Appendix K Scenarios Memo

MEMORANDUM

Title: Future Scenarios for the California Wholesale Water System

Date: September 14, 2009

Subject: Scenarios

This memorandum provides context for the scenarios portion of the Study 1 work and a recommended structure for selecting scenarios to be analyzed through Study 1: Statewide and Regional Water-Energy Relationship.

Introduction

On December 20, 2007 the California Public Utilities Commission (CPUC) issued Decision 07-12-050 which ordered that a model be developed "… of the functional relationship between water use in California and energy used in the water sector that can be used in a predictive mode: Given a specific water delivery requirements developed from precipitation pattern information, what is the expected energy use."[1] The CPUC decision further stipulated:

- "The report should include historic relationships between water deliveries and energy use, and time series embedded energy values (kWh/acre foot or MMBTU/acre foot) for a range of scenarios of future conditions."
- "For the State and Federal project, also assess the impact of United States District Judge Wagner's current injunction against reduced pumping or increased water releases from late December through June."
- "For the State, Federal, and Colorado River projects, provide a response to the question: If water conservation results in reduced demand for water in the service area, will that be reflected in reduced water deliveries by the project, and reduced conveyance energy consumption?"

Subsequently, a Request for Proposals (RFP) was issued by the California Institute for Environment and Energy (CIEE) on behalf of the CPUC. The RFP scope of work stated that "In

[1] California Public Utilities Commission Decision 07-12-050, Appendix B, p.2.

consultation with CPUC staff, the contractor will examine these [*historical relationships between water deliveries and energy use*][2] relationships for a range of scenarios of future conditions in California."[3] In addition, the RFP stated that "The contractor will analyze key regulatory and policy decisions inside and outside of California that may affect the amount of water available to areas in California. For example, for the State and Federal projects, the contractor will assess the impact of District Judge Wanger's decision that required export pumping reductions in order to protect delta smelt. Similarly, for the State, Federal, and Colorado River projects, the contractor will assess the impact of policies promoting water conservation on demand for water in service areas (e.g., will there be reduced water deliveries and reduced energy consumption for conveyance of the water?). The contractor may want to quantify their findings through scenario analysis …"[4]

The team of GEI Consultants and Navigant Consulting was engaged to develop the model and to conduct the scenarios described above. The GEI/NCI Study Team recommended "… consult[ing] with CIEE and CPUC staff and consultants to formulate a specific set of possible future California conditions that will be examined under this task. The Study Team will also solicit input from water and energy stakeholders to select the scenarios for evaluation, especially any official forums that have been specifically established to support implementation of state policy goals such as the Climate Action Team's Water-Energy Technology sub-committee ("WET-CAT") that is helping to develop the water sector's response to greenhouse gas emissions reduction in support of AB32."[5]

A public workshop is being conducted to solicit input from key stakeholders about the types of scenarios that should be evaluated through Study 1. In preparation for this workshop, the GEI/NCI Study Team conducted research and interviews to identify:

- The types of future wholesale water conditions that are being predicted and analyzed by key water and energy stakeholders in California,
- The values and types of assumptions that are being employed in these scenarios, and
- The types of models that are being used to analyze those scenarios.

This memorandum documents the results of the Study Team's research and inquiries with respect to the types of California wholesale water scenarios that are presently being evaluated by state agencies and other key stakeholders. In order to assure consistency with other state policymaking and regulatory proceedings related to the state's water resources, the Study Team recommends that the primary scenarios and assumptions being employed by the Air Resources Board (ARB), the Department of Water Resources (DWR) and the Energy Commission (CEC) be used to develop the Study 1 scenarios.

In order to meet the study schedule, the Study Team is developing the predictive model concurrent with the discussion and selection of scenarios. The model will be designed to

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[2] Bracketed phrase extracted from the same paragraph and inserted here for clarity.
[3] California Institute for Energy and Environment "Embedded Energy in Water Studies, "RFP CP1-007-08, April 30, 2008, p.5.
[4] Ibid.
[5] "Embedded Energy in Water Study 1 Work Plan," January 7, 2009, p.23.

accommodate the changes in key variables indicated by the selected scenarios. The model will calculate the net energy consumption by the water system at the facility, region, Investor Owned Utility (IOU), and state level.

What is a "Scenario?"

Scenario analysis describes a process of hypothesizing about potential future conditions and then projecting the impacts of those potential future conditions. In the context of Study 1, scenarios are being developed to represent the range of potential water deliveries given a wide variety of changes in variables, including but not limited to:

- ***Changes in California's Water Supply Portfolio***; e.g., changes in hydrology; changes to the quantity, timing and location of surface and groundwater supplies; and changes in the mix of water resources in water supply portfolios.
- ***Changes in the Quantity, Timing and Location of Water Consumption***; e.g., due to changes in population; changes in agricultural vs. urban water demand; changes in policies; and changes in water end-use technologies.
- ***Changes in Water Delivery Operations***; e.g., due to changes in policies, regulations, water delivery commitments and/or infrastructure (e.g., more or less conveyance or storage capacity at key points in the wholesale water system).

