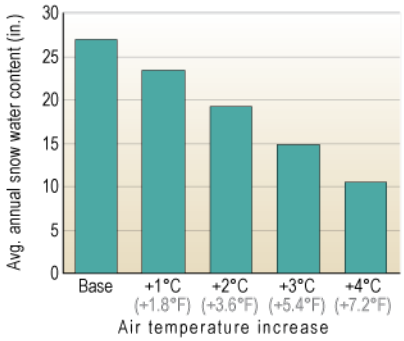
Climate Change:

By and large, California's reservoirs and water delivery systems were designed, and operating rules have been developed, using historical hydrology – an assumption that the past is a good guide to the future. With climate change, that assumption may no longer be valid.

What Has Already Happened?

Looking over the past century, the following changes are evident:

- California's temperature has risen one degree Fahrenheit, mostly at night and during the winter, with higher elevations experiencing the greatest increase.
- Average early spring snowpack in the Sierra Nevada has decreased by about 10 percent, a reduction of 1.5 million acre-feet of water in storage (one acre-foot of water is enough for one to two families for one year). Seasonal snowpack of the Sierra Nevada is California's largest surface water storage.
- Sea level along California's coast has risen 7 inches.
- Flood peaks in the state's rivers have increased.
- Climate patterns are more variable.



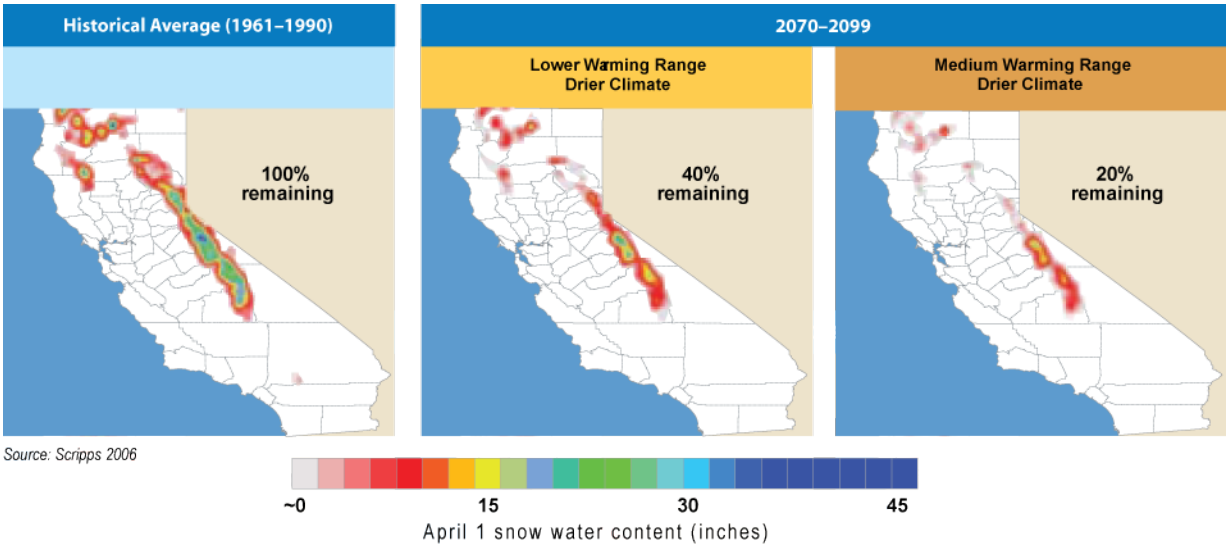
Average Annual Snowmelt for Upper Feather River Basin

Warming air temperatures may cause some of our precipitation to shift from snow to rain. This would lead to a reduction in the amount of snowpack, an important natural reservoir for storing water in the winter and later augmenting the water supply as spring snowmelt. Climate-change-induced shifts in the timing and the amount of snowmelt runoff may require revising traditional water planning practices. The Upper Feather River Basin provides water for Lake Oroville, the main water supply reservoir for the State Water Project.

Source: DWR 2009

Decreasing California Snowpack

These figures show projections of how two climate scenarios may reduce Sierra snowpacks to 40% and 20% of recent historical averages



Source: Scripps 2006

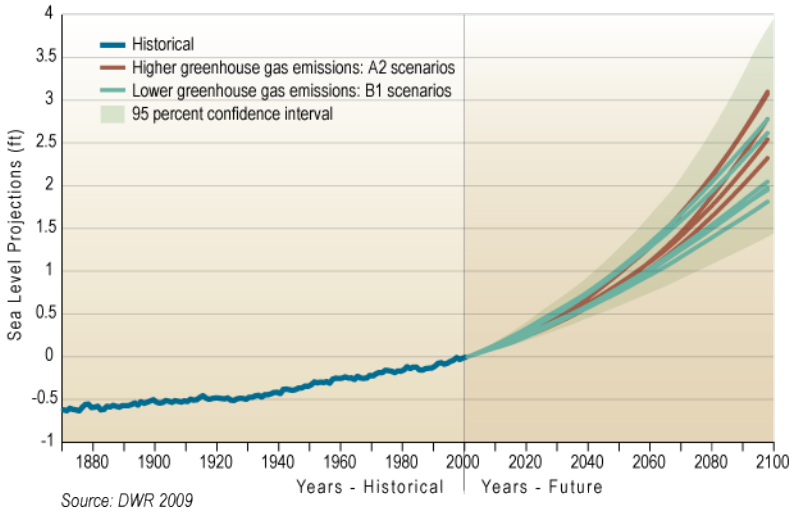
Future Hydrology Unlike the Past

What More is Expected?

Looking forward to the year 2050 and on to the end of the century, more changes can be expected:

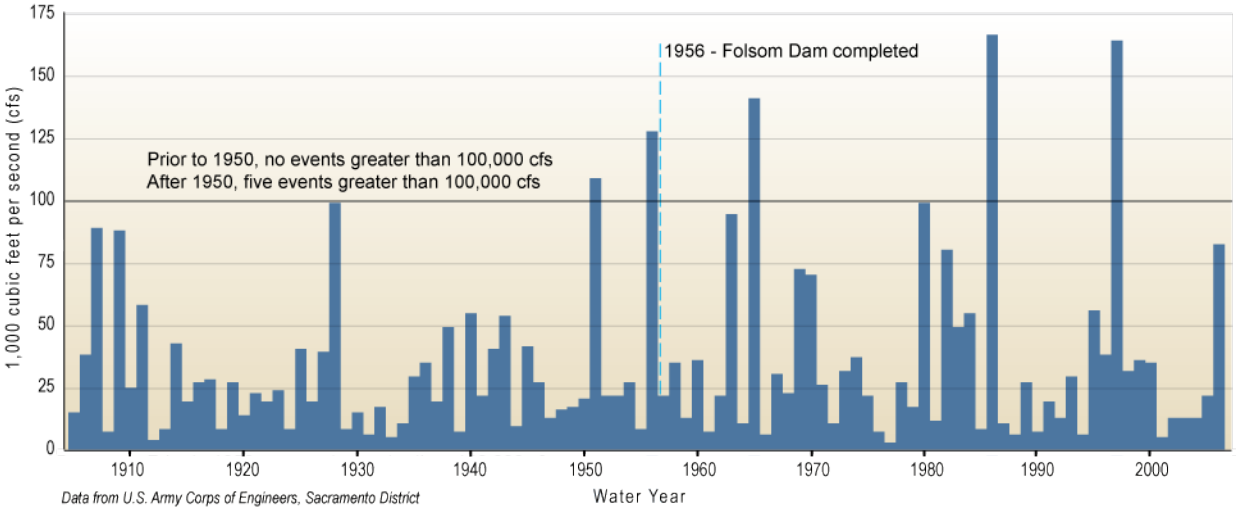
- California's mean temperature may rise 1.5 degrees to 5.0 degrees Fahrenheit by 2050 and 3.5 degrees to 11 degrees by the end of the century.
- Sierra Nevada snowpack may decrease by 25 to 40 percent by mid-century, a storage volume about 3.8 million acre-feet to 6 million acre-feet, from a little less to a little more than the capacity of California's largest constructed surface reservoir.
- Average annual precipitation may show little change, but more intense wet and dry periods can be expected – more floods and more droughts.
- Flood peaks will become higher and natural spring/summer runoff will become lower.
- Studies show a possible global sea level rise of 4 to 16 inches by mid-century and 7 to 55 inches by the end of the century.
- Higher sea levels will increase salinity in the Delta.

Historical and Projected Sea Level at Golden Gate



American River Runoff Annual Maximum 3-Day Flow

The five highest floods of record on the American River have occurred since 1950.



