CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

DRAFT Technical Memorandum

Climate Change Threshold Analysis Work Plan

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STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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Table of Contents

List of Figures

1.0 Introduction

Recent legislation directs the California Department of Water Resources (DWR) to prepare a Central Valley Flood Protection Plan (CVFPP) and submit it to the Central Valley Flood Protection Board by January 1, 2012. The CVFPP will document and assess the current performance of the State-federal flood protection system in the Sacramento-San Joaquin Valley,[1] and make recommendations to improve integrated flood management[2] to achieve long-term sustainability in social, environmental, and economic aspects. The legislation also requires that the CVFPP be updated every 5 years thereafter. The 2012 CVFPP will accomplish the following:

- Promote understanding related to integrated flood management from State, federal, local, regional, tribal, and other perspectives (e.g., agriculture, urban, rural, environmental, environmental justice).
- Create a broadly supported vision for improving integrated flood management in the Central Valley.
- Develop new data and information that can be shared for many purposes.

It is anticipated that CVFPP will include several concept solution sets for the 2012 plan to represent a broad range of potential flood management actions and approaches. Each solution set will have a different focus, or way of addressing problems and opportunities, and will be populated with different combinations of structural and nonstructural management actions (DWR, 2010b).

The development of 2012 CVFPP will be based on existing available information and incorporate new information developed by ongoing projects and programs where possible. It is anticipated that the new

[1] The planning area defined in Government Code 65007: "Sacramento-San Joaquin Valley means any lands in the bed or along or near the banks of the Sacramento River or San Joaquin River, or any of their tributaries or connected therewith, or upon any land adjacent thereto, or within any of the overflow basins thereof, or upon any land susceptible to overflow therefrom. The Sacramento-San Joaquin Valley does not include lands lying within the Tulare Lake Basin, including the Kings River.

[2] Integrated flood management is an approach to dealing with flood risk that recognizes the interconnection of flood management actions within broader water resources management and land-use planning; the value of coordinating across geographic and agency boundaries; the need to evaluate opportunities and potential impacts from a system perspective; and the importance of environmental stewardship and sustainability (DWR, 2008b).

information would contribute to the 2017 update, including updates of hydrology and hydraulics, improved understanding of levee failure modes and contributing factors, and landscape-level environmental conservation strategy. Therefore, it is important to establish a policy and analytical framework that can be adapted as the new information becomes available, but at the same time, allow the delineation of benefits from various improvement actions, the corresponding responsibilities of federal, State, and local entities in implementation, allowing the development of a sustainable financial plan.

The 2012 CVFPP will be developed using an iterative planning process completed in four phases:

- **Phase 1** – Scope Definition and Goal Development
- **Phase 2** – Management Actions and Evaluation Method
- **Phase 3** – Regional Solution Sets Development
- **Phase 4** – System Solution Sets Development

1.1 CVFPP Geographic Scope

For planning and analysis purposes, as well as consistency with legislative direction, four geographical planning areas are relevant to CVFPP development. These areas include the following:

- **State Plan of Flood Control Planning Area** – This area is defined by the lands currently receiving protection from facilities of the State Plan of Flood Control (SPFC).[3] The State's flood management responsibility is limited to this area; and the CVFPP focuses on improving flood management in this area.
- **Systemwide Planning Area** – This area includes the lands subject to flooding under the current facilities and operation of the Sacramento-San Joaquin River Flood Management System (California Water Code

[3] California Water Code Section 8523 defines "State Plan of Flood Control" as the State and federal flood control works, lands, programs, plans, policies, conditions, and mode of maintenance and operations of the Sacramento River Flood Control Project described in Section 8350, and of flood control projects in the Sacramento River and San Joaquin River watersheds authorized pursuant to Article 2 (commencing with Section 12648) of Chapter 2 of Part 6 of Division 6 for which the board or the department has provided the assurances of nonfederal cooperation to the United States, and those facilities identified in Section 8361.

Section 9611).[4] The SPFC Planning Area is completely contained within the Systemwide Planning Area (Figure 1-1). The area includes additional facilities and associated operations that could influence the performance of the SPFC.

A systemwide approach is taken for the CVFPP development. Note that within the CVFPP, structural and nonstructural projects may be identified or proposed anywhere within the watersheds tributary to the Sacramento and San Joaquin rivers to address identified problems and deficiencies within the Systemwide Planning Area; however, actions will not be identified to address problems outside the Systemwide Planning Area It is important to note that while DWR is evaluating potential actions in the Systemwide Planning Area as part of the CVFPP, this evaluation does not presuppose who will be the implementing or maintaining agency of these actions; rather, the CVFPP will identify mutually agreed on responsibilities for State, federal, and local jurisdictions as part of the plan, and describe other FloodSAFE California (FloodSAFE) programs or DWR activities that could address problems outside the scope of the CVFPP.

The Delta will receive a variety of considerations within the CVFPP. First, all lands that receive protection from the SPFC, including lands that are also located within the legal Delta, will be evaluated in the same manner. Second, any impacts because of potential changes in the upstream Sacramento-San Joaquin River Flood Management System will be analyzed and addressed including impacts that occur in the Delta as a result of upstream changes. In addition, the areas in the Delta at regular risk of flooding from the tidal estuary will be evaluated and addressed through other FloodSAFE programs and through federal investigations such as the U.S. Army Corps of Engineers (USACE) Delta Islands Levee Feasibility Study. The results of the additional Delta evaluations will be incorporated into the systemwide perspective of the CVFPP.

[4] California Water Code Section 9611 defines the Sacramento-San Joaquin River Flood Management System as the system that includes the facilities of the State Plan of Flood Control, as amended, and any existing dam, levee, or other flood management facility that is not part of the State Plan of Flood Control if the board determines, upon recommendation of the department, that the facility does one or more of the following: (1) provides significant systemwide benefits for managing flood risks within the Sacramento-San Joaquin Valley; (2) protects urban areas within the Sacramento-San Joaquin Valley (where urban area herein is defined as "*any contiguous area in which more than 10,000 residents are protected by project levees*").