In fact, there are many variables that could affect both the amount and timing of wholesale water deliveries throughout California. Scenarios evaluated through Study 1 will need to consider the potential energy impacts of changing one or all of these variables.

In addition to the variables described above, the Study 1 scope of work requires that the energy impacts of changes in water policies and regulations also be evaluated. The range of potential changes in water policies and regulations is very broad. A strong framework for considering the range of scenarios to be evaluated is needed.

Inherent within each scenario is an associated timeframe that governs several variables including but not limited to: baseline demand, climate change impacts, and realistic amount of infrastructure changes. Scenarios to be evaluated will consider potential energy impacts in 2010, 2020, and 2030. The manner in which Study 1 will structure scenario analyses to evaluate impacts is discussed in the Composite Scenarios Section later in this memorandum.

Given the potential complexity of this effort, the GEI/NCI Study Team conducted research and interviews of California water-energy experts to identify those scenarios that are deemed most likely and significant in context of California's water and energy resources, policies, planning and operations. The primary sources included the designated water-energy leads at the California Department of Water Resources (DWR) and the California Energy Commission (CEC). In addition, a Director of the Water Replenishment District of Southern California was interviewed. The results of these studies and interviews are presented below. A summary of our findings and Strawperson scenarios matrix is provided at the end of this memorandum.

Study 1's focus is on evaluating scenarios that could affect the amount and timing of energy used by the state's wholesale water systems by changing the amount and timing of wholesale water deliveries in California. The effect of potential impacts will be simulated by changing the appropriate user-defined variables in the model.

Mapping each scenario to changes in model variables is an important step in determining how to simulate each scenario. An illustration of the mapping process can be seen in Figure 1.

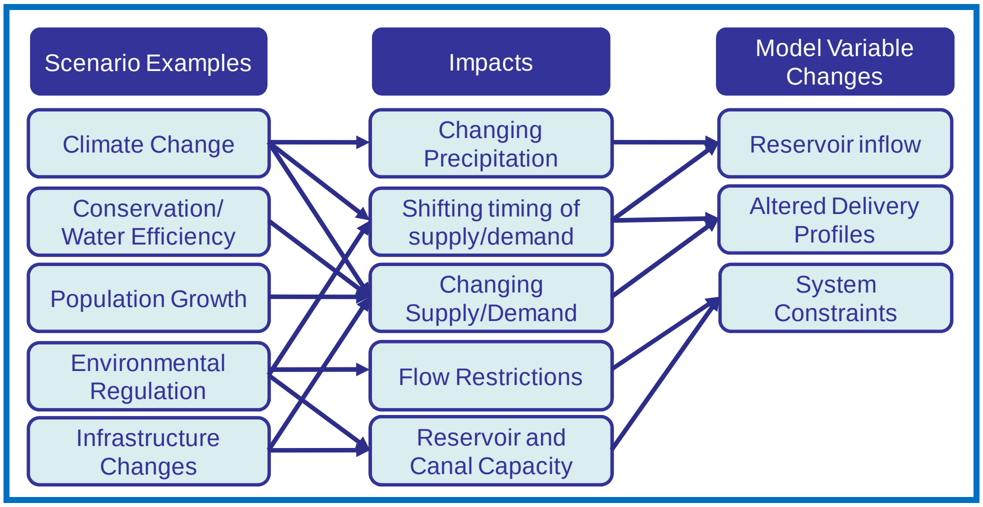

Figure 1: Mapping Scenario Examples to Model Variable Changes

The primary types of scenarios being evaluated by key water, energy and climate stakeholders in California are described in the next section of this memorandum.

Scenario Variable Categories

Possible future scenarios for California's wholesale water system are affected by variables in three main categories: Demand Changes, Policies and Regulation, and Climate Change. The Study Team will develop composite scenarios that evaluate the combined impact of these variables. This section presents the Study Team's research on these variables and how they should be evaluated through Study 1. Draft recommendations developed earlier were presented to key stakeholders to solicit feedback. The recommendations in this document incorporate the input of these stakeholders who include: California Department of Water Resources (DWR), California Energy Commission (CEC), State Water Resources Control Board (SWRCD), Natural Resources Defense Council (NRDC), and Pacific Institute (PacInst).

Changes in Demand

Water demand in the state of California is subject to change due to numerous factors including population growth, changes in land use, regional population shifts, and economic growth. Demand is typically split into urban and agricultural use and environmental needs. Each sector has its own drivers that could potentially increase or decrease water use.

Multiple parameters drive urban and agriculture water demand. Urban drivers include: population growth, population distribution, economic growth, income levels, price elasticity, housing size, and water conservation among others. DWR uses California Department of Finance (DOF) estimates for future population growth see Table 1. Agricultural demand drivers include: state-wide changes in irrigated land area, multi-cropping, amount of water need per area of crop, crop yield, and irrigation practices among other things.

