Tracy Subbasin
GSP Coordination Committee Meeting

Thursday, September 16, 2021
1:00 PM to 3:00 PM

Teleconference Meeting Only
Teleconference Link: https://stantec.zoom.us/j/93541056999
Phone Number: 1-669-900-6833
Meeting ID: 935 4105 6999

NOTICE: CORONAVIRUS COVID-19

On March 18, 2020, Governor Gavin Newsom issued Executive Order N-29-20 recognizing that COVID 19 continues to spread throughout our community resulting in serious and ongoing economic harm. Governor Newsom has therefore waived certain requirements of the Ralph M. Brown Act relating to public participation and attendance at public meetings.

Based on guidance from the California Department of Public Health and the California Governor's Officer, ***effective immediately*** and while social distancing measures are imposed, members of the Tracy Subbasin Groundwater Sustainability Agencies and staff will be participating in this meeting remotely from multiple locations. In order to minimize the spread of the COVID 19 virus, the following options are available to members of the public to listen to these meetings and provide comments to the Committee Members before and during the meeting:

CALL-IN

Member of the public are encouraged to use the call-in number, which will allow them to fully participate in the meeting without having to be present in person. ***Once connected, we request you kindly mute your phone.***

PUBLIC COMMENT

If you wish to make a comment on a specific agenda item, please submit your comment via email by 5:00 p.m. on the Wednesday prior to the meeting. Please submit your comment via email to Matt Zidar, San Joaquin County, at mzidar@sjgov.org. Your comment will be shared with the Tracy Subbasin Groundwater Sustainability Agencies members and placed into the record at the meeting. Every effort will be made to read comments received during the meeting into the record but some comments may not be read due to time limitations. Comments received after an agenda item will be made part of the record if received prior to the end of the meeting.

DISABILITY-RELATED MODIFICATIONS

If you need disability-related modification or accommodation in order to participate in this meeting, please call 1 (209) 468-3089 at least 48 hours prior to the start of the meeting.

AGENDA

I. <u>Opening of Meeting/Roll Call</u>

II. <u>Scheduled Items</u>

A. Approval of August 19 GSP Coordination Committee Meeting Minutes – *Action Item*

B. Public Outreach Update – *Discussion Item*

C. Summary of Public Comments Received on the Draft GSP – *Discussion Item*

D. Revised Budget and Cost Allocation Methodology for GSP Implementation – *Action Item*

E. Amendment to the Memorandum of Agreement – *Discussion Item*

F. GSP Adoption Schedule – *Discussion Item*

G. DWR Status Report – *Discussion Item*

III. <u>Public Comments</u>

IV. <u>Agency Comments</u>

V. <u>Next GSP Coordination Committee Meeting – October 21, 2021</u>

VI. <u>Adjournment</u>

Tracy Subbasin
GSP Coordination Committee Meeting

Thursday, August 19, 2021
1:00 PM to 3:00 PM

Teleconference Meeting Only
Teleconference Link: https://stantec.zoom.us/j/93541056999
Phone Number: 1-669-900-6833
Meeting ID: 935 4105 6999

MINUTES

I. Opening of Meeting/Roll Call

The meeting was called to order at 1:04 PM.

Roll call found the following Groundwater Sustainability Agency (GSA) representatives present via teleconference:

- David Weisenberger, Banta-Carbona Irrigation District GSA
- Greg Young, Byron-Bethany Irrigation District GSA
- Greg Gibson, City of Lathrop GSA
- Lea Emmons, City of Tracy GSA
- Lemar Saffi, City of Tracy GSA
- Matt Zidar, San Joaquin County GSA
- Ryan Alameda, Stewart Tract GSA
- Susan Dell'Osso, Stewart Tract GSA

Other attendees:

- Jackson Cook, California Department of Water Resources (DWR)
- Richard Shatz, GEI
- Carlos Rincon, Member of public
- Kirsten Pringle, Stantec
- Elizabeth Simon, Stantec

II. Scheduled Items

A. Approval of July 15 GSP Coordination Committee Meeting Minutes

Greg Gibson, City of Lathrop GSA, requested that the notes reflect that the next Groundwater Sustainability Plan (GSP) Coordination Committee meeting was to be held on August 19, rather than August 20.

RESULT: APPROVED

MOVER: Matt Zidar, San Joaquin County GSA

SECONDER: Greg Gibson, City of Lathrop GSA

AYES: Banta-Carbona Irrigation District GSA, Byron-Bethany Irrigation District GSA, City of Lathrop GSA, City of Tracy GSA, San Joaquin County GSA

NOES: None

ABSENT: None

ABSTAIN: Susan Dell'Osso, Stewart Tract GSA

B. Public Outreach Update

Kirsten Pringle, Stantec, provided a summary of the format, discussion, and participant questions from the August 10 public workshop. Ms. Pringle stated that David Weisenberger, Banta-Carbona Irrigation District GSA, had requested an informational flyer be created explaining the public comment process for the draft GSP. The flyer will be provided to all GSAs. She noted that the Notice of Intent to Adopt the GSP had been distributed to cities and counties in the plan area on behalf of all GSAs. The draft GSP can be adopted no sooner than 90-days from receipt of the notice. Ms. Pringle also stated template materials will be developed to support GSA staff with GSP adoption.

C. Summary of GSA Comments to Draft GSP

Richard Shatz, GEI, provided a summary of revisions made to the draft GSP to address comments from the GSA representatives and the GSP status. He noted that language in the Executive Summary and Chapter 2 "Agency Information" had been revised to allow for flexibility in the GSAs' cost allocation methodology I for GSP implementation costs. He also noted that Chapter 10 "Projects and Management Actions" had been revised to address comments from Mr. Gibson regarding how the project benefits were quantified. A separate subsection was added to Chapter 10 for supplemental projects to address this concern. Mr.

Shatz stated that a complete draft of the GSP was made publicly available on August 9th for a 30-day public comment period.

D. Amendment to the Memorandum of Agreement and Cost Allocation for GSP Implementation

Ms. Pringle summarized the outcomes of discussions on the Memorandum of Agreement (MOA) and cost allocation method from previous GSP Coordination Committee meetings. She stated that the GSAs previously agreed that individual GSAs will be responsible for costs associated with projects and management actions and any costs for groundwater monitoring that they are already conducting. The remaining costs will be shared by the six GSAs. Ms. Pringle added that the GSP Coordination Committee had previously discussed splitting costs based on the percentage of land each GSA has within the Non-Delta Management Area; however, some of the GSAs have raised concerns about this approach.

The Committee discussed the draft annual budget for GSP implementation. Susan Dell'Osso, Stewart Tract GSA, requested that the latest copy of the budget be circulated to the Committee members. Matt Zidar, San Joaquin County GSA, noted that the percentage of the shared costs funded by Groundwater Investigation Zone No. 2 funds was incorrect. Greg Young, Byron-Bethany Irrigation District GSA, stated that estimated amount to update the groundwater model appeared high and encouraged the GSAs to consider a cost minimization strategy. Mr. Zidar stated his support for reviewing the annual budget to minimize costs.

The Committee then discussed potential methods to split the shared GSP implementation costs. Mr. Young stated that he did not agree with a cost allocation method based only on acreage because agencies like Byron-Bethany Irrigation District that don't use groundwater would pay a significant amount. He requested that the planning team evaluate a 'hybrid' approach that splits costs by acreage, population, and/or groundwater extraction within the Non-Delta Management Area. Mr. Shatz responded that the costs currently attributed to Byron-Bethany Irrigation District are not limited to domestic well pumping; they include high capacity well and irrigation pumping. Mr. Young indicated that he would check this information. Mr. Young also requested a clause be written into the MOA amendment to allow for flexibility in changing the cost splitting method at a future date, if desired.

Mr. Gibson stated that the City of Lathrop is not in favor of splitting costs by groundwater pumping due to the challenges with quantifying it. He noted concerns about the uncertainty and potential inaccuracies with estimating groundwater extraction. Mr. Zidar agreed that lack of pumping information is a data gap. He noted that there are other methods of quantifying groundwater pumping. Mr. Gibson stated his support for a hybrid approach of splitting costs by acreage and population.

David Weisenberger, Banta-Carbona Irrigation District GSA, stated his support for a hybrid approach to splitting costs.

Lea Emmons, City of Tracy GSA, stated support for a hybrid split based on acreage, population, and groundwater pumping.

Ms. Dell'Osso stated they she could not make a decision on the cost allocation model without understanding the total anticipated costs. She noted that Stewart Tract GSA anticipates future population growth.

As a next step, Mr. Shatz will revise the annual budget and circulate it for review; and provide estimates of acreage, population, and groundwater pumping in the Non-Delta Management Area for each GSA. The GSAs agreed to continue the discussion at the next Coordination Committee meeting using the new information.

E. GSP Adoption Schedule

Mr. Shatz provided an overview of the GSP adoption schedule, specifically noting the planned GSP adoption date in late November. He indicated he would change the MOA amendment schedule for October, rather than August.

F. DWR Status Report

Jackson Cook, DWR, indicated that DWR's drought response team is granting up to $500 million for drought related needs. He noted that DWR's Financial Assistance Branch has distributed an electronic survey to collect input on drought response needs and that the survey results will inform guidelines for future drought response grants.

III. Public Comments

There were no comments from members of public on items not on the agenda.

IV. Agency Comments

There were no additional comments from the GSA representatives.

V. Next GSP Coordination Committee Meeting – September 16, 2021

The next GSP Coordination Committee meeting will be held on September 16, 2021.

VI. Adjournment

Ms. Pringle adjourned the meeting at 2:31 PM.

Stantec

Memo

To:	Tracy Subbasin Groundwater Sustainability Agencies	From:	Kirsten Pringle Stantec
File:	Summary of Public Comments on the Draft Tracy Subbasin GSP	Date:	September 10, 2021

Reference: Summary of Public Comments on Draft Tracy Subbasin Groundwater Sustainability Plan

The six Groundwater Sustainability Agencies (GSA) in the Tracy Subbasin held a public comment period for the draft Tracy Subbasin Groundwater Sustainability Plan (GSP) from August 9 – September 9. This memo describes the process the GSAs used to solicit public and stakeholder comments on the draft GSP and summarizes comments received during the public comment period.

PUBLIC COMMENT PROCESS

The Tracy Subbasin GSAs released the draft GSP chapters for an initial public review and comment as they were developed. Draft chapters were posted on the Tracy Subbasin website for a 30- to 45-day public review period. The GSAs sent emails to the Interested Parties Database to notify stakeholders as chapters were released. Comments were collected using a virtual public comment form. Members of the public could also provide comment at monthly Tracy Subbasin GSP Coordination Committee meetings. All comments were reviewed by the planning team and comments that raised substantive technical or policy issues resulted in changes to the draft GSP.

The GSAs released a complete draft of the GSP for a 30-day public comment period on Tuesday, August 6, 2021. The public comment period was closed at 5 p.m. on Thursday, September 9, 2021. A copy of the draft GSP was posted on the Tracy Subbasin website for download and review. Public comments on the draft GSP were accepted via the virtual public comment form, email, and U.S. mail.

The release of the Draft GSP and public comment period were noticed via an email sent to the Interested Parties Database, postings on the Tracy Subbasin website, and notices distributed by each of the GSAs via their email lists, social media accounts, and websites. Two additional emails were sent to the Interested Parties Database to remind individuals of the comment deadline. The GSAs also held an informational public workshop on August 10 to inform interested parties about the content of the draft GSP, explain the public comment process, and answer questions about the plan. Additional outreach was conducted to promote the workshop, including targeted outreach to individuals and organizations representing beneficial users of groundwater in the Subbasin.

SUMMARY OF COMMENTS RECEIVED

The GSAs received two comment letters during the draft GSP public comment period (August 9 – September 9, 2021). One comment letter was received via email. A second comment letter was received via the virtual public comment form. The list of comment letters received is provided in **Table 1.**

Reference: **Summary of Public Comments on Draft Tracy Subbasin Groundwater Sustainability Plan**

Table 1. Comment Letters Received During Public Comment Period

Name of Author	Agency/Organization	Submission Method	Date Received/Post Marked
Jenny Wood	None provided	Virtual public comment form	08/28/2021
Ngodoo Atume Samantha Arthur E.J. Remson Melissa M. Rohde J. Pablo Ortiz-Partida Danielle V. Dolan	Clean Water Action/Clean Water Fund Audubon California The Nature Conservancy The Nature Conservancy Union of Concerned Scientists Local Government Commission	Email	09/03/2021

The following provides a summary of the unique comments provided in the comment letters. The comments have been grouped by the subject area that they address. Duplicate or very similar comments are summarized here as one comment.

IDENTIFICATION OF BENEFICIAL USES AND USERS

- One commenter requested that the GSAs provide the size of the population of each disadvantaged community in the Subbasin.
- One commenter requested that the GSAs provide a map showing all stream reaches in the Subbasin and provide depth-to-groundwater contour maps to help identify interconnected surface water bodies.
- One commenter requested that the GSAs use seasonal data over multiple water year types when mapping interconnected surface water bodies.
- One commenter requested that the GSAs overlay groundwater dependent ecosystem locations with depth-to-groundwater contour maps.
- One commenter requested that the GSAs use depth to groundwater data from multiple seasons and water years to determine the range of depth to groundwater along the polygons identified in the Natural Communities Commonly Associated with Groundwater dataset.
- One commenter requested that the GSAs provide the Subbasin's Communication and Engagement Plan and explain how the GSAs will engage beneficial users during GSP implementation.

SUSTAINABLE MANAGEMENT CRITERIA

Chronic Lowering of Groundwater Levels

- One commenter requested that the GSAs consider and evaluate the impacts of minimum thresholds and measurable objectives on disadvantaged communities and drinking water users.
- One commenter requested that the GSAs include and consider periods of drought when defining undesirable results for chronic lowering of groundwater levels.
- One commenter requested that the GSAs provide specifics on what biological responses would best characterize a significant and unreasonable impact to groundwater dependent ecosystems when defining undesirable results for chronic lowering of groundwater levels.

Degraded Water Quality

- One commenter requested that the GSAs describe impacts on disadvantaged communities when defining undesirable results for degraded water quality.
- One commenter requested that the GSAs evaluate impacts of proposed minimum threshold for degraded water quality on disadvantaged communities.
- One commenter requested that the GSAs set minimum thresholds for degraded quality at the maximum contaminant level for total dissolved solids, nitrate, and boron; and add minimum thresholds for additional constituents of concern (sulfate, 1-2-3-TCP, and arsenic).

Interconnected Surface Water

- One commenter requested that the GSAs consider including a description of potential impacts on instream habitats within interconnected surface water bodies when defining minimum thresholds.

