What's Going to Happen and What Can We Do About It?
Getting Scientific Information to Support
Climate Smart Decision-making in the Bay Area[1]

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Executive Summary

Impacts of climate change on the economy and quality of life in the Bay Area are now apparent and will grow more disruptive over time, making it urgent to plan for this new future. We can protect public health, the environment, and future economic opportunity with thoughtful planning using a mix of existing technical information, nature-based solutions, multi-stakeholder scenario planning efforts and incorporating new information as it becomes available over time.

This can be accomplished by building on our existing capacities, and by enhancing the dialog between scientists, managers and decision makers as we obtain and deliver scientific information about weather, pollution, population trends, and other environmental conditions to support informed decisions. Critical to effective use of this information is its delivery through organized communication and outreach efforts in which the most relevant scientific data given the needs of managers and decision makers is packaged in products that are easily understood and acted upon.

Enhancing our existing capacities requires effective and strategic inter-agency and public-private partnerships, as the nature of the problems we face extend beyond traditional disciplines and jurisdictions. Partnerships are essential for guiding production of data products that are easily used by nonscientists, for encouraging coalitions that create funding opportunities, and for enhancing our ability to communicate with diverse audiences in our region that must be engaged to prepare for climate change.

Enhancing the dialog between scientists, managers and decision-makers is essential to ensure that decision makers are informed about the latest climate science and can clearly articulate their questions and needs to scientists. This interaction needs to be iterative and ongoing for the most cost effective and well-informed decision-making.

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Regional partnerships must develop scientific information to address the general questions (1) what is going to happen in our region as climate changes, (2) how fast will this happen, and (3) what can we do to be resilient to these changes? The following tasks are therefore priorities:

- **Develop a process for making credible projections of future climate available for use by regional and local planners.** Delivering and interpreting credible and authoritative projections of future climate on a reliable schedule will greatly enhance the effectiveness of planning for resiliency in the face of climate change.

- **Develop a monitoring network that measures and regularly reports the effects of climate change and the effectiveness of our efforts to prepare for these changes.** These measurements will be essential for determining (1) the physical, ecological, economic and public health impacts of climate change, (2) if the range of scenarios adopted for planning purposes are accurate or must be revised, (3) whether thresholds for action (if identified in future policy) have been reached, and (4) additional management and other measures are required to reduce impacts and enhance resilience. Monitoring data can also be valuable for improving the accuracy of models used for future projections.

- **Use regional climate projections to prepare for a range of future scenarios to guide regional planning.** Engaging a broad array of stakeholders to work with scientists to prepare future scenarios will develop a compelling case for how climate change could impact the Bay Area's economy, public health and ecological resources, creating support for the investments that will be necessary to build resiliency to climate change in the Bay Area. Facilitated scenario planning exercises amongst stakeholders including scientists, managers and policy makers using available climate projections will clarify the range of future impacts that must be accounted for in planning.

- **Design and test methods for increasing the Bay Area's resilience in the face of expected changes through demonstration projects that are cross-sectoral, cross-jurisdictional, and multi-objective.** A good place to start is a set of demonstration projects that identify the most effective methods that can be implemented at a large scale for making our shorelines more resilient to sea-level rise**.** Sea-level rise and more extreme storm surges will threaten a broad array of vulnerable regional assets located on our shorelines. It is essential to identify the most economical and "climate-smart" methods[2] for protecting our shorelines by testing and evaluating various strategies in pilot projects so diverse coalitions can support the required public investments to deploy successful strategies at larger scales. Shorelines resilient to future sea-level rise

[2] "Climate smart" actions promote nature-based solutions for wildlife and people that reduce climate change impacts, enhance the ability to adapt, and sustain vibrant, diverse ecosystems, and reduce GHG emissions and enhance carbon sinks

can also provide concurrent benefits for water quality, wildlife, and recreation, which will help build these coalitions.

- **Identify the management plans and public processes where climate change vulnerability assessment and resilience planning is required**. Many managers and policymakers must plan for climate change in the context of existing regulatory and management processes. Targeted communication and outreach projects must be implemented to deliver technical and other information in a form and on a schedule that supports the conduct of vulnerability analysis and resiliency planning for both human and green infrastructure strategies as part these existing regulatory and management processes.

Introduction

The emission of greenhouse gases from fossil fuel combustion and the destruction of forests has altered the energy balance of the earth, and heat energy that used to escape to space is now accumulating on the planet. This is changing earth's climate at an extraordinary rate, and will result in higher and more variable air and water temperatures, higher waves and rising sea level, and altered precipitation patterns in California and the Bay Area. Subsequent impacts from these changes include increased risk of fire, flooding, and heat waves, and ecological changes to terrestrial and aquatic ecosystems including the altered abundance and distribution of biological resources, pests and diseases [1-3].

