INNOVATE 2 INNOVATION

An Assessment of California's Innovation Ecosystem

Phase II Report
WATER ACTION TEAM

CALIFORNIA'S WATER FUTURE:
A Science and Technology-Based Water Innovation Road Map

Prepared for the California Legislature
August 2011

Prepared by
California Council on Science and Technology

Executive Summary

Creating and Sustaining a 21st Century Water Innovation System

California's development has been tied to water throughout its history as a state. Water will be as critical to California's economy in the future as it was in the past, but the challenges will be different. By 2050, California's population is projected to increase by almost 48% from 2005 levels, but we cannot expect water availability to increase. For one thing, a general conclusion of global climate models is that arid regions like California should on average expect less precipitation in the coming century. Furthermore, California's 2006 climate change assessment, "Our Changing Climate" forecasts that by 2100 Sierra Nevada snows may decline as much as 90% relative to the 20th century; about 70% of Southern California's water comes from the these sources.

The CALFED Bay-Delta Assessment has documented the vulnerability of the Sacramento Bay and Delta, the main north-south water transfer point, to levee failure and salt-water intrusion of the Sacramento Bay and Delta.

California is the largest producer of agriculture products and the top exporting state, agriculture represents about 2% of the total state economy. Agriculture uses about 80% of California's developed water (extracted or diverted), and so building resilience to reduction or variability of supply is a critical issue. The California Energy Commission (CEC) has estimated that 19% of California's electricity and about a third of non-power plant natural gas is used for various parts of the water system. Energy use, in turn, affects greenhouse gas emissions and air quality, while water is a significant input to many energy systems. The water–energy–pollution nexus has become an important factor in the State's integrated resource planning.

In Phase I of the i2i study, a preliminary survey of California water issues identified areas where science and technology play important roles. Phase II has validated these issues and added some new ones. These will be the primary areas that the i2i team will address in the implementation plan that develops a Water Innovation Road Map including:

- Identifying and developing opportunities for science, technology, and policy innovation in the management of water resources
- Forecasting future water availability and demand under varying scenarios and multiyear cycles
- Building resiliency to seasonal and multi-year changes in weather cycles
- Reducing the water intensity of energy systems and the energy intensity of water systems
- Increasing the efficiency of water use
- Ensuring water quality
- Assuring that groundwater use is monitored and reported
- Developing options for surface storage and ground water recharge
- Restoring watersheds, riparian systems, and habitats
- Enhancing state and local water system(s) to quickly adapt to demand changes due to highly variable water conditions
- Review water supply forecasting methodology including appropriate scenarios to be sure it represents reasonable bounding conditions and provides safeguards for economic and environmental demands based on an ever changing political and climate future

In this Phase II report, the California Council on Science and Technology (CCST) has further identified where innovation in science and technology and targeted deployment can be used to address critical issues facing the state as it addresses the water needs of the future. By tapping into the unparalleled resources of our academic institutions, federal laboratories and industry base, we can create new partnerships, new business opportunities, and new research and technology development that will significantly strengthen the state's water system and boost its competitiveness.

Given how critical water has been to California's economic development, it is no surprise that the State has developed one of the most sophisticated water management systems in the world, and the issues above are well known to California's water planners. The California State Water Plan, which is updated every five years by the Department of Water Resources, contains an evolving strategic plan that looks forward to 2050. The addition of an S&T based innovation component would considerably enhance this plan.

For implementation, we recommend that, at the Legislature's request, CCST work with the Department of Water Resources, the State Water Resources Control Board, the California Energy Commission, the Public Utilities Commission, the California Air Resources Board, California Department of Food and Agriculture and other agencies and constituencies to develop a *California Water Future (CWF) Science and Technology Innovation Road Map* - a 10/25/50-year plan, and integrate it with the State's ongoing long-term planning.

Specific attention will be given to:

- Agriculture and urban water use
- Water quality, reclamation and reuse, especially for urban purposes
- Water, energy and air quality
- Remote sensing and modeling and other evolving technologies
- Sustainability, environmental balance, and the impact of climate and population pressures

The road map will be similar in scope and intent to "California's Energy Future" generated by CCST for the California Energy Commission, which charted a course for the science and technology needed to accomplish the goals of California's Global Warming Solutions Act of 2006 (AB32) and Executive Order S-3-05. The water road map, which by analogy might be called "California's Water Future", will focus on areas where science and new technology will be needed to meet the State's goals.