CLIMATE CHANGE

- One commenter requested that the GSAs integrate multiple climate change scenarios, including extremely wet and dry scenarios, into the projected water budget.
- One commenter requested that the GSAs incorporate surface water flow inputs that are adjusted for climate change into the projected water budget.
- One commenter requested that the GSAs calculate sustainable yield based on the projected water budget with climate change incorporated.
- One commenter requested that the GSAs incorporate climate change into projects and management actions.

Reference: Summary of Public Comments on Draft Tracy Subbasin Groundwater Sustainability Plan

MONITORING NETWORK AND DATA GAPS

- One commenter requested that the GSAs reconcile data gaps in the monitoring network by evaluating potential undesirable results to interconnected surface water bodies, groundwater dependent ecosystems, disadvantaged communities, and domestic well owners with shallow wells.
- One commenter requested that the GSAs provide maps that overlay the monitoring well locations with the locations of the disadvantaged communities and groundwater dependent ecosystems.
- One commenter requested that the GSAs determine what ecological monitoring can be used to assess the potential for impacts to groundwater dependent ecosystems and interconnected surface water bodies.

PROJECTS AND MANAGEMENT ACTIONS

- One commenter requested that the GSAs consider projects or programs to incentivize water conservation and water use efficiency and recharge the upper aquifer, such as incentivizing residential greywater systems, mulching in public areas, and using permeable concrete.
- One commenter requested that the GSAs consider multi-benefit projects that include elements that benefit wildlife and aquatic species, such as recharge ponds, reservoirs, and facilities for managed stormwater recharge.
- One commenter requested that the GSAs provide public notice and engagement before considering and implementing projects and management actions.
- One commenter requested that the GSAs consider a drinking water well impact mitigation program.
- One commenter requested that the GSAs discuss potential impacts to water quality from projects and management actions.
- One commenter requested that the GSAs consider management actions and incorporate climate and water delivery uncertainties.

Attachments: Attachment A - Atume et. al Comment Letter
Attachment B - J. Wood Comment Letter

September 9, 2021

Tracy Subbasin Groundwater Sustainability Agencies
c/o San Joaquin County
1810 E. Hazelton Avenue
Stockton, CA 95201

Submitted via email: mzidar@sjgov.org

Re: Public Comment Letter for Tracy Subbasin Draft GSP

Dear Matt Zidar,

On behalf of the above-listed organizations, we appreciate the opportunity to comment on the Draft Groundwater Sustainability Plan (GSP) for the Tracy Subbasin being prepared under the Sustainable Groundwater Management Act (SGMA). Our organizations are deeply engaged in and committed to the successful implementation of SGMA because we understand that groundwater is critical for the resilience of California's water portfolio, particularly in light of changing climate. Under the requirements of SGMA, Groundwater Sustainability Agencies (GSAs) must consider the interests of all beneficial uses and users of groundwater, such as domestic well owners, environmental users, surface water users, federal government, California Native American tribes and disadvantaged communities (Water Code 10723.2).

As stakeholder representatives for beneficial users of groundwater, our GSP review focuses on how well disadvantaged communities, tribes, climate change, and the environment were addressed in the GSP. While we appreciate that some basins have consulted us directly via focus groups, workshops, and working groups, we are providing public comment letters to all GSAs as a means to engage in the development of 2022 GSPs across the state. Recognizing that GSPs are complicated and resource intensive to develop, the intention of this letter is to provide constructive stakeholder feedback that can improve the GSP prior to submission to the State.

Based on our review, we have significant concerns regarding the treatment of key beneficial users in the Draft GSP and consider the GSP to be **insufficient** under SGMA. We highlight the following findings:

1. Beneficial uses and users **are not sufficiently** considered in GSP development.
    a. Human Right to Water considerations **are not sufficiently** incorporated.
    b. Public trust resources **are not sufficiently** considered.
    c. Impacts of Minimum Thresholds, Measurable Objectives and Undesirable Results on beneficial uses and users **are not sufficiently** analyzed.
2. Climate change **is not sufficiently** considered.
3. Data gaps **are not sufficiently** identified and the GSP **does not have a plan** to eliminate them.

4. Projects and Management Actions **do not sufficiently consider** potential impacts or benefits to beneficial uses and users.

Our specific comments related to the deficiencies of the Tracy Subbasin Draft GSP along with recommendations on how to reconcile them, are provided in detail in **Attachment A.**

Please refer to the enclosed list of attachments for additional technical recommendations:

Attachment A	GSP Specific Comments
Attachment B	SGMA Tools to address DAC, drinking water, and environmental beneficial uses and users
Attachment C	Freshwater species located in the subbasin
Attachment D	The Nature Conservancy's "Identifying GDEs under SGMA: Best Practices for using the NC Dataset"

Thank you for fully considering our comments as you finalize your GSP.

Best Regards,

Ngodoo Atume
Water Policy Analyst
Clean Water Action/Clean Water Fund

J. Pablo Ortiz-Partida, Ph.D.
Western States Climate and Water Scientist
Union of Concerned Scientists

Samantha Arthur
Working Lands Program Director
Audubon California

Danielle V. Dolan
Water Program Director
Local Government Commission

E.J. Remson
Senior Project Director, California Water Program
The Nature Conservancy

Melissa M. Rohde
Groundwater Scientist
The Nature Conservancy

Attachment A

Specific Comments on the Tracy Subbasin Draft Groundwater Sustainability Plan

1. Consideration of Beneficial Uses and Users in GSP development

Consideration of beneficial uses and users in GSP development is contingent upon adequate identification and engagement of the appropriate stakeholders. The (A) identification, (B) engagement, and (C) consideration of disadvantaged communities, drinking water users, tribes, groundwater dependent ecosystems, streams, wetlands, and freshwater species are essential for ensuring the GSP integrates existing state policies on the Human Right to Water and the Public Trust Doctrine.

A. Identification of Key Beneficial Uses and Users

Disadvantaged Communities and Drinking Water Users

The identification of Disadvantaged Communities (DACs) and drinking water users is **incomplete**, based on lack of identification of the population size of DACs in the subbasin.

The GSP provides a map of DAC and SDAC locations (Figure 3-17) and identifies DACs by census tracts (Table 11-1). The GSP also provides adequate mapping of the location of all domestic wells by location and by depth (Figure 3-14) and the density of domestic wells in the subbasin (Figure 3-13). The GSP identifies the sources of water for DACs and what percentage is supplied by groundwater. However, the missing population size element is required for the GSA to fully understand the specific interests and water demands of these beneficial users, to support the development of water budgets using the best available information, and to support the development of sustainable management criteria and projects and management actions that are protective of these users.

RECOMMENDATIONS
• Provide the size of the population in each DAC.

Interconnected Surface Waters

The identification of Interconnected Surface Waters (ISWs) is **insufficient**. The GSP states (p. 5-72): "The creeks in these areas [the lands south of the Old River and Tom Paine Slough] are perennial, not flowing year-round, and therefore the surface water in this area is not considered to be interconnected to groundwater." There are two problems with this sentence. First, a perennial stream is one that does flow year round. Second, this sentence contradicts the the first sentence of the ISW section on p. 5-72, which states: "Interconnected surface water refers to surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted (CCR 2014)." The phrase "at any point" has both a spatial and temporal component. Even short durations of interconnections of groundwater and surface water can be crucial for surface water flow and supporting environmental users of groundwater and surface water.

Figure 5-40 shows the locations of monitoring wells and their hydrographs used to verify the ISW analysis, however the stream reaches are not labeled on this figure, nor is any analysis provided in the text. Furthermore, no backup analysis is provided for the use of the 20-ft criteria provided in the text. The GSP cites Appendix K (Surface Water/Groundwater Interaction Hydrographs) as evidence that when depth to water is less than 20 feet, the surface water can be inferred to be interconnected to the upper aquifer. This appendix, however, is missing.

Because potential ISWs have not been identified, they cannot be adequately managed in the GSP. Until a disconnection can be proven, include all potential ISWs in the GSP. This is necessary to assess whether surface water depletions caused by groundwater use are having an adverse impact on environmental beneficial users of surface water.

RECOMMENDATIONS
• Provide a map showing all the stream reaches in the subbasin, with reaches clearly labeled with stream name and interconnected or disconnected. Consider any segments with data gaps as potential ISWs and clearly mark them as such on maps provided in the GSP. • Provide depth-to-groundwater contour maps using the best practices presented in Attachment D, to aid in the determination of ISWs. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a digital elevation model (DEM) to estimate depth to groundwater contours across the landscape. This will provide accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found. • Use seasonal data over multiple water year types to capture the variability in environmental conditions inherent in California's climate, when mapping ISWs. • Reconcile ISW data gaps with specific measures (shallow monitoring wells, stream gauges, and nested/clustered wells) along surface water features in the Monitoring Network section of the GSP. Data gaps are discussed in general terms on p. 5-78, but very little detail is provided.

Groundwater Dependent Ecosystems

The identification of Groundwater Dependent Ecosystems (GDEs) is **insufficient**, due to a lack of comprehensive, systematic analysis of the subbasin's GDEs. The GSP took initial steps to identify and map GDEs using the Natural Communities Commonly Associated with Groundwater dataset (NC dataset). We commend the GSA for retaining all of the NC dataset polygons in the subbasin as potential GDEs. However, the GSP did not verify the NC dataset with the use of groundwater data from the underlying principal aquifer. Without an analysis of groundwater data to verify the NC dataset polygons, it will be difficult or impossible to adequately monitor and manage the GDEs throughout GSP implementation.

RECOMMENDATIONS
• Overlay GDE locations with depth-to-groundwater contour maps. For these contour maps, note the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a DEM to estimate depth to groundwater contours across the landscape. • Use depth to groundwater data from multiple seasons and water year types (e.g., wet, dry, average, drought) to determine the range of depth to groundwater around NC dataset polygons. We recommend that a baseline period (10 years from 2005 to 2015) be established to characterize groundwater conditions over multiple water year types. Refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer.

Native Vegetation and Managed Wetlands

Native vegetation and managed wetlands are water use sectors that are required[1,2] to be included into the water budget. The integration of these ecosystems into the water budget is **sufficient**. We commend the GSA for including and showing the groundwater demands of these ecosystems in the historical, current and projected water budgets.

B. Engaging Stakeholders

Stakeholder Engagement during GSP development

Stakeholder engagement during GSP development is **incomplete**. SGMA's requirement for public notice and engagement of stakeholders[3] is not fully met by the description in the GSP. The GSP references Appendix P for the Tracy Subbasin Communication and Engagement Plan, however only a placeholder for Appendix P is included in the Draft GSP. While the main text describes how DACs and environmental stakeholders were given opportunities to engage in the GSP development process, the GSP should be improved by including a separate Communication and Engagement Plan that describes outreach to DACs and environmental stakeholders during the GSP *implementation* phase, in addition to the GSP development phase.

[1] "'Water use sector' refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation." [23 CCR §351(al)]

[2] "The water budget shall quantify the following, either through direct measurements or estimates based on data: (3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow." [23 CCR §354.18]

[3] "A communication section of the Plan shall include a requirement that the GSP identify how it encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin." [23 CCR §354.10(d)(3)]

RECOMMENDATIONS
• Include a robust Communication and Engagement Plan. • Describe efforts to engage with stakeholders during the GSP *implementation* phase in the Communication and Engagement Plan. Refer to Attachment B for specific recommendations on how to actively engage stakeholders during all phases of the GSP process.

C. Considering Beneficial Uses and Users When Establishing Sustainable Management Criteria and Analyzing Impacts on Beneficial Uses and Users

The consideration of beneficial uses and users when establishing sustainable management criteria (SMC) is **insufficient**. The consideration of potential impacts on all beneficial users of groundwater in the subbasin are required when defining undesirable results[4] and establishing minimum thresholds.[5,6]

Disadvantaged Communities and Drinking Water Users

For chronic lowering of groundwater levels, the GSP does not sufficiently describe or analyze direct or indirect impacts on DACs or domestic drinking water wells when defining undesirable results. The GSP does not sufficiently describe how the existing minimum threshold groundwater levels are consistent with avoiding undesirable results in the subbasin. For undesirable results, the plan states that "[t]he level when there would be a significant undesirable result will be when 25 percent or more of the representative monitoring wells record groundwater levels that exceed the minimum thresholds for more than 2 consecutive years excluding drought periods." The GSP failed to include periods of drought.

For degraded water quality, SMCs were developed for three of the constituents of concern (COCs) in the subbasin: TDS, nitrate, and boron. SMCs were not developed for the other stated COCs (sulfate, 1,2,3-TCP, and arsenic). Where concentrations are above the maximum contaminant level (MCL) or agricultural water quality objective, minimum thresholds were established at 10% higher than the maximum concentrations historically found at representative monitoring wells. The increase of 10% above the historical levels was developed based on uncertainty in concentrations and due to concentrations in some wells having upward trends (p. 9-18). This method of establishing minimum thresholds is not protective of DACs or drinking water users.

[4] "The description of undesirable results shall include [...] potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results." [23 CCR §354.26(b)(3)]
[5] "The description of minimum thresholds shall include [...] how minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests." [23 CCR §354.28(b)(4)]
[6] "The description of minimum thresholds shall include [...] how state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the agency shall explain the nature of and the basis for the difference." [23 CCR §354.28(b)(5)]

RECOMMENDATIONS

Chronic Lowering of Groundwater Levels

- Consider and evaluate the impacts of selected minimum thresholds and measurable objectives on DACs and drinking water users within the subbasin. Further describe the impact of passing the minimum threshold for drinking water users. For example, provide the number of domestic wells that would be de-watered at the minimum threshold.
- Include and consider periods of drought when defining undesirable results for the basin.

Degraded Water Quality

- Describe direct and indirect impacts on DACs when defining undesirable results for degraded water quality. For specific guidance on how to consider domestic water users, refer to "Guide to Protecting Water Quality Under the Sustainable Groundwater Management Act."[7]
- Evaluate the cumulative or indirect impacts of proposed minimum thresholds on DACs and drinking water users.
- Set minimum thresholds at the MCL for TDS, nitrate, and boron, instead of 10% higher than the MCL at some wells.
- Set minimum thresholds for the additional COCs: sulfate, 1,2,3-TCP, and arsenic. Ensure they align with drinking water standards[8].