Table 1: California Population Projections

Year	Population (Millions)
2009	37
2020	44
2050	55
2100	90

Previous Scenario Analyses

DWR presented California water demand scenarios in its 2005 Water Plan Update by sector (urban and agricultural).[6] Four scenarios are presented: Current Trends, More Resource Intensive, Less Resource Intensive, and Low Water Demand. Additionally, the Pacific Institute developed a fifth demand scenario that modifies DWR assumptions about water prices and the potential for efficiency.[7] The Pacific Institute "High Efficiency Scenario" is more aggressive than any put forth by the DWR. DWR scenarios are briefly described in Table 2.

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[6] Department of Water Resources. *Quantified Scenarios of 2030 California Water Demand.* 2005

[7] The Pacific Institute. *California Water 2030: An Efficient Future*. 2005.

Table 2: DWR Demand Scenarios

Scenario	Description
Current Trends	• Water demand based on current trends • Assumes naturally occurring 10% conservation
More Resource Intensive	• Higher population than current trends • Increase in high-water intensity activities across all sectors • Assumes naturally occurring 5% conservation
Less Resource Intensive	• Lower population than current trends • Decrease in high-water intensity activities across all sectors • Assumes naturally occurring 15% conservation
Low Water Demand	• Slower population growth, increasing conservation, low-water use development. • Agricultural sector becomes more water efficient than expected • Lower urban and agricultural demand allows greater allocations to the environment • Assumes naturally occurring 15% conservation

The DWR scenarios present the range of water demand in the state by region (North, Central, and South, see Figure 2) and sector (urban or agricultural). Figure 3 and Figure 4 depict the statewide water demand under each scenario and the regional distribution of water demand changes.

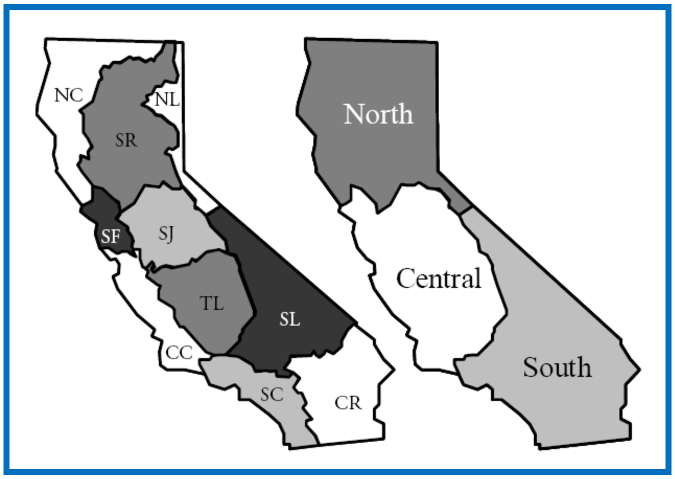
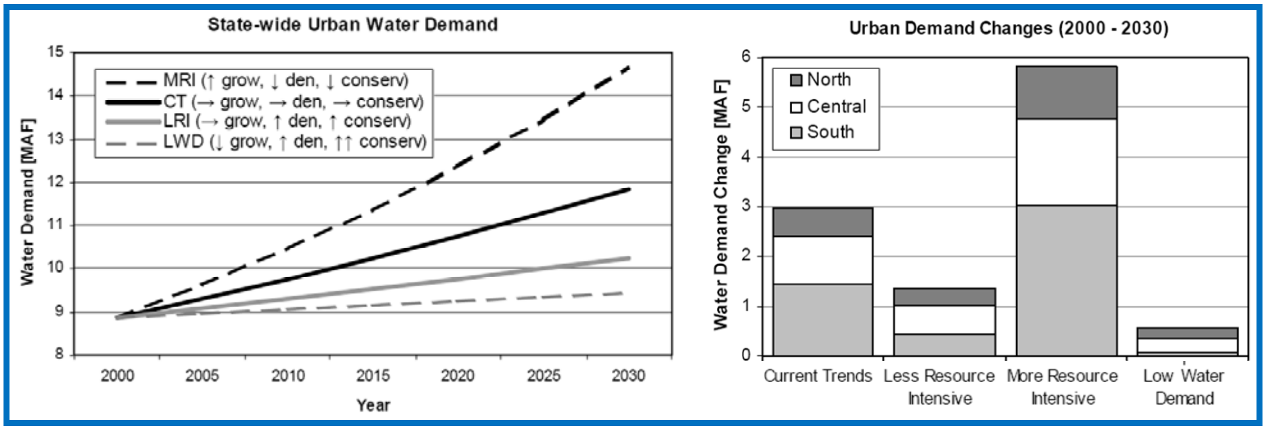
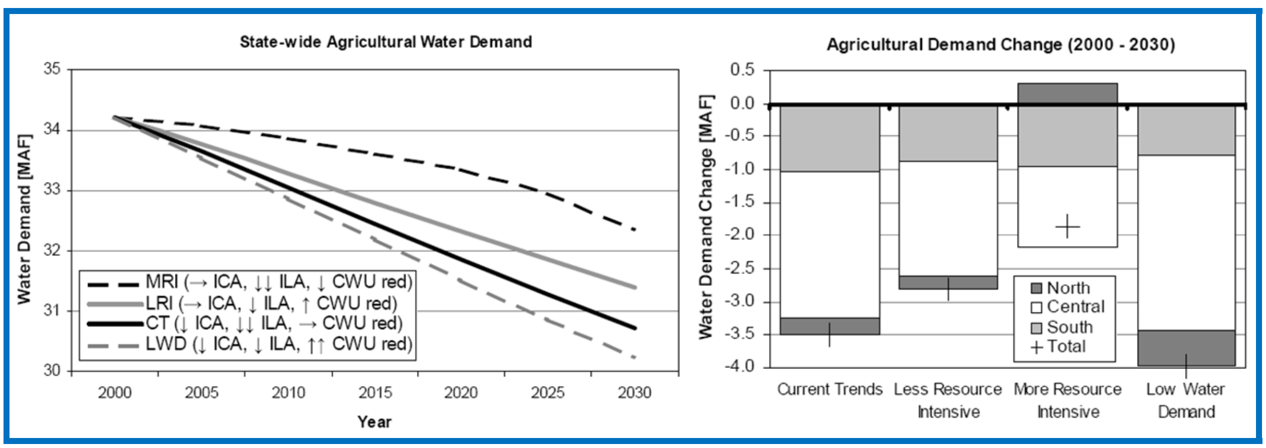


