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sent via email

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Comments on the Sixth Staff Draft Delta Plan

To the Council:

Please accept the following comments on the climate change modeling and the effects of hydrology on California's water supply. They are somewhat detailed, to explain recent climate change modelling, and the policy implications of climate change scenarios in the context of evaluating water supply reliability.

Defining Water Supply Reliability Under Climate Change

The Delta Stewardship Council has not defined "Water Supply Reliability," as referenced in the co-equal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem." Chapter 3 of the Delta Plan, "A More Reliable Water Supply for California," refers to the prediction that sea level rise is increasing the probability that Delta levees will fail. There are references to a simulation which predicts that a large earthquake near the Delta could result in multiple levee failures, and that the operations of the State Water Project could be interrupted for as long as six months.

The Delta Reform Act states that:

85302. (d) The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:

(1) Meeting the needs for reasonable and beneficial uses of water.

(2) Sustaining the economic vitality of the State.

(3) Improving water quality to protect human health and the environment.

It seems clear that that "measures to promote a more reliable water supply" imply a lack of interruption of supplies for the State Water Project and Central Valley Project, as well as local users in the Sacramento Valley. While the Bay-Delta Conservation Plan is attempting to address some of the risks to water supply, it has not sufficiently addressed other risks. For this reason, it is a concern that Chapter 3 does not consider the other potential impacts of climate change on the State Water Project and Central Valley Project. Many climate change scenarios predict lower precipitation in the Central Valley in the future, and increases in the frequency and severity of droughts. This could have major impacts on upstream water supplies and reservoir operations.

Of most concern are simulations of CVP and SWP operations which show depletion in carryover storage of upstream reservoirs from trying to meet current increased export demands under climate change. Several simulations by the Department of Water Resources have shown a large increase in months with "dead storage" in reservoirs, which would result in an interruption of water supply in the Sacramento Valley and would also interrupt or severely curtail exports. The same simulations also showed that, absent augmentation of Sacramento River flows, increases in storage North of the Delta or groundwater banking South of the Delta would only increase the problem.[1]

As a trustee agency for the Delta Plan, the Delta Stewardship Council must adequately and objectively define water supply reliability, and ensure that water supply projects and plans actually meet the coequal goal to increase the reliability of water supplies. The Department of Water Resources has a 50 year history of overly rosy assumptions about hydrology and water supplies available for export. However, experience in recent droughts in California and other Western States has shown that planning for the water supply of millions of people requires conservative assumptions. These concerns particularly important as the State Water Project attempts to meet demands for increased exports that are beyond the 1981 estimated "safe yield" of the State Water Project of 2.3 million acre feet a year.[2] Current understanding of the needs of the Delta ecosystem and the impacts of climate change have only reduced this estimate.

It is for this reason the Delta Stewardship Council must exercise its authority for independent review of the ability of water supply plans and projects to meet the coequal goals, and the mandate for increasing reliability. While the existing policy of reducing reliance on the Delta for state water supplies is a good start, the Council also needs to enact policies which will ensure that any plans adopted as part of the Delta Plan will increase, rather than decrease water supply reliability.

At a minimum, the Delta Stewardship Council should create a policy which requires that the Bay Delta Conservation Plan and any future plans to increase water supply reliability under climate change actually perform adequately under the hydrology predicted in the drier climate change scenarios, which are more likely under "business as usual." The following section describes

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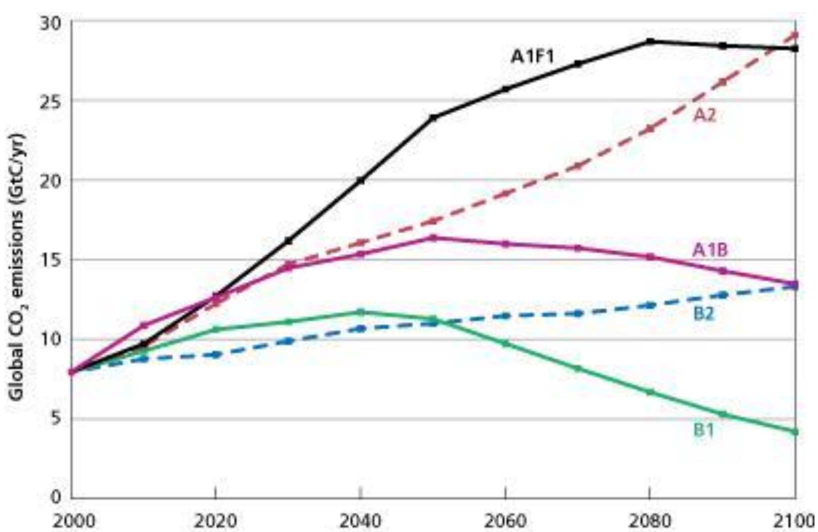
[1] Francis Chung, An Assessment of CVP-SWP Performance Under Alternative Delta Regulations, Infrastructure and Climate Change Scenarios Regarding CAlSiM II, California Water and Environmental Modelling Forum, Feb 22, 2010. Available at http://www.cwemf.org/Asilomar/FrancisChungCWEMFPres.pdf

[2] California Department of Water Resources, State Water Project – Status of Water Conservation and Water Supply Augmentation Plans, November 1981.

standard climate change scenarios, their likelihood given current trends in economic growth, population growth, and greenhouse gas emissions, and associated hydrology under recent climate change modeling.

Climate Change Scenarios and Predicted Hydrology

The graph below shows C02 emissions under the different scenarios from the IPCC Special Report on Emissions Scenarios.



The A2 scenario is a medium-high emissions scenario. It is was one of two emissions scenarios chosen for modelling for California's 2009 Climate Adaptation Strategy, as well as modeling for the 2008 OCAP assessment, and modelling by the Stockholm Environmental Institute in collaboration with researchers at UC Berkeley and the California Climate Change Center.[3],[4] The A2 scenario has continuously increasing population, and regionally oriented economic development.

The A2 scenario has slower growth in C02 emissions than the A1 scenarios. It appears to be less likely than the A1FI scenario under the current economic and political trajectory, but much more likely than the environmentally friendly B1 and B2 scenarios, described below. In California, most A2 scenarios show frequent droughts in mid-century, and reductions in precipitation, but some show precipitation increase.

[3] D.R. Purkey and B. Joyce et. al., Robust analysis of future climate change impacts on water for agriculture and other sectors: a case study in the Sacramento Valley, Climate Change 87 (Suppl. 1) S109-S122 Available at http://meteora.ucsd.edu/cap/pdffiles/Purkey_sacvalley_jan2008.pdf.

[4] B. Joyce and V. Mehta et. al., "Climate Change Impacts on Water Supplies and Agricultural Water Management in the Western San Joaquin Valley and Possible Adaptation Strategies," California Climate Change Center, 2009. Available at http://www.energy.ca.gov/2009publications/CEC-500-2009-051/CEC-500-2009-051-F.PDF

The other scenario used in the California Climate Adaption Strategy was the B1 scenario, which has decreasing emissions after mid-century. The B1 scenario assumes rapid changes towards resource efficient technologies, and population declining after 2050. Some of the B1 scenarios show modest drying, others show a modestly wetter climate.