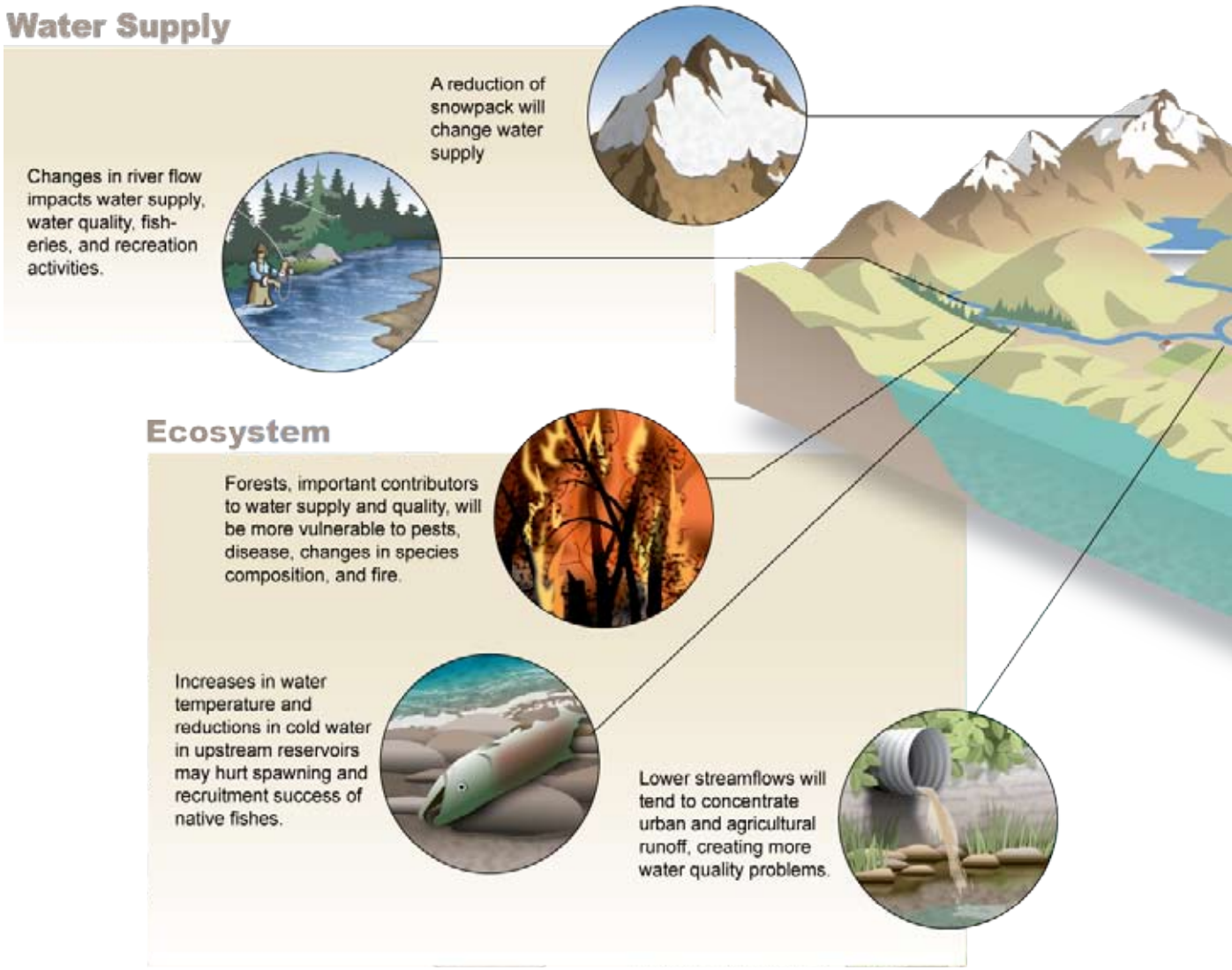
Read more on climate change in Volume 1 Chapter 5 Managing an Uncertain Future and Chapter 6 Integrated Data and Analysis. Find technical and support articles in Volume 4 Reference Guide.

Climate Change:

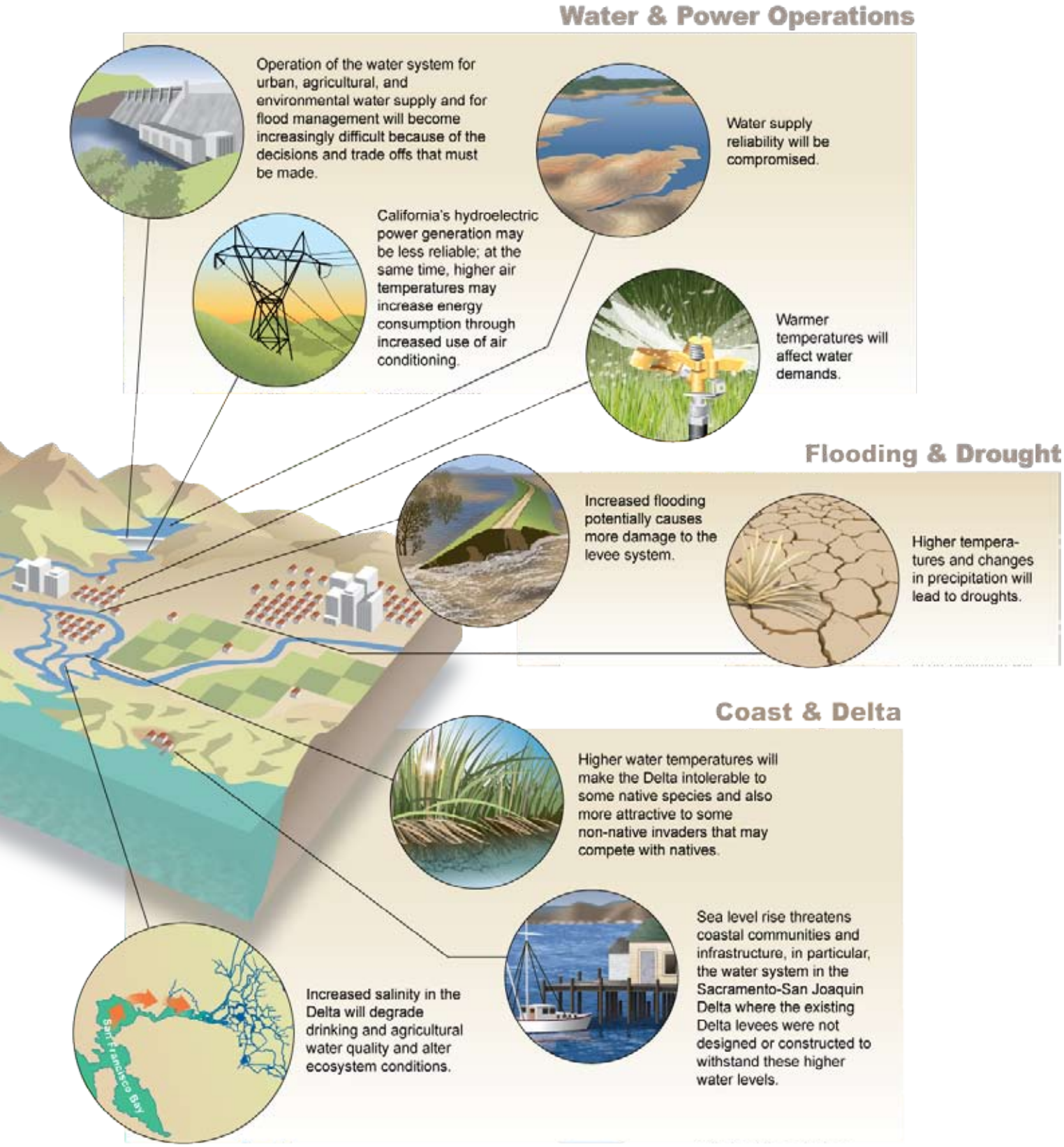
What are the Expected Impacts from These Changes?

Climate change is already having a profound effect on California's water resources as evidenced by changes in snowpack, river flows, and sea levels. Scientific studies show these changes will increase stress on the water systems in the future. Because some level of climate change is inevitable, the water systems must be adaptable to change.

The impacts of these changes will gradually increase during this century and beyond. California needs to plan for water system modifications that adapt to the following impacts of climate change:



Stressing Our Water Systems



California Water Plan Update 2009:

Integrated Water Management

The California Water Plan updates have been important sources of information for water planners since 1957. But unlike prior Water Plan updates, which were primarily products of the Department of Water Resources, Update 2009 truly can be viewed as the state's Water Plan. It has benefited from the first interagency California Water Plan steering committee representing 21 state government agencies with jurisdictions over different aspects of water resources and integrates their companion planning documents. In addition, a 45-member advisory committee, expanded regional outreach, greater involvement of California Native American Tribes, and coordination with federal agencies provided broad participation in plan preparation.

Update 2009 builds on the framework and resource management strategies outlined by California Water Plan Update 2005 promoting two major initiatives:

- **Integrated regional water management** enables regions to implement strategies appropriate for their own needs and helps them become more self-sufficient.
- **Improved statewide water and flood management systems** provides for upgrades to the large physical facilities, such as the State Water Project, and statewide management programs essential to the California economy.

To minimize the impacts of water management on California's natural environment and make sure that the state continues to have the water supplies it needs, the two initiatives are supported by three foundational actions:

- Use water efficiently to get maximum utility from existing supplies.
- Protect water quality to safeguard public and environmental health and secure the state's water supplies for their intended purposes.
- Expand environmental stewardship as part of water management responsibilities.

Unfold to read the details of
Water Plan's Strategic Plan

Building on a Framework

Update 2009 uses the same framework presented in Update 2005 and enhances it in several areas:

- Integrates information and recommendations from many state plans and initiatives, particularly those agencies on the Water Plan Steering Committee.
- Incorporates consideration of uncertainty, risks, and resource sustainability into planning for the future to reduce uncertainties, recognize risks to success, and manage for more sustainable water supply, flood management, and ecosystems.
- Includes integrated flood management and drought contingency plan.
- Advances climate change adaptation and mitigation strategies.
- Includes information from Native American Tribes and proceedings from the 2009 California Tribal Water Summit.
- Updates resource management strategies and regional reports.
- Extends regional and statewide water balances to include eight years.
- Includes a plan for improving data, analytical tools, and information management and exchange.
- Further acknowledges that the Water Plan as a living document will continue to evolve and adapt integrated water management.

Update 2009 integrates information and recommendations from key state plans and initiatives. See Volume 1, Chapter 3 Companion State Plans

Transitioning from Extraction to Sustainable Outcomes

Incorporating the concept of resource sustainability is an ongoing process or approach that will continue to be developed in future Water Plan updates. A system that is sustainable meets today's needs without compromising the ability of future generations to meet their own needs. A sustainable system generally provides for the economy, the ecosystem, and equity.

