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California Central Valley Water Rights in a Changing Climate

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ABSTRACT

Climate change and resulting changes in hydrology are already altering—and are expected in the future to continue to alter—the timing and amount of water flowing through rivers and streams. As these changes occur, the historical reliability of existing water rights will change. This study evaluates future water rights reliability in the Sacramento–Feather–American river watersheds. Because adequate data are not available to conduct a comprehensive analysis of water rights reliability, a condition placed into certain water rights, known as Term 91, is used to model projected water rights curtailment actions. Comparing the frequency and length of the historical and simulated future water diversion curtailments provides a useful projection of water rights reliability and water scarcity in the Sacramento–San Joaquin Delta (Delta) watershed.

Projections of future water rights curtailments show that water rights holders are likely to be curtailed much more frequently, and for significantly longer durations, as we move through the 21st century. Further, many more water rights holders will be affected by curtailment actions in the future. As curtailments last longer and become more common, more water users will have to access other supplies, such as groundwater or water transfers, or will have to fallow land or conserve water in other ways to meet their demands. These activities will likely ratchet up the potential for additional conflicts over water in the Delta watershed.

KEY WORDS

water rights, climate change, Term 91, CalSim-II, Supplemental Project Water, diversions, diversion curtailments

INTRODUCTION

Water rights form the core of California's surface water resources system, and determine who may divert what quantity of water and when. Water rights protect investments and provide for an orderly allocation of water. While there is no guarantee that the holder of a water right will be able to exercise that water right in any given year, the system of water rights establishes reasonable expectations of the relative reliability of each individual water right.

Climate change and resulting changes in hydrology are already altering—and are expected in the future to continue to alter—the timing and amount of water flowing through rivers and streams (Kadir et al. 2013; Stewart et al. 2004). As these changes occur, the historical reliability of existing water rights will change. Some water rights will undoubtedly become less reliable while others may actually become more reliable. This study evaluates future water rights reliability by looking at projected changes in the frequency and duration of water diversion curtailments.

By examining projected changes in hydrology over the 21st century, this study looks at how projected water availability will affect existing water rights holders in the Sacramento–Feather–American river watershed. Projections of future water rights curtailments have been calculated and show that water rights holders are likely to be curtailed much more frequently and for significantly longer durations as we move through the 21st century.

This study does not attempt to comprehensively analyze the effects of climate change on water rights in California, nor does it attempt to explore the entire range of uncertainty of potential effects of climate change. The twelve projections of future climate change used in this study have been used in a range of vulnerability and impact assessments for California resources including water, energy, agriculture, and public health (CAT 2009, 2012), and serve as a useful sampling of potential climate change futures. However, uncertainty exists in how quickly temperatures will change, and how atmospheric changes will drive precipitation changes in California. Further, this study uses a proxy metric (Term 91 supplemental project water) to gauge potential changes in water availability under California's existing water rights system. The proxy metric is coarse and imperfect; nonetheless, the analysis provides insight into the direction of change—and the potential scale of the changes—water rights holders may face.

Assessing the effect of climate change on existing water rights holders in California is not straightforward. California's water rights system is complex. Alone among the states, California recognizes riparian rights, as well as appropriative rights. Moreover, the Legislature has exempted riparian rights and pre-1914 appropriative rights from the State Water Resources Control Board's permitting and licensing jurisdiction. Each of these water rights has different characteristics, priorities, and restrictions. On top of this complexity, data on actual water diversions are spotty, and what data are available come with significant accuracy concerns. Recent legislation and improvements in water diversion monitoring are currently improving this situation, but it is likely to be several years before reliable data exist. In light of these challenges, a comprehensive assessment of the effect of climate change on all water rights holders in California was not practicable. To analyze climate change effects on water rights, we needed a way to determine when water rights would be affected. This study uses a condition placed into certain post-1965 appropriative water rights, known as Term 91, and the frequency and length of the resulting water diversion curtailments as a proxy for changes in water rights reliability and water scarcity in the Sacramento–San Joaquin Delta (Delta) watershed.

TERM 91 AND SUPPLEMENTAL PROJECT WATER

Since at least 1967, the State Water Resources Control Board (Water Board) has been concerned about Delta salinity, and has issued multiple decisions to establish and revise requirements for Delta salinity standards. In recent years, the Water Board has added additional water quality parameters, and Delta inflow and outflow requirements.