The A2 and B1 scenarios were also chosen by the Natural Resources Agency for the Cal-Adapt tool, to be used by local and regional entities in assessing vulnerability under climate change. The draft policy on Climate Adaptation discusses which scenario decision-makers should use:

> "Of the two options provided by Cal-Adapt, the A2 scenario is the more realistic choice for decision-makers to use for climate adaptation planning. The B1 scenario is optimistic in the high level of international cooperation assumed. This cooperation would necessitate sweeping political and socioeconomic change on a global magnitude that is as yet unprecedented. The roughly two billion-person decline in population over the last half of the century is also reliant on broad assumptions of low mortality and low fertility. Generally, the B1 scenario might be most appropriately viewed as a version of a "best case" or "policy" scenario for emissions, while A2 is more of a status quo scenario incorporating incremental improvements."[5]

In addition to the A2 and B1 scenarios, two other scenarios are commonly used in climate modeling.

The A1FI scenario is the scenario with the highest growth in emissions. While it was not included in the California Climate Adaptation Strategy modelling, it has been used by researchers in modelling impacts on water supply in California because it is closest to the growth in GHG emissions from 2000-2007. The A1FI scenario assumes rapid economic growth, with an emphasis on fossil fuels. A1FI was used in modelling by the Stockholm Environmental Institute. [6]

Modelling using A1FI shows strong warming drying. The Stockhom Environmental Insitute models showed frequent droughts in mid-century, on the order of the 91-92 drought, as well as marked reductions in precipitation. These models, and their implications for water supply reliability, are discussed later in this comment letter.

The B2 scenario was not included in the California Climate Change modelling. It assumes local economic growth and slowly increasing population, but has been used in ensemble modeling by the Department of Water Resources. The B2 model is not in agreement with current population growth.

The graph below shows observed C02 emissions vs the IPCC scenarios. From 2000-2007, the growth was closest to the A1FI scenario.

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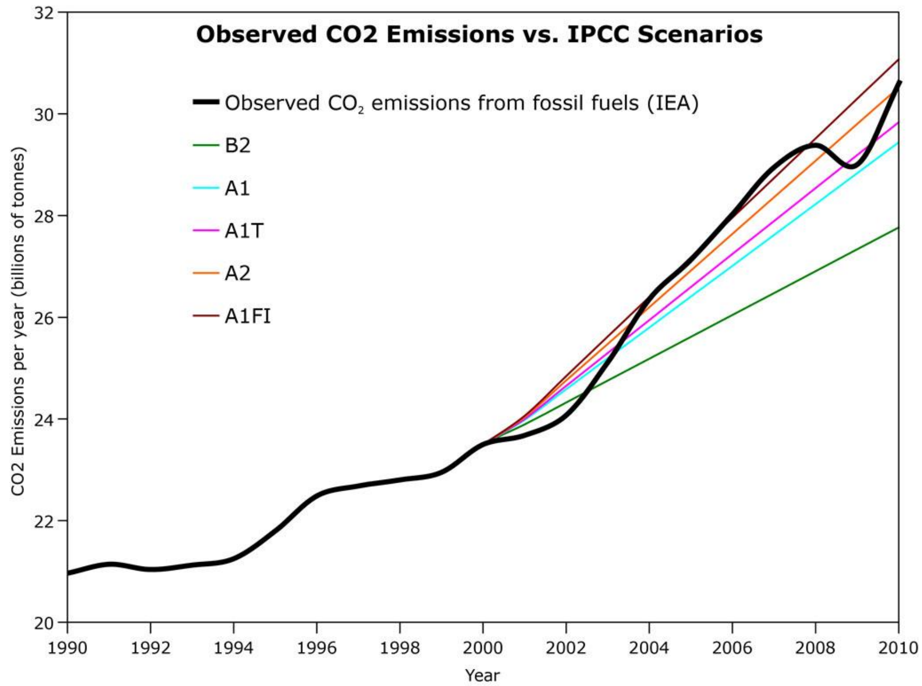
[5] California Natural Resources Agency, draft California Climate Change Adaptation Policy Guide, April 2012. Available at http://resources.ca.gov/climate_adaptation/docs/APG_-_PUBLIC_DRAFT_4.9.12_small.pdf
[6] Ibid.



Global Climate Models

The IPCC climate change scenarios are simulated using different Global Climate Models (GCMs). For the 2009 California Climate Change Adaptation Strategy, modelers chose the National Center for Atmospheric (NCAR) Parallel Climate Model (PCM) and the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluids Dynamics Laboratory (GFDL) models for the analysis.[7] These models were also used in modeling by the Department of Water Resources in 2006, and in later studies by the U.S. Geological Survey in their climate modeling program, and the Stockholm Environmental Institute.

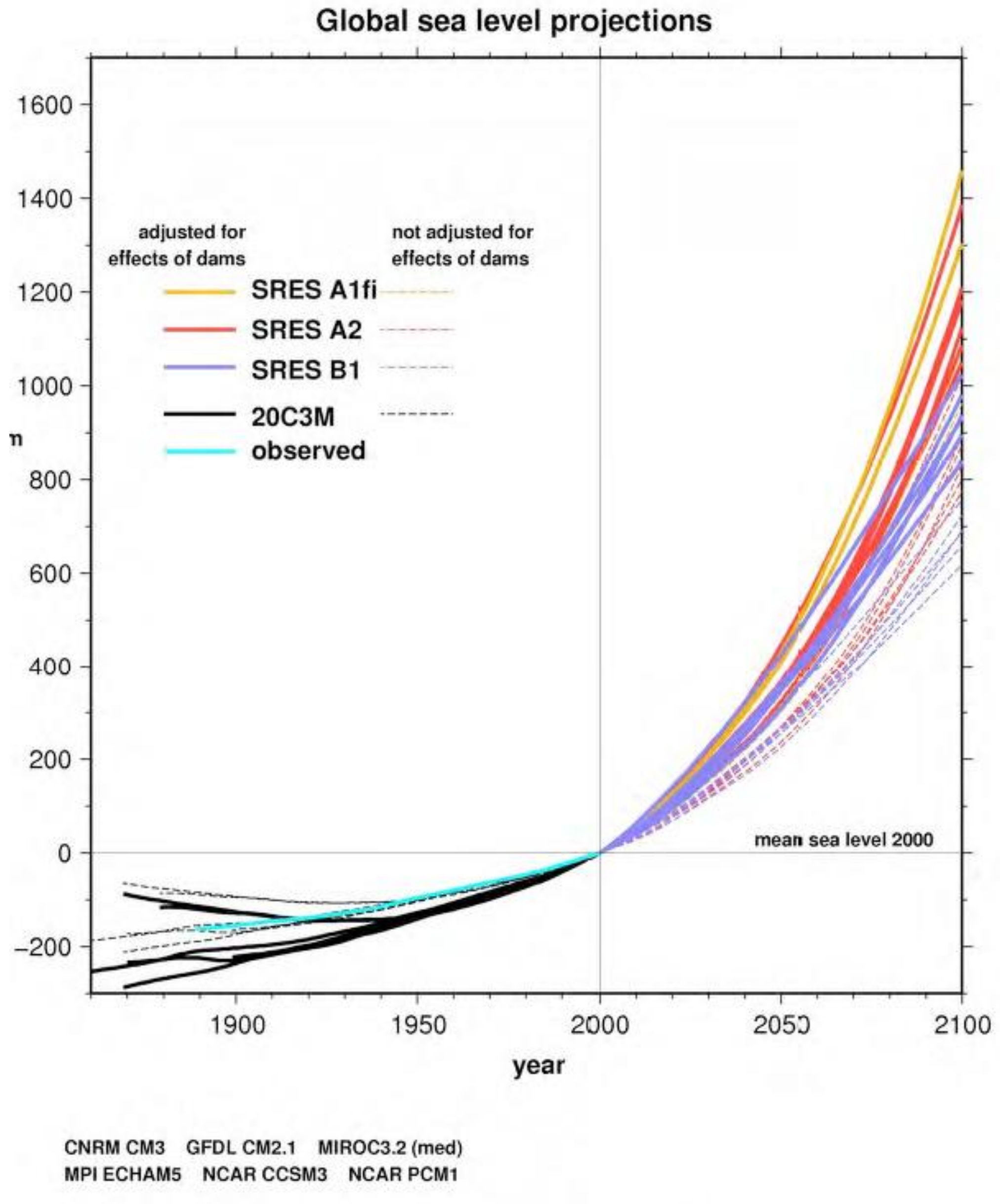
Cayan et. al. discussed the selection of models in a 2009 report from the California Climate Change Center.[8] The report stated that these models were selected