Figure 2: California Hydrologic Regions (left) and Geographic Regions (right)



MRI: "More Resource Intensive" scenario with high population growth, low population density, and low conservation
CT: "Current Trends" scenario with CA DOF defined population growth, current population density and conservation levels
LRI: "Less Resource Intensive" scenario with CA DOF defined population growth, high population density, and high levels of conservation
LWD: "Low Water Demand" scenario with lower population growth, high population density, and significant conservation efforts

Figure 3: DWR Future Urban Demand Scenarios



MRI: "More Resource Intensive"
CT: "Current Trends"
LRI: "Less Resource Intensive"
LWD: "Low Water Demand"
ICA: Irrigated Crop Area
ILA: Irrigated Land Area
CWU red: Crop Water Use Reduction

Figure 4: DWR Future Agricultural Demand Scenario

Environmental flow is the regulatory amount of water required to be discharged into natural waterways to sustain the local ecology and fisheries of river basins. These are stipulated by various agencies including the California Department of Fish and Game, Federal Energy Regulatory Commission, California State Courts, and other groups. Regional and total environmental demand modeled by DWR can be seen in Table 3. The majority of environmental flow needs are in the northern part of the state and volumes are expected to change little over time.

Table 3: Environmental Flow Demand

Water Demand (in MAF)	Year 2000	Year 2030 by scenario: Low Water Demand	Less Resource Intensive	Current Trends	More Resource Intensive
North	33.02	33.81	33.55	33.29	33.02
Central	6.19	6.88	6.65	6.42	6.19
South	0.19	0.19	0.19	0.19	0.19
Total	**39.41**	**40.89**	**40.40**	**39.90**	**39.41**

The Pacific Institute High Efficiency scenario is developed using the same model used by DWR for its planning purposes. The High Efficiency scenario maintains many of the same assumptions used by DWR with several key differences

- Urban and Agricultural water prices increase to higher levels (following historical trends)
- Price elasticity of water demand in the residential increased (demand is more responsive to increased in price)
- Water efficiency increases to +30% savings from 5% under Current Trends
- Changes in Agricultural water use technologies

As a result of these assumptions, the High Efficiency Scenario predicts lower water demand in the urban and agricultural sector as depicted in

Figure 5 and Figure 6.

