Conjunctive Management and Groundwater Storage

A Resource Management Strategy of the California Water Plan

California Department of Water Resources

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Acronyms and Abbreviations

AB	Assembly Bill
af/yr	acre-feet per year.
ASR	aquifer storage recovery
BMO	basin management objective
BMP	best management practice
C2VSim	California Central Valley Groundwater-Surface Water Model
CASGEM Program	California Statewide Groundwater Elevation Monitoring
CDPH	California Department of Public Health
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CWC	California Water Code
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
GAMA	Groundwater Ambient Monitoring and Assessment Program
GIS	geographic information system
GWMP	Groundwater Management Plan
in-lieu recharge	providing surface water to users who would normally use groundwater
IRP	Integrated Water Resource Plan
IRWM	integrated regional water management
IRWMP	Integrated Regional Water Management Plans
IWM	integrated water management
IWRIS	Integrated Water Resources Information System

LGA	Local Groundwater Assistance
maf	million acre-feet
MOU	memorandum of understanding
MWD	Metropolitan Water District of Southern California
RA	Region Acceptance Process
Regions	California's 10 hydrologic regions
SB	Senate Bill
SCVWD	Santa Clara Valley Water District
SWP	State Water Project
SWRCB	State Water Resources Control Board
Water PIE	Water Planning Information Exchange

Conjunctive Management and Groundwater Storage

Introduction

Conjunctive management or conjunctive use refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives. Surface water and groundwater resources typically differ significantly in their availability, quality, management needs, and development and use costs. Managing both resources together, rather than in isolation, allows water managers to use the advantages of both resources for maximum benefit. Conjunctive management thus involves the efficient use of both resources through the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin that is planned to be used later by intentionally recharging the basin when excess water supply is available, for example, during years of above-average surface water supply or through the use of recycled water. The necessity and benefit of conjunctive water management are apparent when surface water and groundwater are hydraulically connected. Well-planned conjunctive management that prevents groundwater depletion by maintaining baseflow to streams and support for ecosystem services not only increases the reliability and the overall amount of water supply in a region, but also provides other benefits such as flood management, environmental water use, and water quality improvement.

In this document, the two terms — conjunctive water management and conjunctive water use are utilized to depict the same water management strategy described above. However, there are water management practitioners who distinguish between the two or view them somewhat differently. Examples of definitions of the terms as used by other practitioners are furnished in Box 1.

Conjunctive management can occur at multiple areal coverages — from local to regional to statewide coverage. As the areal coverage increases, so do the difficulties of and benefits derived from implementing conjunctive management projects. Locally planned conjunctive management projects are easier to design and implement and should be an integral part of water management portfolios of local agencies. At the larger geographic scale, conjunctive management with an appropriate infrastructure and applied in a responsible manner has the potential to span multiple regions and achieve greater benefits than individual, isolated projects. In the long run, failure to integrate surface water and groundwater management across jurisdictions will make it difficult to manage water for multiple benefits and to provide for sustainable use including the ability to identify and protect or mitigate potential impacts on third parties, ensure protection of legal rights of water users, establish rights to use vacant aquifer space and banked water, reduce subsidence potential of aquifers, protect the environment, recognize and protect groundwater recharge and discharge areas, and safeguard natural resources under the public trust doctrine.

Project Feasibility Considerations

One of the roles and goals of California is to seek statewide water supply reliability and sustainability. Similarly, one of the roles and goals of the California Department of Water Resources (DWR) is to strive for sustainable groundwater supplies throughout the state. Conjunctive management is getting increased

Box 1 Examples of Definitions of Conjunctive Water Management and Conjunctive Water Use

Example Definition 1

"Conjunctive water use primarily changes the timing in the flow of existing water sources by shifting when and where it is stored and does not result in new sources of water. Conjunctive use is often incidental as water users intuitively shift between surface water and groundwater sources to cope with changes and shortages. While conjunctive use may prove successful for an individual or group of water users to manage an immediate situation, it is also possible for conjunctive use to unintentionally harm the groundwater basin and other groundwater users who are not involved in conjunctive use but are reliant on the same groundwater basin.

"An alternative to conjunctive water use is conjunctive water management. The difference between the two is more than semantics. Conjunctive water management engages the principles of conjunctive water use, where surface water and groundwater are used in combination to improve water availability and reliability. But, it also includes important components of groundwater management such as monitoring, evaluation of monitoring data to develop local management objectives, and use of monitoring data to establish and enforce local management policies. Scientific studies are needed to support conjunctive water management. They provide important data to understand the geology of aquifer systems, how and where surface water replenishes the groundwater, and flow directions and gradients of groundwater."

Source: Dudley and Fulton 2006

Example Definition 2

"Conjunctive use and conjunctive management describe the interchangeability of ground and surface water. ... Conjunctive use, with its roots in traditional water application, denotes an opportunistic or incidental interchangeability, as when an unplanned shortfall of natural ground or surface water availability causes a user to switch back and forth between sources. Typically, surface water users switch to groundwater available naturally beneath their land when surface supplies fall short of their needs. On the other hand, conjunctive management seeks to actively manage the balance of ground and surface water availability over a period of naturally occurring wetter and drier water cycles. The objective of conjunctive management is to intercede in natural groundwater recharge processes to even out the year-to-year variations in regional water availability with potential peripheral benefits of flood management, environmental water, and water quality improvement. While conjunctive use is an inherently local concept, conjunctive management with an appropriate infrastructure has the potential to span multiple regions."

Source: St. Amant 2012

Example Definition 3

"Conjunctive use of groundwater and surface water in an irrigation setting is the process of using water from the two different sources for consumptive purposes. Conjunctive use can refer to the practice at the farm level of sourcing water from both a well and an irrigation delivery canal, or can refer to a strategic approach at the irrigation command level where surface water and groundwater inputs are centrally managed as an input to irrigation systems. Accordingly, conjunctive use can be characterized as being planned (where it is practiced as a direct result of management intention – generally with a top down approach) compared with spontaneous use (where it occurs at a grass roots level – generally with a bottom up approach).

"…the aim of conjunctive use and management is to maximize the benefits arising from the innate characteristics of surface and groundwater water use; characteristics that, through planned integration of both water sources, provide complementary and optimal productivity and water use efficiency outcomes."

Source: Evans et al. 2012

Example Definition 4

"Conjunctive use of surface water and groundwater consists of harmoniously combining the use of both sources of water in order to minimize the undesirable physical, environmental and economical effects of each solution and to optimise the water demand/supply balance."

Source: Food and Agriculture Organization of the United Nations 1995 attention as one major water resources management strategy to attain these goals, although the strategy in some form has been practiced for more than 100 years by certain agencies in California. The five project feasibility considerations of conjunctive management are:

- **Hydrogeologic feasibility**. Hydrogeologic feasibility takes into consideration the hydrogeologic constraints that must be identified.
    - Where is the recharge zone for the aquifer that is going to be pumped?
    - What is the mechanism and rate of recharge?
    - Is the recharge zone connected to the aquifer that is going to be pumped?
    - What are the soil, sub-soil, and aquifer characteristics – infiltration capacity, porosity, hydraulic conductivity, specific yield – that are important for success of conjunctive management?
- **Available groundwater storage capacity.** Available groundwater storage capacity denotes the space available to recharge the basin.
- **Water source.** Water source provides the supply of water that will be used to store water in the groundwater system. Water sources include imported water, local runoff, and treated wastewater.
- **Conveyance**. Conveyance is necessary to transport the water from water source to recharge location and to distribute water from the groundwater extraction facility to the point of demand. Conveyance systems include lined and unlined canals, pipelines, and streams.
- Recharge and extraction and pre- and post-treatment facilities. Recharge and extraction facilities are essential components of a conjunctive management project. Recharge includes direct spreading, injection, in-lieu recharge, and induced natural recharge. Extraction may be for direct use, pumped back to conveyance systems, and surface water exchange. Additionally, pre- and post-treatment facilities may also be necessary to meet existing water standards.

The five project feasibility considerations of conjunctive management — hydrogeologic feasibility, available groundwater storage capacity, water source, conveyance, recharge and extraction facilities, and pre- and post-treatment facilities (under certain circumstances) — are the fundamental, physical elements that are indispensable for conjunctive management to be functional. If any of these physical elements are missing, it will make conjunctive management impractical and unworkable.

Project Development Components

In practical terms, once the five project feasibility considerations are determined to be satisfactory, a set of five project development components must blend together for a specific conjunctive management project or program:

- **Groundwater planning and management**. Groundwater planning is the process to decide what needs to be accomplished to preserve the natural resource. The outcome of this planning process is a groundwater management plan. Groundwater management denotes the set of activities that direct how to implement management actions identified during the planning step as contained in the groundwater management plan. Formally speaking, groundwater management is the planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource. Groundwater management aims to improve specific aspects of the management of groundwater resources in individual basins or portions of basins across a region or throughout the state. The improvements pertain to many aspects of groundwater management, including implementing programs or projects to manage and protect groundwater, characterizing and increasing knowledge of individual groundwater basins, identifying basin management strategies or objectives, planning and conducting groundwater studies, and designing and constructing conjunctive management projects.

- **Project construction and operation**. Project construction and operation may include construction and operation of treatment facilities, conveyance facilities, or spreading basins as well as installation and operation of monitoring, production, and injection wells, and drilling of test holes.
- **Institutional structures**. As with other types of projects, conjunctive management projects must also adhere to local ordinances in addition to State and federal laws and regulations. Institutional structures include:
  - Laws.
  - Regulations and ordinances.
  - Contracts and agreements.
  - Political support.
  - Public-private partnerships.
  - Governance.
- **Funding**. Funding sources include State and federal grants and loans, State and local bonds, State and local taxes, assessments, and fees, and public-private partnerships. As with other types of projects, a conjunctive management project also has associated cost components, and financing and economics issues. As a result, available sources of funding have to be identified and secured to successfully plan, design, and implement a conjunctive management project.
- **Organizational capacity building.** Organizational capacity building is the process of equipping entities, usually public agencies, with certain skills or competences, or upgrading performance capability by providing assistance, funding, resources, and training. This is important for the continued operation and long-term success of conjunctive management projects.

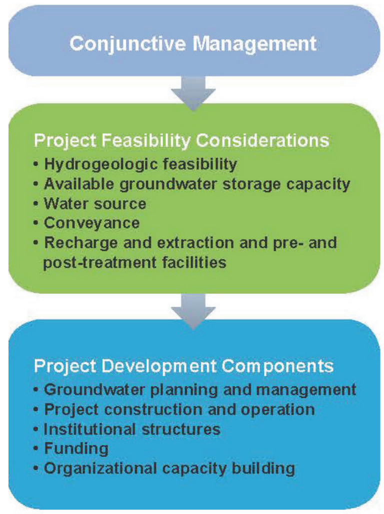
The five project development components — groundwater planning and management, project construction and operation, institutional structures, funding, and organizational capacity building — bring a conjunctive management project to fruition.

Figure 1 presents in a nutshell, practical considerations that need to be thought about and met before planning conjunctive management projects and important components for implementing successful conjunctive management projects.

Groundwater Storage

Understanding terms related to groundwater storage is critical to ensure the success of a conjunctive management project. Groundwater in storage or simply groundwater storage can be defined as the quantity of water found at a given time in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. Groundwater storage capacity — the maximum attainable groundwater storage — is defined as the maximum volume of usable void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin. Available groundwater storage capacity is defined as the

Figure 1 Conjunctive Management - Project Feasibility and Development



volume of usable physical space available at a given time to store water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. These water-filled geologic materials, or aquifers, may receive the water (and be recharged or replenished) from natural hydrologic processes, or the water may be introduced to the aquifer by active groundwater management. The water in these aquifers may be withdrawn through wells, or the water may discharge naturally, contributing to streamflow or to the supply of water for springs, seeps, and wetlands.

Groundwater remains an important water source for municipal drinking water, agriculture, and individual water users across California. Groundwater is also a vital source of flow in many streams, providing support for aquatic and riparian habitat. Benefits of groundwater storage, as compared to surface water storage, include smaller evaporation loss, lower susceptibility to adverse impacts from natural and human induced hazards, and less maintenance costs. Over the years, groundwater has played a leading role in transforming California into the nation's top agricultural producer, most populous state, and the eighth largest economy in the world.

According to the California Department of Public Health (CDPH), an estimated 30 million Californians, more than three quarters of the state's population, receives at least part of their drinking water from groundwater. Groundwater from either private domestic wells or other groundwater-dependent supplies not regulated by the State provides drinking water to an additional one to two million people (State Water Resources Control Board 2012; Department of Water Resources 2013a). Many small- to moderate-sized towns and cities (e.g., Fresno, Davis, and Lodi) rely solely on groundwater for their drinking water supplies. Statewide, about six million people rely 100 percent on groundwater (State Water Resources Control Board 2013). In California, public water supply systems alone use about 13,000 wells to supply water to the public (California Department of Water Resources 2013b). The demand on groundwater will continue to increase as California's population grows from 38 million in 2012 to a projected 51 million by 2050, based on current trends (California Department of Water Resources 2013c). The increased demand on groundwater has caused significant groundwater depletion in many locations, which needs to be recognized and addressed to ensure sustainability of this important resource.