These changes will have profound impacts on the economy and the quality of life in the Bay Area. The better the information that is available about expected future conditions (both in short and long term), the more effectively preparations can be made to reduce social, economic and ecological disruption. Objective measurement of our changing environment using scientific methods is an essential mechanism for providing better information.

To assist the Bay Area in preparing for climate change, this workplan (1) considers how the development and delivery of objective scientific information can be enhanced to improve decision-making now and in the future, and (2) proposes priority objectives for the development and delivery of such information. The desired outcome of this workplan is the efficient use of scientific information in support of evidence-based decision-making to protect public health, the environment, and the economy of the Bay Area, with a focus on employing nature-based, multi-benefit approaches..

This document describes how available knowledge can inform our approach, existing capacity that can be utilized, and six key tasks that can be initiated immediately to develop scientific information vital to building resilience to climate change in the Bay Area.

Approach

Several key considerations inform the approach for developing this workplan. First, we recognize that our knowledge of the impacts of climate change in the Bay Area has evolved over time, and this process will continue as observations accumulate and predictive models are refined. Consequently, the workplan must use existing knowledge to encourage learning over time. Moser and Ekstrom [4] describe an adaptation process that moves from understanding through planning and managing to evaluation and improved understanding (Figure 1), and this process will be active in both the short term (years) and the long term (decades). It is particularly important to recognize that successful climate adaptation efforts will require iterative joint learning with scientists and stakeholders in a long-term context that will span multiple generations.

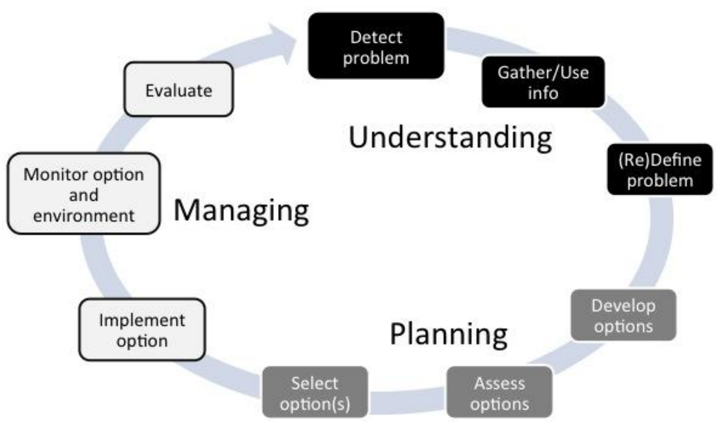

Figure 1: Climate change adaptation as a three-phase process [4].

Scientific methods must therefore be applied to generate information that is directly applicable to management and policy problems. This type of applied research is different than standard academic research, where pursuit of knowledge for its own sake is a standard goal. At its best, applied research begins with robust discussion between scientists and stakeholders, where the questions are defined and prioritized. As data is available, its implications are also discussed with stakeholders, who may identify needs to modify the research. When the applied research is completed, scientists must engage with stakeholders to ensure that the results are presented in an understandable form that can be easily utilized to inform planning and decision-making.

Moreover, even when applied research is conducted and completed, managers and policymakers must receive the information generated by scientists in a form that can be easily utilized. This normally means the standard method of reporting scientific results (a paper in the peer reviewed literature) must be supplemented with products easily understood by nonscientists, and outreach through communications forums accessible to managers and policymakers. The University environment in which many scientists operate often does not provide incentives for this type communication and outreach.

Developing and delivering information in this manner requires that adequate resources are allocated for this purpose so that users experience a reliable and efficient response to their requests for information [5]. Just as our community (at multiple scales) has reliable access to a diverse array of products that forecast weather to support decision-making, we must create products that project future climatic conditions.

In addition, even with the appropriate allocation of resources toward the structure, development and delivery of effective communication products, it is human nature to filter objective information based upon personal values and political objectives [6, 7]. Thus, building the case for action based upon objective information requires delivery of that information by credible messengers who respect the values of target audiences and understand their motivation and incentives.

There is thus a lot of work that must occur to create an adequate exchange of information between the scientific community and the management/political community. Organizations that undertake these tasks have been called "boundary organizations" [8, 9], and a variety of organizations working at the boundary of science and policy will be required to facilitate the delivery and integration of scientific information to support preparing for climate change.

Existing Capacity for Utilizing Scientific Information

The global nature of climate change leads to uncertainty about how to prepare for expected changes at the regional and local level. While some new skills are required (*e.g.*, downscaling and making available the output of global climate models),[3] our existing capacity for utilizing scientific information will allow us to make great progress in supporting local and regional planning and implementation.