Groundwater Dependent Ecosystems and Interconnected Surface Waters

The GSP uses historic low groundwater levels (typically those that occurred during the 2012-2016 drought) as a proxy to establish minimum thresholds for the depletions of interconnected surface water. The GSP assumes that historical conditions are protective of beneficial uses related to interconnected surface water. However, the true impacts to ecosystems under this scenario are not discussed. If minimum thresholds are set to historic low groundwater levels and the subbasin is allowed to operate just above or close to those levels over many years, there is a risk of causing catastrophic damage to ecosystems that is more adverse than what was occurring during the 2012-2016 drought. This is because California ecosystems, which are adapted to our Mediterranean climate, have some drought strategies that they can utilize to deal with short-term water stress. If the drought conditions are prolonged however, the ecosystem can collapse. While ecosystems may have been only water stressed during the recent drought, they could be inadvertently destroyed if groundwater conditions are maintained at or just above those levels in the long-term, since the subbasin would be permitted to sustain extreme dry conditions over multiple seasons and years.

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[7] Guide to Protecting Water Quality under the Sustainable Groundwater Management Act https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328858/Guide_to_Protecting_Drinking_Water_Quality_Under_the_Sustainable_Groundwater_Management_Act.pdf?1559328858.

[8] "Degraded Water Quality [...] collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues." [23 CCR §354.34(c)(4)]

RECOMMENDATIONS

- When defining undesirable results for chronic lowering of groundwater levels, provide specifics on what biological responses (e.g., extent of habitat, growth, recruitment rates) would best characterize a significant and unreasonable impact to GDEs. Undesirable results to environmental users occur when 'significant and unreasonable' effects on beneficial users are caused by one of the sustainability indicators (i.e., chronic lowering of groundwater levels, degraded water quality, or depletion of interconnected surface water). Thus, potential impacts on environmental beneficial uses and users need to be considered when defining undesirable results[9] in the subbasin. Defining undesirable results is the crucial first step before the minimum thresholds[10] can be determined.

- For the interconnected surface water SMC, the undesirable results should include a description of potential impacts on instream habitats within ISWs when defining minimum thresholds in the subbasin[11]. The GSP should confirm that minimum thresholds for ISWs avoid adverse impacts to environmental beneficial users of interconnected surface waters as these environmental users could be left unprotected by the GSP. These recommendations apply especially to environmental beneficial users that are already protected under pre-existing state or federal law[6,12].

2. Climate Change

The SGMA statute identifies climate change as a significant threat to groundwater resources and one that must be examined and incorporated in the GSPs. The GSP Regulations[13] require integration of climate change into the projected water budget to ensure that projects and management actions sufficiently account for the range of potential climate futures.

The integration of climate change into the projected water budget is **insufficient**. The GSP does incorporate climate change into the projected water budget using DWR change factors for 2070. However, the GSP did not consider multiple climate scenarios (e.g., the 2070 extremely wet and extremely dry climate scenarios) in the projected water budget. The GSP should clearly and transparently incorporate the extremely wet and dry scenarios provided by DWR into projected water budgets or select more appropriate extreme scenarios for their basins. While these extreme scenarios may have a lower

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[9] "The description of undesirable results shall include [...] potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results". [23 CCR §354.26(b)(3)]

[10] The description of minimum thresholds shall include [...] how minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests." [23 CCR §354.28(b)(4)]

[11] "The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results." [23 CCR §354.28(c)(6)]

[12] Rohde MM, Seapy B, Rogers R, Castañeda X, editors. 2019. Critical Species LookBook: A compendium of California's threatened and endangered species for sustainable groundwater management. The Nature Conservancy, San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/Critical_Species_LookBook_91819.pdf

[13] "Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow." [23 CCR §354.18(e)]

likelihood of occurring, their consequences could be significant, therefore they should be included in groundwater planning.

The GSP includes climate change into precipitation and evapotranspiration terms of the projected water budget. Surface water deliveries, however, were not adjusted for climate change. Furthermore, the GSP does not calculate a sustainable yield based on the projected water budget with climate change incorporated. If the water budgets are incomplete, including the omission of extremely wet and dry scenarios, and sustainable yield is not calculated based on climate change projections, then there is increased uncertainty in virtually every subsequent calculation used to plan for projects, derive measurable objectives, and set minimum thresholds. Plans that do not adequately include climate change projections may underestimate future impacts on vulnerable beneficial users of groundwater such as ecosystems and DACs.

RECOMMENDATIONS

- Integrate climate change, including extremely wet and dry scenarios, into all elements of the projected water budget to form the basis for development of sustainable management criteria and projects and management actions.
- Incorporate surface water flow inputs that are adjusted for climate change to the projected water budget.
- Calculate sustainable yield based on the projected water budget with climate change incorporated.
- Incorporate climate change scenarios into projects and management actions.

3. Data Gaps

The consideration of beneficial users when establishing monitoring networks is **insufficient**. The representative monitoring sites (RMSs) do not adequately represent water quality conditions or groundwater elevation conditions in the northern DAC communities of the Tracy subbasin. Only one new monitoring well is proposed to supplement the GDE analysis, despite the lack of existing shallow wells to monitor GDEs.

The RMSs for surface water depletion monitoring are located only in the southern half of the subbasin (Figure 8-11). The GSP states (p. 8-25): "Monitoring wells along tributaries were not selected as the tributaries only flow for short periods after rain events and are not connected by a continuous saturated interval with the principal aquifers." As discussed above in the ISW section, this shows a disregard for potential ISWs in the subbasin.

The lack of shallow monitoring wells and the lack of plans for future monitoring threatens GDEs, aquatic habitats, surface water users, DACs, and drinking water users. Potential GDEs are located in areas of the subbasin where no shallow groundwater monitoring currently exists or is proposed, leaving data gaps unfilled. Potential ISWs have been dismissed in the GSP, without proposed recommendations to improve ISW identification, mapping, and estimates of depletions. Appropriate monitoring is necessary so that groundwater conditions are characterized and surface-shallow groundwater interactions are fully integrated into the GSP.

RECOMMENDATIONS

- Provide maps that overlay monitoring well locations with the locations of DACs and GDEs to clearly identify potentially impacted areas. Increase the number of representative monitoring sites (RMSs) across the subbasin for all groundwater condition indicators.
- Reconcile data gaps in the monitoring network by evaluating how the gathered data will be used to identify and map GDEs and ISWs, and identify DACs and shallow domestic well users that are vulnerable to undesirable results.
- Determine what ecological monitoring can be used to assess the potential for significant and unreasonable impacts to GDEs or ISWs due to groundwater conditions in the subbasin.

4. Addressing Beneficial Users in Projects and Management Actions

The consideration of beneficial users when developing projects and management actions in the GSP is **insufficient**, due to the failure to completely identify benefits or impacts of identified projects and management actions to key beneficial users of groundwater such as GDEs, aquatic habitats, surface water users, DACs, and drinking water users. Therefore, potential project and management actions may not protect these beneficial users. Groundwater sustainability under SGMA is defined not just by sustainable yield, but by the avoidance of undesirable results for all beneficial users.

RECOMMENDATIONS

- Recharge ponds, reservoirs and facilities for managed stormwater recharge can be designed as multiple-benefit projects to include elements that act functionally as wetlands and provide a benefit for wildlife and aquatic species. For guidance on how to integrate multi-benefit recharge projects into your GSP, refer to the "Multi-Benefit Recharge Project Methodology Guidance Document"[14].
- For all beneficial users, provide public notice and engagement before consideration and implementation of the management actions and projects identified.
- For DACs and domestic well owners, include discussion of a drinking water well impact mitigation program to proactively monitor and protect drinking water wells through GSP implementation. Refer to Attachment B for specific recommendations on how to implement a drinking water well mitigation program.

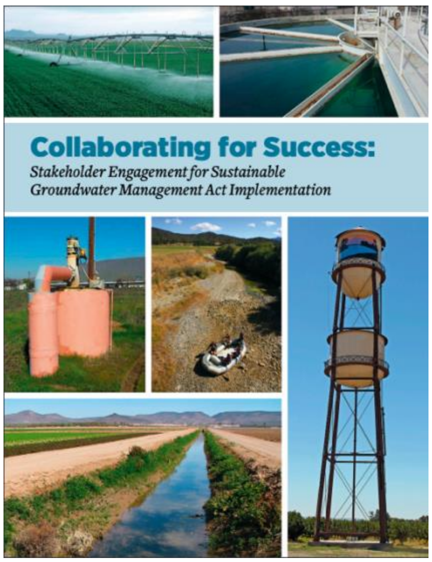
[14] The Nature Conservancy. 2021. Multi-Benefit Recharge Project Methodology for Inclusion in Groundwater Sustainability Plans. Sacramento. Available at: https://groundwaterresourcehub.org/sgma-tools/multi-benefit-recharge-project-methodology-guidance/

- For DACs and domestic well owners, include a discussion of whether potential impacts to water quality from projects and management actions could occur and how the GSA plans to mitigate such impacts.
- Develop management actions that incorporate climate and water delivery uncertainties to address future water demand and prevent future undesirable results.

Attachment B

SGMA Tools to address DAC, drinking water, and environmental beneficial uses and users

Stakeholder Engagement and Outreach



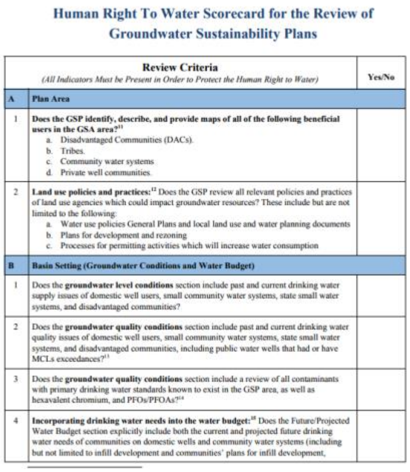
Clean Water Action, Community Water Center and Union of Concerned Scientists developed a guidance document called Collaborating for success: Stakeholder engagement for Sustainable Groundwater Management Act Implementation. It provides details on how to conduct targeted and broad outreach and engagement during Groundwater Sustainability Plan (GSP) development and implementation. Conducting a targeted outreach involves:

- Developing a robust Stakeholder Communication and Engagement plan that includes outreach at frequented locations (schools, farmers markets, religious settings, events) across the plan area to increase the involvement and participation of disadvantaged communities, drinking water users and the environmental stakeholders.

- Providing translation services during meetings and technical assistance to enable easy participation for non-English speaking stakeholders.

- GSP should adequately describe the process for requesting input from beneficial users and provide details on how input is incorporated into the GSP.

The Human Right to Water

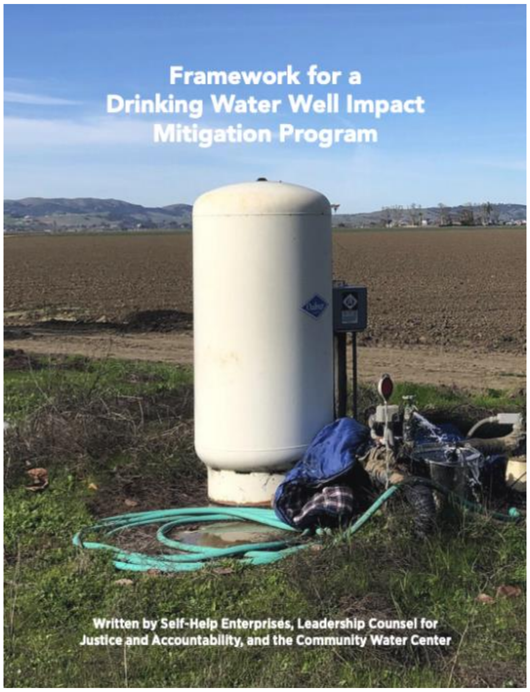


Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans

	Review Criteria *(All Indicators Must be Present in Order to Protect the Human Right to Water)*	Yes/No
A	**Plan Area**	
1	**Does the GSP identify, describe, and provide maps of all of the following beneficial users in the GSA area?**[11] a. Disadvantaged Communities (DACs). b. Tribes. c. Community water systems d. Private well communities.	
2	**Land use policies and practices:**[12] Does the GSP review all relevant policies and practices of land use agencies which could impact groundwater resources? These include but are not limited to the following: a. Water use policies General Plans and local land use and water planning documents b. Plans for development and rezoning c. Processes for permitting activities which will increase water consumption	
B	**Basin Setting (Groundwater Conditions and Water Budget)**	
1	Does the **groundwater level conditions** section include past and current drinking water supply issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities?	
2	Does the **groundwater quality conditions** section include past and current drinking water quality issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities, including public water wells that had or have MCLs exceedances?[13]	
3	Does the **groundwater quality conditions** section include a review of all contaminants with primary drinking water standards known to exist in the GSP area, as well as hexavalent chromium, and PFOs/PFOAs?[14]	
4	**Incorporating drinking water needs into the water budget:**[15] Does the Future/Projected Water Budget section explicitly include both the current and projected future drinking water needs of communities on domestic wells and community water systems (including but not limited to infill development and communities' plans for infill development,	

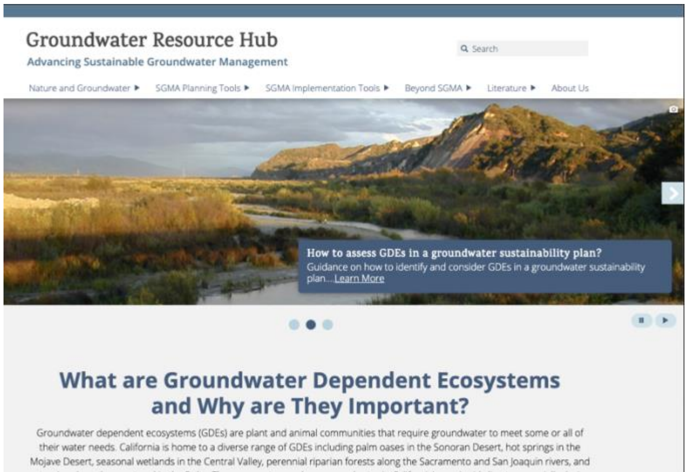
The Human Right to Water Scorecard was developed by Community Water Center, Leadership Counsel for Justice and Accountability and Self Help Enterprises to aid Groundwater Sustainability Agencies (GSAs) in prioritizing drinking water needs in SGMA. The scorecard identifies elements that must exist in GSPs to adequately protect the Human Right to Drinking water.