The importance of groundwater to California water supply is increasingly being recognized. For example, in an average year (based on 2005-2010 data), groundwater meets about 40 percent of California's agricultural, urban, and managed wetlands water uses (about 16.5 million acre-feet per year). Depending on hydrology, this percentage varies from approximately 30 to 50 percent (California Department of Water Resources 2013b). The importance of groundwater as a resource varies regionally. Figure 2 depicts the importance of groundwater as a local supply for agricultural, urban, and managed wetlands water uses in each of California's 10 hydrologic regions (regions). In Figure 2, the map shows the total water use as well as the water use met by groundwater in the different regions. In the same figure, the pie chart shows the percentage of groundwater extraction in each region relative to the total groundwater extraction in the state as a whole.

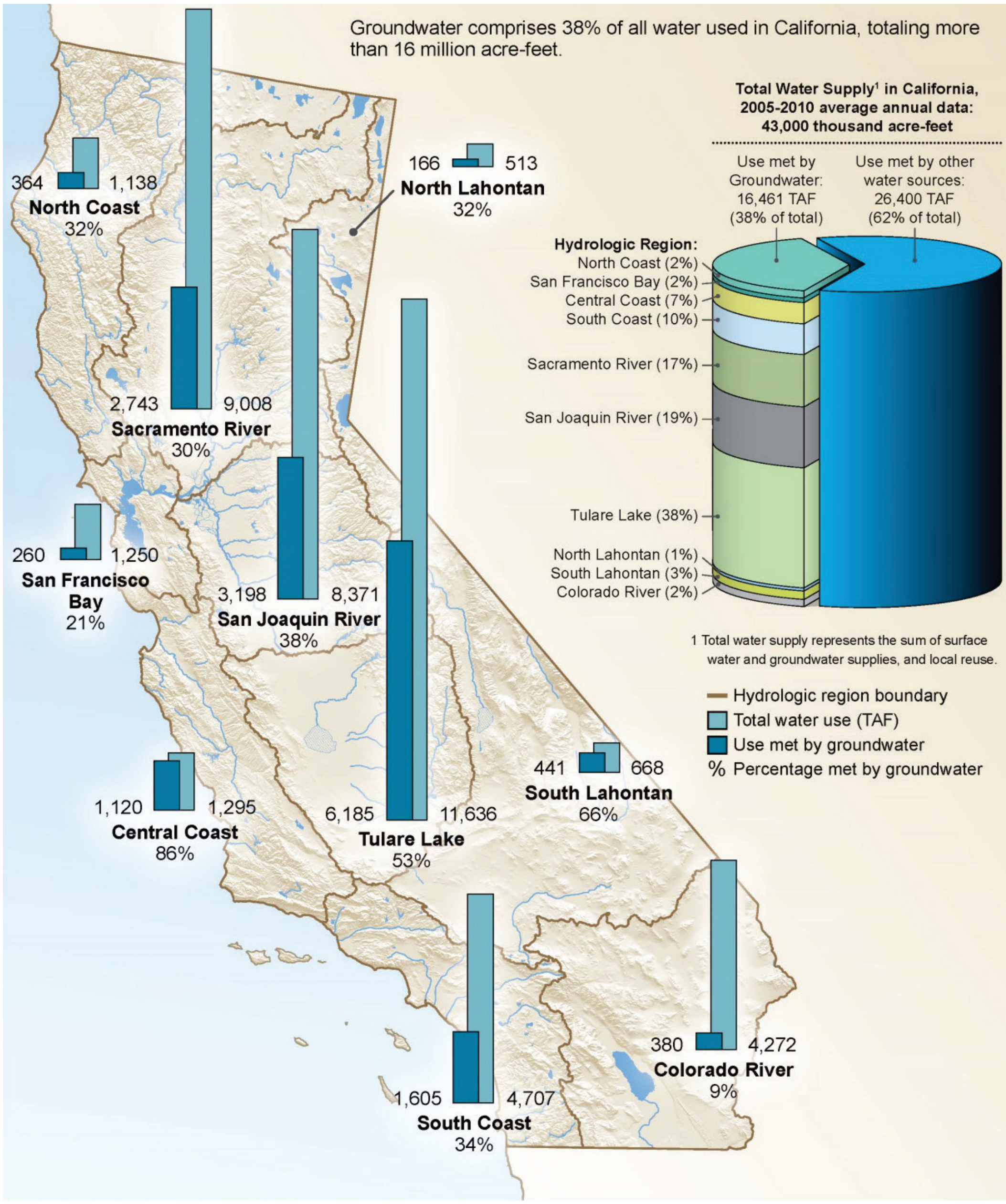
With more than 85 percent of water use met by groundwater in an average year, as shown in the map, the Central Coast Hydrologic Region is heavily reliant on groundwater to meet its local uses. The Tulare Lake Hydrologic Region meets more than 50 percent of its local uses from groundwater, and the South Lahontan Hydrologic Region meets more than 65 percent of its local uses with groundwater. The North Coast, San Francisco Bay, South Coast, Sacramento River, San Joaquin River, and North Lahontan regions meet between approximately 20 and 40 percent of their local uses with groundwater. In terms of percentage, groundwater provides less than 10 percent of supply in the Colorado River Hydrologic Region.

As shown in the pie chart, of all the groundwater extracted annually in the state in an average year (based on 2005-2010 data), more than 35 percent is produced from the Tulare Lake Hydrologic Region. Nearly 75 percent of groundwater extraction occurs in the Central Valley (Sacramento River, San Joaquin River, and Tulare Lake regions combined). More than 15 percent is extracted in the highly urbanized Central Coast and South Coast regions, while about 10 percent is extracted in the remaining five hydrologic regions combined. With the growing limitations on available surface water exported through the Sacramento-San Joaquin Delta (Delta) and the potential impacts of climate change, reliance on groundwater through conjunctive management will become increasingly more important in meeting the state's future water uses.

Groundwater and Surface Water Interrelated

In the past, water resources in many regions have been developed and managed with the underlying assumption that surface water and groundwater are separate resources. Although for a number of basins in California, there has been an intuitive understanding of the interrelationship between surface water and groundwater, only in recent years have water scientists, planners, and managers unmistakably recognized that the extraction and use of one resource affects the other. Groundwater and surface water bodies are connected physically in the hydrologic cycle and interact with each other. At some locations or at certain times of the year, groundwater will be recharged through infiltration from the bed of a stream. At other locations or at other times, groundwater may discharge to the stream, contributing to its baseflow. Similarly, degradation of surface water quality may result in a corresponding degradation of groundwater quality. Pollution of groundwater may result in a corresponding pollution of surface water. Thus, changes in either the groundwater or surface water system will directly affect the other. Although this physical interconnection is understood in general terms, details of the physical, chemical, and residence time relationships remain the topic of a number current studies for certain basins by various State and federal agencies. Effective conjunctive management acknowledges the interconnection of the two resources and

Figure 2 Importance of Groundwater to California Water Supply



requires proper characterization of local and regional interconnections to ensure safety and effectiveness for specific programs and projects and to maximize the beneficial uses of the integrated water system (see Box 2).

Meeting Multiple Objectives

Conjunctive water management projects may be implemented to meet many objectives including improving local or regional water supply reliability, increasing flood protection, meeting environmental needs, improving groundwater quality, countering land subsidence, or reducing groundwater overdraft.

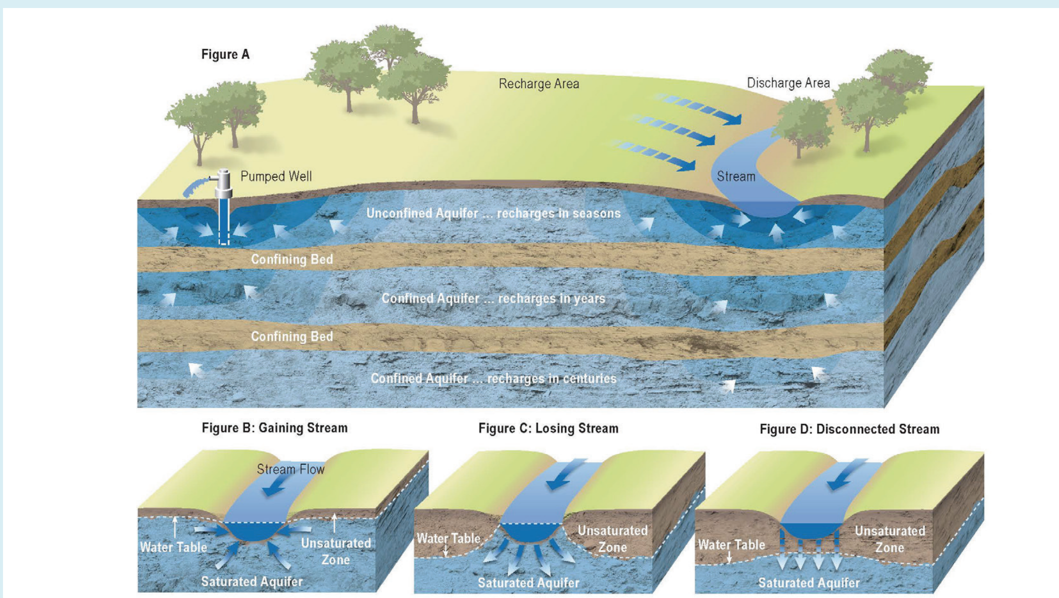
Box 2 Groundwater and Surface Water, a Single Source

Groundwater moves along flow paths of varying lengths from areas of recharge to areas of discharge. The generalized flow paths start at the water table, continue through the groundwater system, and terminate at the stream or at the pumped well. The source of water to the aquifer is infiltration through the unsaturated soil zone resulting from precipitation, irrigation applied water, managed recharge, etc. Flowlines from various aquifers to the stream can be tens to hundreds of feet in length and have corresponding travel times of days to several years or more (see Figure A below).

The interaction of streams with groundwater may take place in three different ways: streams may gain water from discharge of groundwater through the streambed (gaining stream), streams may lose water to groundwater by seepage through the streambed (losing stream), or streams may gain in some reaches (gaining reaches) and lose in some of the reaches (losing reaches). As shown in Figure B, for streams to gain water from groundwater, the stream water surface elevation must be lower than the surrounding groundwater table elevation. In contrast, as shown in Figure C and Figure D, for streams to lose water to groundwater, the stream water surface elevation must be higher than the surrounding groundwater table elevation. Losing streams can be connected to the groundwater system by a continuous saturated zone (Figure C) or can be disconnected from the groundwater system by an unsaturated zone (Figure D). A distinguishing characteristic of a stream that is disconnected from groundwater is that shallow groundwater pumping in the vicinity of the stream does not necessarily induce additional seepage of water from the stream to groundwater (Winter et al. 1998).

The direction of flow between the stream and the groundwater system may change because of storms (or flood flows moving down the stream), causing water to flow from the stream to groundwater. The direction of flow between the stream and groundwater can alter as a result of groundwater pumping near the stream. In the case of a gaining stream, pumping is likely to decrease discharge from the aquifer to the stream and in some cases, high pumping rates can even modify a gaining stream to a losing stream. In the case of a losing stream, pumping is likely to further increase seepage from the stream to the aquifer (Winter et al. 1998).

The characteristics and extent of the interactions of groundwater and surface water in an area will likely define the success of conjunctive management projects. Therefore, a better understanding of the interconnection between groundwater and surface water is instrumental for effective conjunctive management.



into the aquifer through injection wells, spreading the water on permeable ground surfaces in recharge ponds, or introducing the water into streams that are connected to the aquifer through permeable streambeds. The stored water in the aquifer can then be withdrawn at a later time when surface water is not available or too expensive to meet local demands. In some areas, recharge may be accomplished by providing surface water to users who would normally use groundwater (also called in-lieu recharge), thereby leaving more groundwater in place for restoring groundwater levels or for later use. Some agencies also consider programs that reduce demands on groundwater via water conservation or water recycling as in-lieu recharge because these programs have the same effect in restoring groundwater levels as the provision of surface water. For further discussion on natural and managed (also called artificial or intentional) groundwater recharge, see Box 3.

A sustainable conjunctive water management program consists of several components that include investigating the groundwater aquifer characteristics, estimating surface water and groundwater responses, and appropriate monitoring of groundwater level and quality. In addition, reliable institutional systems for ensuring environmental compliance, providing long-term system maintenance, and managing contractual and legal features of the program are critical to sustainability. An important issue pertaining to legal features of a conjunctive water management program is addressing who actually owns the artificially recharged water in a managed recharge project, particularly if the timing of recharge has prevented natural recharge, which would belong to all the overlying landowners. The major legal issue is how to resolve the ownership/ extraction rights related to water that has been artificially added into a multi-jurisdictional/multi- land owner groundwater basin. The question is whether the water that has been artificially added to a groundwater basin is the property of the entity that added it or, once it commingles with the existing groundwater, does it become groundwater governed by the prevailing statutes in the California Water Code (CWC)? A legal and scientific way of settling the issue of extraction rights would be an inescapably important factor in the public discussion of conjunctive management and groundwater storage.

Conjunctive management and groundwater storage are closely linked with other resource management strategies, such as groundwater remediation and recharge area protection. Groundwater remediation may be implemented in areas where the usability of the aquifer for groundwater storage has been compromised by aquifer contamination, thereby partially or fully restoring the capacity of the aquifer for storage or limiting the extent of the water quality problem.

Although conjunctive management programs often involve artificial recharge of aquifers with water from other sources, such as imported or recycled water, most California aquifers and therefore any conjunctive management programs using those aquifers, are heavily dependent on natural recharge of local water. As such, the resource management strategy for recharge area protection is critical to maintaining groundwater storage for long-term reliability of conjunctive management supplies.