In the Bay Area objective evidence is used regularly to encourage economic growth, plan capital expenditures, and manage risk to life, property, and ecosystem services (Table 1). This evidence is developed using measurements from credible sensor networks, validated mathematical models, and scientific research. The evidence is delivered to decision-makers through organized communication and outreach efforts in which the scientific data is packaged in products that are easily understood and acted upon by the public.

[3] While this is a new skill, it is developing rapidly in the Bay Area [18].

Organization	Types of Measurements
Regional Water Quality Control Board	Water chemistry
Department of Fish and Wildlife (Bay Program)	Bay Fish populations
Departments of Public Health	Water and air chemistry, abundance/distribution of agents and vectors of disease
Bay Area Air Quality Management District	Air chemistry
Inventory and Monitoring (Department of Interior)	Wildlife abundance and distribution
National Oceanographic and Atmospheric Administration (National Weather Service, National Geodetic Survey, National Ocean Service)	Ocean and atmospheric physics (currents, sea level, temperature, wave heights, rainfall), biological resources
Bay Area Council Economic Institute	Employment reports, economic reports and forecasts
Department of Water Resources	Snowpack depth, water content, reservoir status
Metropolitan Transportation Commission	Traffic measurement and modeling

Table 1: Examples of programs that use sensor networks and communication products to deliver objective information to the public and decision-makers.

For example, findings of biomedical and ecological research have resulted in laws and subsequent regulations meant to ensure healthy air quality. To assess the status and trends of air quality a monitoring network is operated in our region, and these data are combined in numerical analyses to assess the status air quality and report to the public. The Bay Area Air Quality Management District is able to forecast and report air quality using the US Environmental Protection Agency's *Air Quality Index,* which combines pollutant measurements[4] into a quantitative indicator that citizens can read like a thermometer with "healthy" air at the low end and "very unhealthy" air at the other. This allows citizens and businesses to make daily decisions, and leads to curtailment of activities that exacerbate pollution on bad days (*i.e.*, *Spare the Air* days when it is illegal to burn wood due to projected high concentrations of particulates).

Sensor networks and communication products also provide information to support long term decisions, such actions required to meet water quality standards established by the San Francisco Bay Regional Water Quality Control Board. Monitoring programs established by the Board evaluate pollutant concentrations in San Francisco Bay waters, and report results in print [10, 11] and on-line. These results support long-term decision-making regarding permits pursuant to the Federal Clean Water Act and California's Porter-Cologne Act. Other examples include the sensor networks used to create and deliver weather information by National Weather Service, and the measurement and reporting of the Sierra snow pack by the Department of Water Resources.

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[4] In the air quality index measurements of the concentrations of ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and two sizes of particulate matter are compared to health-based federal air quality standards and then reported on a scale of 1 to 300.

It is important to note that in these instances the capacity that is being utilized is scientific and technical, but the activities undertaken are not scientific research. Instead, long established and standardized methods are being used on a regular basis to provide data products that support management decision-making. Although the word "research" is used often used to describe these efforts, the actual research that led to the capacity to produce the data products is long over and done, and scientists have moved on to new cutting edge research topics. Understanding and accounting for this difference between the manager/policymaker's concept of research and that of the scientific community is essential in order to have valuable exchange of information across this boundary.

The importance of this difference for supporting climate change adaptation was recently identified in the *Global Framework for Climate Services* [12] that was recently adopted by the World Meteorological Organization [13]. A schematic of this framework (Figure 2) presents this relationship between research, data products, and data users.

The benefits of applying scientific research to create useful data products can be seen for California in the forecasting of El Niño. The detection and implications of the El Niño Southern Oscillation (ENSO) in the tropic Pacific Ocean was the result of oceanographic research (based in part on the local knowledge of Peruvian fishermen who coined the term El Niño), and this research led to the first ENSO forecast (a data product) in 1987. Forecasting capacities continued to develop, and the large 1997-98 ENSO was predicted six months in advance. It is estimated that actions taken based on this information saved 850 lives and $20 billion in property damages, particularly due to preparations for flooding taken in California [5].