In a 1971 water right decision, D-1379[1], the Water Board essentially placed the responsibility for maintaining Delta salinity control on the operators of the Central Valley Project (CVP) and State Water Project (SWP), referred to collectively in this paper as "the Projects." The Water Board cited California Water Code Sections 12202, 12203, and 12204 in stating that no water shall be diverted from the Delta unless salinity control in the Delta and the needs of Delta water users are met first. In 1978, the Water Board issued Decision 1485 (D-1485[1]), which established new, more stringent water quality standards and explicitly required the CVP and SWP to maintain those water quality standards in the Delta and Suisun Marsh. After this decision, the U.S. Bureau

1 Available from: *http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/*

of Reclamation (Reclamation), operator of the CVP, and the California Department of Water Resources (CDWR), operator of the SWP, began protesting new water right applications within the Delta watershed, arguing that diversions by new applicants would force the Projects to release more stored water to meet the Delta water quality standards established by D-1485. The Water Board responded to these protests by adopting Water Right Permit Term 91 (Term 91) in 1980 as an interim solution to the problem. Term 91 was placed into appropriative water rights permits and licenses (collectively referred to as water rights throughout this paper) issued within the Delta watershed after 1965[2].

Term 91 requires that certain water rights holders cease diverting when the Delta is in balance (i.e., the projects are being operated to meet Delta water quality requirements) and water being released from storage is in excess of the amount of water required to meet export diversions plus carriage water[3] (Wilson 2012). Put simply, Term 91 prohibits diversions by these water rights holders when the Projects are releasing stored water (in excess of natural flows) to meet the Delta water quality standards.

In 1981, the Water Board adopted Water Right Order 81-15[4], which detailed exactly how it would determine when conditions required the invocation of Term 91 to curtail water diversions. Calculation of the actual amount of water available for diversion in the Delta watershed was and is both extremely complex and subject to substantial error because of the lack of accurate flow and diversion data. Despite these complications, the Water Board, Reclamation, and CDWR agreed on a method known as the Supplemental Project Water (SPW) calculation. This calculation is based on real-time daily data, and Reclamation still calculates it daily and reports it at: *http://www.usbr.gov/mp/cvo/vungvari/term91.pdf*.

2 1965 corresponds closely with the beginning of operation of the State Water Project.

3 Carriage water is additional flows released during export periods to ensure maintenance of water quality standards and help maintain natural outflow patterns in Delta channels.

4 Available from: *http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/index.shtml*

The *SPW* calculation is described by the equation:

$$SPW = SR - D - CW,$$

where:

SPW is Supplemental Project Water (water previously stored by the Projects) being released to the system in excess of natural and abandoned flows to meet in-basin water demands and Delta water quality requirements;

SR is net storage released from Whiskeytown, Shasta, Oroville, and Folsom reservoirs (i.e., outflow from reservoirs minus inflow);

D is Diversions from the Harvey O. Banks Pumping Plant (SWP), C. W. "Bill" Jones Pumping Plant (formerly Tracy, CVP), Contra Costa Canal and Folsom South Canal; and

CW is carriage water (i.e., the amount of additional water required to move a unit of water across the Delta).

When the calculation of *SPW* becomes positive (i.e., storage releases exceed diversions plus carriage water), the two conditions required to invoke Term 91 are met. When this happens, typically in late spring or early summer, the Water Board issues curtailment orders to water rights holders subject to Term 91, requiring that they cease diverting water. When the calculation of SPW becomes negative again, typically in late summer or early fall, Term 91 curtailments are lifted, and restricted water rights holders can begin diverting again. In practice, invocation of Term 91 is more complex because the daily *SPW* calculation can be somewhat volatile as a result of rainfall, tributary flows, or changes in diversions. Thus, the actual start and end of Term 91 curtailments may trail, or in some cases, precede the day at which the *SPW* calculation crosses the zero line.

Since its implementation in 1984, Term 91 curtailments have been invoked in 24 of 29 years. On average, curtailments have begun on June 16 and ended on September 3 (a 79-day average duration). Until 2013, the longest continuous curtailment

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on record was in 1992, lasting from May 21 until November 15 (178 days) (2013 email from Kevin Long, State Water Resources Control Board, to me, unreferenced, see ”Notes”). However, in 2013, Term 91 was invoked from May 7 until September 20 and then again from October 30th until February 11, 2014 (240 days total days curtailed, by far the longest curtailment in history). Then in 2014, Term 91 curtailment began on May 20 and ended November 26 (190 days), breaking the 1992 record by almost 2 weeks.

