Appendix 11

Economic Analysis

Contents

Economic Analysis

Theme Subcommittee Members

The Flood-MAR Economic Analysis Subcommittee is a multi-disciplinary group of academic experts and practitioners representing universities, state and federal agencies, environmental groups, and other non-governmental organizations. The subcommittee consists of 2 co-chairs, 10 subcommittee members, and a theme coordinator and a theme support person. Subcommittee members are listed by name, title, and affiliation below.

Position	Name and Title	Affiliation	Email
State Co-Chair	Emmanuel Asinas, Ph.D., Chief, Economic Analysis	California Department of Water Resources (DWR)	emmanuel.asinas@water.ca.gov
Non-State Co-Chair	Josué Medellín-Azuara, Ph.D., Acting Associate Professor	University of California (UC), Merced	jmedellin-azuara@ucmerced.edu
Sub-committee Member	Maura Allaire, Ph.D., Assistant Professor	UC Irvine	mallaire@uci.edu
Sub-committee Member	Andrew Ayres, Ph.D., Economist, Ecosystems	Environmental Defense Fund	aayres@edf.org
Sub-committee Member	Ellen Bruno, Ph.D., Cooperative Extension Specialist	UC Berkeley	ebruno@berkeley.edu
Sub-committee Member	Anita Chaudhry, Ph.D., Professor	California State University, Chico	achaudhry@csuchico.edu
Sub-committee Member	Robert Gailey, Consulting Hydrogeologist	RM Gailey Consulting Hydrogeologist	rob@rmgailey.com
Sub-committee	Abby Hart, Agriculture Project	The Nature Conservancy	abigail.hart@tnc.org

Position	Name and Title	Affiliation	Email
Member	Director – Water Program		
Sub-committee Member	Ann Hayden, Senior Director, California Habitat Exchange	Environmental Defense Fund	ahayden@edf.org
Sub-Committee Member	John Kucharski, Senior Economist	U.S. Army Corps of Engineers	John.R.Kucharski@usace.army.mil
Sub-committee Member	Kelli McCune, Project Director – Conservation Incentives	Sustainable Conservation	kmccune@suscon.org
Sub-Committee Member	Samuel Sandoval-Solis, Ph.D., Associate Professor, Cooperative Extension Specialist	UC Davis	samsandoval@ucdavis.edu
Theme Coordinator	Jenny Marr, P.E., Supervising Water Resources Engineer	DWR	jmarr@water.ca.gov
Theme Support	Romain Maendly, P.E., Senior Engineer	DWR	romain.maendly@water.ca.gov

Engagement Process

The subcommittee used a combination of videoconference meetings, phone and email communications, survey, literature search and stakeholder consultation to develop an active inventory of existing literature and other information related to the economics of groundwater recharge and other relevant topics. The literature search included a review of literature from academic studies, government documents, and studies undertaken by consultants and non-governmental organizations. The subcommittee State co-chair attended a Flood-MAR listening session, hosted by the California Department of Water Resources (DWR) Flood-MAR Program, at the University of California, Merced. The main goal of the session was to get input from farmers and landowners in the Central Valley on Flood-MAR issues they are facing, such as barriers and challenges for implementing Flood-MAR, costs associated with building, maintaining and operating a recharge project and types of incentives that would encourage their participation. The information gathered from the listening session were valuable in helping the subcommittee identify farmers' preferences as well as gaps in research, data, and tools needed to support Flood-MAR. The collected information and engagement resulted in generating the subcommittee's priority list of research, data, and tool needs or actions.

Available Research, Data, and Tools

Below is a compilation of available research, data, and tools related to the economics of groundwater recharge and other relevant topics. This information was compiled by the subcommittee and the DWR Flood-MAR team. This list is, by no means, exhaustive. It serves as an active inventory of relevant literature useful to inform or assess the economic viability of Flood-MAR projects. It will be updated as soon as other relevant information or new research are found.

Agstner B. Undated. *Significance and State of Affairs of Groundwater Economics in the Governance of Transboundary Aquifers*. IGRAC Internship Report.

Aladjem DRE, Sunding D. 2017. *Marketing the Sustainable Groundwater Management Act: Applying Economics to Solve California's Groundwater Problems*. Natural Resources & Environment, a quarterly publication of the Environment, Energy and Resources Law Section of the American Bar Association, Vol. 30, No. 2, Fall 2015. https://www.downeybrand.com/Resources/Publications/103286/Marketing-the-Sustainable-Groundwater-Management-Act-Applying-Economics-to-Solve-Californias-Groundwater-Problems

American Society of Farm Managers and Rural Appraisers. 2017. *2017 Trends in Agricultural Land and Lease Values, California and Nevada*. California Chapter.

AMEC Geomatrix Inc. 2008. *Merced Groundwater Basin Groundwater Management Plan Update*. Merced County, CA. Submitted to Merced Area Groundwater Pool Interests. July 29.

Arellano, JLR. 2015. *Conceptual Framework to Estimate Economic Feasibility of Groundwater Banking on Agricultural Land*. Thesis, Master of Science, Hydrologic Sciences, University of California Davis.