Over the past few decades, questions have been raised about how sustainable our ecosystems and water, land, and other resources are, given current management practices and expected future changes. California's water resources are finite and now require managing for sustainability—management that may be different than what has been practiced during the first 150 years of the state's history.

To achieve sustainability, resource managers and planners must transition from the past model that places value primarily on water supply yield and extraction to a model that values sustainable outcomes.

Find more about the roadmap to safe and clean water through 2050 in Volume 1 Chapter 2 Imperative to Act and Chapter 7 Implementation Plan.

Unfold to read the details of
Water Plan's Strategic Plan

California Vision 2050:

Update 2009 sets us on a strategic path to managing our water resources in a way that pro

Desired future for California water

California has healthy watersheds and integrated, reliable and secure water resources and management systems that

- Enhance public health, safety, and quality of life in all its communities;
- Sustain economic growth, business vitality, and agricultural productivity; and
- Protect and restore California's unique biological diversity, ecological values, and cultural heritage.

Desired outcomes over the planning horizon 2050

1. California has water supplies that are adequate, reliable, secure, affordable, sustainable, and of suitable quality for beneficial uses to protect, preserve, and enhance watersheds, communities, and environmental and agricultural resources.

2. State government supports integrated water resources planning and management through leadership, oversight, and public funding.

3. Regional and interregional partnerships play a pivotal role in California water resources planning, water management for sustainable water use and resources, and increasing regional self-sufficiency.

4. Water resource and land use planners make informed and collaborative decisions and implement integrated actions to increase water supply reliability, use water more efficiently, protect water quality, improve flood protection, promote environmental stewardship, and ensure environmental justice in light of drivers of change and catastrophic events.

5. California is prepared for climate uncertainty by developing adaptation strategies and investing in a diverse set of actions that reduce the risk and consequences posed by climate change, that make the system more resilient to change, and that increase the sustainability of water and flood management systems and the ecosystems they depend on.

6. Integrated flood management, as a part of integrated water management, increases flood protection, improves preparedness and emergency response, enhances floodplain ecosystems, and promotes sustainable flood management systems.

7. The benefits and consequences of water decisions and access to state government resources are equitable across all communities.

Vision & Mission
•
Goals
•
Guiding Principles
•
Objectives & Actions
•
Recommendations

Table 7 – Climate Change Criteria	
First Solicitation	**Subsequent Solicitations**
Successful grantees must enter into an agreement with DWR to update their IRWM plans to the IRWMP Standards contained in this document within two years of the entering into an agreement with DWR (CWC §83002.(b)(3)(B)). This includes the Climate Change Standard. All applicants, as part of the application, will submit a signed consent form stating they understand that should they be awarded a grant they will sign an agreement to update their plans within two years from the time of agreement execution.	IRWM plans must meet the IRWM Plan Standards contained in this document. This includes: • Quantitative tools for vulnerability analysis • Specific actions identified for adaptation to effects of Climate Change with performance measures • Disclosure and consideration of quantitative analysis of project GHG emissions

Table 8 – Climate Change Standard Requirements	
Region Description	IRWM plans must contain language in their Description of Region Section that describes likely Climate Change impacts on their region. These descriptions should be updated and become **more region-specific** as vulnerability analysis tools become available.
Plan Objectives	*Adapting to Climate Change:* In developing plan objectives, IRWM regions must consider the following: • IRWM Plans should address adapting to changes in the amount, intensity, timing, quality and variability of runoff and recharge. • IRWM Plans need to consider the effects of sea level rise on water supply conditions and identify suitable adaptation measures. *Reducing Emissions* • IRWM plans can also help mitigate Climate Change by reducing energy consumption, especially the energy embedded in water use, and ultimately reducing GHG emissions. • In evaluating different ways to meet IRWM plan objectives, where practical, RWMGs should consider the strategies adopted by CARB in its AB 32 Scoping Plan. • In addition to offsetting emissions, RWMGs also may consider options for carbon sequestration where such options are integrally tied to supporting IRWM Plan objectives.
Resource Management Strategies	*Initial Steps:* Identify and implement "No-Regrets" Adaptation Strategies to the general effects of climate change, such as meadow and forest restoration, flood plain protection, and water use efficiency. • Decisions about adapting water management systems, as well as, mitigating Climate Change through reductions in GHG emissions, should take into account the risks to the region of no action. • IRWM regions should pursue increasing water use efficiency, practice integrated flood management, and seek to enhance and sustain ecosystems. Appropriately applied, these "no regret" adaptations can help a wide variety of water management situations. *Next Steps:* Identify and implement, using vulnerability assessments and tools, Adaptation Strategies that address region-specific climate change impacts. • IRWM Plans should address adapting to changes in the amount, intensity, timing, quality and variability of runoff and recharge. • IRWM Plans need to consider the effects of sea level rise on water supply conditions and identify suitable adaptation measures. • IRWM Plans also can help mitigate Climate Change by reducing energy consumption, especially the energy embedded in water use, and ultimately reducing GHG emissions. • An IRWM region must demonstrate how the effects of climate change on its region are factored into its resource management strategies.

Project Review Process	The Project Review Process must include the following factors: • *Contribution of the project to adapting to climate change*: RWMGs must include potential effects of climate change on their region and consider if adaptations to the water management system are necessary. • *Contribution of the project in reducing GHG emissions as compared to project alternatives*: The RWMG needs to consider a project's ability to help the IRWM region reduce GHG emissions as new projects are implemented over the 20-year planning horizon. Considerations include energy efficiency and reduction of GHG emissions when choosing between project alternatives. *CEQA project-level analyses:* In preparing a project-level GHG emissions analysis, RWMGs and the project proponents should estimate GHG emissions from the project; establish significance criteria; identify those project components that may support carbon sequestration; and, if applicable, explain how the project may help in adapting to effects of Climate Change.
Relation to Local Water Planning	IRWM Plans must consider and incorporate water management issues and climate change adaptation and mitigation strategies from local plans into the IRWM Plan.
Relation to Local Land Use Planning	IRWM regions must demonstrate information sharing and collaboration with regional land use planning in order to manage multiple water demands throughout the state, as described in CWP Update 2009, adapt water management systems to climate change, and potentially offset climate change impacts to water supply in California.
Plan Performance and Monitoring	IRWM Plans should contain policies and procedures that promote adaptive management. As more effects of Climate Change manifest, new tools are developed, and new information becomes available, RWMGs must adjust their IRWM plans accordingly.
Coordination	• RWMGs should stay involved in CNRA's California Adaptation Strategy process to help shape the document through their participation. • Agencies that are part of an IRWM effort should consider joining the California Climate Action Registry (CCAR), http://www.climateregistry.org/.

ADDITIONAL RESOURCES AND REFERENCES

DWR Integrated Regional Water Management Climate Change Document Clearinghouse*:
http://www.water.ca.gov/climatechange/docs/IRWM-ClimateChangeClearinghouse.pdf
**Contains brief summaries of 40 documents potentially relevant for IRWM practitioners*

DWR's Climate Change Website: http://www.water.ca.gov/climatechange

State of California Climate Change Portal: http://www.climatechange.ca.gov

CARB website: http://www.arb.ca.gov/cc/cc.htm

The California CAT website: http://climatechange.ca.gov/climate_action_team/index.html

Association of Environmental Professionals. 2007. *Alternative Approaches to Analyzing Greenhouse Gas Emissions and Global Climate Change in CEQA Documents*.
http://www.counties.org/images/public/Advocacy/ag_natres/AEP_Global_Climate_Change_June_29_Final%5 B1%5 D.pdf

California Climate Action Registry. (2009). *General Reporting Protocol Version 3.1.*
http://www.climateregistry.org/resources/docs/protocols/grp/GRP_3.1_January2009.pdf

Center for Biological Diversity. 2007. The California Environmental Quality Act On the Front Lines of California's Fight Against Global Warming.
http://www.biologicaldiversity.org/publications/papers/CBD-CEQA-white-paper.pdf

U.S. EPA. 2009. Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2007.
http://epa.gov/climatechange/emissions/downloads09/InventoryUSGhG1990-2007.pdf

Incorporating Climate Change Considerations into the IRWM Process

[For the 2010-2011 *Planning Grant* Proposal Solicitation]

Planning Grant Applications due September 28th, 2010

Assess regional vulnerabilities to climate change and incorporate the discussion into ***work plan, schedule and budget*** of grant proposal

See the *DWR Climate Change Document Clearinghouse for background information on expected impacts to various regions from climate change for use in vulnerability assessment

If you are awarded a grant

Refer to Table 8 (pg 74) in the 2010 Prop 84 IRWM Guidelines for assistance with incorporating new climate change standard requirements

Note that implementation grants pursued in subsequent solicitations will require a more detailed analysis of climate change upon submission, including a discussion of vulnerabilities (qualitative discussion) and also quantitative measurements of GHG emissions associated with proposed projects to the extent possible

*DWR Climate Change Document Clearinghouse: http://www.water.ca.gov/climatechange/docs/IRWM-ClimateChangeClearinghouse.pdf

California Department of Water Resources
Integrated Regional Water Management (IRWM)
Climate Change Document Clearinghouse

June 14, 2010

On March 8, 2010, the Department of Water Resources (DWR) released draft IRWM planning guidelines, which require the inclusion of climate change considerations in IRWM planning analyses. In an effort to assist IRWM practitioners, DWR has developed a clearinghouse of climate change documents relevant to IRWM planning.

The documents included in this clearinghouse provide:

- Background information on the current and future impacts of climate change,
- Resource planning strategies for adapting to climate change, and
- Considerations for incorporating climate change analysis into California Environmental Quality Act (CEQA) documents.