Term 91 and the *SPW* calculation serve as a useful proxy metric for water shortages in the Delta watershed. They provide a quantifiable metric over time that describes the degree to which releases from the Projects’ storage facilities are needed to meet the water demands in the basin. However, it must be noted that Term 91 is not a comprehensive metric of water scarcity in the Delta watershed. It doesn’t comprehensively account for all inflows, outflows, demands, and requirements in the system. For example, it doesn’t account for the San Joaquin, Cosumnes, Calaveras, or Tuolumne river inflows to the Delta, inflows from smaller tributaries on the Sacramento or American rivers, or the water users on any of those rivers. And it only provides a start and end date for water shortages, but doesn’t provide an estimate of the depth or severity of the shortage. Only about 120 water rights permits contain Term 91, and those diverters represent a relatively small amount of water.

Nonetheless, even with all of these caveats, this is the actual methodology the Water Board uses to determine when Term 91 curtailment orders are issued and rescinded, and therefore provides a metric that is grounded in actual water rights decisions. Despite the relatively small group of affected water rights holders, Term 91 accounts for the most significant basin conditions (inflow–outflow, to and from reservoirs, Delta exports, and Delta water quality conditions), and therefore serves as a general barometer of overall water scarcity in the basin. Each year, the date at which *SPW* values become positive represents the date on which water that has been previously stored by the Projects must begin to be released to meet in-basin water flow and water export demands. In this way, the *SPW* calculation provides a useful metric to determine at what point each year natural flows in the Delta watershed become insufficient to meet the watershed’s water demands. By tracking this date over time we can gauge how water availability may change in the future.

Limitations on data availability for water diversions and tributary flows, and the complexity of the water rights system in the Delta watershed, make a true comprehensive accounting and projection of future water rights reliability impractical. However, Term 91 curtailments serve as a useful gauge of water rights reliability because Term 91 water rights holders represent the first water users to be curtailed. Changes in Term 91 curtailments may also provide information about other changes in water management and operations, and also may foreshadow conditions that require additional curtailments on other water users not subject to Term 91, as has occurred during previous droughts.

METHODOLOGY

Projections of future Term 91 curtailments are developed by using a series of linked models: downscaled and bias-corrected global climate models (GCMs), the Variable Infiltration Capacity model (rainfall—runoff), CalSim-II (Central Valley water project operations), and Term 91 Supplemental Water Project calculations. This work builds on work CDWR did in 2009 (Chung et al. 2009). Chung et al. (2009) analyzed the potential effect of climate change on Central Valley water project operations by developing projections of future streamflows into major Central Valley reservoirs and the resulting CVP and SWP operations. Future climate conditions were drawn from six different global climate models run with two different greenhouse gas (GHG) emissions scenarios to generate 12 simulations of future climate. Each of the 12 climate simulations is used to generate projections of future Central Valley streamflows. The stream flow projections were then run through the CalSim-II model to simulate future water project operations. This process is summarized by Khan and Schwarz (2010).

Table 1 Comparison of historical observed and historical simulated *SPW* values

Data set	Date range	Average start date of curtailment	Average end date of curtailment	Curtailment duration (days)	Percentage of years with no curtailment
Observed Term 91 dates	1983–2012	June 16	September 03	79	17.9%
CalSim-II (historical run)	1922–2003	June 15	September 03	80	19.8%

This study takes the simulations of the Projects' operations from the 2009 work and uses them to calculate future *SPW* flows and associated Term 91 water diversion curtailments. For each simulation (comprising a GCM, an emission scenario, and a time-period), we extracted output data from the CalSim-II run for each term in the *SPW* calculation for each month of the 82-year simulation. This resulted in 24 unique 82-year time-series simulations of average monthly SPW values.

VALIDATION

To validate the concept that calculations of *SPW* could be accurately simulated using CalSim-II, a historical run of observed streamflows from 1922 to 2003 was used. We calculated *SPW* for each month of the 82-year period using the CalSim-II historical simulation run. We calculated statistics for average start date of curtailment (*SPW* greater than 0), average end date of curtailment (*SPW* returning to negative value), and average percentage of years throughout simulation where no curtailment occurred. We compared these statistics to the statistics for the historical period over which Term 91 has been implemented and for which observational data is available (1984–present).

A comparison (Table 1) shows that CalSim-II indeed does an excellent job of simulating Term 91 historical observed behavior. As shown in Table 1, CalSim-II is able to simulate very closely the beginning and ending of Term 91 curtailments, and the percentage of years where no curtailment takes place.

