# The Economic Impacts of Central Valley Salinity

**University of California Davis**
**Final Report to the State Water Resources Control Board Contract 05-417-150-0**

**March 20, 2009**


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## Executive Summary

The study team was charged with measuring the economic impacts of increasing salinity in the Central Valley to the year 2030. The study was conducted assuming that there is no change in current policy and, as such, represents the economic impacts associated with taking no action. Additionally, the study was conducted on an aggregate valley-wide basis that required averaging the effects of salinity and, in some cases, costs. The growth in salinity in the Central Valley was based on two factors. The first factor was the growth of the areas of shallow saline groundwater based on 30 years of historical records. The second factor was increased levels of salts that result indirectly from imported water. Based on increasing salinity stemming from these factors, the direct economic effects on industry, residential, food processing, confined animal operations, and irrigated agricultural production in the Central Valley were measured. Economic and physical effects were quantified using different physical and economic models. In addition, the team undertook a substantial survey of the population in the Central Valley to establish non-market values for increased salinity and its effect on non-market activities.

The study results showed that if salinity increases at the current rate until 2030, the direct annual costs will range from $1 billion to $1.5 billion. Total annual income impacts to California will range between $1.7 billion to $3 billion by 2030. The income impacts to the Central Valley will range between $1.2 billion and $2.2 billion.

The production of goods and services in California could be reduced from $5 billion to $8.7 billion a year. The Central Valley output reduction would range between $2.8 billion to $5.3 billion. Furthermore, there is $145 million per year of non-market costs. In terms of job losses the increase in salinity by 2030 could cost the Central Valley economy 27,000 to 53,000 jobs. California could lose 34,000 to 64,000 jobs. In short, the problem is substantial and growing steadily. The magnitude of the economic and employment losses justifies a more detailed study of remedial action and correction policies.

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# 1 Introduction

Elevated salinity in surface water and groundwater is an increasing problem affecting much of California, including California's Central Valley, other western states, and arid regions throughout the world. As surface and groundwater supplies become scarcer and as wastewater streams become more concentrated, salinity impairments are occurring with greater frequency and magnitude. The Central Valley Water Board and State Water Board have initiated a comprehensive effort to address salinity problems in California's Central Valley and adopt long-term solutions that will lead to enhanced water quality and economic sustainability. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) is the resulting joint effort to develop and implement a comprehensive salinity management program. The goal of CV-SALTS is to maintain a healthy environment and a good quality of life for all Californians by protecting our water.

The Central Valley hydrologic basins are defined in the Water Quality Control Plans for the Sacramento and San Joaquin River Basins (5A/5B) and the Water Quality Control Plan for the Tulare Lake Basin (5C). For detailed maps of the region, the reader is referred to section 4.

This study assesses the economic and social impacts of increasing salinity in the Central Valley. Economic and social impacts will occur in the Central Valley as salinity levels increase, creating changes in water quality, water supply, production of goods and services, income, and employment. The projections of economic impacts will be to 2030. Among the major issues is to determine the direct (initial changes) and indirect (inter-business commerce) effects of increasing salinity on water demand and usage in various economic sectors. These sectors include municipal and industrial water treatment, food processing, confined animal feeding operations, and agriculture.

For this study, the status quo is defined as the project without implementing a comprehensive salinity management program. Economic and social outcomes of the status quo will include changes in the production of goods and services (gross regional product), income, and employment due to increases in salinity levels under existing policies and regulations. Economic impacts of not implementing a salinity management program will be empirically estimated by assuming salinity continues to accumulate at its current rate.

A proxy for the salinity policy must be formulated to stand in for a likely potential outcome of a comprehensive salinity policy. The second set of projections includes likely effects of a comprehensive salinity management policy and the assumption that such a policy would lessen the accumulation of salinity over time. The difference between the two sets of projections is the economic impact of increased salinity or of not implementing a comprehensive salinity management program. Note again, that neither of these projections specifically involves a comprehensive salinity management program since one has not been defined or specified.

The next step is to project dischargers' reactions to the implementation of future water quality regulations. The ability of dischargers to adjust production and practices as regulations are implemented can be substantial. Regulations will be imposed over a relatively long period of time and some dischargers may have technological options to meet the more restrictive discharge limits and/or to be able to pass costs on to consumers or the next level of production. In other cases, the full cost of complying with the regulations will have to be met by dischargers located in the region. Dischargers subject to water quality regulations will be assessed as to their capabilities to meet existing water quality regulations. Economic sectors most likely to be affected by future salinity management policies are, but not limited to, municipal water and wastewater treatment plants, water purveyors, irrigated agriculture, confined animal operations, agri-business, and food processing.

Projecting economic activity and social conditions to 2030 is accomplished by the use of the Regional Economic Modeling, Inc. (REMI) model (http://remi.com/). This is a sophisticated economic accounting tool that aggregates economic impacts across regions and over time. REMI projections of gross regional product, income, and employment will be made for the state and the Central Valley, projecting economic activity to 2030. These results are then compared to projections of economic activity when salinity effects are accounted for. The difference in economic activity can then be attributed to increases in salinity levels.

Only considering market valuations will understate economic impacts, this report explicitly considers non-market impacts to create a more comprehensive picture of salinity effects. These can be estimated by eliciting perceived personal opinions regarding water quality and land conditions using standard survey procedures. This procedure yields values of benefits that can be realized through the implementation of a comprehensive salinity program. Non-market values are not usually included in standard economic analyses. By including them in this salinity study, the total economic impacts to society are identified.

# 2 Baseline Assumptions on Future Water Quality Policies and Regulations

## 2.1 Introduction

A critical part of this analysis is to project future economic activity under a set of realistic assumptions and conditions relevant to the 2030 time horizon. These assumptions and conditions fall into two types. The first set of assumptions relates to the effectiveness of existing water quality policies and regulations primarily administered by the state and Regional Water Boards. Identifying the assumptions will involve a review of the Basin Plans and associated water quality regulations, such as those concerning impaired water bodies and discharges to land and water.

The second set of assumptions and conditions involve institutional, economic, and physical changes that will directly affect water supply, land use, and economic activity. The Central Valley's water supply is significantly affected by changes in water rights, the Sacramento-San Joaquin Delta, out-of region water demands, and climatic conditions. Land use is largely affected by population and planning determined at the urban and county levels. Because agriculture is a significant industry in the Central Valley, changes in land productivity will also affect land use, water use, and economic activity. The demand for goods and services is mostly the result of domestic market conditions, international trade agreements, and government commodity programs.

## 2.2 Regulatory Overview

The Basin Plans specify existing beneficial uses of water and water quality requirements to facilitate those uses. Basin Plans are developed and adopted by the respective Regional Water Board and are updated as regulations change. Every two years, water quality impaired water bodies are specified as a 303(d) listed water body. A Total Maximum Daily Load (TMDL) program is developed and implemented to reduce discharges for the 303(d) listed water body. The adopted TMDL will then become part of the Basin Plan. Other water quality programs that will be evaluated are regulations on discharges to land known as Waste Discharge Requirements (WDR) and regulations of discharges to water known as National Pollution Disposal Elimination System (NPDES). Probably the most important program in determining future salinity conditions in the Central Valley will be WDR waivers for irrigated agriculture because they are evolving to include monitoring and regulatory practices. This review will serve as a basis to make assumptions regarding the effectiveness of future water quality policies and regulations. This information will also be used to specify changes in the cost of complying with those programs and regulations.

The following sections contain brief overviews of regulatory programs. Details of how these programs are related to specific economic sectors like urban, industry, and agriculture will be included in the sections addressing the various sectors.

### 2.2.1 National Pollution Disposal Elimination System

The NPDES permit program regulates point sources that discharge pollutants into waters of the United States (US). Point sources are discrete discharges, such as pipes, an industrial plant, an agricultural operation, municipal wastewater treatment plants, or stormwater runoff from impervious surfaces such as parking lots that lead directly to a surface water body. Even though the NPDES is a federal requirement, many states are authorized by the US Environmental Protection Agency (USEPA) to administer the program. This is the case for California where the regional water boards' NPDES Wastewater programs are responsible for regulating the point source discharges to the state's surface waters, coastal waters, and groundwater. Non-points sources of pollutions are regulated by the WDR Program. For detailed information about the federal NPDES, such as permitting, permitting tools, statues and regulations, and strategic plans, see http://cfpub.epa.gov/npdes/home.cfm?program_id=45.

For the regional water boards, the NPDES Wastewater Program has responsibility for regulating wastewater discharges to surface waters. Primary program responsibilities include:

Issuing new and renewing NPDES permits

Monitoring discharger compliance with permit requirements through review of discharger self-monitoring reports and compliance inspections

Taking enforcement actions as appropriate, for example, Notices of Violations and Mandatory Minimum Penalties

Investigating spills and illegal discharges and

Handling petitions and litigation.

Three types of NPDES permits related to salinity are agricultural, concentrated animal feeding operations, and combined and sanitary sewer overflows. According to the USEPA, the NPDES regulations exclude irrigated agriculture and agricultural stormwater runoff as requiring permits. Often the constituents related to irrigated agriculture cannot be identified to a source and, as such, is regulated under non-point source statutes. Discharges from concentrated animal feeding operations, concentrated aquatic animal production facilities, discharges to aquaculture projects, and silviculture projects are required to have the necessary NPDES permits.

### 2.2.2 Waste Discharge Requirements

The California Water Code gives authority to the State and Regional Water Boards to conditionally waive WDRs when it is in the public interest to do so. Agriculture is a vital industry to California and to the nation in terms of its prolific ability to produce food, feed, and fiber for domestic and international markets. Regional Water Boards issue waivers for over 40 types of discharges. Those from agricultural lands include irrigation return flows, flows from tile drains, and storm water runoff because they can carry constituents such as salinity, nutrients, pesticides, sediment, pathogens, and heavy metals to surface water bodies. These constituents can travel further along the water cycle into lakes, reservoirs, rivers, estuaries, and eventually groundwater and the ocean. Statewide, approximately 9,500 miles of stream and rivers and approximately 513,000 acres of lakes and reservoirs are listed on the 303(d) list as being impaired by irrigated agriculture (SWRCB(b), 2006).

WDR waivers have historically been conditional and required that discharges do not violate water quality objectives. However, the waivers did not require any water quality monitoring and management plans. Senate Bill 390 was signed into law in 1999 and amended California Water Code section 13269. The amendment required the Regional Water Boards to review existing waivers, renew them or replace them with WDRs, enforce the conditions of the waivers, and to reconsider the renewal of waivers every 5 years. In 2003, section 13269 was amended again to authorize the State Water Board to establish and collect fees for waivers. To comply with these changes, the Regional Water Boards adopted waivers to regulate most of the categorical discharges, such as agricultural waivers. The Central Valley Water Board, along with the Central Coast and Los Angeles Water Boards, modeled agricultural waivers using regulatory models specific to agriculture and implementing extensive enrollment, education, and public outreach programs in their regions. Please see the “Fact Sheet Fee Proposal for Agricultural Waivers” and “About Agricultural Waivers” at http://www.waterboards.ca.gov/agwaivers/ for additional details on waivers, fee schedules, and program information.

### 2.2.3 Clean Water Act Section 303(d) List of Impaired Water Bodies and Total Maximum Daily Limits

Section 303(d) of the Federal Clean Water Act (CWA), enacted in 1972, requires states to compile a list of surface water bodies that are not attaining water quality standards after best available technology has been utilized to maintain a target minimum level of polluting constituents. This list is commonly known as the 303(d) list. For listed water bodies, states are required to develop TMDLs, accounting for all sources of the pollutants that caused the water to be listed. Federal regulations require that TMDLs account for pollutants from point sources and contributions from non-point sources, which are significantly more difficult to identify, quantify, and control. USEPA is required to review and approve the list of impaired water bodies and each TMDL. If a state cannot establish its 303(d) list and/or the required TMDLs, then the USEPA must do so for the state.

The USEPA requires that implementation plans be developed as part of TMDLs and that the permits for point source discharges under the NPDES are consistent with any approved TMDL implementation plans. California's Porter-Cologne Water Quality Control Act requires that TMDL implementation be addressed by incorporation into Basin Plans, known as Basin Plan amendments.

The Central Valley Region has basin plans for the Tulare Lake Basin and one for the combined Sacramento and San Joaquin river basin. These plans were initially adopted in 1975 with major revisions in 1984, 1989, 1994 and 1998. As an integral part of the basin planning process, every three years the Region reviews the existing plans for need to modify existing standards and to redefine basin planning priorities if necessary. Water quality standards in California are defined by two pieces of legislation. Title 40, Code of Federal Regulations, Part 131 requires each state to designate beneficial uses of water that need to be protected. The Porter-Cologne Act also requires Regional Boards to establish water quality objectives to ensure the reasonable protection of beneficial uses.

For detailed discussion of listing, delisting, and area changes for the Central Valley water bodies on the 303(d) list see the documents at http://www.waterboards.ca.gov/tmdl/303d_update.html. For details and documents related to the Central Valley Region's Basin Planning Program and TMDL based amendments see http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/index.html. For a discussion of the TMDL process and a copy of the current 303(d) list, see http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/index.htm.

## 2.3 Urban

Given recent trends in California and across the US, as population increases over time, urban population centers tend to grow larger while rural populations get smaller. As urban population centers grow, they contribute to the interdependent cycles of population, jobs, income, and economic output, where a change in one of these factors will likely be felt in the others. For example, as more people move to the urban areas, there will be an increase in the demand for services, which in turn creates new jobs and induces businesses to expand their purchasing activities. Urban growth also implies that demand for water will increase and that water is of a particular quality as required for public consumption and industrial use. The following sections will provide an overview of projected population, employment, income, and economic output for the Sacramento, San Joaquin, and Tulare basins.

### 2.3.1 Regional Projections

This section provides a description of baseline population growth projections from 2008 to 2030 for the Sacramento, San Joaquin, and Tulare basins. These projections are based on the REMI model. REMI uses the cohort-survival method, which models population as the natural change in population caused by births and deaths plus the net migration change for the study region. Migration is assumed to have two components where one is due to economic conditions and the other is not. When a region experiences an increase in wages, employment opportunities, and the consumer amenities that come with economic growth, people are attracted to that region and migration increases. Migration can occur for non-economic reasons too. For example, retirement, international, and returning military related migration is assumed to occur for reasons that are not directly related to the economic conditions of a specific region. Data for REMI's population projections come from the US Census and US Bureau of Economic Analysis.

Urban economic activity will be discussed in terms of Total Employment, Real Disposable Personal Income, and Output as estimated by REMI. Total Employment is the total number of jobs comprised of farm, government, and private non-farm employment. Real Disposable Personal Income in a region is personal income adjusted for taxes and the cost of living specific to the region. Personal income is primarily compensation plus proprietors' income, property income, and transfer payments (government payments such as social security, welfare, or education grants). Output is comprised of the goods and services produced in a given region that is sold to consumers, other firms, investors, and governments outside the region. This includes international export. Output requires inputs that include labor, capital, fuel, and intermediate goods.

For a more detailed discussion of population and economic development variables, their calculations and adjustments, see the REMI Policy Insight Model Documentation Version 9.0.

#### 2.3.1.1 Sacramento Basin

The population in the Sacramento Basin in 2008 was approximately 3,595,000 people and the projected population in 2030 is about 4,795,000 people (Figure 2.1). This change represents an increase of 1.2 million people or a 33% increase in population over the study period.

Among the three study regions, the Sacramento Basin has the highest total employment at approximately 1,925,000 jobs in 2008. This level is projected to grow to 2,393,000 jobs by 2030, which is an increase of 24% or about 468,000 jobs. Real disposable income was approximately $90.6 billion in 2008 and is projected to grow to $144.5 billion by 2030. This represents a growth of $54 billion or 60%. Output was estimated at $166.4 billion in 2005 and is projected to grow to $350.4 billion by 2030. This represents a growth of nearly 111% or just over $184 billion.

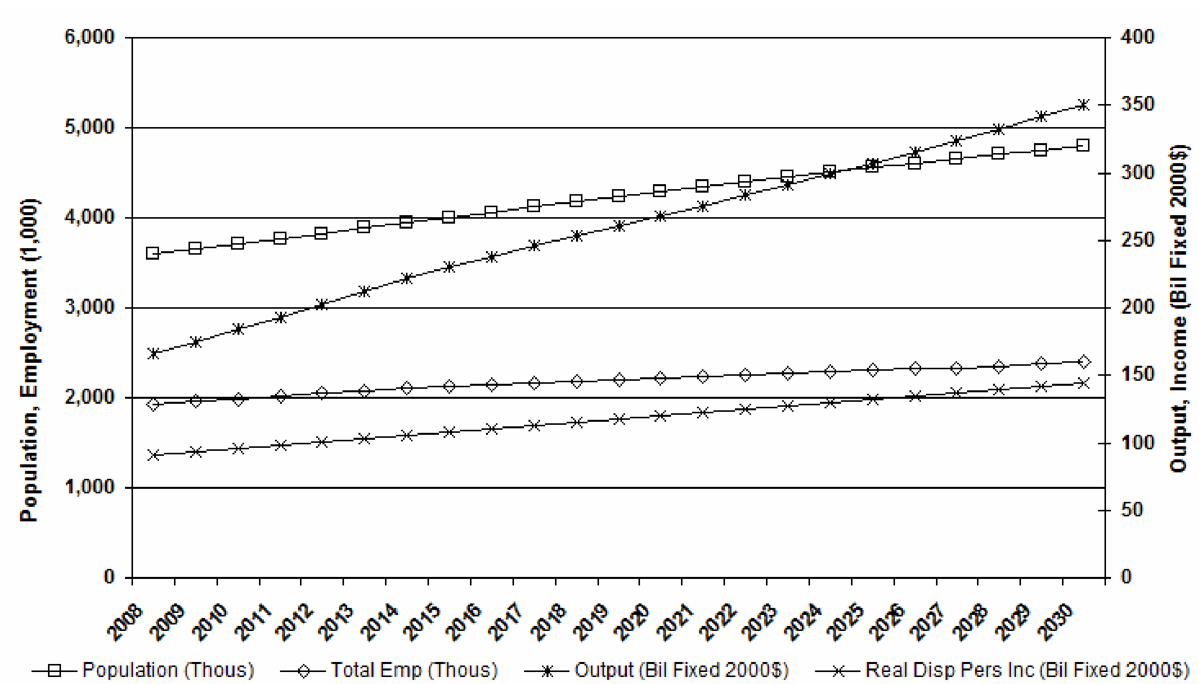



**Figure 2.1 Projected Sacramento Basin Output, Income, Population and Employment, 2008-2030**

#### 2.3.1.2 San Joaquin Basin

Population in the San Joaquin Basin is expected to grow by 31%, from 2,851,000 to 3,744,000 between 2008 and 2030 (Figure 2.3).

Total employment in the San Joaquin Basin in 2008 is 1,310,000 jobs, which is projected to increase to 1,584,000 in 2030. This represents a growth of 21% or about 274,000 jobs. The real disposable income in 2008 is approximately $76 billion and expected to grow 43% to $120 billion by 2030 for a difference of $43 billion. Output is approximately $153 billion in 2008 and expected to be $287 billion by 2030. This is an increase of $134 billion or 88%.

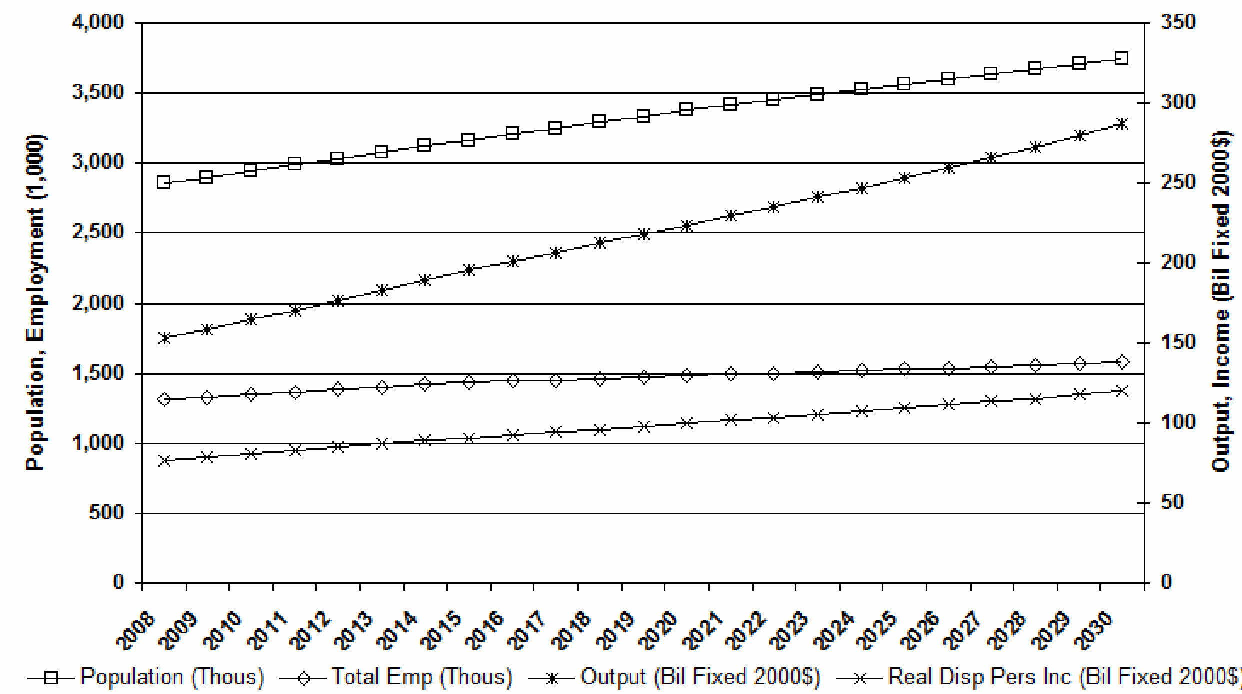



**Figure 2.2 Projected San Joaquin Basin Output, Income, Population and Employment, 2008-2030**

### 2.3.1.3 Tulare Basin

The Tulare Basin is the least populated among the three basins in the study area (Figure 2.3). In 2008, the population is estimated at 2,308,000 people and is expected to grow to 2,844,000 people by 2030. This represents a 24% growth or just over 558,000 people.

The Tulare Basin had a total employment level of 1,080,000 in 2008. This level is projected to increase to 1,231,000 by 2030. This represents approximately 151,000 new jobs or a 14% growth. Real disposable income in 2008 was estimated at $46 billion and projected to be at $68 billion by 2030. This is a growth of 47% or $22 billion. Regarding output, it was estimated at $77 billion in 2008 and expected to be $138 billion in 2030. Output is projected to increase by about $61 billion or by 79% from 2008 to 2030.

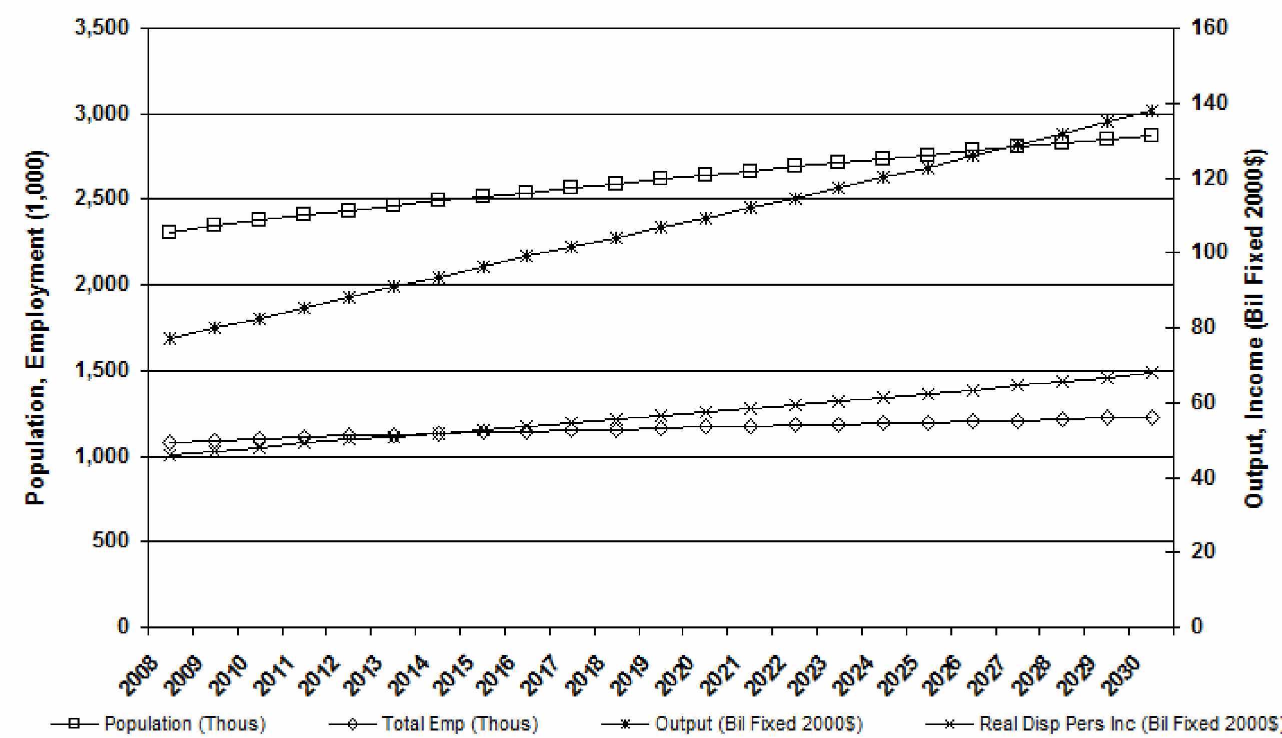



**Figure 2.3 Projected Tulare Basin Output, Income, Population and Employment, 2008-2030**

#### 2.3.1.4 Regulatory Considerations

A significant NPDES issue in urban areas is sewer overflows. Combined sewer systems convey rainwater runoff, domestic sewage, and industrial wastewater in the same pipe to municipal or regional wastewater sewage treatment plants. At the plant the waste water undergoes treatment rendering it safe for discharge to a water body. The capacity of the wastewater treatment plant can be exceeded during severe weather conditions such as a heavy rainstorm or sudden melting of snow over a wide area. At such times, the combined sewer systems are designed to overflow, discharging untreated wastewater that contains among other constituents, pathogens, industrial toxins, and solid matter into the receiving water body.

Combined sewer overflows (CSO) are a serious water pollution concern for approximately 772 U. S. cities. Sanitary sewer systems are designed to collect only sewage and not stormwater, but are still susceptible to overflows (sanitary sewer overflows or SSO) due to infiltration of stormwater during severe weather events, poor maintenance of the system, improper operations of the system, or vandalism. The USEPA estimates that at least 40,000 SSOs occur each year. (USEPA, 2008). As urban development continues to grow in California, the risk of sewer overflows will rise as additional residential and industrial users place greater demands on existing, undersized, or older wastewater systems.

While SSOs and CSOs are significant urban regulatory concerns regarding water quality, they are discussed here only for completeness. The economic and salinity impacts of SSOs and CSOs are beyond the scope of this study. The relationship between salinity and urban impacts will be discussed and analyzed in terms of water treatment and demographic changes.

## 2.4 Industry

Projections of economic output by sector are generated using the REMI model. REMI uses the North American Industry Classification System (NAICS) as its industry aggregation scheme. Additional information about NAICS may be found at http://www.census.gov/epcd/naics02/index.html. Industry sector output for 2008 for the three Basins and the Central Valley is presented in Table 2.1. Manufacturing and utilities will be affected by increased salinity concentrations in water supplies. These sectors produces over $102 billion or 26 percent of the total Central Valley output. Real estate and retail trade are the largest service sectors in the Central Valley combining for $83 billion in output or 21 percent of total output.

**Table 2.1 2008 Central Valley Industry Output by Basin**

| | Sacramento | San Joaquin | Tulare | Central Valley |
|---|---|---|---|---|
| **Sector** | | **Bil Fixed (2000$)** | | |
| Agriculture, Forestry, Fishing | $0.801 | 0.631 | 1.341 | $2.773 |
| Mining | $0.438 | 1.365 | 4.182 | $5.985 |
| Utilities | $2.844 | 2.315 | 2.118 | $7.277 |
| Construction | $12.898 | 9.672 | 5.225 | $27.795 |
| Manufacturing | $30.445 | 46.655 | 18.078 | $95.178 |
| Wholesale Trade | $8.162 | 5.829 | 4.265 | $18.256 |
| Retail Trade | $16.685 | 11.651 | 7.519 | $35.855 |
| Transp, Warehousing | $5.084 | 4.134 | 3.053 | $12.271 |
| Information | $9.244 | 10.403 | 2.763 | $22.410 |
| Finance, Insurance | $13.606 | 11.542 | 3.907 | $29.055 |
| Real Estate, Rental, Leasing | $23.174 | 16.683 | 7.03 | $46.887 |
| Profess, Tech Services | $8.940 | 6.706 | 2.644 | $18.290 |
| Management Services | $2.827 | 2.367 | 1.234 | $6.428 |
| Admin, Waste Services | $4.798 | 3.712 | 2.081 | $10.591 |
| Educational Services | $0.844 | 0.595 | 0.268 | $1.707 |
| Health Care, Social Asst | $13.393 | 10.007 | 6.323 | $29.723 |
| Arts, Entertainment, Rec | $1.668 | 1.11 | 0.41 | $3.188 |
| Accom, Food Services | $5.343 | 3.469 | 2.354 | $11.166 |
| Other Services (excl Gov) | $5.210 | 3.932 | 2.356 | $11.498 |
| **Total** | **$166.404** | **$152.778** | **$77.151** | **$396.333** |

Twenty two manufacturing sectors defined in the REMI model. Their 2008 output levels for the three Basins are presented in Table 2.2. Food processing output makes up 21 percent of the total Central Valley manufacturing output and $16 billion is located in the San Joaquin and Tulare Basin which is expected to experience the greatest increase in salinity concentrations. Petroleum refining output is reported to be $25.963 billion in 2008 or 27 percent of the Central Valley total output. Most of this activity is located in the San Joaquin Basin.

**Table 2.2 2008 Central Valley Manufacturing Output by Basin**

| | Sacramento | San Joaquin | Tulare | Central Valley |
|---|---|---|---|---|
| **Sector** | | **Bil Fixed (2000$)** | | |
| Wood product mfg | $2.111 | $0.769 | $0.325 | $3.205 |
| Nonmetallic mineral prod mfg | $0.814 | $1.072 | $0.402 | $2.288 |
| Primary metal mfg | $0.162 | $0.555 | $0.206 | $0.923 |
| Fabricated metal prod mfg | $1.216 | $1.284 | $0.617 | $3.117 |
| Machinery mfg | $0.616 | $0.626 | $0.835 | $2.077 |
| Computer, electronic prod mfg | $13.060 | $2.548 | $0.881 | $16.489 |
| Electrical equip, appliance mfg | $0.332 | $0.095 | $0.064 | $0.491 |
| Motor vehicle mfg | $0.437 | $0.534 | $0.135 | $1.106 |
| Transp equip mfg. exc. motor veh | $0.672 | $0.455 | $0.702 | $1.829 |
| Furniture, related prod mfg | $0.528 | $0.491 | $0.164 | $1.183 |
| Miscellaneous mfg | $0.609 | $0.719 | $0.398 | $1.726 |
| Food mfg | $3.594 | $8.646 | $8.053 | $20.293 |
| Beverage, tobacco prod mfg | $2.074 | $2.213 | $0.669 | $4.956 |
| Textile mills | $0.046 | $0.006 | $0.010 | $0.062 |
| Textile prod mills | $0.218 | $0.052 | $0.048 | $0.318 |
| Apparel mfg | $0.040 | $0.115 | $0.024 | $0.179 |
| Leather, allied prod mfg | $0.010 | $0.012 | $0.015 | $0.037 |
| Paper mfg | $0.328 | $0.899 | $0.463 | $1.690 |
| Printing, rel supp act | $0.441 | $0.304 | $0.205 | $0.950 |
| Petroleum, coal prod mfg | $0.477 | $22.595 | $2.891 | $25.963 |
| Chemical mfg | $2.098 | $2.034 | $0.416 | $4.548 |
| Plastics, rubber prod mfg | $0.563 | $0.629 | $0.552 | $1.744 |
| **Total** | **$30.446** | **$46.653** | **$18.075** | **$95.174** |

### 2.4.1 Regional Projections

The primary industries that will be discussed in this section are those that are important to the individual Basin or are projected to experience significant growth by 2030. These projections are made to indicate the nature of the change in economic activity and its related change in salt load.

#### 2.4.1.1 Sacramento Basin Projections

The largest sector in the Sacramento Basin is manufacturing with output of just over $30 billion dollars in 2008 (Figure 2.4). Manufacturing is expected to grow by 157% to $78 billion by 2030. The second largest sector in the Sacramento Basin is real estate with output valued at $23 billion in 2008. It is projected to grow to $41 billion by 2030. Retail trade is expected to grow by 122% to $37 billion by 2030. Health care and social assistance is expected to increase by 125% to $30 billion by 2030.

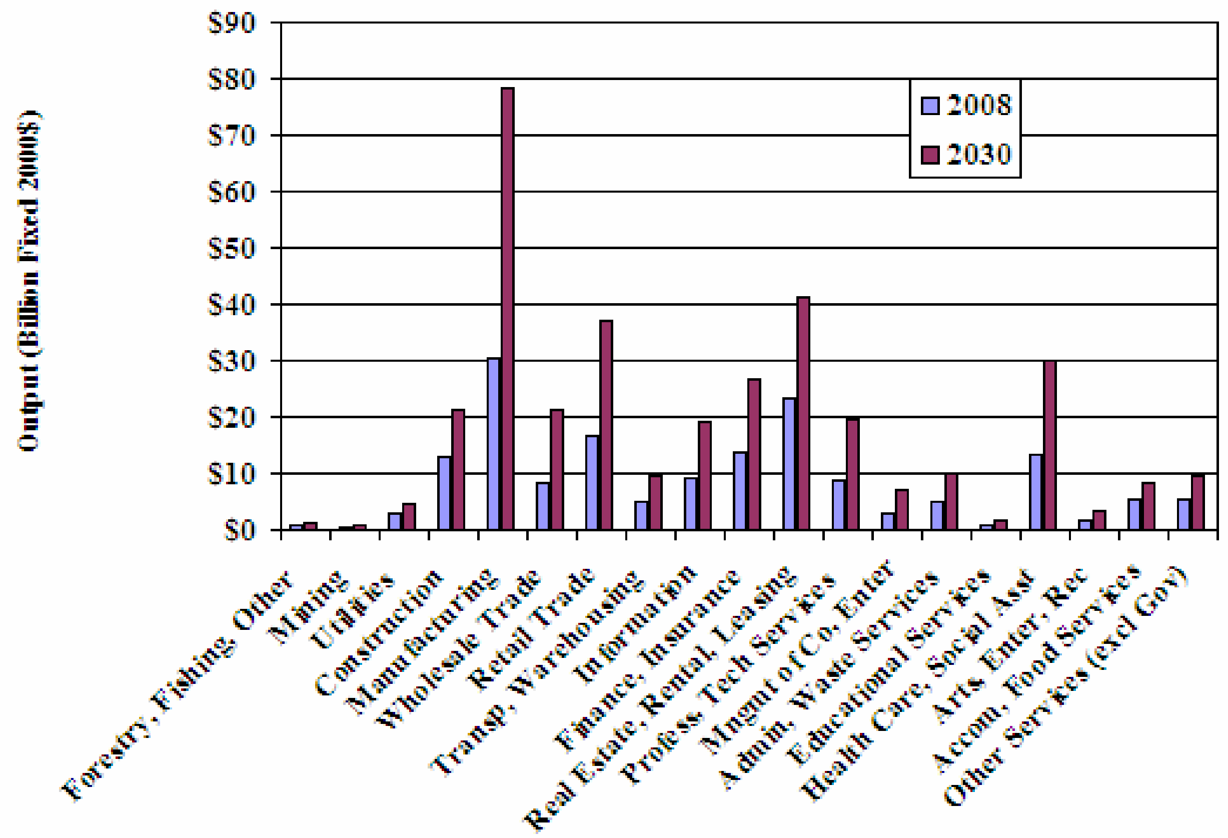



**Figure 2.4 Projected Sacramento Basin Industry Output by Sector 2005-2030**

### 2.4.1.2 San Joaquin Basin Projections

Projections for the San Joaquin Basin is similar to the Sacramento Basin with the exception of manufacturing. Manufacturing is projected to increase by 70% which is much lower than the 157% projected for the Sacramento Basin (Figure 2.5). Like the Sacramento Basin, real estate, retail trade, health care along with construction, information and, finance and insurance are projected to be important contributors to output by 2030.

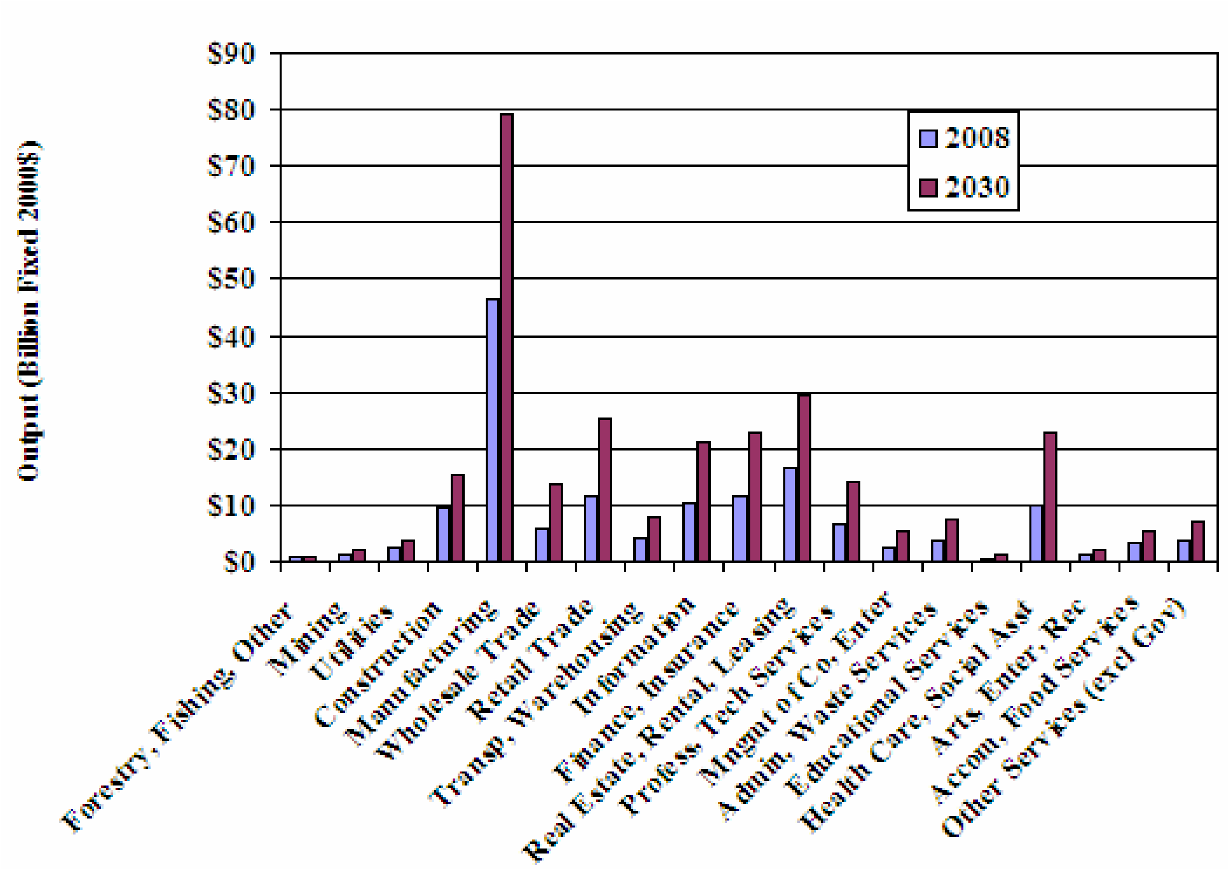



**Figure 2.5 San Joaquin Basin Industry Output by Sector 2005-2030**

### 2.4.1.3 Tulare Basin Projections

The manufacturing in the Tulare Basin was estimated at $18 billion in 2008 and projected to increase to $31 billion by 2030. This represents an increase of 70%. As with the Sacramento and San Joaquin Basins, retail trade, real estate and health care will continue to be an important part of the Basin's economy.

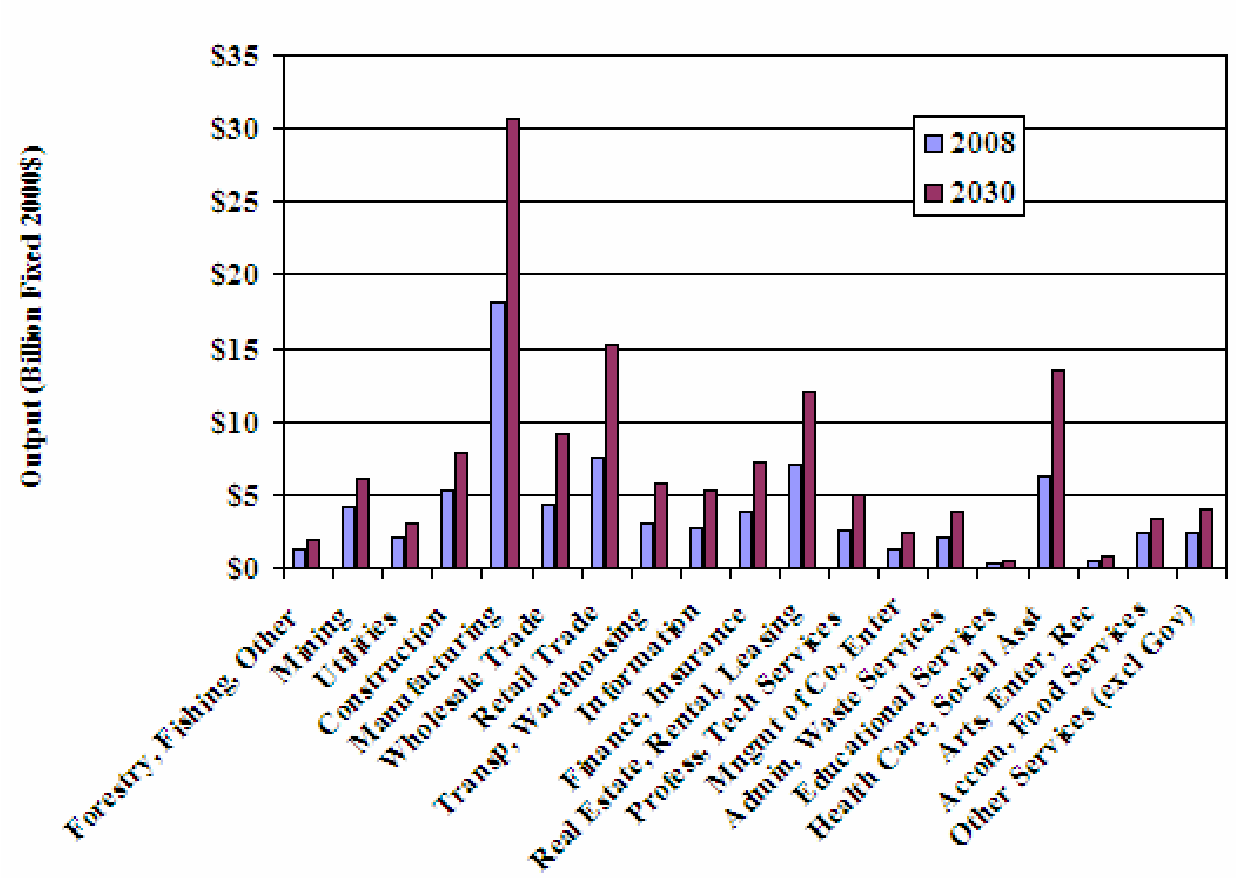



**Figure 2.6 Projected Tulare Basin Industry Output by Sector 2005-2030**

## 2.5 Food Processing

Agriculture is a significant part of the California economy which translates to a substantial need for local food processing facilities. The Central Valley has well over 200 facilities that process food including tomatoes, fruit and vegetables, wine, nuts, meats and dairy. A map of the processing facilities within the boundaries of the Central Valley Regional Water Quality Control Board is shown in Figure 2.7, below.

Food processing waste varies by facility and processing method but is, in general, responsible for saline wastewater applied to the land. This is because, currently, the most cost effective method to dispose of wastewater is land application whereby the facility spreads wastewater over the land allowing it to be naturally absorbed. Land application either occurs directly at the processing facility or after transporting wastewater to a regional Publicly Owned Treatment Works (POTW) (Sunding et al 2006). Shipping wastewater out of basin is currently an extremely expensive alternative, thus facilities focus on in-plant measures in order to reduce wastewater discharge. As such, the costs to food processing facilities as a result of increased levels of salinity are likely manifest through increased regulation which requires increased in-facility abatement.

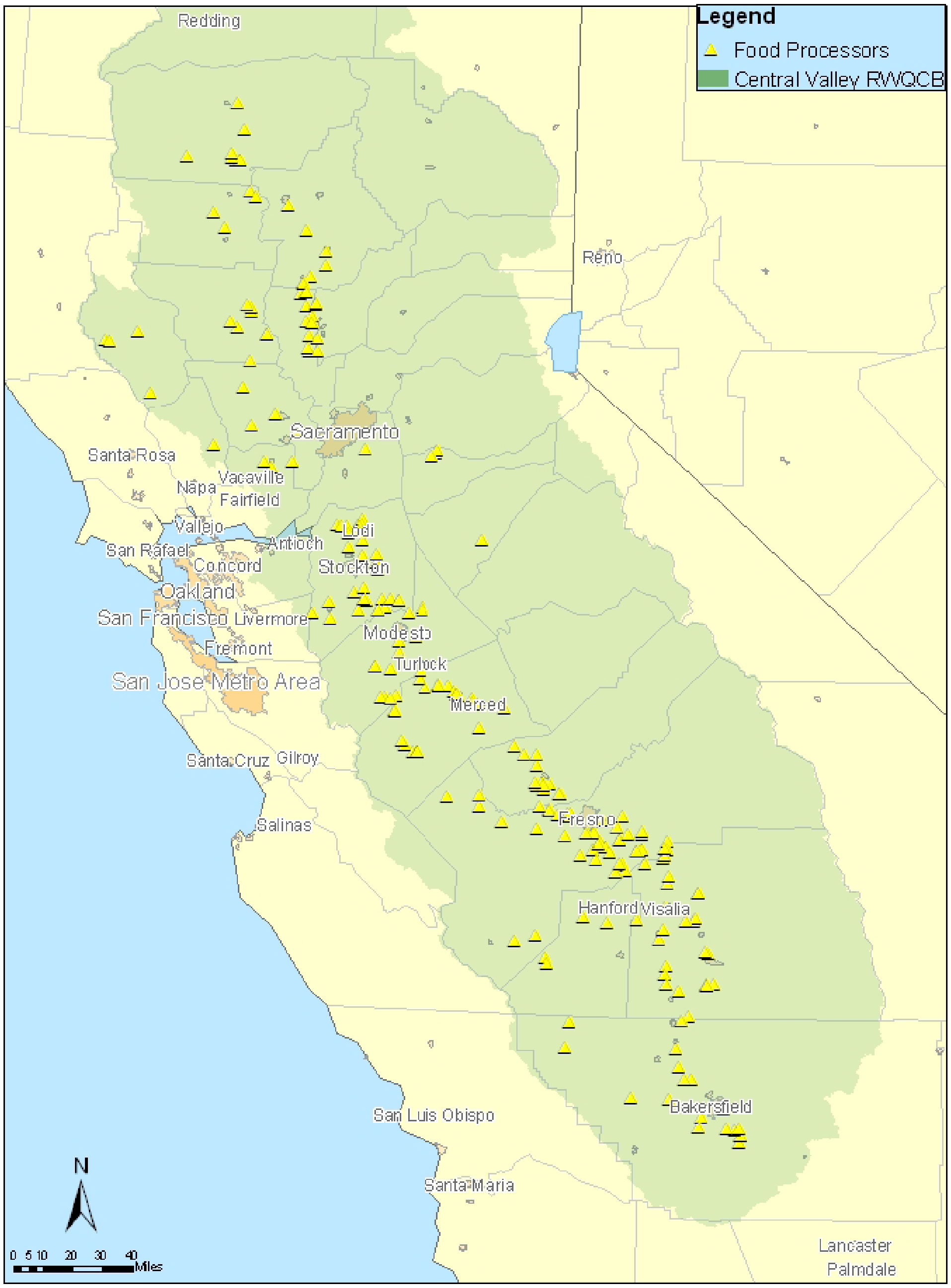
### 2.5.1 Regional Projections

The future of the food processing industry in California hinges on two basic factors: the future of production of agricultural commodities that require processing and future regulations on food processors in the Central Valley. Currently, there are over 200 food processing facilities as detailed in figure 2.7.

As Central Valley crop production increases there will be an increased demand for food processing facilities. In light of the current trends in fuel and transportation costs it is reasonable to assume that there will be a demand for these facilities within the immediate region. However, future agriculture production depends on demand and prices where demand depends on the interaction of several economic driving factors. Driving factors include the interaction of resources, technology and future demands and prices. As such, there is a complicated interaction of forces that will determine future in-region demand for food processors.

Additionally, future growth in the food processing industry also depends on future regulation as this will drive up costs of Central Valley processors. As the costs of Central Valley processors located in-region increase other areas, both out of state and out of region, realize a comparative advantage in lower production costs. All else constant, this would be expected to cause processing facilities to shift out of the Central Valley to regions were regulations are less restrictive. The extent of this shift out of region depends on operating costs in other regions and who bears the burden of the cost increase.

Overall, there is a balance between agriculture production, transportation costs, and regulation that will determine the future of food processors in the Central Valley. A recent report conducted by Sunding et al (2006) for the California Regional Water Quality Control Board – Central Valley Region explores the interaction of these conflicting forces. Sunding et al consider these effects as they apply to processors of wine, cheese, poultry, beef, pork and tomatoes. They find that a one percent increase in the cost of regulation will cause processors in all of these industries to shift production out of region, ranging from 0.5% to 20% of production shifting out of region (Sunding et al 2006, p. 512). This report will scrutinize, re-assess, and extend their findings in section 3.3.