Babbitt C, Hall M, Hayden A, Briones A, Young R, Brozović N. 2017. *2017 Groundwater Trading as a Tool for Implementing California's Sustainable Groundwater Management Act*. Environmental Defense Fund. https://www.edf.org/sites/default/files/documents/water-markets.pdf

Bachand PAM, Horwath WR, Roy S, Choperena J, Cameron D. 2012. *Implications of Using On-Farm Flood Flow Capture to Recharge Groundwater and Mitigate Flood Risks along the Kings River, CA*. In fulfillment of Deliverable: 3c. Technical Analyses and 4a. Final Report for Grant Agreement No. 68-9104-0-128 between Bachand & Associates and the United States Department of Agriculture Natural Resources Conservation Service. September 30.

Bagnasco W, Bourque K, Angosto CL, McPhail L, Schiller A. Undated. *Basin Benefits: Analyzing alternative groundwater replenishment strategies in California's San Joaquin Valley*. Presentation, UCSB Bren School.

Bagnasco W, Bourque K, Angosto CL, McPhail L, Schiller A. 2018. *Multi-Benefit Approaches to Sustainable Groundwater Management. A Framework for California's Groundwater Sustainability Agencies and Stakeholders*. A Group Project submitted in partial satisfaction of the requirements for the degree of Master of Environmental Science and Management for the Bren School of Environmental Science & Management at the University of California, Santa Barbara. April.

Bianchi WC, Lang GJ. 1974. *The City of Fresno's Leaky Acres Ground-Water Recharge Project—Construction and Performance*. Journal American Water Works Association. Vol. 66, No. 3, Ground Water (March 1974), pp. 176-180.

Bland A. 2018. *A New Groundwater Market Emerges in California. Are More on the Way?* Water Deeply June 22.

Borchers JW, Carpenter M. 2014. *Land Subsidence from Groundwater Use in California*. Prepared By Luhdorff and Scalmanini Consulting Engineers, Full Report of Findings. For California Water Foundation, April.

Borchers JW, Grabert VK, Carpenter M, Dalgish B, Cannon D. 2014. *Land Subsidence from Groundwater Use in California*. Full Report of Findings, April.

Botzan TM, Necula AL, Mariño MA, Başağaoğlu H. 1999. *Benefit-Cost Model for an Artificial Recharge Scenario in the San Joaquin Valley, California*. Water Resources Management 13(3):189-203. June.

Bradshaw JL, Luthy RG. 2017. *Modeling and Optimization of Recycled Water Systems to Augment Urban Groundwater Recharge through Underutilized Stormwater Spreading Basins*. Environ. Sci. Technol. 51 (20), pp 11809–11819.

Bruno EM. 2018. *The Economic Impacts of Agricultural Groundwater Markets.* ARE Update 21(6)(2018):9-11. University of California Giannini Foundation of Agricultural Economics. https://giannini.ucop.edu/publications/are-update/issues/2018/21/6/the-economic-impacts-of-agricultural-groundwater-m/

California Department of Water Resources. 2017. *Flood MAR Using Flood Water for Managed Aquifer Recharge to Support Sustainable Water Resources*. White Paper - Discussion Draft. November.

___ 2017b. *Best Management Practices for the Sustainable Management of Groundwater*. Sustainable Management Criteria. Draft. November.

___ 2017c. *Groundwater Sustainability Plans and Projects Proposal Solicitation Package*. September.

___ 2018. *Flood-MAR Research and Data Development Framework*. Discussion Draft. June.

___ 2018 Water Data Library. http://wdl.water.ca.gov/waterdatalibrary/

___ 2018. *Water Available for Replenishment*. Final Report. April.

Calix B.2017. *MID releases stormwater to recharge groundwater sapped amid drought.* Merced Sun Star, January 23.

Chatdarong V. 2001. *Artificial Recharge for Conjunctive Use in Irrigation. The San Joaquin Valley California*. In partial fulfillment of the requirements for the degree of Masters of Engineering in Civil and Environmental Engineering, M.I.T. June.

Dahlke HE. et al., 2018. *Managed Aquifer Recharge as a Tool to Enhance Sustainable Groundwater Management in California: Examples from Field and Modelling Studies*. Chapter 8 in Advances in Chemical Pollution, Environmental Management and Protection Volume 3. Elsevier.

Dahlke HE, Orloff S, Putnam D. *Managed winter flooding of alfalfa recharges groundwater with minimal crop damage*. California Agriculture. Volume 72(1) 65-75, January 16.

Dillon P. 2005. *Future Management of Aquifer Recharge*. Journal of Hydrogeology 13:313–316.

Dillon P, Pavelic P, Page D, Beringen H, Ward J. 2009. *Managed aquifer recharge: an introduction*. Waterlines. Published by the National Water Commission, Canberra.

Earth Economics. 2017. *The Value of Aquifers in Sonoma County*. Tacoma WA.

Farmington Groundwater Recharge Program. 2013. Program Information. http://www.farmingtonprogram.org/

Farmington Groundwater Recharge Program. 2007. Summer 2007 Newsletter. http://www.farmingtonprogram.org/media_folder/newsroom_media/FarmingtonNewsletter2007.pdf

Faunt CC, Sneed M, Traum JT, Brandt J. 2016. *Water availability and land subsidence in the Central Valley, California, USA*. Hydrogeology Journal. Volume 24, Issue 3, pp 675–684 May.

Fisher AT. 2016. *Paying for Groundwater Recharge*. PPIC, May 3.