Supplemental Project Water calculations are done on a daily basis using observational data from throughout the Central Valley. CalSim-II provides simulations of Central Valley conditions on a monthly time-step. This presents some inconsistency between the observed historical behavior and model simulated behavior. We also used a third data set, Reclamation's daily *SPW* calculations from 2002 to 2011, to validate CalSim-II performance. This data set provides the actual daily *SPW* calculations the Water Board used to determine when to invoke the curtailment. Ideally, the CalSim-II historical run would be compared to the daily *SPW* calculations, but this was only possible for 2 years (2002 and 2003) when the two data sets have overlapping data. Figures 1A and 1B show both Reclamation's and CalSim-II *SPW* calculations for years 2002 and 2003. The figures show that the CalSim-II simulation trace (red) does a good job of representing the general behavior of the observed trace (blue). Further, the two most important points—the point at which *SPW* goes positive (start of curtailment) and the point at which *SPW* goes negative (end of curtailment)—are represented extremely well. When these monthly simulations are averaged over the entire simulation period, the precision errors are reduced to a negligible level.

RESULTS

The projections of future climate conditions explore how warmer temperatures—which would result in more precipitation falling as rain and earlier snowmelt runoff—and changes in precipitation distribution and quantity could drive water availability. Each of the six climate models used in the study project slightly different types of shifts in temperature and precipitation and each of the six models is run with an optimistic projection of GHG emissions (Emissions Scenario B1) and a more pessimistic–realistic projection of GHG emissions (Emissions Scenario A2) in the future. The 12 projections for each time period—mid-century (2030 to 2059) and end-of-century (2070 to 2099)—provide

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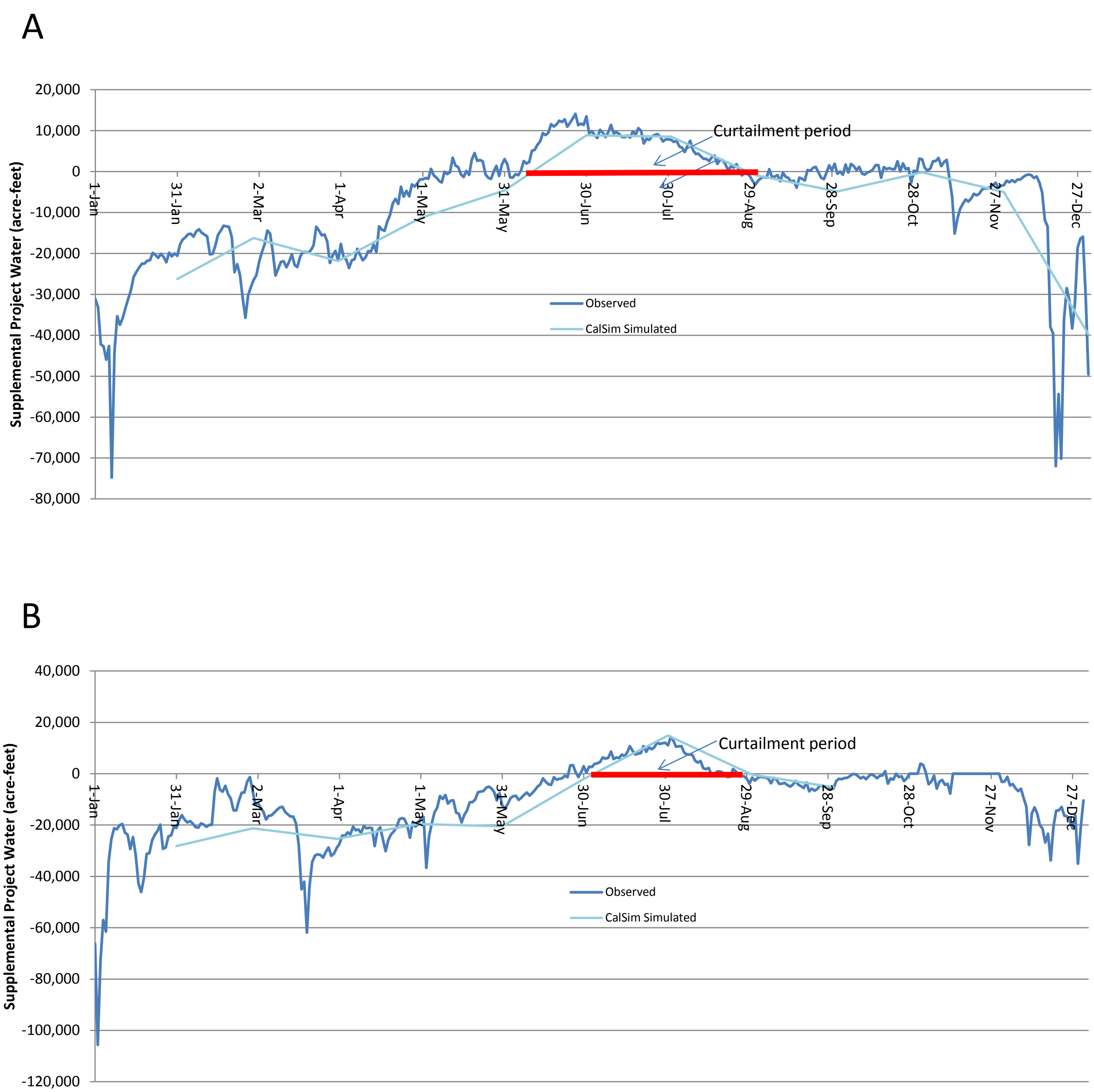