Source: Hilmar SEP, Sunding et al (2006) pg. ii

**Figure 2.7 Food Processors in the Central Valley**

### 2.5.2 Regulatory Considerations

As discussed above, food processors discharge wastewater directly to the land either at the plant site or via a POTW. Wastewater discharge is regulated by the State Water Resources Control which regulates processors in the Central Valley through the Central Valley Regional Water Quality Control Board. See http://maps.waterboards.ca.gov/webmap/rbbound.html for a map of Water Quality Control Board districts and areas covered. Legislation for regulation of food processors is laid out in the Porter-Cologne Water

Control Act, which was last updated in January 2008 (http://www.swrcb.ca.gov/laws_regulations/docs/portercologne.pdf).

Land application regulation is enforced by the Central Valley Regional Water Quality Control Board by waste discharge requirements, conditional waivers, water reclamation requirements, monitoring or technical report requirements and clean up and abatement orders (See the Porter-Cologne Act cited above or Sunding et al. 2006, p. 4). Using these regulatory tools Basin Plans are established that dictate water quality objectives and policies to achieve these objectives. Current Basin Plans include the Sacramento River and San Joaquin River Basin Plan, Tulare Lake Basin Plan and Bay-Delta Plan. Each Basin Plan includes region specific goals including adopting drinking water standards, maximum contaminate levels and land application wastewater quality regulations (Sunding et al 2006).

## 2.6 Concentrated Animal Feeding Operations

The largest of animal feeding operations (AFOs),[1] defined as concentrated animal feeding operations (CAFOs),[2] in California and elsewhere face recently amended federal and state water quality regulations that affect how they manage manure generated within the operation. Manure contains salts and nutrients such as nitrogen and phosphorus that can degrade water quality if they are discharged to water. These new requirements place limits on the amount of manure that can be land applied. The nitrogen and/or phosphorus in the applied manure cannot exceed the nutrient demand for the crops grown on the available land. Current and projected cropping patterns suggest insufficient land is available to apply manure at agronomic rates throughout the San Joaquin River Basin and Tulare Basin. CAFOs in these basins will likely have to compete for available land to spread their manure since the current level of manure-generated nutrients exceeds the assimilative capacity of available cropland. This competition will grow if salinity levels in the Central Valley continue to rise, resulting in a decline in land where manure can be applied. As such, the baseline scenario incorporates the effect of these new water quality regulations on animal production throughout the Central Valley.

### 2.6.1 Federal Water Quality Policy Affecting CAFOs

CAFOs are required under the CWA to obtain a National Pollution Discharge Elimination System (NPDES) permit to specify how they manage manure disposal. In general, NPDES permits are required by point sources (facilities that discharge directly to water resources through a discrete ditch or pipe) before they can discharge into navigable waters. Agriculture is typically exempted from NPDES requirements. However, under regulations developed by the U.S. Environmental Protection Agency (EPA) in 1974, certain AFOs can be designated as CAFOs and be considered a point source under the NPDES program (Ribaudo et al. 2003).

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[1] EPA regulations (contained in 40 C.F.R. §122.23 and Part 122, Appendix B) define an AFO as a facility where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and crops, vegetation, forage growth, or post harvest residues are not sustained in the normal growing season over any portion of the lot or facility where the animals are housed. This does not include fields where manure might be spread.

[2] A CAFO is defined as an AFO that confines more than 1,000 animal units (AUs), or between 301 and 1,000 AUs and discharges pollutants into waters through a manmade ditch, flushing system, or similar manmade device, or directly into waters that pass through the facility, or is determined to be a significant contributor of pollutants to U.S. waters. An animal unit is equivalent to 0.7 dairy cows, 1 slaughter and feeder cattle, 2.5 swine weighing more than 25 kg, 30 laying hens or broilers if a facility uses a liquid manure system, and 100 laying hens if a facility uses continuous overflow watering Gollehon, N., et al. (2001).

In 1999, the U.S. Department of Agriculture (USDA) and EPA announced the development of the Unified National Strategy for AFOs (USDA-EPA 1999); a collaborative strategy to address increasing threats to water quality posed by growing concentration of animal production throughout the United States. The strategy established a framework of actions to minimize water quality and public health impacts from improperly managed animal manure and cites land application as the most desirable method of using manure because of the value of its nutrients and organic matter (Ribaudo et al. 2003). When fully implemented all AFO owners and operators would develop and implement technically sound, economically feasible, and site specific comprehensive nutrient management plans for properly managing the animal manures produced at their facilities, including on-farm application and off-farm disposal, if any (Ribaudo, et al. 2003). Some AFOs would be required to develop these plans while others would not, given their size or actual discharge to water.

At the end of 2002, one of the goals of the Unified Strategy was achieved when EPA revised the CAFO regulations on manure disposal. These revisions changed the requirements for a NPDES permit and their associated Effluent Limit Guidelines for CAFOs by requiring permit holders to develop and implement nutrient management plans for manure nutrients. Under these plans the quantity of manure nutrients that is applied to available cropland must not exceed the generally agreed upon agronomic nutrient demand for the cropland. Other major changes for CAFO NPDES permit and Effluent Limit Guidelines include:

- Eliminating the 25-year/24-hour storm exemption.
- Eliminating the exemption for poultry operations with dry manure handling systems.
- Adopting a zero-discharge requirement with no overflow allowance for new swine, veal, and poultry CAFOs.
- Adopting a duty to apply requirement for actual and potential dischargers to water surface waters.

These new CAFO rules did not go unchallenged. In February of 2005, the U.S. Court of Appeals for the Second Circuit issued a decision on Waterkeeper Alliance et al. v. EPA. The Court determined EPA has the authority to regulate the runoff containing manure that CAFOs have applied to cropland. The Court, however, vacated the “duty to apply” provision. In the new rules, all CAFOs were required to apply for a NPDES permit unless they could demonstrate no potential discharge. The court found the argument supporting this provision to be invalid, given the CWA only applies to actual discharges rather than potential discharges.

### 2.6.2 California Water Quality Policy affecting CAFOs

The State of California complies with the provision of CWA by regulating confined animal facilities (CAFs), which include CAFOs, through the State Water Resources Control Board (SWRCB). Approximately 2,200 dairies, several hundred feedlots, poultry operations, hog operations and other AFOs are classified as CAFs and are regulated by the California Code of Regulations Title 27, Division 2, Chapter 7, subchapter 2, Article 1 (SWRCB 2008). According to the SWRCB, nearly 80 percent of these dairies are located in California’s Central Valley.

California prohibits waste discharge to water and thus does not require NPDES permits for CAFs (SWRCB 2008). To comply with the new federal policy, the SWRCB has instead developed general waste discharge requirements (WDRs) to regulate waste disposal from dairies in particular. The WDRs require CAFs to develop and implement a nutrient management plan for the application of waste to land and report on their waste management plan annually. The general WDR order (Order No. R5-2007-0035) for these dairies clearly states that all waste that is land applied shall be managed in accordance with a certified nutrient management plan that is consistent with the technical standards noted in Attachment C. These technical standards instruct dairies that land apply animal waste to

1. identify all sources of nutrients, including nitrogen and phosphorus, available for each crop wherever waste is applied, and to
2. land apply manure at rates that balance the nutrient demand of the crops grown on the land where manure is applied with the nutrient content of the manure and any other commercial fertilizer applications.

### 2.6.3 Baseline Policy Scenarios

The effect of the new CAFO regulation animal production will depend on the quantity of manure generated by these operations and the availability of cropland where manure can be applied at the rates specified in a nutrient management plan. The regional data used in the analysis does not identify manure from CAFOs or any other AFOs. A percentage of the total manure, and thus manure nutrients, generated throughout the Central Valley is used as an approximation of the manure generated from CAFOs. The estimated quantity of manure production from CAFOs is based on estimates found in Ribaudo et al (2003), who show that CAFOs generate approximately 65 percent of excess nitrogen and 68 percent of excess phosphorus throughout the United States. They add that approximately 60 percent of the manure from the Pacific States (California, Oregon, and Washington). As such, two manure land application scenarios are considered. The first scenario considers that 60 percent of all manure generated is delineated as CAFO manure and complies with the nutrient limits on nitrogen and phosphorus application rates. The second CAFO scenario establishes only 30 percent of the manure from all AFOs be applied according to nutrient constraints. This latter scenario is constructed for illustrative purposes only given considerable uncertainty about actual versus potential discharge, truthful reporting, and enforcement.

The availability of cropland where manure can be land applied depends on farmers' decisions to grow crops where manure can be land applied and their willingness to accept manure (WTAM). Not all crops can be fertilized with manure. Not all farmers who grow crops where manure can be land applied are likely to use manure to fertilize their crops. The actual WTAM among farmers in the Central Valley is unknown. The baseline policy assumes three WTAM rates among farmers (30%, 20%, and 10%). These rates span those estimated by Ribaudo et al. (2003). They found that among the major field crops grown throughout the United States, the share of acres treated with manure ranges from about 15 percent for corn and 10 percent for soybeans to less than 3 percent for wheat. These WTAM rates may be low given most crop farms without livestock, and many farms with livestock, use commercial fertilizers because they are less bulky, easier to apply, and have a more certain nutrient content than manure (Ribaudo et al. 2003). In addition, recent outbreaks of E. coli and salmonella in the United States are assumed to further reduce farmers' incentives to substitute manure for commercial fertilizer, today and in the future.

The analysis does not, however, consider the financial assistance to help AFOs adopt nutrient management plans that comes from the Environmental Quality Incentive Program (EQIP). EQIP provides technical assistance, cost-share payments, and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm. Animal feeding operations can receive financial assistance for waste management structures and for nutrient management. By statute, 60 percent of the available funding for the program is earmarked for practices related to livestock production. EQIP was funded at about $200 million per year from 1996 through 2000 and then increased incrementally from $400 million in 2002 to $1.3 billion in 2007. Negotiations for the latest Farm Bill are underway. Among the topics being discussed is how EQIP resources will be allocated in the future. The analysis contained in this report does not consider the implications of EQIP payments in managing manure given the uncertainty about future payments and the perceived inability of future payments to resolve the excessive disparity between limited available cropland for spreading manure and the abundance of manure requiring land application at acceptable rates.

## 2.7 Irrigated Agriculture

Irrigated agriculture in saline Central Valley regions is a result of the interaction of several economic driving forces. Specifically, irrigated agriculture has always been viewed as the interaction between technology, resources, market demands and future production. Technological innovations have contributed to increasing yields, although the rate of change of technological innovations has slowed in recent years due to decreased funding and, presumably, diminishing returns. Real crop prices have sharply trended upward in recent years leading to increases in profitability of many crops. There is significant debate among experts regarding the long term sustainability of increasing real prices. The general consensus is that prices will level off and resume downward trends in the future. Resource availability is a function of both land use and input use per unit land (extensive and intensive marginal decisions) and depends on region specific economic forces. Similarly, future production will depend on future prices, technology and resource usage at both intensive and extensive margins. Compounding and complicating these economic effects are exogenous factors including water supply availability, climate change, international agricultural production and agricultural policies. It is important to consider these details when estimating effects of salinity on irrigated agriculture.

### 2.7.1 Surface and Groundwater Supplies and Allocations

The level of water infrastructure in operation in 2004 is assumed to continue at its current level until 2030. No new major facilities are assumed to be built. At the time of writing, it is hard to predict any clear action in terms of changes in storage or conveyance. One obvious exception is the possibility of an alternative facility for conveyance around the Sacramento River Delta. Such a facility is likely to have significant effects on both the quantity of water available in the Central Valley and improvements in its quality and reduction in the salt load imported into the Valley. This scenario will be addressed in the future. However, it is assumed that the trend towards rational reallocation of existing water supplies to their highest and best use by voluntary markets will continue. Significant changes in the current level of groundwater pumping and use are not anticipated, despite the average level of groundwater overdraft in the Tulare basin. It is however, anticipated that a continual development of the capacity for conjunctive storage using groundwater aquifers will occur.

### 2.7.2 International Agricultural Markets

A significant proportion of the agricultural and processing output from the Central Valley is exported to international markets. Since it is very difficult to predict how the comparative advantage to California products will change over the next 25 years, the shift in the economic demand for California products is modeled by assuming that California will maintain its share of the growing domestic and international markets. Market growth is modeled, based on predictions of population growth both in California and the US, and the growth in relative income in these two markets. An income elasticity of demand is used to translate this change in income into an increased demand per capita for California products. The change in population enables a prediction of changed quantities demanded by consumers assuming no relative price change. This effect is modeled by shifting the crop specific demand function parameters so that prices are still responsive to production levels, but reflect the effects of competition and California production.

### 2.7.3 US Agricultural Policy

As with international markets, US farm policy is subject to political influences and international conditions. Most industries in the Central Valley are not greatly affected by US agricultural policy, with the exception of the dairy industry and the cotton industry. The effect of changes in subsidies on the cotton industry is likely to be reduced over time due to the shift towards Pima cotton that is not subsidized. While a change in dairy price supports would influence this major California industry, constraints on their ability to dispose of effluent are far more likely to be a rate-limiting variable.

### 2.7.4 Climate Change

The assumptions on the way that climate change will affect California's Central Valley are drawn from Tanaka et al (2006) in which the ability of California's water based economy to adapt to climate change is examined. Climate warming effects were represented for all major hydroelectric inputs, and optimal adaptation was assumed. Changes in population land-use and economic demands are also defined in Tanaka et al (2006). The basic assumptions on temperature and precipitation are derived from the Parallel Climate Model (PCM) global simulations, downscaled to the level of California watersheds and the Central Valley. The change in land use and effective water supplies by 2030, is pro-rated from the 2100 projections in Tanaka et al (2006). An implicit assumption in this approach to project climate change impacts is that new crops, industries, and technologies will evolve to adapt to the increase in temperature and reduction in water supplies, and other climate change related impacts.

### 2.7.5 Regional Projections

Projections of California agriculture to 2030 are difficult since much of the crops grown are subject to changes in consumer preferences, water supplies and land use decisions. Agricultural production in the Central Valley is estimated by the California Department of Food and Agriculture at $23.7 for the year 2006. About 57% of that production originated from the Tulare Basin and 31% from the San Joaquin Basin. Dairy products, grapes, fruits, nuts and specialty crops comprise a substantial portion of the value of the total agricultural production.

The preferred method of projecting agricultural production would be on a commodity basis but this has not been done on any systematic basis that would allow regional projections for the entire agricultural sector. REMI has made projections of output for agriculture sector for the three basins. These projections are derived from USDA projections that are disaggregated to the state level. REMI has furthered disaggregated the USDA projections to the county level. REMI projects a 47% increase in the value of agricultural production in the Central Valley. The variation in the projected increase among the basins is insignificant. The increase in value will probably be due to changes in cropping patterns and yields rather than increases in crop acreages.

### 2.7.6 Regulatory Considerations

Water quality regulations will affect irrigated agriculture and confined animal operations such as dairies, poultry production and feed lots. The regulatory considerations for the concentrated animal operations are covered in that section.

The Central Valley regional conditional agricultural waivers (R5-2006-0053 and R5-2006-0054, adopted June 22, 2006) cover discharges of waste from irrigated pasture, field and row croplands, rice fields, orchards, vineyards, commercial nurseries, nursery stock producers, greenhouses with permeable floors (not regulated under other permits), and managed wetlands such as wildlife refuges and duck clubs. These waivers remove the requirements to obtain WDRs, submit waste discharge reports, and payment of filing fees. However, the waivers have implemented a monitoring and reporting program to measure compliance of the terms and conditions of the waiver, as required by the Water Code. The program is known as the Irrigated Lands Conditional Waiver Program and is an interim program.

Since implementation of the Irrigated Lands Conditional Waiver Program, the Central Valley Water Board has held many workshops and meetings with stakeholders, such as coalition groups, the Farm Bureau, agricultural commissioners, resource conservation districts, water districts, environmental interests such as Delta Keeper, and other interested stakeholders affected by the agricultural community.

To maintain the continued identification of program needs, the Regional Water Board is working with the coalition groups, individual dischargers, water districts, UC Davis Cooperative Extension, State Board programs, and Regional Board programs. An objective of the Irrigated Lands Conditional Waiver Program is to collect sufficient data and information to develop and support a long-term regulatory program. An Environmental Impact Report is being prepared to further the development of a long-term regulatory program (SWRCB(c), 2006).

# 3 Direct Economic Impacts of Increased Salinity Concentrations

Direct economic impacts, as discussed previously, are the most straightforward costs associated with increasing water salinity. Direct impacts are usually measured as direct physical costs on water users including industry, urban and agriculture. Urban users are directly affected through water taste and degradation of water appliances resulting from increased salinity. Industry is affected by accelerated degradation of pipes and other water infrastructure. Animal feeding operations and food processing facilities are forced to meet new regulations in effluent discharge. Thus, since regulations increase as salinity increases these sectors realize higher costs with salinity increases. Finally, salinity has a direct impact on agriculture in the Central Valley through reduced crop yields. Reduced yields force farmers to change rotations to lower value salt tolerant varieties and/or change input application (e.g. water application). All of these sectors are both impacted by and creators of salinity and, consequently, the interaction between each sector and salinity must be considered. The direct economic impacts from salinity are considered in more detail, sector by sector, in the following sections.

## 3.1 Urban Water Users

This section measures the costs of increasing salinity on urban users by considering the effects on residential users. First, a brief review of relevant literature is presented and this is followed by a quantitative analysis of costs. The quantitative results in this section follow the methodology of Metropolitan Water District of Southern California's Salinity Management Report prepared with Bookman-Edmonston Engineering Inc. (BEEI 1999) and the Hilmar Supplemental Environmental Project (Sunding et al 2006). Salinity effects to urban users are captured through changes in water taste, leading to investment in water softeners, and degradation of home water appliances, leading to increased replacement costs.

### 3.1.1 Household Costs of Increasing Salinity

This section provides a brief review of the literature on the cost of increasing salinity in the household water supply.

To determine the costs of salinity directly imposed on households, Ragan et al (1993) sent surveys to households, plumbers, and appliance repair technicians. The sample included 681 households in southeast Colorado, located in the Arkansas River Basin. Salinity levels of tap water in this area varied from 100 to 3,500 milligrams per liter of water (mg/L). Tap water in the San Joaquin Valley for which data are available range from about 300 mg/L to 1,800 mg/L. Tap water in rural areas may contain higher levels of salinity since, in these areas, tap water often comes from unmonitored wells.

The Ragan household survey asked questions about the costs, repairs, and replacements of water using appliances, as well as the service life and costs of fixtures and pumping, vehicle maintenance, laundry habits, and bottled water usage. Ragan et al also asked households how much they value improving water quality up to the point where their appliances, plumbing, and vehicles would not experience scaling or corroding and their tap water would not have a poor taste. The surveys sent to plumbers and appliance repair technicians contained questions concerning the costs of repairs and the frequency with which repairs were needed.

By combining the survey data with data on salinity levels, Ragan et al estimated the effect salinity has on the lifespan of household products. They employed models from accelerated testing methods. These methods are generally used in laboratories that test how environmental factors lead to accelerated product failures. Here, the researchers treated the various levels of salinity like the various levels of the acceleration-inducing factors. With the costs of repairs obtained from all three types of surveys, Ragan et al computed the costs of shorter product life spans.

Table 22 from Ragan et al has been reproduced below as Table 3.1. It shows the costs per year a household faces for a given level of salinity, relative to a salinity level of 0 mg/L, or the complete absence of salts in the water. They compute costs for two distributions of household appliances, fixtures, plumbing, and vehicles. The first assumes all products are new. Since newer products are generally of higher quality and therefore more resistant to the effects of salinity than their corresponding older version, the costs to a household with all new appliances is less than that for a household whose appliances are at various ages. The latter scenario is represented by the steady state distribution. Steady state age distribution refers to the age at which an equilibrium has been reached for salinity effected household items as determined by historical usage.

Table 3.1 Total Excess Cost per Household for Appliance Replacement at an 8% Discount Rate ($1992 Price Level)

| Salinity (mg/L) | "All New" Age Distribution | | Steady-state Age Distribution | |
|---|---|---|---|---|
| | Cost ($/yr) | Std. Error ($/yr) | Cost ($/yr) | Std. Error ($/yr) |
| 100 | 4.47 | 3.39 | 5.43 | 3.69 |
| 200 | 9.23 | 5.22 | 11.17 | 4.69 |
| 300 | 13.71 | 6.10 | 16.59 | 5.45 |
| 400 | 17.59 | 6.64 | 21.32 | 5.98 |
| 500 | 20.76 | 6.97 | 25.26 | 6.28 |
| 600 | 23.29 | 7.17 | 28.48 | 6.48 |
| 700 | 25.32 | 7.32 | 31.13 | 6.62 |
| 800 | 26.98 | 7.43 | 33.33 | 6.72 |
| 900 | 28.39 | 7.54 | 35.21 | 6.81 |
| 1,000 | 29.61 | 7.64 | 36.86 | 6.88 |
| 1,200 | 31.74 | 7.87 | 39.68 | 7.01 |
| 1,400 | 33.64 | 8.11 | 42.12 | 7.14 |
| 1,600 | 35.44 | 8.36 | 44.35 | 7.28 |
| 1,800 | 37.20 | 8.61 | 46.45 | 7.41 |
| 2,000 | 38.96 | 8.86 | 48.50 | 7.55 |
| 2,500 | 43.46 | 9.48 | 53.59 | 7.91 |
| 3,000 | 48.26 | 10.11 | 58.88 | 8.31 |
| 3,500 | 53.45 | 10.74 | 64.53 | 8.75 |
| 4,000 | 59.11 | 11.40 | 70.63 | 9.23 |

Source: Ragan et al (1993).

Coe (1982) looked at cost effects of overall water quality and included total dissolved solids (TDS) among the components of water quality. He sent 3,000 surveys to households in Los Angeles and Riverside counties. Tap water salinity ranges from 228 mg/L to 749 mg/L in these areas. The survey asked about household characteristics, water softening practices, consumption and cost of bottled water, uses of soaps and detergents, appliance life spans, and the damage and replacement of fabrics and fixtures. The survey also asked about the household's additional willingness to pay for "top water quality" that would not cause damage or require bottled water use.

Looking only at correlation coefficients, Coe found a negative correlation between TDS and the life of water heaters, washing machines, faucets, galvanized pipes, and copper pipes. Coe found no correlation between TDS and the life span of toilet mechanisms or willingness to pay for improved water quality.

Coe employed multiple regression analysis in models where household costs were assumed to be linearly related to various water quality levels. Coe found the coefficient on TDS to be positive in models for the costs of water heaters, costs of water basins, costs of sinks, and costs of laundry tubs. The coefficient on TDS was negative in the model of costs of home softening. It was not significant in models of the costs of soap, bottled water, filters, washing machines, toilet mechanisms, pipes, faucets, toilets, or clothes. Assuming total costs to the household are linear in TDS, a salinity increase of 100 mg/L increases monthly costs by $4.70.

Coe found that the additional amount households are willing to pay for improved water quality ranges from $3.21 to $9.39 in 2005 dollars. However, this represents an upper bound for salinity willingness to pay with respect to household water-related expenses since this survey asks about water quality in general instead of salinity specifically.

As part of the Metropolitan Water District (MWD) of Southern California's 1999 Salinity Management Plan, Bookman-Edmonston Engineering, Inc. (BEEI) reviewed and revised previous studies of the impact of salinity to estimate the costs of salinity to households in Southern California (BEEI 1999). Previous work included Andersen and Kleinman (1978), D'Arge and Eubanks (1978), Milliken-Chapman (Lohman and Milliken, 1988), and the above mentioned Ragan (1993). In the years since these studies were undertaken, prices, construction materials, technology, water quality, and demographics have changed, and this section attempts to account for these changes.

BEEI concluded that salinity most likely does not negatively impact copper water supply pipes, waste water pipes, toilet flushing mechanisms, or motor vehicle cooling systems. The relationship between salinity and the lifespan of various household items is shown in Table 3.2.

Table 3.2 Economic Impacts of Reduced Life of Water Using Appliances and Plumbing (1996 Price Level)

| **Appliance/Plumbing Item** | **Percent of Residences with Appliance** | **Replacement Cost** | **Life Span in Years as a Function of TDS in mg/L** |
|---|---|---|---|
| Galvanized Steel Water Supply Pipes1 | 13% | $2,600 | 12+exp(3.4 - 0.0018 TDS) |
| Water Heater | 97% | $300 | 14.63 - 0.013 TDS + 0.689 (10-5)TDS2 - 0.11 (10-8) TDS 3 |
| Faucet | 100% | $442 | 11.55 – 3.05 (10-3) TDS |
| Garbage Disposal | 75% | $120 | 9.23 - 3.87 (10-3) TDS + 1.13 (10-6) TDS2 |
| Washing Machine | 67% | $425 | 14.42 - 0.011 TDS + 4.6 (10-5) TDS2 |
| Dishwasher | 51% | $450 | 14.42 - 0.011 TDS + 4.6 (10-5) TDS2 |

**Tihansky (1974)
Source: Bookman-Edmonston Engineering, Inc. (1999).

Looking at previous studies (Bruvold (1976), Black & Veatch (1967), Howson (1962), Ragan (1993), and Orange County Water District (OCWD) (1972)) involving water softeners, BEEI attempts to adjust these older studies from different locations to current conditions in Southern California. Further data collection was undertaken by M. Cubed and Freeman-Sullivan Co. that resulted in the creation of the cost models shown below in Table 3.3.

Similarly, BEEI looked at previous studies of "dispensed water" or bottled water purchases and filtration systems. Bruvold (1976 and 1990) finds a positive relationship between TDS and purchased water and water filtration. Additional surveys were conducted to update the available data. This new data also revealed a positive relationship between TDS and dispensed water purchases and home water filtration systems, as shown in Table 3.3.

Table 3.3 Economic Impacts of Avoidance of Salinity Impacts by Purchase of Water Softeners; and Dispensed Water and Home Filtration Systems (1996 Price Level)

| Avoidance Method | Annual Cost per Household as Function of TDS [($/year)/(mg/L)] |
|---|---|
| Home Water Softeners | $324 *[6.758 + 0.007 * TDS + (3.01(10-6) * TDS2) + (2.2(10-10) * TDS3)] |
| Dispensed Water and Home Filtration Systems | $62 * (0.611 + 0.0000323 * TDS) |

Source: Bookman-Edmonston Engineering, Inc., 1999.

In a more recent study conducted by Sunding, Rubin, Berkman (2006), the Hilmar Supplemental Environmental Project (Hilmar Report) updates the cost estimates contained in BEEI. The Hilmar Report updates replacement costs to reflect 2006 dollars and captures the changes in appliance cost over the fifteen years since the BEEI report. Similarly, the Hilmar Report updates estimated household appliance use by conducting surveys in the San Joaquin Valley. Functional forms of the cost functions remain unchanged. This analysis follows closely the methodology of BEEI and Hilmar Report, using the updated and region specific estimates of cost and appliance usage found in the latter.

### 3.1.2 Urban Salinity Costs

Following the Hilmar Report, as water quality decreases the impact on urban users is seen through two effects: capital depreciation and taste. Salinity leads to accelerated depreciation of water fixtures, requiring more frequent replacement of pipes and household appliances. This is the capital depreciation effect. Additionally, higher salinity leads to investment in water softeners and water filtration devices to offset the poor taste; this is the taste effect.

This analysis assumes that the effect of increasing salinity is uniform across all residential users. Since the costs of salinity are going to be quantified as either resulting from capital depreciation or taste changes, it is reasonable to assume the single family attached and detached homes will be affected the same. Multi-family dwelling units, such as apartment complexes, are also assumed to be affected in the same way as single family homes. For these dwellings capital depreciation and taste will be costs to the owners of the units instead of the families. It is reasonable to assume that these costs are identical to those of the single family homes.

#### 3.1.2.1 Capital Depreciation

The most direct cost associated with salinity is the cost of capital depreciation of consumer water appliances. This section considers galvanized water pipes, water heaters, faucets, garbage grinders, dish washers, and clothes washers to be the appliances impacted by salinity.

Define $f(T)$ as the lifespan of an appliance as a function of salinity, $T_0, T_1$, where T is measured in TDS (mg/L) with 0,1 denoting base salinity TDS and TDS under hypothesized salinity increase, respectively. C is the cost of replacement, L is the annual loss for each appliance i.

**Equation 1** $$L_i = C\left(\frac{1}{f(T_1)} - \frac{1}{f(T_0)}\right)$$

Where $L_k(T_0, T_1) = \sum_i p_i L_i$ is the overall annual cost of capital depreciation per household; and where $p_i$ is the percentage of residential customers that have appliance i.

Replacement Costs of Appliances are defined as in the Hilmar Report (Hilmar 2006, section III.2). These estimates have been updated from the BEEI 1999 study to reflect changes in replacement costs. These changes are shown in Table 3.4.

**Table 3.4 Updated Economic Impacts of Reduced Life of Water Using Appliances and Plumbing (2006 Price Level)**

| Appliance/Plumbing Item | Percent of Residences with Appliance | Replacement Cost | Life Span in Years as a Function of TDS in mg/L |
|---|---|---|---|
| Galvanized steel water supply pipes** | 5% | $12,450 | 12+exp(3.4 - 0.0018*TDS) |
| Water Heater | 100% | $750 | 14.63 - 0.013*TDS + 0.689*(10-5)*TDS2 - 0.11*(10-8)*TDS3 |
| Faucet | 100% | $905 | 11.55 - 3.05*(10-3)*TDS |
| Garbage Disposal | 82% | $205 | 9.23 - 3.87*(10-3)*TDS + 1.13*(10-6)* TDS2 |
| Washing Machine | 79% | $575 | 14.42 – 0.011*TDS + 4.6*(10-5)*TDS2 |
| Dishwasher | 77% | $575 | 14.42 – 0.011*TDS + 4.6*(10-5)*TDS2 |

**Equation from Tihansky (1974)
Source: Bookman-Edmonston Engineering, Inc. (1999) and updated by the Hilmar Report (2006).

In order to apply this methodology, it is necessary to specify a base TDS and a TDS level under the increased salinity. BEEI 1999 assumes a 100 TDS increase for a cost comparison scenario; the Hilmar Report uses TDS of 500 mg/L as the base for agricultural impact analysis. The literature review, summarized above, found base TDS estimates for tap water of 300 mg/L and 228 mg/L (Ragan et al; Coe). This section will use the average estimate of 264 mg/L as the base urban water TDS.

Using the 30 year time trend of TDS presented in Schoups 2004, average annual TDS has increased by approximately 30% over the period 1967-1997, fitting a linear approximation. Thus, a reasonable approximation for thirty year increased TDS is 343 mg/L, which is in line with the assumed 100 TDS increase in BEEI 1999.

Applying these results to the models from the Hilmar Report, results of Capital Depreciation Costs are summarized in Table 3.5.

**Table 3.5 Urban Impacts from Capital Depreciation (2006 Price Level)**

| Appliance | Lifespan at Base TDS (years) | Lifespan at Increased TDS (years) | Loss |
|---|---|---|---|
| Water Pipes (Galvanized) | 30.63 | 28.16 | $35.64 |
| Water Heaters | 10.72 | 9.36 | $10.17 |
| Faucets | 10.74 | 10.50 | $1.93 |
| Garbage Disposal | 8.29 | 8.04 | $0.77 |
| Washing Machine | 11.73 | 11.05 | $3.02 |
| Dishwashers | 11.73 | 11.05 | $3.02 |
| **Total Impact per Household** | | | **$19.23** |

### 3.1.2.2 Taste Considerations

In addition to accelerated degradation of household appliances, urban users will invest in water softeners and dispensers as taste changes. The base and increased levels of TDS determined above will be assumed for this component of urban cost as well.

To quantify the cost of changes in taste, this section draws from the methodology in the Hilmar Report (Hilmar 2006, section III.2). The functions that follow quantify the relationship between dispensed water and softener demand and TDS. Demand is expressed as a percentage of the total user base, thus multiplying this by the total population and annual cost yields annual cost of operation per household.

Formally, define $C_s, C_d$ as annual per-capita operating costs for water softeners, water dispensers, respectively; and $p_s, p_d$ as the percent of households with water softeners, water dispensers. Then,

**Equation 2** $$L_T(T_0,T_1) = C_s\left[p_s(T_1) - p_s(T_0)\right] + C_d\left[p_d(T_1) - p_d(T_0)\right]$$

is the total annual cost due to changes in taste.

The functions used to define these costs are presented as annual cost per household. These are summarized in Table 3.6 which includes updated costs from the Hilmar Report. The results of this analysis are presented in Table 3.7.

**Table 3.6 Household Annual Cost Increase Due to Taste Concentrations**

| Avoidance Method | Annual Cost per Household as Function of TDS [($/year)/(mg/L)] |
|---|---|
| Home Water Softeners | $434 *[6.758 + 0.007 * TDS + (3.01*(10-6) * TDS2) + (2.2*(10-10) * TDS3)] |
| Dispensed Water and Home Filtration System | $79 * (0.611 + 0.0000323 * TDS) |
| Source: Bookman-Edmonston Engineering, Inc., 1999 and updated from the Hilmar Report 2006. | |

**Table 3.7 Urban Impacts from Changes in Taste (2006 Price Level)**

| Treatment Option | Percent of Users at Base TDS | Percent of Users at Increased TDS | Cost per Household |
|---|---|---|---|
| Water Softeners | 8.82% | 9.52% | \$304.74 |
| Water Dispensers | 0.62% | 0.63% | \$0.20 |
| **Total Impact per Household** | | | \$304.94 |

### 3.1.3 Annual Direct Costs

The direct costs of salinity on urban water users are broken down into two separate effects, capital depreciation and the cost of changes in taste. The total costs per household due to an increase in salinity from 264 mg/l to 343 mg/L are $L_k + L_T$, \$324.17 over a period of thirty years. Assuming that this increase will occur linearly over that time frame, average yearly costs per household are \$10.81. Note that this estimate is in line with previous studies and the identified willingness to pay for reduced salinity.

#### 3.1.3.1 Salinity Accumulation Scenarios

Three salinity accumulation scenarios were formulated. The first is a Base Scenario that assumes conservative conditions regarding projected salinity levels. The second is a Medium Scenario or expected value scenario. The third or High Scenario can be considered an upper bound of salinity damages

The Base Scenario assumes that the Tulare and San Joaquin basins will experience an average annual salinity increase of 2.63 mg/l to the year 2030 and the Sacramento Basin will experience no increase in water supply salinity concentrations. The 2030 Central Valley cost to urban water users is \$27.581 million (Table 3.8). This was calculated by dividing the 2030 REMI population projections by the average household size of 2.59 (Census 2000) and multiplying by the annual household cost. The impacts are assumed to be uniform across single and multi-family homes. It is important to note that the cost functions that drive these estimates are functions of appliance costs under different salinity scenarios. Consequently, these functions do not take into account the fact that some households already have these appliances installed. In this case the cost is overstated by the initial expense of purchasing the new unit.

The salinity assumption for the San Joaquin and the Tulare Basins are consistent for the three scenarios while a .64 mg/l annual increase is used for the Sacramento Basin in the Medium Scenario. Adjusting the damages according to the annual change in salinity concentration, yields an annual cost of \$6.28 per household, a 2030 annual cost of \$4.862 million to the Sacramento Basin and \$32.443 million to the Central Valley.

The High Scenario assumes an annual salinity increase of 1.53 mg/l for the Sacramento Basin. The Sacramento Basin salinity increase assumptions are based on 14 years (1994-2008) of water quality samples taken at the City of West Sacramento water treatment plant located on the Sacramento River approximately 2.14 miles above the confluence of the American River. Samples were analyzed using two methods, the standard method 2510-B laboratory test and the EPA 120.1 field test. The laboratory test data indicated a .64 mg/l average annual increase in salinity, while the field test showed a 1.53 mg/l increase.

The High Scenario assumes an annual cost of \$11.624 million for the Sacramento Basin and a total of \$39.205 million for the Central Valley in 2030. Note that damages for 2008 are presented as zero. This is not to say that no salinity damages currently exist but that only future additional damages are being estimated in this study. Economic damages caused by increased salinity are entered into the REMI model on a yearly basis. This is accomplished by interpolating between the 2030 and 2008 damages.

**Table 3.8 Annual Direct Cost of Three Salinity Scenarios on Urban Water Users**

| | Basis of Regional Allocation | | | | Direct Change | |
|---|---|---|---|---|---|---|
| | | | | | 2008 | 2030 |
| Basin | | | | | | |
| | | | *BASE SCENARIO* | | | |
| | Annual Salinity Increase | Cost/HH year | Population 2008 | 2030 | 2006 $ (M) | |
| Sacramento | 0.00 | $ - | | 4,795,301 | $0.000 | $0.000 |
| San Joaquin | 2.63 | $ 10.81 | | 3,744,337 | $0.000 | $15.622 |
| Tulare | 2.63 | $ 10.81 | | 2,866,422 | $0.000 | $11.959 |
| Total | | | | 11,406,060 | $0.000 | $27.581 |
| | | | *MEDIUM SCENARIO* | | | |
| | Annual Salinity Increase | Cost/HH year | Population 2008 | 2030 | 2006 $ (M) | |
| Sacramento | 0.64 | $ 2.63 | | 4,795,301 | $0.000 | $4.862 |
| San Joaquin | 2.63 | $ 10.81 | | 3,744,337 | $0.000 | $15.622 |
| Tulare | 2.63 | $ 10.81 | | 2,866,422 | $0.000 | $11.959 |
| Total | | | | 11,406,060 | $0.000 | $32.443 |
| | | | *HIGH SCENARIO* | | | |
| | Annual Salinity Increase | Cost/HH year | Population 2008 | 2030 | 2006 $ (M) | |
| Sacramento | 1.53 | $ 6.28 | | 4,795,301 | $0.000 | $11.624 |
| San Joaquin | 2.63 | $ 10.81 | | 3,744,337 | $0.000 | $15.622 |
| Tulare | 2.63 | $ 10.81 | | 2,866,422 | $0.000 | $11.959 |
| Total | | | | 11,406,060 | $0.000 | $39.205 |

## 3.2 Economic Effects of Salinity on Industrial Water Users

This section details the direct economic effects of increasing salinity on industrial water users. As salinity increases, the effect on industrial users is seen through accelerated depreciation of water fixtures and increased costs of treatment. For example, industries that use water in the production process will see degradation of the pipe system with increasing salinity, much in the same way as residential users. For simplicity in calculations we assume that industry in the Central Valley can be classified into a uniform group. This is done in order to focus on the per unit costs of increasing salinity, these per unit costs are then applied uniformly to all industrial users in the Central Valley study area.

Quantifying salinity effects on industry follows the methodology of "Assessing the Cost of Dryland Salinity to non-Agricultural Stakeholders – A Methodology Report" (Wilson 2000). This report details a methodology for determining the number of industrial and commercial buildings in an urban center based on residential population. Next, the costs of salinity on a per building and per unit of water basis is detailed. As such, the results of the analysis in this section rely on the estimates of cost per unit of water to industrial users and are assumed uniform across all industry. Furthermore, the methodology adapted for this analysis uses estimates of cost impacts due to increasing salinity for cooling tower operation, boiler operation, and process water treatment. This report is abstracting from smaller uses of water that would have costs on water piping. These costs are captured in the residential users section. Costs are reported in terms of cost per acre-foot (AF) per year due to a one mg/L increase in salinity.

### 3.2.1 Changes in Operating Costs Due to Salinity

Table 3.9 summarizes the increase in cost due to a one mg/L increase in salinity across the basin. Again, this assumes that the industry in the basin can be considered uniform. Specifically, it does not differentiate between various industrial structures. As such, it is reasonable to expect that this estimate will overstate some buildings and understate others. This report assumes that these essentially balance each other out. Combining the cost per acre foot of water of the three items considered: cooling tower, boiler and water process, the total cost per acre foot is estimated to be just over $20.

**Table 3.9 Cost Increases to Industry Caused by Increased Salinity Concentrations**

| **Cost of 1 mg/L Increase in Salinity** | |
|---|---|
| **Business Item** | **Cost per AF** |
| Cooling Tower Operation | $9.88 |
| Boiler Operation | $5.38 |
| Process Water Treatment | $6.15 |
| **Total Cost per AF** | **$21.41** |

### 3.2.2 Annual Direct Costs

Industry water users increase in annual direct costs due to salinity in 2030 was calculated on the basis of 2030 water use, the change in salinity concentration and the cost of the increase in salinity concentration. First, 2030 water use was estimated by adjusting the CA Dept of Water Resources 2001 water use by the change in industrial output from 2001 to 2030. Second, 2030 economic costs was determined by multiplying 2030 water use times the change in salinity concentration from 2008 to 2030 times the estimated acre-foot damage per mg/l which is $21.41.

As with the urban water users, the industrial Base Scenario assumes an annual salinity concentration increase of 2.63 for the San Joaquin and Tulare Basins and no change for the Sacramento Basin (Table 3.10). The Medium Scenario increases the annual salinity increase to .64 mg/l and the High Scenario to 1.53 mg/l for the Sacramento Basin. Total 2030 Central Valley annual direct costs for industrial users are $508.093 million for the Base Scenario, $604.651 for the Medium Scenario and $738.927 for the High Scenario.

Direct costs of salinity increase to individual industry sectors were allocated on the basis of projected 2030 output levels (Table 3.11).

**Table 3.10 Annual Direct Costs of Three Salinity Scenarios on Industrial Water Users**

| | Basis of Regional Allocation | | | | | Direct Change | |
|---|---|---|---|---|---|---|---|
| | | | | | | 2008 | 2030 |
| Basin | | | | | | | |
| | | | *BASE SCENARIO* | | | | |
| | Annual Salinity Increase | Water Use | | Industrial Output | | | |
| | | 2001 | 2030 | 2001 | 2030 | | |
| Sacramento | 0.00 | 84,500 | 320,309 | $20.673 | $78.364 | $0.000 | $0.000 |
| San Joaquin | 2.63 | 90,100 | 241,666 | $29.484 | $79.082 | $0.000 | $299.751 |
| Tulare | 2.63 | 66,400 | 167,969 | $12.121 | $30.662 | $0.000 | $208.341 |
| Total | | 241,000 | 727,930 | $62.278 | $188.108 | $0.000 | $508.093 |
| | | | *MEDIUM SCENARIO* | | | | |
| | Annual Salinity Increase | Water Use | | Industrial Output | | | |
| | | 2001 | 2030 | 2001 | 2030 | | |
| Sacramento | 0.64 | 84,500 | 320,309 | $20.673 | $78.364 | $0.000 | $96.558 |
| San Joaquin | 2.63 | 90,100 | 241,666 | $29.484 | $79.082 | $0.000 | $299.751 |
| Tulare | 2.63 | 66,400 | 167,969 | $12.121 | $30.662 | $0.000 | $208.341 |
| Total | | 241,000 | 727,930 | $62.278 | $188.108 | $0.000 | $604.651 |
| | | | *HIGH SCENARIO* | | | | |
| | Annual Salinity Increase | Water Use | | Industrial Output | | | |
| | | 2001 | 2030 | 2001 | 2030 | | |
| Sacramento | 1.53 | 84,500 | 320,309 | $20.673 | $78.364 | $0.000 | $230.834 |
| San Joaquin | 2.63 | 90,100 | 241,666 | $29.484 | $79.082 | $0.000 | $299.751 |
| Tulare | 2.63 | 66,400 | 167,969 | $12.121 | $30.662 | $0.000 | $208.341 |
| Total | | 241,000 | 727,930 | $62.278 | $188.108 | $0.000 | $738.927 |

**Table 3.11 High Scenario 2030 Industrial Sector Salinity Costs**

| | Sacramento Basin | | San Joaquin Basin | | Tulare Basin | |
|---|---|---|---|---|---|---|
| Sector | Output (Bil Fixed 2000$) | 2030 Salinity Cost (2006$) | Output (Bil Fixed 2000$) | 2030 Salinity Cost (2006$) | Output (Bil Fixed 2000$) | 2030 Salinity Cost (2006$) |
| Utilities | $4.483 | $12,490,865 | $3.538 | $12,836,123 | $3.098 | $22,803,741 |
| Wood product mfg | $3.560 | $9,919,135 | $1.356 | $4,919,667 | $0.578 | $3,424,017 |
| Nonmetallic mineral prod mfg | $1.435 | $3,998,303 | $1.820 | $6,603,093 | $0.686 | $4,340,769 |
| Primary metal mfg | $0.315 | $877,676 | $1.078 | $3,911,063 | $0.398 | $2,341,586 |
| Fabricated metal prod mfg | $2.386 | $6,648,049 | $2.430 | $8,816,218 | $1.133 | $6,527,722 |
| Machinery mfg | $1.160 | $3,232,078 | $1.167 | $4,233,961 | $1.534 | $9,001,850 |
| Computer, electronic prod mfg | $48.566 | $135,318,174 | $10.080 | $36,570,977 | $3.322 | $6,527,722 |
| Electrical equip, appliance mfg | $0.710 | $1,978,254 | $0.202 | $732,871 | $0.136 | $651,668 |
| Motor vehicle mfg | $0.905 | $2,521,578 | $1.087 | $3,943,715 | $0.273 | $1,457,968 |
| Transp equip mfg, exc. motor veh | $1.352 | $3,767,042 | $0.939 | $3,406,761 | $1.426 | $6,836,988 |
| Furniture, related prod mfg | $1.165 | $3,246,009 | $1.085 | $3,936,459 | $0.352 | $1,590,511 |
| Miscellaneous mfg | $1.316 | $3,666,736 | $1.557 | $5,648,910 | $0.858 | $4,009,413 |
| Food mfg | $5.305 | $14,781,183 | $12.756 | $46,279,700 | $11.710 | $81,591,003 |
| Beverage, tobacco prod mfg | $2.590 | $7,216,449 | $2.797 | $10,147,720 | $0.863 | $6,947,440 |
| Textile mills | $0.064 | $178,322 | $0.009 | $32,653 | $0.014 | $110,452 |
| Textile prod mills | $0.421 | $1,173,021 | $0.099 | $359,179 | $0.089 | $474,944 |
| Apparel mfg | $0.060 | $167,176 | $0.176 | $638,541 | $0.036 | $254,040 |
| Leather, allied prod mfg | $0.019 | $52,939 | $0.024 | $87,074 | $0.029 | $154,633 |
| Paper mfg | $0.598 | $1,666,192 | $1.534 | $5,565,464 | $0.776 | $4,848,849 |
| Printing, rel supp act | $0.778 | $2,167,721 | $0.530 | $1,922,879 | $0.335 | $2,164,862 |
| Petroleum, coal prod mfg | $0.724 | $2,017,262 | $33.856 | $122,832,042 | $4.360 | $32,196,802 |
| Chemical mfg | $3.701 | $10,311,999 | $3.166 | $11,486,479 | $0.613 | $4,627,945 |
| Plastics, rubber prod mfg | $1.234 | $3,438,262 | $1.334 | $4,839,849 | $1.141 | $5,456,336 |
| Totals | $82.847 | $230,834,426 | $82.620 | $299,751,398 | $33.760 | $208,341,263 |

## 3.3 Salinity Effects on Food Processing

As in the Hilmar Supplemental Environmental Project, Sunding, Rubin, and Berkman (2006) report (Hilmar Report), the cost of salinity on food processing can be estimated through the impacts of regulation on the food processing industry. Higher salinity levels may result in additional regulation of the food processing industry leading to increased operating costs. This section considers the effect of a salinity reduction policy that would increase fixed and variable operating costs of processing plants. Under consideration are the long run costs of the food processors. It is assumed that the industry is competitive. Long run total variable cost is approximated by value added, the difference between total value of shipments and total cost of raw agricultural inputs.

The Hilmar Report uses Stanislaus County as a representative area of the San Joaquin Valley. This analysis follows the steps of the Hilmar Report closely, with more recent elasticity estimates from Green, Howitt, and Russo 2007. Additionally, this report considers fruit and vegetable processors; previous studies have omitted these important processors.

In order to incorporate fruit and vegetable processors separately, this report uses the elasticity estimates from Green, Howitt, and Russo 2007. According to the data collected in the Hilmar Report, there are 145 fruit and vegetable canneries in California (no attempt is made to differentiate between fruit and vegetable processors). There are 5 fruit and vegetable processors in Stanislaus County (the focus of this part of the report). This leads to an estimate of 0.0344% regulated processors, this will be used to approximate the variable “s”, defined below as the market share of producers affected by regulation.

In the analysis that follows, the study area is Stanislaus County, which is being generalized to the San Joaquin Valley. These results can be easily generalized to represent any specific region in California.

### 3.3.1 Demand and Supply Elasticities

Existing literature was consulted to determine appropriate estimates of demand and supply elasticities. In general, the literature shows that market demand is generally inelastic whereas long run supply is more elastic, resulting in consumers being expected to bear more of the costs. Elasticity estimates are summarized below in table 3.12.

**Table 3.12 Food Processing Supply and Demand Elasticities**

| Industry | Supply Elasticity | Demand Elasticity |
|---|---|---|
| Tomatoes | 0.69 | -0.18 |
| Cheese | 1.00 | -0.50 |
| Beef | 3.24 | -0.08 |
| Pork | 1.80 | -0.08 |
| Poultry | 10.00 | -0.50 |
| Wine | 1.00 | -1.00 |
| Fruit | 0.27 | -0.50 |
| Vegetable | 0.69 | -0.38 |

Proceeding as in the Hilmar Report, the residual demand elasticity is defined as the difference between total demand and total production by unregulated firms. If processors in the San Joaquin Valley are regulated and face increased costs, processors in other regions would be able to supply the market, thereby leaving regulated processors with only residual demand. The elasticity corresponding to this residual demand is going to be more elastic. The derivation is as follows:

Define:

$Q_R$ - Residual demand facing regulated producers

$Q_T$ - Total demand in the market

$Q_U$ - Supply from unregulated producers

$\varepsilon_R$ - Residual demand elasticity

$\varepsilon_T$ - Total demand elasticity

$\varepsilon_U$ - Supply elasticity

s - Market share of producers affected by regulation

Residual demand is given as $Q_R = Q_T - Q_U$, the difference between total demand and what the unregulated producers supply.