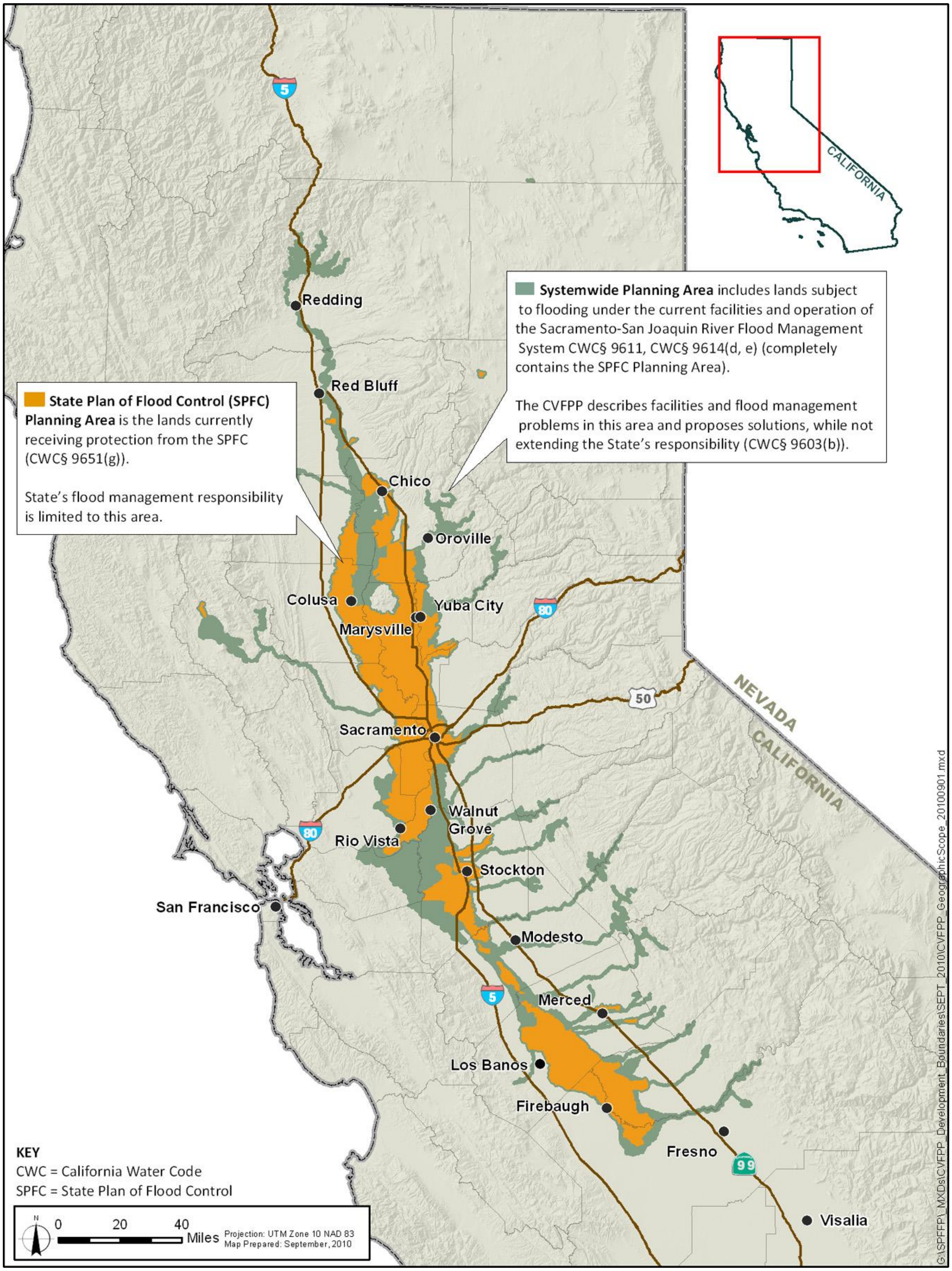


Figure 1-1. Planning Areas Relevant to the Central Valley Flood Protection Plan

1.2 Planning Goals of CVFPP

The CVFPP will describe a systemwide approach for implementing future flood management improvements in the Central Valley at a program level. DWR is identifying a reasonable range of potential implementation approaches to accomplish the primary and supporting goals of the CVFPP, as follows (DWR, 2010b).

1.2.1 Primary Goal

Improve Flood Risk Management – Reduce the chance of flooding, and damages once flooding occurs, and improve public safety, preparedness, and emergency response through the following:

- Identifying, recommending, and implementing structural and nonstructural projects and actions that benefit lands currently receiving protection from facilities of the SPFC

- Formulating standards, criteria, and guidelines to facilitate implementation of structural and nonstructural actions for protecting urban areas and other lands of the Sacramento and San Joaquin river basins and the Delta

1.2.2 Supporting Goals

Improve Operations and Maintenance – Reduce systemwide maintenance and repair requirements by modifying the flood management systems in ways that are compatible with natural processes, and adjust, coordinate, and streamline regulatory and institutional standards, funding, and practices for operations and maintenance (O&M), including significant repairs.

Promote Ecosystem Functions – Incorporate flood management system improvements that integrate the recovery and restoration of key physical processes, self-sustaining ecological functions, native habitats, and species.

Improve Institutional Support – Develop stable institutional structures, coordination protocols, and financial frameworks that enable effective and adaptive integrated flood management (designs, O&M, permitting, preparedness, response, recovery, land use, and development planning).

Promote Multi-Benefit Projects – Describe flood management projects and actions that also contribute to broader integrated water management objectives identified through other programs.

A series of planning principles are also identified for the CVFPP development. More details can be found in the Interim Progress Summary No. 1 (DWR, 2010b).

1.3 Climate Change Considerations in CVFPP

California Water Code Section 9614 requires that CVFPP include a description of possible climate change impacts on the ability of the system to provide adequate levels of flood protection. Potential impacts could be from sea-level rise, increased temperatures, changing location and timing of precipitation, and extreme weather events. Similarly, DWR is currently assessing the likely extent of climate change over the foreseeable future and the potential changes to regional and statewide water resources conditions consistent with Executive Order S-13-08 and related State policies. CVFPP development is in coordination with other ongoing projects and programs.

Climate change impacts in the distal regions of the Sacramento and San Joaquin watersheds will affect flood management throughout the valley. As such, the Threshold Analysis will be conducted for the entire watershed, which encompasses the SPFC and the Systemwide planning areas completely. Subject to further development and considerations, the CVFPP will incorporate considerations of climate change using the Threshold Analysis Approach discussed in this Work Plan. The period of analysis for planning purposes will be consistent with current CVFPP development, from 2015 through 2050. However, it is recognized that it is likely that a longer period of analysis may be necessary for climate change considerations.

1.3.1 Climate Change Scope Definition Work Group

A Climate Change Scope Definition Work Group (CCSDWG) was formed in Phase I of the CVFPP planning process to provide recommendations to DWR on the scope of climate change considerations to be addressed in the 2012 CVFPP and subsequent updates. Topic-specific work groups are used in CVFPP development to develop recommended contents for inclusion considerations (DWR, 2009a). The formulation of and recommendations from the CCSDWG are summarized in a CCSDWG Summary Report (DWR, 2009b), presenting the following:

1. Key aspects of climate change that may affect flood management.

2. Existing problems and expected future challenges within the CVFPP project area related to climate change.

3. A checklist of climate change considerations for the CVFPP.

4. Related climate change projects and programs.

5. Climate change references for the CVFPP.

Where applicable, the input from the CCSDWG for the first two items was incorporated into the Regional Conditions Report – A Working Document (RCR; DWR, 2010a), which was the first major milestone report in CVFPP development. Input on Item 3 is incorporated into the ongoing development, including the current Work Plan development. Input on projects and programs are incorporated into overall coordination efforts, and references into a master compilation for the reference library.

This Work Plan focuses narrowly on one key recommendation to develop a Threshold Analysis approach for incorporating climate change considerations in the CVFPP development.

1.3.2 Climate Change Threshold Approach Work Group

The Climate Change Threshold Approach Work Group (CCTAWG) was chartered as part of Phase II CVFPP development to assist DWR in further development of the Threshold Analysis Approach. This Work Plan presents the outcomes of the CCTAWG's recommendations on development and scope of a Threshold Approach. The CCTAWG consists of DWR representatives, voluntary members, and supporting staff.

DWR Representatives

- Jeremy Arrich, Central Valley Flood Planning Office Chief, Executive Sponsor of the CCTAWG.
- Michael Anderson, State Climatologist.
- Erin Mullin, Central Valley Flood Protection Office.
- Stacy Cepello, FloodSAFE Environmental Stewardship and Statewide Resources Office.
- Abdul Khan, Statewide Integrated Water Management Office.
- Andrew Schwarz, Statewide Integrated Water Management Office.

Volunteer Members

The work group includes the following members with climate change expertise:

- Michael Dettinger, U.S. Geological Survey.
- Nathan Pingel, David Ford Consulting Engineers, Inc.

- David Raff, U.S. Department of the Interior, Bureau of Reclamation.
- Marty Ralph, National Oceanic and Atmospheric Administration (NOAA).
- Stu Townsley, USACE.
- Robert Webb, NOAA.

Supporting Staff

The CCTAWG was supported by the following:

- Yung-Hsin Sun, MWH Americas, Inc. (MWH).
- Matt Young, MWH.
- Susan Sherry, Center for Collaborative Policy.
- Charlotte Chorneau, Center for Collaborative Policy.
- Sam Magill, Center for Collaborative Policy.

1.4 Purposes of the Work Plan

This Work Plan is the only product from the CCTAWG. It defines the Threshold Analysis Approach for the CVFPP, including the 2012 plan and the subsequent updates, and describes the preliminary schedule and major components of its implementation. The overall approach and detailed elements of the approach are subject to refinements in the subsequent planning process and research. At this stage, any individual component of this overall framework can be replaced or updated with improved data, modeling tools, and other compatible components.

As previously mentioned, climate change considerations for different water resources planning studies can have varying focuses and interests. DWR is in the process of surveying existing approaches on ongoing studies to facilitate development of department-wide consistency in climate change analysis for planning purposes.[5] This Work Plan also provides input to that effort.

