Excerpt from Section 8 of the Solano Subbasin Groundwater Sustainability Plan, containing a Project and Management Action prepared by The Freshwater Trust.

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LSCE Team. 2021. Solano Subbasin Groundwater Sustainability Plan, Volume 1, Main Report. Prepared for the Solano Collaborative, November 30, 2021.

Section 8,4.3. Rainfall Managed Aquifer Recharge (Rain-MAR) Demonstration Project was prepared by the Freshwater Trust and submitted to Luhdorff & Scalmanini Consulting Engineers in August 2021.

8.4.3. Rainfall Managed Aquifer Recharge (Rain-MAR) Demonstration Project

8.4.3.1. Project Description

The Rainfall Managed Aquifer Recharge (Rain-MAR) Demonstration Project is a voluntary demonstration to evaluate the use of specific MAR activities on local farms to generate multiple benefits for groundwater sustainability and stormwater management. Working with willing landowners, the project will develop and test methods for maximizing retention of precipitation on and reducing sheet runoff from agricultural fields in the Northwest Focus Area during winter storm events. In addition to recent groundwater level declines, the Northwest Focus Area drains to areas with floodwater and stormwater management issues according to the Dixon Watershed Management Plan.

TFT has worked closely with NRCS and the Dixon RCD to develop preliminary protocols for Rain-MAR practices. TFT also developed prioritization criteria to identify agricultural fields most conducive to Rain-MAR and methods to estimate volumetric benefits and implementation costs at a field scale.

Applying these methods, TFT has identified 108 agricultural fields suitable for Rain-MAR within the Northwest Focus Area, including five fields where both the sump and berm methods are feasible and an additional 103 fields where only the sump method would be feasible. For this demonstration project, suitable sites will require the participation of willing landowners and fields with the following optimal characteristics: soil types, SAGBI rating[8], subsurface soil texture from nearby well construction logs,

[8] California Soil Resource Lab. 2021. Soil Agricultural Groundwater Banking Index. https://casoilresource.lawr.ucdavis.edu/sagbi/ The SAGBI scores for the area are the primary factor limiting eligibility for the berm form of Rain-MAR. Conversely, sumps are dug deeper than the surficial depth evaluated by SAGBI; therefore, low SAGBI values are not a factor in determining site eligibility for the sump method.

groundwater levels as documented by groundwater monitoring efforts, crop types, field size, and topography.

This work has been supported by California NRCS through a Conservation Innovation Grant (CIG Grant # NR209104XXXXG007) and through a Sustainable Groundwater Planning Grant from DWR (Proposition 68 funding, project titled *Solano Subbasin GSP Development and Well Installation Project*). Documentation of the methods and feasibility analysis for recharge in the northern Solano Subbasin is included in Appendix 8B.

The objectives of the Rain-MAR Demonstration Project are to:

A. Implement two methods of Rain-MAR (each on at least one field): (1) using a pre-existing end of field sump or (2) grading temporary 18-inch berms along the field edge, to reduce runoff and increase infiltration of rainwater between December and February for up to three years. Water will be obtained by capturing winter precipitation that falls directly onto the field.

B. Design Rain-MAR practices so they avoid or minimize impacts to the normal use of the demonstration fields for growing healthy and abundant agricultural crops, and to avoid the potential for adverse impacts to neighboring fields.

C. Evaluate the (1) volume and rate of groundwater infiltration (percolation), and (2) the volume of captured runoff resulting from the practice on each demonstration field as compared with similar control fields where the practice is not applied.

D. Monitor and evaluate mounding, crop health, and nitrate risk on both demonstration and control fields.

E. Field-test a groundwater accounting system using a network of monitoring sensors, data transmission technology, and secure web-tools that could be used for tracking and crediting of groundwater recharge actions in the future.

F. Develop recommendations for a future management program that provides incentives to growers for voluntary practices to recharge groundwater and prevent runoff in conjunction with ongoing agricultural production in the Northwest Focus Area.

Demonstration Project Implementation. Once GSAs secure a funding source, the demonstration project would be implemented on two or more annual crop fields in the Northwest Focus Area of the Solano Subbasin, generally located to the east of Highway 505, north of Highway 80, and south of Putah Creek (**Figure 8-2**.). Additional fields will be monitored (with no Rain-MAR activities) as control sites. Depending on local needs, the Solano GSA Collaborative and/or local partners may opt to seek funding to implement the proposed demonstration. Project outcomes will be analyzed, reported, and, if appropriate, applied to the development and implementation of a Rain-MAR program for the Northwest Focus Area.