Figure 1 **(A)** 2002 Supplemental Project Water calculation observed and CalSim-II simulated and **(B)** 2003 Supplemental Project Water calculation observed and CalSim-II simulated

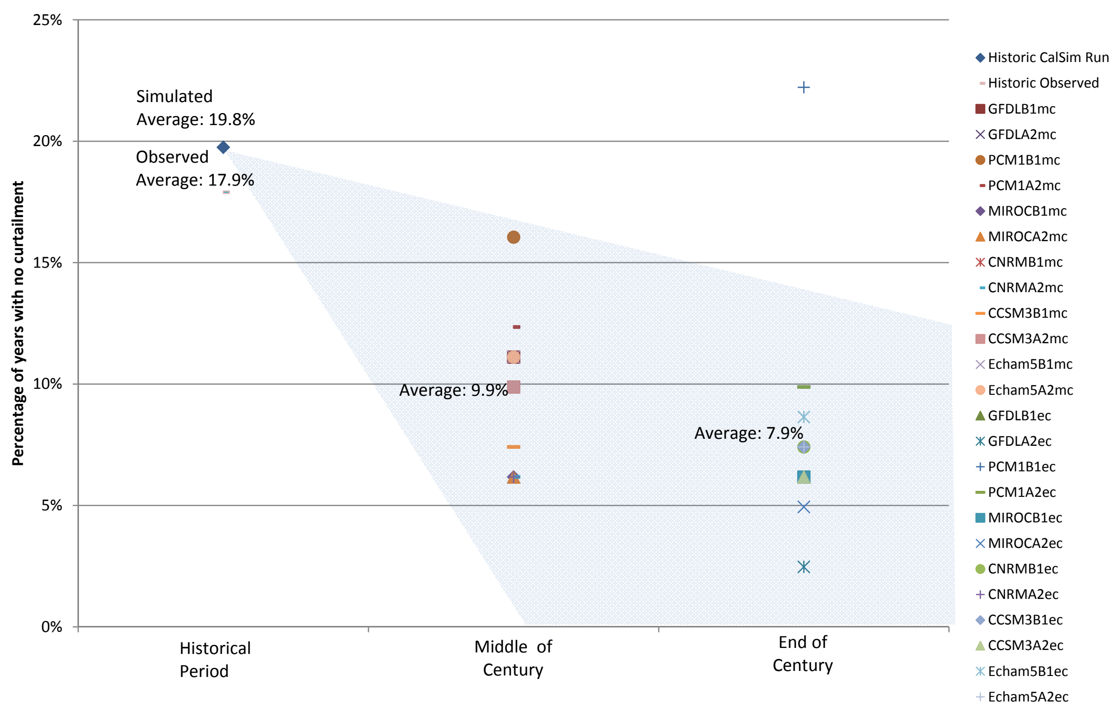

Figure 2 Percentage of years with no Term 91 curtailment

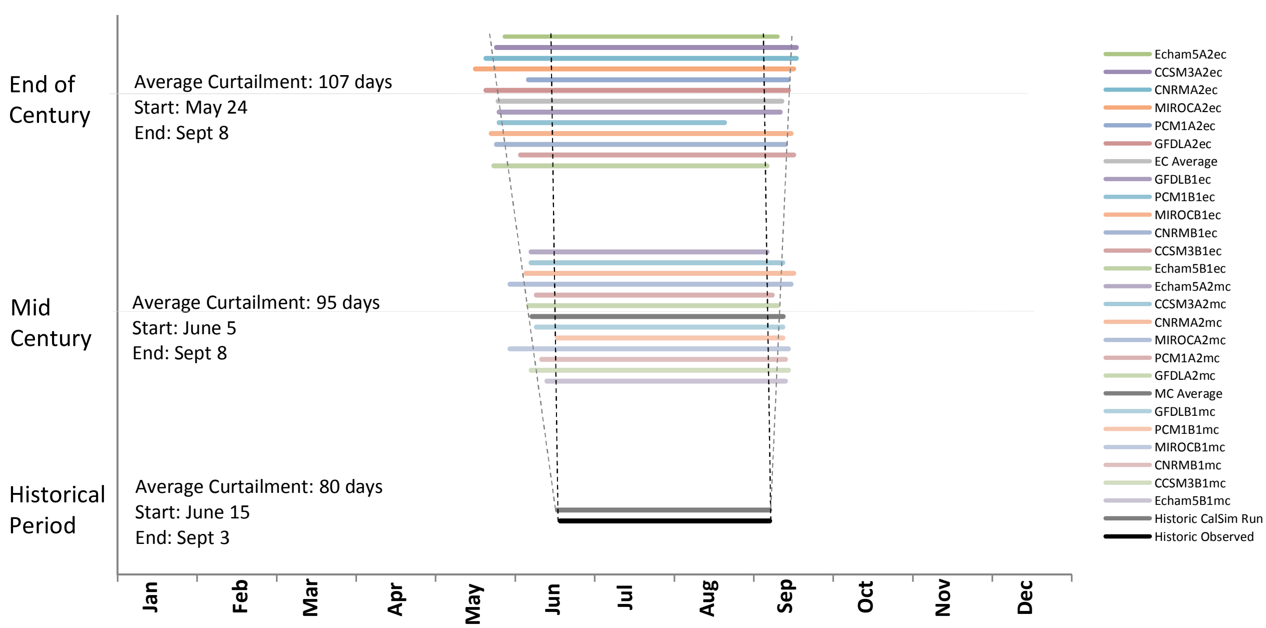

Figure 3 Term 91 curtailment periods: Historical, Mid-Century, End-of-Century

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Table 2 Summary table of Term 91 analysis

Model	Average first curtailment	Average end curtailment	Average curtailment duration (days)	Change in curtailment duration	Percent years with no curtailment	Percent change in years with no curtailment	SPW releases (acre-feet)
CalSim-II simulated baseline	June 15	September 03	80	NA	19.8%	NA	765,133
Mid-century simulations							
Average of B1 emission scenarios	June 07	September 09	94	14	10.5%	–9.3%	1,174,049
Average of A2 emission scenarios	June 04	September 07	96	16	9.3%	–10.5%	1,235,012
Mid-century average (both B1 and A2 scenarios)	June 05	September 08	95	15	9.9%	–9.9%	1,204,530
End-of-century simulations							
Average of B1 emission scenarios	May 24	September 26	103	23	9.7%	–10.1%	1,554,618
Average of A2 emission scenarios	May 23	September 11	111	31	6.2%	–13.6%	1,795,062
End-of-century average (both B! and A2 scenarios)	May 24	September 08	107	27	7.9%	–11.8%	1,674,840

a range of results that show how effects could vary, depending on what climate changes actually occur, how quickly they manifest, and their resulting intensity. The modeling done in this study assumes that the Projects' operations (including reservoirs and Delta export facilities) follow the same constraints as have been applied in the historical operations period.

The projections of future conditions indicate that Term 91 curtailments are likely to become both substantially more common and substantially longer in duration in future years. Historically, Term 91 curtailments occurred in about 82% of years and the remaining 18% of years show no curtailments (observed data set). Historical curtailments lasted an average of 79 days starting around the middle of June and ending in early September.

Mid-Century Projections (2030 to 2059)

These simulations show that by mid-century curtailments would occur in all but 10% of years, and will last around 95 days—a nearly 20% increase (Figures 2 and 3, Table 2). Curtailments would start about 1 week earlier and extend about a week longer than curtailments in the observed data set. Even when the projection of future climate indicates increased precipitation for California, as in the PCM1 model, increases in curtailments and durations of curtailments occur (though to a lesser degree).

End-of-Century Projections (2070 to 2099)

By the end of the century, curtailments would occur in all but 8% of years and last for an average of 107 days—a 26% increase (Figures 2 and 3, Table 2). Curtailments would start in late May, 3 weeks earlier than historically, and extend to early September, a week later than historically.