Fresno Local Agency Formation Commission. 2007. FROM: Rick Ballantyne, Executive Officer; Darrel Schmidt, Deputy Executive Officer. SUBJECT: Consider Adoption – Municipal Service Reviews and Sphere of Influence Updates Prepared for the Following Districts: 1. Consolidated Irrigation District, 2. Fresno Irrigation District, 3. Orange Cove Irrigation District, 4. Riverdale Irrigation District, 5. Tranquility Irrigation District. July 11.

Gailey RM, Fogg GE, Lund JR, MedellÍn-Azuara J (in press). *Maximizing on-farm groundwater recharge with surface reservoir releases: a planning approach and case study in California, USA*. Hydrogeology Journal. (A study for the South American and Cosumnes groundwater basins that combines hydrogeologic factors for successful recharge with economic considerations for large-scale project performance.)

Groundwater Recharge Assessment Tool (GRAT). Sustainable Conservation, https://suscon.org/blog/2017/12/grat/ (A decision support tool that considers factors such as land availability, crop suitability and canal capacity in evaluating desirable location and timing of on-farm Flood-MAR.)

Griebler C, Avramov M. 2015. *Groundwater ecosystem services: a review*. Freshwater Science. 34(1):355–367.

Hanak E, Lund RJ, Thompson B, Cutter W, Gray B, Houston D, Howitt R, Jessoe K, Libecap G, Medellín-Azuara J, Olmstead S, Sumner D, Sunding D, Thomas B, Wilkinson R. 2012. Water and the California Economy. PPIC. http://www.ppic.org/content/pubs/report/R_512EHR.pdf

Hanak E, Jezdimirovic J, Green S, Escriva-Bou A. 2018. *Replenishing Groundwater in the San Joaquin Valley*. PPIC, April. http://www.ppic.org/wp-content/uploads/r-0417ehr.pdf

Jacobs J. 2018. *Farmers tap free-market ideas in bid to rescue aquifer*. Western Water. August 6.

Kasler D, Reese P. 2018. *The Valley floor is sinking, and it's crippling California's ability to deliver water.* Sacramento Bee, July 13 https://www.sacbee.com/news/state/california/water-and-drought/article214631455.html

Kings Basin Water Authority - IRWMP Project List. Adopted 07/18/2012. http://www.krcd.org/_pdf_ukbirwma/UKBIRWMA%20IRWMP%20Project%20List%20-%2007-18-2012.pdf

Kiparsky M, Fisher A, Hanemann W, Bowie J, Kantor R, Coburn C, Lockwood B. 2018. *Recharge Net Metering to Enhance Ground Water Sustainability*. Issue Brief. Berkeley Law, Wheeler Water Institute at Clee, April.

Koundouri, P. 2004. *Current Issues in the Economics of Groundwater Resource Management*. Journal of Economic Surveys 18(5) Pages 703-740.

Lee A. 2005. *Multi-Objective Approaches to Floodplain Management on a Watershed Basis. Floodplain Management Benefit and Cost Analysis Framework*. CDWR Revised Draft, June

Maliva R. 2014. *Economics of Managed Aquifer Recharge*. Water 6, 1257-1279.

Mann, Roger, 2013. *Winter Water Spreading for Groundwater Recharge Economics in the East Central San Joaquin Valley*. Draft. Developed with funding from the Water Foundation. September 23.

M.Cubed. 2018. *Public Benefit Ratio Appeal of Water Storage Investment Program Public Benefit Ratio Review for The Kern Fan Groundwater Storage Project. Appendix E: M.Cubed Technical Memorandum*. Estimate of Benefits from the Kern Fan Groundwater Storage Project. February 23.

M.Cubed. 2017. *Identifying Benefits and Beneficiaries of Groundwater Recharge from Floodwater Diversion*. *Memorandum #1*. Prepared for Sustainable Conservation, March.

M.Cubed. 2016. *Analyzing Cost Effectiveness for Kings Basin Flood Flow Recovery*. Updated Report for Sustainable Conservation – March.

Medellin-Azuara J, MacEwan D, Howitt R, Sumner Da, Lund JR. 2016a. *Economic Analysis of the 2016 California Drought on Agriculture. A Report to the California Department of Food and Agriculture*. Center for Watershed Sciences, UC Davis. Davis, CA, 17 pp.

Medellin-Azuara J, MacEwan D, Howitt R, Sumner Da, Lund JR. 2016b. *Economic Analysis of the 2016 California Drought on Agriculture. Appendix A. The Effect of Declining Groundwater Levels on Supply Well Operations. A Report to the California Department of Food and Agriculture*. Center for Watershed Sciences, UC Davis. Davis, CA, 17 pp.

Medellín-Azuara J, Escriva-Bou A, Jezdimirovic J. 2017. *Water and the Future of the San Joaquin Valley. Technical Appendix C: Potential Economic Impacts of Reducing Water Use on San Joaquin Valley Agriculture*. PPIC.

Medellín-Azuara J, Mendoza-Espinosa L, Pells C, Lund JR. 2013. *Pre-Feasibility Assessment of a Water Fund for the Ensenada Region. Infrastructure and Stakeholder Analyses*. The Nature Conservancy and Center for Watershed Sciences, U. C. Davis, June.

Merced Integrated Regional Water Management Implementation Grant Proposal. 2016. Attachment 8: Benefits and Cost Analysis. NOTE INCLUDES FDR Estimates.

Miller K, Green Nylen N, Doremus H, Owen D, Fisher A. 2018. *When is Groundwater Recharge a Beneficial Use of Surface Water in California?* Issue Brief. UC Water Security and Sustainability Research Institute and UC Berkley Center for Law, Energy and the Environment. August.