> "on the basis of providing a set of relevant monthly, and in some cases daily, data. Another rationale was that the models provided a reasonable representation, from their historical simulation, of the following elements: seasonal precipitation and temperature (Figure 1), the variability of annual precipitation, and El Niño/Southern Oscillation (ENSO)."

[7] California Natural Resources Agency, 2009 California Climate Adaptation Strategy, Final Report. Available at http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf

[8] Dan Cayan, Mary Tyree, Mike Dettinger, Hugo Hidalgo, Tapash Das, Ed Maurer, Peter Bromirski, Nicholas Graham, and Reinhard Flick, Climate Change Scenarios And Sea Level Rise Estimates For Th California 2009 Climate Change Scenarios Assessment , A Paper From the California Climate Change Center. Available at http://www.energy.ca.gov/2009publications/CEC-500-2009-014/CEC-500-2009-014-F.PDF

The graph below, from the Cayan report, shows the ranges of potential sea level rise predicted from the scenarios run for the California Climate Change Adaptation Strategy.



The Department of Water Resources chose the worst case scenarios of sea level rise for modeling under the Bay Delta Conservation Plan. The worst case was the upper bound of 1400 mm, or 55 inches under the A1FI and A2 scenarios.

Modelling of Impacts on Hydrology and Water Supplies

Modelling in 2006 by the Department of Water Resources used the same two scenarios as the California Climate Adaptation Strategy -- A2 and B1, under the GFDL and PCM Global Climate Models. The Department of Water Resources downscaled results from the global climate models and fed the inputs into CALSIM II, attempting to meet demands of 3.4-4.2 MAF/year of exports for the State Water Project, and full Central Valley Project contracts. The results are described in the July 26 Technical Memorandum, "Progress on Incorporating Climate Change into Planning and Management of California's Water Resources."[9] The schematic diagram for the sequence of models is reproduced below:

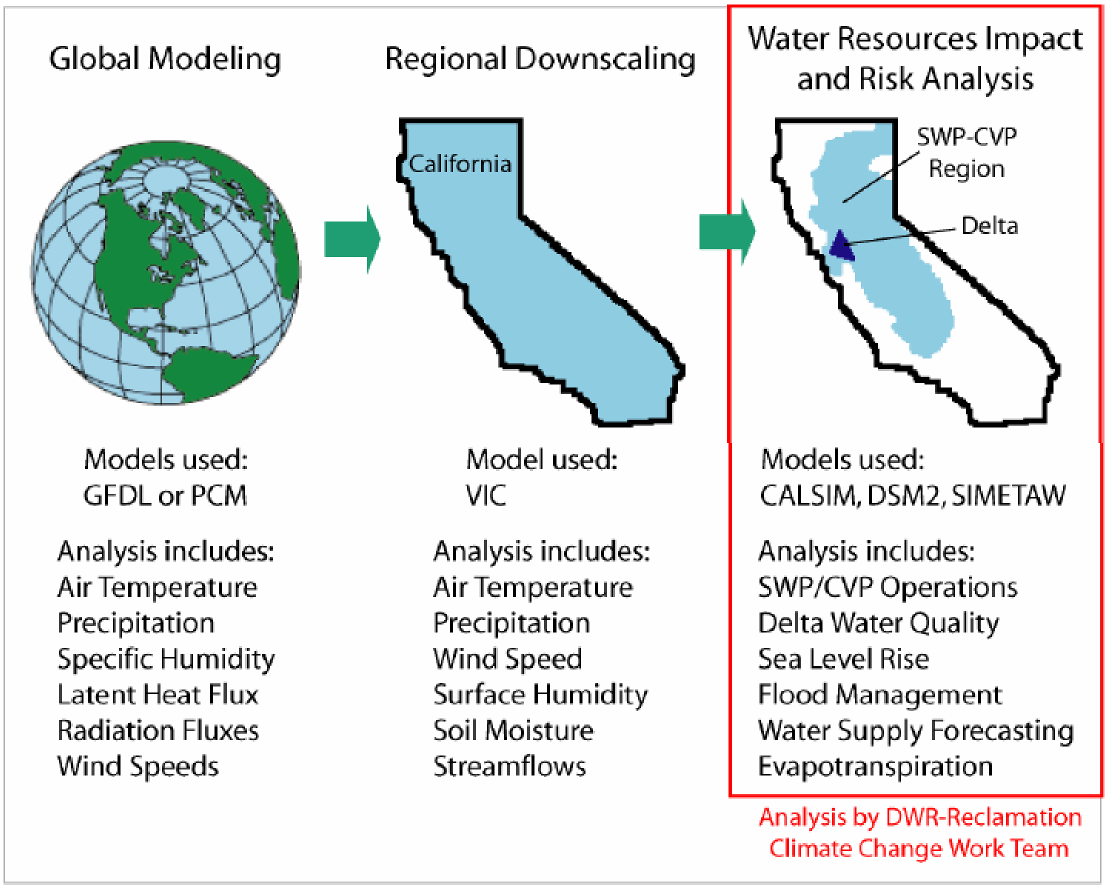


Figure 3.3 Approach for Analyzing Potential Water Resources Impacts of Climate Change

One of the most notable conclusions of the modeling was that upstream storage was decreased, though not as seriously as in later simulations for the Bay Delta Conservation Plan. The graph below is an excedance plot for end of year carryover storage. It is a measure of the amount of water left in the reservoirs at the end of the water year.