Conjunctive management and groundwater storage, in the context of integrated regional water management (IRWM), may be intertwined with many other management strategies, including conveyance, desalination, drinking water treatment and distribution, ecosystem restoration, floodplain management, recycled municipal water, surface storage, urban land use management, water transfers, system reoperation, and watershed management. Examples of these relationships are discussed in this resource management strategy report and elsewhere in *California Water Plan Update 2013*.

Box 3 Groundwater Recharge: Natural and Managed

Groundwater recharge is the mechanism by which surface water moves from the land surface, through the topsoil and subsurface, and into the aquifer, or through injection of water directly into the aquifer by wells. Groundwater recharge can be either natural or managed. Natural recharge occurs from precipitation falling on the land surface, from water stored in lakes, and from streams carrying storm runoff (Figure A). Managed recharge occurs when water is placed into constructed recharge or spreading ponds or basins, or when water is injected into the subsurface by wells. Managed recharge is also known as artificial, intentional, or induced recharge. Two widely used methods for managed groundwater recharge are recharge basins and injections wells. An additional, indirect method of managed recharge is called in-lieu recharge.

Recharge Basins. Recharge basins are frequently used to recharge unconfined aquifers. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Recharge basins concentrate a large volume of infiltrating water on the surface. As a result, a groundwater mound forms beneath the basin. As the recharge starts, the mound begins to grow. When the recharge ceases, the mound recedes as the water spreads through the aquifer (Figure B). The infiltration capacity of recharge basins is initially high, and then as recharge progresses, the infiltration rate decreases as a result of surface clogging by fine sediments and biological growth in the uppermost layer of the soil. It has been found that the operation of recharge basins with alternating flooding and drying-out periods maintains the best infiltration rates. Fine surface sediments may occasionally need to be removed mechanically to maintain the effectiveness of recharge basins.

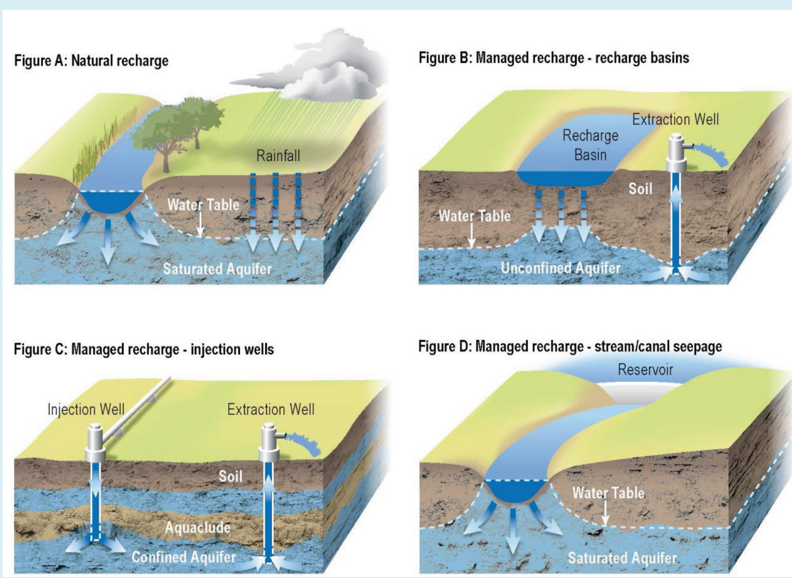
Injection Wells. Injection wells are used primarily to recharge confined aquifers. The design of an injection well for artificial recharge is similar to that of a water supply well. The principal difference is that water flows from the injection well into the surrounding aquifer under either a gravity head or a head maintained by an injection pump (Figure C). As a large amount of water is pushed through a small volume of aquifer near the well face, injection wells are prone to clogging, which is one of the most serious maintenance problems encountered. Clogging can occur in the well perforations, in the well-aquifer interface, and in the aquifer materials. It is suspected that a combination of a build-up of materials brought in by the recharging water and chemical changes brought about by the recharging water are the primary causes of clogging. The most economical way to operate artificial recharge by injection consists of using dual purpose wells (injection and pumping) so that cleaning of the well and the aquifer may be achieved during the pumping period. However, pretreatment of the water to be injected is always necessary to eliminate the suspended matter.

In-lieu Recharge. In some areas, “recharge” may be accomplished by providing surface water to users who would normally use groundwater, thereby leaving more groundwater in place for restoring groundwater levels or for later use. This indirect method of managed recharge is known as in- lieu recharge.

Another widely used method for managed recharge is through release of water into streams beyond what occurs from the natural hydrology (Figure D). Significant amounts of recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance canals.

The major purpose of managed recharge is to increase water supply in an area by supplementing the existing groundwater supply. The use of managed recharge to enhance the availability and quality of groundwater has received increased attention in recent years. Numerous managed recharge projects have been implemented in California and others are planned.

Figure A, B, C, D Groundwater Recharge: Natural and Managed



Chronicle of Conjunctive Management and Groundwater Storage in California

Conjunctive management has been practiced in California to varying degrees since the Spanish mission era (1770s-1830s). The first known managed (artificial or intentional) recharge of groundwater in California occurred in Southern California during the late 1800s, and managed recharge has become an increasingly important part of integrated water management (IWM) in many areas.

Unlike surface water use, groundwater use in California does not have a statewide management program or statutory permitting process. When the Water Commission Act became effective in 1914, surface water appropriative rights became subject to a statutory permitting process. The statutory permitting process is defined under California law, which stipulates that a water user must obtain, modify, or renew water rights permits from the State Water Resources Control Board (SWRCB). The Water Commission Act of 1914 was the predecessor to today's CWC statutes governing appropriation. In addition to surface water, groundwater classified as underflow of a surface water system, a "subterranean stream flowing through a known and definite channel," was also made subject to the statutory permitting process. However, most groundwater in California is presumed to be "percolating water," that is, water in underground basins and groundwater that has escaped from streams and is not subject to a permitting process. As a result, most of the body of law governing groundwater use in California today has evolved through a series of court decisions beginning in early 20th century (California Department of Water Resources 2003).

The California Legislature has repeatedly held that groundwater management is a local responsibility (Sax 2002). The State's role is to provide technical and financial assistance to local agencies and work with them for planning and implementing groundwater management efforts. There are three forms of groundwater management in California: local agency management, local groundwater ordinance, and court adjudication (California Department of Water Resources 2003).

More than 20 types of local agencies are authorized by statute to provide water for various beneficial uses. Many of these agencies also have statutory authority to institute some form of groundwater management, but their specific authority related to groundwater management varies. In 1991, Assembly Bill (AB) 255 authorized local agencies overlying basins that are subject to critical conditions of overdraft, as defined in DWR's Bulletin 118-80, to establish voluntary groundwater management plans within their service areas (California Department of Water Resources 2003).

The passage of AB 3030 in 1992 (CWC Section 10750 et seq.) greatly encouraged local agencies to adopt groundwater management plans for managing their groundwater resources whether or not the groundwater basin is in overdraft condition. In 2002, the Legislature passed Senate Bill (SB) 1938, which contained new requirements for local agency groundwater management plans and required adoption of these plans for groundwater projects to be eligible for public funds. At the time Bulletin 118-2003 was published in 2003, more than 200 local agencies had adopted AB 3030 groundwater management plans. An additional bill, AB 359, passed in 2011, 1) requires local groundwater agencies, as a condition of receiving State funds for groundwater projects, to include a map identifying groundwater recharge areas in their basins in groundwater management plans and to provide the recharge area maps to local planning agencies and, 2) includes additional local agency reporting requirements, including submittal of groundwater management plans to DWR.

With the emphasis in recent years on integrated regional water planning and management, IRWM plans have been prepared for many regions throughout the state, and the portion of the state covered by an IRWM plan is continually expanding as new IRWM plans are developed. In 2009, DWR went through a Region Acceptance Process (RAP) to accept regions into the IRWM Grant Program. As of the second round of RAP, there are a total 48 IRWM regions, two of which are conditionally approved (see http://www.water.ca.gov/irwm/grants/docs/ResourcesLinks/GraphicFiles/IRWM_E_48_Regions_Merged_Template_02132014.pdf).

An important consideration in the coordination of surface water and groundwater resources is the question of potential adjudications of water rights by tribal communities. Additionally, tribal rights to groundwater in some areas could be significant, for example, in San Diego County. Tribal water rights and adjudications, pertaining to both surface water and groundwater, are issues that must be substantively addressed for viable, long-term water resources planning in California.

Over the past few years, voters and the Legislature have provided significant funding to local agencies for improving water supply reliability and groundwater management. Proposition 13, approved by voters in 2000, provided $200 million for grants for feasibility studies, project design and the construction of conjunctive use facilities, and $30 million for loans for local agency acquisition and construction of groundwater recharge facilities and grants for feasibility studies of groundwater recharge projects. AB 303, enacted in 2000, created the Local Groundwater Assistance (LGA) fund and authorized grants totaling $38.5 million from 2001 to 2009 to help local agencies develop better groundwater management strategies to ensure the safe production, quality, and storage of groundwater.

Proposition 50, passed in 2002, and provided $500 million for IRWM projects. Although this funding is not specifically targeted for groundwater projects, many of the projects in the regional proposals would expand groundwater storage, desalt brackish groundwater, or improve groundwater quality to make new supplies available. Proposition 84, approved in 2006, and provided an additional $1 billion for IRWM projects.

Along with providing increased funding for IRWM projects as noted above, in 2009, the Legislature, as part of a larger package of water-related bills, passed SB X7-6, requiring that groundwater elevation data be collected in a systematic manner on a statewide basis and be made readily and widely available to the public. DWR was charged with administering the program, which was later named the California Statewide Groundwater Elevation Monitoring or CASGEM Program. The program is voluntary, although future eligibility of State grant funding for associated agencies could be affected if they choose not to participate. Monitoring outside of the state's 515 alluvial groundwater basins and subbasins listed in DWR Bulletin 118-2003 is not required. SB X7-6 contains the following requirements.

- Local agencies, counties, and associations interested in volunteering to become Monitoring Entities shall notify DWR by January 1, 2011.
- DWR shall review prospective Monitoring Entity notifications and determine designated
- Monitoring Entities for each basin and subbasin.
- DWR shall work cooperatively with local Monitoring Entities to achieve monitoring programs that demonstrate seasonal and long-term trends in groundwater elevations.
- Monitoring Entities shall begin groundwater elevation monitoring in fall 2011 and report elevations to DWR by January 1, 2012.
- DWR shall make these groundwater elevation data widely and readily available to the public.

- DWR will perform groundwater elevation monitoring in basins where no local party has agreed to perform the monitoring functions.
- If local parties (for example, counties) do not volunteer to perform the groundwater monitoring functions and DWR assumes those functions, then those parties may become ineligible for water grants or loans from the State.
- DWR shall report findings to the governor and Legislature by January 1, 2012.
- DWR shall report findings to the governor and Legislature thereafter in years ending in five and zero.

As specified in SB X7-6, DWR has established a statewide groundwater elevation monitoring and reporting program. The following list provides the milestones of the CASGEM program achieved through 2012:

- DWR successfully conducted outreach to develop local support throughout the state.
- DWR developed the CASGEM Web site (http://www.water.ca.gov/groundwater/casgem/) and documents to provide easily accessible, up-to-date program information, and technical support.
- Local agencies, counties, and associations volunteered to become CASGEM Monitoring Entities and notified DWR.
- DWR reviewed the submitted notifications and designated Monitoring Entities for several groundwater basins and subbasins throughout the state.
- DWR worked cooperatively with local Monitoring Entities to develop groundwater elevation monitoring programs for their defined monitoring areas.
- DWR developed an online system for a monitoring plan, well information, and groundwater elevation data submittal, which provided public access to this information and data in both tabular and map formats.
- Monitoring Entities began submitting groundwater elevation data to the CASGEM Online System in fall 2011.
- DWR released the CASGEM Online System to the public in mid-November 2011, allowing access to submitted groundwater elevations.
- DWR released the first report of findings of the CASGEM program to the governor and Legislature in January 2012.

On January 1, 2012, Assembly Bill 1152 made revisions to the CWC related to the CASGEM Program, which include adding a new Monitoring Entity category, allowing alternative monitoring of groundwater basins, and removing the requirement for DWR to seek concurrence of the State Mining and Geology Board regarding adequacy of monitoring plans to demonstrate seasonal and long-term trends in groundwater elevations.