**Equation 3**
$$\varepsilon_R = \left[\frac{1}{s}\varepsilon_T - \frac{(1-s)}{s}\varepsilon_U\right] = \frac{\varepsilon_T}{s} + \left(1 - \frac{1}{s}\right)\varepsilon_U$$

S is determined by considering the percent of processed food products (in each category) that comes from the San Joaquin Valley relative to the total from California. It is assumed that the products of both regulated and unregulated producers are perfect substitutes. This is a key assumption because it says that food processors out of the regulated region are able to produce and ship the same goods as processors in the regulated region. Mathematically, it says that the total demand in the market is met by unregulated and regulated producers. Additionally, assume that regulated and unregulated producers face the same supply curve, thus the same elasticity of supply. Table 3.13 summarizes the residual demand elasticities for various industries.

**Table 3.13 Food Processing Residual Demand Elasticities**

| Industry | Residual Demand Elasticity |
|---|---|
| Tomatoes | **-3.09** |
| Cheese | -10.54 |
| Beef | -600.40 |
| Pork | -123.53 |
| Poultry | -290.00 |
| Wine | -46.62 |
| Fruit | **-21.86** |
| Vegetable | **-30.34** |

### 3.3.2 Cost Share Percentages and Market Transfer

To characterize the effect of increased regulation, assume a one percent increase in food processing. This cost will either be passed forward to consumers in the form of higher prices or backward to farmers in the form of lower crop prices. The proportion of the burden that each market bears can be determined using elasticities.

**Equation 4** Farm burden: $\frac{\varepsilon_D}{\varepsilon_S - \varepsilon_D}$ Consumer burden**:** $1 - \frac{\varepsilon_D}{\varepsilon_S - \varepsilon_D}$

In addition to determining who bears the burden of the cost increase, it is necessary to consider reduction in output. Following Hilmar, consider the market transfer effect, which is the decrease in regional processed food production. Market transfer is calculated as the elasticity of supply times the farm (producer) cost share calculated above. This is because the producer cost share represents the proportion of a one percent increase in cost that goes to the producer. Results are summarized below in table 3.14.

**Table 3.14 Food Processing Cost Transfer Percentages**

| Industry | Producer Share | Consumer Share | Market Transfer % |
|---|---|---|---|
| Tomatoes | **0.82** | **0.18** | **0.56** |
| Cheese | 0.91 | 0.09 | 0.91 |
| Beef | 0.99 | 0.01 | 3.22 |
| Pork | 0.99 | 0.01 | 1.77 |
| Poultry | 0.97 | 0.03 | 9.67 |
| Wine | 0.98 | 0.02 | 0.98 |
| Fruit | **0.99** | **0.01** | **0.26** |
| Vegetable | **0.98** | **0.02** | **0.67** |

### 3.3.3 Variable Cost of Production

The measure of variable costs is from the value added of the respective industry divided by the total quantity output. These measures are directly from the Hilmar Report. Units are converted into tons for the analysis that follows. Fruit and vegetable are assumed to operate at costs identical to that of tomato processors in the region (Table 3.15).

**Table 3.15 Food Processing Cost of Compliance**

| Industry | Variable Cost | Units | Variable Cost in Tons |
|---|---|---|---|
| Tomato | $45.00 | Ton | $45 |
| Cheese | $0.29 | Lb | $580 |
| Beef | $21.82 | Cwt | $436 |
| Pork | $15.53 | Cwt | $311 |
| Poultry | $38.88 | Cwt | $778 |
| Wine | $667.00 | Ton | $667 |
| Fruit | **$45.00** | **Ton** | **$45** |
| Vegetable | **$45.00** | **Ton** | **$45** |

### 3.3.4 Average Cost of Treatment

The average per ton cost of salt removal is calculated based on the engineering costs of various treatment alternatives. As specified in the Hilmar report, a 500 mg/L salinity standard is used. The cost per ton is determined as follows.

First, effluent per ton of output and TDS are determined from in plant measures specific to each industry. Tons of salt per ton of output is calculated by multiplying the effluent per ton of output by the TDS concentration, and two estimated constants: **10^(-9)** and 1.1.

Average cost per ton of salt removal is determined from engineering studies in the Hilmar Report according to the technique used. For each industry, the salt removal technique considered is summarized below in Table 3.16.

**Table 3.16 Food Processing Waste Treatment Methods**

| Industry | Method |
|---|---|
| Tomato | In Plant Treatment |
| Cheese | EOP[1] Effluent Treatment |
| Beef | EOP[1] Effluent Treatment |
| Pork | EOP[1] Effluent Treatment |
| Poultry | EOP[1] Effluent Treatment |
| Wine | Supply Water Treatment |
| Fruit | **POTW** |
| Vegetable | **POTW** |

[1] EOP is end of pipe.

Fruit and vegetable processors are assumed to use publicly owned treatment works (POTW) for treatment. The POTW method is assumed because it is an expensive alternative and serves as a higher bound.

This report assumes target TDS of 500 mg/L and the percent salt removal required is calculated as 1 – (Target TDS / TDS). Finally, cost per ton is calculated as (tons salt per tons of output)*(AC per tons salt removal)*(percent salt removal required). Fruit and vegetable are calculated based on the assumptions above. Treatment costs are summarized in table 3.17.

**Table 3.17 Food Processing Treatment Costs**

| Industry | Effluent per Ton of Output (liters) | TDS | Tons of Salt per Ton of Output | Average Cost per Ton Salt Removal* | Target TDS | % Salt Removal Required | Cost per Ton |
|---|---|---|---|---|---|---|---|
| Tomato | 3,482 | 531 | 0.0020 | -$1,730 | 500 | 5.8% | -$0.21 |
| Cheese | 1,363 | 1,592 | 0.0024 | $1,437 | 500 | 68.6% | $2.35 |
| Beef | 9,311 | 604 | 0.0062 | $3,626 | 500 | 17.2% | $3.86 |
| Pork | 9,311 | 604 | 0.0062 | $3,626 | 500 | 17.2% | $3.86 |
| Poultry | 6,472 | 564 | 0.0040 | $3,626 | 500 | 11.4% | $1.65 |
| Wine | 4,258 | 1,176 | 0.0055 | $1,999 | 500 | 57.5% | $6.33 |
| Fruit | **3,482** | **642** | **0.0024** | **$5,397** | **500** | **22.2%** | **$2.94** |
| Vegetable | **3,482** | **642** | **0.0024** | **$5,397** | **500** | **22.1%** | **$2.94** |

*Source: Rubin, Yoram, David Sunding, and Mark Berkman, “Hilmar Supplemental Environmental Project”, Submitted to the California Regional Water Quality Control Board Central Valley Region, In Compliance With Order No. R5-2006-0025, November 16, 2007

### 3.3.5 Salinity Treatment Costs and Market Impacts

Using the above calculations, the percent increase in variable cost is determined (variable cost plus cost per ton relative to variable cost). Next, to calculate output reduction, the percentage increase in variable cost is multiplied by the market transfer percent, which is shown in Table 3.14. The result is the percent reduction in regional output resulting from a percentage increase in variable cost. Table 3.18 summarizes this result. Table 3.19 summarizes changes in processing output by 2030 by mapping the percent reduction in output into monetary effects.

**Table 3.18 Food Processing Variable Cost and Output Changes Due to Increased Salinity**

| Industry | % Increase In Variable Cost | % Output Reduction |
|---|---|---|
| Tomato | -0.46% | **-0.26%** |
| Cheese | 0.41% | 0.37% |
| Beef | 0.89% | 2.86% |
| Pork | 1.24% | 2.21% |
| Poultry | 0.21% | 2.05% |
| Wine | 0.95% | 0.93% |
| Fruit | 6.52% | **1.71%** |
| Vegetable | 6.52% | **4.40%** |

**Table 3.19 Projected Change in 2030 Food Processing Output Due to Increased Salinity**

| Industry | Percent Change | Gross Output (millions $) | Output Change (millions $) |
|---|---|---|---|
| Tomato | 0.26 | 1,355 | 3.52 |
| Wine | -0.93 | 1,900 | -17.67 |
| Fruit and Vegetables | -3.1 | 2,789 | -86.46 |
| | | **Total** | **-100.61** |
| Beef and Pork | -2.86 | 1,220 | -34.89 |
| Poultry | -2.05 | 576 | -11.81 |
| Cheese | -0.37 | 1,001 | -3.70 |
| | | **Total** | **-50.40** |

Results indicate that all processors considered in this report reduce output, except for tomato processors. The counter-intuitive response by tomato processors is likely a result of small proportion of salts that are required to be removed from the effluent which allows processors to expand production without being affected by new regulations. Other processors see output reduction in the order of less than five percent which is consistent with previous findings.

### 3.3.6 Annual Direct Costs

The REMI model being used for this analysis identifies a food processing sector and a "Beverage, Tobacco Products Manufacturing" sector which includes wineries. Data for the REMI model was separated into the two sectors by Basin according to projected 2030 output (Table 3.20).

**Table 3.20 Winery and Other Food Processing Annual Direct Costs-2030**

| | Sacramento Basin | | San Joaquin Basin | | Tulare Basin | | Totals |
|---|---|---|---|---|---|---|---|
| **Sector** | **Output (Bil Fixed 2000$)** | **2030 Salinity Cost (2006$)** | **Output (Bil Fixed 2000$)** | **2030 Salinity Cost (2006$)** | **Output (Bil Fixed 2000$)** | **2030 Salinity Cost (2006$)** | **2030 Salinity Cost (2006$)** |
| **Wine** | **$2.590** | **-$7,322,448** | **$2.797** | **-$7,907,678** | **$0.863** | **-$2,439,874** | **-$17,670,000** |
| **Food Processing** | **$5.305** | **-$23,760,327** | **$12.756** | **-$57,132,278** | **$11.710** | **-$52,447,395** | **-$133,340,000** |
| **Totals** | **$7.895** | **-$31,082,775** | **$15.553** | **-$65,039,956** | **$12.573** | **-$54,887,269** | **-$151,010,000** |

## 3.4 Confined Animal Feeding Operations

Livestock and poultry production in the Central Valley is a major contributor to the agricultural economy of California. In 2005, gross returns to livestock and poultry production came to $9.7 billion (USDA-NASS 2006), with most of this production occurring in the San Joaquin River Basin and Tulare Basin. Livestock and livestock products in Tulare County alone accounted for 24% of the gross returns in this sector. Merced, Stanislaus, Fresno, and Kings Counties totaled nearly 36% of the remaining gross returns in this sector. In this same year, poultry and poultry products grossed nearly $1.2 billion. Thirty five percent of this production came from operations in Merced County. Fresno and Stanislaus Counties contributed another 45% of the gross value from poultry and poultry products. Perhaps more illustrative of the importance of the animal production in these basins to California's agricultural economy is the observation that milk and cream production in California ranked first among all agricultural products in California in 2005, totaling over $5.3 billion in gross value with Tulare, Merced, Stanislaus, Kings, and Kern Counties alone accounting for 60% of the gross value.

Although, the livestock and poultry production in the San Joaquin River Basin and Tulare Basin contribute significantly to the agricultural economy of California, this production also imports considerable volumes of salt. Feed is imported into the basins, bringing with it salts which are then excreted in animal manure. Further complicating animal production are federal regulations regarding manure nutrients, which will place greater controls on manure nutrients generated at CAFOs. To satisfy these controls (or constraints), CAFOs will most likely land apply the manure to balance its nutrient content with the nutrient demand of the crops grown on the land where manure is applied. Cropping patterns, however, will be affected by increasing salinity levels and as such will affect the ability of CAFOs to meet manure nutrient constraints. Understanding the future implications of increasing salinity levels on animal production in these basins and the effect of changes in animal production on salt loads, requires accurately modeling animal feeding operations and nutrient constraints in the Central Valley. In this section, a mathematical programming model is developed to estimate the effect of increased salinity on animal feeding operations through the Sacramento River Basin, San Joaquin River Basin, and the Tulare River Basin given the imposition of manure nutrient constraints.

### 3.4.1 Analytical Method

The simulation model used to conduct the analysis employs an optimization technique based on the positive mathematical programming (PMP) methodology (Howitt, 1995). The PMP method has been used extensively to study regional changes in agricultural production decisions and is well suited to the analysis proposed herein (see Draper, et al, 2003, Jenkins, et al, 2003, Johansson and Kaplan, 2004, Kaplan, et al, 2004, Key and Kaplan, 2007, Knapp, et al, 2003, Röhm and Dabbert, 2003) The PMP method uses base year data to calibrate the model without the addition of constraints that cannot be justified by economic theory (Howitt, 1995). Furthermore, PMP utilizes information about output and input levels at the farm level, which is easier to collect than information about production costs. These output and input levels are selected following a complicated decision process based in part on a cost function that is difficult or impossible to observe. Costs associated with such factors as the environment, risk, or technology may be known to the farmer but are unobservable to the researcher (Key and Kaplan, 2007). PMP can incorporate these unobservable costs, allowing the researcher to approximate the true underlying cost function.

The model used to evaluate the economic consequences of salinity on animal production in the Central Valley is developed in three stages. First, dual values used to parameterize the quadratic cost function are derived from optimizing a constrained linear programming model. Second, the dual values are incorporated into a quadratic cost function that calibrates the model to base year data. Third, the calibrated model is used for economic analysis by imposing nutrient constraints that change when salinity levels change due to unabated increases in salinity throughout the three basins.

#### 3.4.1.1 Calibration of Dual Values Using Linear Programming

The linear objective is to maximize total net revenues:

**Equation 5**
$$\max_{X1_{i,r}} \sum_{r} \sum_{i} X1_{i,r} (P_i Y_{i,r} - C_i)$$

where the product $X1_{i,r}Y_{i,r}$ is the level of each output i in region r. $X1_{i,r}$ is the activity level and $Y_{i,r}$ the yield. The output price for activity is $P_i$ and the cost of producing each output is $C_i = \sum_j A_{i,j} W_j$ , where $A_{i,j}$ is the amount of input $j$ used to produce output i; and $W_j$ is the input price for the input j. The optimization is subject to the following resource constraints:

**Equation 6** $$\sum_i A_{i,j} X1_{i,r} \le \sum_i A_{i,j} X0_{i,r}, \forall j, r$$

where $X0_{i,r}$ is the initial observed activity level and $\sum_i A_{i,j} X0_{i,r}$ is the initial quantity of input j.

Inputs include capital, feed, and animal head. Activities include dairy, hogs, cattle, broilers, and layers. Output includes milk, average hog liveweight at slaughter, average cattle liveweight at slaughter, chicken meat, and eggs. The calibration constraints for all five activities are:

**Equation 7** $$X1_{i,r} \le X0_{i,r}(1+\varepsilon_1), \forall i, r \quad \text{dual}: \hat{\lambda}_{\mathrm{i,r}}$$

where $\varepsilon_1$ is a small perturbation (Howitt, 1995).

Data on prices $P_i$ and $W_i$, the output levels $X0_{i,r}$, and most of the input-output coefficients $A_{i,j}$ come from the following sources: California Department of Food and Agriculture, the United States Department of Agriculture, Iowa State University Extension, University of California Cooperative Extension, the University of California, Davis, and the Western Beef Development Centre.

#### 3.4.1.2 Quadratic Cost Function Formulation

Next, the dual values ( $\hat{\lambda}_{i,r}$ ) from the previous optimization are incorporated into the quadratic total variable cost function as $\frac{1}{2}\hat{Q}_{i,r} X2_{i,r}^2$, where

**Equation 8** $$\hat{Q}_{i,r} = \left(\hat{\lambda}_{i,r} + C_i\right) / X0_{i,r} \ \textbf{for}\ i = \mathit{dairy}, \mathit{hogs}, \mathit{cattle}, \mathit{broilers}, \mathit{layers}$$

and X2i,r is the output activity level in this stage. The calibrated objective optimized in this stage maximizes total net revenues:

**Equation 9** $$\max_{X2_{i,r}} \sum_r \sum_i P_i X2_{i,r} - \frac{1}{2}\hat{Q}_{i,r} X2_{i,r}^2$$

subject to the resource constraints:

**Equation 10** $$\sum_i A_{i,j} X2_{i,r} \le \sum_i A_{i,j} X0_{i,r}, \forall j, r$$

Solving the non-linear optimization problem defined by Equation 8 and Equation 9 yields results that are nearly identical to the initial output levels $X0_{i,r}$[3].

#### 3.4.1.3 Nutrient Constraints

To properly evaluate the implications of salinity on animal production in the Central Valley, nutrient constraints are imposed on the programming model as such:

[3] The maximum percentage deviation between the base activity levels $X0_{i,r}$ and $X2_{i,r}$ was 1.19%. The median deviation was -0.10% and the average deviation was 0.023%.

**Equation 11** $$\max_{X3_{i,r}} \sum_r \sum_i P3_i X3_{i,r} - \frac{1}{2}\hat{Q}_{i,r} X3_{i,r}^2 - TC_r$$

subject to nutrient constraints

**Equation 12** $$\sum_i (\theta_r \times man\_nut_{i,r,f}(X3_{i,r})) \le \sum_c (WTAM \times Ag\_nut_{r,c,f}(Acre_{c,r})), \forall r, f.$$

Where, $X3_{i,r}$ is the optimal output level given the nutrient constraints. Off-farm manure transportation costs $TC_r$ depend on technology choices that affect nutrient availability to the crop, and consequently the amount of land on which the manure must be spread. Manure transportation costs (TC) depend on the nutrient content of the manure, how it is applied, on the availability of land on which to apply the manure, and on what crops it is applied. Estimates for TC are based on the Fleming, Babcock and Wang (1998) transportation cost model. The following equation is used to calculate TC:

**Equation 13** $$TC_r = \sum_i (Ton_i \times X3_{i,r})(Spread_i + Dis_r \times Haul_i)$$

where *Ton* is the amount of manure produced per animal type i, *Spread* and *Haul* are the spreading and hauling charges for each animal type, and *Dis* is the average distance greater than a mile within a region covered while spreading manure. The fixed costs of specific technology types, such as the cost to purchase hauling equipment or to extend irrigation infrastructure, are excluded from the calculation. To calculate *Dis* it is assumed that transportation of manure only occurs within a region because competition for land throughout each region, as can be inferred from the widespread excess nutrients throughout the regions, will limit the ability of CAFOs to ship their manure outside the region.

The nutrient constraint (Equation 12) explicitly requires the regional livestock and poultry operations to maintain nutrient balance through altering animal production. That is to say, within region r, the sum of each manure nutrient generated (man_nutr,j,f) by CAFOs must be less than or equal to a fixed proportion [Willingness To Accept Manure (WTAM)] of the sum of the agronomic nutrient demand (Ag_nutr,c,f) for each cropping activity c, where f indexes nitrogen (N) and phosphorus (P), respectively[4]. The crops available for land application of manure include alfalfa, cotton, wheat, corn, pasture, sugar beets, and rice. The available demand for manure nutrients will increase as WTAM increases or by increasing the agronomic nutrient demand through changes in cropping patterns. In the analysis, cropping decisions are determined exogenously. The demand for cropland as a disposal site for CAFO manure may create an incentive for farmers to alter cropping patterns to accommodate greater land application of manure nutrients. However, this possibility is not considered given the compensation required to encourage farmers to switch out of producing high valued field crops and orchards where manure is not land applied, and the lack of manure use in the past. The analysis uses two cropping pattern scenarios to measure the effect of increasing salinity on CAFOs throughout the region. The first scenario evaluates the economic consequences of nutrient constraints when cropping patterns are unaffected by increases in salinity levels. The second scenario uses cropping patterns that adjust in response to increasing salinity levels throughout the Central Valley. The estimated cropping patterns come from the analysis discussed in the following section. In addition, two alternative percentages ($\theta_r$) of 60% and 30% are used to represent the CAFO portion of available manure generation for each region and species.

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4 Estimates of available manure nutrients by animal type are net the losses attributable to prevailing storage and handling technology Kellogg, R. L., et al (2000). Agronomic demand is calculated using crop uptake values for N and P, accounting for losses due to denitrification, subsurface flow, runoff, and leaching.

### 3.4.2 Baseline Conditions

A baseline scenario for calibrating the above model comes from data collected from the California Department of Food and Agriculture, the United States Department of Agriculture, Iowa State University Extension, University of California Cooperative Extension, the University of California, Davis, and the Western Beef Development Centre. The model is delineated along Central Valley Production Model (CVPM) regions consistent with the irrigated agriculture analysis. Each CVPM region in the model acts as a single productive unit, which maximizes profits from dairy, hog, cattle, broiler, and layer operations. The prices for outputs and the price paid for inputs are given by the market. They also produce manure nutrients as a result of their production decisions, which must be managed accordingly. Each also generates salt loads. These loads are based on salt load coefficients provided by UC DANR (2003). The results from the analysis are aggregated to the basin level to complement the regional economic analysis to follow. Although all three basins are analyzed, the main concern of salt loads is related to the San Joaquin River Basin and Tulare Basin where the baseline level of salt loadings from all AFOs is approximately 377,832 tons of salt each year.

Table 3.21 shows the initial annual number of animals used to calibrate the model. These data are for the year 2005. Overall, and as noted above, the Central Valley AFOs are predominantly diary, broiler, and layer operations. The Sacramento River Basin is home to approximately 2% of the Central Valley dairy cows, 32% of the hogs, 31% of the cattle on feedlots, and less than 1% of the broilers, and layers. In comparison, 41% of the dairy cows, 26% of the hogs, 40% of the cattle, 23% of the broiler and, most notably, over 99% of the layers can be found in the San Joaquin River Basin. Tulare Basin, in contrast, is home to 56% of the dairy cows, 42% of the hogs, 29% of the cattle, 77% of the broilers, and less than 1% of the layers.

**Table 3.21 Baseline Annual Animal Numbers by Basin**

| Basin | Dairy | Hog | Cattle | Broiler | Layer |
|---|---|---|---|---|---|
| Sacramento River | 36,014 | 6,270 | 51,228 | 130,690 | 21,347 |
| San Joaquin River | 623,896 | 5,138 | 67,246 | 4,156,572 | 8,618,585 |
| Tulare | 843,750 | 8,290 | 49,005 | 14,005,610 | 13,257 |
| Total | 1,503,660 | 19,698 | 167,479 | 18,292,871 | 8,653,189 |

The baseline gross returns from these operations total close to $5.3 billion. As such the model used in this analysis accounts for nearly 55% of the gross returns from all livestock and poultry production in California in 2005. Table 3.22 shows the baseline gross returns by basin. San Joaquin River Basin and Tulare Basin produce comparable annual gross returns of approximately $2.2 billion and $2.8 billion, or 42% and 54%, respectively, of gross returns throughout the Central Valley.

**Table 3.22 Baseline Gross Returns (millions $)**

| Basin | Gross Returns |
|---|---|
| Sacramento | $231.16 |
| San Joaquin | $2,210.31 |
| Tulare | $2,831.71 |
| Total | $5,273.17 |

The baseline nutrient conditions can be seen in Figures 3.1 through 3.4 when 60% of AFO manure and 30% of AFO manure are land applied under alternative WTAM scenarios in accordance with the assimilative capacity of the crops grown in each region. Figure 3.1 and Figure 3.2 illustrates that nearly half of the regions will have difficulty properly disposing of excess N when 60% of the manure is land applied under an N limit. When only 30% of the manure need be land applied, the number of regions affected by the constraint will fall to approximately 25%. Most of these regions correspond to those throughout the San Joaquin River Basin and Tulare Basin. These basins correspond to CVPM regions 8 through 13 and 14 through 21, respectively. Figures 3.3 and 3.4 clearly show that proper disposal of manure P will be limited in many regions of the San Joaquin River Basin and Tulare Basin, even under a 30% WTAM scenario. These baseline excess nutrient levels suggest that CAFOs will need to reduce their output in order to comply with the nutrient constraints. The effect salinity has on animal production in the Central Valley will depend on whether CAFOs face a N-only constraint or both a N and P constraint. If CAFOs face both constraints then the P constraint will limit land application to a greater extent than the N-only constraint given the concentration of each nutrient in animal manures and nutrient demand by the crops where manure is land applied. In other words, CAFOs will apply manure at a much lower rate (i.e., tons per acre) when they face a P constraint, than would be applied under an N-only constraint.

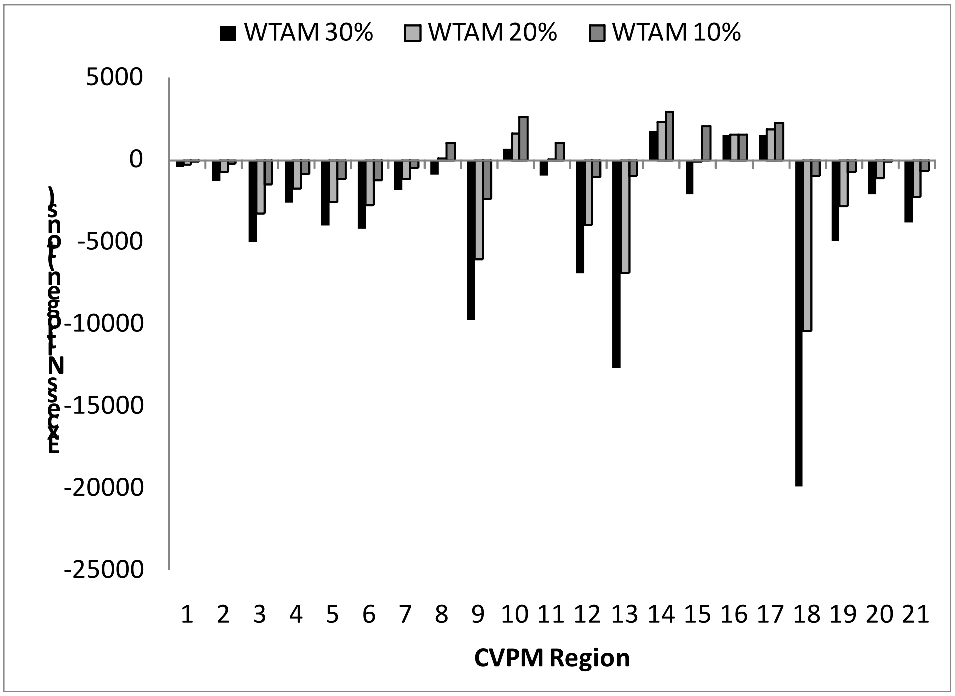



**Figure 3.1 Excess Nitrogen when 60% of Manure is Land Applied**

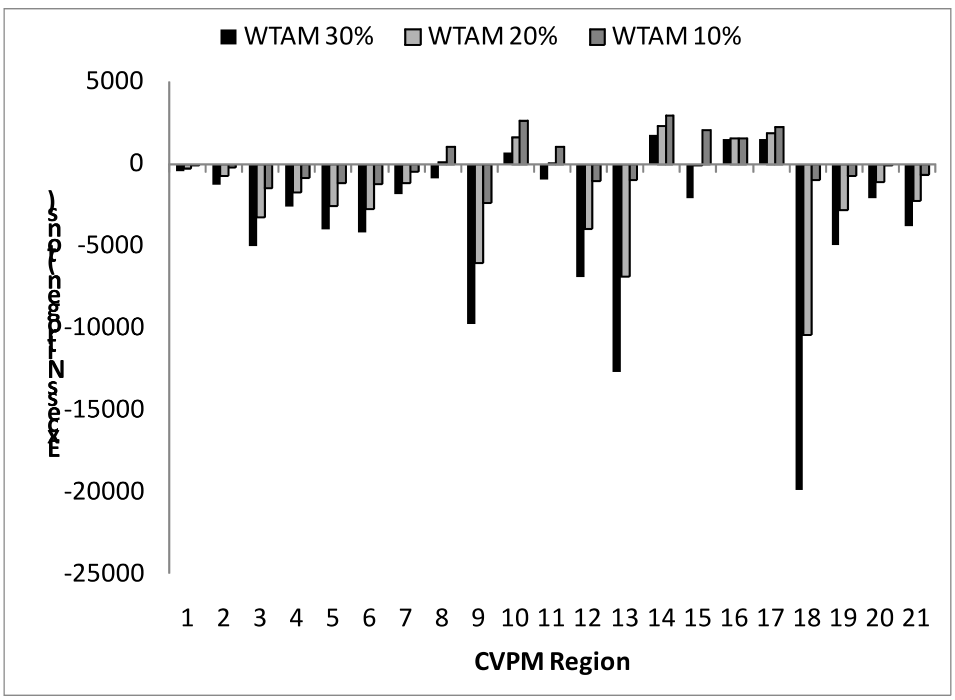



**Figure 3.2 Excess Nitrogen when 30% of Manure is Land Applied**

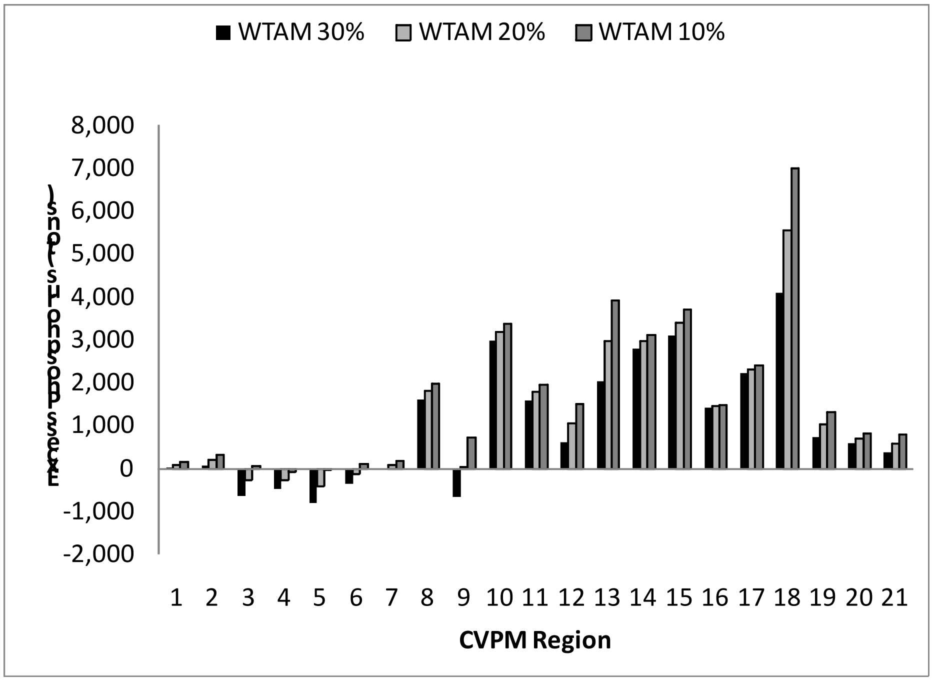



**Figure 3.3 Phosphorous when 60% of Manure is Land Applied**

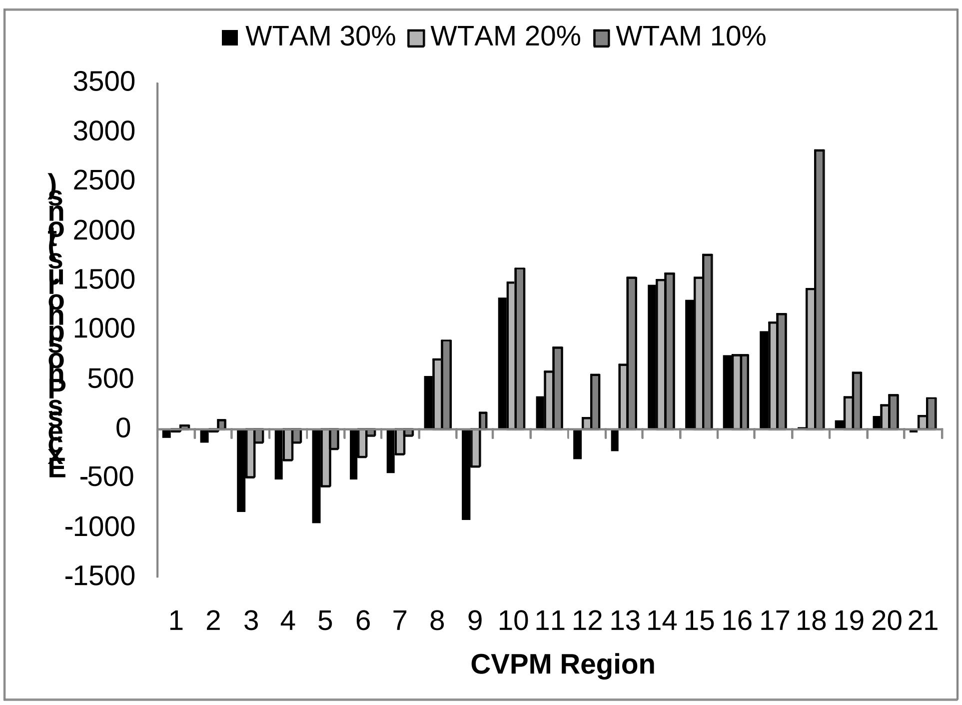



**Figure 3.4 Excess Phosphorus when 30% of Manure is Land Applied**

### 3.4.3 Projected Growth

It is difficult to determine how animal agriculture in the Central Valley will grow over the next twenty to thirty years. Innovation and technology may provide solutions to the current nutrient situation in the Central Valley with AFOs at the center. In the absence of alternatives other than land application of manure nutrients, it is more likely to expect the departure of AFOs from the Central Valley then to see them grow in numbers. The earlier discussion on nutrient constraints suggests that growth in livestock and poultry operations throughout the Central Valley may be limited by nutrient standards. Thus, for the purpose of this analysis it is assumed that these operations will not grow over the next 30 years.

### 3.4.4 Policy Analysis

The future of animal agriculture in the Central Valley will depend on the ability of producers to dispose of animal manure in accordance with federal and state guidelines. A vital factor in determining how costly manure disposal will be is the acceptance of manure for land application by farmers throughout the region. If farmers are reluctant, and it is suspected they have various concerns related to manure use, then it may be very difficult for animal feeding operations to find land where they can properly spread their manure (Ribaudo, et al, 2003). Historically, manure has been used on 10%-20% of grain crops (USDA-ERS 2003). As mentioned earlier, three WTAM scenarios (10%, 20%, and 30%) are simulated to determine the effect salinity will have on CAFOs in the Central Valley.

Also, it is clear from recent court decisions that not all AFOs will be required to meet the nutrient standards established by USEPA. Recent studies suggest up to 60% of the manure produced in the Pacific region comes from CAFOs. However, not all CAFOs will need to comply with nutrient constraints. As such, the scenarios account for two levels of compliance: 60% of the manure in each region is land applied in accordance with nutrient standards and 30% of manure is land applied in accordance with nutrient standards. In some sense, the 30% also accounts for the likelihood that not all CAFOs will comply even if they are required to do so by law. Table 3.23 shows all combinations of acceptance rates and compliance rates as well as the notation used for each scenario.

**Table 3.23 CAFO Scenarios Used to Evaluate Economic and Salinity Impacts**

| Compliance Rate | Manure Acceptance Rate | | |
|---|---|---|---|
| | 10% | 20% | 30% |
| 60% of Manure is Compliant | CAFO10 | CAFO20 | CAFO30 |
| 30% of Manure is Compliant | 30CAFO10 | 30CAFO20 | 30CAFO30 |

Furthermore, to infer the economic consequences of increasing salinity levels, the model simulates CAFO production and land application of manure under two salinity scenarios. The first scenario, denoted as base crop acreage available for manure disposal, considers that cropland available for manure disposal is unaffected by increasing salinity levels in terms of planted acreage. This scenario is then contrasted with a second scenario, denoted as salt-adjusted crop acreage for manure disposal, in which cropland acreage available for manure disposal is affected by increases in salinity levels, resulting in fewer acres being made available for land application of manure. Table 3.24 shows the magnitude of the change in nutrient demand in 2030 given changes in cropping patterns that arise when salinity levels increase over time throughout the Central Valley. Only changes in acreage for those crops where manure is land applied are shown in the table. These five regions are located in the San Joaquin River Basin and Tulare Basin. As such, the effect of increased salinity on CAFOs can be expected to fall mainly in these two basins, and given the significant differences in the magnitude of the changes, it may be expected that the effect will differ among the different nutrient constraint scenarios.

**Table 3.24 Reduction in 2030 Nutrient Demand Due to Salinity**

| CVPM Region | Phosphorus (lbs) | Nitrogen (lbs) |
|---|---|---|
| R10 | 328,861 | 3,831,030 |
| R14 | 1,742,738 | 13,353,062 |
| R15 | 964,883 | 10,388,988 |
| R19 | 830,270 | 5,671,867 |

| | | |
|---|---|---|
| R21 | 456,128 | 3,243,051 |

### 3.4.5 Model Results

Gross returns before the introduction of nutrient constraints and increasing salinity levels were estimated to total nearly $5.3 billion annually for the San Joaquin and Tulare Basins. Table 3.25 presents the simulation results for gross returns in terms of percent change from baseline gross returns for each manure WTAM, and salinity scenario when limits are placed on the land application of N and P. Table 3.26 highlights the change in gross returns attributed to increased salinity levels under these scenarios and nutrient constraints. The Sacramento River Basin is relatively unaffected by the nutrient constraints. This can be explained by the limited animal feeding operations in this region of the Central Valley coupled with the sufficient cropland acreage available for accommodating the manure nutrients.

**Table 3.25 Percentage Change in Annual Gross Returns from Baseline by Region**

| **Base Crop Acreage Available for Manure Disposal** | | | |
|---|---|---|---|
| **Scenario** | **SAC** | **SJR** | **TUL** |
| CAFO30 | -0.08% | -23.66% | -24.99% |
| CAFO20 | -0.08% | -41.05% | -47.74% |
| CAFO10 | -3.13% | -66.29% | -73.26% |
| 30CAFO30 | -0.04% | -7.72% | -7.90% |
| 30CAFO20 | -0.04% | -16.49% | -18.80% |
| 30CAFO10 | -0.04% | -41.04% | -47.74% |
| **Salt-Adjusted Crop Acreage Available for Manure Disposal** | | | |
| **Scenario** | **SAC** | **SJR** | **TUL** |
| CAFO30 | -0.08% | -24.30% | -28.53% |
| CAFO20 | -0.08% | -41.49% | -51.52% |
| CAFO10 | -3.13% | -66.51% | -75.35% |
| 30CAFO30 | -0.04% | -8.93% | -15.97% |
| 30CAFO20 | -0.04% | -17.35% | -23.75% |
| 30CAFO10 | -0.04% | -41.48% | -51.52% |

**Table 3.26 Gross Returns Attributable to Increasing Salinity Levels**

| **Scenario** | **SJR** | **TUL** | **Total** |
|---|---|---|---|
| CAFO30 | -$14,263,000 | -$100,348,000 | -$114,611,000 |
| CAFO20 | -$9,710,000 | -$106,875,000 | -$116,585,000 |
| CAFO10 | -$4,854,600 | -$59,399,700 | -$64,254,300 |
| 30CAFO30 | -$26,862,000 | -$228,265,000 | -$255,127,000 |
| 30CAFO20 | -$19,018,000 | -$140,033,000 | -$159,051,000 |
| 30CAFO10 | -$9,709,000 | -$107,017,000 | -$116,726,000 |

The same cannot be said for the San Joaquin River Basin or Tulare Basin. These regions see large losses in gross returns when the land application of both manure nutrients is constrained. Gross returns across all basins decline at an increasing rate as the nutrient constraint becomes more stringent (i.e., a movement from 30% WTAM to 10% WTAM and from 30CAFO to CAFO). The largest loss of gross returns due to the nutrient constraints are seen in the Tulare Basin. In the most stringent of scenarios (CAFO10), when 60% of the manure is land applied in compliance with P and N land application constraints and only 10% of the cropland is available for manure land application, gross returns in Tulare Basin fall by roughly 75% in each salinity scenario. In the least restrictive scenario (30CAFO30), gross returns fall between 8% and 16%. The effect of increasing salinity levels on gross returns ranges from a low of over $64 million to a high of over $225 million. The losses in gross returns are greater in the more lenient scenarios when only 30% of AFO manure is land applied at agronomic rates. This result occurs because declines in nutrient demand in effect tighten the constraint for the 30CAFO scenarios more than it does for the CAFO scenarios.

Table 3.27 shows gross returns for each scenario in terms of percent change from baseline gross returns for each manure, WTAM, and salinity scenario when limits are placed on land application of N. Table 3.28 provides the change in gross returns for this case when salinity levels increase throughout the Central Valley. Several inferences can be drawn from a comparison across nutrient constraints. First, as more manure is land applied according to agronomic rates and WTAM falls, the greater are the losses to gross returns. Also, when both N and P are constrained, gross returns fall to a greater extent than when only N is constrained. This is as expected given less P can be applied per acre relative to a N only constraint. Thus, the P constraint limits the ability of CAFOs to land applied manure more so than when only N is constrained. Lastly, the negative effect of increased salinity on gross returns is, in most scenarios, greater when CAFOs only face a N land application constraint relative to the case when they face N and P constraints. This result occurs because when both nutrient constraints are imposed, the P constraint is the limiting constraint. When salinity increases and cropland is taken out of production, the reduction in P demand is significantly smaller than the reduction in N demand as shown in Table 3.24.

**Table 3.27 Percentage Change in Annual Gross Returns from Baseline by Region**

| Scenario | SAC | SJR | TUL |
|---|---|---|---|
| **Base Crop Acreage Available for Manure Disposal** | | | |
| **Scenario** | **SAC** | **SJR** | **TUL** |
| CAFO30 | -0.08% | -3.42% | -8.31% |
| CAFO20 | -0.08% | -14.45% | -9.72% |
| CAFO10 | -0.08% | -30.81% | -28.09% |
| 30CAFO30 | -0.04% | -0.01% | -3.65% |
| 30CAFO20 | -0.04% | -0.01% | -6.75% |
| 30CAFO10 | -0.04% | -14.44% | -9.72% |
| **Salt-Adjusted Crop Acreage Available for Manure Disposal** | | | |
| **Scenario** | **SAC** | **SJR** | **TUL** |
| CAFO30 | -0.08% | -6.06% | -10.22% |
| CAFO20 | -0.08% | -16.25% | -14.73% |
| CAFO10 | -0.08% | -31.77% | -32.35% |
| 30CAFO30 | -0.04% | -0.01% | -3.65% |
| 30CAFO20 | -0.04% | -1.58% | -6.75% |
| 30CAFO10 | -0.04% | -16.24% | -14.73% |

**Table 3.28 Change in Gross Returns Attributable to Increasing Salinity Levels when N is Constrained**

| Scenario | SJR | TUL | Total |
|---|---|---|---|
| CAFO30 | -58,175,000 | -54,083,000 | -112,258,000 |
| CAFO20 | -39,768,000 | -141,954,000 | -181,722,000 |
| CAFO10 | -21,352,000 | -120,672,000 | -142,024,000 |
| 30CAFO30 | - | - | - |
| 30CAFO20 | -34,776,000 | - | - 34,776,000 |
| 30CAFO10 | -39,822,000 | -141,917,000 | -181,739,000 |

Table 3.29 details the percent change in the number of animals in each basin under each scenario and both N and P constraints. The AFOs in the Sacramento River Basin are relatively unaffected by the nutrient constraints. In the San Joaquin River Basin and Tulare Basin we see hog, broiler, and layer production bear the brunt of the nutrient constraints. These species generate more P per ton of manure than dairy or cattle, which explains why hog, broiler, and layer numbers decline at a greater rate than dairy and cattle operations. Table 3.30 illustrates the effect of increasing salinity levels on animal numbers in the San Joaquin River Basin and Tulare Basin. Salinity effects on animal number is greatest in the Tulare Basin where cropland acreage reductions are the greatest, resulting in less land available for manure application and thus greater reduction in animal numbers necessary to meet nutrient constraints. Furthermore, the increasing salinity levels appear to mostly affect dairy, cattle, and broiler operations. This occurs because hogs and layers are reduced to negligible levels even when salinity does not increase over time. When land application of manure N is constrained the percent change in animals numbers do not decrease as much, yet changes due to salinity are larger.

**Table 3.29 Percentage Change in Animal Numbers Relative to Current Animal Numbers**

| Base Crop Acreage Available for Manure Disposal | | | | | | Salt-Adjusted Crop Acreage Available for Manure Disposal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SACRAMENTO BASIN | | | | | | SACRAMENTO BASIN | | | | | |
| Scenario | Dairy | Hog | Cattle | Broiler | Layer | Scenario | Dairy | Hog | Cattle | Broiler | Layer |
| CAFO30 | 0.01% | -1.23% | -0.15% | 0.01% | 0.38% | CAFO30 | 0.01% | -1.23% | -0.15% | 0.01% | 0.38% |
| CAFO20 | 0.01% | -1.23% | -0.15% | 0.01% | 0.38% | CAFO20 | 0.01% | -1.23% | -0.15% | 0.01% | 0.38% |
| CAFO10 | -2.67% | -18.02% | -3.39% | -0.10% | -3.47% | CAFO10 | -2.67% | -18.02% | -3.39% | -0.10% | -3.47% |
| 30CAFO30 | 0.00% | -0.56% | -0.07% | 0.00% | 0.27% | 30CAFO30 | 0.00% | -0.56% | -0.07% | 0.00% | 0.27% |
| 30CAFO20 | 0.00% | -0.56% | -0.07% | 0.00% | 0.27% | 30CAFO20 | 0.00% | -0.56% | -0.07% | 0.00% | 0.27% |
| 30CAFO10 | 0.00% | -0.56% | -0.07% | 0.00% | 0.27% | 30CAFO10 | 0.00% | -0.56% | -0.07% | 0.00% | 0.27% |
| SAN JOAQUIN RIVER BASIN | | | | | | SAN JOAQUIN RIVER BASIN | | | | | |
| Scenario | Dairy | Hog | Cattle | Broiler | Layer | Scenario | Dairy | Hog | Cattle | Broiler | Layer |
| CAFO30 | -22.01% | -60.59% | -14.78% | -45.51% | -47.29% | CAFO30 | -22.71% | -60.59% | -14.97% | -46.94% | -47.29% |
| CAFO20 | -38.95% | -71.92% | -25.63% | -66.90% | -77.15% | CAFO20 | -39.46% | -71.92% | -25.77% | -66.90% | -77.15% |
| CAFO10 | -65.82% | -100.00% | -39.12% | -87.73% | -95.41% | CAFO10 | -66.08% | -100.00% | -39.19% | -87.73% | -95.41% |
| 30CAFO30 | -6.70% | -15.45% | -3.01% | -20.21% | -22.01% | 30CAFO30 | -7.96% | -15.45% | -3.35% | -22.77% | -23.06% |
| 30CAFO20 | -14.81% | -60.30% | -10.80% | -36.87% | -37.35% | 30CAFO20 | -15.75% | -60.30% | -11.05% | -38.78% | -37.35% |
| 30CAFO10 | -38.93% | -71.71% | -25.62% | -66.97% | -77.26% | 30CAFO10 | -39.44% | -71.71% | -25.76% | -66.97% | -77.26% |
| TULARE BASIN | | | | | | TULARE BASIN | | | | | |
| Scenario | Dairy | Hog | Cattle | Broiler | Layer | Scenario | Dairy | Hog | Cattle | Broiler | Layer |
| CAFO30 | -24.32% | -79.65% | -11.30% | -40.80% | 0.62% | CAFO30 | -25.93% | -84.18% | -12.83% | -69.96% | -6.50% |
| CAFO20 | -46.99% | -100.00% | -27.70% | -68.26% | -72.17% | CAFO20 | -49.74% | -100.00% | -31.16% | -85.12% | -99.99% |
| CAFO10 | -72.88% | -100.00% | -43.14% | -95.10% | -72.17% | CAFO10 | -75.14% | -100.00% | -45.22% | -95.10% | -100.00% |
| 30CAFO30 | -7.25% | -75.80% | -5.15% | -17.08% | 0.36% | 30CAFO30 | -14.96% | -75.80% | -7.98% | -32.67% | 0.36% |
| 30CAFO20 | -18.63% | -79.56% | -9.33% | -25.88% | 0.36% | 30CAFO20 | -21.97% | -79.56% | -10.32% | -53.42% | 0.36% |
| 30CAFO10 | -46.96% | -100.00% | -27.71% | -68.49% | -72.52% | 30CAFO10 | -49.74% | -100.00% | -31.17% | -85.14% | -100.00% |

**Table 3.30 Difference and Percentage Change in Animal Numbers Due to Increasing Salinity Levels**

| SAN JOAQUIN RIVER BASIN | | | | | | SAN JOAQUIN RIVER BASIN | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario** | **Dairy** | **Hog** | **Cattle** | **Broiler** | **Layer** | **Scenario** | **Dairy** | **Hog** | **Cattle** | **Broiler** | **Layer** |
| CAFO30 | -4,399 | 0 | -129 | -59,455 | 0 | CAFO30 | -0.90% | - | -0.23% | -2.62% | - |
| CAFO20 | -3,183 | 0 | -93 | 0 | 0 | CAFO20 | -0.84% | - | -0.19% | - | - |
| CAFO10 | -1,592 | 0 | -47 | 0 | 0 | CAFO10 | -0.75% | - | -0.11% | - | - |
| 30CAFO30 | -7,858 | 0 | -231 | -106,200 | -90,299 | 30CAFO30 | -1.35% | - | -0.35% | -3.20% | -1.34% |
| 30CAFO20 | -5,865 | 0 | -172 | -79,274 | 0 | 30CAFO20 | -1.10% | - | -0.29% | -3.02% | - |
| 30CAFO10 | -3,183 | 0 | -93 | 0 | 0 | 30CAFO10 | -0.84% | - | -0.19% | - | - |

| TULARE BASIN | | | | | | TULARE BASIN | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario** | **Dairy** | **Hog** | **Cattle** | **Broiler** | **Layer** | **Scenario** | **Dairy** | **Hog** | **Cattle** | **Broiler** | **Layer** |
| CAFO30 | -13578 | -376 | -750 | -4,083,857 | -944 | CAFO30 | -2.13% | -22.28% | -1.73% | -49.25% | -7.08% |
| CAFO20 | -23,253 | 0 | -1,695 | -2,360,145 | -3,688 | CAFO20 | -5.20% | - | -4.78% | -53.10% | -99.95% |
| CAFO10 | -19,120 | 0 | -1,021 | 0 | -3,690 | CAFO10 | -8.36% | - | -3.66% | - | - |
| 30CAFO30 | -65,065 | 0 | -1,389 | -2,183,887 | 0 | 30CAFO30 | -8.31% | - | -2.99% | -18.80% | - |
| 30CAFO20 | -28,213 | 0 | -488 | -3,856,777 | 0 | 30CAFO20 | -4.11% | - | -1.10% | -37.15% | - |
| 30CAFO10 | -23,433 | 0 | -1,698 | -2,331,780 | -3,644 | 30CAFO10 | -5.24% | - | -4.79% | -52.83% | - |

Changes in animal numbers correspond to changes in salt loads from AFOs. Table 3.31 and Table 3.32 show the effect of the nutrient constraints on salt loads across San Joaquin River Basin and Tulare Basin and the effect of increasing salinity levels on salt loads from AFOs in these basins. As might be expected, when animal numbers fall so does the salt loads from AFOs. However, the effect of increasing salinity levels throughout these basins does not significantly reduce salt beyond the reductions attributable to the nutrient constraints. The salt load reductions under the various nutrient constraints range between 19% (30CAFO30) and 73% (CAFO10) when salinity levels increase. These reductions correspond to between 71,619 and 275,999 tons. In comparison, the reduction in salt loads attributable to increasing salinity levels and thus reduction in crop acreage for disposing of the manure nutrients range between 4,592 tons to over 17,375 tons.