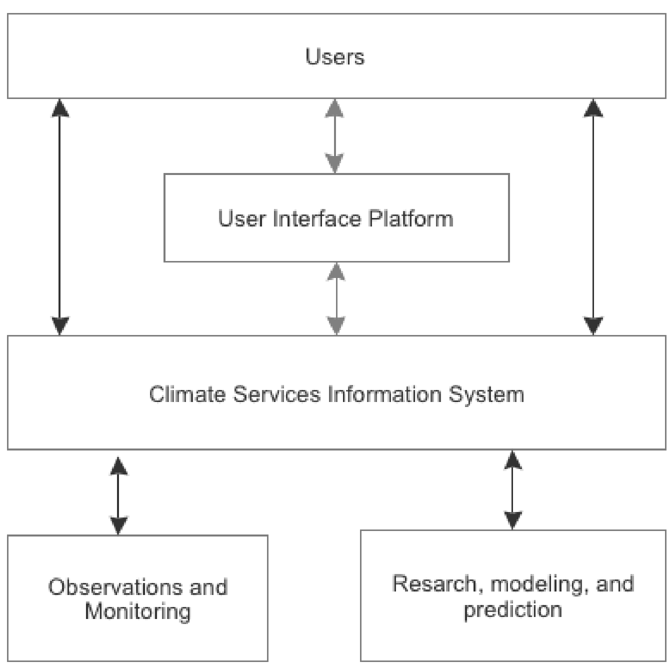

Figure 2: Schematic for Global Framework for Climate Services demonstrating relationship between scientific research and information users (after [12]).

Partnerships Make Existing Capacity More Effective

The existing capacity for utilizing scientific information in decision-making has been enhanced by the creation of inter-agency and public-private partnerships. The importance of partnerships has been driven by the rise of environmental problems with solutions that are interdisciplinary and inter-jurisdictional. Partnerships have been essential to clarify the specific types of measurements, data products, and research that are required to inform decision-making. Partnerships also result in repeated personal contacts build trust among parties[5, 14], and also can allow stakeholders to be involved in the design and evaluation of sensor networks and data products. This engagement increases the salience, credibility, and legitimacy of these products, which essential for generating actionable information [15].

There are many examples of existing partnerships in the Bay Area that are producing actionable information (Table 2). These partnerships include programs that are active at the regional, sub-regional, and local levels. They involve government regulatory agencies, resource management agencies, counties, special districts, and non-governmental organizations (Table 3).[5]

Partnership Name	Product
Regional Monitoring Program	Water quality assessment
San Francisco Estuary Partnership	Comprehensive Conservation and Management Plan and ecological health assessments for the estuary
Integrated Regional Water Management Coordinating Committee	Water quality and supply planning
Bay Area Ecosystems Climate Change Collaborative	Update of Baylands Ecosystem Habitat Goals for climate change, developing regional monitoring network
North Bay Climate Adaptation Initiative	Climate adaption planning for Sonoma County
San Francisco Bay Joint Venture	Wetlands Restoration
South Bay Salt Ponds Restoration Program	Wetlands restoration and flood risk management

Table 2: Examples of partnerships developing programs and products to delivery objective information to decision-makers and the public in the Bay Area.

[5] The proliferation of partnerships has resulted in a growing concern that too many partnerships may diminish effectiveness. A saturation of the region with partnerships, so that key stakeholders feel over-burdened, should result in a consolidation of efforts in order maintain productivity and build support for project funding. It is not clear if this consolidation will occur in an efficient manner.

Types of Organizations	Examples
Special districts	Water, flood, sewer, parks and open space
Regulatory/planning	Land use, water, wildlife, public health
Industry	Ports, refineries
Working lands	Agricultural, ranching
Federal agencies	NOAA, NPS, USFWS, USGS, Army Corps
State agencies	DWR, DFW, BCDC, Coastal Conservancy, Coastal Commission
Local agencies	Counties, cities, ABAG, MTC, public health departments
Non Governmental Organizations	PRBO Conservation Science, San Francisco Estuary Institute, Center for Ecosystem Management and Restoration
Universities	UC Berkeley, State Universities (East Bay, SF, San Jose), Stanford

Table 3: Examples of organizations involved in partnerships using sensor networks to produce objective information for regional decision-making in the Bay Area.

In addition to engaging stakeholders in the design and creation of data products to increase their usefulness, partnerships are also essential for providing funding opportunities to improve sensor networks and information products. When a diverse set of stakeholders can perceive the value in developing to capacity to produce certain data products, it increases the likelihood of finding diverse sources of funding for these activities, especially in the current era of reduced government funding.

Partnerships can also provide essential opportunities for outreach and communication of results beyond the normal communication processes used by the scientific community. Scientists need help, encouragement, and support to communicate in non-scientific terms, particularly when specialized communication efforts are required to engage key constituencies. Knowledgeable partners can help scientists by giving them access and credibility before certain audiences, and by serving as trusted messengers to deliver information about key outcomes.

As noted previously, enhanced development and delivery of relevant scientific information to decision-making involves the work of organizations and individuals and the boundary between science and policy. There are several boundary organizations in the Bay Area, including include the Bay Area Ecosystem Climate Change Collaborative, Center for Ecosystem Management and Restoration, the San Francisco Estuary Institute, PRBO Conservation Science, and the San Francisco Bay Joint Venture. These organizations are contributing to the successful operation of many of the partnerships listed in Table 2. Given that partnerships involve organizations with different missions, cultures, and calendars, successful convening and operation of partnerships requires the specific attention by trained professionals.

