: USEPA Office of Water, EPA 816-R-97-009.

U.S. Environmental Protection Agency, 1999, A review of contaminant occurrence in public water systems: USEPA Office of Water, EPA 816-R-99-006, 78 p.

U.S. Geological Survey, 2002, Report to Congress, concepts for national assessment of water availability and use: USGS Circular 1223, 34 p.

U.S. Geological Survey, 2003, Principal aquifers of the 48 conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands, available online at *http://www.nationalatlas.gov/mld/aquifrp.html*.

The NAWQA Program

The study of public-supply well vulnerability is one of five national priority topics being addressed by the NAWQA Program in its second decade, which began in 2001. Other topics include effects of urbanization on stream ecosystems; ecological effects of nutrient enrichment; mercury in stream ecosystems; and sources, transport, and fate of agricultural chemicals. In addition, anthropogenic organic contaminants in source waters for many of the Nation's largest community water systems are being assessed; concentrations in source waters are being compared to concentrations in finished waters. During the Program's first decade, NAWQA scientists assessed surface- and ground-water chemistry, stream hydrology, habitat, and biological communities in 51 major river basins ("Study Units"; see map at *http://water.usgs.gov/nawqa*). Baseline assessments of pesticides, nutrients, VOCs, trace elements, dissolved solids, and radon, and of the condition of aquatic habitats and fish, insect, and algal communities are described in hundreds of reports, available at the Web site above. Reassessments planned in 42 of the Study Units in the Program's second decade will determine trends at many of the streams and ground-water sites; fill critical gaps in the characterization of water quality; and build upon findings that show how natural features and human activities affect water quality and aquatic ecosystems.

enclosure (18)

Summary of Constituents Above Drinking Water Standards
GAMA Voluntary Domestic Well Assessment Project - Tulare County

Number of Wells Above MCL*	Constituent	Number of Wells Sampled	Range of values	Primary MCL	Secondary MCL	DHS Notification Level
			BACTERIA INDICATORS			
60**	Total Coliform	181	Present	Present		
			INORGANICS			
2	Aluminum	181	275 - 450 µg/L	1000 µg/L	200 µg/L	
3	Arsenic		10.4 - 14 µg/L	10 µg/L		
1	Beryllium		113 µg/L	4 µg/L		
1 ***	Boron		48.4 mg/L			1 mg/L
2	Chromium		76.7 - 91.9 µg/L	50 µg/L		
2	Iron		608 - 650 µg/L		300 µg/L	
2	Manganese		96.5 - 172 µg/L		50 µg/L	500 µg/L
5	Nickel		100 - 213 µg/L	100 µg/L		
75	Nitrate (as Nitrogen)		10 - 54 mg/L	10 mg/L		
5	Nitrite (as Nitrogen)		1.7 - 13.4 mg/L	1 mg/L		
4	Specific Conductance		1820 –2060 µmhos/cm		1600 µmhos/cm	
6	Thallium		2.1 - 7.32 µg/L	2 µg/L		
4	Total Dissolved Solids		1002 - 1014 mg/L		1000 mg/L	
14 ***	Vanadium		50 - 92.9 µg/L			50 µg/L
1	Zinc		17,300 µg/L		5000 µg/L	
			ORGANICS			
8	Dibromochloropropane (DBCP)	181	0.283 - 1.3 µg/L	0.2 µg/L		
1	1,2 Dichloroethane (DCA)		0.78 µg/L	0.5 µg/L		
1 ***	1,2,3 Trichloropropane		0.8 µg/L			0.005 µg/L
			PERCHLORATE			
2 ***	Perchlorate	40	7.9 - 13 µg/L			6 µg/L
			RADIONUCLIDES			
1	Uranium	13	228 pCi/L	20 pCi/L		
1	Radium 226+228		5.1 pCi/L	5 pCi/L		
3	Gross Alpha		15.1 - 602 pCi/L	15 pCi/L		

* MCL – Maximum Contaminant Level for public drinking water supplies established by Calif. Dept of Health Services
** Fifteen of those wells testing positive for total coliform also tested positive for fecal coliform
*** MCLs have not been established for these constituents

mg/L – milligrams per liter
µg/L – micrograms per liter
µmhos/cm – micromhos per centimeter

12/12/06

Project Testing Results Summary

County Focus Area (Year)	Number of Wells Sampled	*Compound*	
		Nitrate	Total Coliform
Yuba (2002)	126*	2%	8%
El Dorado (2003-04)	398	2%	26%
Tehama (2005)	223	1%	25%
Tulare (2006)	181	41%	33%
Cumulative Project Total	928	9%	27%

Number of Wells at or Above CDPH Primary and Secondary Maximum Contaminant Levels (MCL/SMCL) and/or Notification Level (NL). MCLs and NLs are used for comparison since domestic wells are not regulated

** Includes nine wells from 2002 Pilot Study*