Nagappan P. 2016. *Creative Incentives to Boost Groundwater Recharge.* Water Deeply. August 10.

Nelson Timothy, Chou H, Zikalala P, Lund JR, Hui R, Medellín-Azuara. 2016. *Economic and Water Supply Effects of Ending Groundwater Overdraft in California's Central Valley*. San Francisco Estuary and Watershed Science 14(1).

Nightingale HI, Ayars JE, McCormick RL, and Cehrs DC. 1983. *Leaky Acres Recharge Facility: A Ten-Year Evaluation*. Journal of the American Water Resources Association. Volume 19, Issue 3, pages 429–437, June.

Perrone D, Rohde M. 2016. *Benefits and Economic Costs of Managed Aquifer Recharge in California*. San Francisco Estuary and Watershed Science 14(2) https://escholarship.org/uc/item/7sb7440w

Peyton DE. 2003. *Maximizing Infiltration at Leaky Acres*. Southwest Hydrology November/December 2003 page 6. http://web.sahra.arizona.edu/swhydro/archive/V2_N6/dept-ontheground.pdf

Pottinger L. 2018. *Tackling Safe Drinking Water in the San Joaquin Valley*. PPIC October 22. (An interview with Commissioner Herrera).

Quinton A. 2016. *Scientists Flood Almond Orchards to Restore Groundwater in California*. Capital Public Radio. January 20, Sacramento. http://www.capradio.org/articles/2016/01/20/scientists-flood-almond-orchards-to-restore-groundwater-in-california/

Rahman MA, Rusteberg B, Gogu RC, Lobo Ferreira JB, Sauter M. 2012. *A new spatial multi-criteria decision support tool for site selection for implementation of managed aquifer recharge*. Journal of Environmental Management 99: 61-75. Elsevier.

Recharge Roundtable Call To Action: Key Steps for Replenishing California Groundwater. UC Water and Groundwater Resources Association, https://ucmerced.app.box.com/v/rechargeroundtable

RMC. 2015. *Creating an Opportunity: Groundwater Recharge through Winter Flooding of Agricultural Land in the San Joaquin Valley*. October.

RMC Water and Environment. 2012. Subject: *DRAFT Groundwater Recharge Feasibility Study. DRAFT Technical Memorandum. Merced IRWM Plan Development*. Prepared For: Merced IRWM Regional Advisory Committee. December.

RMC Water and Environment. 2013. *Appendix C – Groundwater Recharge Technical Study. Merced IRWMP*. Prepared by: Jim Blanke, August.

Sbranti J.N. 2013. *Merced County is sinking; researchers blame over-pumping of groundwater*. The Modesto Bee, November 21. https://www.modbee.com/news/business/agriculture/article3156994.html

Sears L, Lim D, Lin Lawell C. 2018. *Interjurisdictional Spatial Externalities in Groundwater Management.* U. C. Davis, November.

Sears L, Lim D, Lin Lawell C. 2017. *Spatial Groundwater Management: A Dynamic Game Framework and Application to California*. UC Davis. December. Forthcoming in Water Economics and Policy.

Sears L, Lin Lawell C. 2017. D*ual rights to groundwater: Theory and application to Californi*a. UC Davis. September.

Sears L, Oehninger E, Lim D, Lin Lawell C. 2017. *The economics of sustainable agricultural groundwater management: Recent findings*. UC Davis. February.

Sneed M, Brandt J, Solt M. 2003. *Land Subsidence along the Delta-Mendota Canal in the Northern Part of the San Joaquin Valley, California, 2003–10*. Scientific Investigations Report 2013–5142. Prepared in cooperation with the U.S. Bureau of Reclamation and the San Luis and Delta-Mendota Water Authority.

State Water Resources Control Board. 2018. Water Transfer Program. https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/docs/transproginfo.pdf

Sustainable Conservation. 2014. *On-Farm Infrastructure Needs Assessment and Costs to Implement Groundwater Recharge Using Flood Flows on Cropland.* Prepared by Summers Engineering Inc., Hanford, July.

Sustainable Conservation. 2017. GRAT: User Instructions and Modeling Documentation, August.

Sustainable Conservation. 2018. *Achieving Groundwater Sustainability Is Hard Grat Makes It Easier*. http://groundwaterrecharge.org/

Sustainable Conservation 2019. *Guidance in Establishing On-Farm Recharge Sites for Groundwater Basins*. https://suscon.org/wp-content/uploads/2016/08/On-farm-Recharge-Guidance-Sheet.pdf

Sustainable Groundwater Management Act, and related provisions (as chaptered) as effective January 1, 2016 [rev. 1/15/2016].

Tucson AMA Regional Recharge Committee. 1998. IX. *Recharge Project Site Assessment and Capacity Analysis.*

Tufenkjian C. Uundated. *Integrated Regional Water Management: Kings Basin Water Authority.* The Pacific Institute.

U.S. Army Corps of Engineers, 2003. *Draft Environmental Assessment Farmington Groundwater Recharge Demonstration Project Site #1 – SJAFCA Detention Basin #1 San Joaquin County, California*. Prepared by the Sacramento District. September.

U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center. 2002. *Conjunctive Use for Flood Protection.* Prepared by the Sacramento District. January.

