5

IMPLEMENTATION FACTORS

There are several important considerations when implementing Flood-MAR projects.

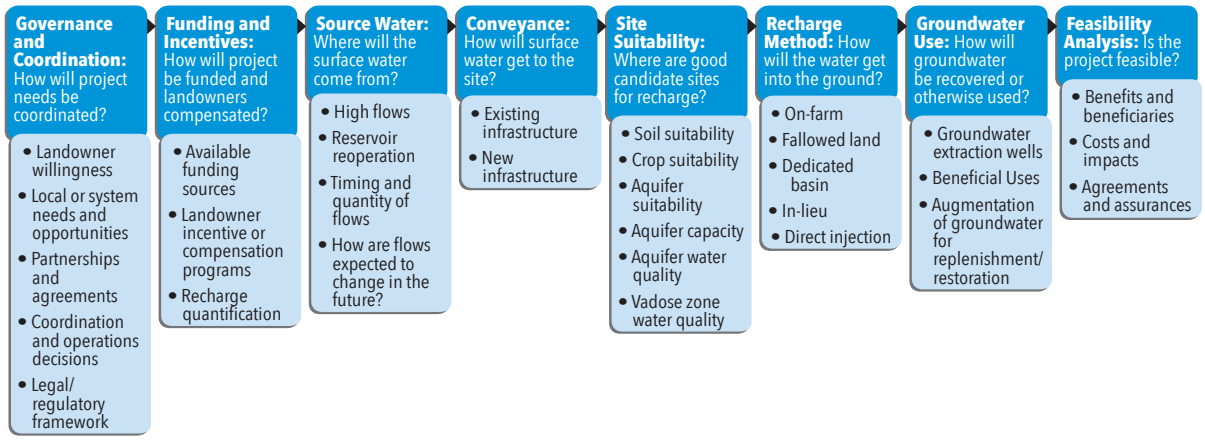
Figure 6 describes the fundamental factors for implementing this resources management strategy. The following pages provide a brief description of these factors.

Governance and Coordination

Governance and coordination may be the most critical factor in developing successful Flood-MAR projects. Governance and coordination is essential to understanding local and system needs and opportunities; developing the necessary partnerships and agreements; navigating the permitting process; and coordinating facility operations and making planned and real-time adjustments.

Water systems in California are very complex, not just in hydrology, but in the way water management is conducted and coordinated. Water infrastructure is owned, operated, and maintained by numerous local, regional, State, federal, tribal, and private entities. Water management decisions need to be coordinated across jurisdictional boundaries, water sectors, interests, uses, and, in some cases, across hydrologic boundaries. Adding to this complexity is the different

FIGURE 6. *Factors for Implementing Flood-MAR*



way surface water and groundwater is managed across the state. Only during the last few years have surface water and groundwater interactions, and the need to manage both resources in an integrated manner, been understood and embraced on a broader scale (with the help of SGMA).

Cooperation of many entities is required for Flood-MAR to be successful. First and foremost, Flood-MAR requires the voluntary participation of landowners, who are compensated for the public benefits from the use of their land. Cooperation among the owners, operators, and maintainers of pertinent water management facilities; potential beneficiaries; and the land owners bearing potential impacts, is required for this resource management strategy to be successful. Successful implementation of Flood-MAR strategies may require new governance structures, decision-making processes, and operations agreements to support cooperation. No one-size-fits-all strategy for governance and cooperation will work throughout the state. Strategies must be appropriate and specific to the location and parties involved.