Proposed Tasks

Given our existing capacities and knowledge we are well positioned to take steps to enhance the delivery of credible information about climate change for regional decision-making. Below are six key tasks for achieving the desired outcome of the efficient use of scientific information in support of evidence-based decision-making to protect public health, the environment, and the economy of the Bay Area.

In very broad terms, these tasks address the following questions:

- What changes are likely in the future (tasks 1, 2, and 4)?
- How fast are these changes happening (Task 2)?
- What can we do to build resilience to these changes (Tasks 1, 4, 5, and 6)?

Each task is presented with a goal (what is to be accomplished), a purpose (why it is important to pursue the task), and an approach (how to go about implementing the task).

Task #1: Support and encourage sustained partnerships among Bay Area stakeholders to address climate change adaptation.

Goal: (1) Establish trust and relationships that foster work across disciplinary, ecological, and jurisdictional boundaries, (2) provide forums that engage a broad array of stakeholders regarding regional vulnerabilities, uncertainty (scientific and political) and risk, and the need for action, (3) identify priority data products and implement demonstration projects related to climate change adaptation.

Purpose: Partnerships that can be sustained through time will encourage joint learning and establish the capacity to respond with a broad coalition when opportunities arise for action. Miles and colleagues note, "…learning within the stakeholder community develops in an evolutionary way, punctuated by short transitions in response to external events." [5] These events will include extreme weather events, such as the 1997-98 El Niño or more recently Hurricane Sandy. When these moments occur, having existing partnerships in place with plans and ideas will be essential to support elected officials from whom responses suddenly will be demanded.

Approach: Given the diverse array of existing partnerships in the region, the first step will be to identify and engage with partnerships already interested in climate change adaptation. Promising partnerships to engage will be those that have already identified resources to support their operations, or are working with boundary organizations to provide logistical support to develop and implement joint agendas.

It has been suggested that the proliferation of partnerships may result in a diminished effectiveness if key stakeholders are spending too much time and meetings and not enough time taking action (this is why engaging with existing partnerships is a key part of the recommended approach). It is not clear whether this point has been reached, but the fact that the issue is being raised suggests some people are experiencing this problem. A saturation of the region with partnerships, so that key stakeholders feel over-burdened, will likely result in a consolidation of efforts in order maintain productivity (people will start making strategic decisions about which partnerships to invest in, including suggesting merger/consolidation). While this may be the solution to "partnership fatigue." it is not clear that such a consolidation will occur in an efficient manner.

Task #2: Facilitate the Development of a Bay Area Climate Monitoring Network

Goal: Develop a collaborative monitoring network that identifies and measures indicators of the effects of climate change, provides an assessment of the effectiveness of management actions and the status of the region's resilience, and provides information required to improve management and projections for future planning.[6]

Purpose: Coordinated measurements of the regional environment will be essential if we are to understand what is happening in our region, and for developing accurate projections of future conditions to improve planning. This will require measurement and assessment across the entire regional landscape, from the coastal ocean through the Bay and the terrestrial environment. These measurements will allow our region to understand the rate and the nature of change, giving us a vital indicator of whether the scenarios adopted for planning purposes are being revealed as too conservative or not conservative enough. Such a measurement network will also allow us to determine if "triggers" or "thresholds" for action (*e.g.*, heat surveillance for public health actions or others as identified in future regional policy) have been reached. The network will also help to identify unanticipated changes that may require policy or management responses.

Approach: Given the diversity of monitoring programs and measurement objectives in our region, developing a comprehensive plan for monitoring seems unnecessary and likely unachievable. Instead, the approach should be to establish a network among the monitoring programs and professionals in the region. Through facilitation of information exchange and specific collaborations among network participants, this task would facilitate the development of valuable products such as assessments of indicators, the calibration/validation of models used to project future conditions, and development of climate-smart actions.

The case for supporting the monitoring network would be made by describing how monitoring will generate vital information for high-stakes decisions that will lead to maximizing benefits and minimizing costs. Such high-stakes decisions that are likely to be made in the coming decade include requirements to enhance nutrient removal from treated wastewater, zoning/insurance requirements related flood risk associated with sea level rise and extreme storms, establishing reserves/easements to optimize the regional mosaic of land uses for wildlife and other ecosystem services, permit conditions to protect endangered species and habitats, investments to control invasive species, and land use decisions to minimize fire risk as temperatures rise and droughts become more severe. The synthesis of monitoring data will play a critical role in both

[6] Indicators of regional resilience to climate change will need to be developed to create a mechanism for assessing the adequacy of our preparations to adapt to climate change. Measuring progress in climate change adaptation is challenging [14].

making the case for taking actions (*e.g.*, the rise of chlorophyll concentrations in the Bay requiring enhanced nutrient treatment) and evaluating the effectiveness of actions taken (*e.g*, endangered species population trends).