U.C. Cooperative Extension Service. Sample Crop Budgets. Cabernet wine grapes, North San Joaquin Valley, crush district 11; Organic raisin grapes, continuous tray, South San Joaquin Valley; Almonds, N San Joaquin Valley, microsprinkler irrigation; Grain corn, field corn, San Joaquin Valley S, 2008.

U.S. Department of the Interior, Bureau of Reclamation 2018. Central Valley Project Schedule of Irrigation Contract, Cost of Service, and Full Cost Water Rates per Acre-Foot by Contractor 2017 Irrigation Water Rates. https://www.usbr.gov/mp/cvpwaterrates/ratebooks/irrigation/2017/irr-2017-sch-a-1.pdf

U.S. Department of the Interior, U.S. Bureau of Reclamation. 2016. *Environmental Assessment Merced Irrigation District Drought Protection Water Management Model Project*. October.

U.S. Geological Survey. 2018. C*urrent Land Subsidence in the San Joaquin Valley*. https://ca.water.usgs.gov/projects/central-valley/land-subsidence-san-joaquin-valley.html

Visser A, Moran JE, Singleton MJ, Esser BK. 2016. *California GAMA Special Study: Importance of River Water Recharge to Selected Groundwater Basins*. Livermore National Laboratory, Final Report for the California State Water Resources Control Board, May.

Water Education Foundation. 2015. *The 2014 sustainable groundwater management act: a handbook to understanding and implementing the law*. Sacramento.

Water Storage Investment Program, 2017. Technical Reference. November.

Weiser M. 2018. *Why California Law Requires a Clear Benefit for Groundwater Recharge*. Water Deeply Oct. 18.

Wong L. 2018. *Why Water Conservation Officials are Intentionally Flooding Central Valley Vineyards*. Fox 40. October 11. https://fox40.com/2018/10/11/why-water-conservation-officials-are-intentionally-flooding-central-valley-vineyards/

WRIME, 2007. Subject: Recharge Characterization for Stanislaus and Tuolumne Rivers Groundwater Basin. Association To: Walt Ward, MID, Tom Lutterman, DWR, CC: Eric Hong, DWR. From: Matt Zidar, Jim Blanke. May 2.

WRIME, 2006. Subject: Kings Basin Conjunctive Use Feasibility Analysis. To: Planning and Steering Committee. From: Matt Zidar. Date: December 1, 2006.

WRIME 2006. *Analysis of Water Demands in Kings Basin. Technical memo Phase 1 Task 3*. Prepared for: The Upper Kings Basin Water Forum and The Kings River Conservation District. In coordination with: The California Department of Water Resources. April.

Research Needs and Gaps

The subcommittee identified 19 needs and gaps in research, data, and tools related to the Economic Analysis theme. Listed below are the 12 most important.

1. **Create a task force to develop an economic analysis guidance document for managed aquifer recharge.**

   A task force will be formed to develop an economic analysis guidance document for managed aquifer recharge. Among others, this guidance document will contain data, methods, guidelines, procedures, and analytical frameworks for conducting financial and economic analyses. A framework is needed to assess the financial and economic feasibility of building and operating Flood-MAR projects over the long term. To justify the implementation of Flood-MAR projects, a standardized set of procedures or guidelines that is applicable at the local, regional and statewide levels needs to be established. Following standard methods employed in economics, these guidelines will provide an authoritative and robust way of determining the financial sustainability and economic viability of Flood-MAR projects.

2. **Identify and measure the benefits and costs of alternative uses of groundwater recharge.**

   A Flood-MAR project essentially diverts low-value flood flows in current wet period to be used for a higher value in a later dry period. Basically, it means building a reservoir underground that will enhance water supply for some users. The big picture economic questions to consider is to identify and measure, to the extent possible, the benefits and costs of alternative uses of stored water. These were the classic questions that developers of cost-benefit analysis (CBA) thought about when evaluating large water projects in the West in the early to mid-20th century. In a simple CBA, the project with the highest net benefits (benefits minus costs) would be the chosen project, but it is important to be mindful that a simple CBA does not pay attention to the income distribution effects. Some of the costs and benefits are harder to measure than others and are likely to be ignored in practical applications.

3. **Transaction cost template for GSAs to plan for costs to account for and support recharge incentives.**

   A fundamental building block to recharge incentive development is a tracking or accounting system. The ability to quickly and cost-effectively measure, track and transact payment, pumping credit or some other incentive from many MAR projects being implemented across a basin is currently undeveloped. Transaction cost considerations of different tracking systems and incentive programs need to be weighed and planned for by GSAs and stakeholders. A transaction cost template would provide GSAs and stakeholders with an easy-to-fill-in tool that can be used to compare MAR project tracking and incentive program design options. Keeping transaction costs low will be critical for supporting GSAs and stakeholders in equitably sharing the costs and benefits of MAR project results that benefit the basin, and ultimately, will support achieving sustainable groundwater management.

4. **Watershed scale multi-benefit floodplain cost-benefit analysis.**

   A fundamental challenge to implementing more MAR projects is the significant uncertainty about how much surface water is available to do recharge. The subcommittee advocates for river runoff modeling under future climate scenarios at the watershed scale in order to better understand the times of year when intense precipitation may occur and provide flows beyond instream needs that if not diverted would cause downstream flood damage. This research needs to be combined with an analysis of where floodplain restoration is best suited so that those peak flows could be parked on restored floodplains that enables aquifer replenishment while also providing wildlife habitat. Finally, the economic research that would need to be done is a cost-benefit analysis that estimates the net benefit subtracting floodplain restoration and water management costs from the multiple benefits that would be achieved, including aquifer replenishment and wildlife habitat benefits and avoided flood damage costs downstream.