[5] Andrew, J. 2010. Personal communication, April.

2.0 Approach Needs

For any planning project or program, the methodology, tools, and data should align with the purpose(s) of the study, the intended decision making, and the information available to inform the decision.

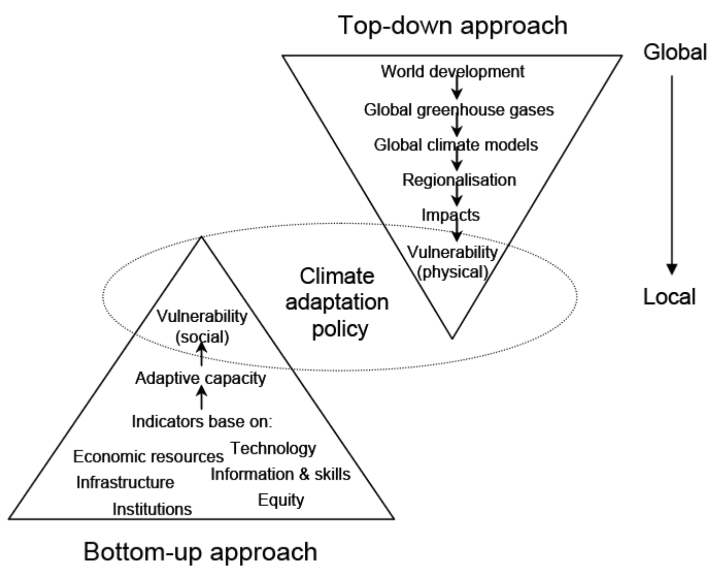
Climate change impacts and considerations have been incorporated in many recent and ongoing California resources planning studies, using various methods. Much of the current analysis of climate and water impacts considers how changes in various mean conditions (e.g., mean temperatures, average precipitation patterns, mean sea level) will affect water resources, water supply in particular. Although many water resource factors are affected by such average conditions, some of the most important impacts, such as flooding and droughts, will result not from changes in averages, but from changes in local extremes (DWR, 2006). Because of the focuses of other ongoing studies, the resulting methodology, resolution, data, and results of these studies are not directly relevant to flooding risk assessment and flood management.

CVFPP will be the first major policy-level study with broad applications that addresses climate change for flood management in California. Flood management requires consideration of extreme (where anticipated occurrences are rare as described below) precipitation and runoff events. These extremes are difficult to project for the future because climate projections from Global Climate Models (GCMs) have difficulty providing regional and local scale precipitation patters, and because of the substantial influence of both human settlement patterns and water-management choices on overall flood risk (DWR, 2005). An extreme weather event is defined by the International Panel of Climate Change (IPCC) as an “event that is rare at a particular place and time of year,” where rare is below 10 percent or above 90 percent of observations (Ray et al., 2008).

Therefore, the approach needs for CVFPP development can be discussed in at least three aspects: (1) perspectives of climate change vulnerability assessment, (2) analytical focus for flood management, and (3) the decision-making process with uncertainties. The three aspects are interrelated in designing the appropriate approach for CVFPP climate change considerations.

2.1 Perspectives for Climate Change Vulnerability Analysis

The purpose of climate change vulnerability analysis is to inform climate adaptation policy development. Vulnerability analysis includes top-down and bottom-up perspectives. Figure 2-1 shows the concept of these two perspectives.



Source: Dessai and Hulme, 2003

Figure 2-1. "Top-Down" and "Bottom-Up" Approaches used to Inform Climate Adaptation Policy

Most of the existing climate change impacts analysis uses a projection-oriented "top-down approach" that considers a range of scenarios of world development, whose greenhouse gas emissions serve as input to GCMs, whose output serves as input to impact models (with or without inclusion of adaptive actions). Under this approach, the discussion of probability of certain impacts could largely depend on the ability of the GCMs to characterize the probability, which may be more subjective than the level of rigor required to support risk-based analysis (Dessai and Hulme, 2003). In flood management, risk based analysis is often based on probabilities derived from event frequency from historical records. On the other hand, the extreme events and their corresponding climate signals are the most uncertain elements of the climate change research. As a result, additional consideration of an appropriate approach for a climate change vulnerability assessment in the flood management context is necessary.

Another approach, the “bottom-up” approach, has been in greater development and application in recent years. The bottom-up approach reflects a focus on the underlying adaptive capacity of the system under study, focusing on broader social impacts. It is place-based and deals with specific resources of interest. Flood managers could start with their existing knowledge of the system and use the evaluation tools to identify what changes in climate may be most threatening to the long-term management goals and practices. In other words, these are the critical system vulnerabilities. The GCM outputs are then used as a reference to assess the likelihood of such system-critical vulnerabilities (Ray et al, 2008; Dessai and Hulme, 2003). This approach may ease concerns for policy makers who are hesitant to move forward with policy decisions while climate uncertainties remain.

2.2 Analytical Focus

Many climate change analyses, including ongoing studies by DWR for various California water planning and management purposes, are based on the most readily available climate change signals in GCMs, such as changes in temperature and precipitation. The analytical time steps are often monthly for water supply and other resources management purposes. As previously mentioned, these indices may be sufficient for assessment of longer term average conditions, especially in the case of temperature, but provide little information for the extreme events. Furthermore, the challenges with projecting precipitation are only amplified when focusing on shorter timescale events.

For flood management, the characterization of hydrographs (e.g., volume, peak) and corresponding antecedent conditions are the key factors for flood damage assessment. Perturbation of these properties from historical storm patterns may be helpful for early investigation, but they may not relate well to climate change conditions and thus, leave decision makers unable to assess the level of urgency for specific adaptive actions. Therefore, it is critical to establish the proper types of climate change signals (in terms of time scale and physical representation) that could be more appropriate for linking to storm hydrologic properties, allowing more meaningful vulnerability assessment.

2.3 Decision-making Considerations

The solution sets (alternatives reflecting various combinations of flood management actions) developed for the CVFPP are anticipated to provide State, local, and other decision makers with the costs, benefits, and tradeoffs associated with key decision points in improving flood management in the Central Valley. Key decision points include investment strategy (e.g., larger initial investment, with smaller subsequent O&M costs; smaller initial investment, with larger subsequent O&M costs), flood risk reduction benefits, related resource benefits (e.g., environmental, water supply, recreation), and levels of responsibility for implementation (e.g., State, federal and local) (DWR, 2010b). All of these solution sets would have climate change conditions incorporated; that is, the outcome from the vulnerability assessment. In addition, flood management decisions would also consider the uncertainties associated with climate change projections in the planning analysis.

Several studies have reviewed various different decision support planning methods for water resources management (Brekke et al., 2009; Western Utility Climate Alliance, 2010). These studies identify potential limitations on applying traditional decision support analysis, with a recognition that the cited limitations have a greater influence if extreme events are the metric of interest. One example is traditional risk-based decision support analysis, which manages uncertainties through analysis of well-characterized probabilities, and recommends optimal strategies. It uses tools such as decision trees or influence diagrams. The application of this type of analysis for flood management would have inherited challenges because of the uncertainties of climate change for extreme events, as previously mentioned.

Another traditional decision planning tool is scenario planning, which focuses on a set of critical uncertainties to form various scenarios that managers agree are plausible and reasonable describe the decision space. While the scenario planning can be beneficial in identifying a range of potential strategies, obtaining consensus on which climate change projections to use for extreme events is challenging.

A third decision process is adaptive management, which “promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood” (NRC, 2004). However, adaptive management is more suited to guiding operational or institutional changes rather than construction of new water facilities. Structural solutions may be hard to reverse unless they are designed to anticipate alternative future conditions with planned upgrades (Brekke, et al., 2009).

Identified by the CCSD Work Group as a useful decision support planning method, robust decision making combines portions of traditional decision analysis and scenario planning (Western Utility Climate Alliance, 2010). Robust decision making methods identify options that perform well over a wide range of possible future scenarios, rather than optimizing for a single scenario. The goal of this method is to reduce the potential to be "surprised" by unexpected events (Brekke et al., 2009). It uses a large ensemble of scenarios for simulations to avoid the need of prioritizing uncertainties and agreements from managers about future conditions.