[9] Available at http://www.water.ca.gov/climatechange/docs/DWRClimateChangeJuly06.pdf

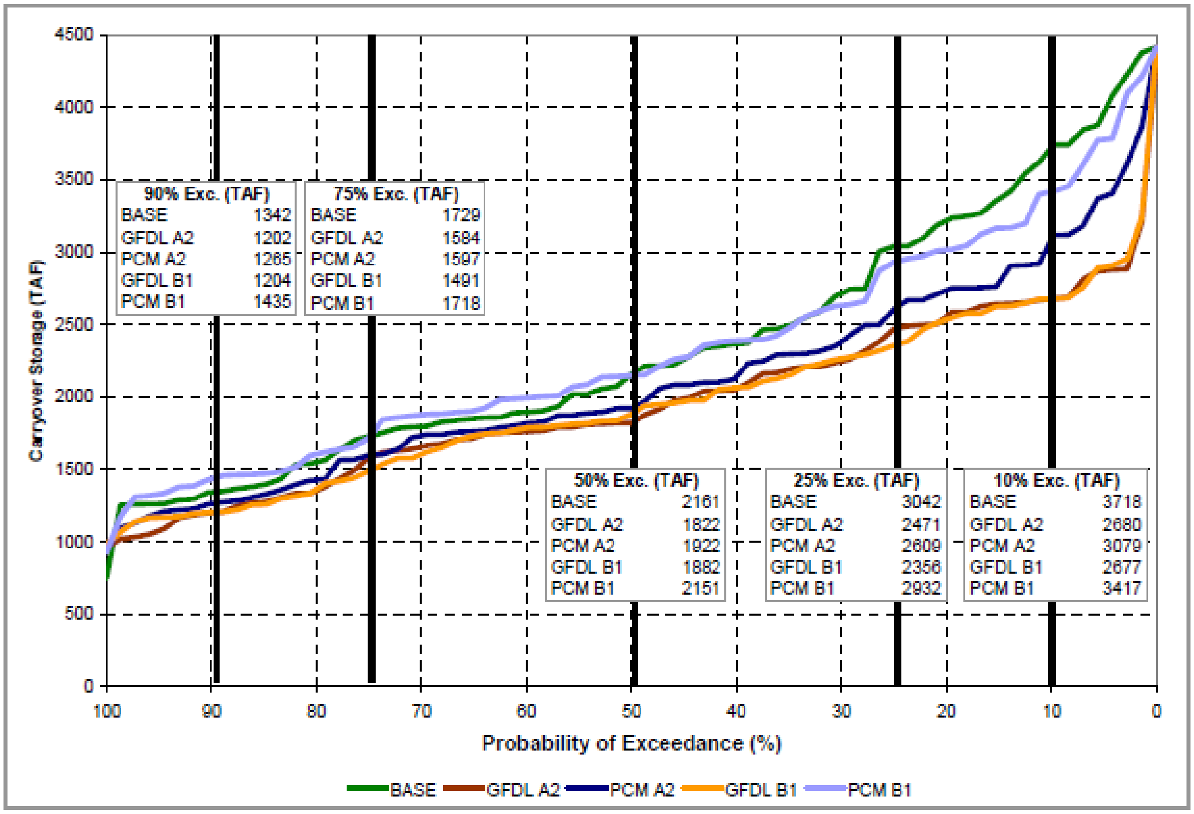


Figure 4.6 Exceedance Probability Plot of SWP Carryover Storage

The modelers noted, "Overall, with the drier climate scenarios, less water was delivered to Table A contractors and more risk with SWP carryover storage was taken to do it." Of particular concern were the number of months of dead storage in upstream reservoirs. These were months when basic demands for water supply for area of origin needs in the Sacramento Valley could not be met. The shortages would also greatly curtail exports.

Table 4.13 Months of Critical Shortages (Storage at Dead Pool)

	Shasta (months)	Oroville (months)	Folsom (months)
BASE	1	0	1
GFDL A2	31	0	28
PCM A2	29	0	22
GFDL B1	21	0	20
PCM B1	0	0	0

It is likely that actual impacts on end of year carryover storage would be much more severe, since the modeling did not attempt to meet requirements for Sacramento River flows to protect salmon. These are the mandated releases from Shasta Reservoir under CVPIA section 3406b(2). The modeling also only used the 2020 level of land development, and only sought to meet 2025 demands for water by Sacramento Valley water users.

Folsom reservoir in 2009, nearing dead pool. Source: Bureau of Reclamation

The Folsom Reservoir is also the water supply for the city of Folsom, and the "dead pool" months would have severe impacts on the city's water supply. According to the city of Folsom 2010 Integrated Regional Water Management Plan Update, the city currently has 64,000 people, and the population is expected to increase to 97,000 by 2035.

The DWR modellers concluded:

> The length of shortages in GFDL A2, PCM A2, and GFDL B1 indicate that the delivery results presented for these scenarios in the next section are not always reliable. Too much risk was taken in the delivery allocation decisions of these three scenarios and not enough storage was carried into the drought periods as a result. In future climate change simulations, modifications to the rule that divides available water into delivery and carryover should be investigated as a means to prevent these shortages. Since CVP allocations are dependent on Shasta and Folsom storage, such modifications will likely alter the resulting delivery capability of the CVP as compared to the results presented in the next section.

It would appear that in trying to meet aggressive export targets, the State Water Project and Central Valley Project are increasing the risk from prolonged droughts.

The graph below shows exceedance plots for SWP deliveries, from the same modelling runs.