5. **Economic risk analysis research.**

   Private landowners are a key group of people who can do more MAR projects on their lands that would benefit many across basins.

   There are potential risks that landowners may perceive or actually face when implementing various recharge methods. Specifically, on-farm recharge raises

concerns about potential crop health and yield impacts as well as nitrate leaching risks. The subcommittee calls for integrative research that combines agronomists, hydrogeologists, and economists to study the potential risk costs associated with on-farm recharge.

Restoring upland habitat in lieu of irrigating a crop to pump less groundwater or restoring riparian/floodplain habitat where water can be parked to replenish groundwater can bring regulatory risks by attracting listed species to their restored habitat. The subcommittee also calls for multi-disciplinary research that combines environmental policy experts with economists to evalute the perceived and real risks of regulatory compliance costs for attracting listed species onto private lands where habitat has been restored.

The economists could develop recommendations for developing risk-reducing incentives that would encourage and support landowners in doing more MAR projects.

6. CBA tool for local/regional flood-mar projects.

A cost-benefit analysis (CBA) tool that catalogues all the potential costs and benefits of a particular project, as well as other considerations of CBA such as discount rates, alternatives, scope of project, and who is considered in benefits. The tool would be a starting point for agencies that are considering recharge programs to think systematically about the different factors that should influence their decision to invest in the project. The tool could potentially calculate a cost-benefit ratio if the user filled in certain categories.

7. Maximize economic efficiency of Flood-MAR (statewide CBA to identify most cost-effective locations).

Where are the most cost-effective areas in the state to do recharge? Work is being done on which soils are best suited, and thus which areas of California are best for recharge in that sense. But what about demand/economic benefits, which also vary spatially and over time? Flood water is a scarce resource that should be allocated efficiency; how can economics be used to think about how to "allocate" flood water across the state? There is a gap in the research in this sense—how to maximize the economic efficiency of flood water. This research question requires/combines knowledge of how much flood water is available for

recharge statewide, how water demand compares across space and time, and which areas have the best physical suitability.

8. Quantification and catalogue of economic benefits of Flood-MAR.

More clarity is required on which benefits should be included when conducting a CBA for MAR and how to quantify them. Some of the benefits of MAR projects are difficult to quantify (e.g., buffer value of groundwater supply/drought resiliency, improved wetland habitat, flood control, increased flexibility in management). There are gaps in the literature in terms of non-market economic valuation of some of these benefits. However, the only benefits that should be included in a CBA are ones that are additional relative to alternative strategies; this topic is missing from the discussion. What are the alternatives given SGMA? Can and should groundwater sustainability be taken as given when comparing the costs and benefits of alternative management strategies?

9. Compatibility of MAR with other management instruments: Monetary incentives and property rights for individual farmers.

How would the incentive structure from a Flood-MAR project overlap with incentive structure from a groundwater market? If agencies are considering both strategies, it will be really important to understand how they would work together and how incentives from one program would influence the efficacy of the other.

10. Groundwater property rights and market frictions.

To better understand the benefits (and costs) of Flood-MAR projects, there is a need for a model of groundwater rights and surface and subsurface water transactions. It is unclear who owns the right to groundwater recharge, which is of particular relevance to Flood-MAR because most of the water being recharged would have been previously impounded by a reservoir where ownership is more certain. Eventually, this water would be recharged on private lands, which may lead to some expectations of ownership. This expectation likely will exacerbate already large frictions in the water resources market, which are apparent in the small number of recorded transactions and large price discrepancies between agriculture-to-agriculture and agriculture-to-urban transfers. The following is recommended: (1) a review of the groundwater rights within the context of Flood-MAR, (2) an investigation into current and

past transactions in the California water resources market, particular as it relates to past floods and droughts, and
(3) a characterization of frictions in the market that lead to a low number of transactions and large price discrepancies in price per volume between transactions. Recommendations 1, 2, and 3 would be a logical first step toward the construction of a theoretical model which can be applied to Flood-MAR projects.

11. Incentives and Funding Mechanisms

Funding and incentives are an important implementation factor in encouraging landowners' support and participation in Flood-MAR projects. Incentives are a private or financial benefit to a landowner such as a farmer. They can offset the costs associated with building, operating, and maintaining a Flood-MAR project. By encouraging landowner's participation in Flood-MAR, incentives can help in the attainment of Flood-MAR public benefits. Existing landowner incentive or compensation programs are available, such as the Regional Conservation Investment Strategy Program of the California Department of Fish and Wildlife and the Conservation Reserve Program of the USDA Farm Service Agency. But funds from these sources are limited and they cannot be used to finance Flood-MAR projects. In addition, with the declining availability of State bond and general fund monies, there is a need to identify and evaluate alternative funding sources and incentives to establish landowner compensation programs and finance the implementation of Flood-MAR. Among other incentives, farmers and landowners in the Central Valley have identified income tax credits and groundwater market or water trading, as some of the incentives that would encourage them to allow their land to be used for Flood-MAR.