Drinking Water Well Impact Mitigation Framework



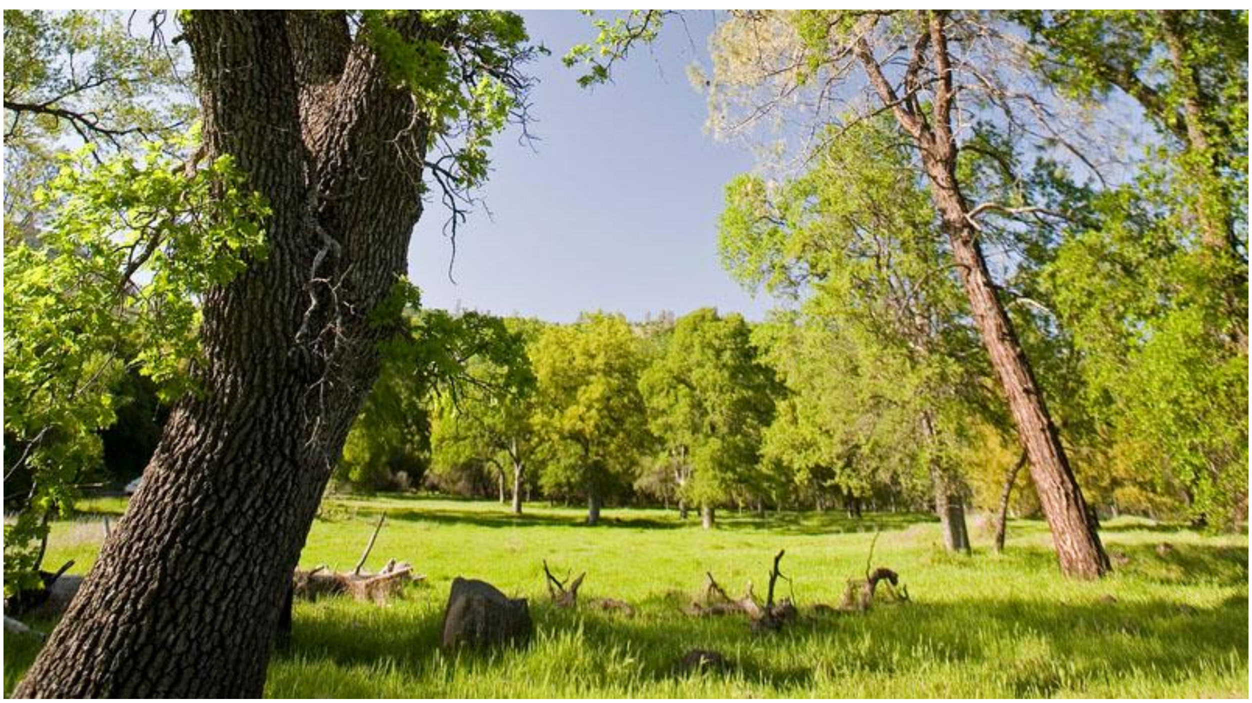
The Drinking Water Well Impact Mitigation Framework was developed by Community Water Center, Leadership Counsel for Justice and Accountability and Self Help Enterprises to aid GSAs in the development and implementation of their GSPs. The framework provides a clear roadmap for how a GSA can best structure its data gathering, monitoring network and management actions to proactively monitor and protect drinking water wells and mitigate impacts should they occur.

Groundwater Resource Hub



The Nature Conservancy has developed a suite of tools based on best available science to help GSAs, consultants, and stakeholders efficiently incorporate nature into GSPs. These tools and resources are available online at GroundwaterResourceHub.org. The Nature Conservancy's tools and resources are intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Rooting Depth Database



The Plant Rooting Depth Database provides information that can help assess whether groundwater-dependent vegetation are accessing groundwater. Actual rooting depths will depend on the plant species and site-specific conditions, such as soil type and availability of other water sources. Site-specific knowledge of depth to groundwater combined with rooting depths will help provide an understanding of the potential groundwater levels are needed to sustain GDEs.

How to use the database

The maximum rooting depth information in the Plant Rooting Depth Database is useful when verifying whether vegetation in the Natural Communities Commonly Associated with Groundwater (NC Dataset) are connected to groundwater. A 30 ft depth-to-groundwater threshold, which is based on averaged global rooting depth data for phreatophytes[1], is relevant for most plants identified in the NC Dataset since most plants have a max rooting depth of less than 30 feet. However, it is important to note that deeper thresholds are necessary for other plants that have reported maximum root depths that exceed the averaged 30 feet threshold, such as valley oak (*Quercus lobata*), Euphrates poplar (*Populus euphratica*), salt cedar (*Tamarix spp.*), and shadescale (*Atriplex confertifolia*). The Nature Conservancy advises that the reported max rooting depth for these deeper-rooted plants be used. For example, a depth-to groundwater threshold of 80 feet should be used instead of the 30 ft threshold, when verifying whether valley oak polygons from the NC Dataset are connected to groundwater. It is important to re-emphasize that actual rooting depth data are limited and will depend on the plant species and site-specific conditions such as soil and aquifer types, and availability to other water sources.

The Plant Rooting Depth Database is an Excel workbook composed of four worksheets:

1. California phreatophyte rooting depth data (included in the NC Dataset)
2. Global phreatophyte rooting depth data
3. Metadata
4. References

How the database was compiled

The Plant Rooting Depth Database is a compilation of rooting depth information for the groundwater-dependent plant species identified in the NC Dataset. Rooting depth data were compiled from published scientific literature and expert opinion through a crowdsourcing campaign. As more information becomes available, the database of rooting depths will be updated. Please Contact Us if you have additional rooting depth data for California phreatophytes.

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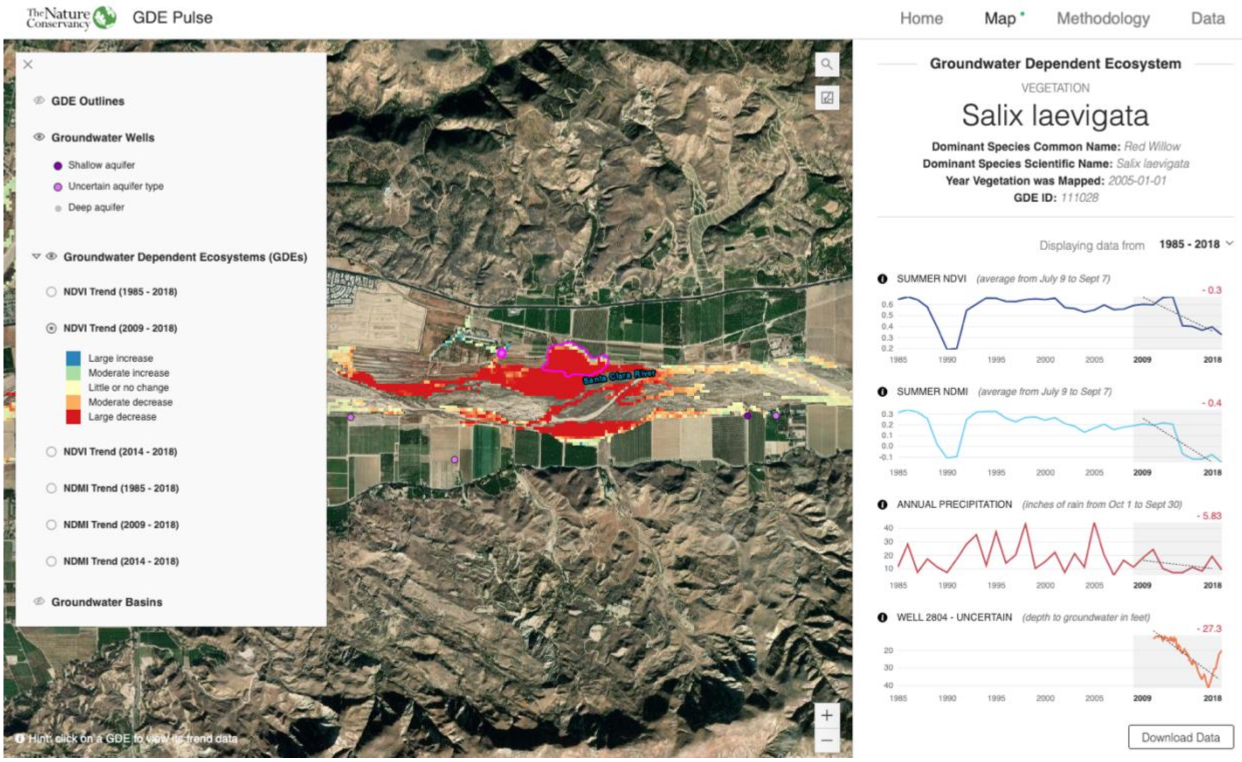
[1] Canadell, J., Jackson, R.B., Ehleringer, J.B. et al. 1996. Maximum rooting depth of vegetation types at the global scale. Oecologia 108, 583–595. https://doi.org/10.1007/BF00329030

GDE Pulse



GDE Pulse is a free online tool that allows Groundwater Sustainability Agencies to assess changes in groundwater dependent ecosystem (GDE) health using satellite, rainfall, and groundwater data. Remote sensing data from satellites has been used to monitor the health of vegetation all over the planet. GDE pulse has compiled 35 years of satellite imagery from NASA's Landsat mission for every polygon in the Natural Communities Commonly Associated with Groundwater Dataset. The following datasets are available for downloading:

Normalized Difference Vegetation Index (NDVI) is a satellite-derived index that represents the greenness of vegetation. Healthy green vegetation tends to have a higher NDVI, while dead leaves have a lower NDVI. We calculated the average NDVI during the driest part of the year (July - Sept) to estimate vegetation health when the plants are most likely dependent on groundwater.

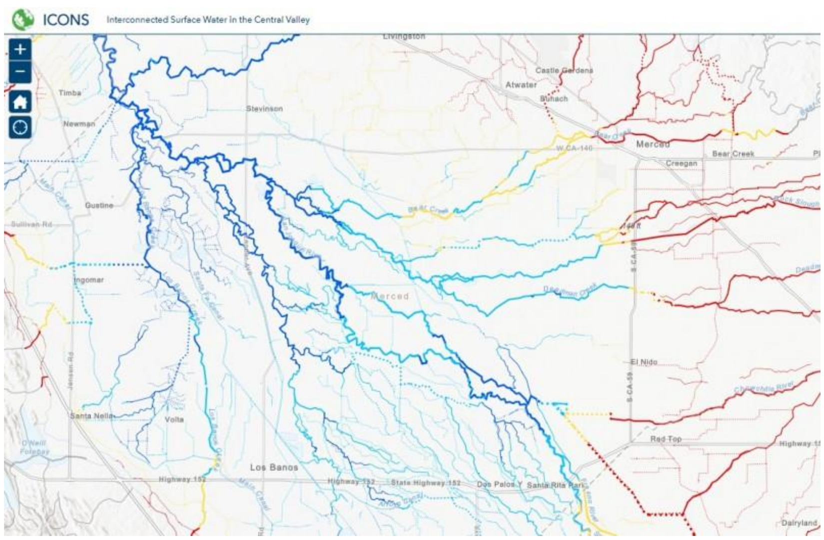
Normalized Difference Moisture Index (NDMI) is a satellite-derived index that represents water content in vegetation. NDMI is derived from the Near-Infrared (NIR) and Short-Wave Infrared (SWIR) channels. Vegetation with adequate access to water tends to have higher NDMI, while vegetation that is water stressed tends to have lower NDMI. We calculated the average NDVI during the driest part of the year (July–September) to estimate vegetation health when the plants are most likely dependent on groundwater.

Annual Precipitation is the total precipitation for the water year (October 1st – September 30th) from the PRISM dataset. The amount of local precipitation can affect vegetation with more precipitation generally leading to higher NDVI and NDMI.

Depth to Groundwater measurements provide an indication of the groundwater levels and changes over time for the surrounding area. We used groundwater well measurements from nearby (<1km) wells to estimate the depth to groundwater below the GDE based on the average elevation of the GDE (using a digital elevation model) minus the measured groundwater surface elevation.

ICONOS Mapper

Interconnected Surface Water in the Central Valley



ICONS maps the likely presence of interconnected surface water (ISW) in the Central Valley using depth to groundwater data. Using data from 2011-2018, the ISW dataset represents the likely connection between surface water and groundwater for rivers and streams in California's Central Valley. It includes information on the mean, maximum, and minimum depth to groundwater for each stream segment over the years with available data, as well as the likely presence of ISW based on the minimum depth to groundwater. The Nature Conservancy developed this database, with guidance and input from expert academics, consultants, and state agencies.

We developed this dataset using groundwater elevation data available online from the California Department of Water Resources (DWR). DWR only provides this data for the Central Valley. For GSAs outside of the valley, who have groundwater well measurements, we recommend following our methods to determine likely ISW in your region. The Nature Conservancy's ISW dataset should be used as a first step in reviewing ISW and should be supplemented with local or more recent groundwater depth data.

Attachment C

Freshwater Species Located in the Tracy Basin

To assist in identifying the beneficial users of surface water necessary to assess the undesirable result "depletion of interconnected surface waters", Attachment C provides a list of freshwater species located in the Tracy Basin. To produce the freshwater species list, we used ArcGIS to select features within the California Freshwater Species Database version 2.0.9 within the basin boundary. This database contains information on ~4,000 vertebrates, macroinvertebrates and vascular plants that depend on fresh water for at least one stage of their life cycle. The methods used to compile the California Freshwater Species Database can be found in Howard et al. 2015[1]. The spatial database contains locality observations and/or distribution information from ~400 data sources. The database is housed in the California Department of Fish and Wildlife's BIOS[2] as well as on The Nature Conservancy's science website[3].