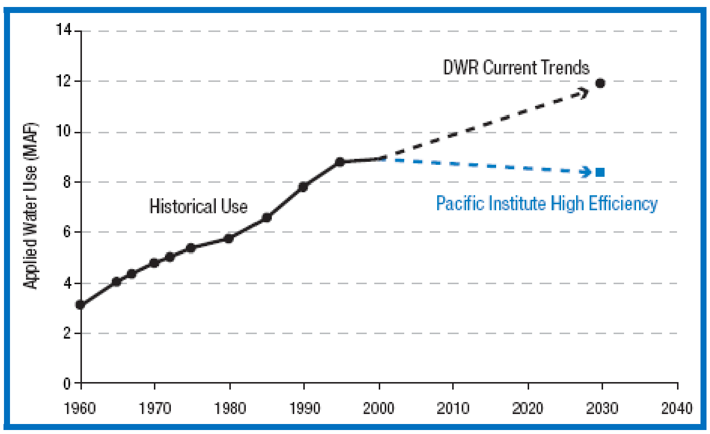


Figure 5: Pacific Institute High Efficiency Scenario - Urban Demand

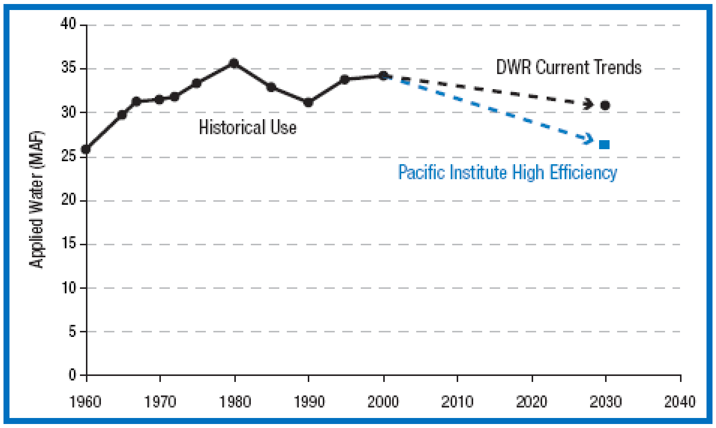
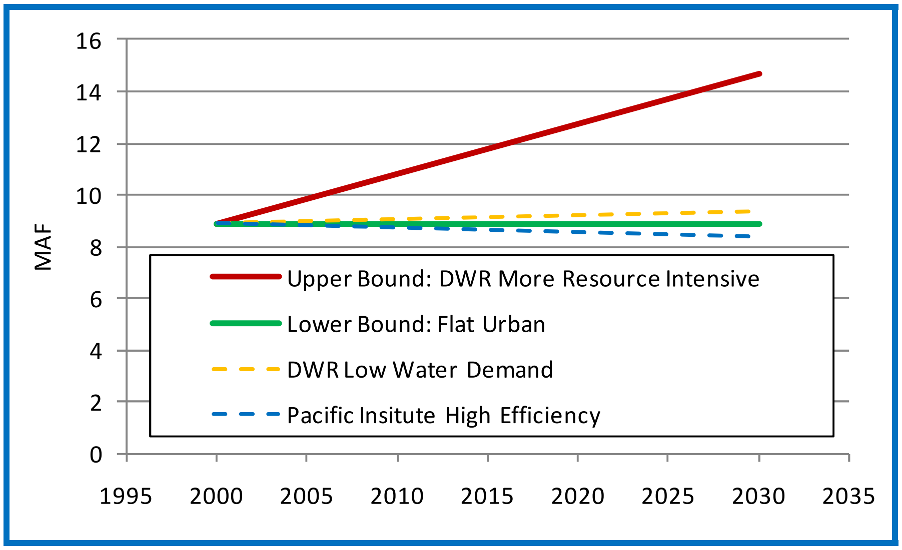


Figure 6: Pacific Institute High Efficiency Scenario - Agricultural Demand

Recommended Variable Changes and Bounds

The Study Team recommends adopting an upper and lower bound for water demand. As the agency responsible for statewide water planning, the Study Team views DWR's demand assumptions as authoritative. However, the Pacific Institute offers an alternative scenario based on other documented assumptions. The Study Team recommends adopting DWR's projection for "High Resource Intensity" as the upper bound for the demand variable. The lower bound should be a situation in which urban demand stays constant while agricultural demand follows DWR's "Low Water Demand" Scenario. When modeling a scenario in a given year, the Study Team will use the corresponding demand projections of high and low water demand for that same year (see Figure 7 and Figure 8 for bounds). Water deliveries to agricultural and urban demand areas will be scaled by the changes indicated by the projections. The Study Team will use regional data available from the DWR similar to the data presented in Figure 3 though Figure 6. Environmental demands are discussed further in the next section as they pertain to policy and regulatory issues.



Note: Lower bound illustrates no change in urban demand; this lies between DWR's Low Water Demand projection and Pacific Institute's High Efficiency projection