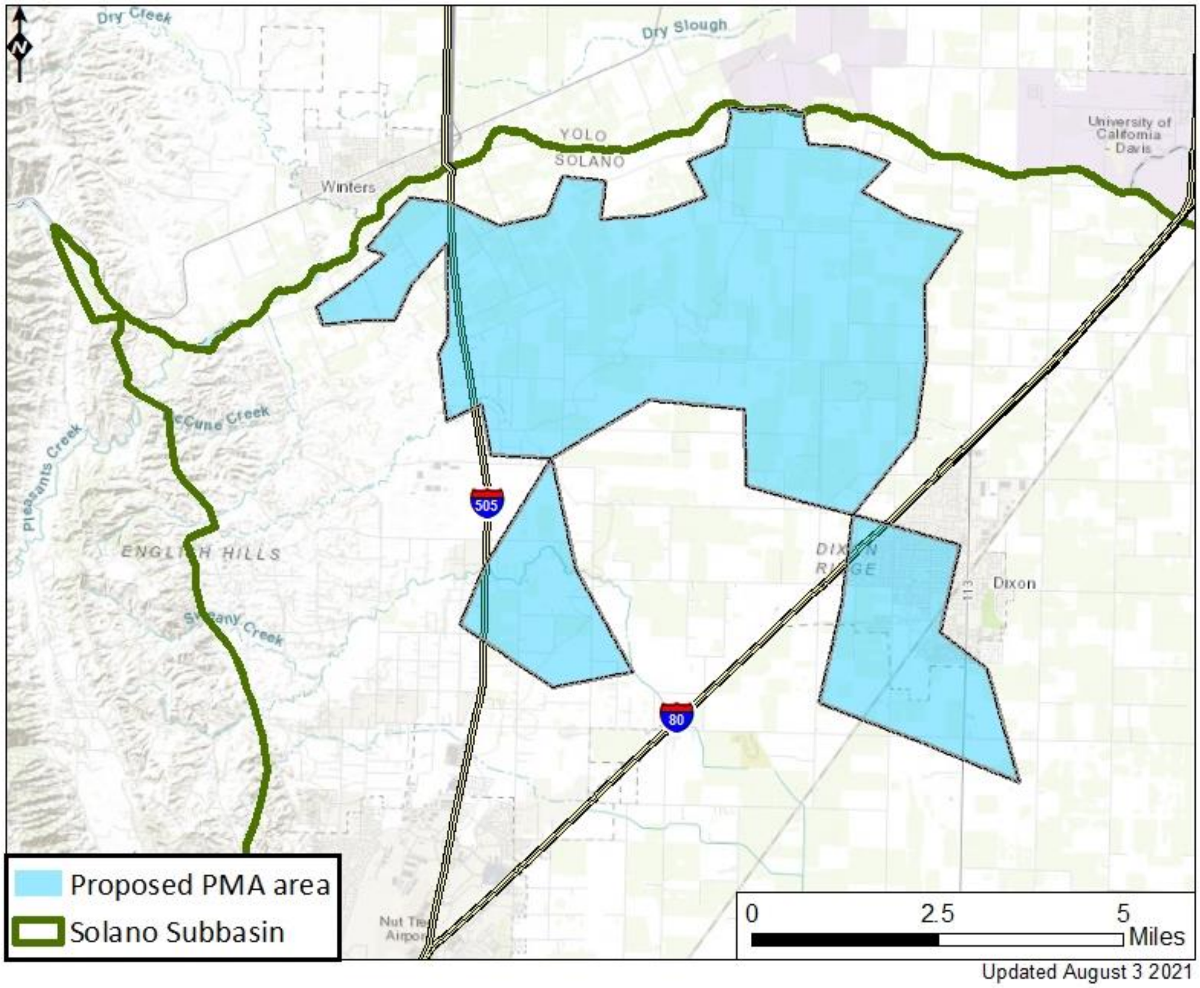

Figure 8-2: Proposed Rain-MAR Demonstration Project Area

The demonstration projects would occur within the portion of the Northwest Focus Area that is east of Highway 505, north of Highway 80, and south of Putah Creek.