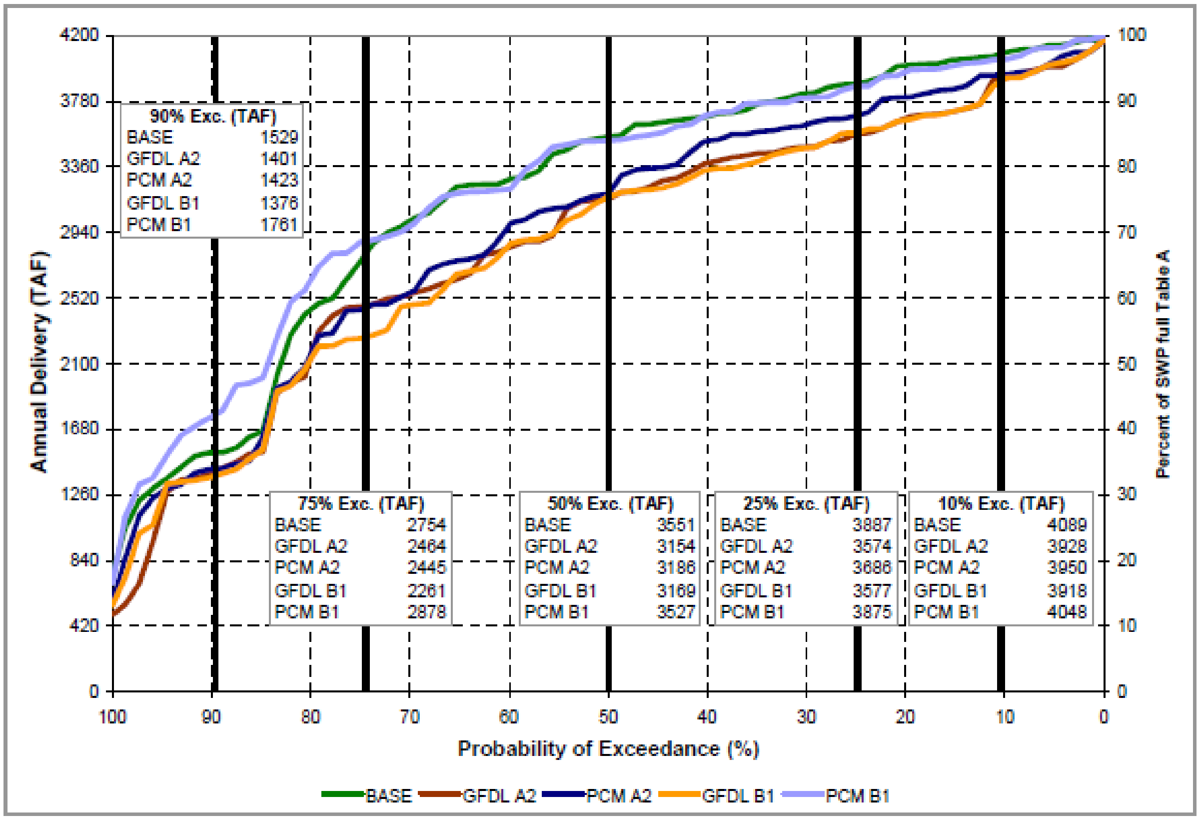


Figure 4.5 Exceedance Probability Plot of SWP Table A Deliveries

The exceedance plots show that the GFDL A2 and B1 scenarios show the greatest reduction in exports in the near term, followed by the PCM A2 scenario. These "worst case" scenarios should be considered in water supply planning.

In later climate change modeling, the Department of Water Resources switched to using ensembles of climate models.[10] The ensemble modelling assumes that all climate change scenarios are equally likely, and produces predictions which capture central tendencies of the collection of models. However, as was noted earlier, this is not the procedure that the Department of Water Resources is using for sea level rise. DWR is using the worst case scenarios for sea level rise, which are the A1FI and A2 scenarios.

It is a standard engineering practice to consider worst case scenarios in design. The A1FI and A2 scenarios are reasonable worst case scenarios to be used in design of a water project that is expected to supply the needs of a large percentage of the state's population for the next 50 years. These are also the scenarios that are most likely under the current growth in greenhouse gas emissions, and the population-weighted percentage of countries that are meeting targets for reduction in emissions.

[10] See, for example, the appendix in the draft BDCP documents on climate change models in BDCP.

This was recently noted in an review of approaches used by the Department of Water Resources. The study found that a range of approaches had been used and that DWR lacks consistency in both characterization of future climate conditions and in its analysis of how climate changes will impact hydrology.[11]

(how will climate changes effect streamflow and State Water Project Operations). For review of water supply reliability in the proposed Bay-Delta Conservation Plan, the Delta Stewardship Council should require that the Department of Water Resources not only provide the current BDCP models of hydrology and water supply under ensembles, but also provide specific results under the A1FI and A2 scenarios as drier climate models, including the GDFL model. This modeling will provide the information needed to assess the actual changes in water supply reliability from the project.

The Delta Stewardship should also ask the Independent Science Board to review the climate change model assumptions used by the Department of Water Resources, and compare the results of DWR's modeling with recent modeling by other agencies and researchers working with the California Climate Center. Most of these models show more severe impacts on precipitation and Sacramento Valley flows than modeling by the Department of Water Resources.

One of the reasons may be the downscaling method used in the Department of Water Resources. DWR is using a statistical downscaling from the Global Climate Models using the Variable Infiltration Capacity (VIC) model. The statistical downscaling has a tendency to reproduce the same frequency and severity of droughts as in the historical period. In an early draft of the 2006 report, one of the modelers for DWR commented,

> "...Furthermore, the method of downscaling global climate model information for CalSim-II input only captures the general trends of average rainfall and seasonal shifts in runoff. There is no information included about changes in weather variability. In each of the scenarios, the frequency and length of the droughts remained the same. If climate change influences these underlying weather phenomena, then we are missing important information necessary todetermine impacts to CVP and SWP operations. "

One can see the effects of this downscaling by comparing DWR models with modeling by David Purkey of the USA branch of the Stockholm Environmental Institute, in collaboration with researchers from UC Berkeley. Purkey's modeling showed marked increases in the structure of drought persistence under the A2 and B1 scenarios, using the Parallel Climate Model (PCM) and Global Fluid Dynamics Lab (GFDL) global climate models.[12], [13]

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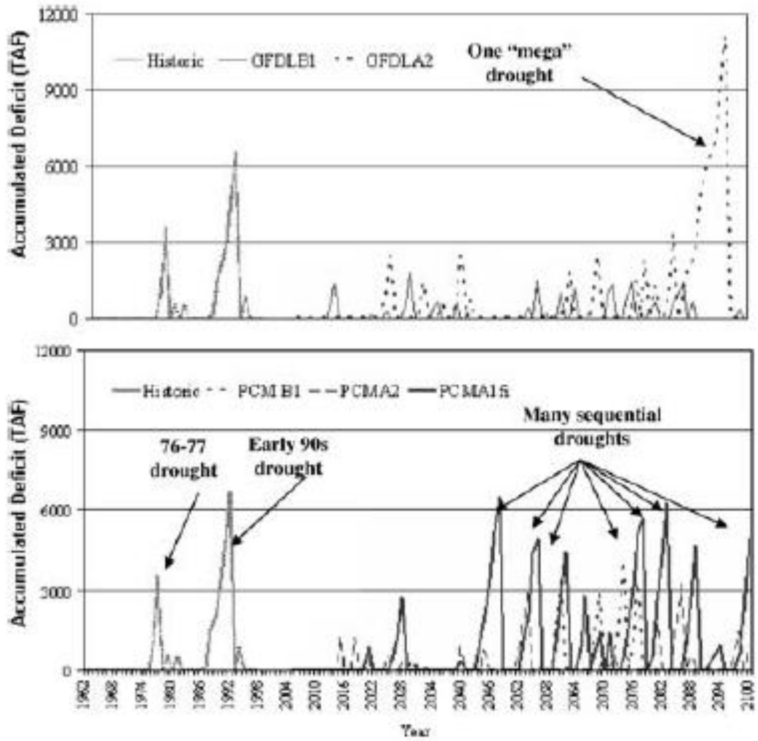
[11] See the report by Khan and Schwarz, "Climate Change Characterization and Analysis in California Water Resources Planning Studies," December 2010, Department of Water Resources. Available at http://www.water.ca.gov/climatechange/docs/DWR_CCCStudy_FinalReport_Dec23.pdf

[12] D.R. Purkey and B. Joyce et. al., "Robust analysis of future climate change impacts on water for agriculture and other sectors: a case study in the Sacramento Valley," op. cit.

[13] B. Joyce and V. Mehta et. al., "Climate Change Impacts on Water Supplies and Agricultural Water Management in the Western San Joaquin Valley and Possible Adaptation Strategies," op. cit.

Fig. 3 Structure of drought persistence under discrete climate scenarios associated with four GCM/emission scenario combinations



Modelling by Purkey et. al. used the Water Evaluation and Planning (WEAP) model for downscaling. This is an independent model that was developed by the Stockholm Environmental Institute and has been used for studies around the world. WEAP has also been used in climate modeling for the 2009 California Water Plan, and is being used in preparing the 2013 California Water Plan.