Scientific Name	Common Name	Legal Protected Status		
		Federal	State	Other
BIRDS				
Laterallus jamaicensis coturniculus	California Black Rail	Bird of Conservation Concern	Threatened	
Actitis macularius	Spotted Sandpiper			
Aechmophorus clarkii	Clark's Grebe			
Aechmophorus occidentalis	Western Grebe			
Agelaius tricolor	Tricolored Blackbird	Bird of Conservation Concern	Special Concern	BSSC - First priority
Aix sponsa	Wood Duck			
Anas acuta	Northern Pintail			
Anas americana	American Wigeon			
Anas clypeata	Northern Shoveler			
Anas crecca	Green-winged Teal			
Anas cyanoptera	Cinnamon Teal			
Anas discors	Blue-winged Teal			
Anas platyrhynchos	Mallard			
Anas strepera	Gadwall			
Anser albifrons	Greater White-fronted Goose			
Ardea alba	Great Egret			
Ardea herodias	Great Blue Heron			

[1] Howard, J.K. et al. 2015. Patterns of Freshwater Species Richness, Endemism, and Vulnerability in California. PLoSONE, 11(7). Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0130710

[2] California Department of Fish and Wildlife BIOS: https://www.wildlife.ca.gov/data/BIOS

[3] Science for Conservation: https://www.scienceforconservation.org/products/california-freshwater-species-database

Aythya affinis	Lesser Scaup			
Aythya americana	Redhead		Special Concern	BSSC - Third priority
Aythya collaris	Ring-necked Duck			
Aythya marila	Greater Scaup			
Aythya valisineria	Canvasback		Special	
Botaurus lentiginosus	American Bittern			
Bucephala albeola	Bufflehead			
Bucephala clangula	Common Goldeneye			
Butorides virescens	Green Heron			
Calidris alpina	Dunlin			
Calidris mauri	Western Sandpiper			
Calidris minutilla	Least Sandpiper			
Chen caerulescens	Snow Goose			
Chen rossii	Ross's Goose			
Chlidonias niger	Black Tern		Special Concern	BSSC - Second priority
Chroicocephalus philadelphia	Bonaparte's Gull			
Cistothorus palustris palustris	Marsh Wren			
Cygnus columbianus	Tundra Swan			
Egretta thula	Snowy Egret			
Empidonax traillii	Willow Flycatcher	Bird of Conservation Concern	Endangered	
Fulica americana	American Coot			
Gallinago delicata	Wilson's Snipe			
Gallinula chloropus	Common Moorhen			
Geothlypis trichas trichas	Common Yellowthroat			
Grus canadensis	Sandhill Crane			
Haliaeetus leucocephalus	Bald Eagle	Bird of Conservation Concern	Endangered	
Himantopus mexicanus	Black-necked Stilt			
Histrionicus histrionicus	Harlequin Duck		Special Concern	BSSC - Second priority
Icteria virens	Yellow-breasted Chat		Special Concern	BSSC - Third priority
Limnodromus scolopaceus	Long-billed Dowitcher			
Lophodytes cucullatus	Hooded Merganser			

Megaceryle alcyon	Belted Kingfisher			
Mergus merganser	Common Merganser			
Mergus serrator	Red-breasted Merganser			
Numenius americanus	Long-billed Curlew			
Numenius phaeopus	Whimbrel			
Nycticorax nycticorax	Black-crowned Night-Heron			
Oxyura jamaicensis	Ruddy Duck			
Pelecanus erythrorhynchos	American White Pelican		Special Concern	BSSC - First priority
Phalacrocorax auritus	Double-crested Cormorant			
Phalaropus tricolor	Wilson's Phalarope			
Piranga rubra	Summer Tanager		Special Concern	BSSC - First priority
Plegadis chihi	White-faced Ibis		Watch list	
Pluvialis squatarola	Black-bellied Plover			
Podiceps nigricollis	Eared Grebe			
Podilymbus podiceps	Pied-billed Grebe			
Porzana carolina	Sora			
Rallus limicola	Virginia Rail			
Recurvirostra americana	American Avocet			
Riparia riparia	Bank Swallow		Threatened	
Rynchops niger	Black Skimmer			
Setophaga petechia	Yellow Warbler			BSSC - Second priority
Tachycineta bicolor	Tree Swallow			
Tringa melanoleuca	Greater Yellowlegs			
Tringa semipalmata	Willet			
Tringa solitaria	Solitary Sandpiper			
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		Special Concern	BSSC - Third priority
CRUSTACEANS				
Branchinecta lynchi	Vernal Pool Fairy Shrimp	Threatened	Special	IUCN - Vulnerable
Branchinecta mesovallensis	Midvalley Fairy Shrimp		Special	
Linderiella occidentalis	California Fairy Shrimp		Special	IUCN - Near Threatened

Hyalella spp.	Hyalella spp.			
FISH				
Oncorhynchus mykiss irideus	Coastal rainbow trout			Least Concern - Moyle 2013
Oncorhynchus tshawytscha - CV winter	Central Valley winter Chinook salmon	Endangered	Endangered	Vulnerable - Moyle 2013
Spirinchus thaleichthys	Longfin smelt	Candidate	Threatened	Vulnerable - Moyle 2013
Acipenser medirostris ssp. 1	Southern green sturgeon	Threatened	Special Concern	Endangered - Moyle 2013
Oncorhynchus mykiss - CV	Central Valley steelhead	Threatened	Special	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV spring	Central Valley spring Chinook salmon	Threatened	Threatened	Vulnerable - Moyle 2013
HERPS				
Actinemys marmorata marmorata	Western Pond Turtle		Special Concern	ARSSC
Ambystoma californiense californiense	California Tiger Salamander	Threatened	Threatened	ARSSC
Anaxyrus boreas boreas	Boreal Toad			
Rana boylii	Foothill Yellow-legged Frog	Under Review in the Candidate or Petition Process	Special Concern	ARSSC
Rana draytonii	California Red-legged Frog	Threatened	Special Concern	ARSSC
Spea hammondii	Western Spadefoot	Under Review in the Candidate or Petition Process	Special Concern	ARSSC
Thamnophis gigas	Giant Gartersnake	Threatened	Threatened	
Thamnophis sirtalis sirtalis	Common Gartersnake			
Anaxyrus boreas halophilus	California Toad			ARSSC
Pseudacris regilla	Northern Pacific Chorus Frog			
INSECTS & OTHER INVERTS				
Hygrotus curvipes	Curved-foot Hygrotus Diving Beetle		Special	
Ablabesmyia spp.	Ablabesmyia spp.			
Apedilum spp.	Apedilum spp.			
Baetis tricaudatus	A Mayfly			
Chironomus spp.	Chironomus spp.			
Coenagrionidae fam.	Coenagrionidae fam.			
Corixidae fam.	Corixidae fam.			
Cricotopus spp.	Cricotopus spp.			

Dicrotendipes spp.	Dicrotendipes spp.			
Enallagma carunculatum	Tule Bluet			
Enallagma civile	Familiar Bluet			
Hydroptila spp.	Hydroptila spp.			
Ischnura cervula	Pacific Forktail			
Libellula luctuosa	Widow Skimmer			
Oxyethira spp.	Oxyethira spp.			
Paratanytarsus spp.	Paratanytarsus spp.			
Phaenopsectra spp.	Phaenopsectra spp.			
Procladius spp.	Procladius spp.			
Simulium spp.	Simulium spp.			
Sympetrum corruptum	Variegated Meadowhawk			
Tanytarsus spp.	Tanytarsus spp.			
MAMMALS				
Castor canadensis	American Beaver			Not on any status lists
Lontra canadensis canadensis	North American River Otter			Not on any status lists
Neovison vison	American Mink			Not on any status lists
Ondatra zibethicus	Common Muskrat			Not on any status lists
MOLLUSKS				
Anodonta californiensis	California Floater		Special	
Fluminicola seminalis	Nugget Pebblesnail		Special	T
Gonidea angulata	Western Ridged Mussel		Special	
Gyraulus spp.	Gyraulus spp.			
Helisoma spp.	Helisoma spp.			
Margaritifera falcata	Western Pearlshell		Special	
Physa spp.	Physa spp.			
Planorbella trivolvis	Marsh Rams-horn			CS
PLANTS				
Carex comosa	Bristly Sedge		Special	CRPR - 2B.1
Eryngium racemosum	Delta Coyote-thistle		Endangered	CRPR - 1B.1
Hibiscus lasiocarpos occidentalis			Special	CRPR - 1B.2
Lasthenia conjugens	Contra Costa Goldfields	Endangered	Special	CRPR - 1B.1
Lilaeopsis masonii	Mason's Lilaeopsis		Special	CRPR - 1B.1

Limosella australis	NA		Special	CRPR - 2B.1
Puccinellia simplex	Little Alkali Grass			
Symphyotrichum lentum	Suisun Marsh Aster		Special	CRPR - 1B.2
Alisma triviale	Northern Water-plantain			
Alnus rhombifolia	White Alder			
Alopecurus saccatus	Pacific Foxtail			
Ammannia coccinea	Scarlet Ammannia			
Anemopsis californica	Yerba Mansa			
Arundo donax	NA			
Azolla microphylla	Mexican mosquito fern		Special	CRPR - 4.3
Baccharis glutinosa	NA			Not on any status lists
Bidens laevis	Smooth Bur-marigold			
Bolboschoenus maritimus paludosus	NA			Not on any status lists
Callitriche longipedunculata	Longstock Water-starwort			
Callitriche marginata	Winged Water-starwort			
Carex aquatilis dives	Sitka Sedge			
Carex nebrascensis	Nebraska Sedge			
Carex obnupta	Slough Sedge			
Carex vulpinoidea	NA			
Cephalanthus occidentalis	Common Buttonbush			
Ceratophyllum demersum	Common Hornwort			
Cicuta douglasii	Western Water-hemlock			
Cicuta maculata bolanderi	Bolander's Water-hemlock		Special	CRPR - 2B.1
Cirsium hydrophilum hydrophilum	Suisun Thistle	Endangered	Special	CRPR - 1B.1
Cotula coronopifolia	NA			
Crassula aquatica	Water Pygmyweed			
Crassula solieri	NA			Not on any status lists
Crypsis vaginiflora	NA			
Cyperus erythrorhizos	Red-root Flatsedge			

Downingia insignis	Parti-color Downingia			
Elatine californica	California Waterwort			
Eleocharis macrostachya	Creeping Spikerush			
Eleocharis parvula	Small Spikerush		Special	CRPR - 4.3
Elodea canadensis	Broad Waterweed			
Epilobium campestre	NA			Not on any status lists
Epilobium cleistogamum	Cleistogamous Spike-primrose			
Eragrostis hypnoides	Teal Lovegrass			
Eryngium aristulatum aristulatum	California Eryngo			
Eryngium articulatum	Jointed Coyote-thistle			
Eryngium spinosepalum	Spiny Sepaled Coyote-thistle		Special	CRPR - 1B.2
Eryngium vaseyi vaseyi	Vasey's Coyote-thistle			Not on any status lists
Euthamia occidentalis	Western Fragrant Goldenrod			
Galium trifidum	Small Bedstraw			
Glyceria leptostachya	Slim-head Mannagrass			
Helenium bigelovii	Bigelow's Sneezeweed			
Helenium puberulum	Rosilla			
Hydrocotyle ranunculoides	Floating Marsh-pennywort			
Hydrocotyle umbellata	Many-flower Marsh-pennywort			
Hydrocotyle verticillata verticillata	Whorled Marsh-pennywort			
Isoetes howellii	NA			
Isoetes orcuttii	NA			
Isolepis cernua	Low Bulrush			
Juncus acuminatus	Sharp-fruit Rush			
Juncus articulatus articulatus				Not on any status lists
Juncus effusus effusus	NA			
Juncus effusus pacificus				
Juncus lescurii				Not on any status lists

Juncus phaeocephalus phaeocephalus	Brown-head Rush			
Lasthenia ferrisiae	Ferris' Goldfields		Special	CRPR - 4.2
Lasthenia fremontii	Fremont's Goldfields			
Leersia oryzoides	Rice Cutgrass			
Lemna minor	Lesser Duckweed			
Lemna minuta	Least Duckweed			
Lepidium oxycarpum	Sharp-pod Pepper-grass			
Limnanthes douglasii nivea	Douglas' Meadowfoam			
Limnanthes douglasii rosea	Douglas' Meadowfoam			
Limosella acaulis	Southern Mudwort			
Ludwigia peploides peploides	NA			Not on any status lists
Lycopus americanus	American Bugleweed			
Lythrum californicum	California Loosestrife			
Marsilea vestita vestita	NA			Not on any status lists
Mimulus guttatus	Common Large Monkeyflower			
Mimulus latidens	Broad-tooth Monkeyflower			
Myosurus minimus	NA			
Myosurus sessilis	Sessile Mousetail			
Najas guadalupensis guadalupensis	Southern Naiad			
Navarretia cotulifolia	Cotula Navarretia			
Navarretia heterandra	Tehama Navarretia			
Oenanthe sarmentosa	Water-parsley			
Panicum acuminatum acuminatum				Not on any status lists
Paspalum distichum	Joint Paspalum			
Persicaria hydropiper	NA			Not on any status lists
Persicaria hydropiperoides				Not on any status lists
Persicaria lapathifolia				Not on any status lists
Persicaria maculosa	NA			Not on any status lists

Persicaria punctata	NA			Not on any status lists
Phacelia distans	NA			
Phalaris arundinacea	Reed Canarygrass			
Phragmites australis australis	Common Reed			
Pilularia americana	NA			
Plagiobothrys acanthocarpus	Adobe Popcorn-flower			
Plagiobothrys greenei	Greene's Popcorn-flower			
Plagiobothrys humistratus	Dwarf Popcorn-flower			
Plagiobothrys leptocladus	Alkali Popcorn-flower			
Plantago elongata elongata	Slender Plantain			
Platanus racemosa	California Sycamore			
Pluchea odorata odorata	Scented Conyza			
Pogogyne zizyphoroides				Not on any status lists
Potamogeton foliosus foliosus	Leafy Pondweed			
Potamogeton illinoensis	Illinois Pondweed			
Potamogeton nodosus	Longleaf Pondweed			
Potamogeton zosteriformis	Flatstem Pondweed		Special	CRPR - 2B.2
Potentilla anserina pacifica				Not on any status lists
Psilocarphus brevissimus brevissimus	Dwarf Woolly-heads			
Psilocarphus oregonus	Oregon Woolly-heads			
Rorippa curvisiliqua curvisiliqua	Curve-pod Yellowcress			
Rorippa palustris palustris	Bog Yellowcress			
Rumex crassus				Not on any status lists
Rumex occidentalis				Not on any status lists
Sagittaria latifolia latifolia	Broadleaf Arrowhead			
Salix babylonica	NA			
Salix exigua exigua	Narrowleaf Willow			

Salix exigua hindsiana				Not on any status lists
Salix gooddingii	Goodding's Willow			
Salix laevigata	Polished Willow			
Salix lasiandra lasiandra				Not on any status lists
Salix lasiolepis lasiolepis	Arroyo Willow			
Samolus parviflorus	NA			Not on any status lists
Schoenoplectus acutus acutus	NA			
Schoenoplectus acutus occidentalis	Hardstem Bulrush			
Schoenoplectus americanus	Three-square Bulrush			
Schoenoplectus californicus	California Bulrush			
Senecio hydrophilus	Great Swamp Ragwort			
Sinapis alba	NA			
Sium suave	Hemlock Water-parsnip			
Sparganium eurycarpum eurycarpum				
Stachys albens	White-stem Hedge-nettle			
Triglochin maritima	Common Bog Arrow-grass			
Triglochin striata	Three-ribbed Arrow-grass			
Typha latifolia	Broadleaf Cattail			

Scientific Name	Common Name	Legal Protected Status		
		Federal	State	Other
BIRDS				
FISH				
HERPS				
INSECTS & OTHER INVERTS				

MAMMALS				
MOLLUSKS				
PLANTS				

Attachment D

July 2019

IDENTIFYING GDEs UNDER SGMA

Best Practices for using the NC Dataset

The Sustainable Groundwater Management Act (SGMA) requires that groundwater dependent ecosystems (GDEs) be identified in Groundwater Sustainability Plans (GSPs). As a starting point, the Department of Water Resources (DWR) is providing the Natural Communities Commonly Associated with Groundwater Dataset (NC Dataset) online[1] to help Groundwater Sustainability Agencies (GSAs), consultants, and stakeholders identify GDEs within individual groundwater basins. To apply information from the NC Dataset to local areas, GSAs should combine it with the best available science on local hydrology, geology, and groundwater levels to verify whether polygons in the NC dataset are likely supported by groundwater in an aquifer (Figure 1)[2]. This document highlights six best practices for using local groundwater data to confirm whether mapped features in the NC dataset are supported by groundwater.