Brekke et al. (2009) emphasize the need for planning frameworks to be flexible enough to incorporate uncertainties related to climate change in managing risks. Planning approaches that incorporate climate change probabilities, robust decision making, and adaptive management are all adaptation strategy options that allow decisions to be more flexible. These approaches also consider future advances in scientific understanding as they become available.

This purpose of this discussion is not to identify the optimal decision support planning method for making flood management decisions in the CVFPP under climate change. Rather, it is to identify potential problems and opportunities associated with various decision support planning method options. While the robust decision making method recommended by the CCSDWG could be an appropriate decision tool, as currently performed it could be very time-consuming for the CVFPP, which studies a large, complex system and with broad management objectives.

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3.0 Threshold Analysis Approach

The approach needs described in previous chapter have been considered in the development of the Threshold Analysis Approach for the CVFPP. The approach is based on the bottom-up approach for vulnerability assessment; however, it has been expanded to include the causal relationships among indices for communities, hydrology, and atmospheric factors to provide a framework allowing a qualitative comparison of the likelihood of exceedence of critical thresholds of vulnerability.

One could consider the concept of robust decision criteria to be included in the Threshold Analysis Approach, as it is applied across the various solution sets of management actions. However, the CVFPP Threshold Analysis Approach does not follow the common execution of robust decision making method, using a large number of simulations.

This chapter provides preliminary details of this approach; it is anticipated that further development and refinements will be necessary. It is also recognized that applying the Threshold Analysis Approach is not straightforward and many elements of this approach require further development.

3.1 Definition of Threshold Analysis Approach

Climate is the prevailing condition of temperature, winds, precipitation, and runoff in a location over the long term (classically defined as 30 years by the World Meteorological Association). Changing climate may significantly alter the magnitude, timing, and frequency of extreme precipitation events and the resulting runoff in the Central Valley. It could also alter the distribution and type of winter precipitation and the timing of annual snowmelt processes that generate runoff. Taken together, these changes could significantly alter the profile of floods in the Central Valley.

> **Threshold Analysis Approach**
>
> An analytical framework to identify vulnerability thresholds that may be exceeded in the next 50 years given the expected, although uncertain effects of climate change, warranting changes in investment strategy and priority for improving regional and/or systemwide flood management in the Central Valley.

A conceptual diagram of the Threshold Analysis Approach is shown in Figure 3-1.

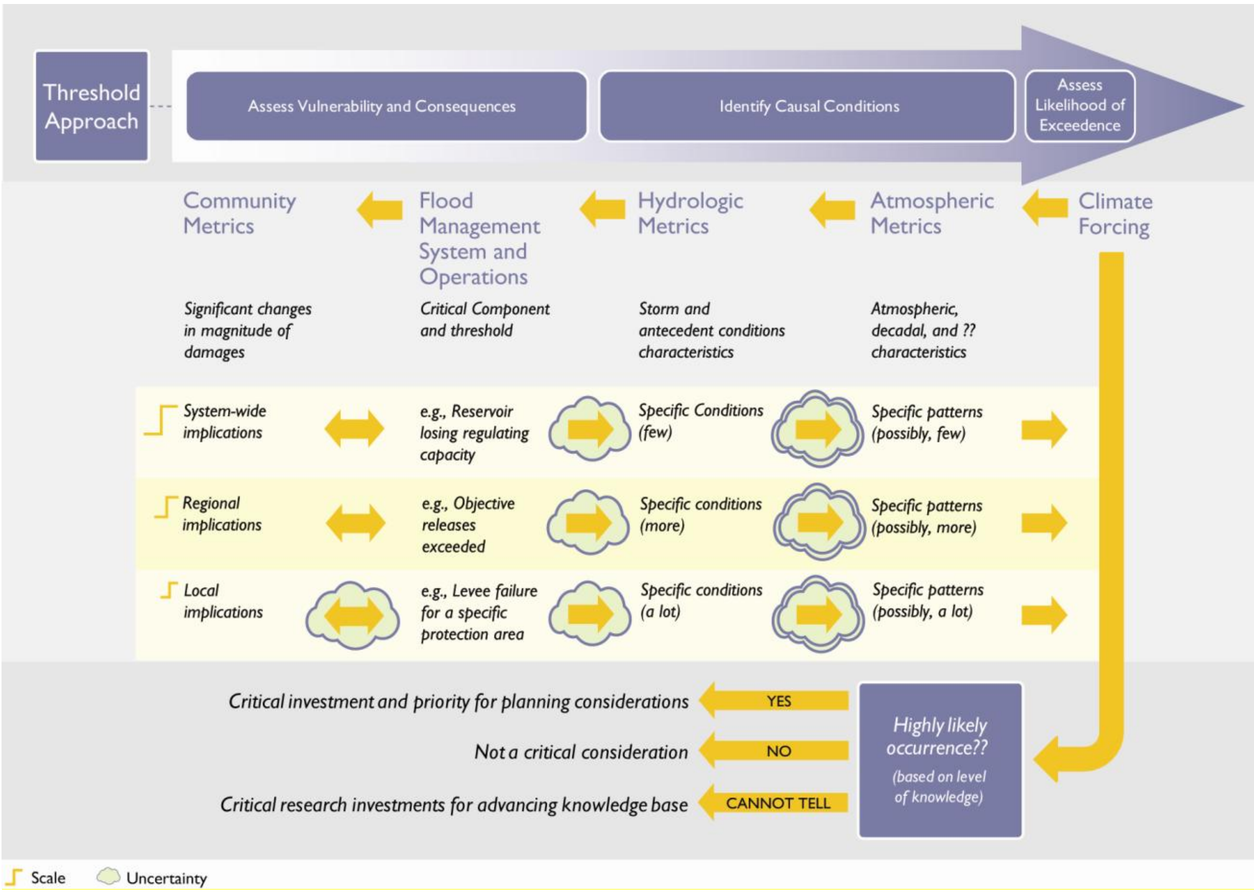

Figure 3-1. Conceptual Diagram of the Threshold Analysis Approach

The arrow along the top of the diagram shows the general work flow. The Threshold Analysis begins with an assessment of vulnerability thresholds at critical system components, and the resulting consequences of crossing those thresholds. Subsequently, an assessment of the conditions that would cause the thresholds to be exceeded would be conducted, followed by an assessment of the likelihood of exceedence.

The second row of the diagram shows the individual pieces of the analysis and the work flow for a more top-down impacts analysis. Below that are illustrations of possible three scales at which the Threshold Analysis may be applied. The clouds surrounding connecting arrows indicate increasing levels of uncertainty. Finally, the long arrow on the right shows that all of this information is aggregated into a decision framework, identifying needed investment in the flood system or in additional research.

An expanded description of the major pieces of the analysis follows:

Assess Vulnerability

- **Flood Management System and Operations –** Critical components of the flood management system have associated thresholds of vulnerability, the crossing of which can cause undesirable consequences. The first step is to identify these components and thresholds, which exist on several spatial scales. Examples include a reservoir losing capacity to regulate flows downstream, a reservoir (or a system of reservoirs) exceeding its objective release, or an infrastructure (e.g., dam, levee) failure.

- **Community Metrics** – Once thresholds for critical system components are identified, the consequences of exceeding the thresholds can be quantified. For example, a reservoir losing its capacity to regulate downstream flows would have large-scale, systemwide consequences. Effects from crossing a systemwide threshold will likely cascade through the system, causing other thresholds to be crossed. Other critical thresholds would have more moderate, regional consequences, such as a reservoir exceeding its objective release. At the smallest, most local scale, a levee failure may have severe impacts to a specific protection area, but less impact on other parts of the flood management system and operations. The consequences of crossing the thresholds are defined using a set community metrics, described in Section 3.2.2.

The definition of which critical thresholds will require analysis requires a level of agreement among the various federal, State, and local entities with flood risk management responsibilities. It is conceivable that the components with potential broader damages to the communities (including natural communities) would be easier for broad agreement for CVFPP systemwide application. On the other hand, for local flood management studies with a more finite project scope, the local critical thresholds could be used without exhausting resources.