CCST will convene experts from universities, federal laboratories, non-governmental organizations, and private industry to identify needed science and technology solutions, propose research and development programs, and set goals for the pace of development. If California successfully addresses its water management challenges using innovative technology, we are confident that employment in California will be boosted and the innovators will find markets in other areas of the US and the world facing similar challenges.

Contents

Introduction

Phase I Background

In 2010 a bipartisan group of California legislators asked the California Council on Science and Technology (CCST) to conduct an assessment of California's Science and Technology (S&T) Innovation Ecosystem. The first phase of this assessment, released in March 2011, focused on identifying potential legislative initiatives and transition plans of the new Governor, and presented findings from several regional leadership roundtables convened by CCST. Through these roundtable discussions, CCST identified three critical issues in California upon which to focus. One of these critical three issues was water.

Water is the most fundamental resource challenge facing California, and its management is a critical underpinning of California's economy. Historically, California has relied on large-scale engineering solutions to address its water needs, including building massive water systems based on dams, canals and pipelines. While such investments remain of high priority today, California now also faces a more complex range of challenges from the inter-related issues of water, energy, agriculture, urban needs, climate change, and environmental stewardship. The state's water system continues to face increasing demands and uncertainty as a result of a growing population, aging infrastructure, and the impacts of climate change. Significant efficiency and flexibility improvements will need to be achieved in order to compensate for continued growth in demand and increasingly irregular precipitation. Improvements will need to be system-wide and extend beyond urban and agricultural consumption. We must learn to manage water as an integrated system of supply and demand. Innovation in public policy and especially technology is essential. Technological innovation in water is also an investment and business opportunity particularly well suited to California.

In Phase I, the i2i study identified the water challenge. It also found that there is no consensus on how to simultaneously maintain water supply reliability, balance changes in water supply with demand and protect the environment.

Phase I recommendations included:

Develop a science and technology-based water road map that will:

1. Improve water-use efficiency and flexibility across the economy to ensure the state's continued prosperity in the 21st century.

2. Identify opportunities for expanding markets, in and outside the state, for innovative California products and services that will help the state and others improve water efficiency.

3. Catalyze the creation of new public-private partnerships and communities of innovation able and willing to go to the next stage of implementation.

In this Phase II i2i document a framework of key water issues facing California is further developed highlighting those areas where science and technology in general, and CCST in particular, could have the most positive impact in contributing to a sustainable, long-term water policy for the state. This framework is intended to serve as a starting point for a comprehensive California Water Future (CWF) Innovation Road Map to be developed, one that supports and strengthens the State's planning ability.

Phase II

Challenges to be Addressed in a Plan for California's Water Future (CWF)

The Phase II Water Action Team, using the information gathered from the regional roundtable discussions hosted by CCST in late 2010 as a starting point, followed up on ways to implement the primary water related recommendations from Phase I, plus explored ways that science and technology could help address all of the issues associated with California's water problems.

A detailed list of issues that need to be addressed in order to resolve our California water problems are identified in Appendix A. These are areas where we believe CCST can help, i.e., those related to how we can now or in the future apply science and technology to address the issues, are identified with an asterisk. Those areas that are critical to establishing an agreed baseline of data with common definitions to be used by all parties are detailed in Section I of Attachment A and need to be aggressively pursued and led by a state agency or delegee of state government.

This Phase II process proceeded over several months of frequent meetings. The outcome was the identification of five key areas where the most benefit can be achieved by seeking science and technology innovation to improve water efficiency in the state.

AGRICULTURAL ISSUES

Quantifying agricultural water use and efficiency has presented policy makers with a host of challenges including contradictory reports and data on demand and supply. Terms need to be clearly defined, data should be vetted, and an emphasis on providing reliable information to policy makers should be undertaken. There is a critical need for science and technology to help provide objective information to form the basis for good policy. The economics of using S&T to improve water use efficiency while understanding third-party impacts of those actions should be explored.