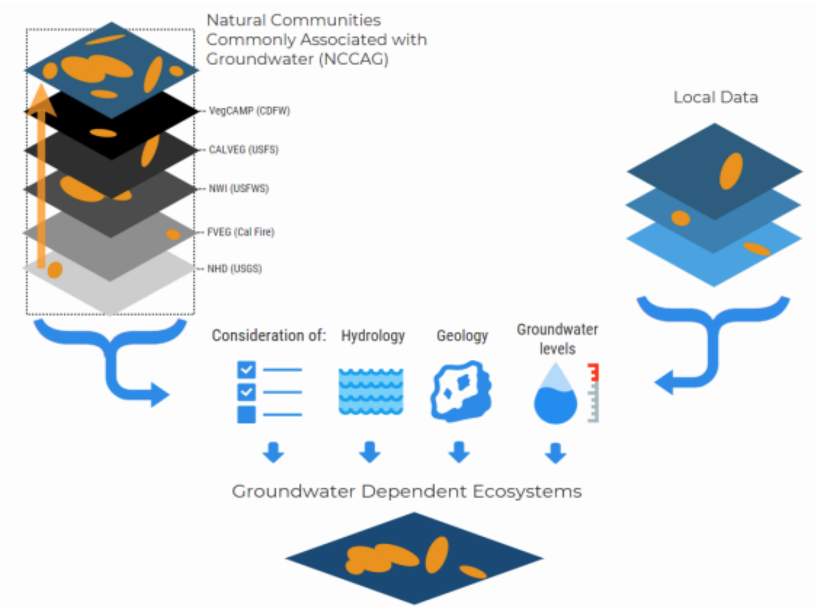


Figure 1. Considerations for GDE identification.
Source: DWR[2]

[1] NC Dataset Online Viewer: https://gis.water.ca.gov/app/NCDatasetViewer/
[2] California Department of Water Resources (DWR). 2018. Summary of the "Natural Communities Commonly Associated with Groundwater" Dataset and Online Web Viewer. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Statewide-Reports/Natural-Communities-Dataset-Summary-Document.pdf

The NC Dataset identifies vegetation and wetland features that are good indicators of a GDE. The dataset is comprised of 48 publicly available state and federal datasets that map vegetation, wetlands, springs, and seeps commonly associated with groundwater in California[3]. It was developed through a collaboration between DWR, the Department of Fish and Wildlife, and The Nature Conservancy (TNC). TNC has also provided detailed guidance on identifying GDEs from the NC dataset[4] on the Groundwater Resource Hub[5], a website dedicated to GDEs.

BEST PRACTICE #1. Establishing a Connection to Groundwater

Groundwater basins can be comprised of one continuous aquifer (Figure 2a) or multiple aquifers stacked on top of each other (Figure 2b). In unconfined aquifers (Figure 2a), using the depth-to-groundwater and the rooting depth of the vegetation is a reasonable method to infer groundwater dependence for GDEs. If groundwater is well below the rooting (and capillary) zone of the plants and any wetland features, the ecosystem is considered disconnected and groundwater management is not likely to affect the ecosystem (Figure 2d). However, it is important to consider local conditions (e.g., soil type, groundwater flow gradients, and aquifer parameters) and to review groundwater depth data from multiple seasons and water year types (wet and dry) because intermittent periods of high groundwater levels can replenish perched clay lenses that serve as the water source for GDEs (Figure 2c). Maintaining these natural groundwater fluctuations are important to sustaining GDE health.

Basins with a stacked series of aquifers (Figure 2b) may have varying levels of pumping across aquifers in the basin, depending on the production capacity or water quality associated with each aquifer. If pumping is concentrated in deeper aquifers, SGMA still requires GSAs to sustainably manage groundwater resources in shallow aquifers, such as perched aquifers, that support springs, surface water, domestic wells, and GDEs (Figure 2). This is because vertical groundwater gradients across aquifers may result in pumping from deeper aquifers to cause adverse impacts onto beneficial users reliant on shallow aquifers or interconnected surface water. The goal of SGMA is to sustainably manage groundwater resources for current and future social, economic, and environmental benefits. While groundwater pumping may not be currently occurring in a shallower aquifer, use of this water may become more appealing and economically viable in future years as pumping restrictions are placed on the deeper production aquifers in the basin to meet the sustainable yield and criteria. Thus, identifying GDEs in the basin should done irrespective to the amount of current pumping occurring in a particular aquifer, so that future impacts on GDEs due to new production can be avoided. A good rule of thumb to follow is: *if groundwater can be pumped from a well - it's an aquifer*.

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[3] For more details on the mapping methods, refer to: Klausmeyer, K., J. Howard, T. Keeler-Wolf, K. Davis-Fadtke, R. Hull, A. Lyons. 2018. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report. San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/iGDE_data_paper_20180423.pdf

[4] "Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans" is available at: https://groundwaterresourcehub.org/gde-tools/gsp-guidance-document/

[5] The Groundwater Resource Hub: www.GroundwaterResourceHub.org

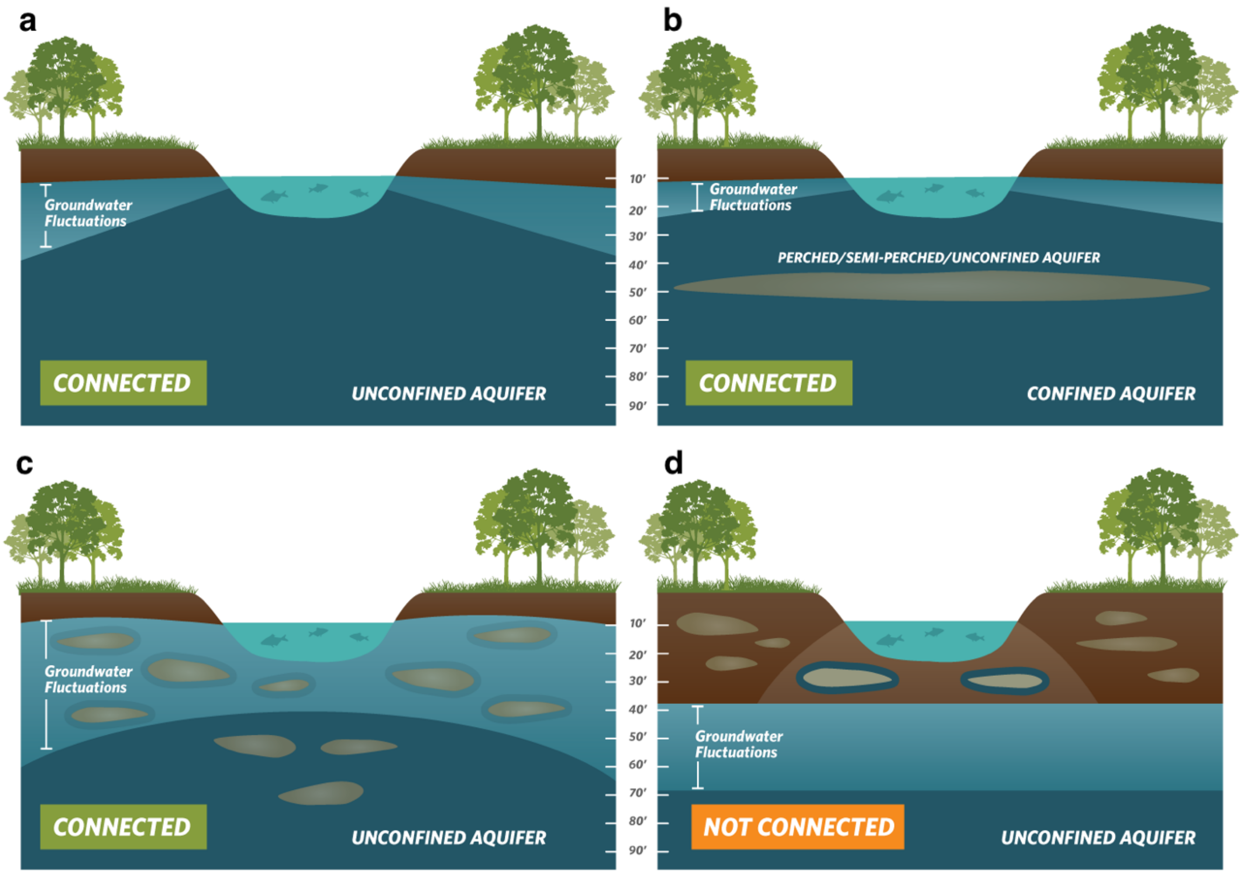

Figure 2. Confirming whether an ecosystem is connected to groundwater. Top: (a) Under the ecosystem is an unconfined aquifer with depth-to-groundwater fluctuating seasonally and interannually within 30 feet from land surface. **(b)** Depth-to-groundwater in the shallow aquifer is connected to overlying ecosystem. Pumping predominately occurs in the confined aquifer, but pumping is possible in the shallow aquifer. **Bottom: (c)** Depth-to-groundwater fluctuations are seasonally and interannually large, however, clay layers in the near surface prolong the ecosystem's connection to groundwater. **(d)** Groundwater is disconnected from surface water, and any water in the vadose (unsaturated) zone is due to direct recharge from precipitation and indirect recharge under the surface water feature. These areas are not connected to groundwater and typically support species that do not require access to groundwater to survive.

BEST PRACTICE #2. Characterize Seasonal and Interannual Groundwater Conditions

SGMA requires GSAs to describe current and historical groundwater conditions when identifying GDEs [23 CCR §354.16(g)]. Relying solely on the SGMA benchmark date (January 1, 2015) or any other single point in time to characterize groundwater conditions (e.g., depth-to-groundwater) is inadequate because managing groundwater conditions with data from one time point fails to capture the seasonal and interannual variability typical of California's climate. DWR's Best Management Practices document on water budgets[6] recommends using 10 years of water supply and water budget information to describe how historical conditions have impacted the operation of the basin within sustainable yield, implying that a baseline[7] could be determined based on data between 2005 and 2015. Using this or a similar time period, depending on data availability, is recommended for determining the depth-to-groundwater.

GDEs depend on groundwater levels being close enough to the land surface to interconnect with surface water systems or plant rooting networks. The most practical approach[8] for a GSA to assess whether polygons in the NC dataset are connected to groundwater is to rely on groundwater elevation data. As detailed in TNC's GDE guidance document[4], one of the key factors to consider when mapping GDEs is to contour depth-to-groundwater in the aquifer that is supporting the ecosystem (see Best Practice #5).

Groundwater levels fluctuate over time and space due to California's Mediterranean climate (dry summers and wet winters), climate change (flood and drought years), and subsurface heterogeneity in the subsurface (Figure 3). Many of California's GDEs have adapted to dealing with intermittent periods of water stress, however if these groundwater conditions are prolonged, adverse impacts to GDEs can result. While depth-to-groundwater levels within 30 feet[4] of the land surface are generally accepted as being a proxy for confirming that polygons in the NC dataset are supported by groundwater, it is highly advised that fluctuations in the groundwater regime be characterized to understand the seasonal and interannual groundwater variability in GDEs. Utilizing groundwater data from one point in time can misrepresent groundwater levels required by GDEs, and inadvertently result in adverse impacts to the GDEs. Time series data on groundwater elevations and depths are available on the SGMA Data Viewer[9]. However, if insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons in the GSP until data gaps are reconciled in the monitoring network (see Best Practice #6).

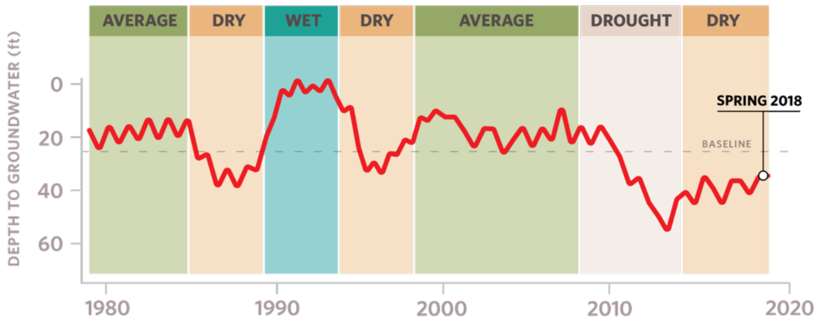

Figure 3. Example seasonality and interannual variability in depth-to-groundwater over time. Selecting one point in time, such as Spring 2018, to characterize groundwater conditions in GDEs fails to capture what groundwater conditions are necessary to maintain the ecosystem status into the future so adverse impacts are avoided.

---

[6] DWR. 2016. Water Budget Best Management Practice. Available at: https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Water_Budget_Final_2016-12-23.pdf

[7] Baseline is defined under the GSP regulations as "historic information used to project future conditions for hydrology, water demand, and availability of surface water and to evaluate potential sustainable management practices of a basin." [23 CCR §351(e)]

[8] Groundwater reliance can also be confirmed via stable isotope analysis and geophysical surveys. For more information see The GDE Assessment Toolbox (Appendix IV, GDE Guidance Document for GSPs[4]).

[9] SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

BEST PRACTICE #3. Ecosystems Often Rely on Both Groundwater and Surface Water

GDEs are plants and animals that rely on groundwater for all or some of its water needs, and thus can be supported by multiple water sources. The presence of non-groundwater sources (e.g., surface water, soil moisture in the vadose zone, applied water, treated wastewater effluent, urban stormwater, irrigated return flow) within and around a GDE does not preclude the possibility that it is supported by groundwater, too. SGMA defines GDEs as "ecological communities and species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" [23 CCR §351(m)]. Hence, depth-to-groundwater data should be used to identify whether NC polygons are supported by groundwater and should be considered GDEs. In addition, SGMA requires that significant and undesirable adverse impacts to beneficial users of surface water be avoided. Beneficial users of surface water include environmental users such as plants or animals[10], which therefore must be considered when developing minimum thresholds for depletions of interconnected surface water.