Funding and Incentives

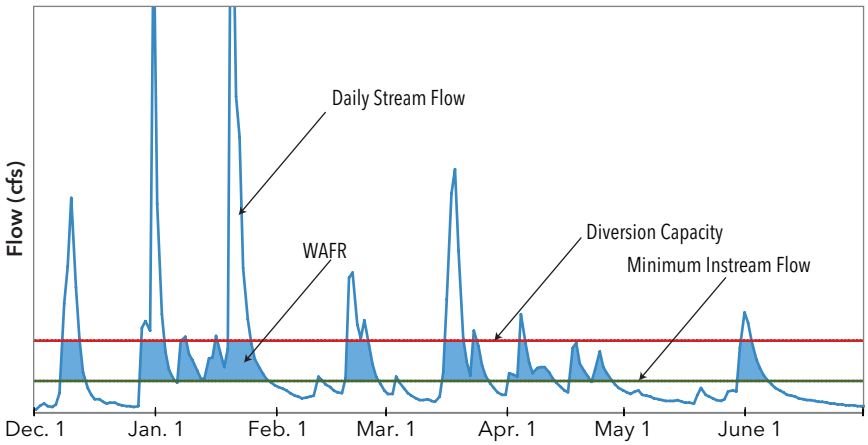
Having sufficient and stable funding to conduct studies, implement pilot and permanent projects, and operate and maintain projects is essential to achieve the intended benefits of Flood-MAR. Currently, most Flood-MAR projects are funded by local entities with some limited support from the State through grant and loan programs. Mechanisms for funding projects in both rural and urban areas will need to be evaluated. Although urban areas have large customer bases to share costs, they still rely on State grant funding to support project implementation. Financing for rural areas is an even greater challenge. Funding partnerships will be critical to wide-scale implementation. Being able to accurately account for recharged water and leveraging multiple benefits to share costs are also critical to funding Flood-MAR projects.

In addition, wide-scale implantation of Flood-MAR projects on private lands will require landowner incentives and/or compensation programs to encourage their participation.

Determining Flood Water Available for Recharge

DWR released the final Water Available for Replenishment (WAFR) report, as required by SGMA, in April 2018. The WAFR report summarizes estimates of surface water available for replenishment that were determined using a synthesis of information—monthly simulated Water Evaluation and Planning (WEAP) model outflows, historical daily gauge data, regulatory environmental flow requirements, water rights, and existing storage and conveyance facilities. Figure 7 provides a simplified hydrograph to illustrate the basic concept used to determine the surface water available for replenishment in the WAFR report (it should be noted that diversion capacity and minimum instream flows are variable, and not static based on several factors, including watershed, upstream reservoirs, and water year type).

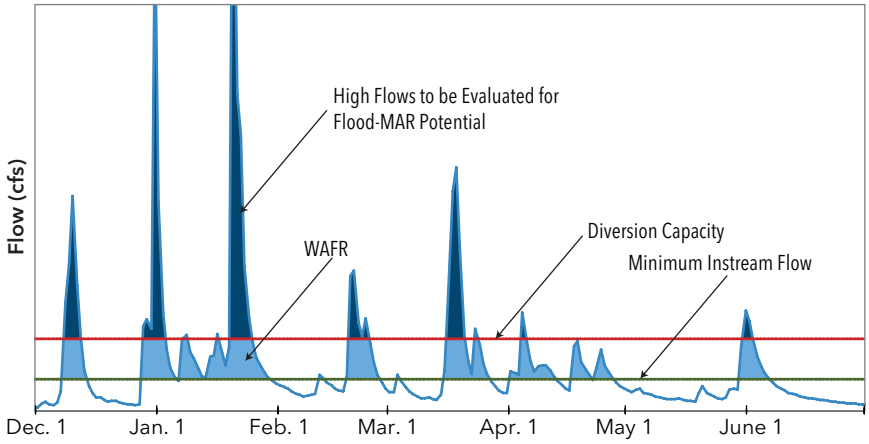
FIGURE 7. *Surface Water Available for Replenishment*



This white paper uses the term *flood water* to designate the flows in a channel that are above regulatory instream flow requirements (the combination of regulatory environmental/water quality flows and water required to satisfy water rights) and are resultant from high precipitation or snowmelt events in a given year. The WAFR analysis generally considered surface water "available" when streamflow exceeded existing water demands and minimum instream flow requirements, and provided some opportunity for additional beneficial use; and "available" water in the WAFR analysis was further limited by the potential division capacity.