Data Collection and Management

Data collected throughout the state are important in planning and developing the conjunctive water management strategies. The data should include, in addition to those collected as part of the CASGEM Program, groundwater management-related information, groundwater quantity and quality, and water use in the state. DWR's Bulletin 118 series, titled *California's Groundwater*, provides information about the state's groundwater resources and its resource management practices. Bulletin 118 was last updated in 2003 and there is no dedicated funding currently for it, although recently the Governor's Water Action Plan made a recommendation to update it. Some agencies in the state continue to collect and analyze groundwater data, and proactively and effectively manage local groundwater resources. For many other agencies, however, without having access to reliable data and analysis on groundwater, the goal to manage this resource better will likely remain unattainable. To respond to this need, as part of Update 2013, DWR has initiated a process to enhance groundwater content in a major way. The objective is to "expand information about statewide and regional groundwater conditions to better inform groundwater management actions and policies through compilation and summarization of data and analysis." This effort will not solve all the statewide and regional issues related to groundwater, but it is intended as a starting point to bring all the available information together from a statewide and regional perspective. The information content on groundwater built through this initiative is anticipated to set the stage for future California Water Plan updates and related activities to provide on a long-term basis additional data, information, and analyses as well as policy needs for California's groundwater planning and management. The major proposed deliverables planned for Update 2013 include the following:

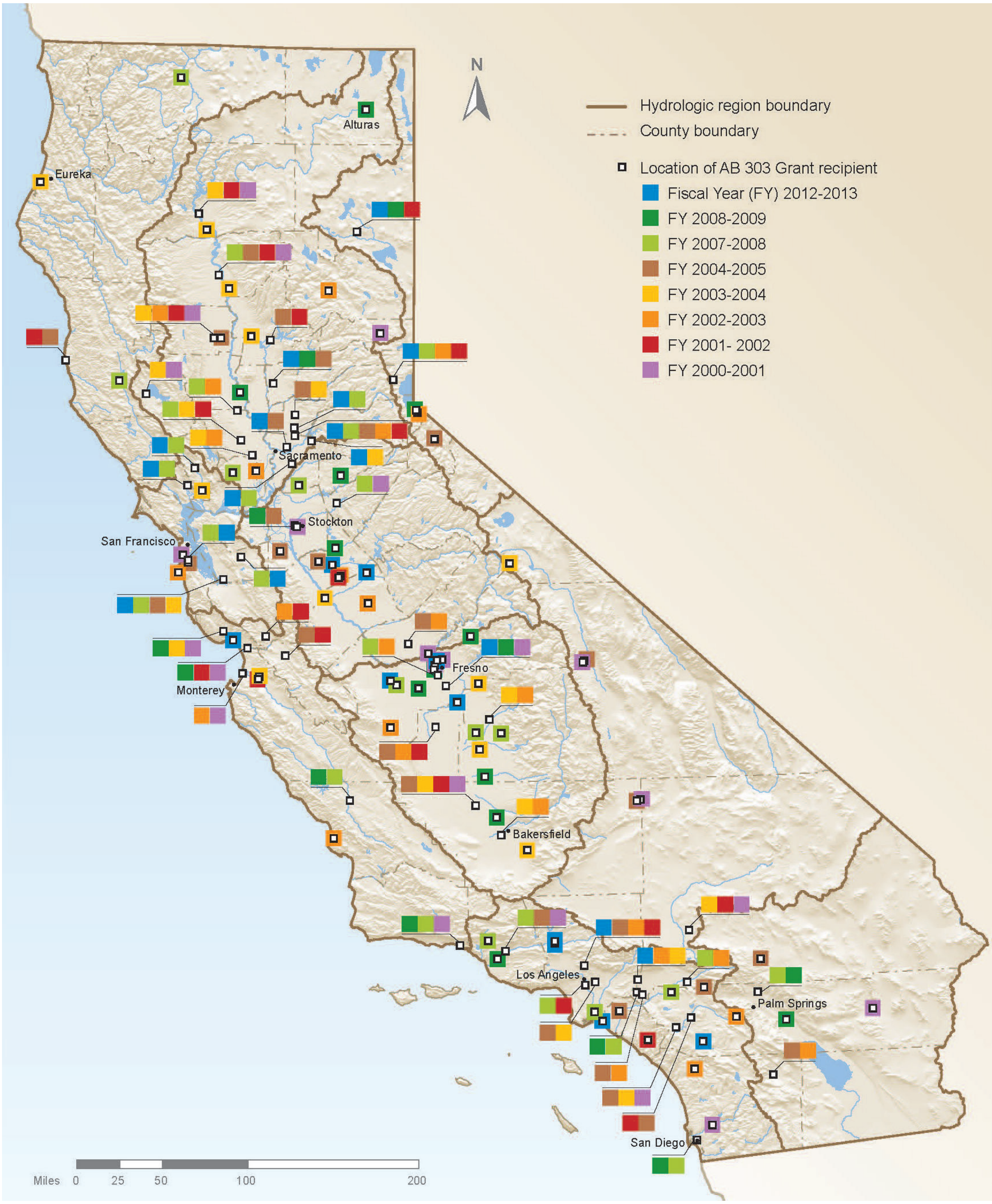
- Consolidated groundwater information from various State, federal, regional, and local water resource planning initiatives.
- Status of regional groundwater conditions, management activities, and problem areas.
- Data gaps to inform future groundwater monitoring needs and activities better.
- Estimates of regional annual change in groundwater storage.
- Illustration of successes and challenges of local and regional management of groundwater.
- Inventory and potential for conjunctive management of groundwater with other supplies.

The data and analyses resulting from the above deliverables were consolidated into a report available online in *California Water Plan Update 2013*, Volume 4, *Reference Guide*, in the article, "California's Groundwater Update 2013." The information also provided groundwater related contents for Volume 1, *The Strategic Plan* and Volume 2, *Regional Reports*, in *California Water Plan Update 2013*.

The Integrated Water Resources Information System (IWRIS), released by DWR in 2008, is the first centralized water data management system developed to help local and regional water management entities integrate and analyze existing data about their groundwater system and potential value of current groundwater management in their integrated planning processes. It serves as a centralized information system for accessing the data about groundwater as well as groundwater management and some DWR grant program funding statewide. Figure 3, generated from DWR IWRIS, shows a distribution of the AB 303 Grants from 2001 to 2008 for helping the development of groundwater management plans which in recent times often include conjunctive management as an important strategy for managing groundwater. Due to a lack of funding, the future of IWRIS remains uncertain. Fortunately, DWR has undertaken a project, Water Planning Information Exchange (Water PIE) that may subsume IWRIS. The ultimate goal of Water PIE is collecting and sharing data and networking existing databases and Web sites using geographic information system (GIS) software to improve analytical capabilities and developing timely surveys of statewide land use, water use, and estimates of future implementation of resource management strategies. Phase I of Water PIE has been initiated, which is intended to develop the business and technical requirements for the web-based system. In Phase 2 of Water PIE, a pilot application will be conducted to assess the developed system and refine requirements and design before full implementation commences.

The groundwater elevation monitoring provisions of the CASGEM Program have increased availability of information useful for planning and implementing conjunctive management in the state. The availability

Figure 3 Distribution of the AB 303 Grants from 2001 to 2013



of information is increasing as local and regional water management entities analyze the existing and potential value of active groundwater management in their integrated planning processes. It is important to have updated information on the various conjunctive water management planning and implementation activities statewide to achieve better coordination among future conjunctive water management planning activities and to avoid potential conflicts. DWR has started developing a statewide inventory of conjunctive management agencies and projects that is included in *California Water Plan Update 2013*. Detailed information on the inventory including communication with water agencies, data items requested, and level of responses received is available online in *California Water Plan Update 2013*, Volume 4, *Reference Guide*, in the article, "California's Groundwater Update 2013." This initial effort in *California Water Plan Update 2013* was not as successful as intended because of the apparent reluctance of local and regional water agencies to release data to build such an inventory. The reluctance of these agencies to provide information was concluded to have emanated primarily from an apprehension about uncertainty in State regulations pertaining to groundwater recharge. This inventory will continue to be updated, refined, and expanded in future California Water Plan updates.

This resource management strategy report deals with general and statewide issues associated with conjunctive water management. Issues specific to individual hydrologic regions are discussed in their respective regional reports in *California Water Plan Update 2013*, Volume 2*, Regional Reports*. However, for general illustrative purposes, two case studies — one from Southern California and one from Northern California — are provided in Box 4 and Box 5.

As noted, conjunctive management and groundwater storage are considered an integral elements of IRWM, and it is actively promoted and supported by the State. In the context of the rapidly evolving IRWM effort in California, the issue of cooperative arrangement among regional water partners is gaining momentum. Box 6 provides a brief description of a four-county program in Northern California initiated to promote cooperation among participating counties for resolving regional water management issues across jurisdictional boundaries. This four-county program eventually expanded and added two additional counties to the group and formed the Northern Sacramento Valley Integrated Regional Water Management group. Cooperative agreements such as this can serve as a model of how legal constraints and issues related to regional water management, including conjunctive management projects, may be resolved.

Potential Benefits

Conjunctive management is used to improve water supply reliability and sustainability, to reduce groundwater overdraft and land subsidence, to protect water quality, and to improve environmental conditions. Overdraft is defined as the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions (California Department of Water Resources 2003). Overdraft may cause land subsidence and damage to the environment and increase energy cost in pumping. An example illuminating the beneficial outcome of conjunctive water management in ameliorating groundwater overdraft is included in Box 7.

Potential benefits from conjunctive management are highly dependent on how well the surface water and groundwater are managed as a single source to adapt to the climate system to maximize use of the water in the managed area. Effective conjunctive management should optimize capture of excess water when it

Box 4 Conjunctive Management Case Study 1 in Southern California

Groundwater storage plays an important role in providing a reliable water supply in areas with limited surface water supplies. The Metropolitan Water District of Southern California (MWD) has performed a groundwater assessment study to analyze groundwater use from 1985-2004. The study shows that groundwater provides nearly 40 percent of the total annual water needs within MWD’s service area. Between 1995 and 2004, an average of 1.56 million acre-feet (maf) of water per year was produced from the groundwater basins. The study also shows that groundwater production varies as much as 30 percent between the wettest and driest year (Metropolitan Water District 2007).

Groundwater is an important part of MWD’s Integrated Water Resource Plan (IRP) for ensuring water supply reliability. To maintain baseline annual production during dry years, the IRP sets out reliability strategies for dry years, and has targeted a dry-year yield from service- area groundwater basins of 275,000 acre-feet per year (af/yr.) by 2010, and 300,000 af/yr. by 2020/25. Because MWD plans for the potential of three consecutive dry years, the yield targets are multiplied by three resulting in dry-year storage targets of 825,000 af by 2010 and 900,000 af by 2020/25 (Metropolitan Water District 2007). These strategies and targets are met by using conjunctive management of surface water and groundwater.

Conjunctive management not only uses groundwater storage for water supply, but also provides recharge and protection to groundwater storage. The 20-year study shows that an average recharge of 758,000 af/yr. resulted from active recharge programs (Metropolitan Water District 2007). About 90 percent of the groundwater recharge — approximately 681,000 af/yr. — was from direct recharge methods (injection or spreading) using imported water, treated recycled water and local runoff, and the remaining 10 percent was from in-lieu recharge (Metropolitan Water District 2007). When surface water supplies are available, MWD encourages in-lieu groundwater recharge by providing financial incentives. As a result of more groundwater recharge facilities becoming available during 1995-2004 as compared to 1985-1994, active recharge using local runoff increased by 7 percent while the proportion of imported water used for recharge declined by 5 percent during the later period (1995-2004). Treated recycled water can be used to prevent salt water intrusion to protect existing groundwater resources and maintain valuable groundwater storage. For example, as part of MWD’s conjunctive management, imported water has been spread at Montebello Forebay and injected in the Central Basin of MWD service areas to control seawater intrusion. Recycled water meeting certain water quality standards are also used for irrigation and recharging the groundwater.

The total developed groundwater management capacity in MWD’s service area currently includes the following (Metropolitan Water District 2007):

- More than 4,300 active production wells (municipal, agricultural, industrial, and private).
- 36 ASR (aquifer storage recovery) wells.
- 5,000 acres of spreading basins.
- 400 acres of water quality wetlands to improve quality of inflows to groundwater.
- 7 seawater intrusion barriers.
- 16 desalters.

is available so that enough water is stored to meet beneficial use needs while providing a sufficient reserve to get through extended dry periods. However, the benefit derived from effective conjunctive management is limited by the combined, current surface water and groundwater production capacity of the management area.

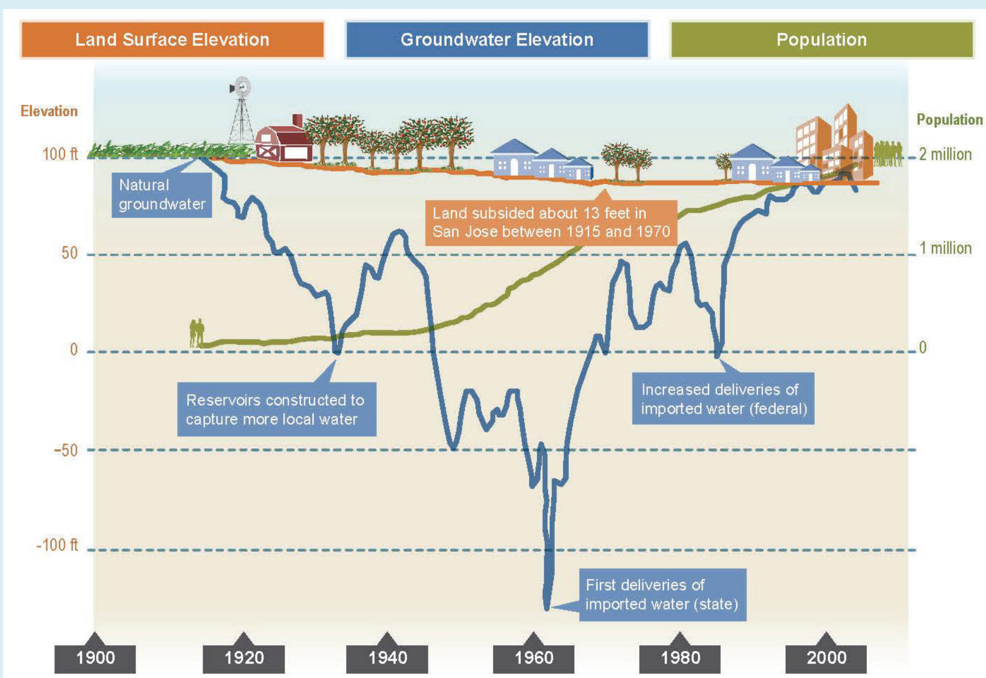
The climate in California can usually be described as consisting of a wet season and a dry season in a water year. Most water (as rainfall and snow) is in the northern part of the state while most people live in the southern part. However, climate varies greatly over the state. Successful conjunctive water management must recognize the climate variability in California and maximize the use of water throughout the state.