URBAN ISSUES

Whereas agricultural water consumption is expected to decline in future years, urban consumption is expected to grow, driven largely by the expected growth in California's population. Significant improvements in efficiency aided by major efforts to assure water quality and the re-use, reclamation and storm water capture will be needed to meet this expected growth in demand and to reduce per capita water use where ever possible. To address both urban and agricultural needs we will also need to know much more about groundwater usage and to pursue more and better ways to achieve groundwater recharge.

THE CONNECTION BETWEEN WATER, ENERGY, AND AIR QUALITY

The nexus between water and energy has emerged in the past decade as a significant challenge and opportunity in California. The California Energy Commission (CEC) has estimated that 19% of California's electricity and about a third of non-power plant natural gas is used for various parts of the water systems. Energy use, in turn, affects emissions and consequently air quality. Water, on the other hand, is a significant input to many, but not all, energy systems. The CEC and the California Public Utilities Commission, along with universities, federal labs, NGOs, and others, have followed up with studies on various aspects of the water-energy relationship that will be integrated into future work.

REMOTE SENSING AND MODELING AND OTHER EVOLVING TECHNOLOGIES

Satellite monitoring, geographical information systems, and numerical modeling have been critical tools for the characterization of land use and land cover change for many years. These and similar tools have dramatically strengthened the capacity to monitor water resources and use, by means of measurements made from satellites and aircraft of such things as soil moisture, snow area, underground aquifer content, and crop health. They are also technologies in which California is a world leader in both creation and deployment. Other technologies need to also be evaluated for their application to the management of our integrated water system if we are to achieve our long-term goal of a sustainable water supply.

SUSTAINABILITY, ENVIRONMENTAL BALANCE, AND THE IMPACT OF CLIMATE AND POPULATION PRESSURES

Climate change is likely to increase both the length and depth of periods of drought and surplus in our weather cycles, demanding additional energy and water to bridge these periods of expected shortages. Likewise, by 2050, California's population is projected to increase by almost 48 percent from 2005 levels, impacting water use, energy use, and greenhouse gas emissions.

Implementation

Building a California Water Future (CWF) Innovation Road Map

Develop a California Water Future (CWF) Science and Technology Innovation Road Map - a 10/25/50-year plan that identifies where science and technology plays an important role and covers a range of future scenarios from surplus to drought.

The road map could be similar in scope and intent to "California's Energy Future" generated by CCST for the California Energy Commission, which charted a course for the science and technology needed to accomplish the goals of California's Global Warming Solutions Act of 2006 (AB32) and Executive Order S-3-05. The water road map, which by analogy might be called "California's Water Future", will focus on areas where science and new technology will be needed to meet the State's goals. CCST will convene experts from universities, federal laboratories, and private industry to identify needed science and technology solutions, propose research and development programs, and set goals for the pace of development. Where California successfully addresses its water management challenges by using innovative technology, we are confident that the innovators will find markets in other areas of the US and the world facing similar challenges.

This effort will require the development of realistic scenarios of supply and demand associated with a 10/25/50-year view; including a top down definition of what a sustainable water use budget could be by sector; establish rules of operation; and determine how market forces can be deployed. These scenarios should be founded on a quantified economic analysis that considers the range of expected real costs of infrastructure development, water, energy and efficiency implementation using a full-cost methodology. The CCST focus for an i2i implementation effort will be on the coordination and management of the science and technology side of the issues where CCST is in a unique position to help.

CWF ROAD MAP FOCUS

CCST's preliminary survey of California water issues has identified the areas below where science and technology play an important role:

1. Forecasting future water availability and demand
2. Building resiliency to seasonal and multi-year changes in weather cycles
3. Reducing the water intensity of energy systems and the energy intensity of water systems
4. Increasing the efficiency of water use in all sectors
5. Assuring that surface and groundwater use is monitored and reported
6. Developing options for surface storage, conveyance and ground water recharge
7. Ensuring water quality standards are met through
   - Improved water management
   - Advanced treatment technologies
8. Restoring watersheds, riparian systems, and habitats

Related to these issues is the following preliminary list of possible applications of science and technology that should be considered:

- Remote sensing and satellite monitoring
- Sensor technology (e.g., distributed and networked), IT, and smart system applications (meters, data management, control systems, etc.)
- Information collection technologies
- Membrane and filtration technology
- Technologies that make agriculture and urban use more water efficient
- Desalinization
- Management and public policy interface technologies
- Weather and climate forecasting