On a technical level it will be important to identify key measurements and take the steps necessary to ensure that these are made. This will likely include expanding and/or refining the sensor networks that are used to make measurements, such as (1) altering the distribution of temperature sensors to include more automated sensors in higher elevation locations as opposed to the valley locations traditionally used for ease of access, (2) establishing a more sophisticated fog sensor network throughout the region, (3) placing additional upward looking radars for detection of atmospheric river events [16],[7] (4) enhancing real-time heat surveillance for public health assessments [17], and (4) distributing sensors in a manner that allows for the calibration and verification of advanced models to increase accuracy of climatic and other ecological projections such as growth of wetlands.

There also will be a need to identify indicators of resiliency (ecologic, economic, human health) that can provide an assessment of our success at increasing the Bay Area's resiliency in the face of climate change. Establishing these indicators will involve multi-stakeholder partnerships combining objective measurements from the region with judgment regarding how measurement trends relate to resilience in the face of change.

Task #3: Develop a coordinated and reliable process for making "downscaled" climate projections available for use by regional and local planners.

Goal: Coordinate and formalize mechanisms for developing, interpreting, and disseminating future projections of regional climate that are driven by the output of global models (*i.e.*, "downscaled" climate projections). These projections will be provided with unambiguous and non-technical guidance for the intended application of the projections (*e.g.*, projections are not predictions). Key expert agencies (*e.g.*, National Weather Service, Department of Water Resources, University of California) and organizations will need to agree to specific roles and processes so that downscaled data can be most efficiently generated and integrated into authoritative and easily accessible regional data products.

Purpose: It is only with credible and authoritative projections available on a reliable schedule and at a meaningful scale that useful planning for resiliency in the face of climate change can be conducted. This task is in essence proposing that a Bay Area

[7] The National Oceanographic and Atmospheric Administration, in collaboration with the California Department of Water Resources and Scripps Institution of Oceanography, University of California San Diego, are currently installing sophisticated new coastal observatories to improve the detection of atmospheric rivers. The observatories, to be installed by 2014, will be located in Bodega Bay, Eureka, Point Sur and Goleta.

"Climate Service" be organized to provide a single source of projections that form the basis for planning and analysis, including the construction of scenarios.

Approach: At present the State of California is providing downscaled projections using its Cal-Adapt website at a scale of 12 km [18], while scientists at the US Geological Survey are using statistical techniques to downscale these projections further and link them with hydrological models [19] using a diverse array of public and private funding. An active partnership or boundary organization must facilitate a regional discussion among authoritative experts (State of California, National Oceanographic and Atmospheric Administration, US Geological Survey) and key user communities (Joint Policy Committee and member agencies, resource managers, flood control districts, water districts, Departments of Public Health) to develop an implementation plan for a regional Climate Service. The development and implementation of the National Drought Information System pursuant to the Drought Information System Act of 2006 (P.L. 109-430) might be a model to pursue, as NDIS was initially conceived in a report from the Western Governor's Association [20].

The California Climate Commons (climate.calcommons.org) has already started to compile and provide downscaled climate information to the Bay Area community. This is still in a highly technical format, however, and for more widespread application this information will need to be distributed in more easily accessible products. While the work of the Commons can be valuable in testing various products, broad scale provision and updating of such products would likely require a larger organization such as the National Weather Service.

Task #4: Use regional climate projections to prepare future scenarios to guide regional planning.

Goal: Engage a broad array of stakeholders in developing future scenarios for the Bay Area based on reasonable projections of future climate. Facilitated scenario planning exercises amongst stakeholders including scientists, managers, public health officials, and policy makers using available climate projections will clarify the range of future impacts that must be accounted for in planning. Use this engagement to build enhance commitment to assess vulnerabilities and prioritize and implement activities to increase resilience.

Purpose: Significant investments will be necessary to build resiliency to climate change in the Bay Area. Despite a strong consensus among economic analyses that "the most expensive thing we can do is nothing," a strong commitment to making significant public and private investment to build resiliency to climate change is still lacking. Scenario planning will generate engaging narratives about how climate change could impact the Bay Area's economy, public health and ecological resources. These narratives will be essential for building the case for taking "climate smart" action now among a diverse array of Bay Area residents and businesses.