Implementation of this project will commence with the selection of suitable sites for multi-benefit recharge. GSAs would conduct outreach to local growers in the Northwest Focus Area through existing communication pathways described in Section 9, potentially with support from TFT and/or local RCDs. Once demonstration sites are selected, site-level project objectives will be defined, an implementation and monitoring plan developed, fields will be prepared, and monitoring equipment deployed on treatment and control sites. At the conclusion of each season, results from treatment and control fields will be analyzed to quantify site level benefits, assess potential unintended impacts, and determine whether objectives are met. Actual project costs will be itemized and evaluated for comparison with pre-project estimates to refine methods for estimating project costs. Monitoring methods are described further below.

Future Program Development. Lessons learned from the demonstration project will be used to develop a future management program to recharge the aquifer, increase baseflows to local streams, or benefit

GDEs in the Northwest Focus Area while providing flood-reduction benefits downstream in an area with chronic flooding and drainage issues.

Results from the demonstration sites may also be used to update and refine project optimization criteria in the Solano Agricultural Scenario Planning System (discussed in Section 8.6.2).

8.4.3.2. Operation and Monitoring

Operations. Rain-MAR will be applied on a minimum of two fields to demonstrate the sump and berm form of the practice. The treatment practices are as follows:

1. "Berm" method: Initial construction of berms is designed to be consistent with NRCS Interim Practice Standards 817 (On Farm Recharge), using the additional Practice Standard 644 (Wetland Wildlife Habitat Management), and 356 (Dike). This practice will construct 18-inch berms around the perimeter of the treatment field, using three passes with a plow, to capture winter stormwater that would otherwise runoff the field via sheet flow. Maintenance is based on the NRCS Practice Standard 378 (Pond) maintenance of embankments, and annually maintains existing berm field perimeters (that may have been impacted by autumn harvest, pruning, etc.) to ensure they will capture winter stormwater. Berm maintenance occurs annually and includes an inspection, cleaning, repairing eroded areas, compaction, and removal of debris.

2. "Sump" method: Based on the maintenance portions of the draft NRCS Practice Standard 815 (Groundwater Recharge Basin or Trench) and NRCS practice 447 (Tailwater Recovery), this practice involves excavating a sump on the lowest elevation edge of a field. Sump maintenance for this practice involves maintaining access to the sump by repairing undercut and eroded areas, periodic cleaning and removal of debris and sediment from traps, trash racks, and structures, periodic re-grading to maintain proper flow lines and functionality, and periodic removal of surface crusts (light tilling) when infiltration rate is reduced significantly. Sump dimensions are assumed to be 40 feet wide, 10 feet deep, and a quarter of the perimeter of the field in length.

Monitoring. One field will be used as a control each year and will be used for comparing expected benefits of MAR on the other demonstration fields. Monitoring will vary depending upon the type of Rain-MAR employed on the demonstration fields.

Prior to berm construction or use of sumps, monitoring instrumentation will be deployed at treatment fields and control sites. For instance, depending on the site-specific monitoring design, pressure transducers or flow meters may be installed at inlets and outlets and in adjacent wells to facilitate measurement of applied water depths and changes in groundwater depth.

For the sump method, water depth in the sump will be measured using a stage gauging ruler and converted to volume of water by a predefined relationship between sump height and volume. A flow measuring device will be required at the outlet of the sump to measure any spillage. A shallow monitoring well, near the sump, will be used to monitor the groundwater elevation.

For the berm method, multiple stage gauging rulers will be set up in the field to get an average depth of ponded water due to captured runoff from the field. A flow measuring device will be required at the outlet of the field to measure any water that may leave the field as surface flow. A shallow monitoring well, on or near the recharge field, will be used to monitor the groundwater elevation.

8.4.3.3. Water Source

Precipitation will be the sole source of water for the project. Other sources of surface water will not be used.

8.4.3.4. Construction Activities and Requirements

The demonstration project will focus on two forms of Rain-MAR: one that uses a sump to capture sheet flow runoff direct to a corner of the field and one that uses berms around much of the perimeter of the field to retain sheet flow on the field. The program is designed to work within existing field infrastructure and irrigation systems, with modest on-farm water management modifications. If suitable sites are available, the sump treatment will be implemented on a field with a pre-existing basin, such as a tailwater return system that can be re-purposed for the project to reduce implementation costs. The berm treatment will be a temporary feature requiring grading of an 18-inch earthen berm on the downslope end of the field margin.