CWF ROAD MAP DEVELOPMENT APPROACH

In order to build the road map, a Water Innovation Action Team will organize workshops that engage experts and public and private stakeholders; these workshops will develop an end-to-end assessment of issues and needs. As part of these workshops we will perform an asset analysis of existing tools and capacities that can be used to increase scientific understanding and build an action plan. We will also identify new technologies and new applications for technologies and processes, in part by inviting participation from sectors of the science and technology community that do not ordinarily work on water issues.

Based on the outcomes from these workshops and its own assessment, the action team will make specific recommendations for innovations in research, technology, public policy, land use, storage, and other areas. The team will also suggest ways to promote links between the science and technology community and water managers through public-private partnerships and other means. Draft workshop outlines have also been developed for agricultural water use (Appendix B), the water-energy nexus (Appendix C), and remote sensing (Appendix D).

Next Steps

- Work with State agencies and legislature and private sponsors to agree on terms of reference for study and secure a mandate from the state
- Seek funding from private and public sources
- Appoint CWF team that will design and host workshops, and develop a California Water Future Innovation Road Map

Appendix A

Draft Framework of California Water Issues

In looking at the full framework for water issues/required actions over the next ten years, each of the areas outlined below will be evaluated for opportunities for science and technology innovation, regulatory reform, and economic and environmental impacts/improvements.

OVERALL DEMAND/SUPPLY BALANCE IN CALIFORNIA

	* WHAT DO WE KNOW AND WHAT DO WE NEED TO KNOW REGARDING CALIFORNIA'S WATER DEMAND AND SUPPLY?
1	*What is the current inventory of the sources and uses of water in California? Do we have accurate information on the amount of water flowing into the system by source (e.g. rain water, snow melt, water reuse, groundwater, etc) on an annual basis and the amount of water actually used by each sector (e.g. residential, commercial, industrial, agricultural, etc.) on an annual basis?
2	What are the areas of alignment and where are the conflicts between the recommendations from prior California water studies? How do we resolve these conflicts?
3	What are the gaps between what information is known and what is needed – e.g. where there are information gaps, definitional conflicts and other issues that need to be addressed so future decision making can be better informed and based on agreed facts.
4	What models exist for looking at California water as a system and what scenarios need to be evaluated in order to better manage California water in the future especially from the context of what is a "sustainable" level of supply and demand when looked at over a multi-year planning cycle?
5	*What additional information is required and how can we get this information? • How does the interface between surface water and ground water work? • What is an accurate current assessment of the water/energy nexus? • How much groundwater is really being used? • How much water is being illegally diverted? • What is the definition of "sustainable supply and demand for water" and how would this definition be applied to normal water cycles (drought to surplus, multi-year scenarios, etc). • What type of goals for water supply and demand should be developed for the short, intermediate and longer term? • What technologies are currently being applied to facilitate the management of the California water system, which technologies are emerging and where is new innovation needed?
6	*Overall, how can we help the State develop a solid and fact based basis (technical, scientific and economic) for policy. This would include a much better approach to identifying and quantifying the multiple costs and multiple benefits of different water management options. This is at the interface of sections II and III below and is critical to the broader issues of environmental protection and the effective use of scarce resources.

* Proposed areas for CCST focus

DEMAND-SIDE MANAGEMENT

	IMPROVE MANAGEMENT OF WATER USE
1	*Increase efficiency, conservation and management in all sectors, recognizing the unique issues in each user community • Residential • Commercial/Industrial • Agricultural • Environmental
2	*Improve adoption of technology and innovation in all sectors including what opportunities are there to create a "growth industry" from this innovation (both domestic and worldwide) • Residential • Commercial/Industrial • Agricultural • Environmental
3	*Remove impediments (economic, legal, social, technical) to and increase opportunities for water reuse and recycling
4	*Better understand and manage the water/energy nexus
5	Address implications of economics (cost of water) and water management decisions