**Table 3.31 Combined Salt Load for San Joaquin and Tulare Basins**

| Base Crop Acreage Available for Manure Disposal | | |
|---|---|---|
| **Scenario** | **Salt Load (tons)** | **% Change from Baseline** |
| CAFO30 | 266,331 | -29.51% |
| CAFO20 | 195,614 | -48.23% |
| CAFO10 | 106,426 | -71.83% |
| 30CAFO30 | 323,589 | -14.36% |
| 30CAFO20 | 288,894 | -23.54% |
| 30CAFO10 | 195,658 | -48.22% |
| **Salt-Adjusted Crop Acreage Available for Manure Disposal** | | |
| **Scenario** | **Salt Load (tons)** | **% Change from Baseline** |
| CAFO30 | 259,642 | -31.28% |
| CAFO20 | 188,148 | -50.20% |
| CAFO10 | 101,833 | -73.05% |
| 30CAFO30 | 306,213 | -18.96% |
| 30CAFO20 | 278,954 | -26.17% |
| 30CAFO10 | 188,171 | -50.20% |
| Note: San Joaquin and Tulare Basin Baseline Salt Loads 377,832 tons | | |

**Table 3.32 Change in Salt Load due to Increasing Salinity Levels**

| Scenario | Change in Salt Load (tons) | Percentage Change |
|---|---|---|
| CAFO30 | -6,689 | -2.51% |
| CAFO20 | -7,467 | -3.82% |
| CAFO10 | -4,593 | -4.32% |
| 30CAFO30 | -17,375 | -5.37% |
| 30CAFO20 | -9,940 | -3.44% |
| 30CAFO10 | -7,487 | -3.83% |

### 3.4.6 Annual Direct Costs

Table 3.26 shows the reduction in gross return to CAFOs as a result of imposing land application limits on N and P. Results are given for six scenarios representing a two manure compliance rates of 60 and 30 percent, and three manure acceptance rates of 10, 20 and 30 percent. Results for the three scenarios representing the 30 percent compliance rates were used for the three total economic impacts (REMI) scenarios because they represent the most realistic of 2030 salinity conditions. The results are presented in Table 3.33.

**Table 3.33 Annual Direct costs of Three Scenarios on CAFOs**

| Scenario | Sacramento Basin | San Joaquin Basin | Tulare Basin | Totals |
|---|---|---|---|---|
| **Base** | **$0** | **-$9.709** | **-$107.017** | **-$116.726** |
| **Medium** | **$0** | **-$19.018** | **-$140.033** | **-$159.051** |
| **High** | **$0** | **-$26.862** | **-$228.265** | **-$255.127** |

## 3.5 Salinity Effects on Irrigated Agricultural Production

Irrigated crop production is the dominant agricultural industry in the San Joaquin Valley and is also the major generator of salinity and, in turn, suffers the greatest economic impact from salinity changes. In addition, much of the employment in the valley is related to agricultural crop production, as is much of the secondary food-processing industry. It is thus critical that any socio-economic analysis of the impact of salinity on this region must accurately model irrigated crop production as the fundamental economic driving variable in the region.

In this section, two modeling approaches are developed to estimate the effect of increased salinity on crop production in the San Joaquin Valley. Both models are combined to project the changing cropping patterns due to salinity accumulation in 2030. The direct economic impacts of crop changes are also calculated. This report shows the effect of increased salinity costs on the crop processing industry, and finally, the effect of increases in these costs on the likelihood of crop processing industries leaving the area.

### 3.5.1 Base Salinity Conditions

For base conditions it is assumed that, on average, 3.7 million AF of water are imported from the Delta-Mendota Canal and the California Aqueduct, with an average salinity of about 300 mg/L measured by TDS. It is projected that current conditions will gradually increase the area affected by a salinized shallow groundwater table, based on a regression equation fitted to data over a subset of the salinity area (417,000 acres) in Schoups (2004). Given the historical rates of change in saline affected areas, it is expect that by 2030, the saline affected area will increase by 12% to 15%. This growth rate is applied to the whole area shown in Figure 3.5.

For simplicity, all costs are calculated on an annual basis, as they will occur in the year 2030 (in 2008 dollars). It follows that salinity costs will increase slowly from the base year to 2030. In reality, the changing cropping patterns will result in higher revenue losses towards the end of the time period.

Salinity in shallow groundwater and the root zone are closely correlated (Schoups, et al, 2005). Here it is assumed that the total saline area within each CVPM region grows by 13% by 2030. The share of acres transferred from the non-saline salt zone to the saline zones (A through E) within each CVPM region is shown in Table 3.34.

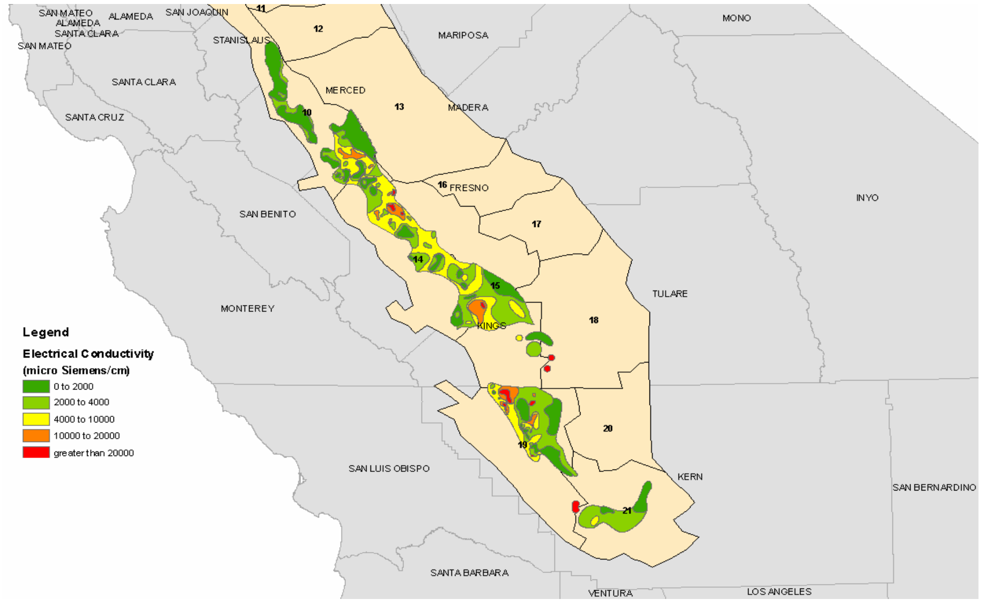



**Figure 3.5 Salinity (as electrical conductivity) in Shallow Groundwater (Source: DWR)**

**Table 3.34 Conversion of Non-saline Area to Saline Zones as a Result of Salt Accumulation by 2030**

| Zone | Salinity Level (EC in shallow groundwater (µS/cm)) | Share of Non-saline Acres Transferred to the Saline Zone (%) |
|---|---|---|
| A | 0-2,000 | 50 |
| B | 2,000-4,000 | 30 |
| C | 4,000-10,000 | 10 |
| D | 10,000-20,000 | 10 |
| E | above 20,000 | 0 |

Source: Adapted from Howitt et al, 2008

Note: Model assumes that 13 percent of non-saline acreage in each CVPM region becomes saline (entering zones A through E) by 2030. Electrical conductivity, a measure of a material's ability to conduct electricity is often used as a measure of salinity in water. Often, total dissolved solids (TDS) are assumed proportional to the electrical conductivity by a factor of 0.64. Thus 1 mS/cm corresponds to 640 mg/l of total dissolved solids.

Figure 3.6 depicts a hypothetical change in the saline zone areas. The largest changes occur at lower levels of salinity (Zones A and B), with smaller increases in the zones with higher salinity (C, D and E). Changing the distribution of the non-saline acres transferred to the saline zones (third column of Table 3.34) did not significantly change the results of this analysis, as losses of agriculture are driven mostly by the conversion of non-saline areas to saline. Changes in crop production are reflected in changes in the relative acreages of different crops grown. In general, the lower-valued crops are more salt tolerant. For the higher salinity regions, some land is taken out of production. The model is calibrated to the actual regional cropping patterns as reflected in the DWR crop surveys. The mathematical programming approach followed in this study was validated in Howitt et al (2008). Checking the analytical programming model using statistical methods in which the change in salinity is related to the change in the probability of a particular crop being grown on a given soil type, it was found that the results of both programming and statistical methods were very similar.

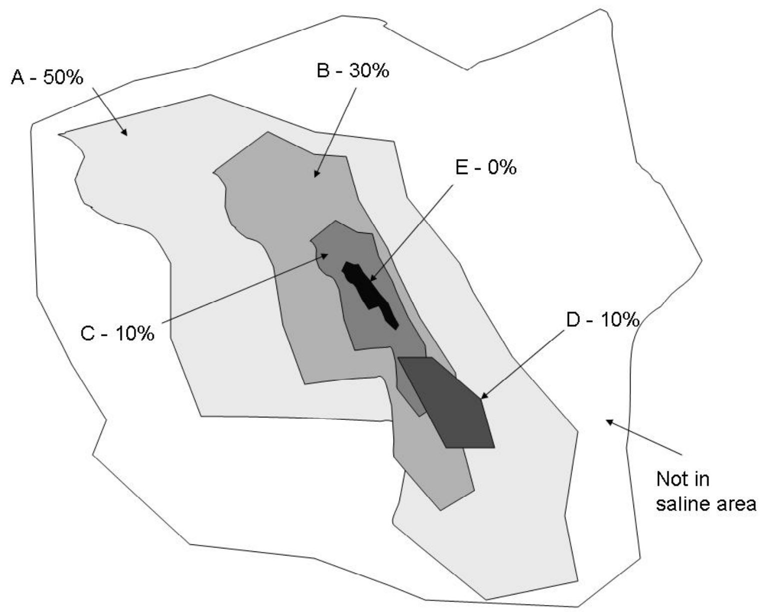



**Figure 3.6 Conceptual Expected Percent Change in Area of the Saline and Non-saline Zones within a CVPM Region**

Thus if 100 acres from a non-saline area are converted to saline areas, 50 of those acres will be relocated to the zone with 0-2000 µS/cm (Zone A), 30 would go to Zone B, and so on. This procedure was undertaken for 3%, 7%, 10%, 13%, and 15 % changes in the salt affected areas. This parameterization can be used to explore the gradual effect of salt accumulation, assuming the salt load drives the change in the saline and non-saline areas. Thirteen percent is a midrange projection of the accumulated increase in saline area expected by year 2030 at current conditions (Howitt et al 2008; Schoups 2004).

The mathematical programming model of Howitt et al (2008) used for this study estimates calibrated production functions per crop group and saline or non-saline area within each CVPM region in the study area, shown in Figure 3.5. The production functions calibrate to observed values of land, water, and labor. In this study, market driven crop prices by 2030 are the same for all areas within a CVPM region; however, it is assumed production costs vary slightly among saline areas. Differential yields for saline and non-saline areas were estimated in Howitt et al (2008) by adapting the yield reduction model of Van Genuchten and Hoffman (1984). The ratio of the salinity in the saturated soil region to the root zone region was calibrated at 2.0. Losses in crop revenues for agriculture south of the San Joaquin Delta occur as a result of overall reduced yields. Salinity affected areas with lower yields gain land relative to the higher-yield agricultural lands. Thus agricultural crop revenue losses depend to a great extent on the increase in the area increase of the salinity affected locations within a CVPM region.

The estimates of areas that go out of production due to salinity include those areas that are planned to be retired through programs proposed by Westlands Irrigation District and the US Bureau of Reclamation (USBR 2002). Since these saline affected areas are included in this analysis, it is assumed that the planned retirements in this area do not change the estimates of the aggregate area and cost due to increased salinity.

### 3.5.2 Analytical Methods

Agricultural production models can be separated into two broad types, inductive and deductive. Inductive models rely more heavily on a rich data set to provide the data with which most or all of the parameter values in the model can be estimated from observed behavior. Deductive models operate with much smaller data sets and use previous estimates for many parameters and close the model by assuming optimizing behavior that can calibrate the model to a much smaller data set. To cross check the deductive approach, an inductive approach is used to estimate agricultural production patterns under increasing salinity conditions. Specifically, production response is modeled using, respectively, positive mathematical programming and a multinomial logit models.

#### 3.5.2.1 Deductive Optimizing Crop Production Model

Positive mathematical programming (PMP), after Howitt (1995) is a deductive approach for evaluating the effects of policy changes on cropping patterns at the extensive and intensive margins. The model presented in this paper is a combination of two preceding models using PMP: the Statewide Agricultural Production Model, or SWAP (Howitt et al 2001) and the Delta Agricultural Model, or DAP (Lund et al 2007).

Both SWAP and DAP are three-step, self-calibrating programming models that assume farmers behave in a profit maximizing fashion. For PMP models, in the first step, a linear program for profit maximization is solved. In addition to the traditional resource and non-negativity constraints, a set of calibration constraints is added to restrict land use to observed values. The second step is parameterization of a quadratic cost function—a non-linear production function itself—from the first order conditions. A third and last step incorporates the recently parameterized functions into a non-linear profit maximization program, with constraints on resource use. The main difference between the two deductive models is that DAP incorporates salinity effects by calculating the reduction in yields due to salinity in the root zone, which is in turn proportional to the level of salinity in the shallow ground water.

There are many management practices that a farmer can take to offset the effect of shallow saline groundwater. For example, blending water of different qualities, or using different water at different stages of growth, better quality water for younger plants, and increased leaching fractions are but a few. However, a statistical analysis with the inductive logit model shows clearly that salinity levels in shallow groundwater do influence the type and ratio of crops grown. This indicates that despite management practices, salinity does influence crop selection, due to the reduced yields from salinity shown in experimental plots. Efforts to directly estimate inductive yield changes by crop and salinity level have not yet succeeded. So a deductive saline region production model is calibrated to the root zone salinities that are assumed to be 50% of the saline level in the underlying shallow groundwater. Details of the model specification and calibration to crop and salinity level are to be found in Appendix A.

The economic effects of salinity changes in the root zone are estimated by changing the salinity level from the base case and measuring the costs of changes in cropping combinations, crop yields, and areas. The base salinity $c_{gi}$ (see Appendix A) is increased. The policy experiment is performed by recalculating input usage and production at the new salinity levels. Cultivated land is then compared to that predicted by the multinomial logit model below.

#### 3.5.2.2 Inductive Econometric Crop Production Model

As a cross check for the deductive approach of the SWAP model, an inductive econometric model was estimated using a multinomial logit specification. Logit models have seen extensive use in economic literature, and are widely used in transportation choice models and are spreading to agriculture and resource research. Multinomial logit models have been used to model irrigation technology adoption and choice (Lichtenberg 1989, Caswell and Zilberman 1985). Similar models have also been applied to crop rotation and tillage choice, (Wu and Babcock 1998; Wu et al 2004) in addition to land use choices (Hardie and Parks 1997, Wu and Segerson 1995). In contrast to previous work, this study uses the multinomial logit model as an inductive tool to measure the differences from the deductive results of SWAP. The probability of observing a crop, given soil quality, salinity, and plot acreage is estimated, and, from these estimates the marginal effects of salinity are calculated and the resulting acreage changes are determined.

As soil salinity levels change, it is expected that changing crop rotations will be observed. An extensive literature exists on the effects of salinity on agriculture, and salinity problems are a global issue (Schwabe et al 2006). Increases in soil salinity reduce crop yields and cause farmers to shift away from high value salt intolerant crops to lower value more salt tolerant rotations. This effect on changing crop rotations is also be seen through a shift to larger plot sizes to accommodate the large scale extensive management systems used on more salt tolerant field. The inclusion of soil quality and plot acreage as explanatory variables in the multinomial logit model will tend to separate out the effects of salinity on crop rotations. Details of the logit model specification are found in Appendix A.

### 3.5.2.3 Model Results

Consistent with SWAP models, the data are analyzed on a CVPM regional basis. Each parcel in the data set contains information on the crop observed, parcel area, soil salinity, and soil quality. The crop type is coded as an integer variable ranging from 1 to 11 (or 12), representing each crop type. CVPM regions 14, 15, and 19 contain 12 alternative crops and CVPM regions 10 and 21 contain 11 alternatives, as tomatoes are not grown in these regions. Parcel acreage is a continuous measure of parcel area in acres and is interpreted as a proxy for farm plot size. Salinity level and soil quality are both represented as integer variables ranging from 0 to 4 and 0 to 7, respectively, with higher values indicating increasing salinity and decreasing soil quality. The data are summarized in Table 3.35 and crop occurrence by CVPM is summarized in Table 3.36.

Each model is specific to a given CVPM region, where each region is assumed independent of neighboring areas. Estimated coefficients are reported in Table 3.37 for reference, marginal effects are estimated later to measure the incremental changes in the effect of salinity on crop choice. Likelihood Ratio tests are reported, test statistics exceed the respective chi-square critical value indicating good predictive power of the models. To test for heteroskedasticity, models were run with robust standard errors resulting in no change in standard error or coefficient estimates, indicating robust results. The majority of coefficient estimates are significant at the 1% - 5% level, with even more significant at the 10% level. Statistically insignificant coefficient estimates are largely due to a poor number of observations of a specific crop. For example, in CVPM 18 Cotton is only observed in 8.3% of parcels in the dataset and coefficient estimates on soil salinity and acreage are insignificant. There is no theoretical basis to justify dropping these crops from the regression models, and the estimation results are not significantly affected. All crops are included in the final models.

Details and variable definitions for the logit model are found in Appendix A. Coefficient estimates of multinomial logit models are difficult to interpret for policy analysis as they are neither elasticities nor marginal probability changes. To yield interpretable results, marginal effects are computed as nonlinear combinations of the predictor variables as shown in Green (Green 2003 p.722). The marginal effects take the form:

**Equation 14**

$$p_{ij}\left(\beta_j - \sum_{l=1}^{12} p_{il}\beta_l\right)$$

The estimated marginal effects have the form $\dfrac{\partial \Pr[crop = i]}{\partial x_i}$ where $x_i$ is the soil salinity variable. In order to capture the true marginal effects of the salinity zone on crop rotation evaluate marginal effects by discreetly increasing salinity zone by one unit from 0-1, 1-2, 2-3, and 3-4, thus yielding 4 sets of marginal effects. All other variables are held constant at their respective means during the computation. Additionally, the marginal effect of salinity evaluated at the mean (the standard approach), yielding a fifth marginal effects estimate and these results are presented in Table 3.38. Marginal effects are interpreted as the percentage change in observing a crop resulting from a one unit (discreet) increase in salinity zone, when all else is held constant at the mean.

**Table 3.35 Summary of SWAP Model Data-Crop Type, Acreage, Salinity Level and Soil Quality**

| Variable | Number of Observations | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| **CVPM 10** | | | | | |
| Crop | 10,455 | 5.12 | 3.18 | 1 | 11 |
| Acres | 10,455 | 65.82 | 92.21 | 0.05 | 1,863 |
| Zone | 10,455 | 0.74 | 0.89 | 0 | 4 |
| Soil | 10,455 | 3.39 | 1.78 | 0 | 7 |
| **CVPM 14** | | | | | |
| **Variable** | **Number of Observations** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Crop | 7,394 | 6.72 | 3.77 | 1 | 12 |
| Acres | 7,394 | 213.55 | 771.37 | 0.05 | 13,644 |
| Zone | 7,394 | 1.4 | 1.38 | 0 | 5 |
| Soil | 7,394 | 6.38 | 1.59 | 0 | 7 |
| **CVPM 15** | | | | | |
| **Variable** | **Number of Observations** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Crop | 11,461 | 5.25 | 3.07 | 1 | 12 |
| Acres | 11,461 | 99.03 | 343.24 | 0.08 | 13,644 |
| Zone | 11,461 | 0.5 | 1.02 | 0 | 5 |
| Soil | 11,461 | 2.76 | 1.25 | 0 | 7 |
| **CVPM 19** | | | | | |
| **Variable** | **Number of Observations** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Crop | 4,705 | 4.42 | 2.89 | 1 | 12 |
| Acres | 4,705 | 135.43 | 325.34 | 0.1 | 6,888 |
| Zone | 4,705 | 1.11 | 1.31 | 0 | 5 |
| Soil | 4,705 | 6.25 | 1.78 | 0 | 7 |
| **CVPM 21** | | | | | |
| **Variable** | **Number of Observations** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| Crop | 4,224 | 5.91 | 3.37 | 1 | 11 |
| Acres | 4,224 | 124.79 | 263.15 | 0.69 | 4,155 |
| Zone | 4,224 | 0.27 | 0.63 | 0 | 3 |
| Soil | 4,224 | 6.27 | 1.36 | 2.11 | 7 |

**Table 3.36 SWAP Model Crop Occurrence by CVPM**

| | Percentage of Crop Acreage Observed by CVPM | | | | |
|---|---|---|---|---|---|
| **Crop** | **CVPM 10** | **CVPM 14** | **CVPM 15** | **CVPM 19** | **CVPM 21** |
| Alfalfa | 18.94% | 5.21% | 14.54% | 19.51% | 11.77% |
| Citrus | 0.56% | 0.32% | 0.46% | 0.79% | 4.19% |
| Cotton | 16.47% | 29.56% | 19.57% | 31.67% | 14.06% |
| Field | 16.93% | 4.15% | 12.83% | 4.78% | 10.84% |
| Grain | 2.62% | 8.63% | 7.04% | 14.22% | 13.26% |
| Orchard | 15.77% | 9.44% | 21.05% | 13.71% | 8.71% |
| Pasture | 5.60% | 0.70% | 3.39% | 0.51% | 1.96% |
| Sugar Beet | 1.70% | 1.70% | 0.84% | 1.55% | 0.17% |
| Table | 0.37% | 2.45% | 8.06% | 2.83% | 7.62% |
| Truck | 14.55% | 11.27% | 0.72% | 4.21% | 18.63% |
| Fallow | 5.52% | 10.75% | 10.15% | 5.10% | 8.78% |
| Tomato | 0.00% | 15.81% | 1.34% | 1.13% | 0.00% |

Table 3.37 Summary of Estimation Results: Coefficient and Standard Error

| Crop | CVPM 10 | | CVPM 14 | | CVPM 15 | | CVPM 19 | | CVPM 21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff | SE | Coeff | SE | Coeff | SE | Coeff | SE | Coeff | SE |
| **Citrus** | | | | | | | | | | |
| Acres | -0.038 | 0.007 | -0.029 | 0.006 | -0.045 | 0.009 | -0.005 | 0.003 | 0.000 | 0.001 |
| Zone | -0.788 | 0.222 | -1.453 | 0.271 | 0.226 | 0.136 | 0.390 | 0.129 | -32.707 | . |
| Soil | 0.144 | 0.096 | 5.718 | 0.048 | 0.212 | 0.128 | 0.206 | 0.178 | -0.542 | 0.060 |
| Constant | -2.185 | 0.350 | -38.561 | . | -2.627 | 0.372 | -4.760 | 1.304 | 2.483 | 0.370 |
| **Cotton** | | | | | | | | | | |
| Acres | 0.005 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.004 | 0.001 | 0.001 | 0.000 |
| Zone | 0.092 | 0.039 | -0.621 | 0.047 | 0.143 | 0.030 | 0.185 | 0.034 | 0.011 | 0.082 |
| Soil | 0.074 | 0.021 | -0.014 | 0.033 | -0.038 | 0.030 | -0.003 | 0.030 | 0.110 | 0.066 |
| Constant | -0.832 | 0.073 | 3.104 | 0.252 | 0.158 | 0.085 | -0.090 | 0.219 | -0.672 | 0.436 |
| **Field** | | | | | | | | | | |
| Acres | -0.005 | 0.001 | -0.003 | 0.001 | -0.004 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 |
| Zone | -0.156 | 0.041 | -0.878 | 0.063 | -0.186 | 0.042 | -0.172 | 0.065 | -0.006 | 0.089 |
| Soil | 0.066 | 0.022 | 0.082 | 0.052 | -0.327 | 0.039 | -0.175 | 0.042 | -0.079 | 0.060 |
| Constant | 0.056 | 0.074 | 1.362 | 0.379 | 1.057 | 0.099 | -0.261 | 0.305 | 0.490 | 0.395 |
| **Grain** | | | | | | | | | | |
| Acres | 0.003 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.004 | 0.001 | -0.001 | 0.000 |
| Zone | -0.130 | 0.068 | -0.595 | 0.053 | 0.208 | 0.037 | 0.207 | 0.040 | -0.083 | 0.087 |
| Soil | 0.090 | 0.035 | -0.111 | 0.036 | 0.056 | 0.037 | -0.199 | 0.031 | -0.137 | 0.056 |
| Constant | -2.049 | 0.123 | 2.462 | 0.273 | -1.175 | 0.111 | 0.294 | 0.224 | 1.113 | 0.365 |
| **Orchard** | | | | | | | | | | |
| Acres | -0.006 | 0.001 | -0.001 | 0.000 | -0.007 | 0.000 | 0.004 | 0.001 | -0.001 | 0.001 |
| Zone | -1.298 | 0.059 | -1.431 | 0.062 | -1.440 | 0.084 | -0.400 | 0.050 | -1.193 | 0.181 |
| Soil | 0.103 | 0.023 | -0.020 | 0.040 | 0.184 | 0.028 | -0.168 | 0.032 | -0.259 | 0.057 |
| Constant | 0.434 | 0.081 | 3.089 | 0.296 | 0.583 | 0.081 | 0.571 | 0.226 | 1.678 | 0.368 |
| **Pasture** | | | | | | | | | | |
| Acres | -0.010 | 0.001 | -0.018 | 0.003 | -0.030 | 0.003 | 0.004 | 0.001 | -0.047 | 0.006 |
| Zone | -0.313 | 0.062 | -0.143 | 0.114 | 0.211 | 0.058 | -0.529 | 0.244 | 0.045 | 0.198 |
| Soil | 0.194 | 0.031 | -0.160 | 0.073 | -0.079 | 0.066 | 0.055 | 0.162 | -0.070 | 0.105 |
| Constant | -1.139 | 0.110 | 1.067 | 0.576 | -0.199 | 0.167 | -4.051 | 1.118 | 0.529 | 0.682 |
| **Sugar Beet** | | | | | | | | | | |
| Acres | 0.002 | 0.001 | -0.002 | 0.001 | 0.000 | 0.001 | -0.008 | 0.003 | 0.000 | 0.002 |
| Zone | 0.627 | 0.083 | -0.209 | 0.081 | 0.162 | 0.085 | -0.220 | 0.120 | -0.484 | 0.625 |
| Soil | 0.181 | 0.048 | -0.029 | 0.058 | 0.350 | 0.068 | 0.143 | 0.132 | 11.387 | 0.066 |
| Constant | -4.044 | 0.191 | -0.169 | 0.444 | -4.004 | 0.252 | -2.750 | 0.940 | -83.562 | . |
| **Table** | | | | | | | | | | |
| Acres | 0.005 | 0.001 | -0.003 | 0.001 | 0.001 | 0.000 | 0.003 | 0.001 | 0.001 | 0.000 |
| Zone | -0.844 | 0.231 | -1.670 | 0.112 | -2.555 | 0.305 | -2.591 | 0.473 | -2.934 | 0.546 |
| Soil | 0.295 | 0.089 | 0.131 | 0.071 | 0.335 | 0.031 | -0.213 | 0.046 | -0.248 | 0.059 |
| Constant | -4.821 | 0.367 | 1.056 | 0.502 | -1.349 | 0.102 | -0.201 | 0.315 | 1.318 | 0.380 |
| **Truck** | | | | | | | | | | |
| Acres | 0.004 | 0.001 | -0.001 | 0.000 | -0.005 | 0.002 | 0.000 | 0.001 | -0.002 | 0.001 |
| Zone | -0.469 | 0.044 | -0.894 | 0.052 | 0.039 | 0.105 | -0.215 | 0.075 | -1.155 | 0.133 |

| Crop | CVPM 10 | | CVPM 14 | | CVPM 15 | | CVPM 19 | | CVPM 21 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff | SE | Coeff | SE | Coeff | SE | Coeff | SE | Coeff | SE |
| Soil | 0.231 | 0.021 | 0.206 | 0.045 | 0.320 | 0.078 | 0.389 | 0.131 | -0.285 | 0.051 |
| Constant | -0.969 | 0.077 | 1.331 | 0.330 | -3.583 | 0.267 | -3.995 | 0.927 | 2.712 | 0.330 |
| **Fallow** | | | | | | | | | | |
| Acres | -0.008 | 0.001 | -0.001 | 0.000 | -0.001 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 |
| Zone | -0.333 | 0.062 | -0.740 | 0.052 | 0.248 | 0.033 | 0.106 | 0.056 | -0.208 | 0.102 |
| Soil | 0.224 | 0.030 | -0.041 | 0.037 | 0.084 | 0.033 | -0.181 | 0.041 | -0.173 | 0.059 |
| Constant | -1.335 | 0.110 | 2.723 | 0.277 | -0.728 | 0.100 | -0.432 | 0.303 | 0.924 | 0.387 |
| **Tomato** | | | | | | | | | | |
| Acres | . | . | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 | . | . |
| Zone | . | . | -0.877 | 0.050 | 0.317 | 0.063 | -0.050 | 0.124 | . | . |
| Soil | . | . | 0.205 | 0.041 | 0.369 | 0.054 | 0.102 | 0.129 | . | . |
| Constant | . | . | 1.506 | 0.305 | -3.938 | 0.204 | -3.447 | 0.932 | . | . |

**Table 3.38 Summary of Marginal Effects of Salinity on Crop Selection**

| Crop | CVPM 10 | | | CVPM 14 | | | CVPM 15 | | | CVPM 19 | | | CVPM 21 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base (%) | Marginal (%) | SE | Base (%) | Marginal (%) | SE | Base (%) | Marginal (%) | SE | Base (%) | Marginal (%) | SE | Base (%) | Marginal (%) | SE |
| Alfalfa | 20.75 | 5.79 | 0.508 | 3.58 | 2.71 | 0.139 | 19.03 | 4.52 | 0.424 | 19.37 | -0.40 | 0.488 | 13.40 | 6.87 | 2,399 |
| Citrus | 0.17 | -0.09 | 0.045 | 0.00 | 0.00 | 0.000 | 0.03 | 0.01 | 0.011 | 0.50 | 0.18 | 0.069 | 0.00 | -0.03 | 18,230 |
| Cotton | 16.97 | 6.30 | 0.438 | 33.42 | 4.57 | 0.430 | 24.45 | 9.30 | 0.446 | 35.20 | 5.80 | 0.574 | 14.88 | 7.80 | 2,663 |
| Field | 17.93 | 2.21 | 0.499 | 3.74 | -0.45 | 0.166 | 13.42 | 0.69 | 0.426 | 5.01 | -0.96 | 0.281 | 21.61 | 6.40 | 2,258 |
| Grain | 3.99 | 0.60 | 2.430 | 9.51 | 1.55 | 0.259 | 8.60 | 3.83 | 0.248 | 15.16 | 2.82 | 0.392 | 15.66 | 6.74 | 2,814 |
| Orchard | 12.07 | -12.29 | 0.456 | 6.96 | -4.69 | 0.241 | 14.47 | -17.40 | 0.691 | 13.53 | -5.68 | 0.462 | 9.14 | -6.22 | 1,707 |
| Pasture | 5.42 | -0.19 | 0.291 | 0.06 | 0.04 | 0.009 | 0.69 | 0.31 | 0.066 | 0.46 | -0.25 | 0.090 | 0.04 | 0.02 | 7.505 |
| Sugar Beet | 1.22 | 1.10 | 0.105 | 1.36 | 0.75 | 0.088 | 0.97 | 0.39 | 0.082 | 0.78 | -0.19 | 0.097 | 0.00 | 0.00 | 0.012 |
| Table | 0.3 | -0.20 | 0.073 | 1.16 | -1.06 | 0.121 | 3.74 | -8.67 | 0.319 | 0.36 | -0.94 | 0.318 | 5.38 | -13.02 | 1,302,700 |
| Truck | 15.58 | -2.95 | 0.468 | 11.49 | -1.56 | 0.293 | 0.80 | 0.22 | 0.083 | 3.21 | -0.76 | 0.226 | 18.34 | -11.78 | 3,420 |
| Fallow | 5.56 | -0.30 | 0.297 | 11.39 | 0.21 | 0.285 | 12.44 | 6.04 | 0.301 | 5.37 | 0.46 | 0.255 | 10.54 | 3.21 | 1,901 |
| Tomato | . | . | . | 17.32 | -2.07 | 0.354 | 1.36 | 0.75 | 0.087 | 1.04 | -0.07 | 0.125 | . | . | . |

The results show strong support for the theoretical salinity reduction model and coincide with SWAP results. All else constant, more salt tolerant crops are more likely to be observed as soil salinity increases. Table 3.39 shows the average marginal effect of salinity by crop against the approximate salt tolerance of the respective crop sorted by CVPM.

**Table 3.39 Average Marginal Effect of Salinity on Crop Yield**

| | | Marginal Effects | | | | |
|---|---|---|---|---|---|---|
| **Crop** | **dS/M*** | **CVPM 10** | **CVPM 14** | **CVPM 15** | **CVPM 19** | **CVPM 21** |
| Citrus | 1.0 | -0.09% | 0.00% | 0.01% | 0.18% | -0.03% |
| Table | 1.0 | -0.20% | -1.06% | -8.67% | -0.94% | -13.02% |
| Orchard | 1.4 | -12.29% | -4.69% | -17.40% | -5.68% | -6.22% |
| Truck | 1.5 | -2.95% | -1.55% | 0.22% | -0.76% | -11.78% |
| Tomato | 1.7 | . | -2.07% | 0.75% | -0.07% | . |
| Grain | 4.5 | 0.60% | 1.55% | 3.83% | 2.82% | 6.74% |
| Sugar Beet | 4.7 | 1.10% | 0.75% | 0.39% | -0.19% | 0.00% |
| Field | 5.0 | 2.21% | -0.45% | 0.69% | -0.96% | 6.40% |
| Cotton | 5.1 | 6.30% | 4.57% | 9.30% | 5.80% | 7.80% |
| Alfalfa | 8.0 | 5.79% | 2.71% | 4.52% | -0.40% | 6.87% |
| Pasture | n/a | -0.19% | 0.04% | 0.31% | -0.25% | 0.02% |
| Fallow | n/a | -0.30% | 0.21% | 6.04% | 0.46% | 3.21% |

* Obtained from http://www.agric.nsw.gov.au/reader/wm-plants-waterquality

### 3.5.3 Spatial Models of Salinity Impacts in the San Joaquin Valley

In response to the inherent spatial dimension of the data, this report investigates possible spatial modeling techniques. The reasons for pursuing this method of estimation are three-fold: theoretical, analytical, and model driven. From a theoretical perspective, if soil salinity is changing over time and crop rotations are adjusting accordingly, as the GIS maps indicate, there may be a diffusion effect to this process. This diffusion process may be captured in a spatial model. Analytically, it is possible that crop rotation is determined by farm management with little attention paid to salinity and soil quality. This would indicate multinomial logit parameter estimates and marginal effects overstate the effect of salinity. Finally, spatial effects are explored to ensure the robustness of multinomial logit model estimates.

In the absence of observations on farm management companies or any temporal component to the data set, spatial methods are explored to capture the above effects. Anselin (1988) outlines the basics of spatial modeling and shows that if there is an omitted spatial variable, parameter estimates are inconsistent. An extensive literature exists on programming for traditional spatial modeling, and limited dependent variable with spatial effects analysis (Anselin and Hudak 1992, Anselin 2002, Flemming 2006, Anselin et al 2004). For ease of computation and clear interpretation of results, the data are converted from discrete to continuous observations. Using GIS, each CVPM was overlaid with a 1 kilometer by 1 km grid. Each 1 km by 1 km cell was assigned a weighted value for "crop" based on low, medium, and high value rotations. Similarly, each cell was assigned a weighted value for soil quality and salinity. Acreage was dropped from the model as all observations were 1 square km.

Using the constructed continuous variables, the following models were investigated: a spatial mixed autoregressive model, a Bayesian spatial autoregressive model, and a locally linear spatial model (LeSage 1998, LeSage 1999). The results showed that there is a spatial component to the data, with statistically significant coefficient estimates for spatial autocorrelation. However, including spatial effects in the models added no predictive power and reduced salinity and soil estimates to near zero. The conclusion is that the clustering of observations is driven by soil quality and salinity content, and adding spatial effects contributes nothing to the model. This reinforces confidence in multinomial logit parameter estimates without spatial effects. It should be noted that a more comprehensive approach to spatial modeling of crop rotations could be conducted to explore the effects of management or diffusion with a data set that included observations over time.

#### 3.5.3.1 Land Use

The California Central Valley is used as the case study for this paper. The agricultural sub regions are defined as 21 CVPMs (Figure 3.7) totaling 12.75 million acres. Cultivated land came from DWR geo-referenced land use surveys available at http://www.landwateruse.water.ca.gov/basicdata/landuse/landuselevels.cfm.

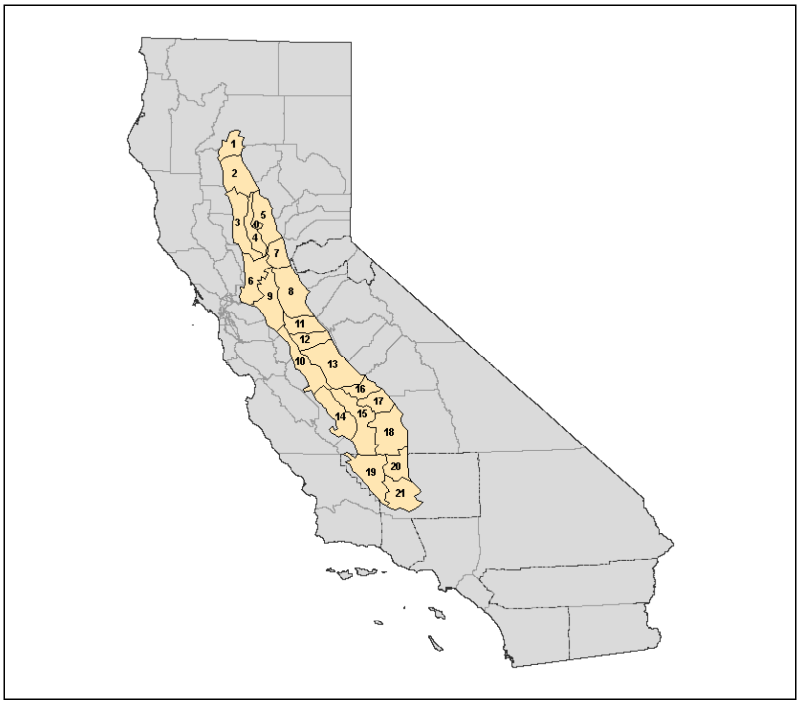


**Figure 3.7 California Agricultural Regions as CVPMs**

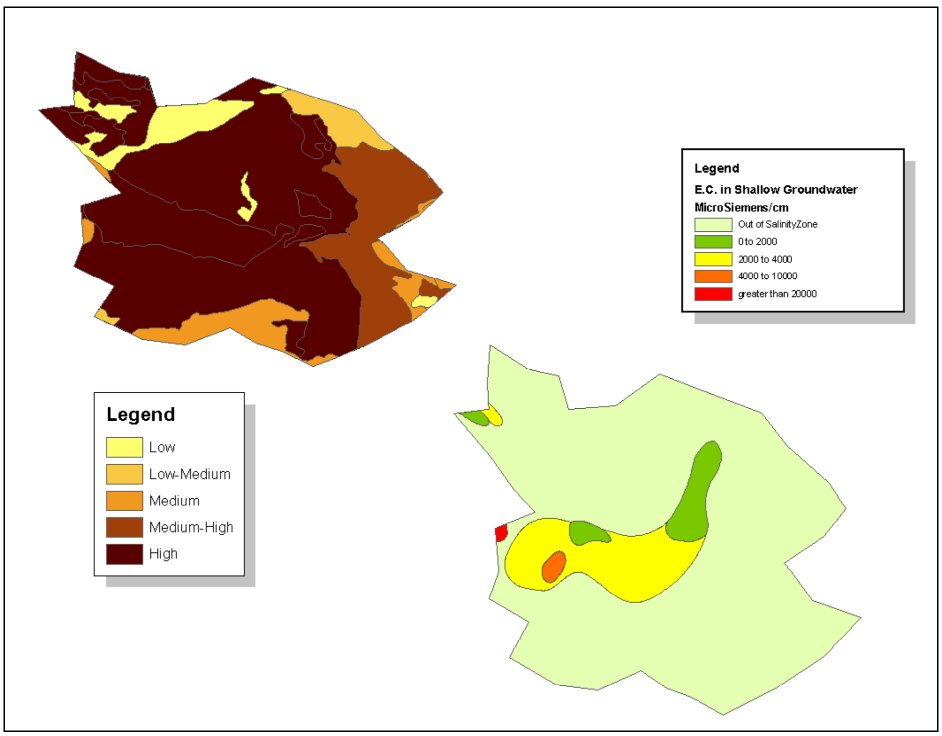
Each geo-referenced element in the land use surveys contains among other information, area, as well as current and previous information on land use. Agricultural land use is defined by crop type, and the data also indicate whether it was fallow land during the surveys. Urban, native, and other land use classes are indicated for each element in the survey too.

Crop groups for the study were alfalfa, citrus, cotton, field crops, grains, orchards, pasture, sugar beet, all grapes, truck, and other crops. An example of crop distribution in CVPM 21 is shown in Table 3.40. It can be noticed in the aforesaid table that low value crops are concentrated in the high salinity zones. Also it can be noticed in Figure 3.8 that the electrical conductivity shows some correlation with soil class.

Production costs and inputs are five years (1999-2004) averages and correspond to those used in a recent SWAP study for historic hydrology for climatic change (Medellin-Azuara, et al, (In Press)). Six CVPM regions are part of this study namely, 10, 14, 15, 18, 19 and 21.

**Table 3.40 Crop Distribution by Salinity Zone at CVPM 21 (Source: DWR)**

| | Salinity Zone (µS/cm) | | | | |
|---|---|---|---|---|---|
| **Crops** | **Out Salinity Zone** | **0 - 2,000** | **2,000 – 4,000** | **4,000 – 10,000** | **Total** |
| Alfalfa | 41,992 | 12,838 | 12,967 | 318 | 68,116 |
| Citrus | 18,931 | - | - | - | 18,931 |
| Cotton | 63,567 | 7,047 | 59,542 | 3,843 | 134,000 |
| Field Crops | 29,362 | 9,472 | 14,273 | 405 | 53,513 |
| Grains | 39,147 | 4,916 | 16,206 | 449 | 60,719 |
| Orchards | 31,664 | 817 | 518 | - | 32,998 |
| Pasture | 1,146 | 578 | 28 | - | 1,751 |
| Sugar Bet | 859 | - | 60 | - | 919 |
| All Grapes | 52,558 | 978 | 161 | - | 53,697 |
| Truck crops | 55,420 | 330 | 2,288 | 599 | 58,637 |
| Fallow Land | 25,762 | 6,090 | 10,016 | 1,951 | 43,819 |
| **Total** | **360,408** | **43,067** | **116,059** | **7,565** | **527,099** |




Source: USDA-NRCS SURGGO, Bureau of Reclamation, DWR

**Figure 3.8 Soil Capacity Class (left) and Electrical Conductivity in Shallow Groundwater (right) at CVMP 21 Crop Distribution by Salinity Zone at CVPM 21**

Salinity data were obtained from the DWR's San Joaquin Valley Drainage Monitoring Program. Geo-referenced salinity data on shallow groundwater was overlaid with CVPM land use surveys. Thus, each of the CVPMs in the study were disaggregated into six electrical conductivity ranges, namely non-surveyed, 0-2,000, 2,000-4,000, 4,000-10,000, 10,000-20,000, and greater than 20,000 µS/cm (see Figure 3.5).

### 3.5.3.2 Soil Class

Soil capacity class data corresponds to the Soil Survey Geographic (SSURGO) database (http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/); the aggregation level was the national database. A weighted average based on area was calculated for the parcels from the DWR surveys Figure 3.9.

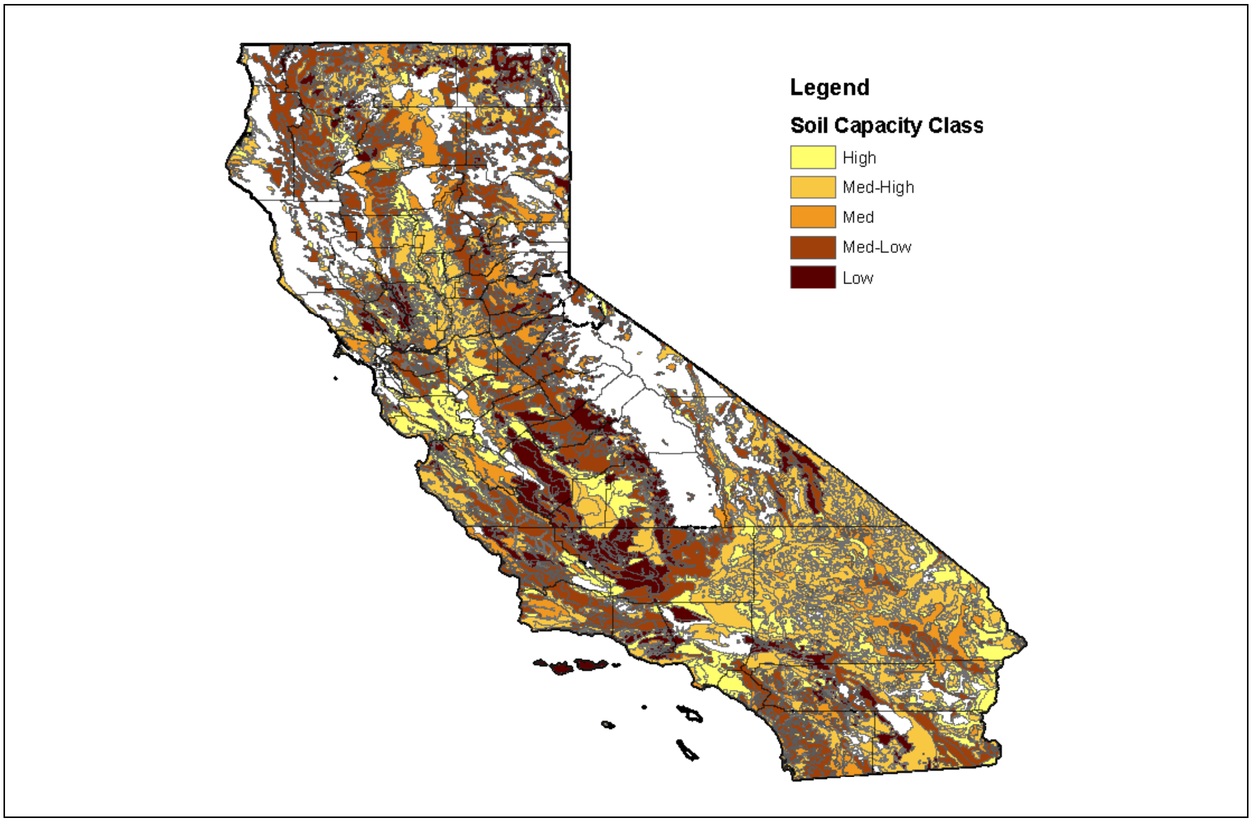



**Figure 3.9 California Soil Capacity Class (Source: SSURGO)**

### 3.5.3.3 Comparison of Analytical and Spatial Modeling Results

In order to compare land use predictions and cropping patterns under deductive and inductive approaches, the base land use at each salinity zone of the CVPM was used to calibrate the parameters of the non-linear profit maximization problem described in the previous section. From there, the policy experiment consists of increasing the salinity zone to the next level for all zones (except if greater than 20,000 µS/cm). Likewise, for the inductive case, the probability of observing a crop in the next salinity zone was estimated. The base acreage for both approaches before the policy experiment is the same.

The predicted cropping pattern using each approach is then compared. The zones that are defined in the model are the cultivated areas that have no saline groundwater, and those areas with electrical conductivities in shallow groundwater 0-2000, 2000-4000, 4000-10,000 and 10,000-20,000 µS/cm. The policy experiment increases salinity to the next level and measures the changes in the cropping pattern (the extensive margin). A change in the highest salinity zone (above 20,000 µS/cm) is not included in the study.

Consistent with expectations, results for both inductive and deductive approaches predict small changes in acres at low levels of salinity and more pronounced changes at higher levels of salinity. In general for the lowest salinity zones, the deductive approach results in smaller changes in both absolute and relative acres (as a percent change from base acres). Conversely, changes in the extensive margin are the greatest using the deductive approach when the salinity zone is at it highest level.