SHIFTING FLOWS AND STORAGE RELEASES

As the figures above show, future projected flow during the spring and summer (April through September) months will need to be increasingly supported by water releases from storage. The last column of Table 2 shows the total average volume of *SPW* released annually. This can be seen as a coarse measure of the degree to which additional storage releases would be needed in the future to keep the system in balance. The changes in *SPW* volume increase rapidly jumping 57% at mid-century and 119% by the end of the century—almost 1 million acre-feet of additional water would need to be released from project reservoirs per year by the end of the century.

The projections also indicate that during fall and winter months (November through March) natural and abandoned flows will increasingly exceed the flows needed to meet in-basin and export demands (i.e., more water will be available in the future than has been available in the past between November and March). And the volume of excess water between November and March increases by over 50% between the mid-century and end-of-century time-periods.

UNCERTAINTY

This study presents a range of projections of future effects on water supply. For the most part, throughout this study, results are reported as the average effect across all climate change projections. As Figures 2 and 3 clearly illustrate, individual projections predict effects that could be greater or lesser than the average. All of the projections in this study were developed using a "delta" method (Wang et al. 2011); as such each represents a repeat of the historical observed precipitation record perturbed to reflect the long-term temperature and precipitation changes indicated by each model. While ensuring that historical precipitation variability is reproduced in future projections, one shortcoming of this method is that it does not preserve future drought patterns indicated by the GCMs that may be shorter or longer than those experienced in the past. This analysis therefore, does not explore the effects of potentially longer droughts in the future. Further, additional global climate models not used in this study may suggest lesser or even greater effects. However, the degree of model agreement in the direction of change and severity of change across all simulations suggests that the uncertainty is not in whether these changes will occur, but when they will manifest themselves and exactly how severe they will be.

DISCUSSION

Water rights holders subject to Term 91 represent only a fraction of the water rights in the Delta watershed. However, these water rights holders, because of their junior status, are the first water users to be affected by water scarcity. Term 91 water rights holders represent a variety of water uses including irrigation, recreation, fish and wildlife preservation, domestic, and municipal (listed in order from most common and largest diversions to the least common and smallest diversions). Each diverter deals with the curtailments a little bit differently, but one common response is to pump groundwater when Term 91 is invoked. This behavior indicates that Term 91 curtailments may not actually result in water supply cut backs for some water users, instead it just means that other supplies are engaged. Of course if curtailments become more common and longer, as would be expected from this analysis, demand for those alternate water supplies will increase. For groundwater it would mean that there are fewer years for groundwater to be replenished and greater likelihood of increased groundwater overdraft.

Another effect of the lengthening of the Term 91 curtailment period is that more and more diverters subject to Term 91 will be affected. Historically, only a fraction of Term 91 water rights holders have even been subject to curtailments, because they only divert outside (before or after) the curtailment period. Historically, curtailments start on average around mid-June and end in mid-August. The earliest curtailment on record started May 15 (1990). A majority of Term 91 water right holders have diversion or storage periods outside that historical curtailment window. But these projections indicate that by mid-century, on average, 30% more water right holders will be affected by curtailments. By end-of-century, over 80% more water rights holders will be affected. As Term 91 curtailments get longer and more common, more water users will be turning to groundwater, fallowing land, or looking for water transfers from others to meet their demands—ratcheting up water scarcity in the Delta watershed and potentially leading to additional conflicts over water.

As mentioned above, these projections indicate that available water will actually increase during winter. Water demands during this time of the year are relatively low and historically much of this "excess" flow has gone out to sea while also providing important geomorphological and ecological functions

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for the Delta and riverine systems (Stevens and Miller 1983; Alpert et al. 1999; Kimmerer 2002). Water rights holders who divert during these seasons are likely to see the reliability of their water rights increase. Further, additional winter and fall flows may present new opportunities for diversion and storage, or increased river flows to benefit aquatic and riparian species.

In addition to effects on individual water rights holders, the changes in Central Valley water project operations highlighted in this study indicate that there may be other more broadly felt effects as well. Term 91 curtailments occur when water must be released from storage to meet in-basin and export demands. Thus, longer curtailment periods indicate an increasing reliance on storage releases to meet water demands—as indicated by annual SPW releases shown in Table 2. Put another way, the shift in average curtailment duration—from an 80-day average historically to 95 days by mid-century and 107 days by end-of-century—represent an additional 2 weeks by mid-century and nearly 4 weeks by end-of-century each year during which water is being released from storage instead of being stored. This effect will undoubtedly result in lower storage levels in CVP and SWP reservoirs. Indeed, Chung et al. (2009) estimated the reduction in carryover storage resulting from climate change at between 15% to 19%. Increases in the number of days during which storage releases occur highlight a growing challenge—storage reserves may not be able to meet all uses in the future and still provide the level of drought protection we desire. Additional curtailments would likely need to be contemplated to preserve stored water for critical periods.