Box 5 Conjunctive Management Case Study 2 in Northern California

The Santa Clara Valley Water District (SCVWD) is the comprehensive water management agency for the residents of Santa Clara County. It supplies clean and safe water, manages local groundwater basins, implements flood protection projects and provides watershed stewardship. It serves approximately 2 million people — 1.8 million residents and 200,000 commuters — in 15 cities and unincorporated areas in the 1,300-square- mile county (Santa Clara Valley Water District 2008).

Similar to many other parts of California, the areas served by the SCVWD also witnessed remarkable agricultural and urban development in the last two centuries. These developments began in the latter half of the 19th Century post-Gold Rush era and continued throughout the 20th Century. The intense urban and agricultural growth resulted in increased groundwater extraction, which in turn, culminated in groundwater level declines of more than 200 feet and land subsidence of nearly 12 feet. To meet the water needs in the valley, in the late 1920s the SCVWD (or its predecessor) was formed (Santa Clara Valley Water District 2009). This set in motion a long succession of facilities construction for surface storage to increase water supply availability and recharge ponds to facilitate conjunctive management through managed groundwater recharge. Since the 1960s, the SCVWD has imported surface water to meet growing demands and reduce dependence on groundwater supplies. Currently, the SCVWD operates and maintains 18 major recharge systems, which consist of both instream and offstream facilities. Local reservoir water and imported water are released in more than 90 miles of more than 30 local creeks for managed instream recharge. In addition, the SCVWD releases locally conserved and imported water to 71 recharge ponds, which range in size from less than 1 acre to more than 20 acres; the total area of the groundwater recharge ponds is more than 300 acres (Santa Clara Valley Water District 2012). Through these streams and recharge ponds, the SCVWD recharges the groundwater basin with about 156,000 acre-feet of water each year (Parker 2007). Figure A illustrates how a conjunctive management approach through SCVWD's recharge programs, imported water deliveries, and treated water programs has resulted in remarkably improving groundwater conditions in the basin (Santa Clara Valley Water District 2012).

Figure A: Conjunctive Management Case Study 2 in Northern California



Note: This graphical representation is not intended as a technical exhibit.

Box 6 Regional Cooperative Arrangements in Northern California

An example of a regional effort that attempts to reach across jurisdictional boundaries is the four-county program. This program revolves around a cooperative memorandum of understanding (MOU), originally signed by the counties of Butte, Glenn, Tehama, and Colusa. The MOU, signed in early 2006, outlines how the counties will work together across jurisdictional boundaries on water management issues that are of concern to their collective constituencies. The MOU is accompanied by an addendum, which lays out how information regarding activities in neighboring counties will be conveyed to other counties within the region to ensure that all processes are transparent and each jurisdiction is aware of activities that have the potential to impact their citizenry. Although local ordinances may not cross jurisdictional boundaries, board members in each county have expressed that they do not want to cause harm to their neighbors. The cooperative efforts outlined in the MOU, and its Addendum One, discuss how the various boards intend to communicate and cooperate with each other (Board of Supervisors of Butte, Colusa, Glenn, and Tehama Counties, 2006; 2007). In 2009, Addendum Two added the County of Sutter to the group and Addendum Three documented a commitment by the counties to begin an Integrated Regional Water Management (IRWM) Planning process (Board of Supervisors of Butte, Colusa, Glenn, Tehama, and Sutter Counties, 2009a; 2009b). Addendum Four added the County of Shasta in 2010 and also renamed the IRWM effort to Northern Sacramento Valley IRWM group (Board of Supervisors of Butte, Colusa, Glenn, Tehama, Sutter, and Shasta Counties 2010).

Any conjunctive management strategy will produce changes to the water system. A sustainable conjunctive management strategy should optimize the beneficial and efficient use of the water in the system while balancing all of the objectives. Because of the uncertainty in water demand resulting from population growth, land use changes, and climate change, risk management and opportunity costs should be considered in conjunctive management planning. A good conjunctive management computer-aided tool can help identify and quantify the benefit and potential risk associated with conjunctive management projects. This tool can be considered one element of an overall robust, adaptive water management system for dealing with future uncertainties and provide safe, responsive, and effective oversight. Unfortunately, no such tool currently exists and developing such a tool is one of the recommendations made to improve conjunctive management, included at the end of this resource management strategy report.

Table 1 lists some of the many potential benefits of conjunctive management and highlights some of the major constraints that influence the usefulness and level of benefit that might be obtained. Example 1 in Table 1 can be used anywhere in the state to adapt to the two-season pattern so that more water can be captured in the wet season for beneficial use. Example 2 recognizes the fact of the relatively wet northern part of the state and shows the benefit of using groundwater storage in the reoperation of the State Water Project (SWP) and the Central Valley Project (CVP) to capture more flood flows, provide flood control benefits, and improve water supply availability and reliability. An example of the magnitude and frequency of variability in California's hydrology is furnished in Figure 2-1 of *California Water Plan Update 201*3, Volume 1, *The Strategic Plan*, Chapter 3, "California Water Today." Figures such as those can be used as a guide for identifying the relatively wet areas in the state. Example 3 demonstrates a way of utilizing groundwater that could be used for agricultural production to urban water use to relieve drought emergencies and to provide induced groundwater recharge. Example 4 shows use of surface water for preventing salt water intrusion in coastal areas. Example 5 provides not only a solution to reduce or contain the flood risks resulting from the increased runoff due to urbanization, but also to maintain the natural groundwater recharge in the project areas and provide opportunity for treating storm water in detention ponds.

Box 7 Groundwater Overdraft and Conjunctive Management

The two hydrographs below show the response of groundwater levels to differing water management regimes. The first hydrograph (Figure A) shows groundwater levels declining in response to agricultural development in the San Joaquin Valley. Groundwater levels recover somewhat during the wet period of the early 1980s, but continue to decline through the 1980s and 1990s in the absence of a focused conjunctive water management action. The second hydrograph (Figure B) shows a similar groundwater level decline in response to development in southern Yuba County. However, groundwater levels begin to recover in the early 1980s when surface water imports from Yuba County Water Agency began, resulting in conjunctive water management. The hydrograph shows a decline in groundwater levels during the early 1990s drought as surface water imports were curtailed and groundwater was relied upon more heavily. Thereafter, continued conjunctive water management action resulted in the refilling of the South Yuba Groundwater Subbasin, which continues up to present.

Figure A Groundwater Overdraft and Conjunctive Management – Kings Basin

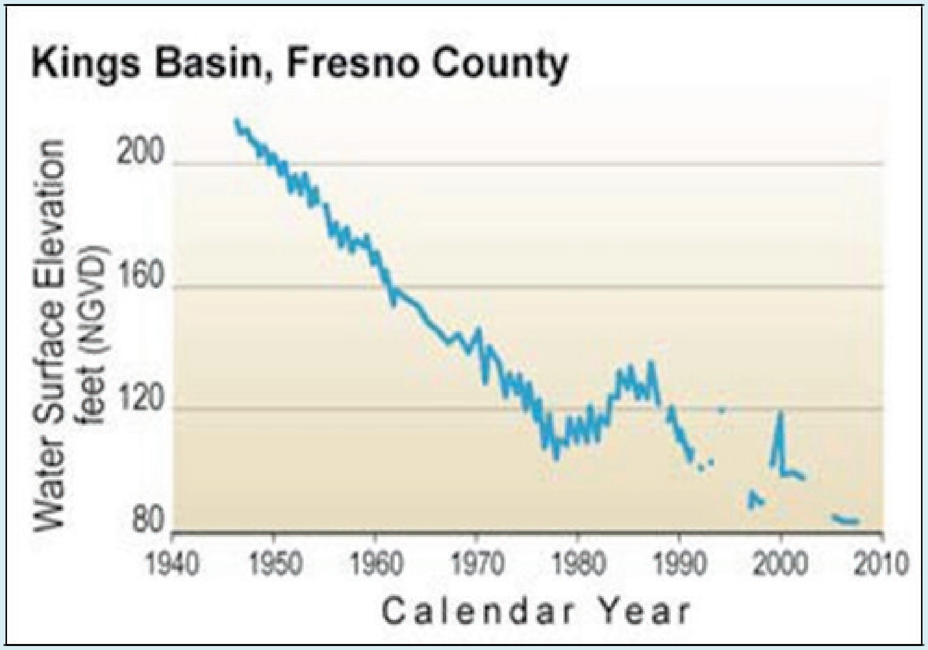


Figure B Groundwater Overdraft and Conjunctive Management – Brophy Water District, South Yuba County

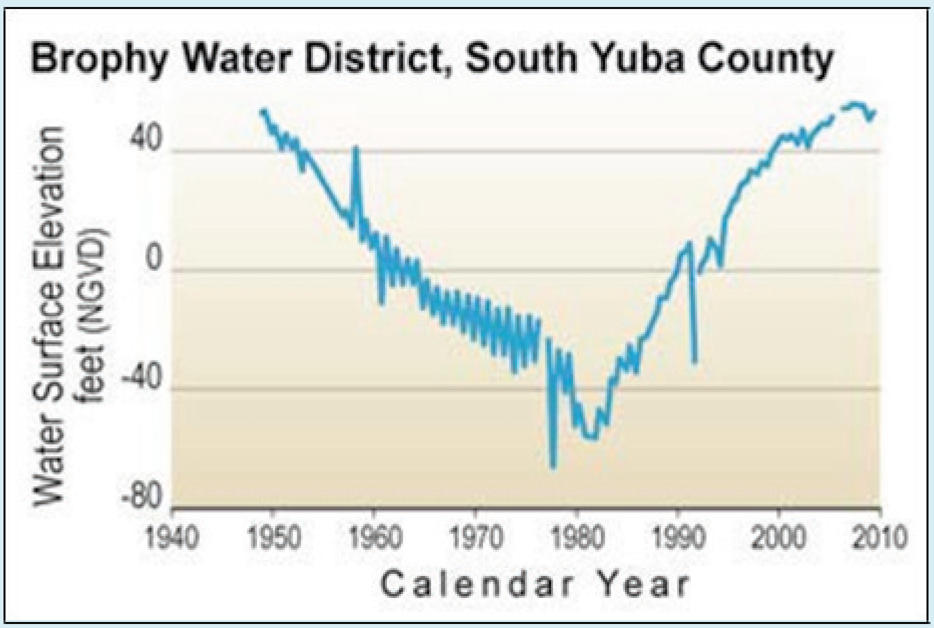


Table 1 Potential Benefits of Conjunctive Management Implementation

Potential Benefit of Managed Groundwater Storage	Example	Major Constraints
Improved local water supply reliability	Imported surface water supplies and/or floodflows are recharged to local alluvial groundwater basin during wet years/seasons, increasing local water supply reliability.	• Availability of surface water supplies. • Limited capacity to capture and recharge high volume, short duration floodflows. • Water quality concern of the recharged water and the impact to the aquifer itself.
Improved statewide water supply reliability	Groundwater storage in the northern part of the state might be used as backup supplies to allow more aggressive operation of surface storages such as Oroville and Shasta reservoirs by permitting reduced carryover storages so that more floodflows in the wet seasons could be captured. This would increase SWP and CVP operational flexibility and could result in improved statewide water supply reliability and sustainability. The reduced carryover storage would be replaced annually by utilizing groundwater storage.	• Availability of a multi-regional/statewide conjunctive water management tool to model surface water and groundwater (including water temperature) responses accurately and to evaluate the proposed management strategy for its benefits, the impacts to third parties and the environment, project cost, etc. • Legal and water rights issues (associated impacts perhaps could be mitigated by compensation to injured parties if any, using the above tool if it were available).
Drought relief for urban water users and potential induced groundwater recharge	Groundwater substitution transfer and agricultural water transfer. Irrigators who are willing sellers stop a specific amount of surface water diversion and pump an equivalent amount of groundwater to replace surface water. As a result, more surface water becomes available downstream for purchase. Groundwater eventually recovers from increased streamflow to the groundwater system.	• A lack of a widely recognized mathematical model to accurately quantify the impact to other groundwater and surface water users and the environment. • Potential land subsidence and its quantification and evaluation.
Protection from salt water intrusion	Recharge groundwater using captured floodflows or recycled water in the vicinity of salt water interface to raise groundwater levels and prevent migration of saline water into freshwater production portions of the aquifer.	• Availability of freshwater supply. • Considerable infrastructure requirements.
Improved flood control and groundwater storage	Development of detention ponds at proposed residential subdivisions located in the groundwater recharge protection areas can offset the increased urban runoff due to the development while maintaining natural groundwater recharge.	• Possible water quality problems at detention ponds requiring effective urban storm water management. • Requiring adoption of local ordinance or legislation to support implementation.

Currently conjunctive management in Southern California provides more than 2.5 maf of average annual water supply (Montgomery Watson and Water Education Foundation 2000). Conservative estimates of additional implementation of conjunctive management indicate the potential to increase average annual water deliveries throughout the state by 0.5 maf (California Department of Water Resources 2003;

Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008). 2008).This estimate is based on the assumption of increased available groundwater through reoperation of existing groundwater systems. More aggressive estimates from studies indicate the potential to increase average annual water deliveries by two maf. For the purpose of comparison, the lower and higher estimates amount to 1.2 and 5.0 percent of the average annual water supply in California, and 3.0 and 12.1 percent of the average annual groundwater supply. The increase in groundwater supply may result in increased competition for the groundwater resources, which could potentially impact the agricultural economy of the state. As noted earlier, the attempt to build a solid inventory of data on conjunctive management projects on a regional water deliveries throughout the state by 0.5 maf (California Department of Water Resources 2003; Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008).This estimate is based on the and statewide basis did not meet with considerable success. As a result, estimates of range of supply increase from potential conjunctive management projects could not be further refined in Update 2013. Better estimates can only be developed once the inventory of conjunctive management projects is properly refined and updated in future California Water Plan updates.