Building on the WAFR analysis, identifying the potential water available for Flood-MAR projects goes beyond using current infrastructure and diversion capacity. In the example hydrograph illustrated in Figure 8, flood waters are considered those highlighted in dark blue. These high-flow events can be evaluated as a potential water source for Flood-MAR strategies, but their ability to be used for Flood-MAR purposes will be dependent on many regulatory and legal factors. Further, tradeoffs and risks must be considered when evaluating the potential water available for managed aquifer recharge. For example, the importance of high-flow events to aquatic communities is becoming better understood and a demonstration that diversion of flows does not degrade habitat quality or adversely affect aquatic and riparian species will be required.

FIGURE 8. *Flood Water to be Evaluated for Replenishment*



Note: Peak flows are anticipated to increase with climate change (see Figure 3).

When considering flows available for groundwater recharge, quantity, and timing are important factors. The quantity represents how much water is potentially available for groundwater recharge. The timing represents when it is available, which is of particular importance if the recharge is to occur on active farmland. Timing is also important for instream aquatic species. It is understood that high-flow events can provide environmental benefits, such as bypass flows for pulse protection designed to protect important species, and not all high-flow events should be used for groundwater recharge. Additionally, for many ecological and functional benefits, minimum instream flows may be dynamic. It is important to note that quantity and timing of flow in the future is expected to change because of the effects of climate change. Analyzing how hydrographs may change because of climate change will be essential in project development.

Hydrographs are anticipated to have higher flood peaks that occur earlier in the rainy season because of climate change. Further, quantity and timing for many waterways is controlled by upstream reservoirs. Current operations and potential reoperation of reservoirs are critical considerations for determining water available for managed aquifer recharge.

Not only are river flows expected to change because of climate change but changes in water management are expected. These changes would be motivated by the reduction in water storage available from snowpack, and the potential strategies in system and reservoir operation to better integrate aquifer storage into California's water management portfolio. Changes in water management as a result of climate change should be considered in any analysis.

Conveyance to Recharge Areas

An important consideration for managed recharge projects is how to get the water to detention basins and/or recharge area. In some cases, such as properties adjacent to rivers, channels, and irrigation canals, existing conveyance is sufficient. But areas that currently rely on groundwater may lack surface water conveyance facilities. In many areas of the state, lack of sufficient conveyance facilities is a constraint for Flood-MAR projects. Also, many critically overdrafted basins do not have sufficient infrastructure for managed aquifer recharge.

The operations and capacities of water management facilities are important factors when analyzing managed aquifer recharge. For example, the conveyance of water will have specific physical characteristics (e.g., conveyance capacity) and system operations that may limit the amount, or affect the timing, of water available at a specific site. Capacity constraints can limit the conveyance of water to a groundwater recharge location. New or modified conveyance facilities, and modified operation of existing facilities, are required to maximize managed aquifer recharge statewide.

Determining Suitability of Potential Recharge Areas

Several physical parameters determine the suitability of a potential site for providing groundwater recharge benefits. Some parameters may require significant research to determine suitability or suitable methods. Not all physical parameters are important for every recharge mechanism (e.g., the requirements for recharge basins are different than those for *in-lieu* recharge). Important physical parameters include the following:

Suitability of Soils – For most direct recharge methods, recharge volume is controlled by the rate at which water can infiltrate into the soil and the underlying geologic sediments. Infiltration rates will be faster for sandy soils, and

much slower for soils with higher amounts of clay. Infiltration capacity is a measure of the volume of water that can be recharged per unit of time. It is determined by multiple factors. Recharge suitability indices are available that help determine potential areas where groundwater recharge is feasible.