Strategy for Implementation

This collaborative research study will involve academic experts, practitioners, Flood-MAR research themes, farmers, landowners, environmental groups, and other stakeholders. The work will be done in two parts. The first part is through literature search and stakeholder consultations, and the second part is modeling and analysis. The first part will involve a literature review or search, which will be conducted to identify available or existing compensation and incentive programs as well as alternative funding sources and incentives in the academic and grey literature. This review will be supplemented by expert focus group and consultations with stakeholder through surveys or in-person

consultations. The second part, modeling and analysis, will involve developing a microeconomic model to evaluate the economic feasibility of incentives to provide Flood-MAR benefits. The model will be implemented using available data on agricultural prices and quantities related to the growing of crops, input costs and quantities (e.g., water prices and quantities) and policy variables (incentives or alternative funding mechanism, water rights, and the like). Two expected outcomes from this study are a research report for practitioners and manuscript for peer review publication.

12. Flood-MAR governance and coordination

Per the Flood-MAR white paper, "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."

Flood-MAR governance can be defined as a framework of rules and practices to coordinate activities and decision-making regarding the implementation of Flood-MAR projects. Because of the nature of water management in California where water infrastructures are owned, operated, and maintained by numerous local, regional, state, federal, tribal, and private entities, decisions would need to be coordinated across jurisdictional boundaries, water sectors, interests, uses, and, in some cases, across hydrologic boundaries. To be successful, Flood-MAR will require the voluntary participation of landowners such as farmers. Thus, collaborative partnerships among all stakeholders are imperative.

Strategy for Implementation

A research committee, to be led by the Flood-MAR Economic Analysis Sub-committee, in partnership with academic experts and practitioners, will evaluate the applicability of existing public-private partnerships such as a consortium approach of governance (similar to how the internet is being governed by a consortium called Internet Engineering Task Force). A Flood-MAR governance consortium will be composed of a steering committee that sits alongside a State government coordination group, technical working committee, and an implementation committee. The committees will be supported by an administrative unit. Another governance structure that may be examined is the

Water Fund. Developed by The Nature Conservancy, the Water Fund is an organization that designs and enhances financial and governance mechanisms. Water funds unite public, private, and civil society stakeholders around a common goal to contribute to water security through nature-based solutions and sustainable watershed management.

Prioritization Process

The subcommittee proposed a total of 19 research, data and tool priority projects or studies (hereafter, actions). A number of these priority actions were similar. So, over a series of videoconference meetings, phone conversations and email communications, the subcommittee consolidated similar actions to come up with its top five priority actions.

To trim down the top five priority actions further and come up with its top three priority actions, the subcommittee formulated a set of criteria. These criteria are described below.

1. **Essential and Additional.** Is the information provided by the proposed research, data or tool priority (proposed action) essential for evaluating the economic feasibility, and informing the development of integrated Flood-MAR projects to achieve multiple public and private benefits? Will the expected outcomes of the proposed action provide information about whether Flood-MAR projects have net social benefits, and additional to benefits that would have happened anyway in their absence (i.e., additional to the benefits that have already been or would be achieved by existing or other water management strategies and programs)?
2. **Address Barriers and Challenges.** Will the expected outcomes of the proposed action provide information to policy and decision-makers, landowners, and other stakeholders on strategies to mitigate or lessen barriers or challenges for implementing Flood-MAR projects?
3. **Reduce Risk and Uncertainty.** Will the expected outcomes of the proposed action improve accounting and quantification of economic risks and uncertainties surrounding the development, maintenance, and operation of Flood-MAR projects? For example, will the proposed action inform the development of risk-reducing incentives to encourage landowners to participate in implementing Flood-MAR projects?
4. **Integration and Collaboration.** Will the conduct of the proposed action encourage collaboration and integration of disciplines and best practices among Flood-MAR research themes? Will the expected outcomes of the proposed action provide information to decision-makers and stakeholders to develop strategies for maximizing integration and collaboration in implementing Flood-MAR projects?

5. **Robustness.** Will the proposed action provide information to improve the robustness of economic analysis of Flood-MAR projects that covers a wider range of outcomes? For example, does the proposed action provide insight on the economics of Flood-MAR that is robust to different institutional outcomes? Or does it provide insight as to how one implementation approach may better promote efficient use of Flood-MAR?
6. **Accounting for Non-Market and Other Difficult-to-Quantify Values.** Will the expected outcomes of the proposed action provide insight as to how Flood-MAR benefits and costs may vary spatially and temporally? Will it advance our understanding of how to quantify non-market or other hard-to-quantify values to better describe the full set of benefits and costs associated with implementing Flood-MAR projects?

The subcommittee used the above criteria to design a Google form survey. Each subcommittee member was asked to participate in the survey. The survey ranks the likelihood by which each priority study or action addresses each criterion. Each survey response has the following equivalent survey score:

- Less likely = 1 point
- Somewhat unlikely = 2 points
- Neutral = 3 points
- Somewhat likely = 4 points
- Most likely = 5 points

The next section discusses the top three actions that garnered the most survey points. Each action has its own description, proposed strategy for implementation, and estimated cost.