Approach: The approach for this task remains to be developed, although there are already a lot of resources already being made available for use in a scenario planning exercise (e.g., projections of the future of San Francisco Bay Tidal Marshes [http://data.prbo.org/apps/sfbslr/] or projections of future wave heights on the coast [http://data.prbo.org/apps/ocof/]). This work could build on related scenario planning efforts (USGS ArkStorm or efforts around earthquake preparedness), and should engage large Bay Area corporations or other organizations that use scenario planning techniques regularly.

Task #5: Design and test methods for increasing the Bay Area's resilience to the effects of climate change through demonstration projects that are cross-sectoral, cross-jurisdictional, and multi-objective. Start with demonstration projects that build shoreline and riverine resilience to climate change.

Goal: Develop and implement pilot projects (with associated monitoring systems) that demonstrate economically efficient methods for building resiliency to sea-level rise and storm surge on Bay Area shorelines, and to provide resilient rivers that convey altered streamflows and minimize flooding to provide protection for the valuable assets in this region.

Purpose: Sea-level rise and more extreme storm surges will threaten a broad array of vulnerable regional assets, as will major runoff events associated with stronger storms. It is essential to identify the most economical methods for protecting our shorelines and riparian zones by testing various strategies in demonstration projects. Including nature-based strategies in these tests is essential, as these strategies often provide multiple benefits at lower costs, particularly when long-term maintenance is considered. Transparently designed and thoroughly evaluated demonstration projects will be essential for identifying credible and legitimate approaches that attract the necessary political and financial support for implementation at scale.

Approach: At present many different individuals and institutions ("stakeholders") are working on or interested in the restoration of tidal and riparian wetlands for multiple purposes. These purposes include restoration of wildlife habitat, maintenance of biodiversity, improvement of water quality, management of flood risk, beneficial re-use of dredged material, increased recreational opportunities, and building our region's reputation for innovation, environmental sustainability, and physical beauty. This task would facilitate a process for developing a near-term work plan for coordinated activities among participants.

Key participants in the process include at a minimum those leading or coordinating the following processes/projects: Baylands Ecosystem Habitat Goals Update, proposed Restoration Authority 2014 ballot initiative, Shoreline Study EIR, Baylands Steering Committee, wastewater treatment plans considering wetlands for nutrient removal, and Flood Control 2.0. This approach takes advantage of the fact that shorelines resilient to future sea level rise can also provide benefits concurrent benefits for water quality, wildlife, and recreation.

Issues to be addressed in the work plan could include (1) identifying changes needed to policy to enhance shoreline resilience (*e.g.*, reuse of dredged material, wastewater as a resource, Bay fill for SLR protection, managing for ecosystem services and multiple goals), (2) testing engineering designs in demonstration projects with robust evaluation elements that allow recommendations for scaling up successful designs, (3) organizing demonstration projects as a regional experimental effort that might allow for efficient and innovative permitting approaches, (4) coordinating communications around climate change and shoreline resilience to developing consistent messages and efficient public education efforts, and (5) funding strategies to support implementation of demonstration projects.

A cross-sectoral and cross-jurisdictional project to build resilience in the terrestrial environment should also be considered. Such a project would engage open space and reserve managers, ranchers, water districts, flood control districts and conservationists around issues such as water retention, riparian restoration, flood control, fire risk, and invasive species.

Task #6: Identify management plans and public processes where climate change vulnerability assessment and resilience planning is required.

Goal: Assist Bay Area professionals with integrating vulnerability assessments and climate resilience planning into their existing management activities, and to identify specific needs for scientific and technical information that is not yet available.

Purpose: While most professionals in the Bay Area responsible for future planning are aware of climate change, many need assistance understanding how to assess the vulnerability of the assets or organizations they manage. There is a vast amount of information presently available about climate change from many sources, and this torrent of information is not helpful for professionals who have limited time to consider climate change within the context of existing management plans and processes. This task will conduct the targeted outreach necessary to assist planners and other professionals with understanding how to integrate assessments of vulnerability to climate change into their existing management processes so that planning for resilience to climate change can proceed more rapidly. Without such outreach, many professionals will be hard-pressed to obtain authoritative and credible scientific and technical information that can be used in the context of existing regulatory and management processes. This task will also clarify specific instances where there is need to develop scientific and technical information in order to allow certain sectors and organizations to carry out planning activities.

Approach: Those who manage organizations and prepare future plans must consider climate change in the context of existing regulatory and management processes. The approach to this task must recognize that these individuals likely do not have the time or resources to initiate a new process to plan for climate change, but rather must integrate climate change into their existing processes (*e.g.*, general plan amendments, habitat conservation plans, water supply plans). Targeted communication and outreach projects must be implemented to deliver technical information in a form and on a schedule that supports the conduct of vulnerability analysis and resiliency planning as part these existing regulatory and management processes.