Each IRWM planning organization will have to consider their specific regional role in addressing climate change; these documents can be used as references to build the necessary understanding of climate change issues and potential impacts. The documents come from a range of sources including international, national, state, and regional entities and therefore provide a wide variety of useful information. IRWM planners should use the summaries provided below to select documents containing information pertinent to their specific circumstances for further reading. ***Documents noted with an asterisk (*) may also be useful for developing climate change analyses and mitigation and adaptation strategies.***

Background Information on Current and Future Climate Change Impacts - General

Global Climate Change Impacts in the United States

US Global Change Research Program – June 2009
http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts
This report synthesizes information from a wide variety of scientific assessments and recently published research to summarize in plain language what is known about the observed and projected consequences of climate change in the United States. The report was prepared with the goal of informing public and private decision making at all levels. The relationship of climate change to water, energy, agriculture and human health in the US are explored. The importance of mitigation of climate change is emphasized by comparisons of impacts resulting from higher vs. lower emission scenarios.

The Copenhagen Diagnosis – Updating the World on the Latest Climate Science

Climate Change Research Centre – 2009

http://www.ccrc.unsw.edu.au/Copenhagen/Copenhagen_Diagnosis_LOW.pdf

The Copenhagen Diagnosis is an interim report prepared by the Intergovernmental Panel on Climate Change (IPCC) which evaluates the evolving, policy-relevant, climate science written for a broad audience of policy-makers, stakeholders, the media, and the public. This report presents the most significant climate change findings related to greenhouse gas (GHG) emissions, melting of glaciers and ice-caps, Arctic sea-ice decline, current and projected sea level rise, and risks associated with crossing critical thresholds resulting in irreversible damage. The science used in this report is based on the most credible and significant peer-reviewed literature available at the time of publication and the report addresses some common misconceptions in climate change science.

Climate Change and Water

Intergovernmental Panel on Climate Change Technical Report VI – June 2008

http://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers_climate_change_and_water.htm

Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. This Technical Paper prepared by the IPCC summarizes findings of recent research studies conducted worldwide on the potential impacts of climate change on temperature and precipitation patterns, drought and flood events, water quality and availability, water infrastructure, and all aspects of the freshwater hydrologic cycle that will impact humans and ecological systems in the future. Observed and projected changes in climate as they relate to water are discussed. Mitigation measures and implications for policy and globally sustainable development are explored within this comprehensive document.

Understanding and Responding to Climate Change: Highlights of National Academies Reports

National Academy of Science – 2008

http://dels-old.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf

The National Academies prepared this booklet to highlight climate change findings and recommendations from numerous National Academies' reports done in the last decade. The booklet provides an overview of the recent scientific findings, the foundations of climate science, impacts of climate change, and how the science is used to inform management decisions. All the reports referenced in the booklet are available at http://www.nap.edu.

Climate Literacy: The Essential Principles of Climate Sciences

US Global Change Research Program – March 2009

http://www.globalchange.gov/whats-new/282-climate-literacy-framework (home page for document)

http://www.globalchange.gov/resources/educators/climate-literacy (download page for document)

The *Climate Literacy* guide resulted from a broad collaboration among science agencies, non-governmental organizations, and individuals through workshops sponsored by the National Oceanic and Atmospheric Administration (NOAA), the American Association for the Advancement of Science, and the National Science Foundation. The guide presents information for individuals and communities to understand about climate and people's influence on climate, and the impacts of climate change to society. Principles in the guide can serve to advance discussion and scientific inquiry.

Background Information on Current and Future Climate Change Impacts – California Specific

Climate Action Team Biennial Report – DRAFT

California Climate Action Team – March 2009
http://www.energy.ca.gov/2009publications/CAT-1000-2009-003/CAT-1000-2009-003-D.PDF
Executive Order S-03-05 mandates the preparation of biennial science assessment reports on climate change impacts and adaptation options for California. This draft report is the second such report and differs from the first 2006 policy-based assessment in that the joint effect of increased urbanization and climate impacts are examined. Six model simulations under two emissions scenarios were run to generate a range of possible future conditions. Impacts of climate change on public health, infrastructure, natural resources, energy, water, transportation, forestry, agriculture and the economy are all explored in depth. State efforts to study and adapt to current and future effects of climate change are described.

*The Future is Now: An Update on Climate Change Science Impacts and Response Options for California

California Climate Change Center– May 2009
http://www.energy.ca.gov/2008publications/CEC-500-2008-071/CEC-500-2008-071.PDF
[Long Version-Technical]
http://www.energy.ca.gov/2008publications/CEC-500-2008-077/CEC-500-2008-077.PDF
[Short Version-Layman]
The California Energy Commission Public Interest Energy Research (PIER) Program prepared this interim summary to demonstrate that the effects of climate change are already being felt in California. The report provides recommendations that encompass both mitigation and adaption for decision makers in California. This report, for use by state agencies and the Legislature, is intended to supplement the PIER Program biennial reports that are focused on impacts related to climate change. Therefore it synthesizes the most recent findings, from published literature, outlines a response strategy, and highlights the benefits to California from implementing actions now.

*Preparing California for a Changing Climate

Public Policy Institute of California – November 2008
http://www.ppic.org/content/pubs/report/R_1108LBR.pdf
This paper promotes a comprehensive statewide adaptation strategy in order to reduce California's vulnerability to unavoidable impacts of a warming planet. Adaptation challenges in six particularly susceptible areas-water resources, electricity, coastal resources, air quality, public health, and ecosystem resources-are examined with regard to how well California's institutions are prepared to address them. Many institutions, such as water agencies, electric utilities, public health agencies and the regional bodies responsible for coastal oversight, are already geared toward dealing with climate related challenges. However, funding constraints, conflicting federal policies, and limited availability of adaptation tools still hinder the State's ability to prepare for a changing climate. Recommendations on priority areas for research to address these weaknesses and legal and regulatory changes that would facilitate adaptation are discussed.

*California Climate Risk and Response

UC Berkeley Department of Agricultural and Resource Economics – November 2008
http://www.next10.org/pdf/report_CCRR/California_Climate_Risk_and_Response.pdf
This report uses the available science on climate damage to assess the economic implications and examine adaptation strategies in seven sectors: water; energy; transportation; tourism and recreation; real estate and insurance; agriculture, forests, and fisheries; and public health.

Additionally, this report recommends several adaptation policies, supported by more intensive and extensive research, which will help the state transition to a more climate resilient future.

Water Resource Planning

*California Water Plan Update 2009

California Department of Water Resources – October 2009
http://www.waterplan.water.ca.gov/cwpu2009/index.cfm
The 2009 California Water Plan Update emphasizes the need to act now to provide integrated, reliable, sustainable, and secure water resources and management systems for the economy, ecosystems, and human health. Aging infrastructure, impaired water bodies, and declining ecosystems are serious problems that must be addressed in the face of climate change and a rapidly growing human population. Update 2009 promotes IRWM as a strategy to maximize water supply security, protect water quality and ecosystems, and adapt to changing conditions. The report contains a thorough discussion of impacts that have already occurred, and additional changes that are expected, which will be useful to IRWM planners as they prepare climate change-related portions of their documents. A sustainable, resilient infrastructure which high levels of regional involvement and coordination is presented as the best way to deal with the challenges to come.

*Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water

California Department of Water Resources – October 2008
http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf
This report recommends a series of adaptation strategies for state and local water managers to improve their capacity to handle change. Many of the strategies will also help adapt our water resources to accommodate non-climate demands such as a growing populations, ecosystem restoration and greater flood protection. Strategies discussed include investment in IRWM, aggressively increasing water use efficiency, enhancing and sustaining ecosystems, expanding water storage and conjunctive management of surface and groundwater resources, increasing hydrologic monitoring, data analysis and management and planning for sea level rise.

*Progress on Incorporating Climate Change into Management of California's Resources

California Department of Water Resources – July 2006
http://baydeltaoffice.water.ca.gov/climatechange/DWRClimateChangeJuly06.pdf
In response to Executive Order S-13-08, DWR produced this document to describe progress in incorporating climate change into existing water resources planning and management tools and methodologies. This large report includes eight chapters presenting the progress and future directions on incorporating climate change science into California's water resource management with focus on assessment methodologies and preliminary study results. Some of the analysis done in this report has been revisited and updated in another document included in this clearinghouse titled ***Using Future Climate Projections to Support Water Resources Decision Making in California.*** In combination, these reports provide guidance to the implications and considerations of climate change effects on IRWM.

*Using Future Climate Projections to Support Water Resources Decision Making in California

California Department of Water Resources – May 2009
http://www.energy.ca.gov/2009publications/CEC-500-2009-052/CEC-500-2009-052-F.PDF
This document describes advances climate projection information in California water resource planning since the 2006 climate change assessment by DWR, ***Progress on Incorporating Climate Change into Management of California's Water Resources*.** Advances include a better understanding of how well current models represent historical climate conditions and refined technologies represent streamflows, outdoor urban and agricultural water demands, and sea level rise. Twelve climate projections are used to assess the reliability of Central Valley Project and the State Water Project operations. This information is particularly useful for addressing the implications and considerations of climate change on changing hydrology.

*Adapting California's Water Management to Climate Change

Public Policy Institute of California – November 2008
http://www.ppic.org/content/pubs/report/R_1108JLR.pdf
Significant water management challenges facing California in the coming decades due to climate change include accelerated sea level and increased temperatures. Sierra Nevada snowpack will be reduced and runoff will shift towards winter months. Changes in timing and amount of precipitation will cause significant flood control challenges. Integrated adaptive responses are needed by all entities responsible for water management in California, including federal, state and local agencies, retail water utilities, and agricultural water districts. IRWM proponents will find a useful discussion of water management adaptation options and associated costs. Institutional capacities and constraints to adaptation as well as the dynamic interaction of climate change mitigation and adaptation actions are also explored.