An aggregation of cultivated land per crop and salinity zone for all CVPM is shown in Table 3.41. In the first column, the crop groups are defined for each salinity zone. The next column lists the aggregate base acreage for all crops at each salinity level. The third column shows the crop acreage after a policy simulation in which the salinity level (as electrical conductivity) is changed to the next level in SWAP/DAP. The acres predicted by the inductive approach are shown in the fourth and fifth columns. The next two columns show the percent difference in acres between the two approaches, whereas the last two columns show two ratio parameters that illustrate the similarities in the approaches. The first parameter, is a ratio deductive versus deductive on the predicted acres (column three divided by column five). The second is a similar ratio for changes in relative acres calculated by dividing column six by column seven. The numbers in bold at the bottom of these last two columns correspond to the weighted average (based on acreage share) of the ratios at each salinity level.

At low levels of salinity, results indicate that the deductive approach is less responsive than the inductive one. One possible explanation is that Van Genuchten and Hoffman formulation and parameters make the yield reduction curve very flat at the low end of electrical conductivity. In contrast, high levels of salinity make responses at the extensive margin more significant than the mathematical programming approach. This can be verified by comparing magnitudes of percent change in acres (columns six and seven in Table 3.41. When an agricultural zone changes from no salinity to low salinity (0-2,000 µS/cm) and from low salinity to medium salinity (2,000-4,000 µS/cm), the deductive approach shows small percent changes in land use compared to the inductive approach. For the last two salinity levels (4,000-1,000 µS/cm and 10,000-20,000 µS/cm), the results show increased response in the deductive approach.

Table 3.42 shows the correlation between the inductive and deductive methods of estimating crop salinity response. The closeness of the predictions is measured by calculating the ratios between the methods. A ratio value of one indicates complete consistency. Table 3.42 shows that the ratios for absolute acres are reasonably close to the unit value, with a global weighted average of 1.54. This indicates that on average, the predicted absolute acres by SWAP are greater than those predicted in the multinomial logit approach. The opposite occurs for the ratio of percent changes in land use, which is approximately 0.5 for all crops and salinity levels.

**Table 3.41 Changes in the Extensive Margin for all CVPMs per Crop and Salinity Zone**

| | Deductive Approach (SWAP) | | Inductive Approach (M. Logit) | | Relative Acres (Extensive Margin) | | Ratio of Absolute Acre | Ratio of % Δ Acres |
|---|---|---|---|---|---|---|---|---|
| | Cultivated Absolute Acres | | Cultivated Absolute Acres | | Deductive | Inductive | | |
| Crop | Out of Salinity | 0 - 2,000 µS/cm | Acres | 0 - 2,000 µS/cm | ABS(% Δ Acres) | ABS(% Δ Acres) | SWAP/ Mlogit | SWAP/ Mlogit |
| Alfalfa | 277,289 | 276,980 | 277,289 | 470,813 | 0.11 | 69.79 | 0.59 | 0.00 |
| Citrus | 18,101 | 17,975 | 18,101 | 18,593 | 0.70 | 2.72 | 0.97 | 0.26 |
| Cotton | 448,574 | 449,397 | 448,574 | 736,929 | 0.18 | 64.28 | 0.61 | 0.00 |
| Field | 218,515 | 218,556 | 218,515 | 349,240 | 0.02 | 59.82 | 0.63 | 0.00 |
| Grains | 181,132 | 180,692 | 181,132 | 345,668 | 0.24 | 90.84 | 0.52 | 0.00 |
| Orchards | 453,582 | 452,033 | 453,582 | 203,115 | 0.34 | 55.22 | 2.23 | 0.01 |
| Pasture | 21,978 | 22,613 | 21,978 | 27,432 | 2.89 | 24.82 | 0.82 | 0.12 |
| S. Beet | 13,697 | 13,683 | 13,697 | 21,815 | 0.10 | 59.26 | 0.63 | 0.00 |
| Grapes | 163,491 | 163,317 | 163,491 | 12,255 | 0.11 | 92.50 | 13.33 | 0.00 |
| Truck | 316,204 | 315,995 | 316,204 | 397,712 | 0.07 | 25.78 | 0.79 | 0.00 |
| **Total** | **2,112,562** | **2,111,242** | **2,112,562** | **2,583,573** | | *Weighted Average* | **1.97** | **0.01** |
| Crop | 0-2,000 µS/cm | 0-4,000 µS/cm | 0-2,000 µS/cm | 0-4,000 µS/cm | ABS(% Δ Acres) | ABS(% Δ Acres) | Ratio ABS Acres | Ratio % Δ |
| Alfalfa | 79,687 | 79,905 | 79,687 | 96,886 | 0.27 | 21.58 | 0.82 | 0.01 |
| Citrus | 567 | 609 | 567 | 691 | 7.43 | 21.94 | 0.88 | 0.34 |
| Cotton | 138,440 | 145,876 | 138,440 | 175,950 | 5.37 | 27.09 | 0.83 | 0.20 |
| Field | 60,938 | 60,108 | 60,938 | 62,826 | 1.36 | 3.10 | 0.96 | 0.44 |
| Grains | 46,609 | 50,826 | 46,609 | 58,296 | 9.05 | 25.07 | 0.87 | 0.36 |
| Orchards | 56,992 | 49,316 | 56,992 | 13,168 | 13.47 | 76.89 | 3.75 | 0.18 |
| Pasture | 11,679 | 11,637 | 11,679 | 10,560 | 0.36 | 9.58 | 1.10 | 0.04 |
| S. Beet | 6,337 | 6,223 | 6,337 | 9,999 | 1.81 | 57.79 | 0.62 | 0.03 |
| Grapes | 9,539 | 4,886 | 9,539 | 616 | 48.78 | 93.54 | 7.93 | 0.52 |
| Truck | 95,264 | 94,306 | 95,264 | 79,096 | 1.01 | 16.97 | 1.19 | 0.06 |
| **Total** | **506,053** | **503,691** | **506,053** | **508,089** | | *Weighted Average* | **1.38** | **0.18** |
| Crop | 0-4,000 µS/cm | 4,000-10,000 µS/cm | 0-4,000 µS/cm | 4,000-10,000 µS/cm | ABS(% Δ Acres) | ABS(% Δ Acres) | Ratio ABS Acres | Ratio % Δ |
| Alfalfa | 110,055 | 93,642 | 110,055 | 125,836 | 14.91 | 14.34 | 0.74 | 1.04 |
| Citrus | 546 | 366 | 546 | 856 | 33.06 | 56.61 | 0.43 | 0.58 |
| Cotton | 245,673 | 249,652 | 245,673 | 276,144 | 1.62 | 12.40 | 0.90 | 0.13 |
| Field | 69,954 | 59,268 | 69,954 | 64,199 | 15.27 | 8.23 | 0.92 | 1.86 |
| Grains | 92,470 | 91,682 | 92,470 | 103,468 | 0.85 | 11.89 | 0.89 | 0.07 |
| Orchards | 35,636 | 22,904 | 35,636 | 8,779 | 35.73 | 75.36 | 2.61 | 0.47 |
| Pasture | 6,511 | 5,725 | 6,511 | 5,704 | 12.07 | 12.39 | 1.00 | 0.97 |
| S. Beet | 12,251 | 11,769 | 12,251 | 17,903 | 3.94 | 46.13 | 0.66 | 0.09 |
| Grapes | 3,092 | 2,435 | 3,092 | 139 | 21.24 | 95.49 | 17.48 | 0.22 |
| Truck | 115,760 | 105,426 | 115,760 | 91,492 | 8.93 | 20.96 | 1.15 | 0.43 |
| **Total** | **691,948** | **642,869** | **691,948** | **694,520** | | *Weighted Average* | **1.08** | **0.52** |

**Table 3.42 Changes in the Extensive Margin for all CVPMs per Crop and Salinity Zone**

| | Deductive Approach (SWAP) | | Inductive Approach (M. Logit) | | Relative Acres (Extensive Margin) | | Ratio of Absolute Acre | Ratio of % Δ Acres |
|---|---|---|---|---|---|---|---|---|
| | Cultivated Absolute Acres | | Cultivated Absolute Acres | | Deductive | Inductive | | |
| Crop | Out of Salinity | 0 - 2,000 µS/cm | Acres | 0 - 2,000 µS/cm | ABS(% Δ Acres) | ABS(% Δ Acres) | SWAP/ Mlogit | SWAP/ Mlogit |
| Alfalfa | 277,289 | 276,980 | 277,289 | 470,813 | 0.11 | 69.79 | 0.59 | 0.00 |
| Citrus | 18,101 | 17,975 | 18,101 | 18,593 | 0.70 | 2.72 | 0.97 | 0.26 |
| Cotton | 448,574 | 449,397 | 448,574 | 736,929 | 0.18 | 64.28 | 0.61 | 0.00 |
| Field | 218,515 | 218,556 | 218,515 | 349,240 | 0.02 | 59.82 | 0.63 | 0.00 |
| Grains | 181,132 | 180,692 | 181,132 | 345,668 | 0.24 | 90.84 | 0.52 | 0.00 |
| Orchards | 453,582 | 452,033 | 453,582 | 203,115 | 0.34 | 55.22 | 2.23 | 0.01 |
| Pasture | 21,978 | 22,613 | 21,978 | 27,432 | 2.89 | 24.82 | 0.82 | 0.12 |
| S. Beet | 13,697 | 13,683 | 13,697 | 21,815 | 0.10 | 59.26 | 0.63 | 0.00 |
| Grapes | 163,491 | 163,317 | 163,491 | 12,255 | 0.11 | 92.50 | 13.33 | 0.00 |
| Truck | 316,204 | 315,995 | 316,204 | 397,712 | 0.07 | 25.78 | 0.79 | 0.00 |
| **Total** | **2,112,562** | **2,111,242** | **2,112,562** | **2,583,573** | | *Weighted Average* | **1.97** | **0.01** |
| Crop | 0-2,000 µS/cm | 0-4,000 µS/cm | 0-2,000 µS/cm | 0-4,000 µS/cm | ABS(% Δ Acres) | ABS(% Δ Acres) | Ratio ABS Acres | Ratio % Δ |
| Alfalfa | 79,687 | 79,905 | 79,687 | 96,886 | 0.27 | 21.58 | 0.82 | 0.01 |
| Citrus | 567 | 609 | 567 | 691 | 7.43 | 21.94 | 0.88 | 0.34 |
| Cotton | 138,440 | 145,876 | 138,440 | 175,950 | 5.37 | 27.09 | 0.83 | 0.20 |
| Field | 60,938 | 60,108 | 60,938 | 62,826 | 1.36 | 3.10 | 0.96 | 0.44 |
| Grains | 46,609 | 50,826 | 46,609 | 58,296 | 9.05 | 25.07 | 0.87 | 0.36 |
| Orchards | 56,992 | 49,316 | 56,992 | 13,168 | 13.47 | 76.89 | 3.75 | 0.18 |
| Pasture | 11,679 | 11,637 | 11,679 | 10,560 | 0.36 | 9.58 | 1.10 | 0.04 |
| S. Beet | 6,337 | 6,223 | 6,337 | 9,999 | 1.81 | 57.79 | 0.62 | 0.03 |
| Grapes | 9,539 | 4,886 | 9,539 | 616 | 48.78 | 93.54 | 7.93 | 0.52 |
| Truck | 95,264 | 94,306 | 95,264 | 79,096 | 1.01 | 16.97 | 1.19 | 0.06 |
| **Total** | **506,053** | **503,691** | **506,053** | **508,089** | | *Weighted Average* | **1.38** | **0.18** |
| Crop | 0-4,000 µS/cm | 4,000-10,000 µS/cm | 0-4,000 µS/cm | 4,000-10,000 µS/cm | ABS(% Δ Acres) | ABS(% Δ Acres) | Ratio ABS Acres | Ratio % Δ |
| Alfalfa | 110,055 | 93,642 | 110,055 | 125,836 | 14.91 | 14.34 | 0.74 | 1.04 |
| Citrus | 546 | 366 | 546 | 856 | 33.06 | 56.61 | 0.43 | 0.58 |
| Cotton | 245,673 | 249,652 | 245,673 | 276,144 | 1.62 | 12.40 | 0.90 | 0.13 |
| Field | 69,954 | 59,268 | 69,954 | 64,199 | 15.27 | 8.23 | 0.92 | 1.86 |
| Grains | 92,470 | 91,682 | 92,470 | 103,468 | 0.85 | 11.89 | 0.89 | 0.07 |
| Orchards | 35,636 | 22,904 | 35,636 | 8,779 | 35.73 | 75.36 | 2.61 | 0.47 |
| Pasture | 6,511 | 5,725 | 6,511 | 5,704 | 12.07 | 12.39 | 1.00 | 0.97 |
| S. Beet | 12,251 | 11,769 | 12,251 | 17,903 | 3.94 | 46.13 | 0.66 | 0.09 |
| Grapes | 3,092 | 2,435 | 3,092 | 139 | 21.24 | 95.49 | 17.48 | 0.22 |
| Truck | 115,760 | 105,426 | 115,760 | 91,492 | 8.93 | 20.96 | 1.15 | 0.43 |
| **Total** | **691,948** | **642,869** | **691,948** | **694,520** | | *Weighted Average* | **1.08** | **0.52** |
| **Crop** | **4,000-** | **10,000-** | **4,000-** | **10,000-** | **ABS(% Δ** | *ABS(% Δ* | **Ratio ABS** | **Ratio** |

| | Deductive Approach (SWAP) | | Inductive Approach (M. Logit) | | Relative Acres (Extensive Margin) | | Ratio of Absolute Acre | Ratio of % Δ Acres |
|---|---|---|---|---|---|---|---|---|
| | Cultivated Absolute Acres | | Cultivated Absolute Acres | | Deductive | Inductive | | |
| | **10,000 µS/cm** | **20,000 µS/cm** | **10,000 µS/cm** | **20,000 µS/cm** | **Acres)** | *Acres)* | **Acres** | **% Δ** |
| Alfalfa | 110,410 | 58,509 | 110,410 | 136,618 | 47.01 | *23.74* | 0.43 | 1.98 |
| Citrus | 858 | 180 | 858 | 1,062 | 79.06 | *23.77* | 0.17 | 3.33 |
| Cotton | 275,604 | 255,163 | 275,604 | 284,278 | 7.42 | *3.15* | 0.90 | 2.36 |
| Field | 39,571 | 24,205 | 39,571 | 30,418 | 38.83 | *23.13* | 0.80 | 1.68 |
| Grains | 90,483 | 70,062 | 90,483 | 95,757 | 22.57 | *5.83* | 0.73 | 3.87 |
| Orchards | 15,329 | 5,175 | 15,329 | 4,235 | 66.24 | *72.38* | 1.22 | 0.92 |
| Pasture | 4,931 | 1,773 | 4,931 | 4,772 | 64.04 | *3.24* | 0.37 | 19.78 |
| S. Beet | 20,378 | 17,511 | 20,378 | 29,001 | 14.07 | *42.31* | 0.60 | 0.33 |
| Grapes | 1,144 | 671 | 1,144 | 1 | 41.33 | *99.91* | | 0.41 |
| Truck | 107,149 | 79,935 | 107,149 | 82,270 | 25.40 | *23.22* | 0.97 | 1.09 |
| **Total** | **665,857** | **513,185** | **665,857** | **668,410** | | ***Weighted Average*** | **0.80** | **2.29** |

### 3.5.4 Annual Direct Costs

Having performed a calibration test using econometrics for the programming model of this study (SWAP), salinity projections for 2030 were incorporated as part of the assessment. This section describes the steps undertaken to account for 2030 demand projections, price, and expected salinity accumulation.

Three elements underlie the estimated costs of salinity for irrigated agriculture by year 2030. These elements are land conversion from agriculture to other uses, endogenous prices and salinity accumulation towards year 2030. However, revenue losses shown below are after demand and land use changes have taken place. Parameters in the production function take into account the estimated yield reduction following the van Genuchten and Hoffman (1984) formulation.

Land conversion follows Landis and Reilly (2002) study for California. Percent of land converted from agriculture by 2030 averages 10% for all CVPMs in the Valley. However some of the CVPMs forfeit more than 30% of their total land for non-farm uses.

Demand projections and endogenous prices follow the procedures described in Medellin-Azuara et al (2007). However, demand shifts and land conversion projections were scaled to year 2030 as two-thirds of the 2050 projection. Demand shifts take into account income projections for California, income elasticity of demands for agricultural products, and agricultural imports versus exports as well as other considerations. Price volatility of each crop group was assumed the same for all CVPMs. However, prices of crop groups, factor costs, and input usage were disaggregated at the CVPM level. A weighted price for each crop was estimated. Year 2030 prices for each crop group are the product of a non-linear optimization program to maximize producer's surplus in the Central Valley for each crop and CVPM. It was assumed that the 2030 crop prices at the CVPM level are the same within the CVPM.

Two scenarios were formulated regarding the land area affected by increased salinity accumulations. The first scenario assumes that 13 percent of the land area is subject to saline increases and the second is that 22 percent of the land area is subject to saline increases. These scenarios become the REMI Base Scenario and the REMI High Scenario. The REMI Medium Scenario is the average of the Base and High Scenarios.

**Table 3.43 2030 CVPM Annual Per Acre Crop Revenue Change for Two Salinity Scenarios**

| CVPM | Increase in Salinity Affected Land 13% | 22% |
|---|---|---|
| 10 | -$29.46 | -$47.45 |
| 14 | -$64.53 | -$128.43 |
| 15 | -$63.29 | -$106.61 |
| 19 | -$37.61 | -$74.78 |
| 21 | -$27.41 | -$66.72 |
| **Weighted Average** | **-$51.00** | **-$97.33** |

Table 3.43 shows the projected change in annual crop revenue for each salinity affected CVPM for 2030 under the assumption that the area affected by increased salinity increases by 13 percent. The total reduction in 2030 crop revenue is projected to be $184.714. Fifty five percent or $102,713 is expected to come from decreases in cotton production.

**Table 3.44 2030 CVPM Annual Crop Revenue Changes Assuming a 13% Increase In Saline Land Acreage ($1,000)**

| Crop | CVPM 10 | CVPM 14 | CVPM 15 | CVPM 19 | CVPM 21 | Total Revenue |
|---|---|---|---|---|---|---|
| Alfalfa | -$979 | -$3,439 | -$13,109 | -$1,229 | $175 | -$18,582 |
| Citrus | -$15 | 0 | -$8 | -$8 | -$65 | -$96 |
| Cotton | -$25,733 | -$35,869 | -$35,782 | -$1,372 | -$3,959 | -$102,714 |
| Field crops | $17,599 | -$4,727 | $3,671 | -$2,562 | -$311 | $13,670 |
| Grain | -$3,061 | -$15,918 | $4,494 | -$15,542 | -$6,896 | -$36,922 |
| Orchard | -$1,010 | -$9,717 | -$2,481 | -$1,027 | -$90 | -$14,324 |
| Pasture | -$744 | $55 | -$406 | -$314 | $2 | -$1,407 |
| Sugar Beet | $28 | -$1,318 | -$180 | -$63 | - | -$1,533 |
| All Grapes | -$35 | -$2,408 | -$1,149 | -$343 | -$105 | -$4,041 |
| Truck | -$618 | -$17,616 | -$180 | -$215 | -$136 | -$18,765 |
| **Regional Revenue** | **-$14,569** | **-$90,956** | **-$45,128** | **-$22,676** | **-$11,385** | **-$184,714** |

The total reduction in 2030 crop revenue is projected to be $359,467 if area affected by salinity increases by 22 percent. Decreases in cotton production represent 66 percent of the total revenue losses.

**Table 3.45 2030 CVPM Annual Crop Revenue Changes Assuming a 22% Increase In Saline Land Acreage ($1,000)**

| Crop | CVPM 10 | CVPM 14 | CVPM 15 | CVPM 19 | CVPM 21 | Total Revenue |
|---|---|---|---|---|---|---|
| Alfalfa | -$14,805 | -$3,439 | -$19,162 | -$4,107 | $322 | -$41,190 |
| Citrus | -$32 | $0 | -$6 | -$52 | -$101 | -$193 |
| Cotton | -$24,476 | -$121,762 | -$68,387 | -$4,483 | -$20,594 | -$239,702 |
| Field crops | $23,966 | -$4,727 | $4,178 | -$10,108 | -$952 | $12,356 |
| Grain | $576 | -$15,918 | $5,926 | -$19,299 | -$5,835 | -$34,550 |
| Orchard | -$2,331 | -$10,881 | -$2,745 | -$2,775 | -$155 | -$18,886 |
| Pasture | -$5,075 | $55 | -$427 | -$2,790 | $2 | -$8,235 |
| Sugar Beet | $92 | -$1,867 | -$161 | -$170 | - | -$2,106 |
| All Grapes | -$74 | -$2,679 | -$1,281 | -$745 | -$169 | -$4,948 |
| Truck | -$1,301 | -$19,793 | -$134 | -$560 | -$226 | -$22,015 |
| **Regional Revenue** | **-$23,461** | **-$181,011** | **-$82,199** | **-$45,089** | **-$27,707** | **-$359,467** |

Projected 2030 per acre crop revenue changes range from $51 under the 13 percent increase in saline affected areas to $97.33 under the 22 percent increase in saline affected areas, a 91 percent increase (Table 3.45). CVPM regions are affected very differently by the salinity increase. CVPM 14 and 15 are affected the most by increase salinity and least affected (see Figure 3.7).

These results were entered into The REMI model by assuming that the 13 percent land change scenario represents the Base or Low condition and the 22 percent scenario represents the High Scenario. The Medium Scenario was formulated by using the midpoint between the two results. All of the impacts occur in the Tulare Basin.

The following Table summarizes the annual direct costs to irrigated agriculture for the three REMI Scenarios. These impacts occur in the Tulare Basin only.

| REMI Scenario | Annual Direct Costs ($1,000) |
|---|---|
| Base | -$184,714 |
| Medium | -$272,091 |
| High | -$359,467 |

# 4 Total Economic Impacts on California of Central Valley Salinity Accumulations

The State Water Resources Control Board sets statewide water quality policy, coordinates and supports the Regional Water Boards' efforts, and reviews petitions that contest Regional Board actions. There are nine semiautonomous Regional Boards located based on watersheds (Figure 4.1). The mission of the Regional Boards is to develop and enforce water quality objectives and implementation (basin) plans that will best protect the State's waters, recognizing local differences in climate, topography, geology and hydrology. Each Regional Board makes critical water quality decisions for its area, including setting standards, issuing waste discharge requirement, determining compliance with those requirements, and taking enforcement actions.


**Figure 4.1 Regional Water Quality Control Boards**

The salinity issue will become an important determinant in employment, income and economic growth of the Central Valley. Failure to control salinity will result in the continued decline of Central Valley water quality and an increase in costs to all water users, eventually creating even greater hardship for the environment, agriculture, industry, municipal utilities, and the economy of the valley and the State.

This study will assess the economic and social impacts of increasing salinity in the Central Valley if a comprehensive salinity management program is not implemented. Economic and social impacts will occur in the Central Valley as salinity levels increase, creating changes in water quality and water supply.

For this study, the status quo is defined as not implementing a comprehensive salinity management program. Economic and social outcomes of the status quo will include changes in the production of goods and services (output), income and employment because of increases in salinity levels under existing policies and regulations. These outcomes may be altered by starting a salinity management program. Such a program would likely reduce the salinity levels in the Central Valley and temper the economic and social changes. Economic effects of a salinity management plan will be estimated by comparing two sets of economic projections. The first set of projections is made assuming the status quo and no changes in land use, water use or water quality. Standard projections of economic activity do not take into account resource limitations such as the effects of salinity accumulations. The second set of projections includes the effects of increased salinity on land and water use. The difference between the two sets of projections is the economic impact of increased salinity, or of not implementing a comprehensive salinity management program.

## 4.1 Regional Economic Models, Inc. (REMI)

REMI Policy Insight is probably the most widely applied regional economic policy analysis model (http://www.remi.com). The REMI model is a dynamic forecasting and policy analysis tool that integrates econometrics and input-output modeling in a general equilibrium framework. By incorporating the strengths of each methodology the model overcomes many of the limitations of one approach. The result is a comprehensive model that answers "what if…?" questions about a regional economy.

REMI models contain detailed industries. At its core, the model incorporates inter-industry relationships found in input-output models. The model has a sequential framework for data input and results which demonstrates economic changes over time, allowing firms and individuals to change their behavior in response to changing economic conditions. These responses are based partly on the general equilibrium economic theory. The underlying equations and response estimations are based on econometric models.

The economy's spatial dimension is represented by the underlying "New Economic Geography" structure of the REMI model. This incorporates the productivity and competitiveness benefits due to the concentration, or agglomeration, of economic activity in cities and metropolitan areas, and the clustering of industries.

Uses of the model to predict the regional economic and demographic effects of policies cover a range of issues including electric utility restructuring in Wyoming, the construction of a new baseball park for Boston, air pollution regulations in California, and the provision of tax incentives for business expansion in Michigan. The model is used by government agencies on the national, state, and local level, as well as by private consulting firms, utilities, and universities.

The original version of the model was developed as the Massachusetts Economic Policy Analysis *(MEPA, Treyz, Friedlander, and Stevens)* model in 1977. It was extended into a model that could be generalized for all states and counties under a grant from the National Cooperative Highway Research Program. In 1980, Regional Economic Models, Inc. was founded to build, maintain, and advise the use of the REMI model for regions. REMI was established to further the theoretical Model Documentation – Version 9.5 3 framework, methodology, and estimation of the model through ongoing economic research and development.

## 4.2 The Central Valley REMI Model

The Central Valley Regional Board encompasses 60,000 square miles, or about 40 percent of the State's total area. Thirty-eight of California's 58 counties are completely or partially within the Regional Board's boundaries, formed by the crests of the Sierra Nevada on the east, the Coast Ranges and Klamath Mountains on the west, the Oregon border on the north, and the Tehachapi Mountains on the south. Included are 11,350 miles of streams, 579,110 acres of lakes and the largest contiguous groundwater basin in California. The Sacramento and San Joaquin rivers, and their tributaries, drain the major part of this large area through an inland Delta, before emptying into San Francisco Bay (Figure 4.2). The Delta is the focal point of the State's two largest water conveyance projects, the State Water Project and the federal Central Valley Project. Together, the Sacramento and San Joaquin rivers and the Delta furnish more than half of the State's water supply. The southern third of the Central Valley contains the Tulare Lake Basin, a closed hydrographic unit, except during wet years.

The Central Valley is one of the most important agricultural centers of the world. Its largest city is Sacramento, the state's Capitol.

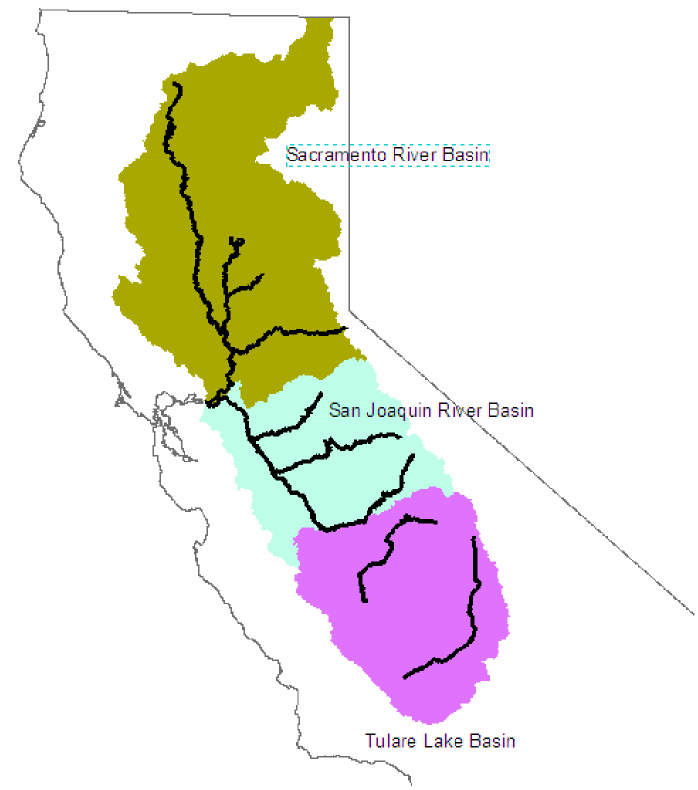



**Figure 4.2 Central Valley Region Water Quality Basins**

REMI regions are configured as a county or a group of counties that provides the basis for the economic data used in the model. The Central Valley REMI Model was configured as a four- region model made up of the Sacramento, San Joaquin and Tulare basins, and the rest of California (Figure 4.3). The rest of California is included as a region because of the economic links of the Central Valley to the state's economy.

Determining the counties that represent the REMI region is important since counties are not delineated entirely by hydrologic criteria. To select the counties that would represent the basins, the California county map was overlaid on the Central Valley Basin map (Figure 4.3). From the overlay, it is evident that certain counties could or could not be included in the basin designation. Siskiyou, Modoc, Lassen, Napa, Solano, Contra Costa and Kern counties have substantial areas inside and outside of the Central Valley delineation. Another problem is presented by Fresno County. Although located entirely within the Central Valley, it is divided between the San Joaquin and the Tulare basins.

Since aggregations of county data represents each region, the effect of including or excluding each county needs to be assessed. Counties were included in the REMI model if a substantial portion of the counties population and economic activity was affected by the actions of the Central Valley Regional Water Board.

Figure 4.3 shows the counties that were included in each basin. The shaded areas outside of the Central Valley boundary indicate areas where county data are included in the basin representation. Non-shaded area inside the Central Valley boundary represents areas where county data are not included in the basin representation.

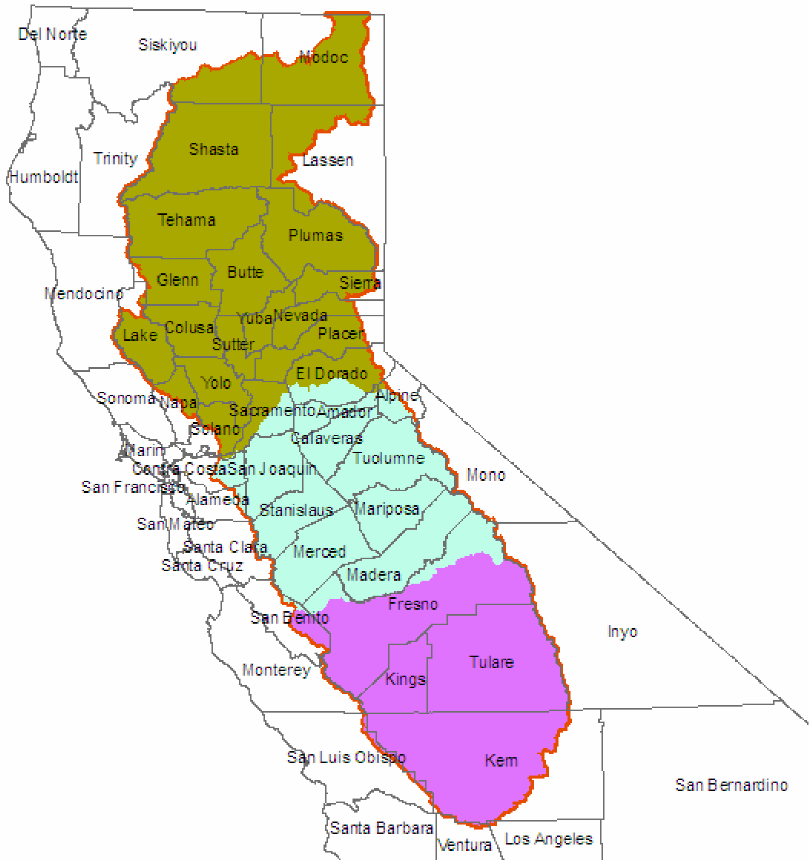



**Figure 4.3 Central Valley Regional Water Quality Control Board and Related Counties**

## 4.3 Policy Variable Selection

Total economic impacts of salinity accumulations were estimated by the REMI model using the direct economic effects that were estimated for the three basins and reported in Chapter 3. Sectors affected by salinity accumulations include households, manufacturing, wine production, food processing, confined animal operations and irrigated agriculture. Table 4.1 contains a summary of those sector costs and production changes for the three basins in the Central Valley and the corresponding REMI variables and data input units.

**Table 4.1 Direct Changes in Sector and Regional Economic Activity, 2030**

***Sector***

| REMI Variable | Units | Basin | Base | Medium | High |
|---|---|---|---|---|---|
| | | | | $1,000,000 | |
| ***Household Expenditure Changes due to Increased Salinity Concentrations in Water Supply*** | | | | | |
| Household Operation Cost Increase | 2006 Chained National $ (M) | Sacramento | $0.000 | $4.862 | $11.624 |
| | | San Joaquin | $15.622 | $15.622 | $15.622 |
| | | Tulare | $11.959 | $11.959 | $11.959 |
| | | **Total** | **$27.581** | **$32.443** | **$39.205** |
| Consumption Reallocation due to Household Operation Cost Increase | 2006 Chained National $ (M) | Sacramento | $0.000 | -$4.862 | -$11.624 |
| | | San Joaquin | -$15.622 | -$15.622 | -$15.622 |
| | | Tulare | -$11.959 | -$11.959 | -$11.959 |
| | | **Total** | **-$27.581** | **-$32.443** | **-$39.205** |
| ***Industrial Production Cost Changes due to Increased Salinity Concentrations in Water Supply*** | | | | | |
| Production Cost (amount): by Utility and Manufacturing sector | 2006 Fixed National $ (M) | Sacramento | $0.000 | $96.558 | $230.834 |
| | | San Joaquin | $299.751 | $299.751 | $299.751 |
| | | Tulare | $208.341 | $208.341 | $208.341 |
| | | **Total** | **$508.093** | **$604.651** | **$738.927** |
| ***Wine Production Changes due to Salinity Disposal Requirements*** | | | | | |
| Firm Sales (amount) Beverage, tobacco, prod mfg | 2006 Fixed National $ (M) | Sacramento | -$7.322 | -$7.322 | -$7.322 |
| | | San Joaquin | -$7.908 | -$7.908 | -$7.908 |
| | | Tulare | -$2.440 | -$2.440 | -$2.440 |
| | | **Total** | **-$17.670** | **-$17.670** | **-$17.670** |
| ***Food Processing Changes due to Salinity Disposal Requirements*** | | | | | |
| Firm Sales (amount) Food mfg. | 2006 Fixed National $ (M) | Sacramento | -$23.760 | -$23.760 | -$23.760 |
| | | San Joaquin | -$57.132 | -$57.132 | -$57.132 |
| | | Tulare | -$52.447 | -$52.447 | -$52.447 |
| | | **Total** | **-$133.340** | **-$133.340** | **-$133.340** |
| ***CAFO Production Changes due to Salinity Disposal Requirements*** | | | | | |
| Firm Sales (amount) Agriculture | 2006 Fixed National $ (M) | Sacramento | $0.000 | $0.000 | $0.000 |
| | | San Joaquin | -$9.709 | -$19.018 | -$26.862 |
| | | Tulare | -$107.017 | -$140.033 | -$228.265 |
| | | **Total** | **-$116.726** | **-$159.051** | **-$255.127** |
| ***Irrigated Agricultural Production Changes due to Increases in Soil Salinity*** | | | | | |
| Firm Sales (amount) Agriculture | 2006 Fixed National $ (M) | Sacramento | $0.000 | $0.000 | $0.000 |
| | | San Joaquin | $0.000 | $0.000 | $0.000 |
| | | Tulare | -$184.714 | -$272.091 | -$359.467 |
| | | **Total** | **-$184.714** | **-$272.091** | **-$359.467** |
| **Total** | | | **-$988.123** | **-$1,219.245** | **-$1,543.736** |

This section briefly explains the REMI structure, the process of entering the direct economic impacts into the REMI model, and the results that describes the character and the extent of economic impacts.

The REMI model is a structural representation of the economy characterizing the interaction of population and labor supply, the demand for goods and services, the production of goods and services (output), the demand for labor, capital and resources, and the nature of wages, costs and prices (Figure 4-4).

The REMI model brings together all of the above elements to determine the value of a variable for each year in baseline and policy forecasts. Introducing policy changes into the model is accomplished by introducing changes in external variables and running REMI to project the results over a specified time. The analysis requires that the direct economic impacts be specified for the appropriate variable.(This sentence is a repeat.) The selection of policy variables and the model interaction used to calculate the major impacts are shown below.

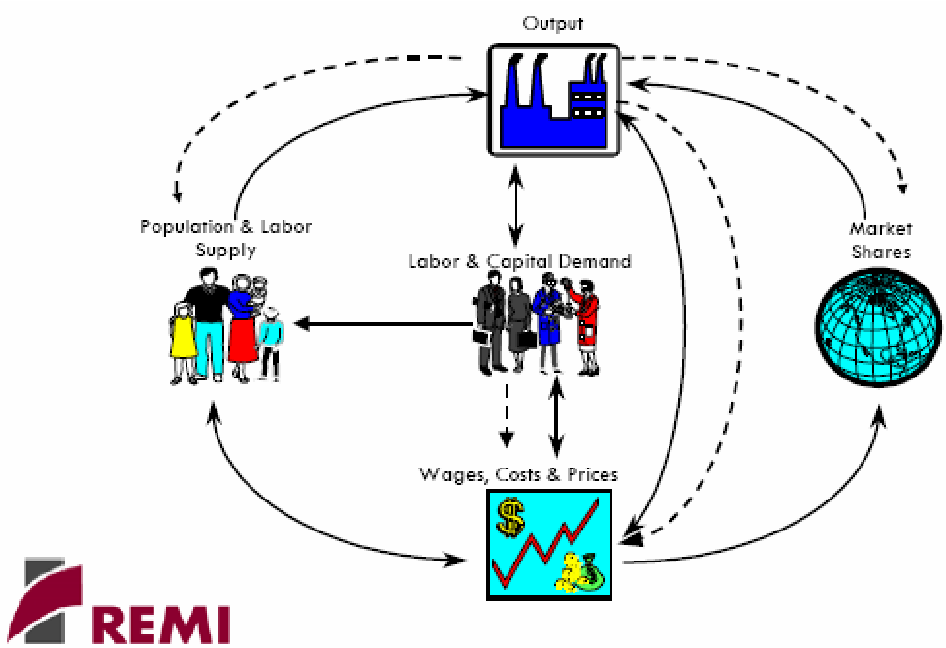



**Figure 4.4 REMI Model Structure**

### 4.3.1 Household Expenditure Changes

Estimates of economic impacts are calculated in REMI by solving sets of simultaneous equations represented by the five blocks in Figure 4.4. Salinity related household expenditures such as water conditioners and replacing appliances and fixtures are estimated to increase to $27.581 million under the base scenario and $39.205 million under the high scenario by 2030 (Table 4.1). Estimating the economic impact of the expenditure is explained using detailed depictions of the various blocks. The changes in household expenditures are specified in the "Consumption Spending of Residents" section of the Output Block (Figure 4-5). This affects output or the production of consumption items and the associated employment and income. This is calculated in the Labor and Capital Demand Block (Figure 4.6). Population impacts are then calculated in the Population and Labor Supply Block (Figure 4.7) using the employment impacts. Population changes affect labor supply, housing prices, and local government revenue and spending.

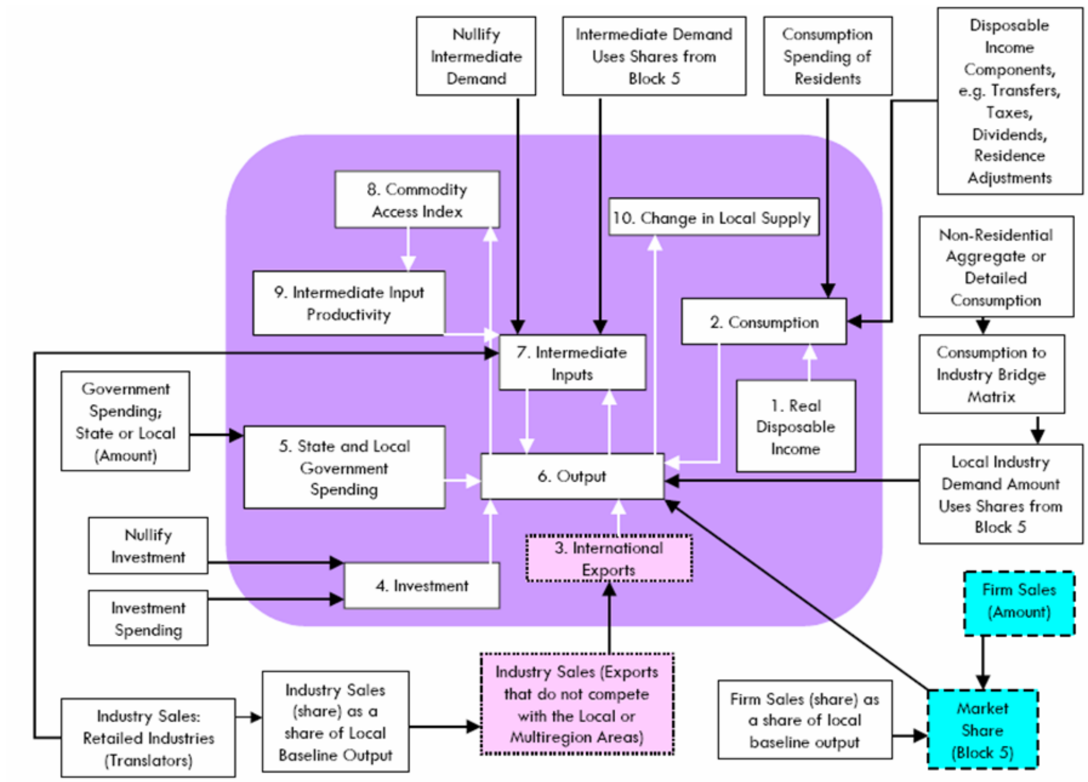



**Figure 4.5 Output Block Key Policy Variables**

These expenditures will be offset by decreases in other household expenditures such as food and clothing or entertainment. The assumption used in this analysis is that the change in salinity related expenditures will be equally offset by reductions in other expenditures. This is accounted for in a separate variable defined within the REMI model and identified in the second item of Table 4-1. REMI reduces expenditure categories in proportion to historical spending patterns. The salinity impacts on households will affect changes in certain production, wholesale and retail sectors, but have little impact on total income and employment.

### 4.3.2 Industrial Production Cost Increases

Increases in water supply salinity concentration will increase industrial production costs (Table 4.1). This will cause a decline in regional and state income, output, employment and population. Estimates of these impacts is accomplished in REMI by entering the cost increase to each industrial and utility sector in the “Production Cost” section of Wages, Prices, and Costs Block (Figure 4.8). The cost increase reduces the share of domestic markets and international exports because competitors outside of the Central Valley will not experience similar cost increases. This computation is detailed in the Market Shares Block (Figure 4.9). This block calculates the reduction in shares of the domestic and international markets which is used by the Output Block, to estimate changes in the production of goods and services for each sector and region.

Other changes that will occur are shown in the Wages, Prices, and Costs Block, such as decreases in composite wage rates and increases in consumer prices. Employment impacts are calculated by the Labor and Capital Demand Block (Figure 4.6). This block factors in the substitution of labor for capital and energy resources and the resulting change in employment.

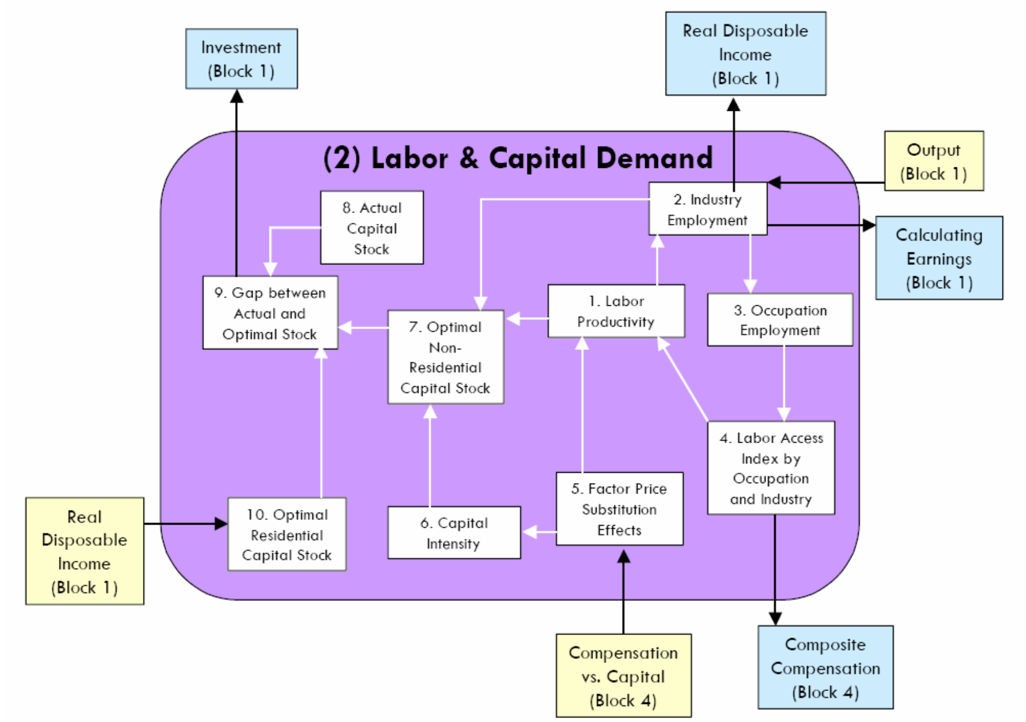



**Figure 4.6 Labor and Capital Demand Block Key Policy Variables**

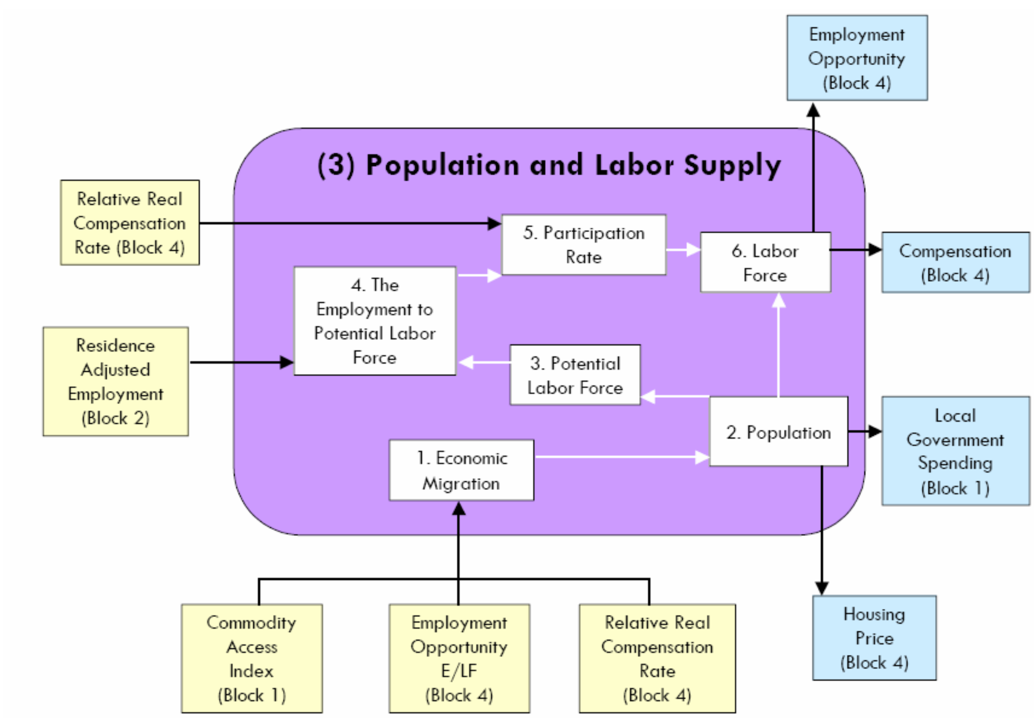



**Figure 4.7 Population and Labor Supply Block Key Policy Variables**

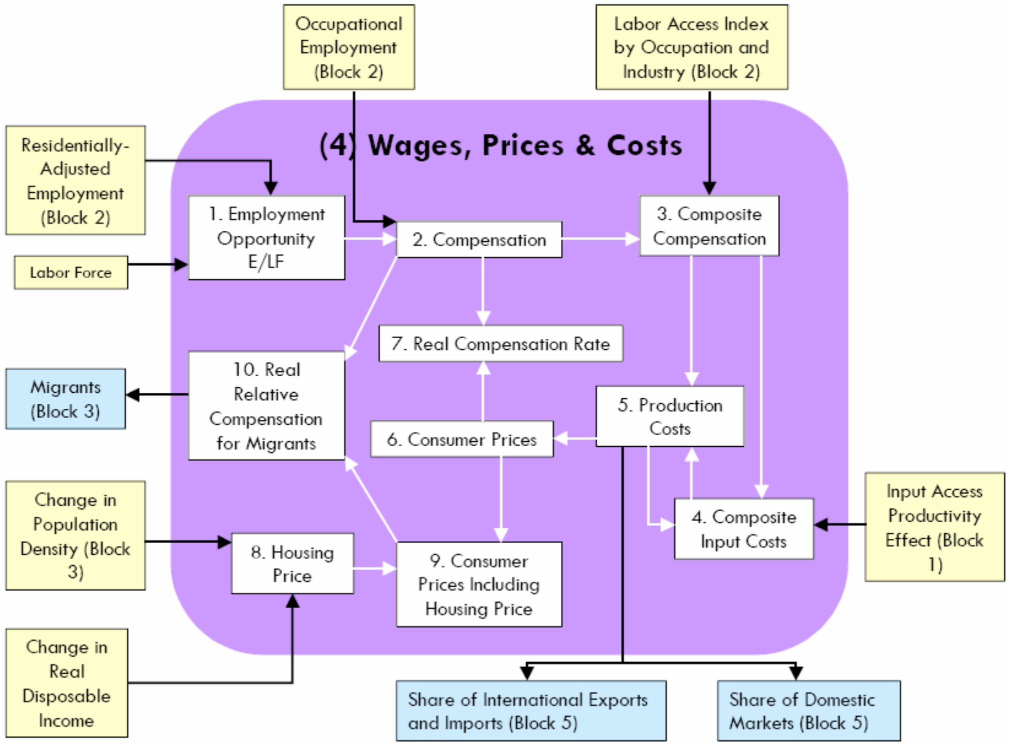



**Figure 4.8 Wages, Prices, and Costs Block 4 Key Policy Variables**

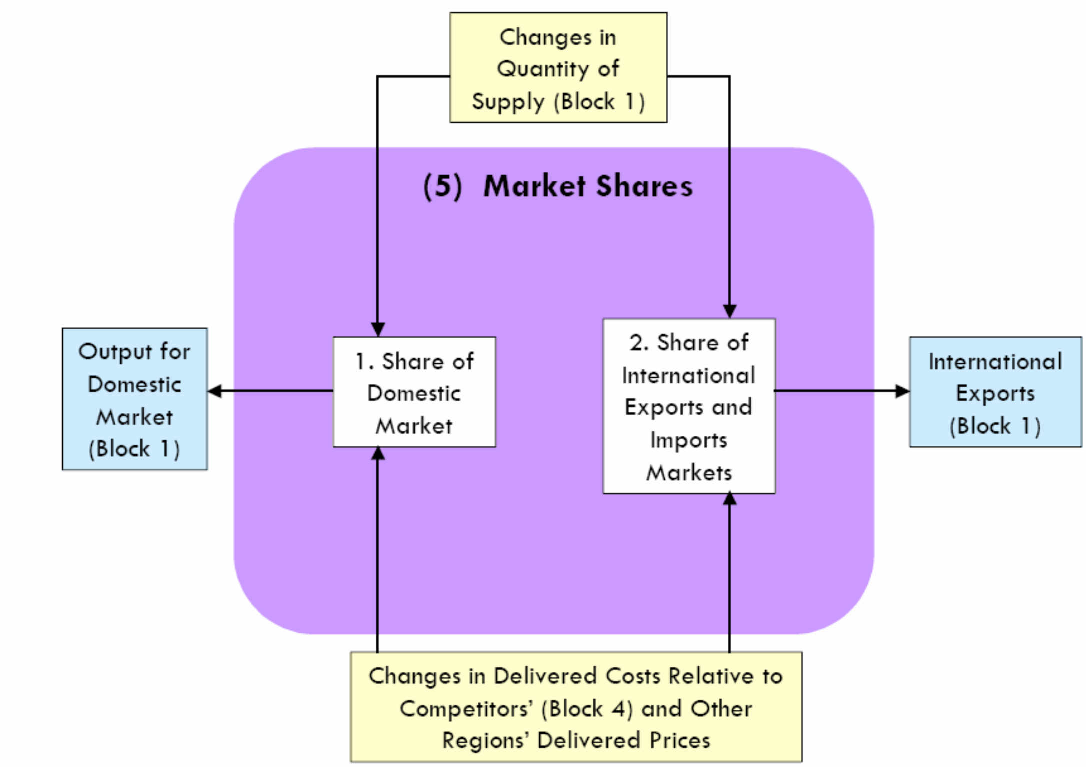


**Figure 4.9 Market Shares Block Key Policy Variables**

### 4.3.3 Agricultural Production Decreases

Agricultural production changes resulting from increased salinity concentrations were estimated for four sectors: wine, food processing, concentrated animal feeding operations, and irrigated agriculture (Table 4.1). Industrial and household salinity costs were entered into REMI and production and demand change estimates were estimated . This was not done for agricultural production. Agricultural production and demand changes were estimated using existing cost and demand models that were more detailed than what exists in REMI, and final production changes rather than costs were entered into the Output Block of the REMI model (Figure 4.5). Output changes affect employment (Figure 4.6), income (Figure 4.8) and population (Figure 4.7).