SUPPLY-SIDE MANAGEMENT

	EXPAND ABILITY TO EFFECTIVELY MANAGE AND MAINTAIN/INCREASE THE SUPPLY OF WATER TO ACHIEVE SUSTAINABILITY FROM ALL SOURCES IN AGGREGATE OVER A MULTI-YEAR (short and long term) PLANNING HORIZON
1	Improve Management of Surface Water including Restoring/Better Utilization of the California River Systems and the Bay Delta • Ensure permanent protection (land use planning) of floodplain and wetlands areas in support of multi-year planning for climate change driven drought/flood cycles. • *Better integrate existing reservoirs and new storage concepts (including water banking) into overall river system functionality (improved conveyance) • *Gain alignment on steps to manage/preserve the Delta (salt water intrusion, flood control, conveyance options, island stability, invasive species, and other water quality and environmental protection issues, etc) (focus on multi-species & habitat areas) • Other surface water issues (Colorado River, others) • Create a win-win in the North/South and other regional conflicts reflecting historic and emerging demands for water
2	Improve Management of Groundwater • Agree and Implement Comprehensive Groundwater Standards (yield and water quality) • *Improve statewide Groundwater Monitoring and Reporting • *Assess Alternatives to Achieve Recharge of Groundwater • *Assess Opportunities for Technology and Innovation in all aspects of Groundwater Management

EXPAND ABILITY TO EFFECTIVELY MANAGE AND MAINTAIN/INCREASE THE SUPPLY OF WATER TO ACHIEVE SUSTAINABILITY FROM ALL SOURCES IN AGGREGATE OVER A MULTI-YEAR (short and long term) PLANNING HORIZON	
3	*Evaluate and Prioritize Desalination Opportunities
4	*Evaluate and Prioritize Storm Water/Rain Catchment Opportunities
5	*Evaluate Opportunities to Model the Demand/Supply Equation under various Scenarios (including climate change) including Surface Water/Groundwater interaction (Goal: Create a Systems Focused Methodology for Making Decisions)
6	*How can technology and innovation help in these areas? E.g. the role of innovation in addressing the overall Supply Side issues (satellite monitoring of groundwater, sensor technology, water smart grid, desalinization, better understanding of water as a system)

IMPROVE COMMITMENT AND ALIGNMENT OF ALL CONSTITUENCIES AND INSTITUTIONALIZE NEEDED CHANGE

1	Regulatory Issues • Ownership and use rights • Beneficial use statute • Efficient (statewide) agency management and coordination/ improve institutional infrastructure • Economics: costs, uses and rates • Land use planning, policy and decisions • What public policy changes can facilitate better (equitable) water system management?
2	Expand Public-Private Partnerships
3	Enhance Communication, Education and Public Alignment

Appendix B

Workshop Outline - Agricultural Water Use

Quantifying agricultural water use and efficiency has presented policy makers with a host of challenges including contradictory reports and data on demand and supply. There is a critical need for science and technology to provide unbiased information to form the basis for good policy. To this end, the following represent opportunities for CCST:

- Identify and develop local and remote measurement techniques that monitor changes in groundwater supplies
- Identify a systems approach to monitor, manage and record on-farm water & energy use
- Develop a long-term sustainable water supply (volume) estimate for agriculture over an extended time-period
- Identify technologies and techniques that increase flexibility to irrigated fields during periods of water shortage and excess
- Create a better understanding of on-farm irrigation efficiency, basin efficiency and flow through design water management practices
- Develop a better understanding of where unintentional exchanges of ground/surface water occur due to irrigation practices (distribution & on-farm) and the consequences of changing current practices on third parties
- Better understand the environmental impacts of drip/micro irrigation practices, including water use, water quality, energy use, air quality, and other resource issues
- Develop a common data base across a wide range of water supply sources and uses
- Create a better understanding of future water supply and demand scenarios for agriculture

Composition of Agricultural Water Use Workshops

1. State government agencies: DWR, SWRCB, CPUC and CEC
2. Industry representatives from data monitoring and data analysis companies
3. Federal agencies: Ames/NASA, BOR, NRCS
4. NGO's including environmental justice groups
5. Associations: groundwater, irrigation, commodities
6. University faculty and researchers

Workshop Duration/Frequency: 3 to 4 workshops (single day in duration each) or
Single day event with 2-3 day duration
Possible Co-Hosts CCST to include any or all participants