The more aggressive estimates are based on assumptions that require major reoperation of existing surface water storage and groundwater storage to achieve the benefits and do not fully consider the conveyance capacity constraints for exports through the Delta and other conveyance facilities (California Department of Water Resources 2003; Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008). This estimate could be considerably lower if either major reoperation of existing surface water storage and groundwater storage is not feasible, or existing conveyance capacity constraints for exports through the Delta and other conveyance facilities are taken into consideration.

Potential Costs

Costs for implementation of conjunctive management and groundwater storage may include a wide range of facilities and depend on the site-specific nature of the program. Accordingly, the cost for a unit increase in water supply or delivery is highly variable.

Some projects require relatively minor changes in operations or upgrades of existing infrastructure, such as increased sizing of pumps in existing wells or increased releases of water from existing conveyance canals. Other projects may require extensive new facilities such as canal turnout structures, new pipelines and pumps, injection or extraction wells, or construction of new recharge basins. The highly variable nature of implementation costs requires that the feasibility of new conjunctive management projects or programs be evaluated carefully on a case-by-case basis. Generalizations of implementation costs without site-specific information on issues, such as available water supply and access to conveyance and groundwater storage, are rarely accurate.

The wide range of costs results from many factors including project complexity, regional differences in construction and land costs, availability and quality of recharge supply, availability of infrastructure to capture, convey, recharge, and extract water, intended use of water, and treatment requirements. Additional issues that may also need to be addressed are who has ownership of the water and who compensates for disputes among neighbors and impacts to or from third parties. In general, urban uses can support higher project costs than agricultural uses.

Major Implementation Issues

Uncertainty in Surface Water Availability from State and Federal Water Projects

For many regions in the state, water supply from SWP and CVP is a potential source for groundwater recharge. However, its availability has become increasingly uncertain because of the deterioration of environmental conditions in the Delta. Recent legal decisions (Wanger 2007a; 2007b; 2008a; 2008b; 2010; 2011a; 2011b) and biological opinions (U.S. Fish and Wildlife Service 2008, 2011; National Marine Fisheries Service 2009, 2011) have narrowed the time window of Delta pump operations. As a result, less water can be exported for delivery to south of the Delta. Information about SWP water supply reliability (updated every two years) can be obtained at http://baydeltaoffice.water.ca.gov/swpreliability/. The increased uncertainty in surface water availability from SWP and CVP could be a critical limiting factor to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

Uncertainty in Evaluating Impacts of Groundwater Pumping on Surface Water Flows and Aquatic Ecosystems

Groundwater and surface water are usually connected hydraulically. Conjunctive water management can change existing surface water and groundwater interaction significantly. There are some regional groundwater flow models available for the Central Valley, and they can be used to evaluate the surface water and groundwater flow interaction. However, the accuracy of analysis, model resolution, and the size of the modeling area often limit their application for evaluation of local and regional as well as statewide conjunctive water management opportunities. Impacts to aquatic ecosystems often require the modeling of water temperatures and solute transport, land subsidence analysis, and identification of environmental flow targets. These modeling tools are not well developed or integrated for conjunctive management planning as discussed in the “Lack of Data and Tools” section, below.

Effects of Land Use Changes on New or Enlarged Recharge Facilities and Recharge Area Protection

A natural recharge area may be reduced or eliminated because of a new development or contamination from a development. The protection and the improvement of natural recharge areas are important in maintaining and improving groundwater storage. In California, floodplains and wetlands that provide natural recharge areas have been urbanized at a steady pace, although the pace has somewhat stabilized since the economic slowdown beginning in 2008. Proximity of some developments to existing groundwater recharge facilities precludes expansion of recharge area.

Land use planning that will preserve natural recharge areas by limiting the encroaching development (for example, by purchasing the land or by zoning the land for recharge-friendly uses) would be beneficial. However, protecting an important natural recharge area sometimes may not be a high priority for the county or local land use authorities, particularly if the groundwater basin being pumped is in another jurisdiction. Although federal, State, county, and local requirements may mitigate impacts of increased runoff resulting from new developments, these requirements may need to be further strengthened by additional provisions that may also include local land use ordinances. While recognizing that there is variability in hydrology, and local conditions and needs, these provisions or ordinances should generally be geared toward ensuring that new developments incorporate detention ponds so that the increased runoff and lost natural recharge can be offset by the planned detention ponds, accomplished in such a way that groundwater quality is not compromised. However, instead of this approach and if workable, an alternative basin-wide or watershed-scale approach may also be taken to mitigate the effects of new developments in a more cost-effective way at the basin or watershed level. The proposed detention ponds can provide flood protection and also help maintain natural recharge. Managed recharge facilities may be used to inject the increased runoff to the underlying groundwater basin. One significant initial step in this direction was the passage of AB 359 in 2011, which requires local groundwater agencies to include a map in groundwater management plans that identify groundwater recharge areas in their basins and to provide these recharge area maps to local planning agencies. The issues related to land use and recharge area protection are further discussed in resource management strategy reports, *Urban Stormwater Runoff Management* and *Recharge Area Protection*.

Recently, Calaveras County has added a new dimension to the on-going discussion of land and water use nexus by introducing the concept of water element in its general plan. The county defines a water element as "a self-contained document that identifies and articulates goals, policies, and objectives for the multiple uses of water. It can address all or some of these uses, such as water supply, wastewater, water quality, stormwater management, flood management, watershed management, protection of habitat, and erosion control. It does not dictate land use planning; it informs land use planning." The goal as articulated by the county is "by integrating these various aspects in a Water Element there will be greater opportunity for improving the linkage between land use decisions and water planning; standardizing services; increasing public awareness; and…." (Montgomery Watson Harza 2009).

Inconsistency and Uncertainty in Regulatory Status with Respect to Recharge and Surface Commingling of Different Quality Water

Groundwater recharge involves using water from various sources to recharge a groundwater basin. The quality of water used for recharge is usually different from the water in the receiving groundwater basin. Uncertainty in regulatory status with regard to the quality of recharging and receiving waters increases the uncertainty in the planning effort of conjunctive management and may increase cost or even make a conjunctive water management project infeasible during implementation.

Lack of Data and Tools

Data and tools are very important in developing a reliable and advanced conjunctive water management strategy. Data are needed to understand the groundwater resource, to monitor and measure the progress of water management strategies, and to calibrate and validate computer modeling tools. However, data are often lacking. Tools are also not readily available for use and may need to be developed. Existing tools may also need to be refined and improved, as discussed later in this section.

Data are needed to evaluate conditions and trends laterally and vertically in a geographic area and over time. The CASGEM Program has been implemented to monitor groundwater elevations and the Groundwater Ambient Monitoring and Assessment Program (GAMA) has been implemented to monitor groundwater quality. Besides these two programs, there are few comprehensive basin- wide networks to monitor groundwater levels, water quality, land subsidence, and interaction of groundwater with surface water and the environment. There is no integrative web portal or information system providing access to various groundwater monitoring networks operated by various State and local agencies. DWR released the first such product called the Integrated Water Resources Information System (IWRIS) in May 2008 to the public, but IWRIS does not include or provide access to much of the available water quality data.

To understand the groundwater resources on a statewide basis, data from throughout the state are needed. Although it is common that groundwater data are not monitored in remote areas by local authorities, these data are important for understanding the statewide groundwater system. A statewide multi-resolution groundwater modeling tool can help identify cost-effective and necessary locations and frequency of groundwater monitoring for areas where monitoring is lacking or could be improved. An integrated statewide data and information management system such as IWRIS can also help visually identify the spatial data gaps in the state. Because of the lack of resources, incentives, or conflicts of interest, individuals or local agencies are usually not able to fill the spatial data gaps outside their management areas. State agencies could help fill the data gaps by providing the necessary resources to local agencies. Better cooperation and coordination are also needed among the agencies to best use available resources to develop a statewide groundwater monitoring program by minimizing data gaps and overlaps. The greatest obstacle to the continuation and success of any data program is the lack of dedicated funding for program execution by State agencies and participating local agencies. Success of these important data monitoring programs can only be ensured through long-term commitment and funding at the State and local levels.

One important aspect in data collection effort that is often overlooked is its coordination with the development of computer models. Computer models help identify potentially critical data collection locations (stations) and the desired frequency of collection, leading to improved monitoring of groundwater systems and performance measurement of management strategies. The coordination between data collection and model development would also help improve model calibration and reduce cost of data collection by minimizing data gaps and overlaps. While a model may have its own set of limitations, an easy-to-use computer aided conjunctive management tool is needed for assessing the management strategies and quantifying the values of the strategies. Ideally, State and federal agencies should collaborate with and assist local agencies to develop such a tool. The tool should allow resources managers to define and prioritize objectives and specify constraints in an easy-to-use interface. The tool should also be able to perform integrated surface water and groundwater modeling, land subsidence analysis, and economic evaluation.

Computer models have been developed to assist water resources planning and management and there is continued development of these models. CalSim II (Close et al. 2003), jointly developed by DWR and the U.S. Bureau of Reclamation, is a recognized water resources planning model for SWP and CVP operations running in monthly time step. Groundwater models are also under development for selected hydrologic regions. One of the groundwater models covering the Central Valley is the California Central Valley Groundwater-Surface Water Model (C2VSim). It simulates three groundwater layers and model calibration was recently completed (Brush 2013). The model was officially released in June 2013. A similar model, called the Central Valley Hydrologic Model (CVHM), was developed and released by the U.S. Geological Survey (Faunt 2009). However, before either C2VSim or CVHM can be used for local groundwater management, its modeling resolution needs to be improved. Effort to improve the spatial resolution of C2VSim has commenced recently. Availability of a model with finer spatial resolution is extremely important because while the State's goal is to encourage conjunctive water management statewide, the effects of bad management are felt locally by citizens dependent on groundwater. While many areas in the state rely on surface water or has access to surface water, in some areas more than 70 percent of the agriculture is groundwater dependent, as documented and available online in *California Water Plan Update 2013*, Volume 4, *Reference Guide*, in the article "California's Groundwater Update 2013."

A recently published report documents a planning level analysis performed to assess and quantify general viability of conjunctive water management projects in the Sacramento Valley. The analysis was conducted by sequentially using a simplified surface water model in conjunction with CalSim-II to simulate CVP/SWP operations and SacFEM based on MicroFEM (Hemker 2013) to assess impacts of proposed projects on groundwater levels and streamflows. The analyses provided a general estimate of potential benefits resulting from the proposed projects. However, the report notes that the analysis will need to be refined for specific project implementation by clearly incorporating infrastructure and operational protocols and analyzing response of the simulated surface and groundwater water system (CH2MHill and MBK Engineers 2010)

A recent effort to integrate C2VSim with an updated version of CalSim II called CalSim III (California Department of Water Resources 2013d), may offer a broader water resources modeling system and provide an opportunity for developing an integrated groundwater and surface water modeling system for the entire state (Young 2007; Joyce 2007). To be a good conjunctive water management tool, more modeling capabilities need to be added and integrated in the modeling system. Modeling capabilities that need to be added are:

- Water temperature modeling.
- Daily time step modeling of CalSim instead of monthly time step.
- A user-friendly interface.
- Capability to specify management objectives and constraints.
- Groundwater modeling beyond the Central Valley to cover possible salt water intrusion and address groundwater issues relevant to other hydrologic regions.
- Environmental and economic analysis.
- Analysis of climate change effects under a range of projected climate scenarios.

Other available models or modeling system also lack these capabilities. As conjunctive management is sensitive to the temperature shifts as well as the type, amounts, and patterns of precipitation that affect the hydrologic system, model refinements must also allow incorporation of variable climatological scenarios to provide confidence in its projections for conjunctive management. Although there has been recent increased effort to do that, these refinements need to be further improved to ensure that climate change projections are properly reflected in model simulations. Along with development of statewide modeling tools, the State should also support investigation of local and regional groundwater conditions by local agencies with funding and technical tools.

The lack of data and tools to evaluate the groundwater and surface water interaction has hindered conjunctive water management and water transfer practices because of the failure to quantify compensations to injured parties. The inability to identify the impact of groundwater pumping on surface water and aquatic ecosystems fully, adds to the risk of effective conjunctive water management planning. To overcome this hurdle, sufficient funding must be committed to State agencies and where applicable, local and regional agencies to ensure that the required data and tools are incrementally developed and refined.

Public Access to Well Completion Reports

Although there are many wells in the state, the well completion reports are not accessible to the public because of confidentiality requirements (CWC Section 13752). If the relevant CWC section is changed to remove confidentiality of well completion reports while upholding the coordinated national program to protect the nation's critical infrastructure, the geologic and groundwater related information in the existing well completion reports would be accessible to the public, which in the long-run could save money and time for collecting aquifer and groundwater information. To that end, SB 263 (Well-Reports-Public Availability) was introduced in 2011. It passed through the Senate and Assembly, but the governor vetoed it citing amendments to the bill that unduly restricted the use of the well completion reports and imposed severe criminal penalties for disclosure. A modified version of the bill, SB 1146, was introduced in 2012 to make well logs public information. The bill would have required DWR to make the well reports public subject to specified limitations. It was defeated in the Senate floor, but another version of the bill is expected to be introduced in the future.