Currently, there are a few recharge suitability tools or indices recently developed for California:

1. University of California, Davis (UC Davis) Soil Agricultural Groundwater Banking Index (SAGBI) is a suitability index that uses five major indicators for evaluating soil suitability (O'Geen et al, 2015). This tool is fundamentally based upon the Natural Resources Conservation Service's (NRCS) soil surveys, with additional assumptions governing its interpretation and use. UC Davis has identified 3.6 million acres of agricultural land in the state that have excellent or good potential for recharge. https://casoilresource.lawr.ucdavis.edu/sagbi/

2. Recharge Suitability Index developed by Land IQ and the Almond Board of California builds on SAGBI with subsurface geology characteristics from the U.S. Geological Survey, and depth-to-groundwater information from DWR, to provide greater information about site suitability for intentional groundwater recharge.

3. University of California, Santa Cruz has developed methods for identifying shallow and deep integrated mapping that incorporates vegetation, soils, underlying geology and available runoff. http://www.rechargeinitiative.org/

4. AquaCharge is a planning tool developed by Stanford University that helps urban water utilities develop efficient and cost-effective systems to replenish aquifers.

5. Almond Board of California and Lawrence Berkeley National Laboratory partnered to develop a better understanding of subsurface water storage, quality, and movement in relation to almond orchard groundwater recharge test sites. This partnership expands work to identify which orchards are suitable for recharge, and gauge groundwater recharge effects on almond trees, among other efforts.

It must be noted that these tools are generalized planning tools. Implementation at a site requires ground truthing of these data sources including discussions with land owners, engineers, scientists, and irrigation specialists familiar with the area.

Traditional MAR strategies have focused on highly permeable sites, limited to soils with excellent infiltration conditions. Flood-MAR on agricultural lands is not limited to selection of high infiltration rate-lands, but may be suitable for and implemented at low infiltration rates over very large areas of land (e.g., winter irrigation with micro-irrigation systems).

Land Use and Crop Compatibility – Current or proposed land use is an important consideration for determining the suitability of potential recharge areas. Traditionally, groundwater recharge occurs through direct injection using wells or infiltration via dedicated recharge basins. Flood-MAR includes expanding recharge on agricultural and working landscapes. There are specific challenges associated with planted agricultural land uses. Crop compatibility with interim flooding or off-season irrigation must be determined, specifically the ability of the crop's root zone to tolerate saturated conditions for necessary durations or wet conditions during off-season irrigation. This is particularly important for perennial crops and vines, because of the risk of root damage, disease, and crop loss. Further, for trees and vines the timing of ground saturation before or after budbreak affects the crop's tolerance to saturation. Areas planted with annual

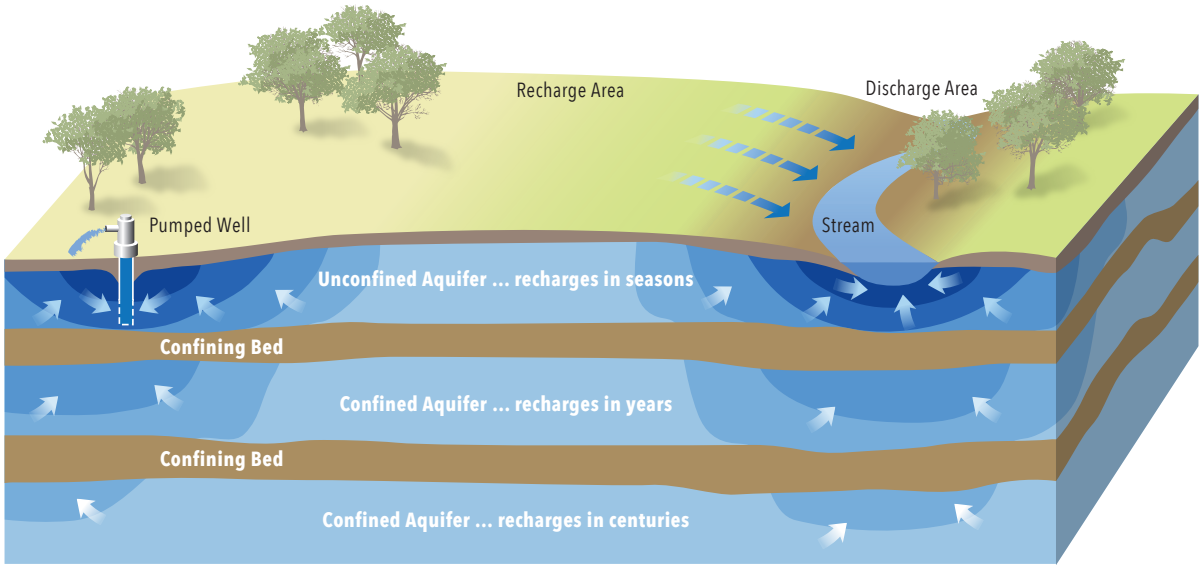
crops and fallowed land have less risk related to crop damage and disease, but timing of saturation is important for next season planting. In addition, crop-type considerations are also important based on the types of fertilizers and pesticides that may be applied and the potential for transporting those chemicals into the aquifer.