## 4.4 Total Income, Output, Employment and Population Impacts of Increased Salinity

The model shares two key assumptions with mainstream economic theory: households maximize utility and producers maximize profits. Businesses produce goods to sell to other firms, consumers, investors, governments, and purchasers outside of the region. The output is produced using labor, capital, fuel, and intermediate inputs. The demand for labor, capital, and fuel per unit of output depends on their relative costs, since an increase in the price of any one of these inputs leads to substitution away from that input to other inputs.

The productivity of labor and intermediate inputs depends on the availability of access to them and the quality of those inputs. The supply of labor in the model depends on the number of people in the population and the proportion of those people who participate in the labor force. Economic migration affects the population size. People will move if the real after-tax wage rates, the likelihood of being employed, and the access to consumer goods increase in that area.

Supply and demand for labor in the model determine the wage rates. These wage rates, with other prices and productivity, determine the cost of doing business for every industry in the model. An increase in the cost of doing business causes an increase in production costs and the price of the goods or service, which decreases the share of the domestic and foreign markets supplied by local firms. This market share, combined with the demand described above, determines the amount of local output. The model has other feedbacks. For example, changes in wages and employment impact income and consumption, while economic expansion changes investment and population growth impacts government spending.

Salinity accumulations in water supplies will impact the regional economies of California but the impacts will not be uniform across regions, industries, income groups or occupations. This analysis attempts to identify regions and groups that will be affected the most.

Annual income, output, employment and population impacts from Central Valley salinity accumulations were estimated by REMI from 2008 through 2030, three salinity scenarios and four regions (Table 4-2). Under the medium set of assumptions regarding salinity accumulations, annual California income is expected to decline by $2.251 billion, output by $6.485 billion, employment by 46,299, and population by 65,013 in the year 2030. Under the low or base salinity assumptions, impact estimates are reduced by approximately 25 percent and under the high assumptions, increased by approximately 35 percent.

**Table 4.2 Total Economic Impacts of Salinity by Region and Scenario, 2030**

| | Sacramento | San Joaquin | Tulare | Rest of CA | California |
|---|---|---|---|---|---|
| **Income (Bil 2008$)** | | | | | |
| **Low** | -$0.075 | -$0.201 | -$0.875 | -$0.533 | -$1.685 |
| **Medium** | -$0.160 | -$0.242 | -$1.177 | -$0.673 | -$2.251 |
| **High** | -$0.278 | -$0.289 | -$1.620 | -$0.859 | -$3.047 |
| **Output (Bil 2008$)** | | | | | |
| **Low** | -$0.226 | -$1.014 | -$1.580 | -$2.085 | -$4.905 |
| **Medium** | -$0.766 | -$1.099 | -$1.968 | -$2.652 | -$6.485 |
| **High** | -$1.513 | -$1.206 | -$2.538 | -$3.447 | -$8.704 |
| **Employment (thousand)** | | | | | |
| **Low** | -1.057 | -3.087 | -22.680 | -6.861 | -33.685 |
| **Medium** | -2.378 | -3.931 | -31.160 | -8.830 | -46.299 |
| **High** | -4.210 | -4.795 | -43.600 | -11.580 | -64.185 |
| **Population (thousand)** | | | | | |
| **Low** | -1.610 | -4.066 | -33.530 | -8.352 | -47.558 |
| **Medium** | -3.375 | -5.178 | -45.920 | -10.540 | -65.013 |
| **High** | -5.830 | -6.372 | -64.110 | -13.530 | -89.842 |

### 4.4.1 Income Impacts

The Tulare Basin is projected to receive most of the economic impacts from salinity with income reduction estimates ranging from $875 million to 1.62 billion (Figure 4.10) depending on the salinity scenario. This represents about 52 percent of the total state income impacts. The rest of California will receive about 30 percent of the projected total income impacts.

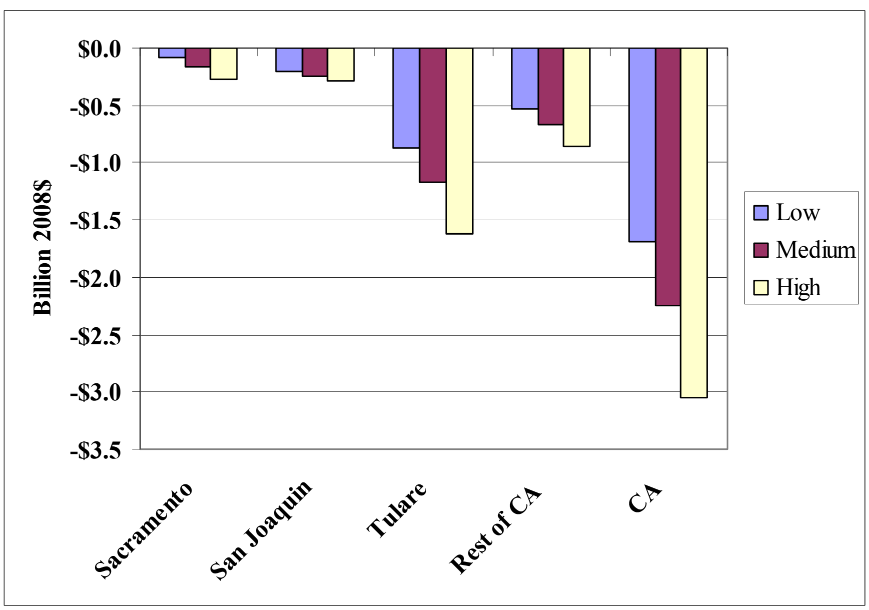



**Figure 4.10 Annual Income Impacts from Increased Salinity, 2030**

Changes in economic activity affect wage and income groups differently. Figure 4.11 shows percent reductions in income for five income groups. The annual income groups were defined using industry data from the Bureau of Economic Analysis employment and wage series. REMI ranked annual incomes in ascending order and then divided into five equal groups.

The lower income groups in the Tulare Basin bear the brunt of the economic impacts caused by increased salinity. An income reduction of more than 8 percent is projected for those earning less than $20,000 a year and a 2 percent reduction for those earning between $20,000 and $30,000. Other regions will experience smaller reductions and much more even reductions across income groups.

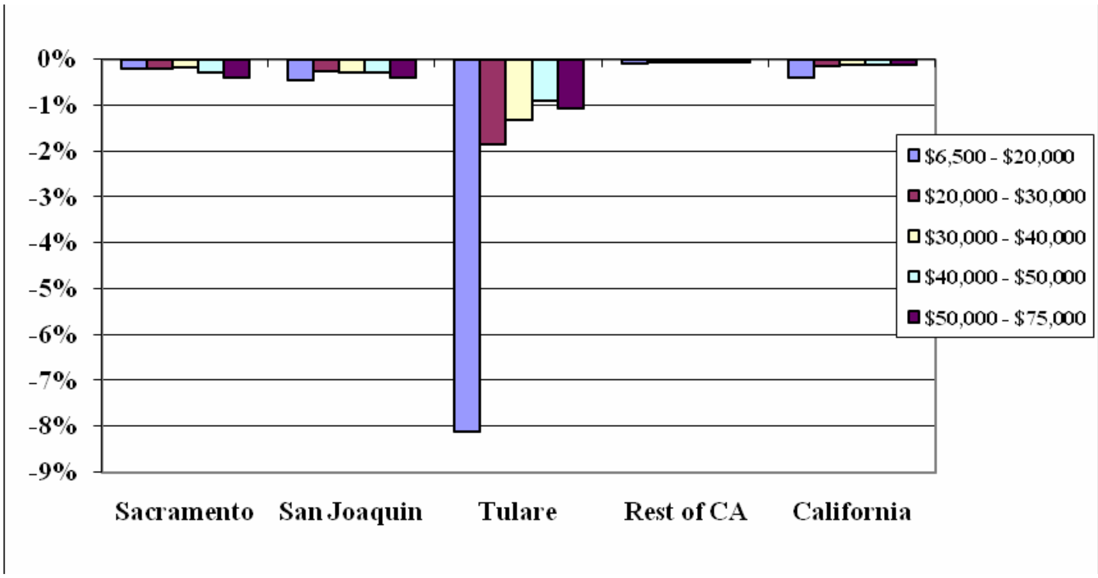



**Figure 4.11 Income Impacts by Annual Industrial Wage Rate Group and Region**

### 4.4.2 Output Impacts

Depending on the three direct economic loss scenarios, annual industrial output is projected to decline by $4.905 billion under the low salinity scenario and $8.704 billion by 2030 under the high salinity scenario (Table 4.2). In contrast to the regional distribution of income impacts, approximately 40 percent of the state's output reductions are projected to occur outside of the Central Valley while the Tulare Basin is projected to receive about 30 percent of the state's output impacts (Figure 4.12).

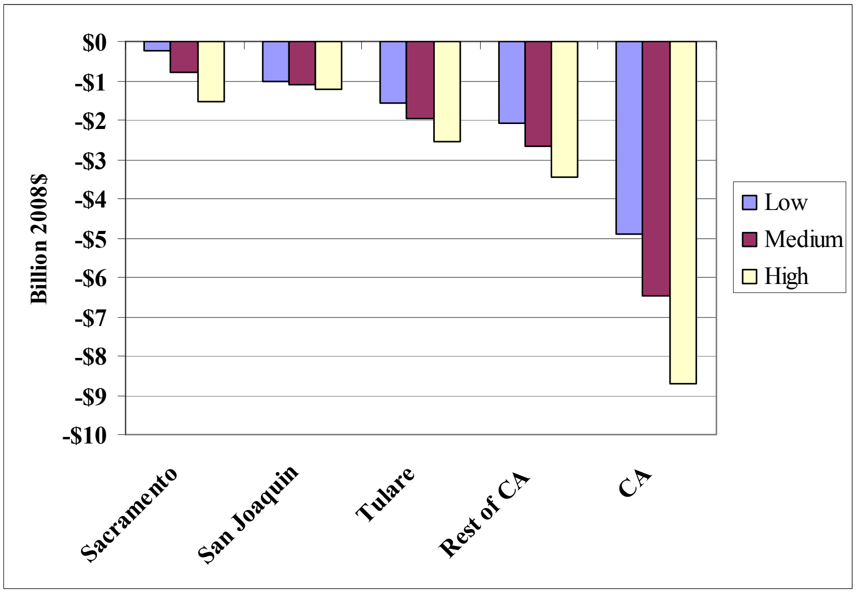



**Figure 4.12 Annual Output Impacts from Increased Salinity, 2030**

Salinity's effect on economic activity outside of the Central Valley is not surprising but the extent of the reduction is. This large decrease in rest of California output indicates that a substantial proportion of the products produced in the Central Valley is processed and/or used in other manufacturing activities outside of the Central Valley and that those activities are not labor intensive. Figure 4.13 identifies those sectors which are wholesale trade, information, finance and insurance, real estate, rental and leasing.

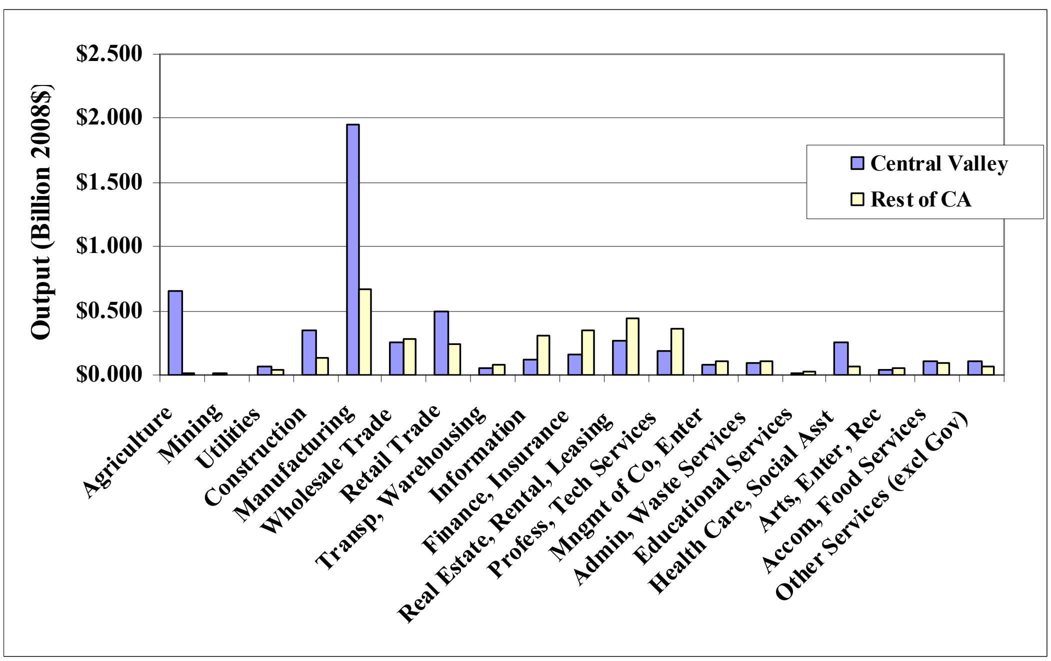



**Figure 4.13 Central Valley and Rest of California Output Reductions by Industry, 2030**

Agricultural production is expected to decline by $327 million to $667 million which is mostly caused by direct impacts of higher salinity (Table 4.3 and Figure 4.14). The reduction in manufacturing output of $1.572 billion to $2.616 billion is the result of increased salinity and indirect economic effects.

Significant reductions in output are expected in secondary sectors such as construction, wholesale trade, retail trade, information, and financial and technical services.

**Table 4.3 California Industrial Output Impacts from Salinity, 2030**

| | 2030 Billion (2008$) | | |
|---|---|---|---|
| **Sector** | **Base** | **Medium** | **High** |
| Agriculture | $0.327 | $0.468 | $0.667 |
| Mining | $0.014 | $0.014 | $0.015 |
| Utilities | $0.058 | $0.076 | $0.102 |
| Construction | $0.266 | $0.360 | $0.494 |
| Manufacturing | $1.572 | $2.010 | $2.616 |
| Wholesale Trade | $0.296 | $0.394 | $0.532 |
| Retail Trade | $0.409 | $0.541 | $0.727 |
| Transp, Warehousing | $0.085 | $0.109 | $0.143 |
| Information | $0.232 | $0.311 | $0.422 |
| Finance, Insurance | $0.280 | $0.373 | $0.503 |
| Real Estate, Rental, Leasing | $0.380 | $0.515 | $0.704 |
| Profess, Tech Services | $0.301 | $0.406 | $0.553 |
| Mngmt of Co, Enter | $0.110 | $0.145 | $0.192 |
| Admin, Waste Services | $0.114 | $0.153 | $0.209 |
| Educational Services | $0.025 | $0.033 | $0.044 |
| Health Care, Social Asst | $0.172 | $0.234 | $0.322 |
| Arts, Enter, Rec | $0.053 | $0.071 | $0.097 |
| Accom, Food Services | $0.118 | $0.150 | $0.196 |
| Other Services (excl Gov) | $0.094 | $0.125 | $0.169 |
| **Total** | **$4.905** | **$6.487** | **$8.704** |

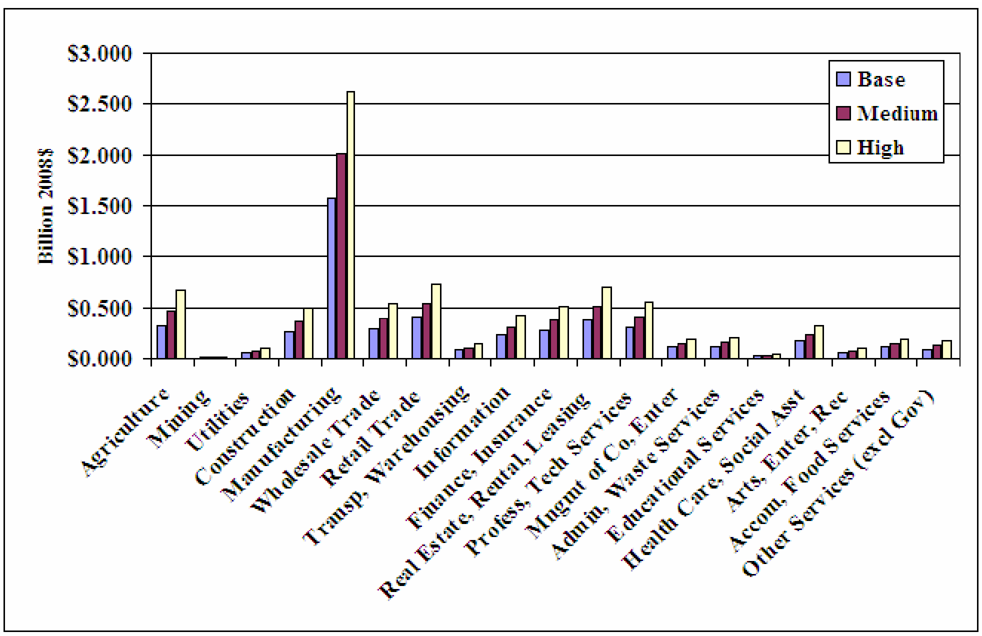



**Figure 4.14 Industrial Output Reductions from Salinity, 2030**

REMI provides a breakdown of the output reductions for the manufacturing sectors (Table 4.4 and Figure 4.15) manufacturing output by individual sectors, and identifies which industry groups will be affected by increased salinity. The manufacturing of computer and electronic products is projected to decline by

$447 million to $1.073 billion annually by 2030. As noted in Chapter 2 this sector is projected to experience substantial growth by 2030 as a result of technological advances that reduce the use of labor and increases the use of more advanced technologies. Any decline in the basic industries such as agriculture and related manufacturing will dictate a substantial decline in the electronics sector. A high variation in the electronics sector is also projected for the three scenarios. This results because the medium and high salinity scenarios assume that the Sacramento Basin will experience costs to households and industrial water users and large electronic manufacturing firms in the Sacramento Basin.

**Table 4.4 California Manufacturing Output Impacts from Salinity, 2030**

| | Billion (2008$) | | |
|---|---|---|---|
| Sector | Base | Medium | High |
| Wood product mfg | $0.022 | $0.033 | $0.049 |
| Nonmetallic mineral prod mfg | $0.025 | $0.031 | $0.039 |
| Primary metal mfg | $0.018 | $0.020 | $0.024 |
| Fabricated metal prod mfg | $0.052 | $0.065 | $0.083 |
| Machinery mfg | $0.055 | $0.066 | $0.082 |
| Computer, electronic prod mfg | $0.447 | $0.709 | $1.073 |
| Electrical equip, appliance mfg | $0.016 | $0.021 | $0.029 |
| Motor vehicle mfg | $0.031 | $0.039 | $0.049 |
| Transp equip mfg. exc. motor veh | $0.030 | $0.035 | $0.042 |
| Furniture, related prod mfg | $0.023 | $0.030 | $0.039 |
| Miscellaneous mfg | $0.051 | $0.064 | $0.082 |
| Food mfg | $0.351 | $0.372 | $0.402 |
| Beverage, tobacco prod mfg | $0.056 | $0.065 | $0.076 |
| Textile mills | $0.002 | $0.003 | $0.004 |
| Textile prod mills | $0.007 | $0.009 | $0.013 |
| Apparel mfg | $0.037 | $0.044 | $0.054 |
| Leather, allied prod mfg | $0.005 | $0.006 | $0.007 |
| Paper mfg | $0.031 | $0.036 | $0.043 |
| Printing, rel supp act | $0.016 | $0.020 | $0.026 |
| Petroleum, coal prod mfg | $0.161 | $0.169 | $0.181 |
| Chemical mfg | $0.097 | $0.124 | $0.162 |
| Plastics, rubber prod mfg | $0.039 | $0.047 | $0.059 |
| **Total** | **$1.572** | **$2.009** | **$2.615** |

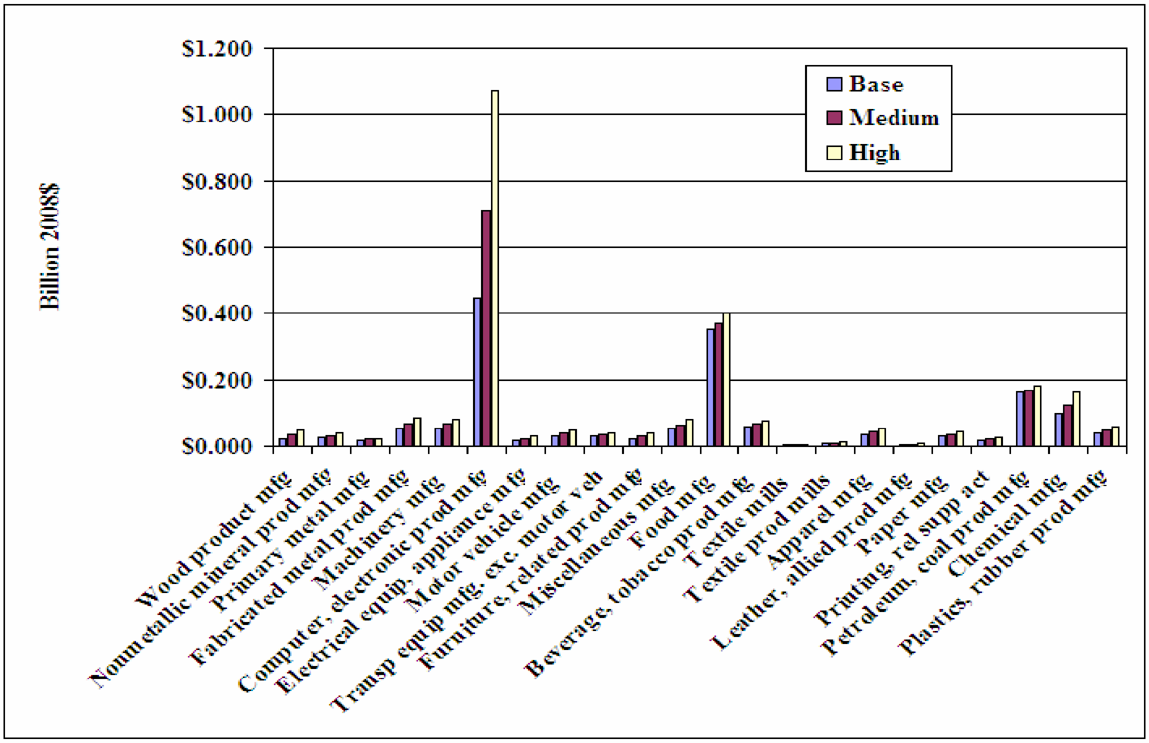



**Figure 4.15 California Manufacturing Output s from Salinity, 2030**

### 4.4.3 Employment and Population Impacts

About 67 percent of employment reductions are projected for the Tulare Basin (Figure 4.16). The rest of California is expected to receive less than 20 percent of the total employment. The disparity between the Tulare Basin and the rest of California income and employment reductions is due to the wage and salary differential between the two employment groups in the two regions. Figure 4.17 shows the percent of reduction in employment for five occupational wage groups (as described above, the wage groups were derived by the BEA). (WHAT IS BEA?) This indicates that employment in the lowest wage rate group is projected to decline by 6.5 percent which is considerably more than the employment reductions in higher wage rate groups.

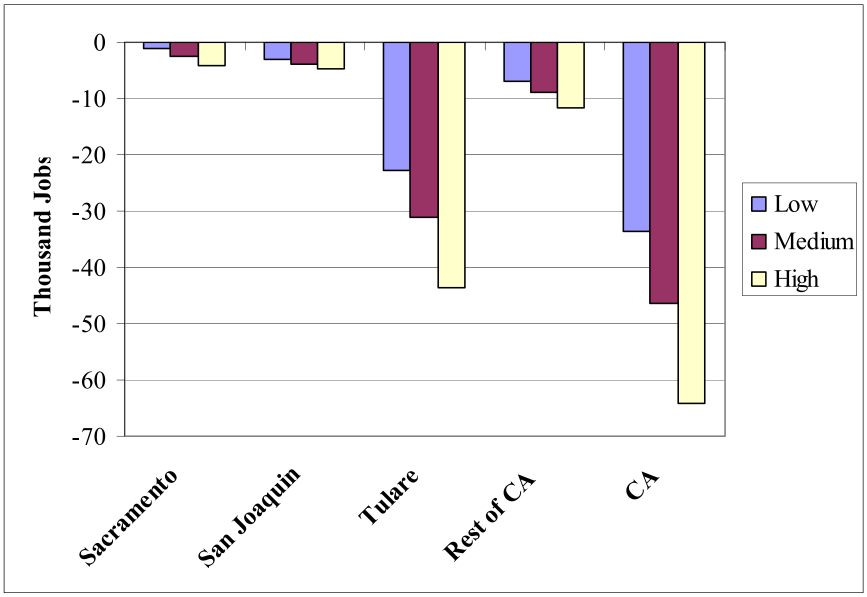



**Figure 4.16 Annual Total Employment Impacts from Increased Salinity, 2030**

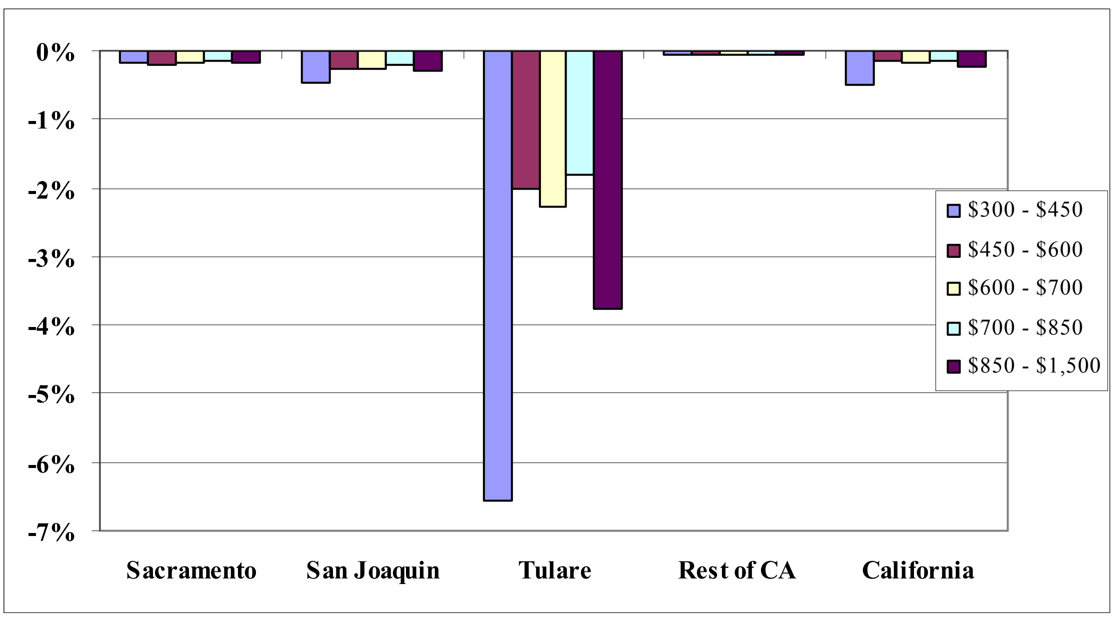



**Figure 4.17 Employment Impacts by Weekly Occupational Wage Rates and Region, 2030**

California’s population is projected to decline by 90,000 people by 2030 with 64,000 or about 70 percent of those losses in the Tulare Basin (Figure 4.18). About 15 percent of the state’s population losses will occur outside of the Central Valley while population losses in the San Joaquin and Sacramento basins will be minimal.

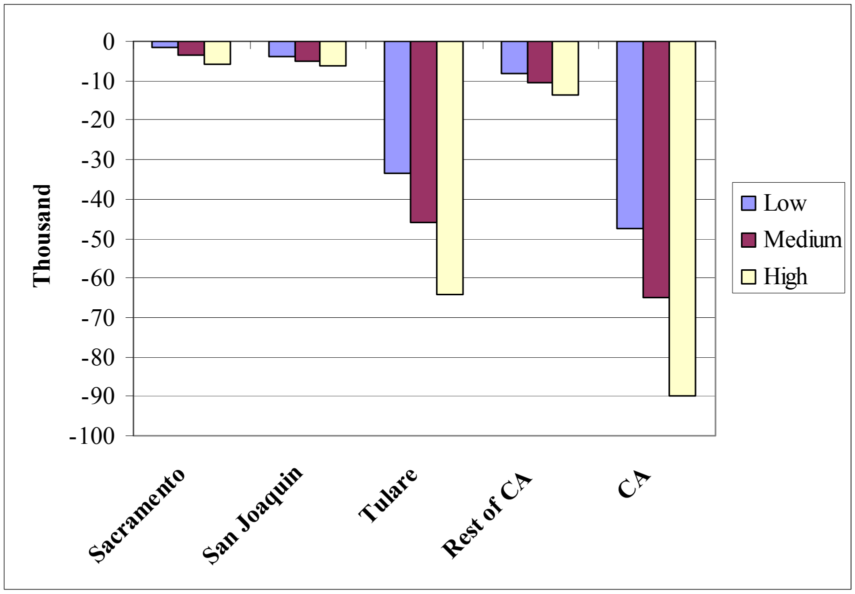



**Figure 4.18 Annual Population Impacts from Increased Salinity, 2030**

Annual reductions in California's employment and population from increased salinity from 2008 to 2030 are shown in Figure 4.19. The graph illustrates the lag effect of employment on population. Initially, unemployment is high and population will remain stable but over time out-migration occurs and population declines.

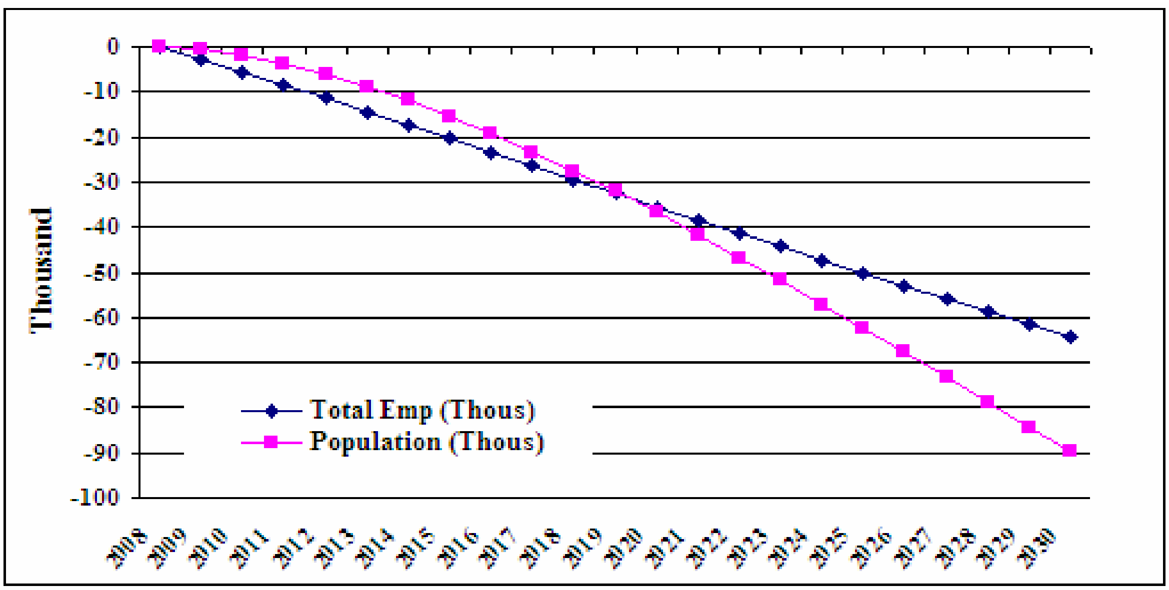



**Figure 4.19 California Employment and Population Impacts from Increased Salinity, 2008-2030**

# 5 Non-Market Economic Benefits of Reducing Salinity Discharges

## 5.1 Central Valley Non Market Salinity Benefits

The San Joaquin Valley is a hub of business activity, urban and suburban development, and agricultural productivity. These aspects of Valley life, while beneficial in many ways, have for many years caused slow increases in the salinity (or saltiness) of surface water and groundwater in the region. When businesses, households, and farmers use water in the course of their everyday activities, often what is returned to the region's groundwater and surface waters has a little more salt and minerals than before it was used. This process occurs in all areas of the State, but unlike in most other areas of California, in large parts of the San Joaquin Valley used water does not flow to the ocean. Instead, it remains in the Valley, and is reused over and over as it is pumped from the ground and the surface to meet the region's water needs.

The survey had several sections, the first of which asked about respondents' opinions and attitudes concerning different uses of water, how they themselves used water, and their opinions about their household water quality. Next, a series of questions asked about water-based recreational activities the household undertook in the San Joaquin Valley, and how they might change under different conditions. Respondents were then asked about their willingness to fund programs that would halt the increase in salinity of Valley waters. Another section asked about their preferences between salinity management programs that would differ in several key respects, depending on how the programs are organized and implemented. These include land in agricultural production, land areas devoted to wetlands, health outcomes measured by premature deaths from particulate air pollution, and household costs. These four key features are expected to vary depending on how salinity management plans are organized and implemented. A final section collected some basic demographic information about each respondent and his or her household, so that respondents to the survey can be compared to the general San Joaquin Valley and California populations, and their responses statistically adjusted to more accurately reflect those populations.

This report is the first of several analyses to be conducted on the data collected in the survey, and summarizes all of the responses received. First, the design and conduct of the survey will be discussed. Then the responses to questions from the survey itself are presented and briefly explained.

## 5.2 Design of the Survey

With the help of a private sampling firm, a random sample of 1,000 households was selected. The San Joaquin Valley was divided into three geographic regions. The area north of Highway 182 was designated as Northern, the area between Highway 182 and Highway 198 was designated as Central, and the area south of Highway 198 was designed as Southern. Each of these regions was then divided into rural and urban. Rural areas are those 5-digit zip codes with populations of less than 50,000 people, and urban areas are those 5-digit zip codes with populations of more than 50,000 people. With these 3 geographic divisions and 2 demographic divisions, there were 6 groups in total, from which an equal number of households was selected.

Each household received a mailing consisting of a 12 page booklet, a 2 page insert, a cover letter explaining the survey's purpose and asking for the household's participation, and a postage-paid return envelope. For the first mailing (of 3 total), the packet included a dollar bill as both a token of appreciation and a signal of the survey's importance. The survey was conducted following the principles of the Total Design Method (Dillman 1978).

As part of the survey development process, twenty-two focus groups and individual interviews were held to assess reactions to questions and information and clarity of the survey design. These were held in Davis, Modesto, and Fresno, during February and March of 2007. After completion of the focus groups, a pre-test survey was mailed to 150 randomly selected households in the San Joaquin Valley. The results and comments of these surveys were evaluated and used to improve the survey.

The first survey mailing occurred on April 9, 2007 and a reminder postcard was sent approximately one week later. On April 18, 2007, a reminder letter accompanying a survey packet was mailed to those households whose surveys had not yet been received. The final mailing of survey packets took place on May 29, 2007.

Since a significant proportion of San Joaquin Valley residents speak Spanish in their homes, the letter accompanying the first round of surveys contained a sentence at the bottom written in Spanish, asking households to check the adjacent box if they would like a survey version in Spanish. For the next 2 mailings, Hispanic names were identified in the mailing list, and these households received both English and Spanish cover letters and surveys. In total, 20 households completed and returned Spanish versions of the survey.

Of the 1,000 surveys sent in the initial mailing, the postal service returned 51 due to an incorrect address or lack of a mail receptacle or because they were unclaimed. Seven family members returned surveys indicating that the addressee was deceased. The postal service returned an additional 40 surveys from the 2nd mailing and returned 15 from the 3rd mailing. Family members returned 5 surveys from the 2nd mailing, indicating that the addressee was deceased. A total of 389 completed surveys were returned, as well as 33 surveys that were blank, duplicates, or refusals to participate. The overall response rate, the percent of deliverable surveys returned, was about 44%. Table 5.1 and Table 5.2 summarize the survey response statistics.

**Table 5.1. Survey Response Rates as of (October 1, 2007) for the Total Population**

| Outcome | Number | Percentage of Total Mailed |
|---|---|---|
| Total Number Mailed | 1,000 | 100% |
| Undeliverable Surveys | | |
| Deceased | 12 | 1.2% |
| Incorrect Address | 96 | 9.6% |
| Unclaimed | 6 | 0.6% |
| No Mail Receptacle | 3 | 0.3% |
| Out of Town | 1 | 0.1% |
| Surveys Delivered | 882 | 88% |
| Surveys Returned | | |
| Completed | 389 | 39% |
| Duplicate Responses | 2 | 0.2% |
| Incapable of Completing Survey | 4 | 0.4% |
| Refused | 15 | 1.5% |
| Returned with No Responses | 12 | 1.2% |
| Response Rate (completed as percent of delivered) | 44% | - |

**Table 5.2. Response Rate by Region**

| Region | Percent Completed | Standard Deviation |
|---|---|---|
| North | 47% | 8.7 |
| Central | 44% | 8.5 |
| South | 41% | 8.4 |
| | | |
| Rural | 42% | 9.0 |
| Urban | 44% | 11.7 |
| | | |
| North, Rural | 49% | 6.1 |
| North, Urban | 45% | 6.1 |
| Central, Rural | 38% | 5.3 |
| Central, Urban | 49% | 6.5 |
| South, Rural | 36% | 3.7 |
| South, Urban | 42% | 7.5 |

## 5.3 Survey Results and Tabulations

The following sections briefly discuss each of the questions contained in the survey and present summaries of the responses received.

### 5.3.1 Survey Section 1: Your Opinions about Water

The first section of the survey asks some general questions about participants' opinions on issues in the San Joaquin Valley, uses of water, and their own tap water. The survey contains these questions to gather information about households' views and beliefs and also to induce the respondents' reflection on what issues they think are important.

Given the significance of agriculture in the Valley, the survey begins with a question regarding the respondents' concern for protecting agriculture in the Valley. Almost two thirds of participants indicated that they are "extremely concerned," and 91% are at least "somewhat concerned"; see Table 5.3.

**Table 5.3. How concerned are you about protecting agriculture in the San Joaquin Valley?**

| Degree of Concern | Number | Percent |
|---|---|---|
| Extremely Concerned | 248 | 65% |
| Somewhat Concerned | 106 | 27% |
| Not too concerned | 13 | 3.3% |
| Not at all Concerned | 3 | 0.8% |
| No Response | 19 | 4.9% |
| **Total** | **389** | **100%** |

The second question then asks about respondents' concern for the environment. 63% are extremely concerned, and 93% are at least somewhat concerned; see Table 5.4.

**Table 5.4. How concerned are you about protecting the environment?**

| Degree of Concern | Number | Percent |
|---|---|---|
| Extremely Concerned | 243 | 63% |
| Somewhat Concerned | 116 | 30% |
| Not too concerned | 8 | 2.1% |
| Not at all Concerned | 2 | 0.5% |
| No Response | 20 | 5.1% |
| **Total** | **389** | **100%** |

The third question reminds respondents that other issues, such as crime, health care, race relations, education, jobs, and the economy may be important to them. For 53% of respondents, protecting agriculture is extremely important compared to these other issues, while 5% think it is not too or not at all important relative to these other issues; see Table 5.5.

**Table 5.5. Crime, health care, race relations, education, jobs, and the economy are some social issues that may concern you. Compared to these issues, how important is protecting agriculture?**

| Degree of Importance | Number | Percent |
|---|---|---|
| Extremely Important | 204 | 52% |
| Somewhat Important | 145 | 37% |
| Not too Important | 16 | 4.1% |
| Not at all Important | 3 | 0.8% |
| No Response | 21 | 5.4% |
| **Total** | **389** | **100%** |

The fourth question asks respondents to consider the importance of protecting the environment relative to other social issues. Fifty-five percent said protecting the environment is extremely important relative to these social issues while 4% indicated that it is not too or not at all important relative to the other issues; see Table 5.6.

**Table 5.6. Crime, health care, race relations, education, jobs, and the economy are some social issues that may concern you. Compared to these issues, how important is protecting the environment?**

| Degree of Importance | Number | Percent |
|---|---|---|
| Extremely Important | 210 | 54% |
| Somewhat Important | 140 | 36% |
| Not too Important | 16 | 4.1% |
| Not at all Important | 2 | 0.5% |
| No Response | 21 | 5.4% |
| **Total** | **389** | **100%** |

The next set of questions asks respondents to consider various uses of water and how important each of these uses is to them. Table 5.7 shows the ratings scale used, for which a value of 0 indicates that the issue is not important while a value of 5 indicates that the issue is very important. Figure 5.1 and Table 5.8 how the distribution of responses for different uses of water.

**Table 5.7. Importance Scale for Uses of Water**

| **Not Important** | | | | | **Very Important** |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |

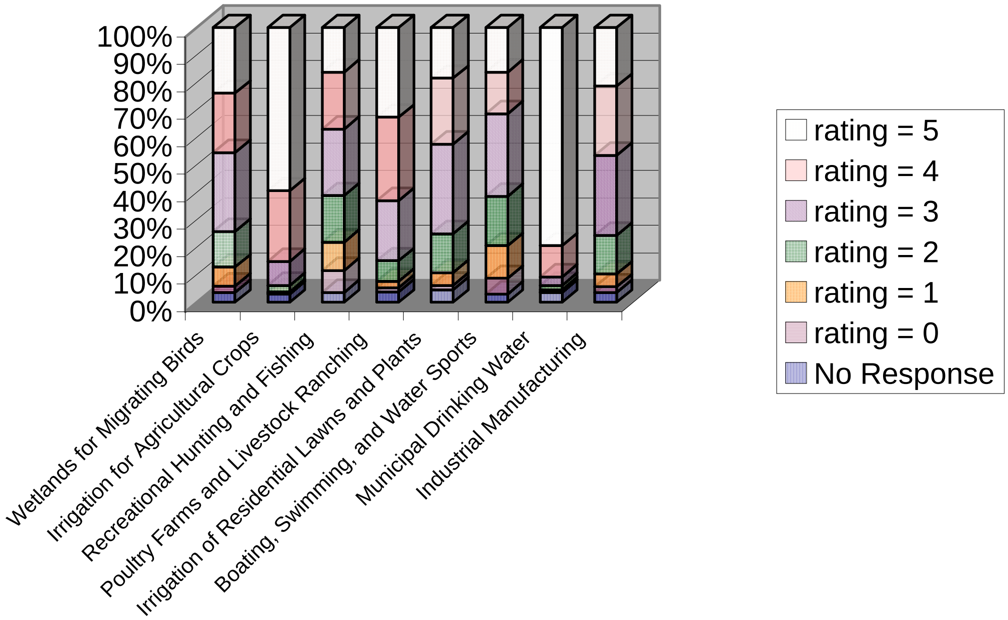



**Figure 5.1. Respondents' Ratings of the Importance of Uses of Water**

**Table 5.8. Tabulation of Respondents' Ratings of the Importance of Uses of Water**

| Response | Wetlands for Migrating Birds | Irrigation for Agricultural Crops | Recreational Hunting and Fishing | Poultry Farms and Livestock Ranching | Irrigation of Residential Lawns and Plants | Boating, Swimming, and Water Sports | Municipal Drinking Water | Industrial Manufacturing |
|---|---|---|---|---|---|---|---|---|
| No Response | 14 | 12 | 14 | 15 | 18 | 12 | 14 | 14 |
| rating = 0 | 9 | 1 | 31 | 6 | 6 | 22 | 1 | 8 |
| rating = 1 | 27 | 2 | 40 | 9 | 18 | 46 | 3 | 18 |
| rating = 2 | 50 | 9 | 66 | 29 | 55 | 70 | 6 | 55 |
| rating = 3 | 112 | 34 | 94 | 85 | 127 | 117 | 12 | 113 |
| rating = 4 | 84 | 100 | 81 | 118 | 93 | 59 | 44 | 98 |
| rating = 5 | 93 | 231 | 63 | 127 | 72 | 63 | 309 | 83 |

A set of questions about the quality of the household's tap water follows the section on uses of water. On the ratings scale used for these questions (Table 5.9) a value of 0 indicates poor quality while a value of 5 indicates excellent quality. When asked to rate the taste of their tap water, 30% gave it a 3. Thirty-one percent gave it a 0, 1, or 2, and the remaining gave it a 4 or 5. When asked to rate the smell of their tap water, 25% of respondents gave it a 0, 1, or 2, and 53% gave it a 3 or a 4. The color of households' tap water seems to be the best of the three attributes mentioned thus far. Only 16% gave it a value of 0, 1, or 2. Thirty-three percent rated it as a 4 Finally, the survey asks households to rate how well their tap water cleans their clothing and dishes. The results for both types of cleaning are similar. Household water quality responses are summarized in table 5.9 and figure 5.2.

**Table 5.9. Scale for Rating Household Water Quality**

| Poor | | | Fair | | Excellent |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |

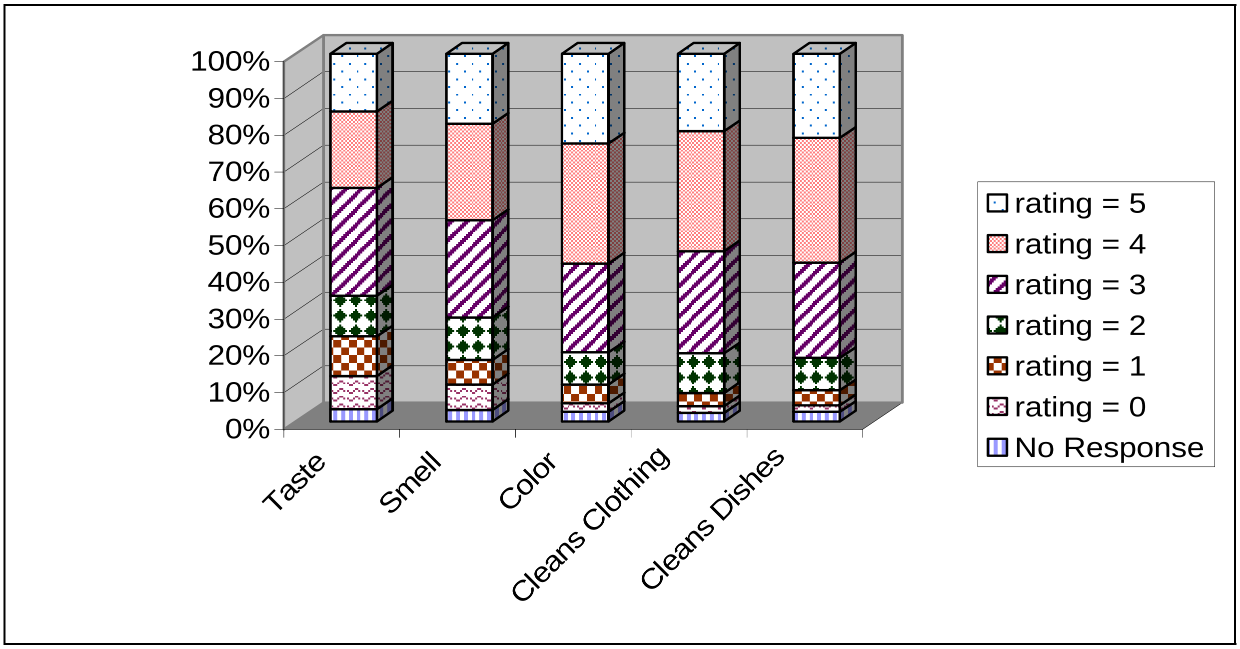



**Figure 5.2. Ratings of Tap Water Quality**

**Table 5.10. Tabulation of Tap Water Quality**

| Response | Taste | Smell | Color | Cleans Clothing | Cleans Dishes |
|---|---|---|---|---|---|
| No Response | 13 | 12 | 10 | 9 | 10 |
| rating = 0 | 35 | 27 | 9 | 7 | 7 |
| rating = 1 | 42 | 26 | 20 | 14 | 16 |
| rating = 2 | 43 | 45 | 34 | 42 | 34 |
| rating = 3 | 114 | 103 | 94 | 108 | 101 |
| rating = 4 | 81 | 102 | 127 | 127 | 132 |
| rating = 5 | 61 | 74 | 95 | 82 | 89 |

### 5.3.2 Survey Section 2: Your Uses of Water

A more objective section on how households actually use water both in their home and in the outdoors follows the initial subjective section. The survey contains these questions to collect information on how San Joaquin Valley residents use water and also to encourage respondents to consider how they use water.