Appendix C

Workshop Outline - Water-Energy Nexus

The nexus between water and energy has emerged in the past decade as a significant challenge and opportunity in California. The California Energy Commission (CEC) has estimated that 19% of California's electricity and about a third of non-power plant natural gas is used for various parts of the water systems. Water, on the other hand, is a significant input to many, but not all, energy systems. The CEC and the California Public Utilities Commission, along with universities, federal labs, NGOs, and others, have followed up with studies on various aspects of the water-energy relationship. The following aspects can be addressed by the CCST effort:

- Assessment of opportunities for science and technology to contribute toward reductions in energy inputs to water systems, and water inputs to energy systems
- Development and application of methodologies and models to better understand both systems and identify opportunities
- Discussion of scenarios for different water management strategies and implications for energy systems (e.g. greater reliance on desalination)
- Discussion of scenarios for different energy supply strategies (e.g. solar thermal vs. PV applications) and implications for water resource management
- Implications of different scenarios for greenhouse gas emissions

Composition of a Water-Energy Workshop

Selected members

1. Researchers at universities and colleges
2. Researchers at federal labs (e.g. LBL, LLL, Sandia, NREL, etc.)
3. Federal agencies, DOE, EPA
4. State agencies, including California Energy Commission, Public Utilities Commission, Department of Water Resources, State Water Resources Control Board, California Air Resources Board, Office of Planning and Research, and other entities such as the WETCAT (climate team)
5. Water and energy utilities (government/municipal and IOUs)
6. Energy project developers, IT companies (e.g. IBM, SAP, etc.), and others
7. Experts from engineering and consulting firms engaged in this work
8. NGOs active on the energy-water issue (Pacific Institute, EPRI, etc.)

Duration of Workshop: 2-3 days
Possible Co-Hosts CCST (most of the entities listed above)

Appendix D

Workshop Outline - Remote Sensing

In relation to the potential for a workshop on the subject of the role of remote sensing in water management, following is a list of potential topics that can be explored.

- Availability of remotely sensed information about the elements of the hydrologic cycle such as:

    1. Rainfall measurement
    2. Snow estimation both in terms of snow cover and snow depth
    3. Evaporation
    4. Soil moisture
    5. Groundwater monitoring
    6. Surface water monitoring
    7. Groundcover information such as vegetation type, urban characteristics including percentage of pervious vs. impervious, agricultural characteristics such as crop type, shift in cropping patterns, etc.
    8. Monitoring of Coastlines in terms of algae growth, pollution detection, etc.

- Discussion of the limitations (i.e. resolution both in time and space, accuracy, etc.) of the available RS information about the elements listed above.
- Discussion of what is currently being done or being planned to address some of the above issues.
- A frank assessment of the users needs and expectations vis-à-vis what is available and practical with an eye towards bridging the gap between theory/technology and application.
- Given that much of the RS information is used in various types of models for either predictive purposes or water resources management, it becomes crucial to insure that even if RS information is available that the models have kept up with the expanded ability to ingest such data and information.

Composition of an Remote Sensing Workshop

Selected members

1. Faculty at Institutions of Higher Institution (UC, Stanford, USC, Caltech, CSU, etc.)
2. NASA, DOE, USGS, and others
3. State agencies such as DWR, Energy Commission
4. Private Industry involved in RS technology (e.g. Northrop Grumman)

Duration of Workshop: 2-3 days
Possible Co-Hosts CCST to include any or all participants

Appendix E
Water Action Team

Jude Laspa, Chair
Former Executive Vice President and Director
Bechtel Group, Inc.

Soroosh Sorooshian
Distinguished Professor and
Director, Center for Hydrometeorology & Remote Sensing (CHRS)
University of California, Irvine

Robert Wilkinson
Director, Water Policy Program
University of California, Santa Barbara

David Zoldoske
Executive Director
Water Resources and Policy Initiatives
California State University

Overall Support and Assistance Provided By
CCST Staff
Susan Hackwood, CCST Executive Director
Lora Lee Martin, Director, Strategic Policy Initiatives
Donna King, Senior Project Coordinator and Accountant
Sandra Vargas-De La Torre, Project Coordinator and Report Layout
and Collaborative Economics