For agricultural land uses, the type of infrastructure used for irrigation, such as conveyance facilities for flood irrigation, can facilitate Flood-MAR projects. Some farmers have already installed, or are evaluating the installation of, dual drip and flood irrigation systems that allow for the flooding of land when water is plentiful, and the use of drip irrigation when water is scarce and needs to be conserved.

Aquifer Suitability – Water must not only migrate through the soil surface, but from there it must travel into and through the aquifer system that is used for regional or local groundwater supply. Underlying geology and depth to groundwater are important characteristics for potential recharge areas, and can vary significantly across the state. In the various depositional systems found in the Central Valley, there are locations where surface soils with high-infiltration capacities overlie less-permeable aquifer units. These less-permeable units impede the flow of infiltrated water and limit the amount of water that may reach the target aquifer. In those environments, water may move laterally to downgradient aquifer areas of higher permeability or to surface water bodies. If these are not available, lack of infiltration into the aquifer will limit the available infiltration rates at the land surface.

A schematic of general groundwater flow paths is shown in Figure 9. The less-permeable confining beds tend to be laterally discontinuous, but are abundant in most of California's groundwater basins. Because of California's geologic history, including mountain glaciation in the Sierra Nevada, there exist relatively deep, coarse channel deposits that locally incise through these confining beds, providing ideal 'avenues' for accomplishing shallow and deep recharge (Weissmann et al., 2004). These "incised valley-fill" deposits exist on nearly every major river system on the east side of the Central Valley, yet very few of them have been discovered and mapped. An essential part of augmenting recharge will be the improved characterization of the subsurface geologic architecture that strongly controls where, how, and how fast, groundwater exits and enters these multi-aquifer systems.

FIGURE 9. *General Groundwater Flow Paths*



Available Groundwater Storage Capacity – For shallow unconfined aquifers, available storage capacity is defined as the volume of a basin that is unsaturated and capable of storing additional groundwater. In general, aquifers in the San Joaquin Valley Groundwater Basin are more depleted and have larger storage capacities than those in the Sacramento Valley Groundwater Basin.

Water Quality – Vadose zone and groundwater water quality are important concerns for recharging groundwater. Constituents of concern will vary based on the intended end use of the water, but can include total dissolved solids, nitrate, lead, arsenic, boron, and organics, such as pesticides. Constituents may be anthropogenic or naturally occurring. Taste of extracted water is also an important concern for municipal use. Water quality must be considered for both the groundwater within the aquifer and the surface water being used to recharge the aquifer. Recharging aquifers can have positive and negative impacts on an aquifer. For example, recharging groundwater can dilute an already contaminated aquifer and have beneficial impacts on groundwater quality. Conversely, recharge water can mobilize surface or near surface nitrates or salinity into the aquifer causing negative groundwater quality affects. Even so, there may be long-term improvements in groundwater quality because of recurring recharge with flood waters that are low in salts and nitrates (Bachand et.al. 2014). Short- and long-term groundwater water quality affects will be site specific and an important factor for site suitability.