Top Three Research, Data, and Tools Actions

Table 1 Develop an Economic Analysis Guidance Document for Groundwater Recharge Projects

Category: Tool
Scale: State, Regional, Local
Availability: Gap

Other Themes That Will Benefit:

2. Reservoir Operation
3. Infrastructure Conveyance and Hydraulics
4. Crop Suitability
6. Land Use Management
7. Water Quality
8. Recharge and Extraction Methods & Measures
9. Environment
10. People and Water
12. Local, State, Federal Policies, and Other Legal Constraints
13. Tool and Application Development

Implementation Factors:

8. Feasibility Analysis

Description, including Connection to Flood-MAR:

Financial and socioeconomic feasibility is a key consideration to inform and guide decisions in the planning, establishment, operation and maintenance of Flood-MAR projects. An economic analysis guidance document will be developed to provide practitioners, decision-makers, analysts, and other stakeholders a set of guidelines, standard procedures and methods for conducting financial and socioeconomic analyses. This guidance document will have statewide, regional, and local application.

Draft Strategy for Implementation:

Product: Economic analysis guidance document or Flood-MAR economics guidebook that provide practitioners, decision-makers, analysts and other stakeholders a set of guidelines, standard procedures and methods for conducting financial feasibility and socioeconomic analysis.

Implementation Lead: Flood-MAR Economic Analysis Subcommittee supported by two graduate assistants or research staff.

Implementation Partners: DWR executives, other Flood-MAR research themes, Flood-MAR program team, DWR SGMA team, GSAs, landowners, practitioners, and

other concerned stakeholders.

Estimated Timeline: 18–24 months.

Estimated Cost: Roughly $250,000. This amount will cover costs for two graduate students or research staff for two years at $110,000 each, and costs associated with coordination meetings, facilitation, and publication expenses, which are estimated at $30,000.

Table 2 Evaluate Economic and other Incentives for Flood-MAR Implementation

Category: Research

Scale: State, Regional, Local

Availability: Gap

Other Themes That Will Benefit:

2. Reservoir Operation
3. Infrastructure Conveyance and Hydraulics
4. Crop Suitability
6. Land Use Management
8. Recharge and Extraction Methods & Measures
9. Environment
10. People and Water
12. Local, State, Federal Policies, and Other Legal Constraints
13. Tool and Application Development

Implementation Factors:

2. Funding and Incentives

Description, including Connection to Flood-MAR:

Funding and incentives are important implementation factors in encouraging landowners' support and participation in Flood-MAR projects. Existing landowner incentive or compensation programs are available, such as the Regional Conservation Investment Strategy program of the California Department of Fish and Wildlife and the Conservation Reserve Program of the USDA Farm Service Agency. But funds from these sources are limited and they cannot be used to finance Flood-MAR projects. In addition, with the declining availability of State bond and general fund monies, there is a need to identify and evaluate alternative funding sources and incentives to establish landowner compensation programs and finance the implementation of Flood-MAR. Among other incentives, farmers and landowners in the Central Valley have identified income tax credits and groundwater markets or water trading, as some of the incentives that would encourage them to allow their land to be used for Flood-MAR.

Draft Strategy for Implementation:

Products: A research report that can be used by practitioners and decision-makers, and a manuscript that will be submitted for publication in academic journals such as the Journal of Water Resources Planning and Management.

Implementation Lead: Flood-MAR Economic Analysis Subcommittee supported by one graduate assistant or research staff.

Implementation Partners: Other Flood-MAR research themes, Flood-MAR program team, DWR executives, SGMA team, GSAs, landowners, practitioners, and other concerned State, federal, and local agencies.

Estimated Timeline: 12–18 months.

Estimated Cost: The total estimated cost is $200,000. This amount will cover staff time for attending meetings, travel and performing the work, as well as expenses for office supplies and publication.

Table 3 Assess Groundwater Ownership Rights and Market Issues Associated with Flood-MAR

Category: Research, Tool

Scale: State, Regional, Local

Availability: Gap

Other Themes That Will Benefit:

6. Land Use Management

9. Environment

10. People and Water

12. Local, State, Federal Policies and Other Legal Constraints

13. Tool and Application Development

Implementation Factors:

1. Governance and Coordination

8. Feasibility Analysis

Description, including Connection to Flood-MAR:

The legal and regulatory framework surrounding groundwater recharge rights is an important consideration in Flood-MAR. There is a need for a model of groundwater rights and surface and subsurface water transactions to better understand the benefits and costs of Flood-MAR projects. It is unclear who has the right to groundwater recharge, which is of particular relevance to Flood-MAR because most of the flood water being recharged would have been previously impounded by a reservoir where ownership is more certain. That water would eventually be recharged on privately

owned land, which may lead to some expectations of ownership. This expectation likely will exacerbate already large frictions in the water resources market, which are apparent in the small number of recorded transactions and large price discrepancies between agricultural-to-agricultural and agricultural-to-urban transfers.

Draft Strategy for Implementation:

Product: A research report that can be used by practitioners and decision-makers.

Implementation Lead: Flood-MAR Economic Analysis Subcommittee supported by one graduate student or research staff.

Implementation Partners: DWR executives, State Water Resources Control Board, State Water Project Analysis Office, other Flood-MAR research themes, Flood-MAR program team, SGMA team, academic and legal experts, and other concerned State, federal, and local agencies.

Estimated Timeline: 12–18 months

Estimated Cost: Estimated total cost is $200,000. This amount will include the cost for the graduate student ($82,500) for 18 months. The remaining amount will cover costs associated with project team travel, meetings, office supplies, report preparation and publication.

Next Steps

The subcommittee co-chairs will work with the members to develop a project proposal to implement each action. Among other things, each proposal will identify the potential funding sources for the action. The subcommittee will ask the implementation partners to review the proposals.