This section begins by asking households if they have a yard, to which 91% responded in the affirmative (Table 5.11). Those households that did not have a yard were instructed to skip those questions that consequently did not pertain to them.

**Table 5.11. Do you have a yard (private or shared?)**

| Response | Number | Percent |
|---|---|---|
| Yes | 355 | 91% |
| No | 23 | 5.9% |
| No Response | 11 | 2.8% |
| **Total** | **389** | **100%** |

To identify households with larger yards and potentially different water needs and attitudes, the survey asks if the respondent's yard is larger than 1 acre. Only 7% of respondents answered yes to this question. The next question asks whether the household has sprinklers or an irrigation system in their yard. Four fifths of respondents indicated that they do have sprinklers or an irrigation system. Given the rural nature of some of the areas included in the sample, the survey asks whether or not the household's residence has a well. About one-fifth of respondents indicated that they do have a well. Figure 5.3 and Table 5.12 summarize the responses with respect to households with larger yards.

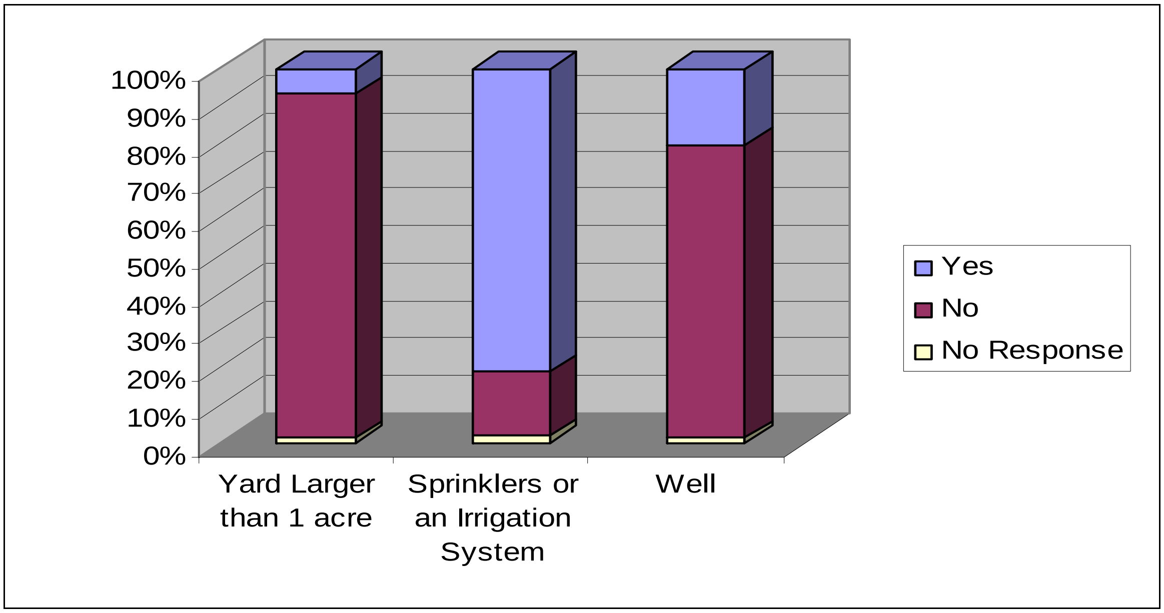



**Figure 5.3. Does your household have the following?**

**Table 5.12. Does your household have the following?**

| Response | Yard Larger than 1 acre | Sprinklers or an Irrigation System | Well |
|---|---|---|---|
| Yes | 24 | 287 | 72 |
| No | 326 | 61 | 278 |
| No Response | 5 | 7 | 5 |
| **Total** | **355** | **355** | **355** |

Since various uses of yards consume different amounts of water, the survey asks respondents to indicate which on a list of eight items their yards contain. Ninety-four percent of households' yards contain grass. Shade trees were the next most common, with 76% of households indicating their presence. A little less than half of respondents had domestic pets and fruit or nut trees in their yards (see Table 5.13).

To learn about households' drinking water habits, the survey asks about water softener use and purified water purchases. About 15% of households use water softeners and about half purchase purified water or use a water delivery service (see  and Table 5.14).

**Table 5.13. Does your yard contain any of the following? (Please check all that apply.)**

| Response | Number | Percent |
|---|---|---|
| Grass | 332 | 94% |
| Shade Trees | 271 | 76% |
| Domestic Pets | 176 | 50% |
| Fruit or Nut Trees | 159 | 45% |
| Vegetable Garden | 90 | 25% |
| Pool | 84 | 24% |
| Hot Tub | 35 | 9.9% |
| Chickens | 7 | 2.0% |

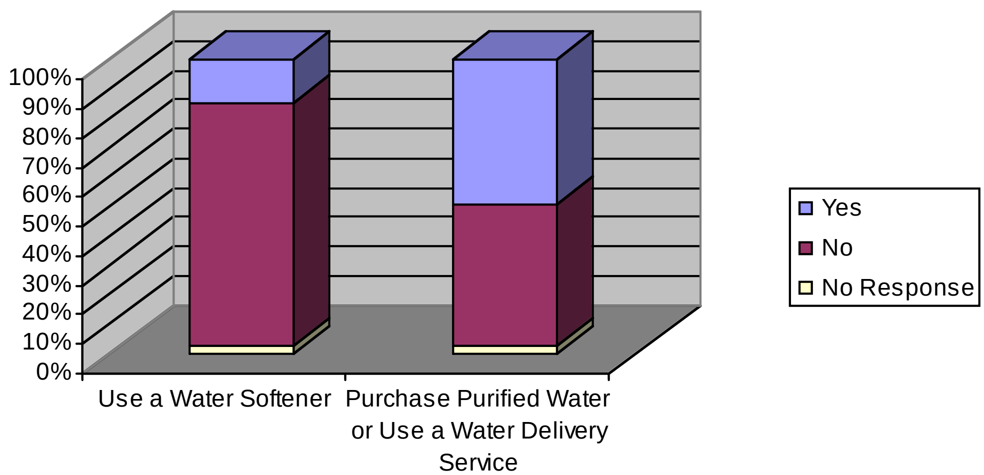


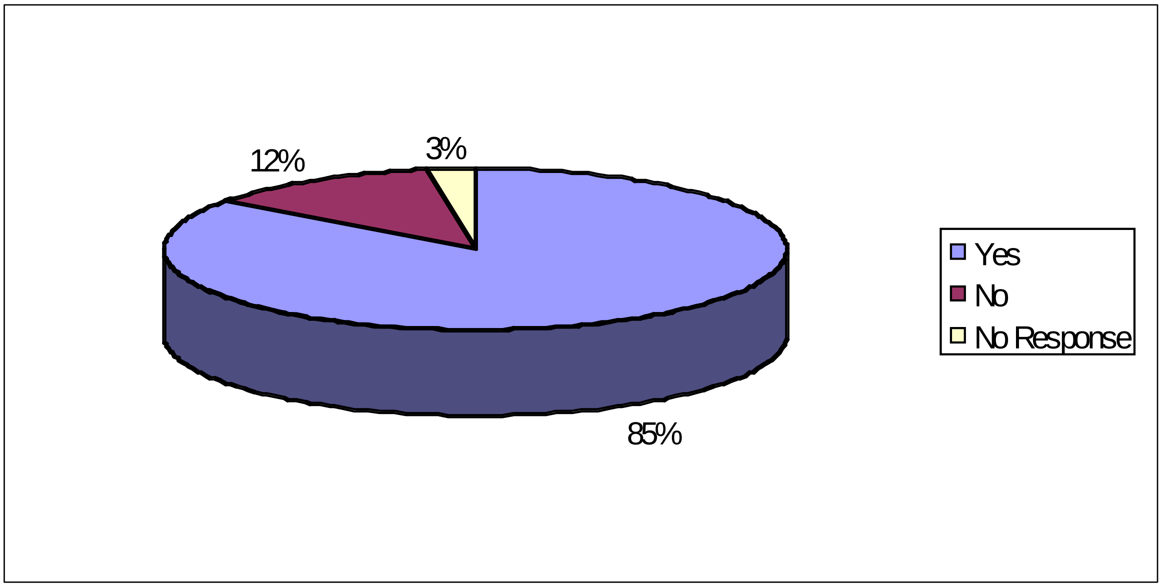

**Figure 5.4. Household Water Habits**

**Table 5.14. Tabulation of Household Water Habits**

| Response | Use a Water Softener | Purchase Purified Water or Use a Water Delivery Service |
|---|---|---|
| Yes | 57 | 192 |
| No | 321 | 186 |
| No Response | 11 | 11 |
| **Total** | **389** | **389** |

Even though half of households purchased water, 85% still indicated that they use tap water. The majority of households (69%) who use tap water, use unfiltered tap water for cooking, and 52% of tap water using households use filtered tap water for drinking ( and Table 5.15).

**Figure 5.5. Does your household use tap water for cooking or drinking?**



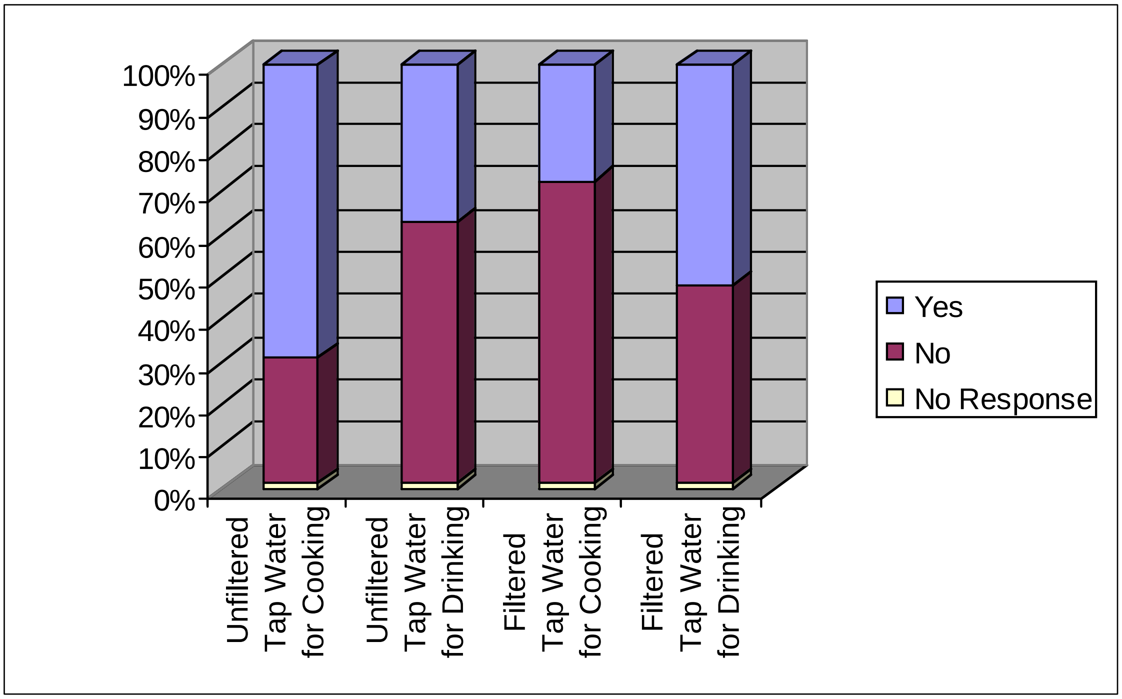



**Figure 5.6. Uses of Tap Water**

**Table 5.15. If your household uses tap water, please tell us how by checking all that apply.**

| Response | Unfiltered Tap Water | | Filtered Tap Water | |
|---|---|---|---|---|
| | Cooking | Drinking | Cooking | Drinking |
| Yes | 229 | 123 | 91 | 172 |
| No | 97 | 203 | 235 | 154 |
| No Response | 5 | 5 | 5 | 5 |
| Total | 331 | 331 | 331 | 331 |

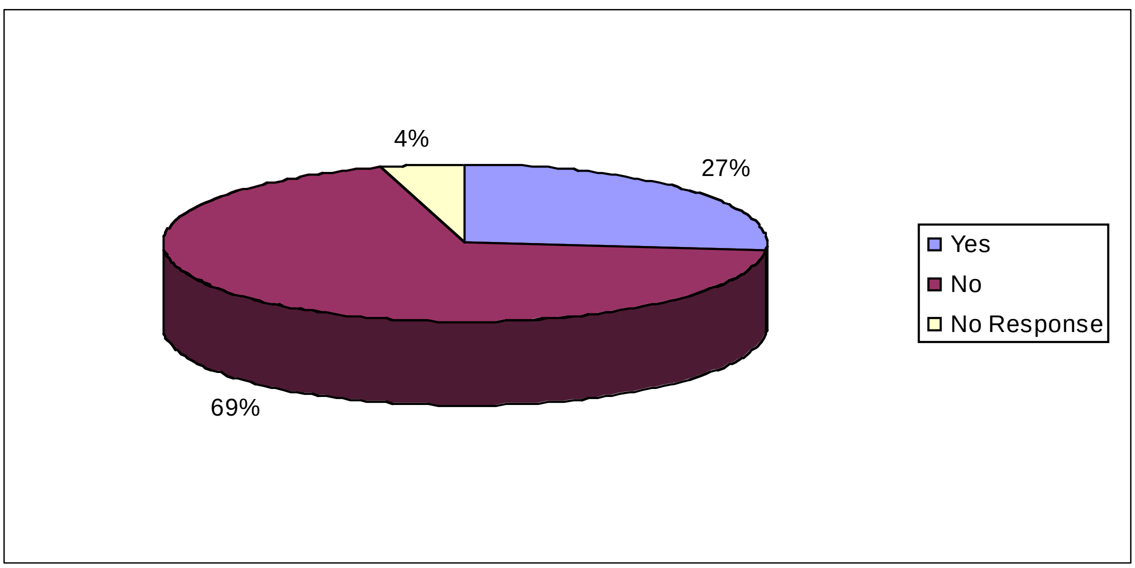
The survey then follows up with a question on the types of filters used. Forty percent said they do not use a filter, and among filters used, refrigerator mounted filters are the most common, with 35% of respondents indicating that they use them (Table 5.16).

**Table 5.16. Does your household use any of the water filters listed below? (Please check all that apply)**

| Response | Number | Percent |
|---|---|---|
| A Refrigerator Mounted Filter | 134 | 34% |
| A Sink Mounted Filter | 69 | 18% |
| A Pitcher Filter | 37 | 9.5% |
| A Reverse Osmosis Water System | 32 | 8.2% |
| No Filter | 155 | 40% |
| No Response | 13 | 3.3% |
| **Total** | **389** | **100%** |

After asking respondents about their uses of water in the home, the survey asks about outdoor recreation involving water. Twenty-seven percent indicated that during 2006, they spent some time hunting, boating, or viewing wildlife on the San Joaquin Valley floor (Figure 5.7). Wildlife viewing is the most common form of recreation among the three activities discussed. Seventeen percent of respondents participated in wildlife viewing in 2006. Twelve percent boated, and 8% hunted in the Valley in 2006 (Table 5.17).

**Figure 5.7. During 2006, did you spend any time hunting, boating, or viewing wildlife on the San**




**Joaquin Valley floor?**

**Table 5.17. Percentage of Respondents who Indicated They Participated in the Following Activities in 2006 in the San Joaquin Valley Floor**

| Response | Number | Percent |
|---|---|---|
| Hunting | 30 | 7.7% |
| Boating | 47 | 12% |
| Wildlife Viewing | 67 | 17% |

Among those who participated in hunting, boating, and wildlife viewing, the average number of days spent doing each of these activities was 11, 12, and 57 respectively (). Wildlife viewing was divided into 2 categories: viewing when viewing is the main purpose of the outing and viewing when viewing is incidental to other activities such as driving or biking along Valley roads. The majority of wildlife viewing occurs incidentally, with an average of 43 days spent viewing wildlife on outings for a different purpose. To see how far people are willing to travel for each of these activities, the survey asks how many miles the household traveled to where they hunted, boated, or viewed wildlife most often. Both hunters and boaters traveled an average of 31 miles, while wildlife viewers traveled an average of 34 miles (Table 5.18).

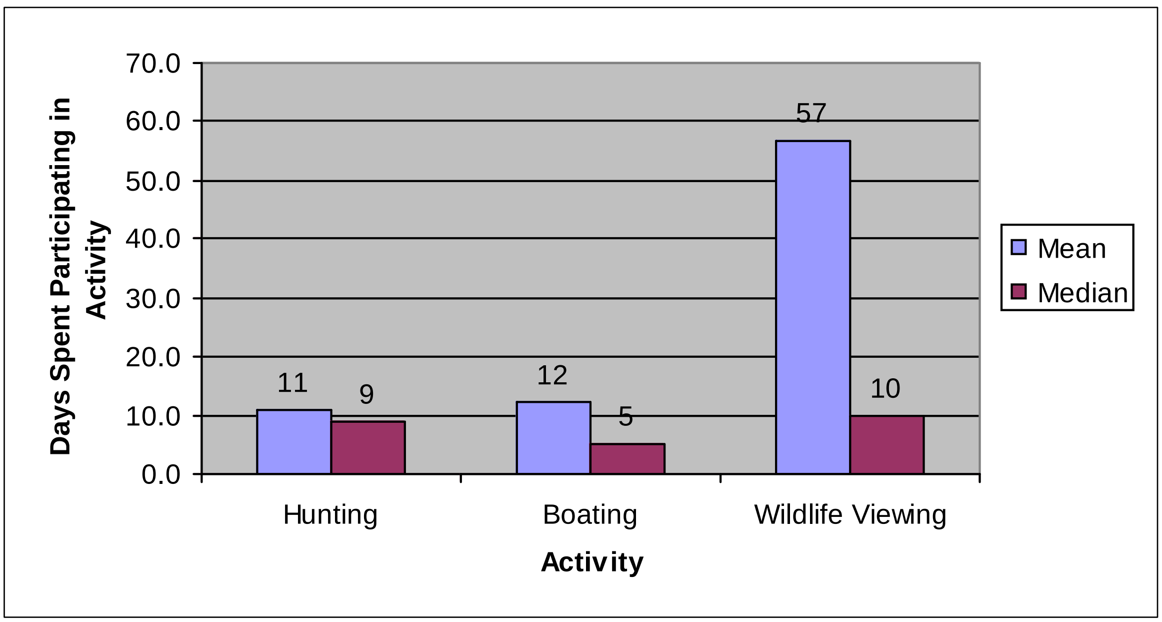



**Figure 5.8. How many days did you participate in the following activities on the San Joaquin Valley floor in 2006?**

**Table 5.18. How many miles did you travel (one-way) to where you participated in the following activities the most?**

| Response | Mean | Median |
|---|---|---|
| Hunting | 31 | 30 |
| Boating | 31 | 28 |
| Wildlife Viewing | 34 | 20 |

Of those who indicated that they hunted in 2006, the survey asks how many of each type of animal the hunter took in 2006. Most respondents just checked the type of animal instead of indicating how many. Hunters most commonly hunted doves, with 43% of hunters indicating that they took doves in 2006. Thirty percent of hunters hunted pheasants and deer (Table 5.19).

**Table 5.19. Number and Percent of Hunters Who Took Each of the Following Types of Animals in 2006**

| Response | Number | Percent |
|---|---|---|
| Doves | 13 | 43% |
| Deer | 9 | 30% |
| Pheasants | 9 | 30% |
| Squirrels | 5 | 17% |
| Ducks | 5 | 17% |
| Turkeys | 2 | 6.7% |
| Geese | 2 | 6.7% |
| Other | 5 | 17% |
| Quail | 2 | 6.7% |
| Boar | 1 | 3.3% |
| Coyote | 1 | 3.3% |
| Fish | 1 | 3.3% |
| No Response | 3 | 10.0% |

### 5.3.3 Survey Section 3: The Salinity Management Plan

The third section provides information about the causes and effects of water salinity in the San Joaquin Valley. It then discusses the steps a salinity management plan would take to stop the increase of salinity in the Valley, which would result in more land in agricultural production and wetlands, and fewer premature deaths due to air pollution, compared with having no salinity management plan in place. Finally, it informs the respondents that a surcharge on monthly water and sewer bills of businesses and households would collect funds to cover the costs of the plan.

Two response formats were used for this question, with households being assigned randomly to one or the other. In one format (the "Single Bound" surcharge), after providing information about the plan, respondents were asked if they would pay a surcharge of a specified amount. In the other (Double Bound) format, a follow-up surcharge question was asked after the first one. If they responded "yes" to the initial surcharge amount, respondents receiving this version of the question were asked if they would pay a higher amount. If they responded “no” initially, they were asked if they would be willing to pay a given lower amount. The mean values of the initial, higher, and lower surcharge amounts are shown in Table 5.20 below.

**Table 5.20. Mean Values of the Initial, High, and Low Monthly Surcharge**

| Response | Mean |
|---|---|
| Single Bound | |
| Surcharge | $16.34 |
| Double Bound | |
| Initial Surcharge | $14.58 |
| High Surcharge | $32.43 |
| Low Surcharge | $8.36 |

Among those respondents who received surveys with a single bounded question, 73% answered that they would not pay the amount given, while 6% gave no response to the question (Table 5.21).

**Table 5.21. Patterns of Responses to the Surcharge Question for Those Respondents Receiving Single Bounded Questions**

| Response | Number | Percent |
|---|---|---|
| Yes | 29 | 20% |
| No | 105 | 73% |
| No Response | 9 | 6% |
| **Total** | **143** | **100%** |

Among those respondents receiving initial and follow-up surcharge questions, 18% answered yes to the initial surcharge question. Of those who answered yes, 23% then answered yes to the higher surcharge amount. Sixty-one percent answered no to the initial surcharge question, and within this group, 13% answered yes to the lower surcharge amount. Twenty-one percent did not respond to the initial surcharge question (Table 5.22).

**Table 5.22. Patterns of Responses to the Initial and Follow-up Surcharge Questions for Those Respondents Receiving Double Bounded Questions**

| Initial Surcharge | Follow-up Surcharge | | | | No Response | Total |
|---|---|---|---|---|---|---|
| | Higher | | Lower | | | |
| | Yes | No | Yes | No | | |
| **Yes** | **10** | **30** | **-** | **-** | **4** | **44** |
| **No** | **-** | **-** | **33** | **110** | **8** | **151** |
| **No Response** | **2** | **7** | **13** | **5** | **24** | **150** |
| **Total** | | | **46** | **115** | **36** | **246** |

To those who answered "no" to the initial and lower surcharge amount (or just the initial surcharge for those receiving the Single Bound format), the survey asks if the respondent would be willing to pay any amount to fund the salinity management plan. Among those respondents receiving the single bounded question, 35% were willing to pay some amount, with the mean amount being $5.73. Among those respondents receiving the double bounded questions, 24% were willing to pay some amount, with the mean amount being $3.67 (Table 5.23).

**Table 5.23. Would you pay any amount to fund the Salinity Management Plan?**

| Response | Single Bounded | | Double Bounded | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| No (Not willing to pay anything) | 61 | 59% | 78 | 71% |
| Yes (Willing to pay something) | 36 | 34% | 26 | 24% |
| Mean amount | $5.73 | - | $3.67 | - |
| Median amount | $5.00 | - | $5.00 | - |
| No Response | 8 | 7.6% | 6 | 5.5% |
| **Total** | **105** | **100%** | **110** | **100%** |

Since different versions of the survey contain different bid levels, the responses to these different levels can be used to determine how the proportion of the sample saying "yes" (they would pay for the Salinity Management Program) varies with the surcharge they would have to pay. Table 5.24 and Table 5.25, below, show the numbers of "yes" and "no" responses received for each surcharge level respondents faced. A graphical depiction of the information in these tables can be found in and .

**Table 5.24. Responses to Different Surchage Levels by Respondents Receiving Double Bounded Questions**

| Surcharge Level | Yes | No | No Response |
|---|---|---|---|
| $3 | 12 | 11 | 5 |
| $5 | 13 | 17 | 11 |
| $6 | 5 | 7 | 3 |
| $7 | 4 | 6 | 4 |
| $8 | 14 | 25 | 9 |
| $9 | 2 | 12 | 1 |
| $10 | 11 | 20 | 7 |
| $12 | 17 | 43 | 17 |
| $14 | 11 | 46 | 8 |
| $16 | 3 | 12 | 3 |
| $18 | 3 | 15 | 2 |
| $20 | 3 | 15 | 4 |
| $22 | 4 | 29 | 8 |
| $24 | 0 | 5 | 5 |
| $25 | 3 | 15 | 3 |
| $30 | 0 | 5 | 2 |
| $37 | 1 | 6 | 0 |
| $42 | 0 | 6 | 1 |
| $48 | 1 | 2 | 1 |
| $54 | 0 | 11 | 3 |

**Table 5.25. Responses to Different Surcharge Levels by Respondents Receiving Single Bounded Questions**

| Surcharge Level | Yes | No | No Response |
|---|---|---|---|
| $10 | 4 | 13 | 4 |
| $12 | 6 | 13 | 2 |
| $16 | 4 | 17 | 2 |
| $18 | 7 | 20 | 0 |
| $20 | 7 | 43 | 1 |

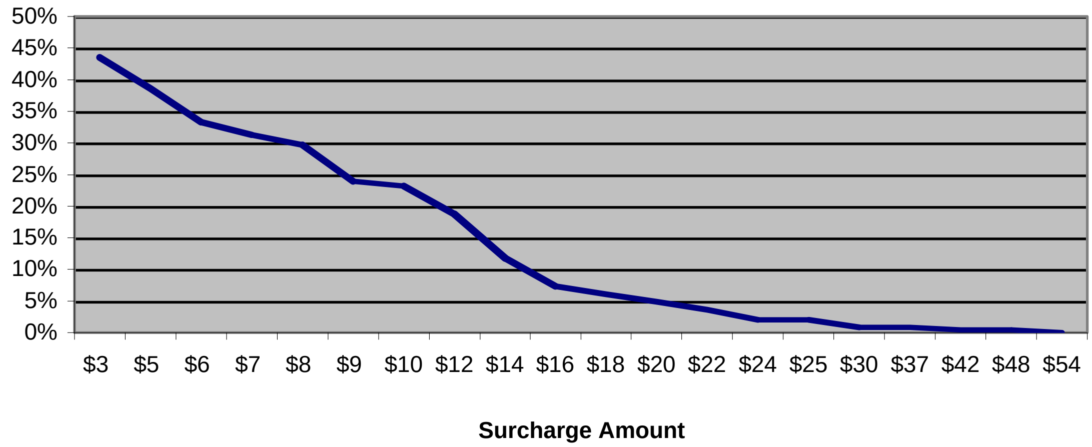



**Figure 5.9. Proportion of Respondents Saying They Would Pay the Surcharge, by Surcharge Level (Double Bound Version)**

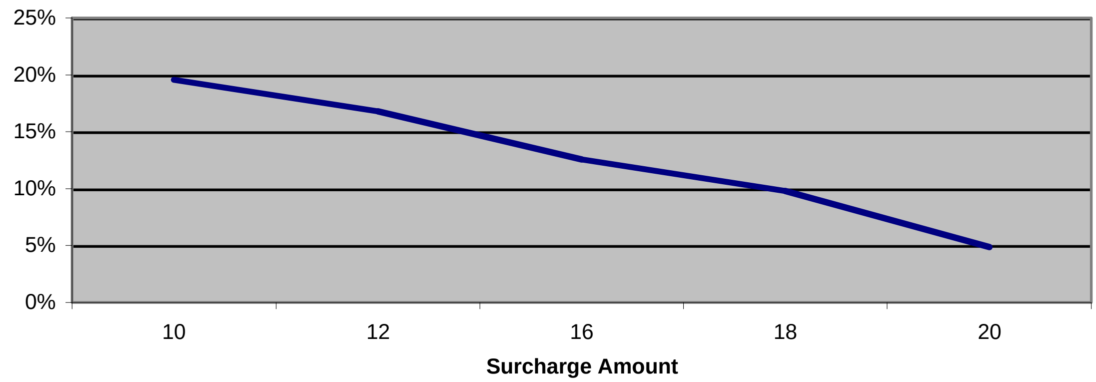



**Figure 5.10. Proportion of Respondents Saying They Would Pay the Surcharge, by Surcharge Level (Single Bound Version)**

If the respondent indicated that they are not willing to pay any amount to fund the salinity management plan, the survey asks why they are not willing to pay anything. Twenty-six percent of respondents are not willing to pay any amount because they do not believe they receive any benefit from the plan (Table 5.26), while 19% indicate that it is more important to spend their money on other things, and 16% say the government should not be involved in reducing salinity. Forty percent of respondents chose “other” and wrote in reasons. Almost half of these written-in reasons made reference to low incomes or high expenses or qualms about the government. If these responses are added to those who believe “it’s more important to spend my money on other things” or that “the government shouldn’t be involved in reducing salinity,” the percentages for these categories increase to 32.5% and 21.7%, respectively.

**Table 5.26. Why were you not willing to pay any amount to fund the Salinity Management Plan?**

| Response | Number | Percent |
|---|---|---|
| I don't feel I get any benefit from this plan. | 40 | 26% |
| It's more important to spend my money on other things. | 30 | 19% |
| The government shouldn't be involved in reducing salinity. | 26 | 17% |
| Other | 63 | 40% |
| No Response | 16 | 10% |

### 5.3.4 Survey Section 4: Would Your Activities Change?

After discussing the possible steps needed to reduce salinity, the survey discusses what will happen to wildlife if no action is taken. It then asks how households' outdoor activities would change if the populations of animals hunted and viewed decreased. Four formats were used. Each format contained a scenario with either a 20% or 30% decrease in hunting success rates and a scenario with either a 35% or 50% decrease in number of birds and wildlife viewed (Table 5.27).

**Table 5.27. Levels of Hunting Success Rate and Birds and Wildlife Viewing Decreases**

| Format | Success Rate Decrease | Viewed Wildlife Decrease |
|---|---|---|
| 1 | 20% | 35% |
| 2 | 30% | 35% |
| 3 | 20% | 50% |
| 4 | 30% | 50% |

Nineteen respondents who indicated that they hunt or view wildlife in the Valley received surveys with formats 1 and 3. Fifty-eight who hunted or viewed wildlife received surveys containing formats 2 and 4. Of those facing a 20% decrease in success rates, 58% said the number of days they hunted would not have changed. One person responded that they would hunt more, and no one said they would hunt less. Of those facing a 30% decrease in success rates, 53% said the number of days they hunted would not change, while 12% said they would hunt less, and 5% said they would hunt more (Table 5.28).

**Table 5.28. If success rates for the species you hunted in 2006 dropped by the percent shown below, would you change the number of days you spent hunting on the San Joaquin Valley floor?**

| Decrease in Hunting Success Rate | Number | Percent |
|---|---|---|
| 20% | | |
| More | 1 | 5.3% |
| Less | 0 | 0.0% |
| No Change | 11 | 58% |
| No Response | 7 | 37% |
| 30% | | |
| More | 3 | 4.9% |
| Less | 7 | 12% |
| No Change | 32 | 53% |
| No Response | 19 | 31% |

The survey asked a similar question about wildlife viewing. Among those who faced a 35% decrease in numbers, 78% said they would not change the number of days they viewed wildlife, while 9% said they would spend more days viewing, and 9% said they would spent fewer days viewing. Of those respondents facing a 50% decrease, 69% said they would not change the number of days they viewed, 9% said they would view more, and 11% said they would view less (Table 5.29).

**Table 5.29. If the number of birds and wildlife you viewed on outings in 2006 dropped by the percent shown below, would you change the number of days you spent viewing on the San Joaquin Valley floor.**

| Decrease in Successful Viewing Rate | Number | Percent |
|---|---|---|
| 35% | | |
| More | 4 | 8.9% |
| Less | 4 | 8.9% |
| No Change | 35 | 78% |
| No Response | 2 | 4.4% |
| 50% | | |
| More | 3 | 8.6% |
| Less | 4 | 11% |
| No Change | 24 | 69% |
| No Response | 4 | 11% |

### 5.3.5 Survey Section 5: What Policy Choices Would You Make?

This section of the survey sought to determine which salinity effects Valley residents feel most strongly. In this section, respondents were presented with a series of comparisons between two different salinity management plans, as well as the option of doing nothing to manage salinity, and the expected consequences of each. The expected consequences were different levels of land in agricultural production, land in seasonal and permanent wetlands, and air quality effects measured in deaths per year. Each salinity management plan also had a monthly cost to the household, while doing nothing costs nothing (Table 5.30). Depending on the version of the survey received, households were presented with either 3 or 5 of these comparisons between two alternative salinity plans and doing nothing. The respondent was then asked to choose their most preferred option in each comparison.

In total, the surveys contained 9 different comparisons between salinity management plans (though no one person received more than 5). Table 5.31 below shows the attribute levels for each plan and the number of people preferring that plan. The percent preferring that plan is the portion that chose a given plan among those who were asked to make the comparison.

**Table 5.30. Attribute Levels for the Salinity Management Plan Comparisons**

| Level | Land in Agricultural Production | Land in Seasonal and Permanent Wetlands | Air Quality Effect | Price |
|---|---|---|---|---|
| Lowest | *1,900,000 acres*[a] | *24,000 acres* | - | *$0/month* |
| Low | 2,100,000 acres | 57,000 acres | 8,900 deaths/year | $9/month |
| Medium | 2,300,000 acres | 88,000 acres | 9,500 deaths/year | $15/month |
| High | 2,600,000 acres | 112,000 acres | 10,100 deaths/year | $28/month |
| Highest | - | - | *10,900 deaths/year* | - |

[a] Italicized levels are the best estimates of what would happen with no Salinity Management Plan.

**Table 5.31. Results of the Comparison between Salinity Management Plans**

| Com-parison | Plan | Land in Agricultural Production | Land in Seasonal and Permanent Wetlands | Air Quality Effect | Price | Number Preferring | Percent Preferring |
|---|---|---|---|---|---|---|---|
| 1 | A | High | High | High | Low | 79 | 39% |
| | B | Medium | Low | Medium | High | 19 | 9.5% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 55 | 27% |
| | No Response | | | | | 48 | 24% |
| 2 | A | High | Low | Low | Low | 90 | 39% |
| | B | Low | High | Medium | Medium | 23 | 10% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 67 | 29% |
| | No Response | | | | | 50 | 22% |
| 3 | A | High | Medium | High | Medium | 73 | 33% |
| | B | Low | High | Medium | High | 24 | 11% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 76 | 34% |
| | No Response | | | | | 50 | 22% |
| 4 | A | Low | Low | Low | High | 31 | 14% |
| | B | High | Medium | High | Low | 71 | 32% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 69 | 31% |
| | No Response | | | | | 49 | 22% |
| 5 | A | Low | Medium | High | Medium | 19 | 11% |
| | B | Medium | Low | Medium | Low | 69 | 42% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 46 | 28% |
| | No Response | | | | | 32 | 19% |
| 6 | A | Low | Medium | Medium | High | 8 | 4.8% |
| | B | Medium | High | Low | Low | 81 | 49% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 39 | 24% |
| | No Response | | | | | 38 | 23% |
| 7 | A | Medium | Low | Low | Medium | 67 | 40% |
| | B | Low | High | High | High | 7 | 4.1% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 52 | 31% |
| | No Response | | | | | 43 | 25% |
| 8 | A | Medium | Medium | Low | Low | 44 | 39% |
| | B | High | High | High | Medium | 11 | 9.8% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 29 | 26% |
| | No Response | | | | | 28 | 25% |
| 9 | A | Medium | Medium | Medium | High | 11 | 6.7% |
| | B | High | Low | Low | Medium | 63 | 38% |
| | No Plan | Lowest | Lowest | Highest | Lowest | 52 | 32% |
| | No Response | | | | | 38 | 23% |

### 5.3.6 Survey Section 6: About You

The final section contains demographic questions whose purpose is to understand in what ways the survey respondents are similar to and differ from the populations of the San Joaquin Valley and California as a whole. This section begins by asking respondents their gender. Sixty-four percent are male, 33% are female, and 3% did not respond to this question (). Next, respondents are asked their age. Twenty-two percent were aged fifty-one to sixty years. Ages ranged from 18 to 89 years. The average age was 54.6 and the median age was 54.

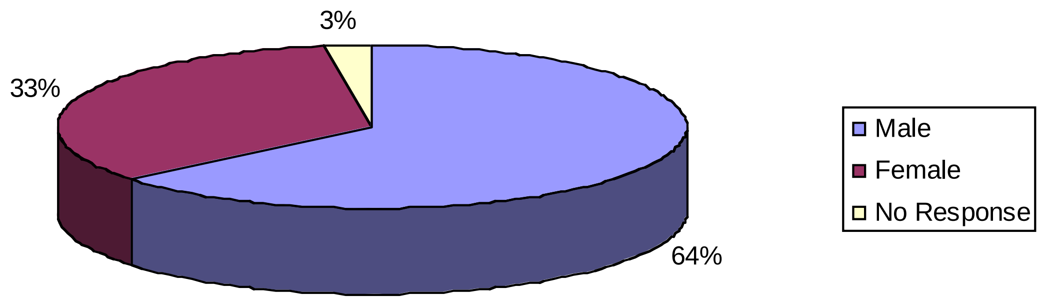



**Figure 5.11. What is your gender?**

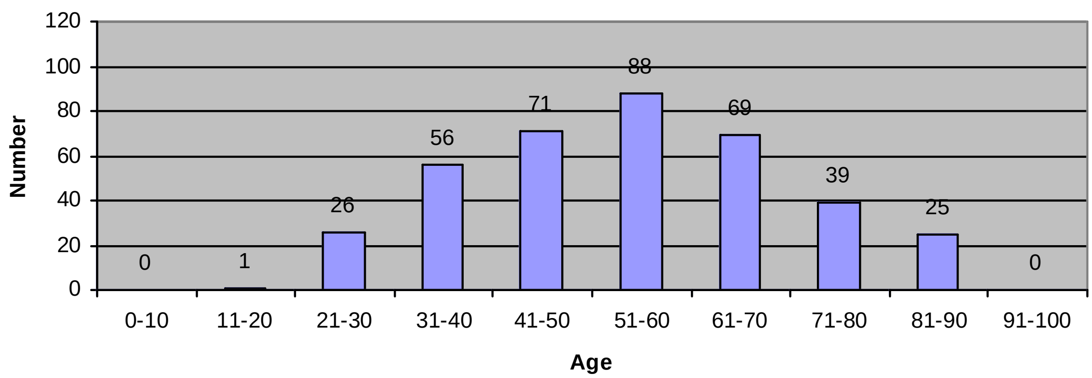



**Figure 5.12. What is your age?**

Next, respondents are asked how long they have lived in the San Joaquin Valley. Responses ranged from 0 to 85 years with a mean length of 33.7 years and median length of 33 years. While the age distribution is clearly unimodal and relatively symmetric, the length of San Joaquin residency distribution is bimodal and asymmetric ().

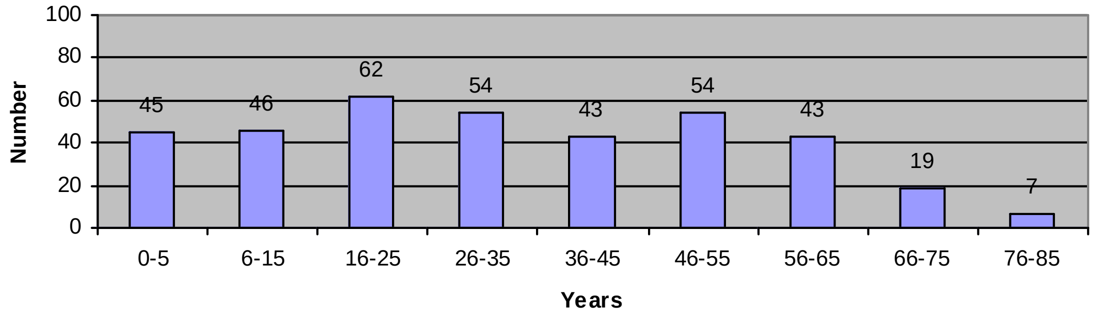



**Figure 5.13. How long have you lived in the San Joaquin Valley?**

Following the question on residency, the survey asks about tenancy. The majority of households, 77%, own their current residence, while 18% rent and 5% did not respond to this question ().

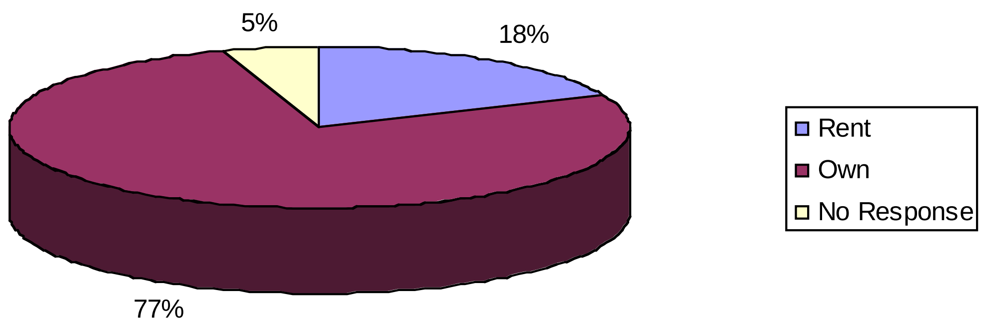



**Figure 5.14. Do you rent or own your current residence?**

The survey then asks what languages are spoken at home. Eighty-nine percent speak English at home, while 19% speak Spanish and 6% speak a language other than English or Spanish (Table 5.32).

**Table 5.32. What languages are spoken in your household? (Please check all that apply.)**

| Language | Number | Percent |
|---|---|---|
| English | 347 | 89% |
| Spanish | 73 | 19% |
| Other | 22 | 5.7% |
| Portuguese | 5 | 1.3% |
| Hmong | 3 | 0.8% |
| Chinese | 2 | 0.5% |
| Pilipino | 2 | 0.5% |
| Tagalog | 2 | 0.5% |
| Armenian | 1 | 0.3% |
| Cherokee | 1 | 0.3% |
| Italian | 1 | 0.3% |
| Japanese | 1 | 0.3% |
| Laos | 1 | 0.3% |
| Norwegian | 1 | 0.3% |
| Vietnamese | 1 | 0.3% |
| No Response | 12 | 3.1% |

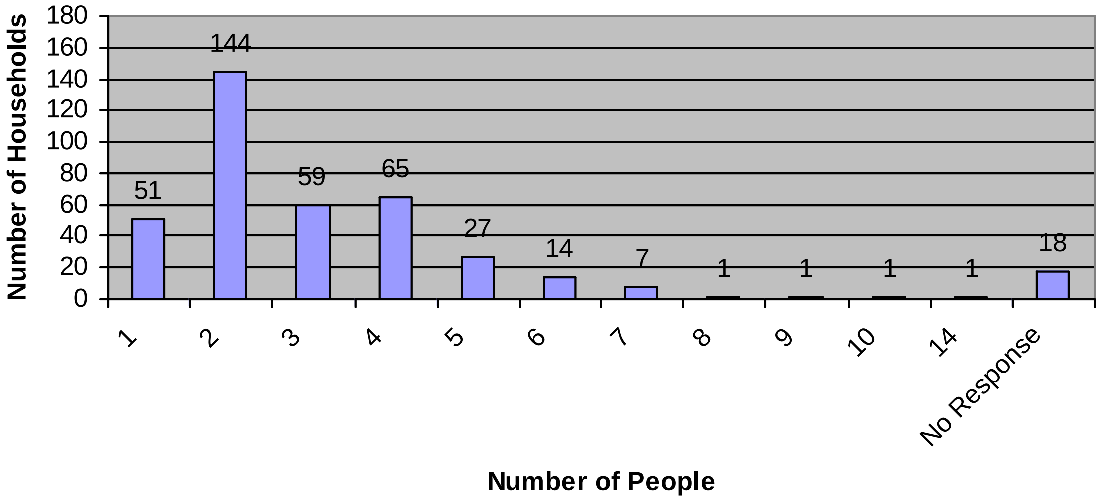
Also in this section, the survey asks about education completed. Thirty-five percent of respondents have at least a college degree. Four percent of respondents chose not to answer this question (Table 5.33).

**Table 5.33. How many years of schooling have you completed? (Please check the highest level completed.)**

| Level of Schooling | Number | Percent |
|---|---|---|
| Elementary (K-8) | 28 | 7.2% |
| High School | 91 | 23% |
| Some College | 116 | 30% |
| College | 81 | 21% |
| Post-College | 56 | 14% |
| No Response | 16 | 4.1% |
| **Total** | **389** | **100%** |

To learn about household size and composition, the survey asks respondents how many people live in their households and then how many people fall into various age categories. About half of all households contain 1 or 2 members. Thirty-two percent contain 3 or 4 members, and 7% contain 5 or more members (Figure 5.15).

**Figure 5.15. Including yourself, how many people currently live in your household?**




Sixty-three percent of households contain at least 1 member who is between the ages of 19 and 59. Thirty percent contain children between the ages of 6 and 18, and 18% contain children under 6 years of age. There was a relatively high non-response rate of 11% for this question (Table 5.34).

**Table 5.34. Age Distribution within Households**

| Age Distribution | Number of households | Percent of households | Mean Number (among households with members in this category) | Median Number |
|---|---|---|---|---|
| Children under 6 | 68 | 18% | 1.4 | 1.0 |
| Children Ages 6-18 | 117 | 30% | 1.8 | 2.0 |
| Ages 19-59 | 243 | 63% | 2.0 | 2.0 |
| Over Age 60 | 142 | 37% | 1.5 | 2.0 |
| No Response | 43 | 11% | | |

Since health problems are among the effects of salinity, the survey asks about common health issues. Forty six percent of respondents report suffering from allergies and 39% take blood pressure medication. Nineteen percent have asthma and use an inhaler. Seventeen percent of households reported not suffering from many of the mentioned health problems (Table 5.35).

**Table 5.35. Below are some common health problems. (Please check all that apply to your household.)**

| Ailment | Number | Percent |
|---|---|---|
| Has allergies | 176 | 45% |
| Takes blood pressure medication | 151 | 39% |
| Uses an inhaler | 74 | 19% |
| Has asthma | 74 | 19% |
| Smokes tobacco | 64 | 17% |
| Has heart disease | 63 | 16% |
| Has hypertension | 45 | 12% |
| Suffers from chronic bronchitis | 14 | 3.6% |
| Has none of the above health | 67 | 17% |
| No Response | 21 | 5.4% |

Following this question, the survey asks about the number of people in the household working for pay. Sixty percent of households had 1 or 2 people working, while 20% had no one working (Table 5.36).

**Table 5.36. How many people in your household work for pay?**

| Number of Household Members | Number | Percent |
|---|---|---|
| 0 | 78 | 20% |
| 1 | 125 | 32% |
| 2 | 109 | 28% |
| 3 | 26 | 6.7% |
| 4 | 7 | 1.8% |
| 5 | 2 | 0.5% |
| No Response | 42 | 11% |
| **Total** | **389** | **100%** |

Finally, the survey asks what the household's annual income was before taxes in 2006. Twelve percent of households chose not to answer this question. Twenty percent of respondents made less than $25,000, while another 20% made $95,000 or more ().