Currently, DWR's Regional Offices fill requests for well completion reports as provided for in the CWC. Each year, thousands of well completion reports are made available to governmental agencies, persons doing groundwater clean-up studies, well owners, and other people as provided by the CWC.

It is unlikely that a change in the law to make well completion reports public would save the State money and time in the short-run. Indeed it would probably cost DWR time and money for several years. DWR may save time and money if all well completion reports were scanned and made available on the Web and if an online filing system were developed for well drillers to submit new well completion reports in the future. However, both of these systems would require significant amounts of money and time to develop.

Thus, changing CWC Section 13752 must be done based on sound and compelling arguments. The following capture some of the important considerations in that regard:

- Sufficient funds should be provided to cover the cost to implement changes in CWC Section 13752.
- Language must be included in the law for DWR to recover actual costs of providing well completion reports to the public.
- The law should ensure continuation of collecting the same level of information as is collected currently on the well completion reports, i.e., the usefulness and value of the well completion reports should not be diminished or sacrificed.
- The law should ensure that the quantity and quality of the information provided by the well drillers does not diminish.

Infrastructure and Operational Constraints

Physical capacities of existing storage and conveyance facilities are often not large enough to capture surface water when it is available in wet years. Conveyance capacity for surplus imported water supplies is most available during the wetter and cooler months when water demand is low. However, this wetter period also coincides with reduced ability to accomplish in-lieu recharge (due to lower water demands) and with increased spreading of local runoff, which may limit the ability to recharge other sources of water. During the very wet year of 2004-05, active recharge throughout the Metropolitan Water District service area used only 60 percent of the total recharge facility capacity available throughout the course of the year (Metropolitan Water District of Southern California 2007).

Operational constraints may also limit the ability to use the full physical capacity of facilities. For example, permitted export capacity and efforts to protect fisheries and water quality in the Delta often limit the ability to move water to groundwater banks south of the Delta. Facilities that are operated for both temporary storage of floodwater and groundwater recharge require more frequent maintenance to clean out excessive sediment often present in floodwater.

The need to improve coordination of infrastructure and operations for flood control and recharge of storm flows for conjunctive management cannot be overstated. In Southern California as well as in other areas of California, the considerable opportunity to enhance groundwater recharge by local runoff remains unrealized because of a lack of streamlined and effective coordination.

Another issue that cannot be overstated is the urgent and crucial need for increased capacities for both surface water storage systems and Delta conveyance facilities. As a result of more stringent regulatory requirements coupled with potentially detrimental effects of climate change, availability of surface water is anticipated to follow more extreme cycles of extended dry spells intervened by short, high intensity wet spells. In the new reality of regulatory restrictions and climate change, absence of additional surface water storage and Delta conveyance would be critical limiting factors to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

Surface Water and Groundwater Management

In California, as in other states, water management practices and the water rights system traditionally have treated surface water and groundwater as two unconnected resources. However, as explained previously, there is often a high degree of hydraulic connection between the two. Under predevelopment conditions, many streams receive dry-weather flow or baseflow from groundwater, and streams provide wet weather recharge to groundwater. Water quality and the environment can also be influenced by the interaction between surface water and groundwater. Incomplete understanding of these connections can lead to unintended consequences. The planning of conjunctive management should consider and evaluate potential impacts resulting from groundwater and stream interaction, including those on the environment. For example, studies by the University of California, Davis indicate that long-term groundwater pumping in Sacramento County has reduced or eliminated dry season baseflow in sections of the Cosumnes River with potential impacts on riparian habitat and anadromous fish (Fleckenstein et al. 2004).

The authority for managing different aspects of groundwater and surface water resources in California is separated among federal, tribal, State, and local agencies. Several examples highlight this issue.

1. State Water Resources Control Board regulates surface water rights dating from 1914, but not rights prior to 1914.
2. Regional water quality control boards regulate waste discharges that might impact groundwater quality, but not the rights to use groundwater.
3. County groundwater ordinances and local agency groundwater management plans often apply only to a portion of the groundwater basin, and counties or local agencies with jurisdictions that overlie the same groundwater basin do not necessarily have consistent management objectives in their groundwater ordinances or management plans.

4. Except in adjudicated basins and in some areas with adopted groundwater management plans, individuals have few restrictions on how much groundwater they can use, provided the water has beneficial uses. Because of the connection between surface water and groundwater, unmanaged groundwater use will eventually affect other water users and may have significant impacts on the environment and economy. Incomplete understanding of these connections can lead to unintended consequences if projects are designed and built to increase groundwater extraction without adequate safeguards to forestall the potential adverse impacts.

Because most groundwater systems are slow responding systems, any damage to the system may require long periods to recover and any effects on third parties may take a considerable time to reach detectable levels. Planning, monitoring, evaluating, and maintaining a management structure that is able to react to unplanned consequences is key for successful groundwater management. Sustainable conjunctive water management is an important strategy to deal with the existing and future water supply challenges. Management of the entire groundwater basin or hydrologic region is essential for effective conjunctive water management. Conjunctive management will be more effective and efficient if multiple hydrologic regions work together so that the weaknesses and strengths of regions can be coordinated and used for mutual benefit. However, the existing legal and regulatory framework on groundwater use will make it very difficult to plan any large-scale conjunctive water management strategies because groundwater management is a local responsibility (Sax 2002). Under this legal framework, the conjunctive management strategy that can be pursued with minimal effort is limited to groundwater recharge at the local level with local surface water. The State's role in conjunctive management is limited to providing funding to help willing local agencies plan and implement conjunctive management.

Most groundwater management ordinances restrict out-of-county groundwater uses. Some groundwater management plans specify trigger levels for groundwater levels in the basin management objectives (BMOs) to prevent overdraft or water quality problems. However, in many cases there are no mechanisms to address the non-compliance with the BMOs. The current groundwater ordinances, AB 3030 and SB 1938 groundwater management plans and local BMO activities, which were intended for localized groundwater management, appear not to be well suited for implementing regional groundwater management. Recent development in water planning through the collaborative IRWM framework may, however, pave a way to increase cooperation and collaboration among local and regional water entities to design and implement regional conjunctive management programs and projects that will preserve and promote the interests of all stakeholders. Legal and scientific ways of settling the issue of ownership/ extraction rights in a multi-jurisdictional/multi-land owner groundwater basin would be a crucial hurdle to overcome to make regional conjunctive management projects viable and successful.

Water Quality

Groundwater quality can be degraded by naturally occurring or human-introduced chemical constituents, low quality recharge water, or chemical reactions caused by mixing water of differing qualities. Recharge water can also improve groundwater quality. For example, the recharge of surface water with low nitrate will lower the nitrate in groundwater. Protecting human health, the environment, and groundwater quality are all concerns for programs that recharge urban runoff or recycled water into groundwater. The intended end use of the water can also influence the implementation of conjunctive management projects. For example, agriculture can generally use water of lower quality than is needed for urban use, but certain crops can be sensitive to some constituents such as boron.

New and changing understanding of water quality constituents, including emerging contaminants and their risks to human and ecological health, result in changing water quality standards. While this may lead to more healthful water supplies, it also adds uncertainty to planning and implementing conjunctive management projects. A water source may, at the time it is used for recharge, meet all drinking water quality standards. Over time, however, constituent detection capabilities improve and new or changed water quality standards become applicable. As a result, contaminants that were not previously identified or detected may become future water quality problems creating potential liability. In some cases, conjunctive management activities may need to be coordinated with groundwater cleanup activities to achieve multiple benefits to both water supply and groundwater quality.

When water is diverted from streams providing inflows to the Delta, there should be an evaluation of the possible impacts on Delta salinity. Increasing surface storage releases is an option to reduce the impacts on Delta salinity. Various alternative options to address salinity and other critical issues in the Delta are being analyzed and evaluated under the Bay Delta Conservation Plan (California Natural Resources Agency 2013). The preliminary drafts of the plan have been released in multiple stages during March and April 2013.

Environmental Concerns

Environmental concerns related to conjunctive management projects include potential impacts on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters are typically considered water that is “available” for recharge. However, flood flows serve an important function in the ecosystem. Removing or reducing peak flood flows may impact the ecosystem negatively. A key challenge is to balance the instream flow and other environmental needs with the water supply aspects of conjunctive management projects. There may also be environmental impacts from construction and operation of groundwater recharge basins and new conveyance facilities. Conversely, groundwater recharge facilities in some locations may provide important habitat for a variety of wildlife.

Climate Change

Significant changes to California’s hydrologic cycles have been measured by DWR and others in recent years. In the past 100 years, changes in snowpack, runoff timing, and sea level rise have all affected water manager’s ability to capture and deliver water when needed. The anticipated future effects of climate change in California include more extreme flood events in the winter, an overall decrease in Sierra Nevada snowpack, more frequent droughts, and a continued sea level rise (California Department of Water Resources 2008). Managing California’s water supply under 21st century climate conditions will involve adapting and reacting to changes while finding ways to minimize associated energy use. Higher temperatures and changes in runoff patterns resulting from climate change are expected to make droughts occur more frequently and continue for longer periods. As a result, many areas will rely more on groundwater due to reduced surface water supplies. In order to meet this challenge posed by climate change, surface and groundwater resources should be managed conjunctively with the long-term goal of sustaining both these resources.

Adaptation

The planning process for conjunctive management should consider the potential climate change impacts described above and include projects to increase regional resilience. Projects that provide climate adaptation benefits may include surface water storage and groundwater recharge facilities to capture flood flows, injection wells to prevent salt water intrusion in coastal areas and protect water quality, and conveyance facilities to move water from regions with excess supply to drought-affected areas. Conjunctive management plans that integrate floodplain management, groundwater banking, and surface storage could help facilitate system reoperation and provide a framework for the development of local projects with widespread benefits for larger regions.

Additional information on the potential for conjunctive management as a climate change adaptation strategy can be found in Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water (California Department of Water Resources 2008).

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Conjunctive management can be a useful mitigation tool. Groundwater recharge prevents water tables from dropping and then being pumped from lower depths with high energy costs. Managing water in a way that keeps it available within a region during peak use periods prevents the use of energy-intensive alternative water sources. Conjunctive management can also be a source of greenhouse gas emissions from energy consumed by injection wells, conveyance systems, or the building and maintenance of conjunctive management facilities. Therefore, costs and benefits must be carefully weighed.

Funding

There is generally limited funding to develop the infrastructure and monitoring capability for conjunctive management projects. Funding is available as incentives to local agencies to cooperate in the development and implementation of IRWM and groundwater management plans, to study and construct conjunctive management projects, and to track (both statewide and regional) changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, surface water flow, surface water quality, and the interaction of surface water and groundwater.

Recently, St. Amant (2013) in an insightful document further illuminates critical issues that could potentially hinder widespread implementation of conjunctive water management in the Sacramento Valley. The ten issues raised by St. Amant are listed below:

- Effects on non-participating neighbors.
- Problems related to water movement across property boundaries.
- Effects on shallow aquifers from threat of groundwater drainage into deeper aquifers.
- Database for safe and effective conjunctive management and impacts analysis.
- Potential salt water intrusion into aquifers that could result from increased pumping.
- Potential for aquifer compaction and subsidence.
- Gain in water availability from conjunctive management versus streamflow decrease.
- Monitoring of critical benchmarks for potential damage to the natural environment.
- Water quality standards for artificial recharge.
- Institutional system to protect interests of current water users.

Recommendations

1. **Implement a program to promote public education about groundwater.**
   A. By January 31, 2016, DWR and SWRCB will work with other State, tribal, local, and regional agencies and organizations to develop a program and materials for use in schools and other venues to teach groundwater concepts.
   B. Beginning on January 31, 2017, DWR and SWRCB will conduct regularly scheduled public events to explain the following:
      i. Reasons for changes in availability of groundwater.
      ii. Interconnection of surface water and groundwater.
      iii. Benefits of recharging groundwater with surface water and recycled water.
      iv. Importance of protecting groundwater quality and recharge areas.
      v. Reasons for developing a groundwater budget.
      vi. Seasonal versus long-term changes in groundwater levels.
      vii. Potential impacts of climate change on groundwater resources.
2. **Improve collaboration, coordination, and alignment among State, federal, tribal, local, and regional agencies and organizations to help implement sustainable groundwater management to ensure evaluating and sharing data and tools, coordinating programs, and minimizing duplication.** By January 31, 2017, and on an ongoing basis, DWR and the SWRCB will coordinate with State, federal, tribal, local, and regional agencies and organizations to conduct the following activities:
   A. Provide State incentives to local water management agencies to coordinate with tribes and other agencies to take actions that ensure the long-term sustainability of groundwater supply and suitable water quality.
   B. Improve coordination among State, federal, tribal, and local agencies to:
      i. Prevent conflicting rules or guidelines.
      ii. Provide timely regulatory approval.
   C. Form an interagency task force to expedite environmental permitting process for the development, implementation, and operation of conjunctive management, recharge, groundwater cleanup, and water banking facilities when facility operations increase ecosystem services, and include predefined benefits/mitigation for wildlife and wildlife habitat.
   D. Establish a process led by the SWRCB to simplify the water rights permitting process for water transfers designated for conjunctive management in which the recharged water is part of a groundwater management plan and is a beneficial use.
3. **Develop a statewide groundwater management planning Web site or portal to promote easy access to groundwater information such as well completion reports, well drilling, construction, and abandonment standards, groundwater supply and demand, groundwater level and quality, land subsidence, groundwater recharge and conjunctive management, groundwater management plans, and basin studies**. DWR will coordinate with State, federal, tribal, local, and regional agencies and organizations to conduct the following activities:
   A. By January 31, 2016, DWR will prepare an estimate of additional resources needed to implement the required activities as well as the expected benefit of the action for improving management of groundwater in the state.