GSAs are only responsible for impacts to GDEs resulting from groundwater conditions in the basin, so if adverse impacts to GDEs result from the diversion of applied water, treated wastewater, or irrigation return flow away from the GDE, then those impacts will be evaluated by other permitting requirements (e.g., CEQA) and may not be the responsibility of the GSA. However, if adverse impacts occur to the GDE due to changing groundwater conditions resulting from pumping or groundwater management activities, then the GSA would be responsible (Figure 4).

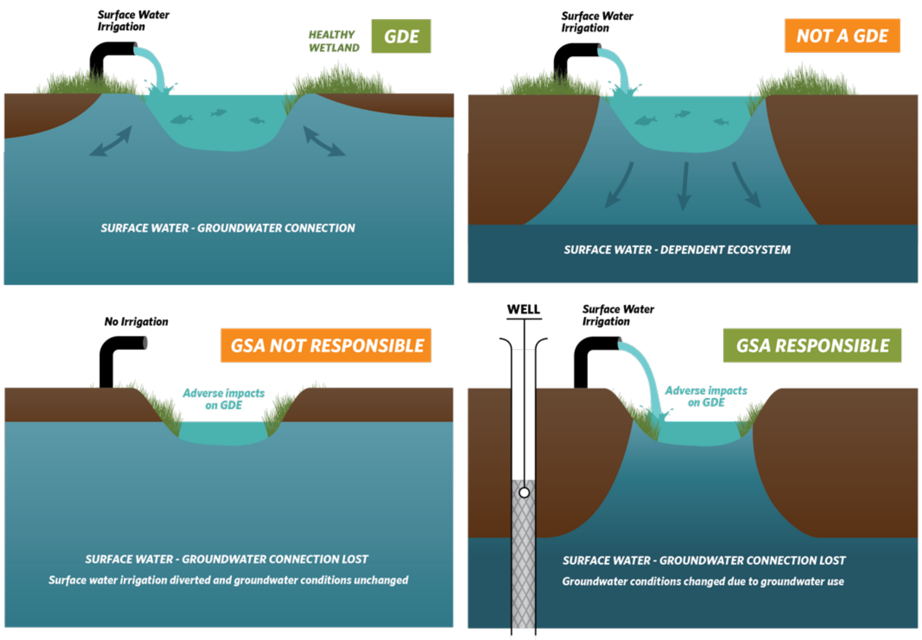

Figure 4. Ecosystems often depend on multiple sources of water. Top: (Left) Surface water and groundwater are interconnected, meaning that the GDE is supported by both groundwater and surface water. **(Right)** Ecosystems that are only reliant on non-groundwater sources are not groundwater-dependent. **Bottom: (Left)** An ecosystem that was once dependent on an interconnected surface water, but loses access to groundwater solely due to surface water diversions may not be the GSA's responsibility. **(Right)** Groundwater dependent ecosystems once dependent on an interconnected surface water system, but loses that access due to groundwater pumping is the GSA's responsibility.

[10] For a list of environmental beneficial users of surface water by basin, visit: https://groundwaterresourcehub.org/gde-tools/environmental-surface-water-beneficiaries/

BEST PRACTICE #4. Select Representative Groundwater Wells

Identifying GDEs in a basin requires that groundwater conditions are characterized to confirm whether polygons in the NC dataset are supported by the underlying aquifer. To do this, proximate groundwater wells should be identified to characterize groundwater conditions (Figure 5). When selecting representative wells, it is particularly important to consider the subsurface heterogeneity around NC polygons, especially near surface water features where groundwater and surface water interactions occur around heterogeneous stratigraphic units or aquitards formed by fluvial deposits. The following selection criteria can help ensure groundwater levels are representative of conditions within the GDE area:

- Choose wells that are within 5 kilometers (3.1 miles) of each NC Dataset polygons because they are more likely to reflect the local conditions relevant to the ecosystem. If there are no wells within 5km of the center of a NC dataset polygon, then there is insufficient information to remove the polygon based on groundwater depth. Instead, it should be retained as a potential GDE until there are sufficient data to determine whether or not the NC Dataset polygon is supported by groundwater.

- Choose wells that are screened within the surficial unconfined aquifer and capable of measuring the true water table.

- Avoid relying on wells that have insufficient information on the screened well depth interval for excluding GDEs because they could be providing data on the wrong aquifer. This type of well data should not be used to remove any NC polygons.

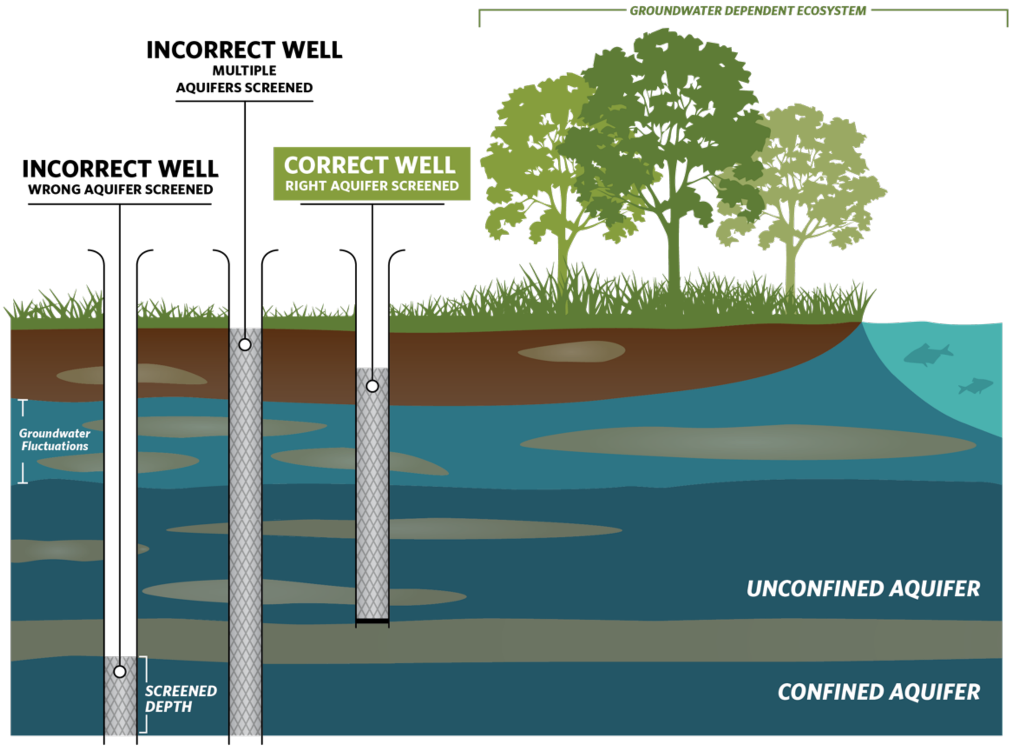

Figure 5. Selecting representative wells to characterize groundwater conditions near GDEs.

BEST PRACTICE #5. Contouring Groundwater Elevations

The common practice to contour depth-to-groundwater over a large area by interpolating measurements at monitoring wells is unsuitable for assessing whether an ecosystem is supported by groundwater. This practice causes errors when the land surface contains features like stream and wetland depressions because it assumes the land surface is constant across the landscape and depth-to-groundwater is constant below these low-lying areas (Figure 6a). A more accurate approach is to interpolate **groundwater elevations** at monitoring wells to get groundwater elevation contours across the landscape. This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM)[11] to estimate depth-to-groundwater contours across the landscape (Figure b; Figure 7). This will provide a much more accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found.

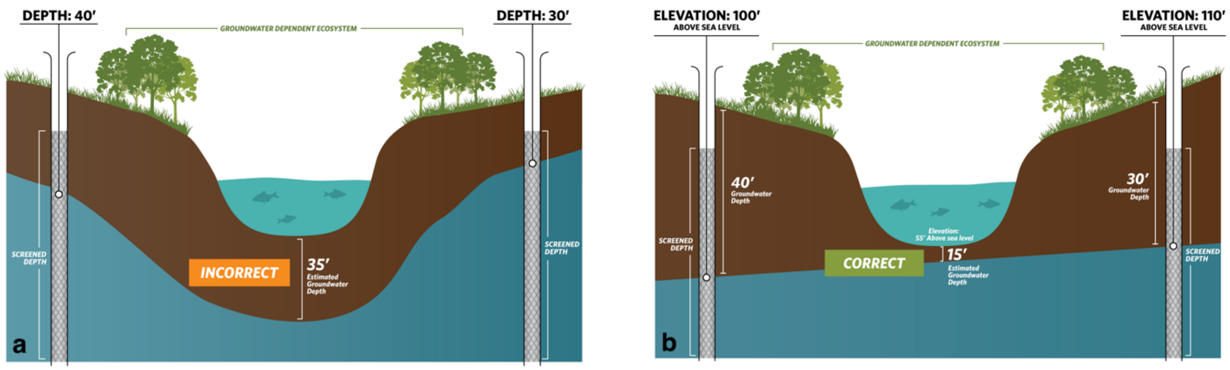

Figure 6. Contouring depth-to-groundwater around surface water features and GDEs. (a) Groundwater level interpolation using depth-to-groundwater data from monitoring wells. **(b)** Groundwater level interpolation using groundwater elevation data from monitoring wells and DEM data.

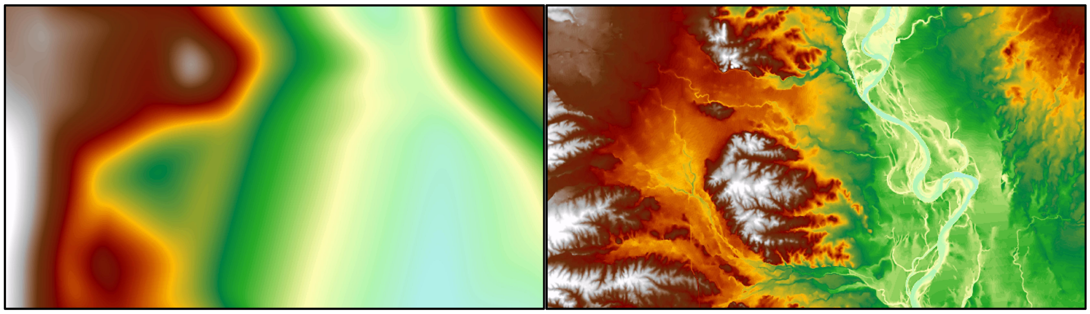

Figure 7. Depth-to-groundwater contours in Northern California. (Left) Contours were interpolated using depth-to-groundwater measurements determined at each well. **(Right)** Contours were determined by interpolating groundwater elevation measurements at each well and superimposing ground surface elevation from DEM spatial data to generate depth-to-groundwater contours. The image on the right shows a more accurate depth-to-groundwater estimate because it takes the local topography and elevation changes into account.

[11] USGS Digital Elevation Model data products are described at: https://www.usgs.gov/core-science-systems/ngp/3dep/about-3dep-products-services and can be downloaded at: https://iewer.nationalmap.gov/basic/

BEST PRACTICE #6. Best Available Science

Adaptive management is embedded within SGMA and provides a process to work toward sustainability over time by beginning with the best available information to make initial decisions, monitoring the results of those decisions, and using the data collected through monitoring programs to revise decisions in the future. In many situations, the hydrologic connection of NC dataset polygons will not initially be clearly understood if site-specific groundwater monitoring data are not available. If sufficient data are not available in time for the 2020/2022 plan, **The Nature Conservancy strongly advises that questionable polygons from the NC dataset be included in the GSP until data gaps are reconciled in the monitoring network.** Erring on the side of caution will help minimize inadvertent impacts to GDEs as a result of groundwater use and management actions during SGMA implementation.

KEY DEFINITIONS

Groundwater basin is an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom. *23 CCR §341(g)(1)*

Groundwater dependent ecosystem (GDE) are ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. *23 CCR §351(m)*

Interconnected surface water (ISW) surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. *23 CCR §351(o)*

Principal aquifers are aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. *23 CCR §351(aa)*

ABOUT US

The Nature Conservancy is a science-based nonprofit organization whose mission is *to conserve the lands and waters on which all life depends*. To support successful SGMA implementation that meets the future needs of people, the economy, and the environment, TNC has developed tools and resources (www.groundwaterresourcehub.org) intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Jenny Wood 8/28/2021 1:11 PM

×

hank you for this opportunity to comment on this draft GSP. First I want to commend all those who worked on it. It is a comprehensive and incisive document and it is obvious that a lot of research and collaboration went into it. I appreciate the attention to the ecosystem through monitoring surface water to ensure we donâ t deplete that and concern for vegetation in the environment, not just agricultural or human use.

My comment comes with the growing threat of climate change and the understanding that we must do all we can to mitigate its effects. While I appreciate that climate change was considered in the Water Budget portion of the report, I donâ t think the full impact of it can possibly be predicted or accounted for and so I hope to begin a conversation about the use of greywater in home gardens, and other ecologically sustainable practices, as a way to reduce the demand for surface and groundwater.

I would like to suggest that some of the projects or management actions be around encouraging or even incentivizing residents to create greywater systems to water their landscapes. This could be through easing restrictions in the permitting process, creating incentives through the City of Tracy utility, and developing ways to educate the public about the use of greywater and how to make systems for themselves. These things are already being implemented in other communities in California and proving to reduce the use of city water and groundwater. I am attaching a study by Greywater Action in collaboration with the City of Santa Rosa and Ecology Action of Santa Cruz about â Residential Greywater Irrigation Systems in Californiaâ that provides some great information on this subject.

Other ideas to increase the recharge of the upper aquifer would be to use heavy mulch in public areas and using permeable concrete in new developments in the city in order to retain rainwater, allowing it to sink into the ground rather than being washed into the sewers. These methods not only help recharge the upper aquifer, they also reduce the need and energy used for treating sewer water to create recycled water and improve the soil in order to retain more water in the long-run. Tracy is a fast growing city with many developments planned in the future. It is critical that we plan these developments with our ecosystem and water system in mind.

Thank you again for your consideration and I hope that we as a community can start to plan for the future using environmentally sustainable practices, along with the great projects you are already working on. If it is too late to include these in this iteration of the GSP, I would ask that you consider them in future 5-year updates.

Attachments:

GW_Study_revised1.pdf

Close

Public Draft GSP - 10. Projects and Management Actions	to comment on this draft GSP. First I want to commend all those who wo...	1:11 PM

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The West Side Irrigation District

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Residential Greywater Irrigation Systems in California:

An Evaluation of Soil and Water Quality, User Satisfaction, and Installation Costs

Greywater Action

in collaboration with
City of Santa Rosa and Ecology Action of Santa Cruz

Residential Greywater Irrigation Systems in California:

An Evaluation of Soil and Water Quality, User Satisfaction, and Installation Costs

November, 2012, revised September 2013

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Please send questions, comments and suggestions to Laura Allen (laura@greywateraction.org).