Framework for Implementation of Water Management Planning

California Partnership for the San Joaquin Valley – March 2009
http://www.sjvpartnership.org/uploaded_files/WG_doc/CWIfinalversionExtractCPSJV10222009.pdf
A Water Work Group commissioned by the California Partnership for the San Joaquin Valley has developed a framework for long-term Valley water management. The framework embraces the creation of IRWM plans and identifies information gathering and dissemination tools that outline core information needs for participants at every level. While this document was specifically generated for San Joaquin Valley water users, the information applies to other statewide IRWM planning efforts.

*Options for Improving Climate Modeling to Assist Water Utility Planning for Climate Change

Water Utility Climate Alliance – December 2009
http://www.wucaonline.org/assets/pdf/actions_whitepaper_120909.pdf
The Water Utility Climate Alliance prepared this report focusing on how several large water utilities (Denver, New York City, Portland, San Francisco, Seattle, and Southern Nevada) have used global climate models (GCMs) and downscaling techniques to examine climate change impacts and the scientific uncertainties associated with those techniques. The report provides the history behind the science being used and the limitations associated with both the GCMs and the downscaling techniques when they are applied to water utilities planning efforts or other water management planning efforts.

*Decision Support Planning Methods: Incorporating Climate Change Uncertainties into Water Planning

Water Utility Climate Alliance – January 2010
http://www.wucaonline.org/assets/pdf/actions_whitepaper_012110.pdf
This white paper presents multi-outcome planning techniques for water utilities interested in incorporating climate change adaptation into their own planning processes. The document guides those utilities on how to include the large range of climate projections and new information into water utility planning, as well as move forward with the adaptation process. Decision Support Planning Methods (DSPMs) and case studies are presented to help utilities and other water resource management entities characterize and understand the multiple uncertainties associated with climate change. The white paper discusses five DSPMs that provide frameworks to help water resource managers decide on how to direct their planning in order to adapt to climate change.

*Climate Change and Water Resources Management: A Federal Perspective

US Department of Interior, US Geological Survey – 2009
http://pubs.usgs.gov/circ/1331/Circ1331.pdf
This interagency report prepared by the United States Geological Survey, US Army Corps of Engineers, Bureau of Reclamation (Reclamation), and NOAA explores strategies to improve water management by tracking, anticipating, and responding to climate change. The authors acknowledge that climate change is one of many challenges facing water managers, and that a holistic approach to water resources management includes all significant drivers of change such as population, land use, economic development, groundwater development and social values. Adaptation options and approaches for decision-making and long-range planning in the face of uncertainties and multiple dynamic processes are explored.

Literature Synthesis on Climate Change Implications for Reclamation's Water Resources

United States Bureau of Reclamation – September 2009
http://www.usbr.gov/research/docs/climatechangelitsynthesis.pdf
The resources in this literature synthesis document are intended to provide region-specific support for long-term water management planning in the western United States. While the document was prepared specifically for Reclamation staff involved in planning and environmental compliance activities, staff from other governmental agencies and nongovernmental entities associated with Reclamation projects and activities will also find it useful. Emphasis was placed on documents pertaining to climate change as it relates to hydrology and water resources and application of climate change science in the western United States. Historical climate and hydrology, projected future climate and hydrology, studies of impacts on environmental resources, and historical sea level rise and projected sea level rise under climate change are assessed for each of the five western Reclamation regions. Downscaled regional climate change projections and map resources are provided.

Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation

Colorado Water Conservation Board – October 2008
http://cwcb.state.co.us/Home/ClimateChange/ClimateChangeInColoradoReport/
This report is a synthesis of climate change science relevant to Colorado's water supply for use by water managers and planners. The document focuses on observed trends, modeling, and projections of temperature, precipitation, snowmelt, and runoff. It also provides a scientific basis to support further studies of water resources impacts in Colorado. A detailed chapter on climate models, emissions scenarios and downscaling methodology is provided, which is useful information for IRWM planners.

Drought

Urban Drought Guidebook

California Department of Water Resources, Office of Water Use Efficiency and Transfers – 2008 Updated Edition

http://www.water.ca.gov/pubs/planning/urban_drought_guidebook/urban_drought_guidebook_2008.pdf

DWR, in conjunction with Reclamation and the California Urban Water Conservation Council, developed this guidebook to provide technical assistance to local water suppliers and help local agencies and communities prepare for dry weather conditions and water supply interruptions. Drought, climate change, natural disasters, and environmental protections can all affect water supplies. Good planning and preparation can help IRWM practitioners and water agencies maintain reliable water supplies and reduce the impacts of supply interruptions. The guidebook presents examples of efforts by water suppliers throughout California and the United States and a wide array of approaches to address the variable water supply and demand scenarios throughout the state. Water suppliers will be able to use this guidebook to design programs that reflect local and regional conditions. The guidebook is in the process of being updated again; however, IRWM practitioners can use the current version until the update is finalized.

General Resource Planning

*2009 California Climate Adaptation Strategy

California Natural Resources Agency – December 2009

http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF

Multiple state agencies, led by the California Natural Resources Agency (CNRA), developed the *Climate Adaptation Strategy* in response to Gov. Schwarzenegger's November 2008 Executive Order S-13-08 to identify how these agencies can respond to rising temperatures, changing precipitation patterns, sea level rise, and extreme natural events. The document summarizes climate change impacts in seven specific sectors (i.e., Public Health; Biodiversity and Habitat; Ocean and Coastal Resources; Water Management; Agriculture; Forestry; and Transportation and Energy Infrastructure) and provides recommendations on how to manage against climate change threats. DWR was one of the agencies involved in the development of this document and the water sector strategies closely match the strategies laid out in ***Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water***. IRWM planners will find the strategies useful for preparation of climate change sections of their IRWM plans and funding proposals.

*Climate Change in California: Scenarios for Adaptation

Public Policy Institute of California – November 2008

http://www.ppic.org/content/pubs/report/R_1108ALR.pdf

This report provides an overview of mid-century climate change scenarios for California and explores how these might be used in state and regional planning efforts in the future. Over the near term (10-30 years), an effective strategy is likely to be identifying and pursuing actions that strengthen the ability to cope with today's climate variability, while also accounting for the most likely climate impacts over that time period. Such an approach will build resilience while new information continues to come in regarding the trajectory of future climate change. Uncertainties inherent to the various trajectories and their relation to emissions scenarios are discussed.

*Climate Change Scoping Plan: A Framework for Change

California Air Resources Board – December 2008
http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm (background for document)
http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm (home page for document)
http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf (actual document)
The California Air Resources Board (ARB), in coordination with the Climate Action Team (including DWR), developed the *Scoping Plan* in response to meeting one of the requirements of Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006, which Governor Schwarzenegger signed into law in 2006. This law requires a reduction of GHG emissions to 1990 levels by 2020. ARB is the lead agency for implementing AB 32, and has developed a list of discrete early actions to begin reducing GHG emissions, assembled an inventory of historic emissions, established GHG emission reporting requirements, and set the 2020 emissions limit. The *Scoping Plan* outlines the state's strategy to achieve the 2020 GHG emissions limit and proposes actions designed to reduce overall GHG emissions in California, improve the environment, reduce the state's dependence on oil, diversify energy sources, save energy, create new jobs, and enhance public health. Since all activities within the state will be required to comply with the scoping plan by 2012, all IRWM planning entities should review this plan and evaluate its potential impact on their activities.

*Sierra Climate Change Toolkit: Second Edition

Sierra Nevada Alliance – 2007
http://www.sierranevadaalliance.org/publications/db/pics/1133215571_14593.f_pdf.pdf
This document reviews the science of climate change on the global, national, state, and regional levels. An overview of the effects of GHG emissions and suggested reduction actions by individuals are provided. Climate change adaptation planning strategies for water, watershed management, species protection, forest management, wildfire management, and land use planning are included and make up the bulk of this document. The principles provided in the document are useful tools in the assessment of regional climate change adaptation and actions for addressing GHG emissions.

Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments

University of Washington - Center for Science in the Earth System – September 2007
http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf
This guidebook emphasizes that waiting until climate change impacts are completely clear entails risk of being poorly equipped to manage the social, economic and ecological consequences, as well as losing the opportunity to take advance of potential benefits. Creating climate resilient communities are the end goal of this process. The guidebook explains how to conduct vulnerability and risk assessments and how to develop and implement a "preparedness plan."

The Washington Climate Change Impacts Assessment

University of Washington - The Climate Impacts Group – June 2009
http://cses.washington.edu/cig/res/ia/waccia.shtml
This assessment of the future ecological and economic impacts of climate change in the state of Washington presents a complete and up to date picture of the future climate of the Pacific Northwest. Global climate model projections from the IPCC Fourth Assessment are used to develop regionally-specific climate change scenarios which are then examined in relation to the consequences for eight important sectors: urban stormwater infrastructure, hydrology and water management, energy, agriculture and economics, salmon and ecosystems, forests, human health, and coasts. IRWM planners will find much information useful for local planning efforts.

Water-Energy Nexus

California's Water-Energy Relationship

California Energy Commission – November 2005
http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF
This report examines how energy is used - and how it can be saved - in the water use cycle. The strategies and goals for a comprehensive statewide water-energy program would achieve incremental energy benefits for water and energy utilities. The report proposes to provide stakeholders with incentives to continuously identify and implement strategies optimizing the state's water and energy resources and assets on an integrated, coordinated, and collaborative basis. The report evaluates actions and methods that can boost the synergistic efficiencies of both the energy and water sectors. These and many other recommendations in the report are useful for IRWM planners.