8.4.3.5. Relationship to Sustainability Criteria

In a typical agricultural site, the captured rainwater may serve a variety of functions for groundwater management, each with associated benefits to either aquifer storage, GDEs, or baseflows in streams. Rain-MAR practices can be prioritized on farms where it will provide one of these specific benefits, if monitoring of the Subbasin indicates that support of storage, ecosystems, or baseflows is needed. Individual sites where Rain-MAR is considered should be evaluated for the potential benefit, using the data generated under the development of this GSP to determine the likely fate of infiltrated water.

Infiltrated water can benefit aquifer storage, particularly in the unconfined portion of the aquifer system. In some winters, precipitation will not be sufficient for infiltrated water to reach aquifer; however, Rain-MAR may have the effect of retaining soil moisture longer into the spring than without the practice, allowing delayed early season irrigation.

Infiltrated water can benefit GDEs by raising the elevation of the groundwater table.

Infiltrated water can benefit baseflows by reducing seepage in a losing stream, increasing baseflows in a gaining stream, or increasing stage at a period of critical flow for various species.

Infiltrated water can benefit local small water systems and private domestic water supply wells in areas where these wells are threatened by dewatering from excess nearby groundwater pumping. Potential benefits to private domestic water supply wells and small community water systems will be factored into project selection.

Project selection analyses also include criteria to avoid contributing to undesirable results. Fields would be removed from consideration where recharge may contribute to groundwater quality concerns in the vicinity of community water systems or private domestic water supply wells.

8.4.3.6. Expected Benefits

Demonstration Project: Expected Volumetric Benefits. Two representative fields were chosen to estimate the volumetric benefits of the proposed Rain-MAR demonstration project, including one field for the sump method and for the berm method. The selection of the fields were based on the amount of additional precipitation retained per acre. **Table 8-8** summarizes the estimated volumetric benefits and implementation costs for each method on the demonstration fields.

The estimated benefits include a range of values in representative DWR Water Years, “critical” and “wet”, as classified for the Sacramento Valley. CIMIS data from Water Years 2015 and 2017 were used to represent a Critical and Wet year, respectively, representing both ends of the precipitation spectrum. The estimated costs include implementation and maintenance of the sump and berm on the representative treatment fields. The sump method assumes use of any pre-existing basin.

Table 8-8: Demonstration project: estimated volumetric benefits of Rain-MAR (AF)

	Sump method		Berm method	
Project Acreage (representative field)	141		117	
	Total volume	*Per acre*	*Total volume*	*Per acre*
Annual additional infiltration, wet year (AF)	95.9	0.68	65.6	0.56
Annual additional infiltration, critical year (AF)	53.0	0.38	40.7	0.35
Prevented annual runoff, wet year (AF)	112.8	0.80	77.1	0.66
Prevented annual runoff, critical year (AF)	62.3	0.44	47.9	0.41
Average annual cost*	$13,270	$94	$1,975	$17
10-year cost*	$132,699	$941	$19,747	$168

**Methods and details of cost estimates are described below in Section 8.4.3.10 (“Cost Factors”)*

The cost estimate reflects expenses for implementation of the practice and does not include agency costs for outreach, recruitment, and the design and deployment of project monitoring. In general, an additional 20% should be added for these tasks.

As shown in **Table 8-8**, the volumetric benefit of both forms of Rain-MAR, even when optimal fields are chosen, result in less than one AF of additional infiltration per year. To have an impact on groundwater level, baseflows, or GDEs, MAR practices would need to be implemented on a substantial number of fields distributed across the Northwest Focus Area.

Volumetric Benefits of Hypothetical Multi-Benefit Incentive Program in Northwest Focus Area

If groundwater levels decline near or below minimum thresholds, a program may be needed to support recharge in those areas where undesirable results may occur.

To illustrate the efficacy of distributed MAR practices over a broader area, a hypothetical scenario was developed for the Northwest Focus Area. to calculate the expected benefits of a multi-benefit incentive program. Approximately 6,000 acres of MAR-suitable fields were identified. Assuming a $100,000 annual investment over ten years, fields were ranked based on infiltration potential. Results are summarized in **Table 8-9**.