Identify Causal Conditions

- **Hydrologic Metrics**. The next step is to define the hydrologic conditions required for a given threshold to be exceeded. These conditions can be described by a set of hydrologic metrics identified in Section 3.3.1. Critical thresholds at large-scale, systemwide components will be affected by relatively fewer sets of hydrologic matrices. In contrast, critical thresholds at local components will be influenced by significantly more sets of hydrologic metrics at various locations throughout the flood management system.

- **Atmospheric Metrics**. The hydrologic conditions leading to threshold exceedence are linked to atmospheric patterns that can be affected by climate change. These patterns can be described by a set of atmospheric metrics that can be sampled from a future projection of climate and translated into hydrologic metrics planning (Section 3.3.2). Subject to additional investigation, it is anticipated that for systemwide components, relatively fewer sets of atmospheric metrics will correspond to the hydrologic metrics, which in turn, correspond to critical thresholds, and more sets for critical thresholds at local components.

Assess Likelihood of Exceedence

- **Role of climate**. The final step in the approach is to assess the likelihood of threshold exceedence. It is anticipated that this would be an assessment against the baseline conditions or other base of comparison, and will be conducted qualitatively based on available GCMs.[6] It remains to be determined whether current climate change science can provide adequate information to inform the process. If so, an analysis of the likelihood of crossing critical thresholds can be performed, and the results will inform planning analysis for further investment in the flood management system. If not, the identification of vulnerabilities will help identify areas of needed climate science investment to obtain adequate information.

[6] It is a critical agreement among members that a quantitative assessment on likelihood would be a futile effort, resulting in unnecessary arguments on refined details of probability derivation and numerical scale of significance level.

3.2 Vulnerability Assessment

The vulnerability assessment includes a description of the critical component and its associated threshold, and a description of the consequences of exceeding the threshold.

3.2.1 Critical Components and Thresholds

The Threshold Analysis will be applied to features of the SPFC, which includes flood management facilities, lands, programs, conditions, and modes of O&M. More detail on the specific definition of each of these terms is included in the Draft SPFC Descriptive Document (DWR, 2010a). Major facilities for each of the two basins are listed below.

Major SPFC facilities along the Sacramento River and tributaries are shown in Figure 3-2 and include the following:

- About 440 miles of river, canal, and stream channels (including an enlarged channel of the Sacramento River from Cache Slough to Collinsville)
- About 1,000 miles of levees (along the Sacramento River channel, Sutter and Yolo basins, and Feather, Yuba, Bear, and American rivers)
- Four relief bypasses (Sutter, Tisdale, Sacramento, and Yolo bypasses)
- Knights Landing Ridge Cut, connecting the Colusa Basin to the Yolo Bypass
- Five major weirs (Sacramento Weir, built in 1916; Fremont Weir, built in 1924; and Moulton, Tisdale, and Colusa weirs, built in 1932 and 1933)
- Two sets of outfall gates
- Five major drainage pumping plants
- Cache Creek Settling Basin, maintaining the flood conveyance integrity of the Yolo Bypass
- Numerous appurtenant structures such as minor weirs and control structures, bridges, and gaging stations.

Figure 3-2. Design Flood Flow Capacities Within the Sacramento River, Bypasses, and Major Tributaries and Distributaries in the Sacramento River Basin

Major SPFC facilities along the San Joaquin River and tributaries are shown in Figure 3-3 and include the following:

- Chowchilla Canal Bypass (and levees), which begins at the San Joaquin River downstream from Gravelly Ford, diverts San Joaquin River flows, and discharges the flows into the Eastside Bypass
- Eastside Bypass (and levees), which begins at the Fresno River, collects drainage from the east, and discharges to the San Joaquin River between Fremont Ford and Bear Creek
- Mariposa Bypass, which begins at the Eastside Bypass and discharges to the San Joaquin River (and levees)
- Approximately 99 miles of levees along the San Joaquin River
- Approximately 135 miles of levees along San Joaquin River tributaries and distributaries
- Six instream control structures (Chowchilla Bypass Control Structure, San Joaquin River Control Structure, Mariposa Bypass Control Structure, Eastside Bypass Control Structure, Sand Slough Control Structure, and San Joaquin River Structure)
- Two major pumping plants

Figure 3-3. Design Flood Flow Capacities Within the San Joaquin River, Bypasses, and Major Tributaries and Distributaries in the San Joaquin River Basin

Many of the multipurpose storage facilities that contribute to flood management in the Sacramento and San Joaquin river basins are also operated for other purposes, such as water supply and power generation, but are not part of the SPFC because they include no State assurances to the federal government. Major multipurpose storage facilities are shown in Figure 3-4. Note that Oroville Dam is the only major multipurpose project listed that is part of the SPFC.

Figure 3-4. Locations of Multipurpose (Including Flood Control) Dams and Reservoirs in the Sacramento and San Joaquin River Basins

While the entire SPFC will be impacted by climate change, there are critical components within the flood system that have the potential to greatly impact other components of the system. While there are many potential critical components and thresholds, they can be generally fit into a hierarchy of consequences, with systemwide, regional, or local implications. An example of each is below.

- **Uncontrolled release from a major flood control reservoir.** Reservoir operations are a key for managing flood reserve space and downstream flows given changes to the pattern of inflows. If a major flood control reservoir is forced to spill water from its spillway, the reservoir no longer provides flood regulating capacity to the system. This would have significant systemwide effects.

- **Objective Release Exceedence.** Objective releases from a reservoir are often controlled by restrictions in channel capacity downstream. If a reservoir exceeds its objective release, it will have regional effects on levees and floodplains.

- **Levee failure**. At the local scale, the Threshold Analysis could be applied to levees or other pieces of infrastructure that are vulnerable, and identify thresholds where the probability of failure would increase past an unacceptable level.

DWR currently conducts geotechnical exploration to identify levee failure modes, and assesses the current risk of levee failure (baseline conditions). The resulting baseline description of the current risk is a critical reference for the Threshold Analysis.

3.2.2 Community Metrics and Threshold

Community metrics are designed to measure the consequent chance of flooding and/or consequence of flooding in an area under a certain management scenario and climate change.

The work group's discussion on potential community metrics and thresholds was mixed. However, it is recognized that while it is possible to establish critical thresholds based on community metrics, it would introduce additional layers of multiple-to-one relationships between the operation and reliability of the flood management system, and the thresholds of community metrics, especially for downstream communities that could be influenced by various upstream influences. Therefore, it is recommended that, at least in its initial implementation, the critical thresholds be established on a system component level, not based on community metrics.

The following metrics are examples based on work group discussions for their potential applicability. However, no specific recommendations were formed because of the above recognition of the benefits of assigning thresholds on system component levels.

Two example sets of metrics for measuring community thresholds have been identified: metrics on chance of flooding and metrics on consequences of flooding. Examples of metrics on the potential chance of flooding include the following:

- **Level of protection** – The level of protection is a legislatively mandated metric for measuring flood risk. It identifies the frequency of flooding from which an area is protected. For example, an area with a 200-year level of protection can withstand flooding that has a 1-in-200 chance of occurring in any given year. However, level of protection may be a problematic metric for vulnerability in the future, as a changing climate may alter the magnitude of the flood that occurs at a given frequency.

- **Upstream flood management capacity** – This metric measures the total flood space in reservoirs, channels, bypasses, and detention basins upstream from a point in the system. This type of metric is also problematic because of the challenge in defining upstream capacity in a consistent way.

Potential impact metrics include both upfront costs for adapting to climate change and the impacts themselves. Examples of potential impact metrics include, but are not limited to, the following:

- **Infrastructure Costs** – Altered hydrologic regimes because of climate change create the need for proactive investment in infrastructure to reduce the consequences of flooding, often at significant cost. In addition to costs for re-sizing or reoperation of flood management infrastructure, this metric would also include costs for relocation from vulnerable areas of buildings, utilities, transportation corridors, water and wastewater treatment plants, and other public infrastructure.

- **Operations and Maintenance cost** – Costs for O&M of the existing flood system represent a substantial fraction of current flood management costs. Climate change may alter these costs by changing the frequency, magnitude, or timing of flood flows.