Groundwater quality information can be found through multiple sources, including local monitoring efforts, DWR's Water Data Library, State Water Boards Groundwater Ambient Monitoring and Assessment Database, and the U.S. Geological Survey's groundwater quality programs.

Regional Considerations – Much of the focus on implementing Flood-MAR has been associated with the Central Valley, in large part because of SGMA. Yet, Flood-MAR projects are being considered in other areas as well, such as the Sierra Nevada and coastal areas. In these applications, other considerations become evident, such as topography, more layered or heterogeneous soils, temperature effects on soils and frost lines, and fewer opportunities for managing upstream flows. Regional considerations also include regional infrastructure and water management, as well as potential impacts on disadvantaged communities that may be reliant on groundwater.

Methods of Recharge

Flood-MAR focuses on the ability to use direct spreading on large acreages of active agricultural land, fallowed land, working landscapes, dedicated recharge basins (new or existing), or open space. For active farmland, recharge water is anticipated to be applied during the non-irrigation season, using existing or additional irrigation equipment or conveyance facilities.

Two methods are often used to replenish groundwater:

1. ***Active Recharge*** includes direct spreading recharge and aquifer injection.

Direct spreading is accomplished by ponding water in dedicated percolation basins, or spreading across confined landscapes where it infiltrates downward into unconfined aquifers. Direct spreading in areas with highly permeable geologic materials can result in a rapid, efficient, and economical way to recharge the aquifer. This recharge method usually

requires large, dedicated land areas. Some recharge also occurs with the use of unlined water conveyance facilities.

Aquifer injection is another active recharge technique. Water is injected into aquifers using injection wells. Aquifer injection has the advantage of working in many geologic conditions, and in relatively small areas, where direct spreading recharge is less suitable. But, this technique is prone to clogging and some degree of maintenance is needed to sustain well-injection performance. Aquifer injection has a higher energy requirement for maintaining adequate water pressure for injection.

2. In-Lieu Recharge

In some areas, recharge may be accomplished by providing an alternative source of water to users who would normally use groundwater, leaving groundwater in place and increasing the potential to improve the groundwater levels, or for later use. In-lieu recharge is not being considered in this white paper.

Capacity for Recovery of Recharged Groundwater

To be considered a water supply benefit, recharged water must be recoverable. To recover the water, enough wells must be present near the sites to extract water from the target aquifers. Some portion of recharged water will not be recoverable. Determining the percentage of recharged water that can be considered recoverable requires development of accounting tools, groundwater monitoring networks, and groundwater modeling tools. Water that is not recoverable for water supply is still beneficial for aquifer replenishment. Also, groundwater that supplements surface water flow (i.e., flows from the aquifer to provide streamflow benefit) is not recoverable from the aquifer for other uses.

Costs to recover recharged water must also be considered in project planning. The cost to install and operate extraction wells can be prohibitive.

Pilot Projects and Feasibility Analysis

Robust pilot projects and feasibility studies will be required to test and illustrate the potential benefits and impacts of Flood-MAR projects. The economic, environmental, and operations aspects of Flood-MAR projects need to be well understood to ensure successful partnerships and leverage multiple funding sources. Project proponents will need to understand:

- Water resources operations and socioeconomic, ecosystem, and water quality conditions, with and without the project.
- Physical changes caused by the project and if changes are beneficial or detrimental.
- How benefits and impacts can be monetized.
- Costs to construct, as well as operate and maintain, projects.
- How to allocate costs to beneficiaries and compare benefits to costs.