Refining Estimates of Water-Related Energy Use in California

Prepared for California Energy Commission By Navigant Consulting, Inc. – December 2006
http://www.energy.ca.gov/pier/project_reports/CEC-500-2006-118.html
The 2006 report was a continuation study of the 2005 report titled ***California's Water-Energy Relationship***. It reviews and updates estimates for the magnitude and intensity of water-related energy consumption by segment of the water-use cycle. It further provides adjusted water-energy proxies that are sufficient for informing policy and prioritization of research and development investments. A phased approach is recommended to continually refine water-related energy intensity estimates on an ongoing basis.

Methodology for Analysis of the Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits through Integrated Water-Energy Efficiency Measures

UC Santa Barbara – January 2000
http://www.es.ucsb.edu/faculty/wilkinson.pdfs/Wilkinson_EWRPT01%20DOC.pdf
This exploratory study for the California Institute for Energy Efficiency examines the energy intensity of water use in specific geographic areas of the state, and it estimates the potential energy benefits of efficiency improvements of water use. The analysis indicates that significant potential *energy* efficiency gains are possible through implementation of cost-effective *water* efficiency improvements. This exploratory study identifies significant potential cost-effective energy efficiency benefits from integrated energy, water, and wastewater efficiency programs.

Sea Level Rise

A Report on Sea Level Rise Preparedness

California State Lands Commission – December 2009
http://www.slc.ca.gov/Reports/SEA_LEVEL_Report.pdf
Sea level rise presents a very serious threat to coastal communities and infrastructure, including transportation facilities, electric utility systems and power plants; storm water systems and wastewater treatment plants and outfalls; coastal wetlands; and other human and natural systems. This report discusses the role of the State Lands Commission (Commission) in addressing the threat of sea level rise through oversight of development on coastal lands managed by the Commission. The report also summarizes the results of a survey conducted by Commission staff to assess the extent to which major grantees and sublessees have considered the potential impacts of sea level rise on facilities located on sovereign lands. Recommendations

to better assess the impacts are provided. Efforts by California, federal agencies, and other coastal states to address the issue are well summarized.

The Impacts of Sea-Level Rise on the California Coast

California Climate Change Center – May 2009
http://www.pacinst.org/reports/sea_level_rise/report.pdf
Flooding and erosion already pose a threat to communities along the California coast and there is compelling evidence that these risks will increase in the future. Under medium to medium-high GHG emission scenarios, mean sea level along the California coast will rise from 1.0 to 1.4 meters by the year 2100. A wide range of critical infrastructure will be at increased risk of inundation in a 100-year flood event, and accelerated erosion could result in a loss of 41 square miles of California's coastline. National studies on the economic cost of sea-level rise suggest that while adapting to climate change will be expensive, so are the costs of doing nothing, as substantial investments are already at risk and vulnerable. This report updates and expands a 1990 comprehensive regional assessment of sea level rise using more comprehensive data, new climate scenarios and modern computerized analytical tools.

Flood Protection in the Netherlands: Framing Long-Term Challenges and Options for a Climate-Resilient Delta

Netherlands Environmental Assessment Agency – December 2009
http://www.rivm.nl/bibliotheek/rapporten/500078004.pdf
Sea level rise and flooding vulnerabilities in the Netherlands are analyzed in this report, which indicates that the country has a good capacity to cope with both potential impacts of a warming climate. Three scenarios for adapting to anticipated changes are examined. Increased flood resilience in areas surrounding major rivers is promoted as a means to reduce risk of economic damage and casualties and provide flexibility for water management changes. This document is relevant for local IRWM planning efforts since similar risks of increased flooding and sea level rise are faced by IRWM stakeholders in California.

Biological Resource Impacts

The Impact of Climate Change on California's Ecosystem Services

California Climate Change Center – March 2009
http://www.energy.ca.gov/2009publications/CEC-500-2009-025/CEC-500-2009-025-D.PDF
This report projects the impact of future climate change on California's biodiversity and the natural provision of four key ecosystem services in California – carbon sequestration, forage production, water for instream flows for salmon, and snow recreation. The provision of all four ecosystem services will decline under most climate change scenarios, leading to a decline in economic output and well-being for the state. Continued development of our understanding of the links between climate, ecosystems and economic value through a comprehensive research program is urged. Consideration of potential regional changes to ecosystem services would enhance IRWM grant proposals and IRWM plans.

Ecological Impacts of Climate Change

National Academy of Sciences/National Research Council - 2008
http://dels-old.nas.edu/dels/rpt_briefs/ecological_impacts.pdf
Adequate planning for climate change in IRWM documents entails a necessary understanding of the magnitude and implications of potential changes on local and regional ecosystems. This document presents a series of examples of ecological impacts of climate change that have already been observed across the United States. The lives of all animals, plants and microorganisms are strongly attuned to changes in climate. If the changes in climate are modest and slow, the majority of species will likely adapt successfully. If the changes in climate are rapid

or large, more and more species will face ecological changes to which they may not be able to adapt. Given that ecosystems provide imperative ecosystem services such as food, fiber, fuel, medicine, environmental regulation, and more, humans should attempt to minimize the magnitude of ecological impacts from climate change.

CEQA and Climate Change Considerations

NEW CEQA Guideline Amendments

http://ceres.ca.gov/ceqa/guidelines/

On December 30, 2009 the CNRA adopted amendments to the CEQA guidelines for GHG emissions, as directed by Senate Bill 97 (SB 97). The amendments became effective March 18, 2010. The new guidelines state that lead agencies should quantify GHG emissions where quantification is possible, or perform qualitative analysis, or both as appropriate in the context of the particular project, in order to determine the amount, types, and sources of GHG emissions resulting from the project. The guidelines preserve the discretion of lead agencies in making determinations of significance but recommend that lead agencies consider the adoption of broad programmatic approaches for reducing GHG emissions from their activities. All IRWM activities which require CEQA analyses must comply with these new guidelines.

*CEQA and Climate Change

CAPCOA – January 2008

http://www.capcoa.org/CEQA/CAPCOA%20White%20Paper.pdf

The California Air Pollution Control Officer Association prepared this white paper for public agencies to use as they develop procedures for reviewing GHG emissions from projects. The paper reviews policy choices, analytical tools, mitigation strategies, mitigation measures, and provides examples from guidance documents developed in Massachusetts, Washington, and California. It also presents methodologies for residential, commercial, specific and general plan scenarios and information on estimating emissions from solid waste facilities, wastewater treatment plants, and construction. This document may be particularly helpful for developing strategies for determining the significance of environmental impacts for GHG emissions.

Office of the Attorney General Information on CEQA and Climate Change

http://ag.ca.gov/globalwarming/ceqa.php

This website, maintained by the Office of the Attorney General, contains information about CEQA and ways that climate change can be analyzed by as part of the process of evaluating and disclosing the significant environmental impacts of proposed projects. Project level mitigation measures are proposed in a document titled ***Addressing Climate Change at the Project Level***, a link to which can be found on this webpage. Extensive background information on global warming is also available.

*CEQA and Climate Change: Technical Advisory

Office of Planning and Research – June 2008

http://opr.ca.gov/index.php?a=ceqa/index.html (home page for document)

http://opr.ca.gov/ceqa/pdfs/june08-ceqa.pdf (actual document)

The Governor's Office of Planning and Research (OPR), in collaboration with the CNRA, the California Environmental Protection Agency and the ARB, published this *Technical Advisory* containing informal guidance for public agencies as they address the issue of climate change and GHG emissions in their CEQA documents. Since the passage of AB 32 (Global Warming Solutions Act of 2006), this *Technical Advisory* provides OPR's perspective on the issue and precedes the climate change and GHG regulations for CEQA. Technical resources, modeling tools to estimate GHG emissions, and examples of GHG reduction measures are included in the *Technical Advisory*.

***DWR CEQA Guidance Documents**
California Department of Water Resources – January 2010
http://www.water.ca.gov/climatechange/docs/CEQA_GHG_Guidance.pdf
DWR as the responsible agency for most IRWM grant making activities will be responsible for reviewing and approving CEQA documents prepared for projects funded through DWR's grant making process. As such, DWR expects that all DWR funded IRWM implementation projects will meet the requirements for climate change analysis in CEQA documents outlined in the CEQA Guideline Amendments approved by the CNRA on December 30, 2009. These DWR guidance documents are being provided to IRWM planning agencies as references to help them document the GHG emissions associated with their proposed projects and analyze the significance of these emissions for CEQA purposes.

Internet Sites with Additional Information on Climate Change

Links preceded by asterisks [**] contain GHG calculation tools

California Air Resources Board
http://www.arb.ca.gov/cc/cc.htm

******California Climate Action Registry
http://www.climateregistry.org/

California Climate Change Portal
http://www.climatechange.ca.gov/

California Climate Change Research Center
http://www.climatechange.ca.gov/research/index.html

California Department of Water Resources Climate Change Home Page
http://www.water.ca.gov/climatechange/

California Natural Resources Agency
http://www.resources.ca.gov/

California Office of the Attorney General
http://ag.ca.gov/globalwarming/index.php

Center for Climate Action
http://www.centerforclimateaction.org/cop15/

******Cool California
http://www.coolcalifornia.org/

**I.C.L.E.I. – Local Governments for Sustainability
http://www.icleiusa.org/programs/climate

Intergovernmental Panel on Climate Change
http://www.ipcc.ch/

NASA Goddard Institute for Space Studies
http://data.giss.nasa.gov/gistemp/

National Climatic Data Center
http://www.ncdc.noaa.gov/climate-monitoring/

National Oceanic and Atmospheric Administration Climate Services
http://www.climate.gov/#climateWatch

Pew Center on Global Climate Change
http://www.pewclimate.org/

**The Climate Registry
http://www.theclimateregistry.org/#

**The Greenhouse Gas Protocol Initiative
http://www.ghgprotocol.org/calculation-tools/all-tools

Union of Concerned Scientists - Climate Choices
http://www.climatechoices.org/

US Climate Change Science Program
http://www.climatescience.gov/default.php

**US Department of Energy Carbon Dioxide Information Analysis Center
http://cdiac.esd.ornl.gov/

US Environmental Protection Agency - Watershed Academy Web
http://www.epa.gov/watertrain/climate_water/

US Forest Service Climate Change Resources Center
http://www.fs.fed.us/ccrc/

US Global Change Research Program
http://www.globalchange.gov/

From the California Climate Change Portal: http://www.climatechange.ca.gov/publications/faqs.html

FAQs
Frequently Asked Questions About Global Climate Change

The Science of Climate Change

- What is Climate Change?
- What is the Greenhouse Effect?
- Is the Earth Warming?
- How Certain is the Climate Change Science?
- Where Do Greenhouse Gases Come From?