Figure 7: Urban Demand Bounds

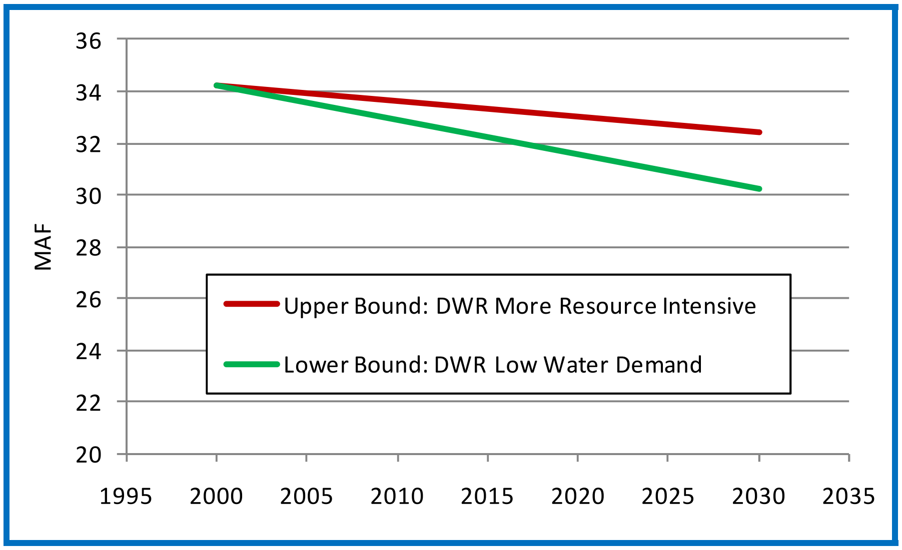


Figure 8: Agricultural Demand Bounds

New Policies and Regulation

State and local policies and regulations govern the operations of the wholesale water system. For example, they can govern the maximum or minimum flow through an aqueduct, promote conservation, affect the amount of storage, or allow infrastructure changes. The list of possible policies and regulations is vast and those currently in place are constantly changing. DWR's lead modeler[8] stated that given the number and frequency of new policies and regulations, it is very difficult to model each one.

Examples of existing and past policies and regulations that affect the wholesale water system are:

- Bay Delta environmental flow restrictions
- Colorado River Aqueduct contract enforcement
- Delta withdrawals
- Reservoir releases mandatory storage levels
- Flood control reservations
- In-stream flow releases
- Water quality standards

The Study Team developed a categorization system to match each policy scenario to an impact listed in Figure 1. Each policy or regulatory scenario proposed will have one or more of the below impacts on the wholesale water system, see Table 4.

Table 4: Categorization of Regulation and Policy Scenarios

Impacts	EXAMPLE Regulations and Policies
Shifting Timing and mix of Demand	• Conservation (20% in 2020 goal, AB49) • Environmental flow requirements
Shifting Timing and mix of Supply	• Regional self reliance (desalination, recycling, etc) • Emerging groundwater contaminants • Flood control • Environmental flow requirements • Flood control
Flow Restrictions	• Environmental flow requirements • Water rights
Reservoir and Canal Capacity	• Delta conveyance • Increased storage • Flood control

To capture the range of impacts on the California wholesale water system, each policy or regulation can be qualitatively ranked with respect to the level of impact it is likely to have on the state's water system. These qualitative judgments have been made in conjunction with key stakeholders that are knowledgeable about these issues before including them in the Study 1 scenarios. A full list of policies discussed with stakeholders can be seen in Appendix A along with their description, impact category, and likely qualitative effect on energy consumption.

[8] Francis Chung, Ph.D., P.E. Chief of Modeling Support Branch – California Department of Water Resources. Interviewed: June 26th 2009.

Recommended Variable Changes and Bounds

The Study Team interviewed experts in the field of water policy and regulation to obtain their input as to the types of future conditions that Study 1 should examine through scenario analyses.[9,10,11,12] More potential future conditions were cited than can be examined through Study 1 within the existing scope, budget and timeline. In addition, there is significant diversity of opinion as to the relative importance of various potential conditions when viewed in context of the future operations of the state's wholesale water system. For this reason, the Study Team recommends mapping potential water policies and regulations to a range of potential impacts on California's wholesale water systems and operations based on input received from the public workshop and internal discussions with the study team.

To capture the range of impacts that policies and regulations collectively have, the Study Team has assembled two policy and regulation scenarios. One is a package that represents actions that will reduce energy consumption statewide by the water sector. The other is a package that could result in increased energy consumption statewide by the water sector. This idea is illustrated in Figure 9; these packages will bound the range of impacts from policies and regulations. The policies and regulations listed in Figure 9 are only illustrative. The model will simulate the general trend that these scenarios have in increasing or decreasing water supply and demand.