- **Lives/Casualties** – Protection of public safety is a key component of the FloodSAFE vision. The number of casualties in a given year is an important metric for measuring flood impacts.

- **Economic damages** – Flooding results in significant damages to local and State economies. Losses include lost jobs and income as well as damages to infrastructure, homes, and businesses.

- **Resilience/Capacity to recover** – Resilience describes the ability of a system to return to its pre-impact state. After a flood event, communities have different capacities to recover and resume economic growth. The time required for a community to recover from a flood event may be used as a metric.

- **Ecosystems/Natural resources** – Potential metrics to measure loss of ecosystems and natural resources include acreage lost (e.g., critical habitat, wetlands, riparian woodlands), or the value of ecosystem services lost.

- **Permanent loss/concessions** – Flooding may result in irreparable cultural losses, as happened in portion of New Orleans after Hurricane Katrina. In addition, areas that are frequently inundated may need to be conceded as not able to be protected by the flood system.

3.3 Identification of Causal Conditions

3.3.1 Hydrologic Metrics

The following hydrologic metrics describe attributes of a flood moving through the system. These conditions are the proximate cause of critical threshold exceedence at system components. However, it is recognized that the relationship between hydrologic metrics and a specific critical threshold could be a multiple-to-one relationship.

Examples of hydrologic metrics include the following:

- **Peak flow** – A 3-day peak flow is a widely used metric for measuring flood magnitude in reservoir operations. Instantaneous peak flow is another important metric, useful for assessing levee overtopping and unregulated flows.

- **Volume of flow** – The volume of a flow has significant impacts on the flood system, especially in increasing pressure on flood management reservoirs. Volume metrics should include flow volumes over 1, 3, 7, 15, and 30 days.

- **Duration of flow** – The flow duration determines the amount of time the flood control system is engaged during a flood event. Longer duration high flows will create additional strain on the system. Duration of inundation is also an important metric for the health of natural floodplains.

- **Timing of flow (seasonality)** – Flood risk in California occurs at specific periods of the year, so a metric measuring the timing of flows is necessary. Several methods are currently in use to measure the seasonality of flow including spring pulse onset, center of mass, date of maximum flow, and monthly seasonal fractional flows, among others. Seasonality is also an important factor in ecosystem health.

- **Time to peak flow –** The time to peak flow provides important information on the rate at which a flood moves through the system.

3.3.2 Atmospheric Metrics

Atmospheric metrics describe the weather and climate patterns that influence hydrologic conditions. Atmospheric metrics need to be designed such that they can be sampled from GCMs or associated downscaled products and translated into a specific set of hydrologic metrics.

Examples of potential atmospheric metrics include the following:

- **Atmospheric River Index –** Atmospheric River (AR) events have been associated with the majority of major flood events in California (Dettinger et al., 2009). An Atmospheric River Index (ARI) to characterize the amplitude and frequency of AR events would be a useful metric for characterizing the potential for these high-impact events to affect flooding in the Central Valley. The index could potentially be related to the depth, width, and persistence of the atmospheric moisture plume.

- **Freezing elevation –** The freezing elevation impacts the area contributing rainfall runoff to a river. A higher freezing elevation results in a larger catchment area contributing runoff. However, the magnitude of the effect of increased freezing elevation varies from watershed to watershed, based on topography (Dettinger et al., 2009).

- **Rain-on-Snow Events** – A hydrologically useful definition of a rain-on-snow event is a day when both precipitation occurs and snow depth decreases (McCabe et al. 2007). Building on an existing method for counting rain-on-snow events (McCabe et al., 2007), the number of rain-on-snow events in a given year may be used as a metric.

3.4 Assessment of Likelihood of Crossing Critical Thresholds Under Climate Change

The proposed threshold analysis methodology differs from a traditional impacts analysis, in which temperature and precipitation information sampled directly from downscaled GCM results are input into hydrologic, hydraulic, and operations models. In the threshold approach, metrics representing general circulation features associated with extreme precipitation processes will be sampled and related to the identified atmospheric metrics. The atmospheric metrics will subsequently be related to the hydrologic metrics. Based on these relationships, a qualitative assessment on the likelihood of occurrence in comparison with a baseline conditions or among solution sets could be possible. As the science underlying estimation of climate change probabilities advances in the future, a quantitative assessment could be possible. It should be noted that many of the relationships between these metrics are not currently well defined and will require significant further development. Relationships between atmospheric and hydrologic metrics will likely to be on a many-to-one basis, which may require a sensitivity analysis for selection of appropriate models to better determine their connections.

The results of the overall analysis will be influenced by the technical methodologies used to assess the likelihood of crossing critical thresholds. These technical decisions will include the methodology used to sample GCMs, downscaling methodology, the consideration of sea-level rise, and the choice of modeling tools. A brief discussion of each follows.

3.4.1 Extreme Event Sampling Methodology

This overall approach is proposed because extreme precipitation processes rely at least in part on processes that occur at too fine a spatial or temporal scale to be properly represented in the GCMs. Extreme events are, by definition, temporally rare. Thus even a highly detailed simulation or downscaled version of high-temporal resolution 21st century climate change will not generally be sufficient to allow evaluation of changes in extreme event frequencies. A potential solution to this problem could be to obtain multiple realizations of each combination of emissions scenario and GCM. This would result in having realizations of multiple extreme events in the period of interest.

Because of the difficulties in sampling extreme precipitation events from GCMs, it may be necessary to carry out a sensitivity analysis on the method used to sample extreme precipitation metrics from a future climate distribution to determine a method that provides useful information but is not affected by the sampling strategy. Examples of two sampling strategies used in other DWR planning efforts include the scenario subset methodology employed for the Climate Action Team analyses and the ensemble informed approach used in the Bay Delta Conservation Plan.

In the scenario subset approach, a selection of GCMs is sampled from the population of GCM runs. The selection criteria can include things such as variables available to sample from the GCM run or runs that have a metric matching a specified criterion. In the ensemble-informed approach, a small tractable set of realizations of future projection information is generated by segmenting the future projection distribution and creating a set of ensemble projection information associated with each segment. An alternative to these two methods is the sampling of the entire set of GCM runs. This would only work if the desired information to inform the atmospheric metrics were available in all GCM output information; depending on the final selection of atmospheric metrics, this may not be the case.

3.4.2 Downscaling Methodology

The resolution of current climate models is too coarse to capture key features of California climate such as the orographic effects of the Sierra Nevada range and microclimate over the San Francisco Bay Area. To make use of information from the climate projection simulations and generate the atmospheric metrics that are useful at the Central Valley and sub-Central Valley resolutions, it is necessary to downscale the global climate model results to the spatial and temporal scales useful for the planning process. In general there are two basic approaches to downscaling: dynamical and statistical.

Statistical downscaling uses statistical relationships between coarse resolution and detailed resolution of climate variables. Statistical methods therefore are often much faster at generating the downscaled data than dynamical methods. However, statistical downscaling methods assume stationarity, relying on relationships that are developed based on historical data. It is not certain if these relationships are always preserved with a changing climate. Comparisons of the types of methods can be found in Murphy (1999), Hay and Clark (2003), Hanssen-Bauer et al., (2003), and Wood et al., (2004). It should be noted that for the CAT reporting process of 2006 and 2009, statistical downscaling methods were used, as described by Wood et al. (2004).

The primary alternative to statistical downscaling is dynamical downscaling. Dynamical downscaling makes use of numerical models of the atmosphere and land system at a higher resolution and uses the global climate simulations as initial and boundary conditions. Because they operate at more detailed spatial resolution, the areal extent of the model simulation must be smaller to maintain a reasonable computation time for the climate projection simulation. In addition to these simulations, some post-processing of the results is often necessary to remove systematic bias from the regional climate model outputs. Dynamical models are able to put aside many of the assumptions of stationarity that are implicit in the statistical methods. However, dynamical models are constrained by a high computational burden, which limits their potential use to shorter downscaled periods. These short segments of dynamically downscaled climates and responses would be of little use for determining changes in frequencies and magnitudes of extreme events.