Table 8-9: Hypothetical Rain-MAR Program for the Northwest Focus Area: Estimated volumetric benefits (AF)

	Cost Efficient Program Scenario ($100,000 annually, optimized for maximum infiltration)	
Total Project Acreage	1,098	
Number of Fields	13	
	Total	*Per acre*
Annual additional infiltration, wet year (AF)	860	0.78
Annual additional infiltration, critical year (AF)	466	0.42
Prevented annual runoff, wet year (AF)	1,011	0.92
Prevented annual runoff, critical year (AF)	548	0.50
10-year Cost*	$969,404	$882
Average annual cost*	$96,940	$88

**Methods and details of cost estimates are described below in Section 8.4.3.10 ("Cost Factors")*

Modeling of Hypothetical Rain-MAR Program in Northwest Focus Area

To estimate the effect of this program on the groundwater budget and groundwater levels in the Northwest Focus Area, a potential configuration of the hypothetical Rain-MAR program was modeled in the Solano IHM. The hypothetical model scenario was conceptualized recognizing that a Rain-MAR incentive program should be open to most or all growers willing to participate, particularly those whose fields are potentially suitable for recharge. The modeling scenario was thus developed to estimate the total potential recharge from areas that could participate in the Rain-MAR program, including areas beyond just the cost-efficient program scenario optimized for maximum infiltration (described in the previous section).

The hypothetical Rain-MAR program model scenario was developed assuming that up to 50 percent of growers with fields suitable for recharge would participate in the program in an average year. Areas that are potentially suitable for recharge were identified primarily by recharge potential and cropping. Recharge potential was quantified based on the area-weighted SAGBI rating of fields in the Northwest Focus Area, considering only fields with a SAGBI rating of "moderately good" or higher. Crop areas suitable for recharge were evaluated based on 2018 Land IQ spatial land use data (Land IQ, 2021), filtering land areas by crop type to exclude permanent crops, rice, crops with growing seasons unsuited to rainfall capture, and non-agricultural areas. Based on these criteria, the total potential recharge area assumed to participate in the Rain-MAR program was estimated to be approximately 6,100 acres.

The Rain-MAR program was simulated in the Solano IHM by retaining the simulated runoff of precipitation on selected fields within the Northwest Focus Area that correspond to crop types and areas identified as suitable for recharge. Across the 6,100 acres estimated to participate in the Rain-MAR program, the average annual simulated increase in deep percolation of precipitation captured on participating fields was approximately 3,000 AF/yr. This additional recharge helped to stabilize simulated groundwater levels over the projected future water budget period.

8.4.3.7. Timetable for Implementation

This is a voluntary PMA that is intended to inform protocols for the implementation of Rain-MAR projects on a programmatic scale. As such, the demonstration projects would ideally occur in the early years of GSP implementation.

Once funded and initiated, willing landowners will be recruited, and site-specific implementation and monitoring designs will be developed for demonstration sites. Installation of berms and sumps should occur after fall harvest prior to the late fall/winter precipitation to retain maximum rainwater for infiltration, generally following the timeline in **Table 8-10**.

Table 8-10: Rain-MAR Demonstration Project: Implementation Timeline

Timeline Activity	Start	End
Participant Applications	April-May	August-September
Site Selection	June-July	July-September
Site Preparation and Monitoring Design	June-July	July-September
Operation (Field Flooding)	November-December	February-March
Financial Incentive Payment (If Applicable)	October	June

8.4.3.8. Notice to Public and Other Agencies

The general public, stakeholders, impacted users and other agencies will be engaged in project implementation activities through outreach and communication channels, as identified in Section 9 of the GSP.

8.4.3.9. Legal Authority, Permitting Processes, and Regulatory Control

These Rain-MAR projects use no other sources of surface water, and they leverage common and existing agricultural practices to manage precipitation to reduce flood peaks. The following agencies may have roles for recharge projects in general: the respective GSA, Solano County, and the State Water Resources Control Board (SWRCB).

State and local public agencies in California are required to comply with the California Environmental Quality Act (CEQA) when they take discretionary actions, including implementing a project or program that makes a significant change to the environment. The demonstration project is exempt from CEQA under a class 6 categorical exemption for data collection. However, any resulting program will need to comply CEQA, potentially an initial study with a mitigated negative declaration.