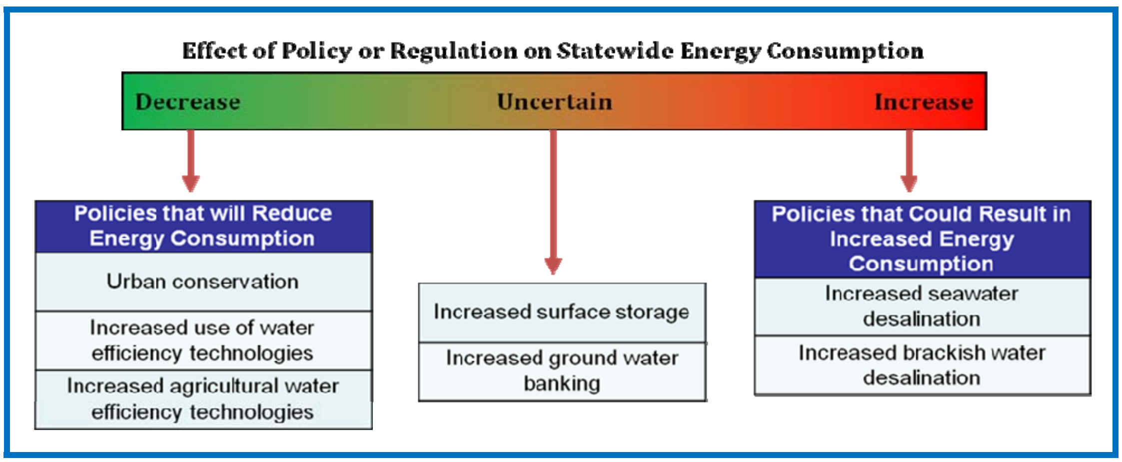


Figure 9: Policy and Regulation Grouping

Climate Change

Over the past 200+ years, the burning of fossil fuels and deforestation has contributed to

[9] John Andrew. Executive Manager for Climate Change – Department of Water Resources. Interviewed: June 18th, 2009

[10] Lorraine White. Specialist – California Energy Commission. Interviewed: June 22th, 2009

[11] Lillian Kawasaki. Director – Water Replenishment District (WRD) of Southern California. Interviewed: June 22th, 2009

[12] Peter Gleick (PacInst), Heather Cooley (PacInst), Ronnie Cohen (NRDC). Interviewed during stakeholder meeting: July 29th, 2009.

increased concentrations of heat-trapping "greenhouse gases" (GHG) in our atmosphere. As the concentrations of these gases continue to increase, the Earth's temperature is climbing above past levels. The Earth's average surface temperature has increased by about 1.2 to 1.4°F in the last 100 years according to data from NASA. Other aspects of the climate are also changing such as rainfall patterns, snow and ice cover, and sea level. If GHGs continue to increase, climate models predict the average temperature at the Earth's surface could increase from 3.2 to 7.2°F above 1990 levels by 2100, though significant effects can occur as early as 2030. The Intergovernmental Panel on Climate Change (IPCC) reports the "impacts of climate change on freshwater systems are mainly due to the observed and projected increases in temperature, sea level and precipitation variability." These impacts include: shifts in the timing of river flow, rising sea levels affecting coastal groundwater sources, increased risk of flooding, increased demand, and exacerbated water pollution.

Previous Scenario Analyses

Three state agencies are evaluating climate change impacts on the California wholesale water systems: the California Department of Water Resources (DWR), the California Energy Commission Public Interest Energy Research Program (CEC-PIER), and the Scripps Institution of Oceanography (Scripps). These studies are summarized in Table 5.

Table 5: Summary of Recent Climate Change Studies on the California water System

Group	Scenarios Tested	Notes
DWR (2009)	12 Scenarios defined by CAT – 2 IPCC emissions scenarios – Each emissions scenario is run through 6 GCMs	• Examines State Water Project (SWP) and Central Valley Project (CVP) • Scenarios A2 and B1 bound the range of climate change scenarios offered by the IPCC • Climate change models are downscaled to estimate the changes in average reservoir inflow to all major SWP and CVP reservoirs
CEC-PIER (2009)	2 Scenarios based on the A2 Emissions Scenario – Warm only – Warm and dry	• Uses CALVIN model to examine water management adaptation strategies • Climate change models are downscaled to estimate the changes in average reservoir inflow to 37 reservoirs in the state
CEC-PIER (2009)	Agricultural demand under climate change scenarios	• Uses the WEAP model to examine agricultural demand under climate change scenarios • Examines the Sacramento River and San Joaquin Valley only
CEC-PIER (2003)	12 Scenarios: – Temperature rise: 1.5-5°C – Precipitation increase: 0-30%	• Examines statewide system • Scenario temperatures tested fall within range of IPCC emissions scenarios • Climate change models are downscaled to estimate reservoir inflow • Increased temperatures increase evaporative losses
Scripps (2008)	4 scenarios bounded by the A2 and B1 Emissions Scenarios – reduction in runoff: 10-30%	• Using a water balance model with Monte Carlo simulation, examines Lake Mead (Colorado River) to estimate when the reservoir will effectively dry up

Details of the Study Team's research on climate change, emissions scenarios, climate models, previous studies, and data is available by request.

Recommended Methodology for Modeling Climate Change

Effects of climate change will not be modeled in this study. While the Study Team acknowledges that climate change could have a significant impact on state water systems in the long term, modeling its effects go beyond the scope of this project. Additionally, the model is intended to estimate the energy impacts prior to 2030; there is little work on climate change effects prior to 2030 that the study team could have leveraged.