Downscaling will be an important element for providing inputs to the atmospheric metrics. Further evaluation will likely be required to determine whether existing downscaled data sets offer sufficient information to do this or if more research effort in this area will be needed. Initially the CVFPP process may have to rely on statistically downscaled data. It is anticipated that more useful dynamically downscaled climate projection data will be available in the near future and that this data can be used for the CVFPP Threshold Analyses as they become available.

3.4.3 Sea-Level Rise Considerations

Increasing temperature results in sea-level rise because of the melting of land-based glaciers, snowfields, and ice sheets, along with thermal expansion of the ocean as the surface layer warms (DWR, 2008a). In the last century, sea level has risen about 20 centimeters (cm) (7 inches) along California’s coast (DWR 2008a). Recent studies suggest that since 1990, global sea level has been rising at a rate of approximately 3.5 millimeters per year (mm/yr) (0.14 inch per year (in/yr)). Continuation or acceleration of this sea-level rise, in combination with changes in precipitation and runoff patterns, would significantly augment flood problems in the Central Valley (Knox, 1993; Florsheim and Dettinger, 2007).

Sea-level rise is likely to produce more frequent and potentially more damaging floods, increasing risks for those already at risk, and increasing the size of the coastal floodplain, placing new areas at risk (CEC, 2009a). The increased risk of storm surge and flooding is expected to increase risks for California’s coastal residents and infrastructure, including wastewater treatment plants (DWR, 2008a).

Sea-level rise impacts would be most significant for the Delta, where a rise in sea level would increase hydrostatic pressure on levees currently protecting low-lying land, much of which is already below sea level. These effects threaten to cause potentially catastrophic levee failures that could inundate communities, damage infrastructure, and interrupt water supplies throughout the State (Hanak and Lund, 2008). Roos (2005) found that a 1-

foot rise in sea level could increase the frequency of the current 100-year peak high tide to a 10-year event. The resulting higher tides, in combination with increases in storm intensity and flood volumes, would significantly aggravate the existing flood problems in some upstream areas along the Sacramento and San Joaquin rivers.

Although it is generally accepted that sea levels will continue to rise on a global scale, the exact rate of rise remains unknown. Recent peer-reviewed studies estimate a rise of between 0.6 and 4.6 feet by 2100 along California's coast (DWR, 2008a). Another projection based on 12 future climate scenarios selected by the California Climate Action Team (CAT) indicates a 1.8- to 3.1-foot rise in sea level (see Figure 2-5; CEC, 2009b). A California Energy Commission (CEC) report prepared by The Pacific Institute on sea-level rise along the California coast estimated that a 4.6-foot sea-level rise will put 480,000 people at risk of a 100-year flood event, given the existing population (CEC, 2009a).

U.S. Army Corps of Engineers Sea-Level Rise Policy

The USACE has developed guidance for incorporating sea-level rise considerations into civil works programs (USACE, 2009). This framework will be used to incorporate sea-level rise into climate change analysis for the 2012 CVFPP.

The USACE framework relies on two documents:

- The Climate Change Science Program Synthesis and Assessment Product 4.1, Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region (U.S. Climate Change Science Program, 2009).
- The National Research Council's (NRC's) 1987 report Responding to Changes in Sea Level: Engineering Implications.

USACE recommends evaluating alternatives using "low," "intermediate," and "high" rates of future sea-level change. The historic rate of sea-level change should be used as the "low" rate.

The "intermediate" rate should be estimated using the NRC-I modified eustatic sea-level rise curve (NRC, 1987). The most recent IPCC projections and modified NRC projections should be considered and added to the local rate of vertical land movement.

The "high" rate of local sea-level change should be estimated using the modified NRC Curve III (NRC, 1987). The most recent IPCC projections and modified NRC projections should be considered and added to the local rate of vertical land movement. This "high" rate exceeds the upper bounds of IPCC estimates from both 2001 and 2007 to accommodate potential rapid loss of ice from Antarctica and Greenland.

National Research Council Sea-Level Rise Review

The State of California, along with several federal agencies and the states of Oregon and Washington, has commissioned the NRC to conduct a scientific review of sea-level rise for the West Coast. The NRC study will provide estimated values or ranges of values for sea-level rise for planning purposes for Years 2030, 2050, and 2100. The Coastal and Ocean Climate Action Team (CO-CAT) Sea-Level Rise Task Force, a working group comprised of senior-level staff from California State agencies with ocean and coastal resource management responsibilities will provide feedback to the NRC so that the guidelines they develop will reflect the range of planning needs in California. The sea-level rise estimates are anticipated to be completed by 2012, and will be included in climate change analysis for the 2017 CVFPP.

3.4.4 Hydrologic and Operations Modeling Tools

DWR has an existing methodology and a set of tools for assessing hydrologic conditions in a forecasting and project planning capacity. Current model capabilities include the National Weather Service River Forecasting System, the USACE HEC-HMS modeling system and Corps Water Management System, the USGS watershed model PRMS, and the Variable Infiltration Capacity model. Before any one tool is selected for use in a Threshold Analysis, it will be beneficial to compare the advantages and disadvantages of each model, and conduct a parameter sensitivity analysis for the hydrologic model based on inputs from GCMs.

Investment is currently being made in the further development of these and other tools and models to accommodate a greater range of simulation capabilities, including climate change impacts assessments. The current and future versions of the CVFPP will rely on these modeling capabilities to simulate hydrologic metrics and the impacts of climate change upon those metrics to provide information to assess the community metrics.

3.4.5 Implications for Flood Risk Management in CVFMP

Analyses of flood risks are traditionally based on past data and on a fundamental assumption that peak floods are “random, independent, and identically distributed events.” This assumes that climatic trends or cycles are not affecting the distribution of flood flows and that the future climate will be similar to past climate. Natural variability, a changing climate, and altered hydrology have called this method into question (NRC, 1998). The Threshold Analysis will deviate from traditional flood risk analysis by investigating the different points where various thresholds may be surpassed that increase flood risk. This approach offers more detail in defining flood risk and more flexibility to accommodate changes.

DWR does not currently have a standard approach to address flood impacts of climate change, but is working to develop a consistent framework. However, a team led by DWR Climate Change Executive John Andrew is in the process of reviewing contemporary climate change characterization and analysis in California water resources planning studies. Subsequently, a collaborative work group will meet to contribute to development of a consistent approach. This effort to develop the Threshold Analysis will inform that process. The methods developed in this Threshold Analysis will pioneer a new approach for incorporating climate change considerations into flood management planning. Because this is a new approach, it will need to be revised over time as challenges are identified and scientific knowledge improves.

4.0 Implementation Plan

The Threshold Analysis will be implemented iteratively as the CVFPP is updated every 5 years. Figure 4-1 below shows a timeline for implementation of the Threshold Analysis and contributing studies.