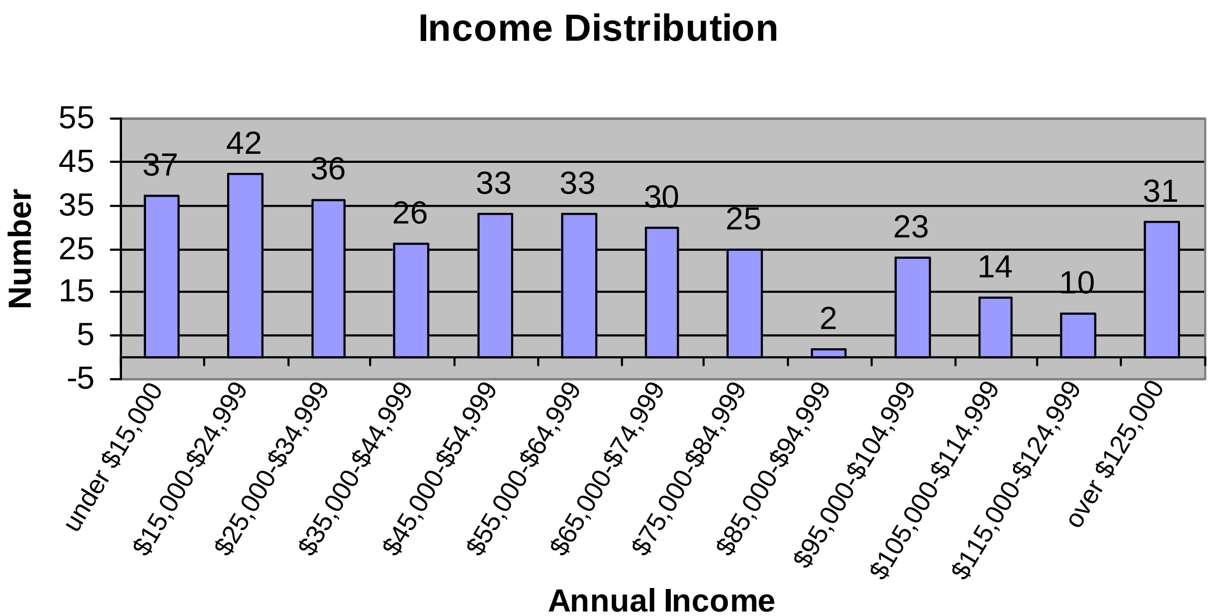



**Figure 5.16. What was your total annual household income last year (before taxes)?**

One hundred forty of the surveys received had a box that respondents could check if they wished to receive the survey results, while 245 did not contain the box. Instead, respondents receiving this latter group of surveys were instructed in the cover letter to write "Survey Results Requested" on their survey if they wished to receive results. Fifty-three percent of respondents receiving a survey with a box to check requested results while only 7% of those without a box requested results (Table 5.37).

**Table 5.37. Results Requested by Survey Type**

| Availability of Check Box | Number | Percent |
|---|---|---|
| Box Available to Check | 75 | 53% |
| No Box Available | 16 | 6.5% |
| **Total** | **91** | **23%** |

### 5.3.7 Descriptive Statistics for the Willingness to Pay Analysis

The principal variables used in the contingent valuation analysis are summarized in Table 5.38 (all observations) and Table 5.39 (observations used in the empirical analysis). Table 5.38 provides a broader look at the sample of people whose information is used in the analysis, and identifies the item nonresponse for each variable (the column labeled Missing). The variable definitions are:

- **Rural, North, Central**—refer to the region of the San Joaquin Valley the respondent lives in and give the proportion residing in each;
- **Hispanic, English, OthLang**—refer to the main language spoken at home, and give proportions of each;
- **Hhsize, Hhu6, Hh618, Hh1959, Hho59**—refer to total household size and the number of members under 6 years of age, 6 to 18, 19 to 59, and over 59, respectively;
- **Female**—refers to a dummy variable with the value 1 if respondent is female, 0 otherwise;
- **Age**—refers to respondent age, in years;
- **SJVR**—refers to the number of years respondent has been a San Joaquin Valley resident;
- **Rent—**refers to a dummy variable taking the value 1 if respondent rents their home, 0 otherwise;
- **Asthma, Smokes, Blood Pressure, Hypertension, Allergy, Bronchitis, Inhaler**—refers to dummy variables taking the value 1 if respondent said one or more people in the household suffered from these symptoms;
- **Workers**—refers to the number of wage-earners in the household;
- **Income**—refers to household income before taxes;
- **Dblbound—**refers to a dummy taking the value 1 if the double-bound format was used, 0 otherwise;
- **Elementary, High school, Some college, College, Post-college—**refer to the highest level of education completed by the respondent, and are dummy variables taking the value 1 if that level is the highest completed, 0 otherwise;
- **Ed45—**refers to a dummy variable taking the value 1 if respondent has completed college or more;
- **Edu**—refers to the number of years of schooling, assigning 10 for elementary, 12 for high school, 14 for some college, 16 for college, 18 for post-college;
- **Health**—refers to the number of health symptoms reported for the household;
- **Health2**—refers to a dummy variable taking the value 1 if the household reported at least one symptom, 0 otherwise;
- **Ncent—**refers to a dummy variable taking the value 1 if respondent lives in northern or central San Joaquin Valley, 0 otherwise.
-

Table 5.38. Descriptive Statistics for the Willingess to Pay Sample

| Variable | Mean | Standard Deviation | Minimum | Maximum | Valid | Missing |
|---|---|---|---|---|---|---|
| Rural | 0.3657 | 0.4823 | 0 | 1 | 391 | 0 |
| North | 0.3606 | 0.4808 | 0 | 1 | 391 | 0 |
| Central | 0.3325 | 0.4717 | 0 | 1 | 391 | 0 |
| South | 0.3069 | 0.4618 | 0 | 1 | 391 | 0 |
| Hispanic | 0.1893 | 0.3922 | 0 | 1 | 391 | 0 |
| English | 0.9208 | 0.2703 | 0 | 1 | 379 | 12 |
| Spanish | 0.1926 | 0.3949 | 0 | 1 | 379 | 12 |
| OthLang | 0.0580 | 0.2341 | 0 | 1 | 379 | 12 |
| Hhsize | 2.9223 | 1.6303 | 1 | 14 | 373 | 18 |
| Hhu6 | 0.2686 | 0.6121 | 0 | 4 | 350 | 41 |
| Hh618 | 0.6257 | 1.0571 | 0 | 6 | 350 | 41 |
| Hh1959 | 1.3966 | 1.1801 | 0 | 8 | 348 | 43 |
| Hho59 | 0.6254 | 0.8176 | 0 | 3 | 347 | 44 |
| Female | 0.3412 | 0.4747 | 0 | 1 | 381 | 10 |
| Age | 54.6592 | 15.8936 | 18 | 89 | 377 | 14 |
| SJVRes | 33.6373 | 21.3783 | 0 | 85 | 375 | 16 |
| Rent | 0.2016 | 0.4017 | 0 | 1 | 372 | 19 |
| Asthma | 0.2000 | 0.4005 | 0 | 1 | 370 | 21 |
| Smokes | 0.1730 | 0.3787 | 0 | 1 | 370 | 21 |
| Blood pressure | 0.4108 | 0.4926 | 0 | 1 | 370 | 21 |
| Hypertension | 0.1216 | 0.3273 | 0 | 1 | 370 | 21 |
| Allergy | 0.4784 | 0.5002 | 0 | 1 | 370 | 21 |
| Heart disease | 0.1703 | 0.3764 | 0 | 1 | 370 | 21 |
| Bronchitis | 0.0378 | 0.1911 | 0 | 1 | 370 | 21 |
| Inhaler | 0.2000 | 0.4005 | 0 | 1 | 370 | 21 |
| Workers | 1.3238 | 1.0035 | 0 | 5 | 349 | 42 |
| Income | 61,795 | 43,447 | 7,500 | 160,000 | 344 | 47 |
| Dblbound | 0.6292 | 0.4836 | 0 | 1 | 391 | 0 |
| Elementary | 0.0716 | 0.2582 | 0 | 1 | 391 | 0 |
| High school | 0.2353 | 0.4247 | 0 | 1 | 391 | 0 |
| Some college | 0.2992 | 0.4585 | 0 | 1 | 391 | 0 |
| College | 0.2072 | 0.4058 | 0 | 1 | 391 | 0 |
| Post-college | 0.1432 | 0.3507 | 0 | 1 | 391 | 0 |
| Ed45 | 0.3504 | 0.4777 | 0 | 1 | 391 | 0 |
| Edu | 14.240 | 2.3239 | 10 | 18 | 374 | 17 |
| Health | 1.6957 | 1.3912 | 0 | 6 | 391 | 0 |
| Health2 | 0.7724 | 0.4198 | 0 | 1 | 391 | 0 |
| Ncent | 0.6931 | 0.4618 | 0 | 1 | 391 | 0 |

Table 5.39 summarizes the values of the main variables examined in the willingness to pay analysis, after observations containing missing values were deleted. One of the principal reasons that observations were dropped was missing household income (47 missing values), which is fairly typical.

**Table 5.39. Descriptive Statistics for the Estimation Sample**

| Variable | Mean | Standard Deviation | Minimum | Maximum | Valid | Missing |
|---|---|---|---|---|---|---|
| Rural | 0.3432 | 0.4755 | 0 | 1 | 338 | 0 |
| North | 0.3432 | 0.4755 | 0 | 1 | 338 | 0 |
| Central | 0.3254 | 0.4692 | 0 | 1 | 338 | 0 |
| South | 0.3314 | 0.4714 | 0 | 1 | 338 | 0 |
| Hispanic | 0.1864 | 0.3900 | 0 | 1 | 338 | 0 |
| Female | 0.3402 | 0.4745 | 0 | 1 | 338 | 0 |
| Income | 62,374 | 43,536 | 7,500 | 160,000 | 338 | 0 |
| Elementary | 0.0769 | 0.2669 | 0 | 1 | 338 | 0 |
| High School | 0.2396 | 0.4275 | 0 | 1 | 338 | 0 |
| Ed3 | 0.3077 | 0.4622 | 0 | 1 | 338 | 0 |
| Ed4 | 0.2160 | 0.4121 | 0 | 1 | 338 | 0 |
| Ed5 | 0.1598 | 0.3669 | 0 | 1 | 338 | 0 |
| Ed45 | 0.3757 | 0.4850 | 0 | 1 | 338 | 0 |
| Educ | 14.2840 | 2.3548 | 10 | 18 | 338 | 0 |
| Health | 1.7751 | 1.3704 | 0 | 6 | 338 | 0 |
| Health2 | 0.8018 | 0.3993 | 0 | 1 | 338 | 0 |
| Ncent | 0.6686 | 0.4714 | 0 | 1 | 338 | 0 |

### 5.3.8 Contingent Valuation Analysis

In this section of the survey, the salinity management program is described in detail, and the respondents are asked either one (single bound) or two (double bound) questions about their willingness to pay for the program. About 63% of the sample received the double bound format and 37% received the single bound. The empirical estimation method is maximum likelihood, and seeks to maximize the probability that the pattern of yes and no responses actually observed is predicted by the model of a consumer’s willingness to pay.

Appendix C contains the detailed derivation of the probability statements used in the maximum likelihood estimation of response probabilities. For single bound respondents, a dichotomous choice model is used. For double bound respondents, two related but different models are estimated, the double bounded d choice model and the bivariate probit model.

### 5.3.9 Estimation Results from the Contingent Valuation Analysis

The explanatory factors expected to be important in explaining the contingent valuation willingness to pay responses were expected to be: household income, with a positive (+) sign; number of health problems in the household (+), female gender of respondent (+), Rural (-), Hispanic (-), Education (+), presence of health-sensitive people in the household (+), and geographic location (no clear sign).

The estimation results for the single bound/double bound dichotomous choice model are given in Table 5.40. The signs on individual coefficients conform largely to *a priori* expectations. *Edu*, *Female*, and *Health* had a positive and statistically-significant signs, while *Hispanic* had the expected negative sign. In addition, the geographic variable *North* was significant with a positive sign. Variables addressed at differences in respondents' attitudes toward agriculture relative to the environment (*ProAg*, the difference between Likert scale (1-5) ratings of the importance of agriculture and the importance of the environment) and presence of young children or older adults in the household (*Hhu6)* were not significant. Several covariates were included as shifters of the standard error of *wtp*, but only one (North) played any appreciable role.

Predictions of willingness to pay for the Salinity Management Plan specified in the contingent valuation come from substituting the parameter estimates from Table 5.41 into the wtp expression given earlier, applied to each person in the sample given the level of their covariates. Since measuring a respondent's willingness to pay for the plan is of interest, a negative wtp is taken to mean the respondent would not pay anything for the plan. The results, averaged across the sample, are given in Table 5.41.

About 53% of the sample had positive willingness to pay for the Salinity Management Plan, and the mean payment per month from this group was $5.90. Averaged across the whole sample, including those not willing to pay, the mean *wtp* was $3.14/month.

The single bound dichotomous choice/bivariate probit double bound model results are presented in Table 5.42. Qualitatively, the results are similar to the previous model, though there are some differences in what is statistically significant. Two sets of coefficient estimates are generated for the bivariate probit part of the model, pertaining to the two *wtp* equations. The covariates of $wtp_2$ are defined as differences from their counterparts in $wtp_1$, but none of these was significant, beyond the constant term ($C_2$) and the standard error ($\sigma_2$). The correlation between $wtp_1$ and $wtp_2$ was moderate (0.31), and not statistically significant.

**Table 5.40. Single/Double Bound Dichotomous Choice Estimates of Willingness to Pay for a Salinity Management Plan**

| Variable | Coefficient | Standard Deviation |
|---|---|---|
| ***Mean of WTP*** | | |
| Constant | -31.0024** | (10.7748) |
| RURAL1 | -3.5714 | (3.0046) |
| EDU | 1.7422** | (0.6566) |
| INC | 0.0302 | (0.0272) |
| NORTH | 5.5200* | (3.0641) |
| FEMALE | 5.2833** | (2.1029) |
| HISPANIC | -6.0242* | (3.3318) |
| PROAG | -0.7315 | (1.8475) |
| HEALTH | 1.8662** | (0.7738) |
| HHU6 | -0.0026 | (0.0031) |
| ***Standard Error of WTP*** | | |
| C1 | 3.5014** | (0.5261) |
| RURAL | -0.1461 | (0.2345) |
| EDU | -0.0568 | (0.0357) |
| INCOME | 0.0347 | (0.0243) |
| NORTH | -0.4619** | (0.2346) |
| Log L | -258.6 | - |
| Number of cases | 322 | - |

* Significant at the 10% level
** Significant at the 5% level, one-tailed test

**Table 5.41. Estimated Willingness to Pay for a Salinity Management Plan: Contingent Valuation Results ($/month)**

| Variable | Mean | Standard Deviation | Minimum | Maximum | Number |
|---|---|---|---|---|---|
| *Wtp\|wtp*>0 | 5.90 | 4.05 | 0.04 | 18.02 | 171 |
| *Wtp* (full sample) | 3.14 | 4.17 | 0.00 | 18.02 | 322 |

**Table 5.42. Single/Double Bound Dichotomous Choice Estimates of Willingness to Pay for a Salinity Management Plan**

| Variable | Coefficient Estimate | Standard Deviation |
|---|---|---|
| ***First wtp Equation*** | | |
| **Constant$_1$** | **-13.4444** | **(8.6352)** |
| **RURAL1** | **-2.3706** | **(1.8532)** |
| **ED451** | **3.1031*** | **(1.8441)** |
| **INC1** | **0.0491**** | **(0.0230)** |
| **NCENT1** | **3.2581*** | **(1.8939)** |
| **FEMALE1** | **3.2183*** | **(1.8121)** |
| **HISPANIC1** | **-2.4169** | **(2.4471)** |
| **HEALTH1** | **1.4009**** | **(0.6575)** |
| ***Second wtp Equation*** | | |
| **Constant$_2$** | **10.7964*** | **(6.2432)** |
| ***Standard Errors*** | | |
| $\sigma_1$ | **2.8891**** | **(0.3337)** |
| $\sigma_2$ | **-0.7409**** | **(0.3066)** |
| ***Correlation*** | | |
| $\rho$ | **0.6617** | **(0.4844)** |
| **Log L** | **-205.9** | **-** |
| **Number of cases** | **338** | **-** |

*** Significant at the 10% level**
**** Significant at the 5% level, one-tailed test**

As with the single/double bound dichotomous choice model, the willingness to pay estimates are generated for each person in the sample using their covariates and the coefficients from Table 5.42, with negative values taken to mean zero *wtp* for the salinity management plan. As there are two *wtp* equations, there are two *wtp* estimates, corresponding to responses to the first and second questions, respectively (Table 5.43). There is a substantial literature on why the first and second equation estimates of *wtp* are often different in bivariate probit models, but this goes beyond our purpose here. A practical solution is to take the mean of the two sets of estimates, which would imply a willingness of approximately $3.28 per month averaged across the whole sample.

**Table 5.43. Estimated Willingness to Pay for a Salinity Management Plan: Contingent Valuation Results ($/month)**

| Variable | Mean | Standard Deviation | Minimum | Maximum | Number |
|---|---|---|---|---|---|
| $wtp_1 \mid wtp_1 > 0$ | **2.30** | **2.16** | **4.67** | **9.04** | **48** |
| $wtp_2 \mid wtp_2 > 0$ | **6.85** | **3.86** | **14.86** | **19.83** | **312** |
| $wtp_1$ **(full sample)** | **0.32** | **1.13** | **1.28** | **9.04** | **338** |
| $wtp_2$ **(full sample)** | **6.24** | **4.17** | **17.40** | **19.83** | **338** |

### 5.3.10 Choice Experiments Analysis

The choice experiments involve a best choice of salinity management program from 3 alternatives. The standard models for estimation are logit models, of which there are two common types. Standard logits explain the probability of choosing a particular alternative as a function of the attributes of the alternative and demographics of the chooser. A well-known limitation of standard logits is that the ratio of the probabilities of choosing any two alternatives is independent of the presence or absence of other alternatives (also known as independence of irrelevant alternatives). The nested logit model relaxes this assumption by presuming there is a hierarchy of choice among attributes. While the choice of how alternatives nest matters in the nested logit, and can seem arbitrary in settings where there is a large number of attributes, there is a clear nesting structure in the present setting. Two of the alternatives (Plan A and Plan B) are clear departures from the status quo (No Plan), so it is natural to presume that the respondent first decides whether or not to choose a new salinity management plan (A or B), and then to choose which between A and B s/he prefers. The nested logit model encompasses the standard logit as a special case, so it is straightforward to test whether the nested or standard logit provides a better fit to the data.

The logit framework is slightly different from the contingent valuation framework, in that it begins with the respondent's indirect utility function (rather than willingness to pay) as a function of observable characteristics of the choices and the chooser. The derivation of the indirect utility function and the logit framework are in Appendix C.

### 5.3.11 Estimation Results from the Choice Experiments Analysis

The results of the nested and standard logit model estimation are presented in Table 5.44. There are a few more observations in this analysis than in the *wtp* analysis, because several unfruitful variables (notably young and old household members and attitudes toward agriculture relative to the environment) were dropped from the analysis. In the standard logit analysis, acres of agricultural land preserved, premature deaths, and cost are highly significant attributes of the salinity management plans, with the expected signs. In addition, the demographic characteristics of the choosers are highly significant, also with the expected signs. *Income*, *edu*, *female*, and *health* problems are all positive, while *Hispanic* has a negative sign. However, this model is restrictive in that it holds the parameter $\theta_p$ equal to 1. In the Nested Logit column, which relaxes this restriction, it can be seen that $\theta_p$ is significantly different from zero and (more to the point here) is significantly different from 1. This indicates that the data reject the standard logit restriction, and the nested logit, not surprisingly, provides a significantly better fit overall. In this model, while the demographic variables remain strongly significant, the attributes of individual salinity management plans become less significant, with only cost and premature deaths showing significance (with the correct signs). Even though specific attributes of Plan A and Plan B are less significant, the demographic factors all enter the model as program-specific constants, meaning that they are explaining the decision to choose a plan (A or B) over the status quo (No Plan). Thus the model shows strong significance of the decision to choose (and pay for) a plan to manage and limit salinity, although the specific attributes of A and B are less important. This is perhaps not surprising, in light of the earlier discussion about how the public goods aspects of salinity management are subtle and indirect.

**Table 5.44. Nested and Standard Logit Estimates of Utility Function Coefficients from the Choice Experiments**

| Variable | Coefficients (Standard Deviation) | |
|---|---|---|
| | Standard Logit | Nested Logit |
| AGLAND | 0.8833** (0.3715) | 0.2230 (0.2476) |
| WETLAND | -0.0004 (0.0029) | -0.0002 (0.0016) |
| PDEATH | -0.5490** (0.1340) | -0.2278* (0.1285) |
| COST | -0.0672** (0.0089) | -0.0243* (0.0130) |
| $\theta_p$ | 1.0000 - | 0.3149** (0.1590) |
| PROGASC | -2.8780** (0.7387) | -2.4438** (0.5797) |
| INCOME | 0.0072** (0.0018) | 0.0070** (0.0018) |
| EDU | 0.1304** (0.0319) | 0.1283** (0.0315) |
| HISPANIC | 0.4621** (0.1711) | -0.4459** (0.1690) |
| FEMALE | 1.0720** (0.1490) | 1.0495** (0.1475) |
| HEALTH | 0.2085** (0.0484) | 0.2022** (0.0479) |
| Log L | -1089.8 | -1083.0 |
| Number of Cases | 338 | 338 |

* Significant at the 10% level
** Significant at the 5% level, one-tailed test

The coefficients in Table 5.45 are the coefficients of indirect utility behind the observed choices in the choice experiments. These can be used to evaluate any level of provision of each of the public goods attributes, in addition to providing a salinity management plan that controls salinity but provides the same level of public goods as the status quo (No Plan).

Since only premature deaths was statistically significant (in addition to cost) in the statistically-superior nested logit model, estimates of willingness to pay are provided in Table 5.45 for the three levels of this public good. In addition, an estimate is provided for the scenario where there is no change in the associated public goods when the salinity management plan that halts the increase in salinity is put in place.

**Table 5.45. Estimated Willingness to Pay for a Salinity Management Plan: Choice Experiments Results ($/month)**

| Scenario | Mean | Standard Deviation | Minimum | Maximum | Number |
|---|---|---|---|---|---|
| ***Full Sample*** | | | | | |
| No Change in Public Goods | 4.75 | 19.30 | 0.00 | 159.68 | 338 |
| ***Premature Deaths*** | | | | | |
| 10,1000/yr | 6.42 | 22.78 | 0.00 | 174.54 | 338 |
| 9,500/yr | 10.76 | 29.95 | 0.00 | 201.28 | 338 |
| 8,900/yr | 14.90 | 35.30 | 0.00 | 219.11 | 338 |
| ***WTP is positive*** | | | | | |
| No Change in Public Goods | 50.20 | 41.17 | 2.76 | 159.68 | 32 |
| ***Premature Deaths*** | | | | | |
| 10,1000/yr | 49.28 | 43.66 | 1.21 | 174.54 | 44 |
| 9,500/yr | 55.96 | 46.42 | 0.72 | 201.28 | 65 |
| 8,900/yr | 55.94 | 48.94 | 0.27 | 219.11 | 90 |

Averaged across the whole sample, willingness to pay for a salinity management plan that provides no change in public goods is $4.75 per month, while willingness to pay ranges from $6.42 per month to $14.90 per month for increasing improvements in air quality along with salinity control. However, the bottom part of Table 5.45 shows that according to this model, the willingness to pay is highly concentrated among a minority of respondents who are willing to pay substantial amounts ($50-56 per month), and that most people are not willing to pay anything.

# 6 Summary

This is a summary of the projected direct economic costs that a continued increase in the salt load will impose on the Central Valley and State economy in 2030. Due to absence of detailed regional data on groundwater salinity levels and depths, we have had to aggregate the economic impacts over very large regions, thus missing the regional differences in water supply and quality that characterize the central valley.

In the most recent and comprehensive study of salinity in the valley, Shoups and Hopmans (2006 ) show that the net increase in the saline load in the San Joaquin and Tulare valleys induces changes in the shallow saline groundwater areas and the average salinity of the deep aquifer. In calculating the economic effects, we only consider the effects of perched saline water on agriculture. In this study, we ignore the relatively small yield effect that an increase of 170 ppm in groundwater salinity by 2030 will have on crop yields due to the use of groundwater for irrigation. If the deep groundwater salinity is concentrated more in certain areas, then the local increase in salinity could be significantly higher with consequently larger reductions in crop yields. Thus, the direct losses to crop agriculture are slightly understated.

## 6.1 Salinity Scenarios

Three salinity accumulation scenarios were formulated. The first is a Base Scenario that assumes conservative conditions regarding projected salinity levels. The second is a Medium Scenario or expected value scenario. The third or High Scenario can be considered an upper bound of salinity damages

The Base Scenario assumes that the Tulare and San Joaquin basins will experience an average annual salinity increase of 2.63 mg/l to the year 2030 and the Sacramento Basin will experience no increase in water supply salinity concentrations.

The salinity assumption for the San Joaquin and the Tulare Basins are consistent for the three scenarios while a .64 mg/l annual increase is used for the Sacramento Basin in the Medium Scenario. The High Scenario assumes an annual salinity increase of 1.53 mg/l for the Sacramento Basin.

## 6.2 Direct Economic Impacts

Table 6.1 contains the estimates of direct economic losses for the three scenarios and the three basins. The total direct losses are estimated to range from $988,123 to $1.543,736 for the year 2030 depending on the salinity scenario. Total annual agricultural damages will range from $452,450 to $765,604 by the year 2030. Industrial water users will experience from $508,093 to $738,927. Household damages are estimated at $27,581 to $39,205. Most of the household and industry impacts is projected for the San Joaquin Basin.

**Table 6.1 Direct Economic Impacts by the Year 2030**

| Basin | Scenario | | |
|---|---|---|---|
| | Base | Medium | High |
| | | $1,000,000 | |
| | ***Increased Household Cost*** | | |
| Sacramento | $0.000 | $4.862 | $11.624 |
| San Joaquin | $15.622 | $15.622 | $15.622 |
| Tulare | $11.959 | $11.959 | $11.959 |
| **Total** | **$27.581** | **$32.443** | **$39.205** |
| | ***Increased Industrial Production Cost*** | | |
| Sacramento | $0.000 | $96.558 | $230.834 |
| San Joaquin | $299.751 | $299.751 | $299.751 |
| Tulare | $208.341 | $208.341 | $208.341 |
| **Total** | **$508.093** | **$604.651** | **$738.927** |
| | ***Decreases in Wine Production*** | | |
| Sacramento | -$7.322 | -$7.322 | -$7.322 |
| San Joaquin | -$7.908 | -$7.908 | -$7.908 |
| Tulare | -$2.440 | -$2.440 | -$2.440 |
| **Total** | **-$17.670** | **-$17.670** | **-$17.670** |
| | ***Decreases in Food Processing*** | | |
| Sacramento | -$23.760 | -$23.760 | -$23.760 |
| San Joaquin | -$57.132 | -$57.132 | -$57.132 |
| Tulare | -$52.447 | -$52.447 | -$52.447 |
| **Total** | **-$133.340** | **-$133.340** | **-$133.340** |
| | ***Decreases in CAFO Production*** | | |
| Sacramento | $0.000 | $0.000 | $0.000 |
| San Joaquin | -$9.709 | -$19.018 | -$26.862 |
| Tulare | -$107.017 | -$140.033 | -$228.265 |
| **Total** | **-$116.726** | **-$159.051** | **-$255.127** |
| | ***Decreases in Irrigated Agricultural Production*** | | |
| Sacramento | $0.000 | $0.000 | $0.000 |
| San Joaquin | $0.000 | $0.000 | $0.000 |
| Tulare | -$184.714 | -$272.091 | -$359.467 |
| **Total** | **-$184.714** | **-$272.091** | **-$359.467** |
| **Total Impacts** | **-$988.123** | **-$1,219.245** | **-$1,543.736** |

## 6.3 Total Economic Impacts

Annual income, output, employment and population impacts from Central Valley salinity accumulations were estimated by the REMI model for the time period 2008 through 2030 for three salinity scenarios and four regions (Table 6.2). Under the medium set of assumptions regarding salinity accumulations, annual California income is expected to decline by $2.251 billion, output by $6.485 billion, employment by 46,299, and population by 65,013 in the year 2030. Under the low or base salinity assumptions, impact estimates are reduced by approximately 25 percent and under the high assumptions, increased by approximately 35 percent.

**Table 6.2 Total Economic Impacts by the Year 2030**

| | Sacramento | San Joaquin | Tulare | Rest of CA | California |
|---|---|---|---|---|---|
| **Income (Bil 2008$)** | | | | | |
| **Low** | -$0.075 | -$0.201 | -$0.875 | -$0.533 | -$1.685 |
| **Medium** | -$0.160 | -$0.242 | -$1.177 | -$0.673 | -$2.251 |
| **High** | -$0.278 | -$0.289 | -$1.620 | -$0.859 | -$3.047 |
| **Output (Bil 2008$)** | | | | | |
| **Low** | -$0.226 | -$1.014 | -$1.580 | -$2.085 | -$4.905 |
| **Medium** | -$0.766 | -$1.099 | -$1.968 | -$2.652 | -$6.485 |
| **High** | -$1.513 | -$1.206 | -$2.538 | -$3.447 | -$8.704 |
| **Employment (thousand)** | | | | | |
| **Low** | -1.057 | -3.087 | -22.680 | -6.861 | -33.685 |
| **Medium** | -2.378 | -3.931 | -31.160 | -8.830 | -46.299 |
| **High** | -4.210 | -4.795 | -43.600 | -11.580 | -64.185 |
| **Population (thousand)** | | | | | |
| **Low** | -1.610 | -4.066 | -33.530 | -8.352 | -47.558 |
| **Medium** | -3.375 | -5.178 | -45.920 | -10.540 | -65.013 |
| **High** | -5.830 | -6.372 | -64.110 | -13.530 | -89.842 |

All these measures show that the effects of allowing salinity to accumulate at the present rate, whether measured by direct economic costs of lost production, in direct effects on income in the Central Valley and California as a whole are very significant. In addition, the non-market measures of jobs lost due to salinity increase, and the willingness to pay to avoid salinity effects also showed substantial costs of inaction.

## 6.4 Caveats and Suggestions for Additional Research

As this research project has evolved, it has become increasingly clear that the hydro-geological knowledge of salinity, its levels, distribution, and accumulation in the Central Valley are not currently sufficiently precise to support the important regional policy conclusions that are required to control the costs of salinity. This study clearly shows that, on average, salinity in the Central Valley is a growing problem with very substantial economic and social impacts. The principal uncertainties associated with the results are caused by a lack of information on the physical parameters of salinity accumulation rather than the economic parameters. Conclusions for future research can be summarized by stating that additional research expenditures should be spent on improving the hydrological knowledge of salinity accumulation, before additional improvements to the economic methodology are implemented.

Specific information shortfalls were encountered in hydro-geology and economics.

### 6.4.1 Hydro-geological Information Shortfalls

- The projection of the area and level of salinity in the Central Valley over the next 30 years had to be estimated based on one set of projections and the existing salinity profiles from the California Department of Water Resources. The projections of salinity growth are particularly difficult, since the balance between the two contributing factors of salt mobilization within the Valley and net imports of salinity in imported water are hard to disentangle, and thus associate with a particular policy change.

- The variability of salinity in the basic water supply is not documented on a consistent basis throughout the valley. Clearly there is a wide range of salinity and its resulting economic impacts over different regions.

- A third factor that influences shallow aquifer salinity, and the long-term effect on groundwater is the degree of percolation of salinity through the Corcoran clay layer to the deep aquifer. Only one estimate of this important parameter was found. Also, the effect of percolating salinity on the ambient salinity in the deep aquifer depends on its movement through the aquifer and effective pumping depth that groundwater users will face in the future. More work is needed to define these parameters.

- A fourth variable of great uncertainty is the linkage between subsurface salinity, one to three meters below the surface, and the effective salinity in the crop root zone. Current agronomic measures of yield impacts are based on root zone levels, however there are many actions taken by farmers, such as increased leaching requirements that reduce salinity impact on the root zone. The degree to which these actions are restricted by subsurface salinity needs to be estimated directly from farmer’s responses.

### 6.4.2 Economic Information Shortfalls

- Projecting economic impacts many years into the future inevitably results in uncertainty over the effect of future markets of California crops on the crop type grown and its salinity response. In addition, changes in water policy that increased the scarcity of water supplies in the Central Valley would, in consequence, change irrigation methods, drainage levels, and thus change and salinity accumulation.

- Potential climate change over the next 30 years may also modify the crops grown in the valley, water supplies, and the net evapotranspiration requirements of crops. It is likely that these effects will tend to reduce the salinity burden in the valley.

- Urban growth in the Central Valley and land availability for it will also change projections of salinity costs. The urbanization trend will reduce subsurface salinity caused by drainage, and increase the cost of ground water salinity increases.

- The growth and regulation of CAFO operations in the Central Valley will influence both the change in salinity and other groundwater contaminants. The study shows that the existing CAFO development faces limitations on the economic ability to dispose of animal waste.

In summary, this study has shown that under the best current parameter estimates, projecting salinity growth at its current rate until 2030 would result in an annual loss of economic income by 2030 of $1.685 billion to $3.047 billion a year, and 34 thousand to 64 thousand jobs. Clearly this is a serious problem for the future growth and well-being of the Central Valley. In the short term, additional research needs to concentrate on resolving the principal uncertainties over the hydrogeological accumulation, spatial variation, and projection of salinity growth.

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## *Appendix A. Irrigated Agriculture*

### *A.1 Deductive Optimizing Production Model (SWAP)*

A Constant Elasticity of Substitution (CES) production function is defined, and the parameters are calibrated as in Howitt (2006). Elasticity of substitution is assumed to vary by crop but not by region. The specification of the generalized CES production function (Beattie and Taylor, 1985) is:

$$Y_{gi} = \tau_{gi} \left[ \sum_j \beta_{gij} X_{gij}^{-\rho_i} \right]^{-\upsilon/\rho_i} \qquad \text{(A-1)}$$

Sub-index *g* corresponds to the CVPM region, *i* refers to crops, and *j* to production factors or inputs. The model in this study has three inputs: land, labor and water. Also in equation A- above, $Y_{gi}$ represents the output for crop *i* in region or group *g*. The scale parameter of the CES production function is referred as $\tau_{gi}$, whereas the share parameters for the resources for each crop, are represented by $\beta_{gij}$. The $X_{gij}$ denotes usage of factor *j* in production of crop *i* of region *g*.

The functional form is homogeneous of degree $\upsilon$, and the elasticity of substitution for crop *i*, $\sigma_i$ is given by $\sigma_i=1/(1+\rho_i)$. The function coefficient (returns to scale) is also given by parameter $\upsilon$.

The first step in PMP is devoted to obtaining marginal values for the calibration constraints to parameterize a quadratic cost function in the second step. The linear program with calibration constraints is as follows:

$$Max_{x\geq 0} \prod = \sum_g \sum_i (v_{gi} yld_{gi} - \sum_j \omega_{gij} a_{gij}) x_{gi,land}$$ (A-**Error! Bookmark not defined.**)

$$Ax \leq b \qquad \text{(A-2)}$$

$$Ix = \tilde{x} + \varepsilon \qquad \text{(A-3)}$$

$$Ix = \tilde{x} - \varepsilon \qquad \text{(A-4)}$$

Equation **Error! Reference source not found.** is the objective function of the linear program. Decision variables are $x_{gi,land}$ that are the total acres planted for region or group *g* and crop *i*. The marginal revenue of crop *i* in region g, is given by $v_{gi}$. Average yields are given by $yld_{gj}$ take into account reductions in salinity due to the base soil salinity levels following van Genuchten and Hoffman (1984).

Average variable costs $\omega_{gji}$ are used also in the linear profit objective function **Error! Reference source not found.**. The Leontieff coefficients $a_{gji}$ are given by the ratio of total factor usage to land. In other words, all production inputs are normalized with respect to land, therefore $a_{gi,land}$ is expected to be one for all crops and regions.

Equations **Error! Reference source not found.-Error! Reference source not found.** are in matrix form. In the resource constraint set (equation **Error! Reference source not found.**), matrix **A** is three-dimensional (G I K) with regional Leontief coefficients $a_{gkj}$ as elements. K is a subset of the resources set, that includes only those resources in limited amounts. In the same equation, **x** is a (K by 1) column vector of the decision variables $x_{gi,land}$. Vector **b** is the regional limit on the resource with dimensions J by 1. The last two sets (**Error! Reference source not found.** and **Error! Reference source not found.**) are for the upper and lower bounds of the calibration constraints, where **I** is a J by J identity matrix, the *x-tilde* is the observed value of resources usage, whereas $\varepsilon$ is small perturbation that decouples the resource and calibration constraints.

The second step in PMP estimation is to calculate parameters needed by the exponential cost function and the CES production function. The cost function is given by equation **Error! Reference source not found.** below:

$$TC_{gij}(x_{gij}) = \delta_{gi} e^{\gamma_{gi} x_{gi,land}} \tag{A-5}$$

where $\delta_{gi}$ and $\gamma_{gi,land}$ are respectively intercept and parameter of an exponential cost curve. These parameters are obtained from an ordinary least squares regression with restrictions on the PMP formulation and elasticities of supply for each crop.

The last step in PMP is to solve a non-linear constrained profit maximization program. The objective function becomes:

$$Max_{x\geq 0} \prod = \sum_g \sum_i yred_{gi} v_{gi} Y_{gi} - \sum_g \sum_i \delta_{gi} e^{\gamma_{gi} x_{gi,land}} - \sum_g \sum_i \sum_{j,j\neq land} (\omega_{igj} x_{gij}) \tag{A-6}$$

subject to: $Ax \leq b$ (A-7)

$$xm_{gm} \leq \sum_i met_{gim} x_{gi,water} \quad \forall g,m \tag{A-8}$$

$$\sum_m xm_{g,m} \leq availwater \cdot b_{water,g} \quad \forall\, g \tag{A-9}$$

In equation **Error! Reference source not found.**, $Y_{gi}$ is defined by the production function in above, the derivation of parameters $\tau_{gi}$ and $\beta_{gij}$ of the production function is detailed in Medellin-Azuara (2006). The second term in the equation has now the PMP calibrated cost function. Constraint **Error! Reference source not found.** is as in **Error! Reference source not found.** above, except that all resources are included not just those limited.

Yield reductions in equation **Error! Reference source not found.** of van Genuchten and Hoffman (1984) are detailed in equation **Error! Reference source not found.** below, in which $Ymax_{g,i}$ is the maximum average yield of crop *i* in region *g;* $c_{gi}$ is the salinity in the root zone, $c_{50gi}$ is the salinity at which the yield is reduced by 50%, and *p,* is an empirical constant.

$$yred_{gi} = \frac{Y_{\max gi}}{1 + \left( c_{gi} / c_{50_{gi}} \right)^P} \tag{A-10}$$

A new constraint set on monthly water use has been included. Variable $xm_{gm}$ in equation **Error! Reference source not found.** is monthly water use in region *g* in month *m*. Three underlying assumptions are worth discussing. First, water is interchangeable among crops within a region. Second, a farm group (or region) maximizes profits on a yearly basis, equalizing marginal revenue to marginal costs every month. Third, a region or farm group picks the crop mix that maximizes profits within the region. In other words, the shadow value of water will be the same for all months and for all crops *i* in a region or farm group *g*. This assumes sufficient levels of water storage and internal water distribution capacity and flexibility.

The last constraint set (**Error! Reference source not found.**) is for regional water in which, $b_{water,g}$ corresponds to that in the right hand side of equation **Error! Reference source not found.** for water. The parameter *availwater* can be used later to obtain shadow values of water by constraining water regionally, such that 0<availwater ≤ 1. The constraint set assumes that yearly water is available in a limited amount for every region or group. Less realistically, it also implies that water is not re-traded across groups or regions under the basic calibration assumptions.

## *A.2 An Inductive Logit model of Crop choice*

Given that plot size, salinity levels, and soil quality are invariant across crop alternatives the appropriate model is multinomial logit (MNL) (Green 2003 p.720). Proceeding as in Green (2003, p.721), let $p_{ij} = \Pr[y_i = j]$, the probability of observing crop j on field plot i. Since we do not seek to capture the effect of microclimate in the multinomial logit model, we specify six independent models, one for each CVPM, where microclimate has been controlled for. The multinomial logit models can be written as:

$$p_{ij} = \frac{e^{\mathbf{x}_i'\beta_j}}{\sum_{l=1}^{12} e^{\mathbf{x}_i'\beta_l}}, \text{ where } j = 1,2,...,12 \text{ for CVPM's 14, 15, and 19} \qquad \text{(A-11)}$$

$$p_{ij} = \frac{e^{\mathbf{x}_i'\beta_j}}{\sum_{l=1}^{11} e^{\mathbf{x}_i'\beta_l}}, \text{ where } j = 1,2,...,11 \text{ for CVPM's 10 and 21} \qquad \text{(A-12)}$$

Define $\mathbf{x}$ as a vector of the alternative invariant regressors: parcel acreage, soil salinity level, and soil quality measure. Since $\sum_{j=1}^{12} p_{ij} = 1$, i.e. the probabilities sum to one, it is necessary to impose a restriction to ensure identification (Green 2003 p.721). For our model we restrict $\beta_1 = 0$. Consequently, all estimates are produced with alfalfa (crop 1) as the base outcome. All coefficient estimates are interpreted as: compared to alfalfa the likelihood of observing a crop j changes by $\beta_j$.

***Appendix B.***

## *B.1 Analytical Methods Non-market Valuation*

The next sections describe the probability statements used in the maximum likelihood estimation of response probabilities. For single bound respondents, a dichotomous choice model is used. For double bound respondents, two related but different models are estimated, the double bounded dichotomous choice model and the bivariate probit model. The next subsections explain each model briefly.

## *B.2 Single Bound Format (One wtp question)*

The consumer is assumed to have willingness to pay represented by

$$wtp = \mathbf{X}\boldsymbol{\beta} + \sigma\varepsilon, \qquad \text{(B-1)}$$

where *wtp* is willingness to pay for the salinity program, **X** is a matrix of explanatory variables (the empirical form of which will be discussed below), β is a vector of coefficients, σ is a number representing the standard error of willingness to pay, and ε is a N(0,1) statistical error. When asked if s/he would pay an amount $B^0$ for the program, the probability that the respondent says "no" should be the probability that his or her *wtp* is less than $B^0$, or

$$\begin{aligned}\Pr(no) &= \Pr(wtp < B^0) \\ &= \Pr(\mathbf{X}\boldsymbol{\beta} + \sigma\varepsilon < B^0) \\ &= \Phi(\varepsilon < \frac{B^0 - \mathbf{X}\boldsymbol{\beta}}{\sigma}) \end{aligned} \qquad \text{(B-2)}$$

where $= \Phi(\cdot)$ is the cumulative normal distribution function. Since there are two outcomes, the probability of observing a "yes" response is just 1.0 less the probability of a "no" response, or

$$\begin{aligned}\Pr(yes) &= 1 - \Pr(yes) \\ &= 1 - \Phi(\varepsilon < \frac{B^0 - \mathbf{X}\boldsymbol{\beta}}{\sigma}). \end{aligned} \qquad \text{(B-3)}$$

## *B.3 Double Bound Format (Two wtp questions)*

The double-bound format is identical to the single-bound format, except that a followup *wtp* question is asked, so that both responses can be analyzed together. In this format, if the person answers "yes" to the first *wtp* amount $B^0$, a second, higher amount $B^H$ is asked, and the "yes" or "no" response is recorded. In similar fashion, a respondent answering "no" to $B^0$ is asked a lower followup amount $B^L$. This generates four observed response patterns: *yy* ("yes" to both questions), *yn* ("yes" to the first and "no" to the second), *ny* ("no" to the first and "yes" to the second), and *nn* ("no" to both questions).

Two principal ways of analyzing the pair of responses are used, depending on whether one treats the two responses as coming from two separate *wtp* distributions (one for the first response and one for the second), or as both coming from the same *wtp* equation. Treating the responses as coming from separate *wtp* distributions (a bivariate probit analysis) is common in telephone or personal interview surveys, where there is a distinct time delay between answering the first question and asking the second, and during that interval the respondent may reconsider or adjust their thinking about the good's value. In this study, a mail survey was used, so that even though two questions were asked, both are seen simultaneously. This functions most similarly to a random payment card, the answers to which are usually treated as having a single *wtp* distribution (double-bounded dichotomous choice). It seems most reasonable to use the latter approach here, therefore, though both are investigated.

### *B.4 Double-Bounded Dichotomous Choice Probabilities*

Here both answers are viewed as coming from a single *wtp* function. The probability of observing *nn* is

$$\begin{aligned}\Pr(nn) &= \Pr(wtp < B^0, wtp < B^L) \\ &= \Pr(wtp < B^L) \\ &= \Phi(\frac{B^L - \mathbf{X\beta}}{\sigma})\end{aligned} \qquad \text{(B-4)}$$

Analogously to the single-bound case of a no response. Observing a "no" first and a "yes" second means that

$$\begin{aligned}\Pr(ny) &= \Pr(B^L < wtp < B^0) \\ &= \Phi(\frac{B^0 - \mathbf{X\beta}}{\sigma}) - \Phi(\frac{B^L - \mathbf{X\beta}}{\sigma}),\end{aligned} \qquad \text{(B-5)}$$

and the remaining two probabilities are

$$\begin{aligned}\Pr(ny) &= \Phi(\frac{B^H - \mathbf{X\beta}}{\sigma}) - \Phi(\frac{B^0 - \mathbf{X\beta}}{\sigma}) \\ \Pr(yy) &= 1 - \Phi(\frac{B^H - \mathbf{X\beta}}{\sigma}).\end{aligned} \qquad \text{(B-6)}$$

### *B.5 Bivariate Probit Choice Probability*

With this model, each answer is viewed as coming from a separate *wtp* function. Since there are two responses, there are two wtp functions,

$$wtp_1 = \mathbf{X\beta}_1 + \sigma_1\varepsilon_1 \qquad \text{(B-7)}$$

and

$$wtp_2 = \mathbf{X\beta}_2 + \sigma_2\varepsilon_2, \qquad \text{(B-8)}$$

and their errors can be expected to be correlated so a bivariate distribution (usually bivariate normal) is used to characterize the probabilities of the responses received. The probability of observing *nn* here is

$$\begin{aligned}\Pr(nn) &= \Pr(wtp_1 < B^0, wtp_2 < B^L) \\ &= \Pr(\mathbf{X\beta}_1 + \sigma_1\varepsilon_1 < B^0, \mathbf{X\beta}_2 + \sigma_2\varepsilon_2 < B^L) \\ &= \Phi_2(\frac{B^L - \mathbf{X\beta}_1}{\sigma_1}, \frac{B^L - \mathbf{X\beta}_2}{\sigma_2}, \rho),\end{aligned} \qquad \text{(B-9)}$$

Where $\Phi_2(\cdot,\cdot,\rho)$ is the bivariate cumulative normal distribution and $\rho$ is the correlation between the two *wtp* equations. Following the same logic, the probabilities of the other choice patterns are

$$\Pr(ny) = \Phi(\frac{B^0 - \mathbf{X\beta}_1}{\sigma_1}) - \Pr(nn) \quad \text{(B-10)}$$

$$\Pr(yn) = \Phi(\frac{B^H - \mathbf{X\beta}_2}{\sigma_2}) - \Pr(nn) \quad \text{(B-11)}$$

$$\Pr(yy) = 1 - \Pr(ny) - \Pr(yn) + \Pr(nn) \quad \text{(B-12)}$$

### *B.6 Likelihood Function*

Since the estimation sample contains respondents from both the single-bound and double-bound formats, and the observations are independent, the log-likelihood functions for the contingent valuation analysis are

$$LL = \sum_{i \in sb} D_i \cdot \ln(\Pr(i)) + \sum_{j \in db} D_j \cdot \ln(\Pr(j)), \quad \text{(B-13)}$$

where $\Pr(i)$ refer to the single bound probability statements given above, $\Pr(j)$ are the probability statements for the double bound format (either dichotomous choice or bivariate probit, depending on the model; and $D_i$ ($D_j$) are dummy variables taking the value 1 when response i (j) is given by the respondent.

### *B.7 Choice Experiment Analysis*

The logit framework is slightly different from the contingent valuation framework, in that it begins with the respondent's indirect utility function (rather than willingness to pay) as a function of observable characteristics of the choices and the chooser. Writing indirect utility of salinity management plans as

$$\text{(Plan A)} \quad V_A = C_p + \beta X_A + \alpha Y_p + \varepsilon_A, \quad \text{(B-14)}$$

$$\text{(Plan B)} \quad V_B = C_p + \beta X_B + \alpha Y_p + \varepsilon_B, \quad \text{(B-15)}$$

$$\text{(No Plan)} \quad V_N = \beta X_N + \varepsilon_N, \quad \text{(B-16)}$$

where $C_p$ and $Y_p$ are an alternative-specific constant and covariates for the first-level choice of whether to choose something other than status quo (i.e., A or B), and $X_i$, i=A, B, N are the attributes of each specific management plan, with a suitable distributional assumption on the random errors $\varepsilon_i$, i=A, B, N, the nested logit (unconditional) probabilities of choosing each alternative are

$$P(NP) = \frac{e^{X_N \beta}}{e^{Y_p \alpha + \theta_p \ln(e^{X_A \beta} + e^{X_B \beta})} + e^{X_N \beta}} \quad \text{(B-17)}$$

$$P(A) = \frac{e^{X_A \beta + Y_p \alpha + (\theta_p - 1) \cdot \ln(e^{X_A \beta} + e^{X_B \beta})}}{e^{Y_p \alpha + \theta_p \ln(e^{X_A \beta} + e^{X_B \beta})} + e^{X_N \beta}} \quad \text{(B-18)}$$

and

$$P(B)=\frac{e^{X_B\beta+Y_p\alpha+(\theta_p-1)\cdot\ln(e^{X_A\beta}+e^{X_B\beta})}}{e^{Y_p\alpha+\theta_p\ln(e^{X_A\beta}+e^{X_B\beta})}+e^{X_N\beta}}. \tag{B-19}$$

The standard logit holds in the special case where $\theta_p=1$, and in this case the choice probabilities become

$$P(NP)=\frac{e^{Y_{np}\alpha+\theta_{np}X_N\beta}}{e^{Y_{prg}\alpha+X_A\beta}+e^{Y_{prg}\alpha+X_B\beta}+e^{X_N\beta}} \tag{B-20}$$

$$P(A)=\frac{e^{X_A\beta+Y_{prg}\alpha+(\theta_p-1)\cdot\ln(e^{X_A\beta}+e^{X_B\beta})}}{e^{Y_{prg}\alpha+\theta_p\ln(e^{X_A\beta}+e^{X_B\beta})}+e^{Y_{np}\alpha+\theta_{np}X_N\beta}} \tag{B-21}$$

and

$$P(B)=\frac{e^{X_B\beta+Y_{prg}\alpha+(\theta_p-1)\cdot\ln(e^{X_A\beta}+e^{X_B\beta})}}{e^{Y_{prg}\alpha+\theta_p\ln(e^{X_A\beta}+e^{X_B\beta})}+e^{Y_{np}\alpha+\theta_{np}X_N\beta}}. \tag{B-22}$$