Composite Scenarios

Two composite scenarios will be developed to examine the future; they will be compared against a Baseline. The Baseline will represent the current water system infrastructure and operations, given DWR-estimated demand in 2010. Scenarios will be evaluated against this baseline condition.

Using the previously described two primary variables –high vs. low water demands and bundles of potential water policies and regulations - the Study team will develop a matrix of scenarios to test that combine multiple variables into a smaller, more manageable set of up to 2 scenarios:

- Scenario 1 – A low-energy scenario that assumes low demand and a package of policies that will reduce energy consumption
- Scenario 2 – A high-energy scenario that assumes high demand and a package of policies that may increase energy consumption

These composite scenarios are structured to provide a likely range (high vs. low) of potential energy impacts on the state's wholesale water systems. To capture this range, high water demand will be coupled with the policy package that could increase energy use while low water demand will be coupled with the policy package that will decrease energy use. These scenarios are subject to change pending the public workshop on water energy scenarios. Most likely to change are the policies and regulations and their combinations in the composite scenarios.

As previously discussed, there is an inherent timeframe associated with each composite scenario. The corresponding high and low projections of potential water demand associated with the timeframe of each scenario will be used. Table 6 displays the Study Team's suggested timeframe for scenario analysis. This figure reveals a total of 5 scenario runs. The Baseline Scenario is run for 2010 to allow comparison to all other scenarios. The two future scenarios are analyzed for years before 2030, consistent with the California Water Plan.

The Study Team recommends selecting the 2 scenarios described above to be evaluated through Study 1 with the objective of focusing stakeholder attention on those potential conditions that are most important to understanding the potential impacts of wholesale water operations on the state's energy resources and infrastructure.

The following table illustrates how the 2 scenarios (plus the baseline) are proposed to map to future time periods.

Table 6: Timeframe for Composite Scenarios (Example)

	Timeframe to simulate		
Scenario	**2010**	**2020**	**2030**
Baseline	X		
Scenario 1: Low Energy		X	X
Scenario 2: High Energy		X	X

The above matrix contemplates running one Base Case against which 5 scenario runs of potential future conditions will be evaluated. The net energy consumption at the facility, region, IOU, and state level will be calculated for each of the 5 scenarios.

Conclusions

This Memorandum has suggested several scenarios on Demand Changes and Policies and Regulation based on other recent work and information from interviews and stakeholder meetings. A methodology for combining the effects of individual scenarios into composite scenarios has also been presented. Additional suggestions will be solicited during a special workshop tentatively scheduled for September 17, 2009. These scenarios can then be modeled and the impacts of the scenarios on California's wholesale water systems and the related energy impacts can be predicted.

Appendix A: List of Policies and Regulations Discussed with Stakeholders

		Impact Category			
Policy or Regulation	**Description**	**Shifting Timing and mix of Demand**	**Shifting Timing and mix of Supply**	**Flow Restrictions**	**Reservoir and Canal Capacity**
Environmental flow requirements	Further restrictions on minimum flows and maximum withdrawals from the Bay Delta		x	x	
Flood control	Lowering reservoir levels required for flood control for additional security against floods		x		x
Urban conservation (20% in 2020 goal)	CA urban water agencies decrease per capita demand by 20% by 2020 per the Governor's goal. AB49 attempts to codify this into law.	x			
Increased use of water efficiency technologies	use of more efficient water consuming devices and appliances	x			
Increased Agricultural water efficiency technologies	use of more efficient water irrigation methods	x			
Regional self reliance	See line items below:				
Increased seawater desalination	An increased number of desalination plants come online in Southern CA to displace current or future demand from the imports	x	x		
Increased brackish water desalination	An increased number of brackish desalination plants come online in Southern CA to displace current or future demand from the imports	x	x		
Increased recycled water	An increased number of RW plants displace current or future demand from imports	x	x		
More storm water recharging	Using storm water runoff to recharge GW reservoirs instead of effluent to natural waterways or ocean		x		

Emerging GW/SW contaminants	As more bodies of water are classified as contaminated, additional treatment or new sources will be required		x		
Delta conveyance (peripheral canal)	Three major options are on the table to construct a canal to bypass the Bay delta avoiding environmental concerns		x		x
Increased Surface storage	Expanding existing reservoirs (Los Vaqueros, Shasta, and Pardee) or building new reservoirs (Sites or Temperance Flats)		x		x
More Groundwater banking	Increased GW banking in Central and Southern CA	x	x		
Integrated Regional Watershed Management Plans			x		
Dam Removal	Removing select dams to restore natural habitats		x		x
Increased requirements for Salt Management	Preventing salts from penetrating into GW basins. Will save energy required to desalinate or find other sources		x		
Canal lining	Reduces transport losses effectively increasing the available water		x		x
Renewable Energy Development	Wholesalers develop renewable energy generation on the land they own				
Groundwater metering	Addition of flow meters to agricultural GW pump customers and rural residential customers for more accurate pricing and the ability to enforce pumping limits	x			