This task will compile a catalog of these existing planning processes (starting with organizations described in Table 3), and utilize an understanding of these processes to develop targeted information for specific groups of professionals to assist them integrate climate change as an element of their work. This targeted information could include (1) principles for "climate smart" planning (such as those compiled by the National Wildlife Federation or the Resources Legacy Fund) to assist organizations that need to build internal commitment to planning for climate change, and (2) case studies of climate change planning being conducted by other organizations in their sector or sub-region. This task will also develop a very specific description of information needs that can be used to stimulate scientific investigation or the create of specific data products.

Literature Cited

1. Ekstrom, J. A.; Moser, S. C. *Climate Change Impacts, Vulnerabilities, and Adaptation in the San Francisco Bay Area: A Synthesis of PIER Program Reports and Other Relevant Research. California Energy Commission. Publication number: CEC-500-012-71.*; 2012.

2. NOAA *Climate Change Impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report of a Joint Working Group of the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries Advisory Councils*; Marine Sanctuaries Conservation Series ONMS-11-04; 2010; p 121.

3. Ackerly, D. D.; Ryals, R. A.; Cornwell, W. K.; Loarie, S. R.; Veloz, S.; Higgason, K. D.; Silver, W. L.; Dawson, T. E. *Potential impacts of climate change on biodiversity and ecosystem services in the San Francisco Bay Area*; California Energy Commission: 2011.

4. Moser, S. C.; Ekstrom, J. A., A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences Online Early Edition* **2010**.

5. Miles, E. L.; Snover, A. K.; Whitely Binder, L. C.; Sarachik, E. S.; Mote, P. W.; Mantua, N., An approach to designing a national climate service. *Proceedings of the National Academy of Sciences* **2006,** *103*, (52), 19616-19623.

6. Leiserowitz, A., Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change* **2006,** *77*, 45-72.

7. Maibach, E.; Leiserowitz, A.; Roser-Renouf, C.; Mertz, C. K., Identifying like-minded audiences for climate change public engagement campaigns: An audience segmentation analysis and tool development. *PLoS ONE* **2011,** *6*, (3), e17571.

8. Buizer, J.; Jacobs, K.; Cash, D., Making short-term climate forecasts useful: Linking science and action. *Proceedings of the National Academy of Sciences* **2010**.

9. Miller, C., Hybrid Management: Boundary Organizations, Science Policy, and Environmental Governance in the Climate Regime. *Science, Technology, & Human Values* **2001,** *26*, (4), 478-500.

10. San Francisco Estuary Partnership *The State of San Francisco Bay 2011*; San Francisco Estuary Partnership: Oakland, CA, 2011.

11. San Francisco Estuary Institute *The Pulse of the Estuary: Pollutant Effects on Aquatic Life*; San Francisco Estuary Institute: Richmond, CA, 2011; p 100.

12. Hewitt, C.; Mason, S.; Walland, D., The Global Framework for Climate Services. *Nature Climate Change* **2012,** *2*, (12), 831-832.

13. World Meteorological Congress *Extraordinary Session Abridged Final Report with Resolutions*; World Meteorological Congress: Geneva, Switzerland, 2012.

14. Brunner, R.; Nordgren, J. *Climate Adaptation as an Evolutionary Process: A White Paper*; Kresge Foundation: Troy, MI, 2012.

15. Packard Foundation *Linking Knowledge with Action*; Packard Foundation.

16. Ralph, F. M.; Dettinger, M. D., Storms, Floods, and the Science of Atmospheric Rivers. *EOS, Transactions, American Geophysical Union* **2011,** *92*, (32), EOS, Transactions, American Geophysical Union.

17. English, P. B.; Sinclair, A. H.; Ross, Z.; Anderson, H.; Boothe, V.; Davis, C.; Ebi, K.; Kagey, B.; Malecki, K.; Shultz, R.; Simms, E., Environmental health indicators fo climate change for the United States: findings from the State environmental health indicator collaborative. *Environmental Health Perspectives* **2009,** *117*, (11), 1673-1681.

18. Koy, K.; Van Wart, S.; Galey, B.; O'Connor, M.; Kelly, M., Cal-Adapt: Bringing Global Climate Change Data to a Local Application. *Photogrammetric Engineering and Remote Sensing* **2011,** *77*, (6), 546-550.

19. Micheli, E.; Flint, L.; Flint, A.; Weiss, S.; Kennedy, M., Downscaling future climate projections to the watershed scale: a North San Francisco Bay Estuary case study. *San Francisco Estuary and Watershed Science* **2012,** *10*, (4), 1-31.

20. Western Governor's Association *Creating a Drought Early Warming System for the 21st Century: The National Integrated Drought Information System.*; Denver, CO, 2004; p 16.