B. By January 31, 2016, the Legislature will consider changes to CWC Section 13752 to improve public access to well completion reports while addressing key infrastructure security and private ownership concerns.

C. If legislative efforts related to item B are successful, then by January 31, 2018, State agencies will work collaboratively with water agencies, local permitting agencies, and driller organizations to:
   i. Develop an online well completion report submittal system.
   ii. Digitize and make available to the public existing well completion reports to allow improved analysis of groundwater data.
   iii. Build upon efforts started in 2012 to update well drilling, construction, and abandonment standards.

D. By December 31, 2018, DWR will work with SWRCB to implement a Web-based Water Planning and Information Exchange (Water PIE) system that improves state- level integration of groundwater data and provides online access to:
   i. Groundwater supply and demand information.
   ii. Groundwater level and quality data.
   iii. Groundwater recharge and conjunctive management activities.
   iv. Land subsidence information.
   v. Groundwater management plans.
   vi. Groundwater basin studies.

4. **Build essential data to enable sustainable groundwater management by expanding and funding the California Statewide Groundwater Elevation Monitoring (CASGEM) Program with the purpose of maintaining baseline groundwater level data, funding, and providing technical assistance to improve local groundwater management for long- term sustainability, and monitoring impacts of droughts on groundwater resources.**

   A. By January 31, 2015, the Legislature will consider amending the appropriate CWC(s) to commit long-term, dedicated funding to the CASGEM Program established by SB X7-6, and expand the scope of the program to implement monitoring, assessment, and maintenance of baseline groundwater levels data, including data for fractured rock aquifers in areas that are deemed important. The funding should be renewable in each five-year cycle ending in eight and three.

   B. By January 31, 2015, and renewable in each five-year cycle ending in eight and three, the State will continue funding for local groundwater monitoring and management activities and feasibility studies that increase the coordinated use of groundwater and surface water by giving priority to projects that include filling regional and statewide data gaps and conjunctive management conducted in accordance with an IRWM plan. This will provide incentives to local water management agencies to implement groundwater monitoring programs to provide additional data and information needed for adequate characterization of a groundwater basin, subbasin, aquifer, or aquifers under the jurisdiction of the agency or adopted groundwater management plan. Box 8 lists the items that a data collection program should include.

   C. By January 31, 2018, fund, develop, and integrate with CASGEM a program for monitoring impacts of droughts on groundwater resources, including using information from remote sensing-based monitoring of land subsidence associated with increased groundwater extraction by water users due to surface supplies cutback under extremely dry conditions.

Box 8 Components of a Data Collection Program

Data collection programs should include

1. Hydrogeologic characterization of the aquifers.
2. Changes in groundwater levels.
3. Groundwater flow (interbasin flow as well as flow to or from streams).
4. Groundwater quality.
5. Land subsidence.
6. Surface water flow.
7. Surface water quality.
8. Interaction of surface water and groundwater.

5. **Under the CASGEM Basin Prioritization, improve understanding of California's high priority groundwater basins by conducting groundwater basin assessment in conjunction with the CWP five-year production cycle, identifying basins in decline with recognition of both short- and long-term aquifer health, assessing impacts of climate change, identifying management practices for sustainable groundwater management that will prevent waste and unreasonable use of groundwater, and reporting key findings to the Legislature.** By December 31, 2018, DWR will coordinate with State, federal, tribal, local, and regional agencies to utilize the CASGEM Basin Prioritization information to conduct the following groundwater basin assessment activities:
   A. Develop the initial and reoccurring schedule and scope for groundwater basin assessments that will allow data and information sharing under the CWP five-year production cycle.
   B. Use CASGEM and other data, reports, groundwater basin studies, and best available science to compile and evaluate new and existing groundwater supply and demand information, groundwater level and quality data, groundwater recharge and conjunctive management activities, surface water/groundwater interaction, groundwater management planning, and land subsidence information. The State should not duplicate information already being reported by local agencies that may be actively managing CASGEM high priority basins. The State should consult with agencies that have implemented successful conjunctive management programs for insights into specific problems or hurdles that, if removed, would increase the ability for multi-region cooperation to implement conjunctive management projects.
   C. Utilize local groundwater management agency information and data, when available, and develop detailed groundwater basin assessment reports by hydrologic region and groundwater basin with a special focus on high priority basins that currently are not actively managed. The assessment reports will:
      i. Characterize the groundwater basins.
      ii. Identify basins in decline.
      iii. Assess the sustainability of groundwater resources in terms of historical and existing trends.
      iv. Evaluate anticipated impacts of climate change on groundwater resources using future scenario projections with a special focus on basins where groundwater budgets and management practices currently have not been established.

v. Identify recommended incentives to establish basin-wide groundwater budgets and adaptive management practices which will promote sustainable groundwater quantity, quality, and the maintenance of groundwater ecosystem services. Box 9 lists the inflow and outflow components that make up a groundwater budget.
vi. Develop a summary report to the Legislature depicting the California's groundwater, which will highlight key findings and recommendations associated with the groundwater basin assessments.

6. **Convene a Statewide Groundwater Management Plan (GWMP) Advisory Committee to develop a GWMP Acceptance Process, evaluate and approve the completeness of existing GWMPs with a special focus on high priority basins that currently are not actively managed, prepare a guidance document of groundwater best management practices (BMPs), and develop improved standards for sustainable groundwater management by utilizing a public process.** In coordination with State, federal, tribal, local, and regional agencies DWR will conduct the following activities:
   A. By January 31, 2015, the Legislature will consider amending the appropriate CWC(s) to authorize DWR to evaluate and assess groundwater management and planning, improve standards for sustainable groundwater management, develop groundwater management and implementation guidance documents, and assist local agencies to equip themselves to manage groundwater resources sustainably.
   B. By January 31, 2017, convene a GWMP Advisory Committee, which will be composed of local and regional water supply and groundwater management entities throughout the state. With guidance from the GWMP Advisory Committee, conduct the following activities:
      i. Implement outreach to local and regional agencies to determine the best path for moving forward by better understanding where and what the needs are.
      ii. Develop a GWMP Acceptance Process.
      iii. Evaluate and approve the completeness of existing GWMPs using the GWMP Acceptance Process.
      iv. Develop a groundwater management and planning and program implementation guidance document that will provide a clear roadmap for GWMP development and implementation based on groundwater BMP.
      v. Identify tools and data sharing needed to improve groundwater management.
      vi. Develop a Web site for local agencies to upload groundwater management documents and allow interested stakeholders to download them.
   C. By January 31, 2018, with guidance from the GWMP Advisory Committee and utilizing a public process, develop improved standards and groundwater BMPs, which should include:
      i. GWMP verification and implementation.
      ii. Goals, objectives, performance measures, and a clear description of additional management steps to be taken if performance measures are not met.
      iii. Groundwater budgets to help understand the total inflow and outflow from the groundwater system.
      iv. Addition of ecosystem services into basin management objectives.
      v. Annual reporting of GWMP implementation activities and performance.
      vi. Reporting groundwater quantity and quality sustainability under current and future scenario projections.

Box 9 Components of a Groundwater Budget

A groundwater water budget quantifies the amount of water flowing into and flowing out of a groundwater basin, subbasin, and aquifer. Using groundwater monitoring data, streamflow data, and groundwater extraction data that are collected by a local agency, the groundwater budget for each groundwater basin, subbasin, and aquifer under the jurisdiction of the local agency or of an associated basin-wide or regional agency should be developed using the following equation:

Inflow – Outflow = Change in Storage

Inflow:

- Infiltration of precipitation.
- Infiltration from stream channels and unlined canals.
- Groundwater flow into the aquifer.
- Artificial recharge.
- Deep percolation from irrigation.

Outflow:

- Contribution of groundwater to surface water flow out of the basin.
- Groundwater flow out of the aquifer.
- Groundwater extraction (pumping).
- Consumptive use.
- Evapotranspiration.

The most uncertain components in the groundwater water budget should be identified to assess potential sources of error.

vii. Conduct impacts assessment (economic and environmental) under current and future scenario projections.
viii. Post GWMPs and annual reports online with groundwater budgets.

7. **Advance groundwater management within the framework of IWM by identifying and including the goals and objectives of local GWMPs in Integrated Regional Water Management Plans (IRWMPs), ensure no transfer of impacts among regions, make regions accept responsibility for addressing risks due to climate change, population growth, and groundwater depletion, adopt stronger standards for local and regional groundwater management, and consider legislation to provide the necessary local and regional authority to effectively manage groundwater resources.**
   A. By January 31, 2015, encourage IRWMPs to identify and include the goals and objectives of local GWMPs.
   B. By January 31, 2017, the Legislature will consider enacting legislation to ensure that local and regional agencies have the incentives, tools, authority, and guidance to develop and enforce groundwater management plans that protect groundwater elevation and quality as well as surface water-groundwater interaction regime and groundwater ecosystem services.
   C. By January 31, 2017, the Legislature will consider enacting legislation to define local and regional responsibilities, give local and regional agencies the authority necessary to manage groundwater sustainably, and ensure no groundwater basin is in danger of being permanently damaged by overdraft which results from operating or utilizing groundwater

basins in an unsustainable manner. The State will be given authority to protect basins that are at risk of permanent damage in the event that local authorized agencies have not made sufficient and timely progress to correct the problem until such time that an adequate local program is in place.

8. **Review analytical tools currently being used and assist local agencies to develop improved tools to assess conjunctive management and groundwater management strategies.** By December 31, 2018, DWR and SWRCB, in collaboration with State, federal, tribal, local, and regional agencies will conduct the following activities:
   A. Develop a conjunctive management tool that will help identify conjunctive management opportunities (projects) and evaluate implementation constraints associated with:
      i. Availability of aquifer space.
      ii. Availability of water for recharge.
      iii. Available means to convey water from source to destination.
      iv. Water quality issues.
      v. Environmental issues.
      vi. Jurisdictional issues.
      vii. Costs and benefits.
      viii. Potential interference between a proposed project and existing projects.
   B. The State will provide incentives to local and regional agencies to develop or adopt analytical tools to support integrated groundwater/surface water modeling and scenario analysis for assessing alternative groundwater management strategies as part of their IRWM planning activities.
9. **Increase local and regional groundwater recharge and storage to reduce groundwater depletion and enhance statewide water resource resiliency.** In coordination with State, federal, tribal, local, and regional agencies the following activities will occur:
   A. By January 31, 2015, under legislative directive and with guidance from the GWMP Advisory Committee, DWR and SWRCB will jointly review and recommend revised or new policies, regulations, and a timeline for implementing this action.
   B. By January 31, 2016, based on the recommendations by DWR and SWRCB, the Legislature will consider revising the CWC to:
      i. Create disincentives for actions which cause groundwater basin overdraft resulting from operating or utilizing groundwater basins in an unsustainable manner.
      ii. Provide incentives to actions that increase recharge.
   C. By January 31, 2016, DWR will make the groundwater recharge maps developed by local agencies as required by AB 359 available to the public and identify priority recharge areas in the state.
   D. By January 31, 2017 and on an ongoing basis, State agencies will work with federal, tribal, local, and regional agencies on other actions to increase local and regional groundwater recharge and storage including:
      i. Cataloging the best science and technologies applied to groundwater recharge and storage.
      ii. Improving interagency coordination and alignment.
      iii. Aligning land use planning with groundwater recharge area protection.
      iv. Completing rulemaking for groundwater recharge with recycled water.

v. Identifying additional data and studies needed to evaluate opportunities for multi-benefit projects, such as capturing and recharging stormwater flows and other water that is not used by other consumers or the environment.

vi. Identifying and evaluating local and regional opportunities to reduce runoff and increase recharge on residential, school, park, and other unpaved areas.

E. By January 31, 2017 and on an ongoing basis, State agencies will work with federal, tribal, local, and regional agencies to support a comprehensive approach to local and regional groundwater management by funding distributed groundwater recharge and storage projects that are identified in groundwater management plans and removing obstacles to implementation of such projects.

10. **Evaluate reoperation of the State's existing water supply and flood control systems**. In collaboration with willing participants, DWR will complete a system reoperation study by 2015. The study will evaluate and document the potential options for reoperation of the state's existing water supply and flood control systems to achieve the objectives of improved water supply reliability, flood hazard reduction, and ecosystem protection and enhancement. The reoperation options will focus on integrating flood protection and water supply systems, reoperating the existing water system in conjunction with effective groundwater management, and improving existing water conveyance systems.

11. **DWR and the U.S. Bureau of Reclamation should:**

A. By the end of 2015, complete the North-of-the-Delta Offstream Storage, Shasta Lake Water Resources, and Upper San Joaquin River Basin Storage investigations.

B. By the end of 2016, complete the investigation of the further enlargement of the Los Vaqueros Reservoir.

C. By the end of 2016, complete an investigation to enlarge/raise B.F. Sisk Dam and San Luis Reservoir.

These projects will also:

D. Evaluate the potential additional benefits of integrating operations of new storage with proposed Delta conveyance improvements, and recommend the critical projects that need to be implemented to expand the state's surface storage.

E. Identify the beneficiaries and cost-share partners for the non-public benefits by 2015.

F. Request funding from the water bond for the public benefits portion through the California Water Commission by 2016, if a state water bond passes in 2014.

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