It is important to compare the results for predicted frequency and severity of droughts from the WEAP method of downscaling with the VIC method of downscaling used in BDCP modeling. Given the recent experience with the prolonged and severe drought in Texas, the issue of bias towards historical frequency of droughts in BDCP climate change modelling should should be addressed.

The US Geological Survey released a paper in February using the A2 scenario with the Global Fluid Dynamics Lab (GFDL) climate model. [14] The study was done by R.T. Hanson and other researchers at USGS in collaboration with Daniel Cayan, who oversaw the modeling for the California Climate Adaptation Strategy.

The paper uses the GFDL A2 scenario for predictions. This is a drier scenario which was used

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[14] R.T. Hanson et. al., "A method for physically based model analysis of conjunctive use in response to potential climate changes," Feb 4, 2012. Available at http://ca.water.usgs.gov/projects/cvhm/Hanson_etal_2012_WRR.pdf.

in the California Climate Adaptation Strategy. On the next page is a graph of predicted river flows in the Central Valley. The USGS models predict a 16-17% reduction in Sacramento River flows from 2020-2030 and 2040-2050, and a 34% reduction by 2080-2090. Similar reductions are predicted for the Tuolumne and Kern Rivers.

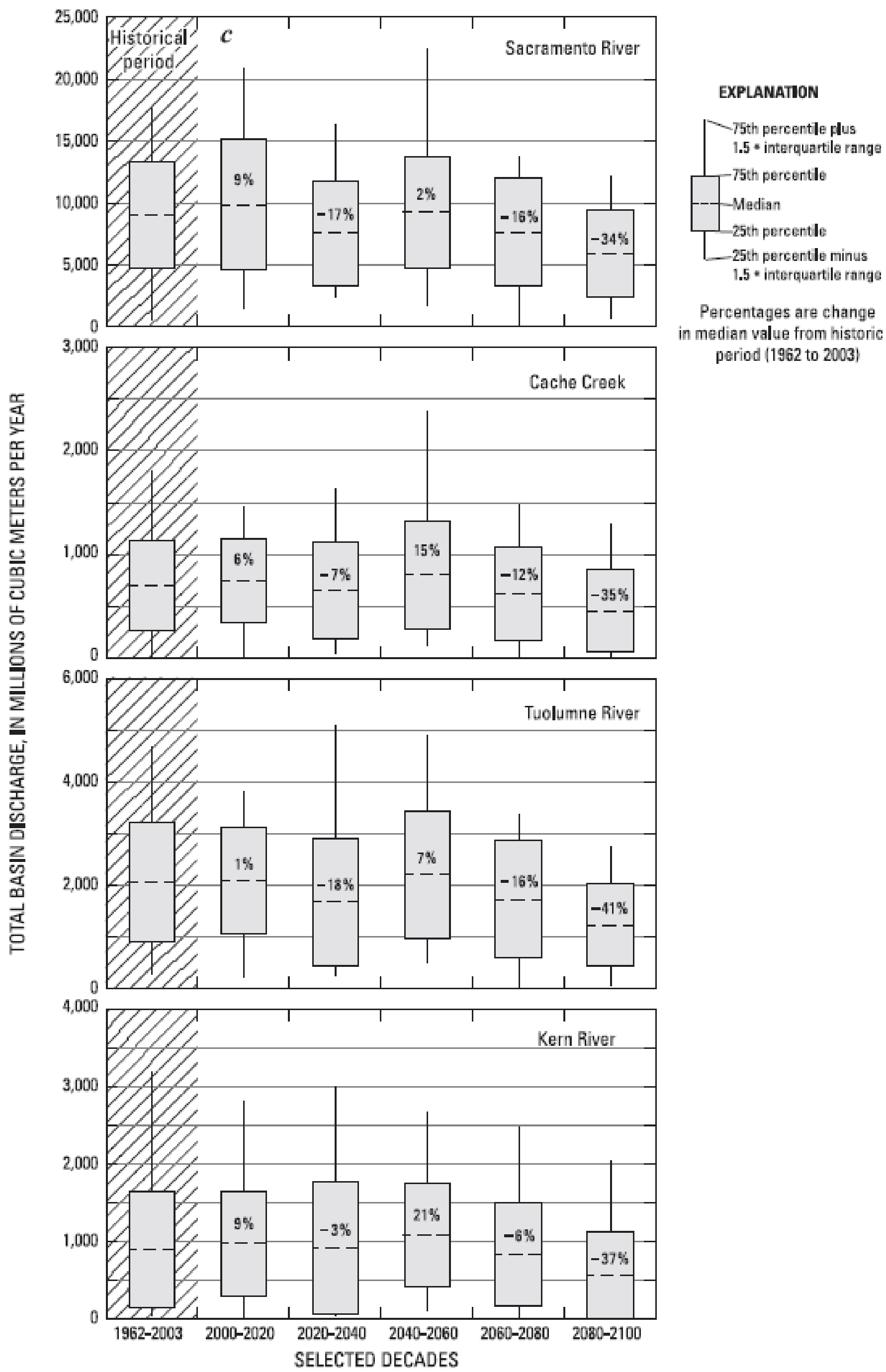


Figure 3. (continued)

The maps below show details of the reduction in river inflows from the USGS modeling. The different basins are color-coded, based on flow. There is a marked reduction in flows in all basins in the Central Valley by the end of the century.