REFERENCES

Alpert P, Griggs F, Peterson D. 1999. Riparian forest restoration along large rivers: initial results from the Sacramento River Project. Rest Ecol 7(4):360–368.

[CAT] Climate Action Team. 2009. Final 2009 Climate Action Team biennial report to governor and legislature [Government report]. [Sacramento (CA)]: California State Government.

[CAT] Climate Action Team. 2012. Our changing climate 2012 vulnerability and adaptation to the increasing risks from climate change in California [Government report]. [Sacramento (CA)]: California State Government.

Chung F, Anderson J, Arora S, Ejeta M, Galef J, Kadir T, Kao K, Olson A, Quan C, Reyes E, Roos M, Seneviratne S, Wang J, Yin H. 2009. Using future climate projections to support water resources decision making in California [Government report]. [Sacramento (CA)]: California Department of Water Resources. [cited 2013 02 01]. Available from: *http://www.water.ca.gov/pubs/climate/using_future_climate_projections_to_support_water_resources_decision_making_in_california/usingfutureclimateprojtosuppwater_jun09_web.pdf*

Khan A, Schwarz A. 2010. Climate change characterization and analysis in California water resources planning studies [Government report]. [Sacramento (CA)]: California Department of Water Resources. [cited 2013 02 01]. Available from: *http://www.water.ca.gov/climatechange/docs/DWR_CCCStudy_FinalReport_Dec23.pdf*

Kadir T, Mazur L, Milanes C, Randles K. 2013. Indicators of climate change in California. [city? (CA)]: California Environmental Protection Agency and Offices of Environmental Health Hazard Assessment. [cited 2014 04 22]. Available from: *http://oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicatorsReport2013.pdf*

Kimmerer W. 2002. Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25(6B):1275–1290. doi: *http://dx.doi.org/10.1007/BF02692224*

Stevens D, Miller L. 1983. Effects of river flow on abundance of young Chinook Salmon, American shad, Longfin smelt, and Delta Smelt in the Sacramento-San Joaquin River System. North Am J Fish Manag (3):425–437.

Stewart I, Cayan D, Dettinger M. 2004. Changes in snowmelt runoff timing in western North America under a "Business as Usual" climate change scenario. Climatic Change 62:217-232. doi: *http://dx.doi.org/10.1023/B:CLIM.0000013702.22656.e8*

Wilson C. 2012. Term 91: stored water bypass requirements. A report to the State Water Resources Control Board and the Delta Stewardship Council. Sacramento (CA): State Water Resources Control Board. Available from: *http://www.waterboards.ca.gov/board_info/agendas/2012/dec/120412_10.pdf*

Wang J, Yin H, Chung F. 2011. Isolated and integrated effects of sea level rise, seasonal runoff shifts, and annual runoff volume on Califonia's largest water supply. J Hydrol 405(1-2):83-92. doi: *http://dx.doi.org/10.1016/j.jhydrol.2011.05.012*

ADDITIONAL REFERENCES

State Water Resources Control Board. 1971. Water Right Decision D-1379. Available from: *http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/*

State Water Resources Control Board. 1978. Water Right Decision D-1485. Available from: *http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/*

State Water Resources Control Board. 1981. Water Right Order 81-15. Available from: *http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/orders/index.shtml*

U.S. Bureau of Reclamation. 1986. Long-term Central Valley Project operations criteria and plan (OCAP). Sacramento (CA): U.S. Dept. of the Interior, Bureau of Reclamation, Mid-Pacific Region.

U.S. Bureau of Reclamation. 1986. Agreement between the United States of America and the Department of Water Resources of the State of California for coordinated operation of the Central Valley Project and the State Water Project (COA). Sacramento (CA): U.S. Dept. of the Interior, Bureau of Reclamation, Mid-Pacific Region. 68 p. Available from: *http://archive.org/stream/agreementbetween00wash/agreementbetween00wash_djvu.txt*

United States Congress. 1986. Public Law (PL) 99-546, 1986. Water Resource and Small Reclamation Projects. 100 Stat. 3050. October 27, 1986.

NOTES

Long K. 2013. E-mail communication from Kevin Long (State Water Resources Control Board, Water Rights Division) to Andrew Schwarz dated May 28th, 2013.

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