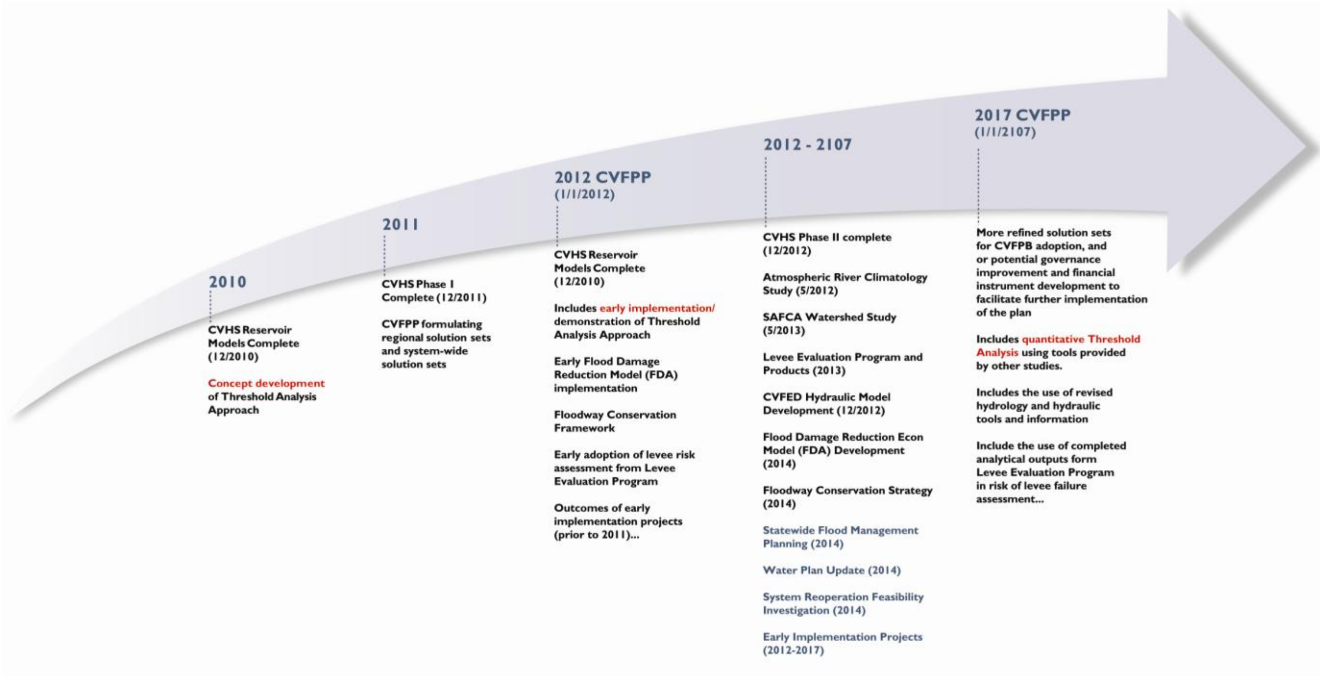

Figure 4-1. Timeline of CVFPP and contributing studies.

4.1 Scope of Analysis for 2012 CVFPP

The 2012 CVFPP will identify the framework for incorporating considerations of climate change flood management. It will introduce the new Threshold Analysis Approach, which is more appropriate for flood management planning than other more traditional methods of analysis with respect to climate change. It will also update the current status of climate change analysis. Specific metrics and thresholds will not be identified in this iteration of the CVFPP.

The 2012 CVFPP will include an early implementation or demonstration project that illustrates the application of the Climate Change Threshold Analysis to a specific flood system component.

4.2 Scope of Analysis for 2017 CVFPP and Beyond

The 2017 CVFPP will provide a more detailed, quantitative analysis of climate change impacts. DWR will articulate specific details and recommendations of the Threshold Analysis and begin to work through problems encountered in implementation. In addition, climate analysis in the 2017 CVFPP will take advantage of studies currently being conducted or in the planning phase (Section 3.3). As the CVFPP is updated every 5 years, it will use the best available climate science to inform the analysis.

4.3 Other Studies Contributing to Threshold Analysis

4.3.1 Central Valley Hydrology Study

DWR has contracted with USACE to develop the next concept of Central Valley hydrology. The Central Valley Hydrology Study (CVHS) contains tools to analyze characteristics of the flood at any place in the system. It will be completed in two phases. The goal of Phase I is to define and characterize the expected peak flood flow volumes and water levels to support various Central Valley flood mapping and management activities by 2012. In this phase, floods will be analyzed under historical climatic conditions. Phase II will provide pilot studies on targeted watersheds to analyze the impact of rising snow lines and selected changes in precipitation characteristics on the unregulated curves using watershed models. This will act as a starting point that allows modeling of the application of a variety of regulatory regimes to the unregulated curves to generate a range of possible regulated curves. This study will provide input to the flood metrics used in the CVFPP Threshold Analysis.

The CVHS will likely not be completed by the 2012 CVFPP, although reservoir models have been completed that can inform the analysis of flood vulnerability in the valley. The CVFPP will be updated every 5 years, and CVHS findings can be provided in future CVFPP updates.

4.3.2 Atmospheric River Climatology: Present and Future

DWR, NOAA, and the Scripps Institute of Oceanography are involved in an ongoing collaborative effort to determine effects of (1) climate change and its impact on availability of water resources in California, and (2) atmospheric river characteristics and how they might change as a result of climate change (evaluate historical patterns for future projections). The goal of the study is to describe the historical and projected distribution of atmospheric river characteristics that drive extreme precipitation in California. This study will help refine the atmospheric metrics used in the CVFPP Threshold Analysis.

4.3.3 Sacramento Area Flood Control Agency American/Feather River Watershed Controls for Flood Processes

The Sacramento Area Flood Control Agency (SAFCA) project is a watershed modeling study focusing on the American, Feather and Yuba watersheds. The study will examine the changes in watershed response to changes in storm characteristics under current and future climate conditions. This study will show how different parts of the watershed can be the dominant runoff- producing element for different storm impact angles and how flood parameters such as peak flow, timing, and duration vary with different storm characteristics. This study will inform the CVFPP threshold study by illustrating connections between climate metrics and hydrologic metrics and illustrating how different collections of hydrologic metrics can be generated.

4.3.4 DWR Water Plan Climate Change Technical Advisory Group

As a part of the California Water Plan Update's efforts to include climate change in its analyses, an advisory group was formed to provide input and review efforts completed by DWR for the Water Plan Update. This advisory group is also available to other planning processes in the Department. The CVFPP will take advantage of the expertise housed in this advisory group because of the innovative and unique nature of the methods being employed. This effort will also facilitate efforts to maintain some level of consistency in the incorporation of climate change in planning processes within DWR.

4.3.5 Central Valley Floodplain Evaluation and Delineation

The Central Valley Floodplain Evaluation and Delineation (CVFED) Program has multiple goals, including improving the quality and accuracy of flood hazard data and mapping available to local communities. The program is developing new topographic data and updating hydrologic and hydraulic data and models, which will be used to better understand the risk of flooding in the Central Valley and to support evaluation and design of potential actions and projects to help manage the risk. Updated hydrologic models are scheduled to be available in December of 2012.

4.3.6 Levee Evaluation Program

DWR is conducting geotechnical exploration, testing, and analysis of state and federal levees that protect highly populated urban areas. Levee evaluations are being conducted in a fast-track manner over a two- to three-year period. During this time, technical specialists are reviewing existing levee historical data; conducting field explorations (including drilling and geophysical methods, along with associated laboratory testing); performing engineering, stability and seepage analyses; and preparing preliminary design and construction estimates for repairing and upgrading the levees, where needed.[7]

4.3.7 CalWater

CalWater is an extensive field program sponsored by NOAA and the CEC with two primary scientific goals: to determine the impact of aerosols on precipitation and the role of ARs in water supply and flooding. Both of these goals are focused on quantifying their respective roles in creating uncertainty in climate projections of precipitation in California in the future. Increased understanding of AR events will provide useful insight to the atmospheric metrics in the Threshold Analysis.

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[7] A fact sheet describing the Levee Evaluation Program may be found at: http://www.dwr.water.ca.gov/levees/evaluation/docs/factsheet-levee-eval-prog.pdf

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6.0 Acronyms and Abbreviations

AR............................Atmospheric River
ARI...........................Atmospheric River Index
CAT..........................Climate Action Team
CCSDWG.................Climate Change Scope Definition Work Group
CCTAWG.................Climate Change Threshold Approach Work Group
CEC ....California Energy Commission
cm ....centimeter
CAT..........................Climate Action Team
CO-CAT ....Coastal and Ocean California Climate Action Team
CVFPP ....Central Valley Flood Protection Plan
CVHS ....Central Valley Hydrology Study
Delta.........................Sacramento-San Joaquin River Delta
DWR ....California Department of Water Resources
FloodSAFE...............FloodSAFE California
GCM.........................Global Climate Model
HAFOO ....Hydrology and Flood Operations Office
in/yr ....inches per year
IPCC ....Intergovernmental Panel on Climate Change
mm/yr ....millimeters per year
MWH ....MWH Americas, Inc.
NOAA.......................National Oceanic and Atmospheric Administration
O&M.........................Operations and Maintenance
NRC ....National Research Council
NWSRFS..................National Weather Service River Forecasting System
RCR ....Regional Conditions Report – A Working Document
SAFCA ....Sacramento Regional Flood Control Agency
SPFC ....State Plan of Flood Control
USACE.....................U.S. Army Corps of Engineers

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STATE OF CALIFORNIA
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