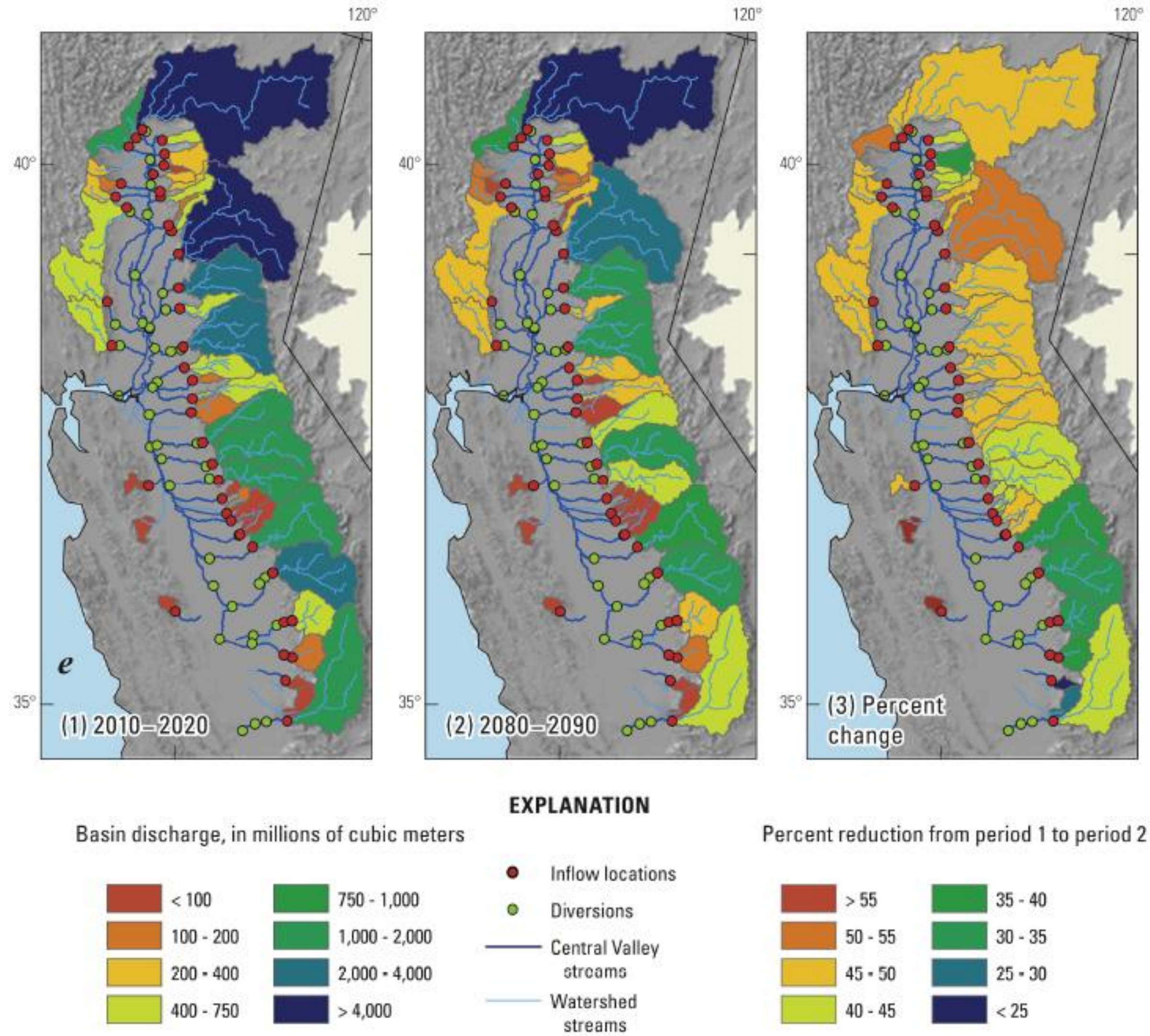


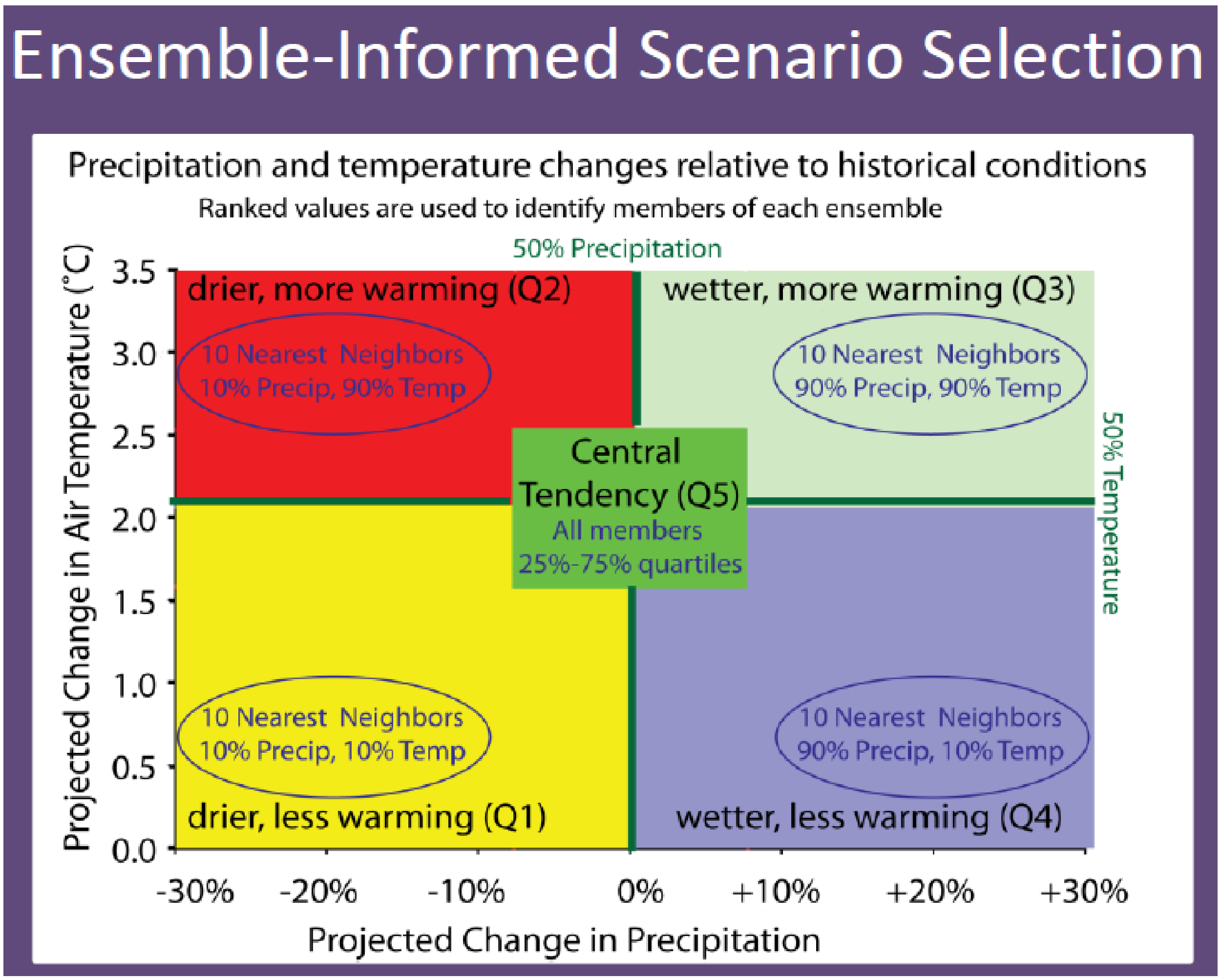
Figure 3. (continued)

The climate change modeling for the Bay-Delta Conservation Plan has predicted much smaller effects on streamflows. This has to do with the structure of the ensemble modeling used by BDCP. BDCP uses 112 climate change models, clustered under four different quartiles:

- Drier, less warming
- Drier, more warming

- Wetter, less warming
- Wetter, more warming

Each cluster of models is used to produce an ensemble model for each quartile. The cluster models are then combined to make a single, global ensemble prediction. The global ensemble prediction captures the central tendency of all four quartiles of models. In general, this ensemble structure will produce a global prediction that is close to current norms of temperature and precipitation. The graph below, from a recent presentation by Jamie Anderson on selection of climate change scenarios, illustrates the ensemble scheme.[15]