How Might Climate Change Impact California?

- What are the Potential Impacts for California's Water?
- California's Agriculture?
- California's Fishing Industry?
- California's Coastline?
- California's Forests?
- Impacts Related to Air Pollution in California?
- California's Energy Supply and Demand?
- California's Ecosystems?

I. The Science of Climate Change

A. What is Climate Change?

Climate change refers to long-term changes in temperature, precipitation, wind patterns, and other elements of the earth's climate system. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "any change in climate over time, whether due to natural variability or as a result of human activity." An ever-increasing body of scientific research attributes these climatological changes to greenhouse gases (GHGs), particularly those generated from the human production and use of fossil fuels.

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B. What is the Greenhouse Effect?

Historically, atmospheric gases such as water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), ozone (O3), halocarbons (HFC's) and others have trapped terrestrial radiation in the Earth's atmosphere, which has maintained a temperature and climate hospitable to life over much of the Earth. This is a condition known as the "greenhouse effect." Different greenhouse gases have different effects on the Earth's energy balance.

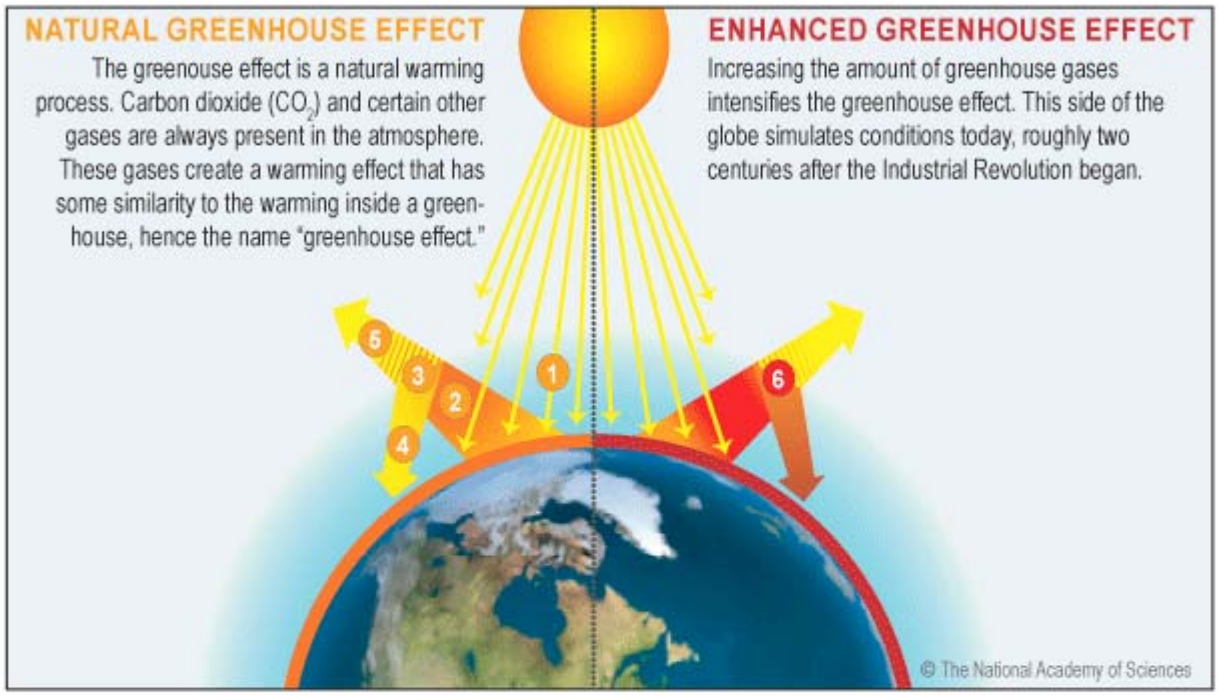

Illustration of the greenhouse effect (courtesy of the Marion Koshland Science Museum of the National Academy of Sciences). Visible sunlight passes through the atmosphere without being absorbed. Some of the sunlight striking the earth 1 is absorbed and converted to heat, which warms the surface. The surface 2 emits infrared radiation to the atmosphere, where some of it 3 is absorbed by greenhouse gases and 4 re-emitted toward the surface; some of the heat is not trapped by greenhouse gases and 5 escapes into space. Human activities that emit additional greenhouse gases to the atmosphere 6 increase the amount of infrared radiation that gets absorbed before escaping into space, thus enhancing the greenhouse effect and amplifying the warming of the earth.

Image Source: The National Academy of Sciences

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C. Is the Earth Warming?

Scientists believe that the earth is warming faster than at any time in the previous 1,000 years. The average global surface temperature has increased by 1.1 degrees Fahrenheit since the 19th century. The 10 warmest years of the last century all occurred within the last 15 years - 1998 was the warmest year on record. As atmospheric concentrations of greenhouse gases rise, so do temperatures, because less heat is able to escape the atmosphere. This rise in temperature is accompanied by climatic changes, some dramatic and some subtle, that affect how organisms live, adapt, and survive on the planet.

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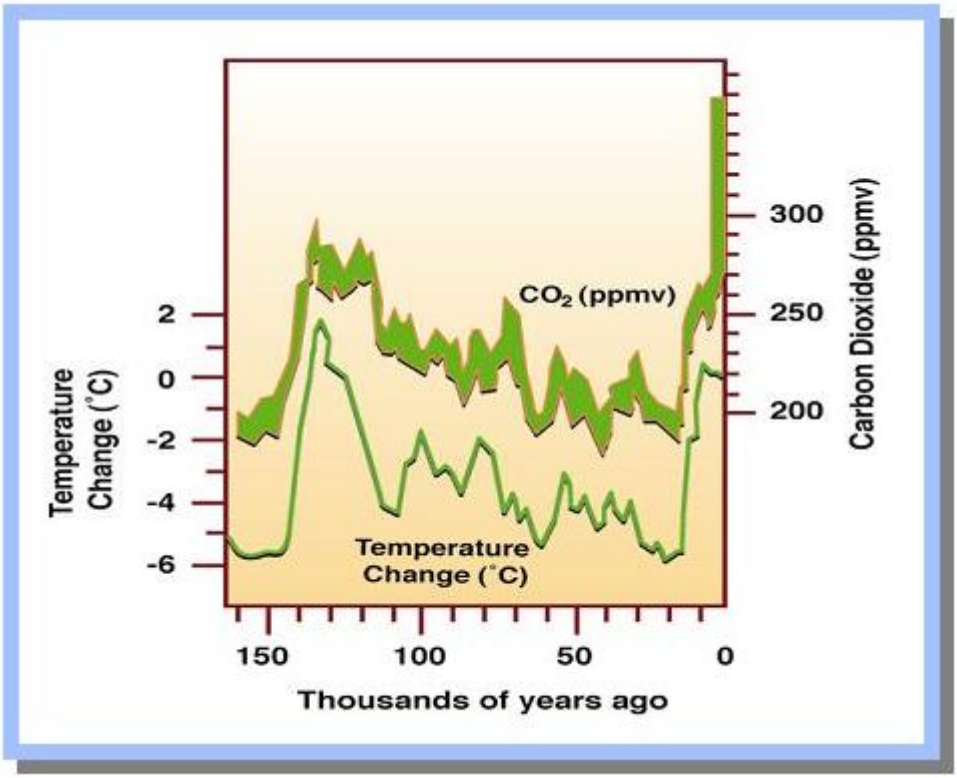
D. How Certain is the Climate Change Science?

While the climate system is very complex and difficult to model precisely, the Intergovernmental Panel on Climate Change (IPCC) is increasingly certain that humans have a discernible influence on the global climate. Confirmation of the measured warming trend is substantiated by the rise in sea level of between four and 10 inches that has occurred since 1900 and the decrease in the average snow cover and glacial ice worldwide. Unseasonable weather phenomena are becoming commonplace and intensities appear to be increasing. A continued increase in greenhouse gas emissions, and the associated temperature rise, is likely to accelerate the rate of climate change, producing further impacts.

The primary greenhouse gas contributor is CO2. Scientists have established direct links between increased CO2 concentrations and the atmospheric warming that has occurred since the industrial revolution. After remaining relatively constant from 1000 to 1700 c.e., CO2 concentrations began to rise sharply and have increased 30% since pre-industrial times. They are continuing to increase by approximately one-half percent per year.

Additional Information: www.ipcc.ch



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E. Where Do Greenhouse Gases Come From?