8.4.3.10. Cost Factors

Methods for Cost Estimates. Cost estimates for Rain-MAR are derived from crop enterprise budgets from the University of California Davis, the most recent NRCS cost scenarios for the respective practices, and peer-reviewed literature, with adjustments made for local circumstances in the Solano Subbasin based on technical reports and communication with local growers or other technical experts. All values were transformed into a per acre (variable) or per practice (fixed) values. Cost estimates are based on the following factors:

- *Planning and Design:* Planning and design costs are based on NRCS practice standard 142 - Fish and Wildlife Habitat Plan – Written, Scenario #26 - Fish & Wildlife Habitat Management CAP (2 Land Uses).
- *Capital Costs:* Capital costs include materials and labor for installation of flashboard risers. Cost estimates assume participating growers will already have the necessary machinery and equipment (plows, tractors, and excavators) to create and maintain berms and sumps.
- *Operations and Maintenance:* Operations and maintenance costs consist of labor costs for grading fields, cleaning trash racks, maintaining access, excavating the top layer of accumulated sediment, etc.

Opportunity costs and impact mitigation. Cost estimates assume that the sump does not replace any land currently used to grow crops. The feasibility assessment used to identify suitable fields attempts to eliminate fields where the practice may cause flood damage or would negatively impact agricultural production or crop yield. Therefore, opportunity costs or costs to mitigate potential impacts associated with Rain-MAR practices are not included in the project cost estimates.

Data limitations. Cost estimates may overestimate actual implementation costs. The cost model assumes all fields would require new construction of sumps or berms, even though some fields already have sumps or berms that are used during summer irrigation. For the fields that have existing sumps (tailwater recovery pits) and berms, nearly all the establishment (Year 1) costs would be eliminated. Another potential area for reduced costs would be if a grower owns multiple neighboring fields that all drain into a single sump (as is typically the case with practice for tailwater recovery ponds).

Cost Estimate for Demonstration Project. The demonstration project will involve recruitment of willing participants and implementation of Rain-MAR on at least two fields, one using sumps, the other berms. Estimated annual and 10-years costs are summarized in **Table 8-8** above.

Example Cost Scenario for Potential Multi-Benefit Incentive Program in Northwest Focus Area. Results for programmatic implementation of Rain-MAR throughout the Northwest Focus Area are summarized in **Table 8-9**. This example program scenario assumes $100,000 is available annually to implement Rain-MAR practices within the targeted portion of Northwest Focus Area over ten years. The resulting optimized landscape-level scenario includes 13 fields and results in an additional 466 AF to 860 AF of additional infiltration per year, depending on precipitation. The most cost-efficient feasible projects were included in this optimized scenario, which included five projects using the berm method of Rain-MAR and eight projects using the sump method. Overall, the cost of achieving additional infiltration is approximately $113/AF in a wet year and $208/AF in a critical dry year. The program would also result in flood mitigation via prevented annual runoff during the rainy months.

8.4.3.11. Project Uncertainty

The Rain-MAR practice is designed as an alternative to methods of MAR that require applying excess surface waters to fields (Flood-MAR, Ag-MAR). MAR methods that rely on the delivery of surface water have the potential to infiltrate larger volumes of water on a given field because the volume of applied water is not constrained by precipitation. However, these methods also require more infrastructure for water diversions, conveyance, and on-farm distribution and must address constraints relating to surface water rights, access to excess flows, establishing legal authority, and procuring permits. Conversely, Rain-MAR is immediately implementable across a significantly larger number of fields.

The Westside Streams project (Section 8.4.2) proposes to work with willing landowners to divert excess winter flows from local streams to fields in the Northwest Focus Area. As such, the Westside Streams PMA will help to address constraints to the use of surface water for Flood-MAR on fields in the Solano Subbasin.

A future program in the Northwest Focus Area will incorporate lessons learned from both the Westside Streams and Rain-MAR PMAs to offer a portfolio of practices that can maximize multi-benefit outcomes and tailored to the needs of local growers. Likewise, GSAs may work with Solano Irrigation District, private irrigation systems and drainage districts, and local growers to apply these lessons learned to develop MAR practices that deliver excess surface waters for strategic groundwater recharge.