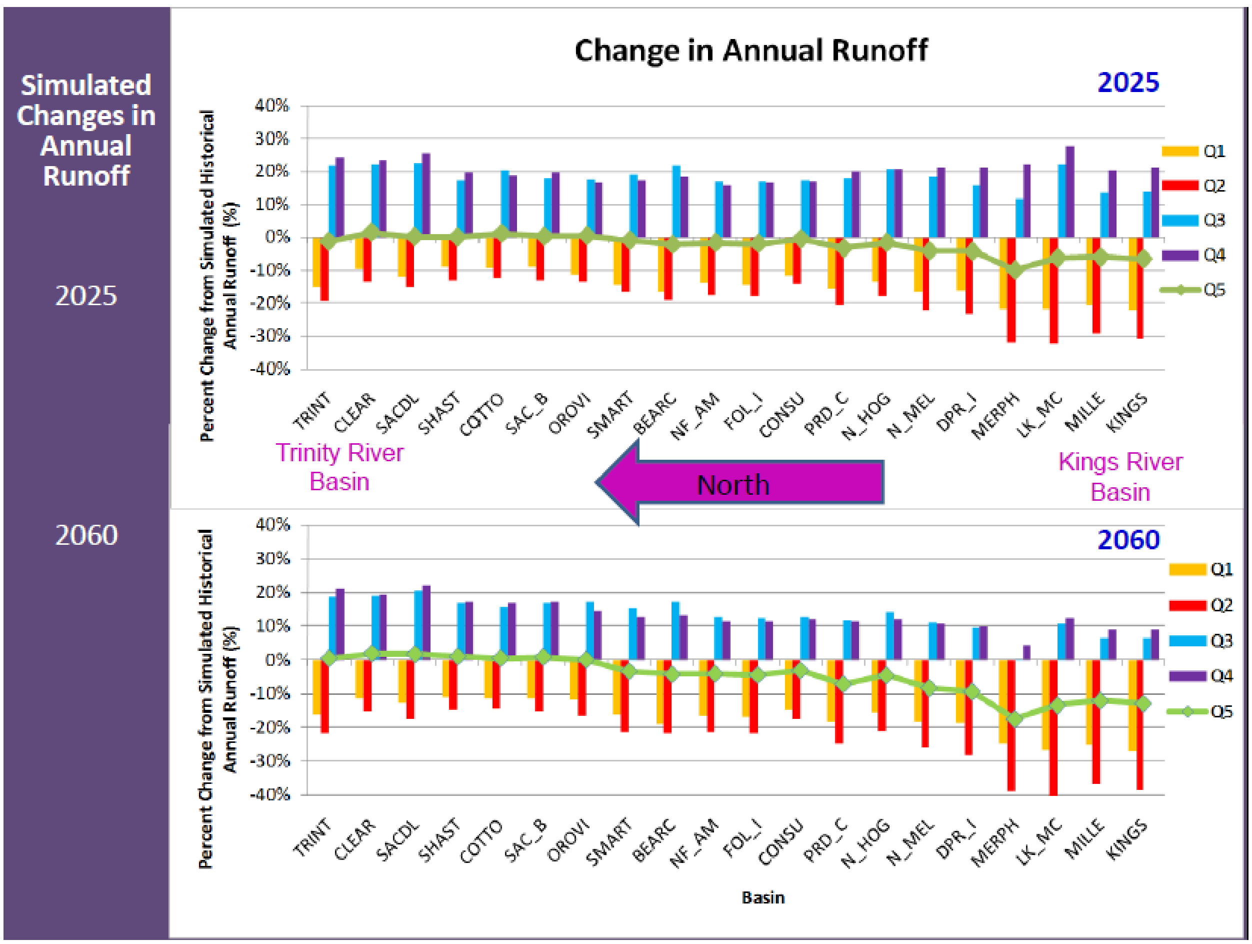


The graph below, also from Anderson, shows different trends in river runoff for the different quadrants under BDCP. The drier, more warming Q2 model predictions include the worst case

[15] Jamie Anderson, presentation on Climate Change Approaches, Department of Water Resources, March 2012. Available at http://www.water.ca.gov/climatechange/docs/CCTAG_climate_change_approaches%20final_3-28-12_Jamie%20Anderson_with%20extra%20slides.pdf

scenarios under A1FI and A2, discussed earlier. The drier, less warming Q1 model predictions are similar to the B1 models which showed weaker but still noticeable drying. The predictions of these models are red and yellow, and all show significant reductions in streamflows, more by the end of the century.

The Q3 wetter, more warming and Q4 wetter, less warming quartiles represents model which are less common in the space of all models. These climate change models include some of the A2 scenario models, and some of the B1 and B2 models. The graph below shows the different predictions of these wetter quartiles in light and dark blue. All the wetter models show increases in streamflow, but less by the end of the century, particularly in the San Joaquin Valley



The predictions of the final quartile, Q5, are shown in grey. Q5 is a combination of the four different wetter and drier models, Q1 to Q4. This is the central tendency of the set of models, when broken out by quartile. As you can see, the central tendency model tends to reproduce the historical precipitation patterns in the near term. It is only over the long term, when the severe potential drying under the drier models far outweigh the effects of the wetter models, that the central tendency model begins to show some drying.

The issue with this central tendency ensemble model is that it will tend to center on little to no change from historical precipitation patterns. Using this ensemble model for BDCP could significantly underestimate effects of climate change in reducing precipitation and streamflow.

The central tendency models are not appropriate for a water supply reliability analysis, which should look at the worst case scenarios, and particularly the warmer and much drier scenarios that are more likely under current trends in growth of population and greenhouse gas emissions.

Problems with Upstream Storage Reported in BDCP Modelling

Although BDCP climate change modeling may greatly underestimate the effects of climate change on reducing flows into reservoirs, modelers are still reporting severe problems with upstream storage.

In 2010, Francis Chung, head of the DWR climate change modelling team, presented results on modeling for BDCP at the California Water and Environmental Modelling Forum at Asilomar.[16]

Chung showed results from a range of models, including the proposed operations under the "Preferred Project" with a 50% probability of excedance of 5.5 MAF/year SWP and CVP exports. The models showed that there was a huge increase in months with dead storage in North of Delta reservoirs. The Table is reproduced below.

Numbers of Dead Storage Months for North-of-Delta Reservoirs from Climate Change

Scenario	Trinity	Shasta	Oroville	Folsom	Total
D1641	3	6	0	6	15
(+) Wanger with CC	9	24	21	25	79
(+) BDCP with CC	12	21	10	39	82
(+) NODOS with CC	15	24	17	42	98
(+) SOD GW Bank with CC	17	27	23	46	113

[16] Francis Chung, An Assessment of CVP-SWP Performance Under Alternative Delta Regulations, Infrastructure and Climate Change Scenarios Regarding CAlSiM II, California Water and Environmental Modelling Forum, Feb 22, 2010. Available at http://www.cwemf.org/Asilomar/FrancisChungCWEMFPres.pdf

Chung concluded, "Results appear to be unsustainable. The relative frequency of dead storage conditions in upstream reservoirs indicate that significantly modified operations will be required with climate changed conditions." and went on to say,

"We recommend that DWR develop a reoperation strategy for the CVP and SWP that includes modified operations scenarios to mitigate the effects of dead storage during climate change conditions prior to release of any studies (either these or BDCP) that include climate change."

Unfortunately, it appears that no such strategy has been considered. Such a strategy is critically important in protecting the water supply for 25 million people.

The Delta Stewardship Council must ensure that these problems are not swept under the rug, by requiring explicit reporting of total months of dead storage in the final BDCP proposed project. If the state cannot afford one interruption in water supply from an earthquake in the Delta, it certainly cannot afford many interruptions from exhaustion of upstream water supplies by overly optimistic exports.