Greenhouse gas emissions resulting from human activities are substantially increasing the atmospheric levels of the greenhouse gases which include carbon dioxide, methane, halocarbons (HFCs), and nitrous oxide. Carbon dioxide emissions have increased 30% during the past century largely due to fossil fuel combustion which produces the largest amount of CO2 emissions (about 80% of United States GHG emissions and about 87% of California emissions). In California, approximately 43% of the CO2 emissions come from cars and trucks. Methane emissions have doubled in the past 100 years. Over the same period, nitrous oxide levels have risen about 15%. Agriculture is a major source of both methane and nitrous oxide, with additional methane coming primarily from landfills. Halocarbons are another greenhouse gas. Most halocarbon emissions come from their use as refrigerants, solvents, propellant agent, and industrial processes. Manufactured compounds, like HFCs, persist in the atmosphere for long periods of time and have far greater effects at lower concentrations as compared to CO2. Although the amount released of these compounds is small, they are very effective at trapping heat in the atmosphere.

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II. How Might Climate Change Impact California?

Because California has such a diverse topography, producing a variety of drastically different microclimates, the effect of climate change on California is complex. Climate variability and change will impact natural ecosystems and water resources. Major alterations to natural ecosystems due to climate change could possibly have negative consequences for our economy, which depends in part on our state's lands, waters, and native plant and animal communities.

A. What Are The Potential Impacts For California's Water?

Over the past 150 years, monitored mountain glaciers have been shrinking. If glaciers continue to shrink, summer water flows will drop sharply, disrupting a source of water for irrigation and power in many areas that rely on mountain watersheds. This in turn will likely lead to more flooding during the winter and worsen drought conditions. In California's Central Valley, for example, melting snow provides much of the summer water supply; warmer temperatures would cause the snow to melt earlier and thus reduce summer supplies even if rainfall increased during the spring. Instead of increasing the amount of water supply available, the disrupted cycle is likely to cause excess rainfall and run-off, thus causing flooding and overflow of reservoirs which are not equipped to contain such large inflows of water.

The shortage of water in the summer due to runoff changes could worsen drought and increase diversions of rivers in California. This would mean higher cost and further adverse effects downstream. Together with changing temperatures, flows, and the ability of watersheds to assimilate wastes and pollutants, changing runoff patterns could also have the potential to alter water quality significantly. Additionally, sewage systems could be overwhelmed by storm runoff and high tides.

Rising sea levels can cause an increase in the intrusion of salt water into coastal aquifers, contaminating fresh water supplies. Sea level rise could especially affect the Sacramento San Joaquin River Delta, the hub of California's water transfer system. Higher tide levels would pose additional problems to the precarious Delta levee systems with a risk of more inland inundation and the corresponding threat to export water quality.

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B. What Are The Potential Impacts For California's Agriculture?

Potential impacts, such as reduced water supply, more severe droughts, more winter floods, and drier growing seasons will affect agriculture (a $26 billion Californian industry in 1997). Many farms especially in the fruit and nut business require long-term investments, making fast

adaptation difficult, and could thus experience serious losses if decisions continue to be made with no regard to expected climate changes.

Water is needed year-round, especially for perennial crops. Perennial Crop growers can not shift quickly to new types of cultivars and they need reasonable water supply projections such as several decades for trees and vines. Problems with crops can persist many years if there is an extreme weather or pest-related event. Fruit trees are particularly vulnerable. Too much rain or too little rain can be a problem, as well as pest impacts, too much or too little fog, less frost days, and changes in the timing of the season can all disrupt their market.

In order to better deal with water shortage issues, irrigation practices need to improve, because there is already an increase in salts in the land. Some areas may lose productive capacity in a matter of decades with or without climate change, but climate change could make the problem worse. Even vineyards can be susceptible to fungi because of increased rainfall at the wrong time.

Coastal agriculture is also at risk due to potential impacts of sea level rise. Even if farmers move crops closer to the fog, they may permanently lose agriculture lands to the ocean.

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C. What Are The Potential Impacts For California's Fishing Industry?

Studies found that as a result of changes in ocean conditions, the distribution and abundance of major fish stocks will change substantially. Impacts to fisheries related to El Nino/ Southern Oscillation illustrate how climate directly impacts marine fisheries on short term scales. Higher sea surface temperatures in 1997-1998 during the El Nino had a great impact on market squid, California's largest fishery by volume. The California Regional Assessment reports that landings fell to less than 1,000 metric tons in that season, down from a 110,000 tons in the 1996-1997 season. Other unusual events also occurred such as poor salmon returns, a series of plankton blooms, and seabird die-offs.

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D. What Are The Potential Impacts For California's Coastline?

With climate changes, recreational facilities and developed coastlines will also be more vulnerable to hurricanes, storm surges, flooding increases. Increasing population growth in coastal areas is a reason for further concern, since these areas could be more vulnerable to climate change impacts. Impacts of expected sea level rise and increased storm surges are numerous. Beachfront homes and harbors as well as wetlands may flood. Sewage systems may be overwhelmed by storm runoff and high tides. Coastal airports are vulnerable to flooding (San

Francisco, Oakland and Santa Barbara). Jetties and seawalls may have to be raised and strengthened to protect harbors which are used for shipping, recreation, and tourism.

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E. What Are The Potential Impacts For California's Forests?

The California Regional Assessment notes that an increase in the number and extent of areas burned by wildfires in recent years, and modeling results under changing climate conditions suggest that fires may be hotter, move faster, and be more difficult to contain under future climate conditions. The factors which contribute to the risk of catastrophic fires (fuel loads, high temperatures, dry conditions, and wind) are typically present already in summer and fall seasons in California, but can exist at other times of the year, especially in drought conditions. Public safety is an issue as more home and tourism developments on coastal hills and mountains and the foothills and higher elevations in the Sierra Nevada are highly susceptible to catastrophic wild fires.

Other climate impacts affecting forestry are: Higher CO2 concentrations which may increase growth, drought which can kill forests, changes in mineral nutrients, and pest population dynamics. However, more research is needed to understand whether total plant material is expected to increase or decrease in California due to climate changes. Today's models of the Sierra Nevada and North Western California provide contradictory results on this subject.

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F. What Are The Potential Impacts For Air Pollution In California?

Projected climate changes will impact the quality of California's air, public health, and environment. Higher temperatures increase the formation of ground level ozone and particulate matter, making it more difficult to meet the health-base air quality standards for these pollutants. Ground-level ozone has been shown to aggravate existing respiratory illnesses such as asthma, reduce lung function, and induce respiratory inflammation. Ambient ozone also reduces agricultural crop yields and impairs ecosystem health.

The particulate matter of most concern - PM10 - has a diameter smaller than 10 micrometers and can easily pass into the lung, contributing to the development of lung tissue damage. PM10 has been implicated in exacerbation of cardiovascular disease, asthma, other respiratory diseases, and associated with increased mortality. Air pollution is also made worse by increases in natural hydrocarbon emissions and evaporative emissions of fuels and solvents which leads to higher levels of ozone and PM10 during hot weather. Warmer temperatures that cause increased use of air conditioners can cause increased air pollutants from power plants and from vehicle operation. In addition, warming, drying, and increased winds could mean hotter, harder-to-control wildfires.

These wildfires could result in increased levels of fine particulate matter that could also exceed State and federal standards and harm public health.

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G. What Are The Potential Impacts For California's Energy Supply?

California's electricity generation is currently relatively efficient when it comes to emissions of greenhouse gases. The national average for the electricity generation share of total greenhouse gas emissions is approximately 40%, while California electricity accounts for only 16% of statewide emissions. This is in part due to California's significant amount of imported electricity, mild climate, and lack of energy-intensive industry. Over the past two decades, California has developed one of the largest and most diverse renewable electricity generation industries in the world. However, changes in climate of the magnitude predicted by the IPCC would substantially affect electricity generation throughout California and the entire Western States grid, particularly for hydroelectric facilities.

Less snowpack would result in lower levels of hydro generation in the summer and fall seasons due to reduced runoff in those seasons. Additional hydropower may be available during the winter and the spring. However, on balance hydropower is more useful and valuable within the grid mix of generation sources when it is available throughout the peak summer and fall seasons. The Natural gas distribution system may also be damaged because of landslides and fires. Flooding could also impact pipelines, wells and related petroleum extraction equipment. Warmer weather would result in an increased demand for electricity for cooling appliances in homes, and businesses.

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H. What Are The Potential Impacts For California's Ecosystems?

The current distribution, abundance, and vitality of species and habitats are strongly dependent on climatic (and microclimatic) conditions. Climate change is expected to result in warmer temperatures year-round, accompanied by substantially wetter winters. Rising sea level will significantly affect coastal wetlands because they are mostly within a few feet of sea level. As the sea rises, these wetlands will move inland. The overall acreage of wetlands will be reduced due to constraints by existing urban development and steeper slopes immediately inland of existing wetlands. Tidal rivers, estuaries, and relatively flat shoreline habitats will be more subject to damage by flooding and erosion. More severe storm surges from the ocean, due to higher sea levels, combined with higher river runoff could significantly increase flood levels by more than the rise in sea level alone. Erosion of beaches would decrease habitat for beach-dependent species, such as seals, shorebirds, and endangered species (for example, snowy plover and least tern). Aquatic habitats are also likely to be significantly affected by climatic changes.

Most fish have limits to how hot or cold the water can be before they must either find more hospitable temperatures or die. As temperatures warm, many fish will have to retreat to cooler waters.

Changes in temperature and precipitation patterns would also shift California's current climate zones, and thus habitats associated with these zones, northward by approximately 100 - 400 miles, as well as upwards in elevation by 500-1500 feet. Global climate change would alter the composition, structure and arrangement of the vegetation cover of the state (forest and wildland). Species distribution would move geographically as the climate changes, with forest stands, woodlands and grassland species predicted to move northward and higher in elevation. The entire vegetative community may be affected if non-native invasive species occupy sites and replace native plants. Outbreaks of insects and diseases could compromise forest health and the capability of the forest stands reproduce and to store carbon on a landscape basis. Forest fires are likely to become more frequent and severe if soils become drier. Changes in pest populations could further increase the stress on forests.