1

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All errors are our own.

Table of Contents

Appendices

Introduction

As water shortages become increasingly common, new and innovative ways to conserve and reuse water are critically important. Widespread reuse of household greywater has the potential to contribute significant water savings, up to 40% of residential consumption (Cohen, 2009), although how much water is actually saved depends on how people design and maintain their systems. Lack of scientific data on how greywater affects soils and plants has been a barrier for widespread implementation of greywater systems for residents and public agencies alike. Lack of data regarding the costs of installation, permitting and maintenance for greywater systems also present barriers for households that are considering greywater reuse. We seek to collect this data through a multi-faceted study of residential greywater systems in Central California.

In 2009 California rewrote its greywater code, making low-tech greywater systems legal for the first time, and excluding clothes washer systems from permit requirements (CBSC, 2010). The legalization of greywater reuse in California has stimulated many local governments and water utilities to invest in public education and incentive programs. The increase in public interest and installation of greywater systems has also generated concerns from some water districts, public agencies, and states about potential environmental problems resulting from using greywater. Despite these concerns, greywater systems have been legal and widely implemented in states like Arizona and New Mexico for many years with no reports of health or environmental problems.[2]

Few U.S. greywater studies have investigated residential greywater systems *in situ*, and those that have typically only evaluated a handful of systems (City of LA, 1992; Bennet et al., 1999; Little et al., 2000). Field studies of greywater systems in other countries have provided some information, however the results do not account for differences in local conditions, such as soaps used, water use patterns, soils, or types of plants grown (Al-Hamaiedeh and Bino 2010, Gross et al. 2005). This comprehensive study of 66 households, comprising a total of 83 residential greywater irrigation systems, seeks to fill critical scientific data gaps by evaluating indicators of soil and greywater irrigation water quality, plant health assessment, water consumption data, user satisfaction, and greywater system installation and permitting costs.

Background

Definition of Greywater

"Greywater", as we use the term, refers to water discharged from washing machines, showers, baths, and sinks. Greywater does not include water from toilets or wash water with fecal material (eg. soiled diapers). Kitchen sink water is often classified as "dark greywater", though currently some states in the United States, including California, classify it as "blackwater" and prohibit on-site reuse.

Reuse of greywater has many potential benefits; it can reduce overall potable water consumption, thus decreasing the demand for surface and groundwater. Greywater reuse can reduce energy consumption, as it offsets the need to treat water to potable quality for irrigation, and can protect water quality by reducing

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2 Allen, L. Personal communication with Charles Graf (ADEQ) and Val Little (Water CASA) on 7/2/09 and 7/16/09

flows on over-loaded septic systems.

However, greywater may contain pathogens due to fecal contamination or food handling. Greywater system design and safe management should prevent direct contact with greywater other than when performing system maintenance or repairs. Many systems distribute greywater subsurface, thus eliminating direct contact. Other systems deliver the water at the ground surface, where it quickly soaks in, thereby limiting opportunities for direct contact. Systems that allow for untreated greywater to pond or pool on the soil surface create a potential for direct contact with greywater.

Previous Greywater Studies

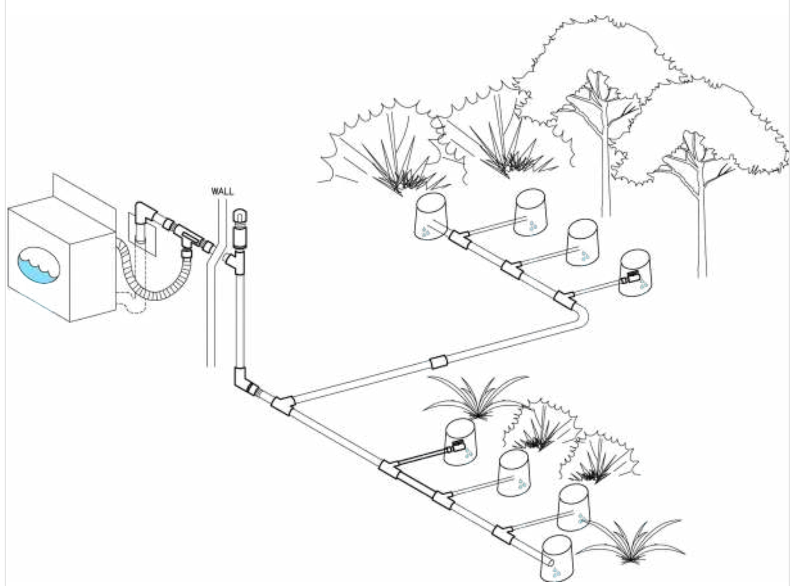
In an effort to understand the benefits and risks of greywater use, researchers have investigated the chemical and biological characteristics of greywater, the public health risks posed by different sources of water and different types of greywater systems, and the effect of different sources and distribution methods on soils and plants (Al-Hamaiedeh and Bino, 2010; Ottosson and Stenstrom, 2003; Pinto et al., 2009; Travis et al., 2010). A growing literature from Australia, the Middle East, and Europe documents the costs, water savings, maintenance requirements, effects on soil and plants, and social aspects of residential greywater systems.

A variety of studies look at the public health risks of greywater. Many have found fecal indicator bacteria present, (Casanova et al., 2001a; Ottoson and Stenstrom, 2003a; Friedler, 2004), demonstrating the potential for greywater to contain faecal transmitted pathogens. Nevertheless, few studies have found specific pathogens. Neither the City of Los Angeles nor the Water CASA study found disease causing organisms when they tested for salmonella, shigella, and entamoeba histolytica (City of LA, 1992) or *Cryptosporidium spp.* and *Giardia spp.* (Little, et al., 2000). However, *Cryptosporidium spp.* and *Giardia spp.* have been detected in greywater from other studies (Casanova et al., 2001b; Birks et al., 2004), as well as skin pathogens such as *Staphylcoccus aureus* (Kim, et. al 2008). Furthermore, there have been no documented cases of illness from greywater (Sheikh, 2010; Ludwig, 2009; Winward et al., 2007). In contrast, there are an estimated 3.5 million documented cases of illnesses in the United States each year caused by recreational contact with surface waters contaminated by sewage (American Rivers). Regardless, due to greywater's non-potable quality, care should be taken to avoid direct contact and irrigation of root vegetables should be avoided to prevent accidental ingestion of greywater.

In the United States a major focus of greywater educators is the use of "plant friendly" household products, those without salts and boron. Studies conducted internationally in places without availability of "plant-friendly" products found that, though it did not harm the soil or plants, the irrigation quality of greywater was lower than other sources of water. For instance, a study in Jordan found that the salinity and sodium adsorption ratio (SAR) of the soil increased over the one year study period, (Al-Hamaiedeh and Bino 2010) but that chemical properties of the crops were not changed. In another project study in Israel, researchers compared and analyzed soil and water quality on crops irrigated with freshwater, freshwater mixed with fertilizer (fertigation), and untreated greywater on crops over a three year period. They found that while water quality properties of the greywater can be lower than other sources of water with regard to contaminants of boron, surfactants, and SAR, the soil salinity in the greywater irrigated plot was similar to a site irrigated with fertilized water, and below concentrations harmful to plants (Gross et al. 2005). An Australian study on tomato plants irrigated with laundry greywater found that though the water was more saline, the tomato plants grew significantly more biomass than plants irrigated with tap water. The greywater irrigated tomato plants also contained significantly more nutrients than the plants irrigated with tapwater. The researchers concluded that "laundry greywater has a promising potential for reuse as irrigation water to grow tomatoes" (Misra et al., 2010).

Description of the Types of Greywater Systems in this Study

Greywater systems can be classified as those designed for outdoor irrigation and those for indoor non-potable use. In general, residential systems for outdoor irrigation are simpler and easier to maintain, while larger, mechanized systems for indoor non-potable use, such as toilet flushing, are more complicated. The systems surveyed in this study are residential systems, predominantly "laundry to landscape" and "branched drain" systems. These systems do not have tanks, pumps or filters, and irrigate landscape plants directly, though a few systems we studied did incorporate pumps. Figure 4 shows the breakdown of the types of systems studied.



igure 1: Laundry to landscape system. Credit: Cleanwater Components

In the "laundry to landscape" system, shown in figure 1, the washing machine pump sends greywater from the drain hose of the machine directly to the landscape (usually gravity based). The system does not alter the existing plumbing of the house and does not require a permit in the state of California or several other states, like Arizona, New Mexico, and Montana, if basic guidelines are followed.

The "branched drain" greywater system (not shown) uses gravity to distribute greywater from showers, sinks, and baths. "Branched drain" systems typically divert greywater through the drainage plumbing of the house, which is then distributed to plants via a series of branching drainage-type pipes.

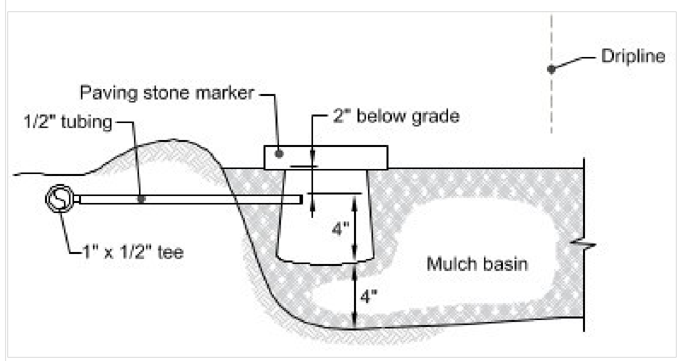
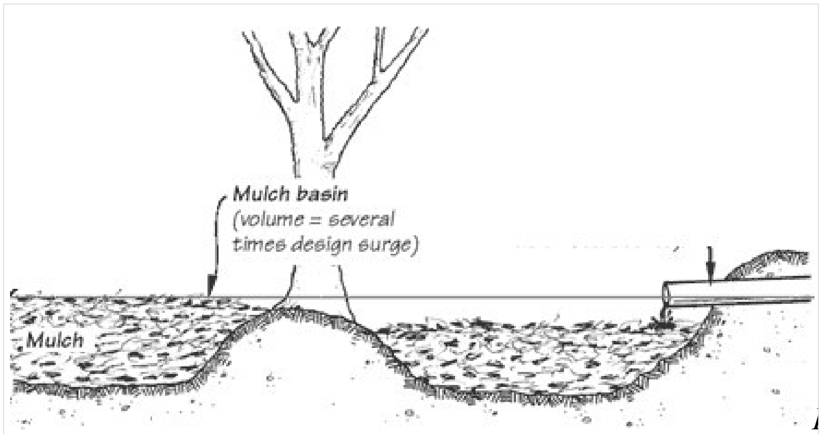


Figure 2: Subsurface irrigation. Credit: SFPUC

Both types of systems discharge greywater into "mulch basins", which are excavated trenches in the ground, usually 6 to 20 inches deep, 1 to 2 feet wide and 3 to 10 feet long, and filled with wood chips or other woody organic material (see figures 2 and 3). These basins require periodic maintenance to replace mulch and remove decomposed material. The frequency of maintenance depends on several factors, including the particle size of the mulch, the size of the mulch basin, soil texture type, and the quantity and source of greywater entering the basins. The experience of greywater installers and Greywater Action members is that basins need maintenance about once a year, although kitchen sink systems may need more frequent maintenance due to build up of organic matter and grease. Neglecting this maintenance can lead to slower infiltration, pooling, or runoff of greywater.

The two types of pumped systems in the study, "pump no filter," and "pump with filter," both have a small surge tank to temporarily collect greywater. Inside the tank is a pump, which send the water to the landscape. The "pump no filter" system sends unfiltered greywater to the landscape, typically using 1" pipe or tubing, whereas the "pump with filter" first filters the greywater and sends it out through smaller tubing, typically 3/4" mainline with 1/2" irrigation lines with ¼" emitters.



igure 3: Mulch basin. Credit: Oasis Design

Study Group

The study group consisted of 66 households with one or more greywater systems located in the San Francisco Bay Area (Albany, Berkeley, El Cerrito, Oakland, Piedmont, Richmond, San Francisco, San Leandro, and San Pablo), the Monterey Bay area (Aptos, Monterey, Pacific Grove, Santa Cruz, Seaside, and Watsonville), and the Santa Rosa area (Cotati, Petaluma and Santa Rosa).

The San Francisco Bay Area is home to 1.6 million people, the Monterey Bay area to 732,708, and the Santa Rosa area to 234,000 people (US Census, 2010). Annual rainfall in the East Bay is approximately 24" and San Francisco 21". Average annual rainfall in the Santa Rosa area is approximately 31". Average annual rainfall in the Monterey Bay Area ranges from 42.8" in the Santa Cruz Mountains to 20" on the Monterey Peninsula The climate is "Mediterranean", with mild, wet winters, and warm, dry summers. Average summertime high temperatures range from 66 to 83 , and winter lows from 37 to 47 degrees Fahrenheit. (The Western Regional Climate Center, 1919-2005, 1931-2005)

The participants for this survey were identified through the networks of the investigators ("snowball" sampling method). Greywater systems had been installed by homeowners, by independent professional installers, or through training programs led by local governments and NGOs.[3]

Methods

Structured Interview of Greywater System Users

We conducted a one-hour structured interview at each of the 66 households, representing a total of 83 greywater systems. Following the interview, w e collected greywater and soil samples and recorded qualitative plant health metrics for greywater-irrigated plants at each site. Interviews were conducted between May and July of 2012 by the principal investigators and trained enumerators.

Interview questions elicited demographic information, details about the greywater system(s) and other water

3 Greywater Action, Ecology Action of Santa Cruz, or the City of Santa Rosa

conservation practices (e.g rainwater harvesting), laundry and soap products used, and irrigation methods and frequencies. The interviews were recorded on a hand- held Android device using the program ODK (opendatakit.org) for data collection. See appendix IV for the survey questionnaire.

We interviewed the principal caretakers of the greywater system at each site. On sites where multiple people maintained the system we interviewed whoever was available at the time of the interview.

Greywater Testing

One sample of greywater was collected per system. For the "laundry to landscape" systems, we asked household members to wash a load of dirty laundry following their usual practice, then collected greywater at an accessible outlet in the landscape. The samples passed through the system before collection, and represent the typical irrigation water that plants receive. Shower, sink, and bath greywater from "branched drain" systems was either collected though a similar method (plugging the tub for a shower and collecting greywater from an outlet in the yard), or, in a few cases, were collected in the house by mixing a small quantity of products typically used in the system. Because this method of collection used less water than would be generated in typical usage, the concentration of constituents in greywater in the shower/sink samples may be higher than would be present in the actual greywater generated from these fixtures, and also did not pass through the greywater distribution pipes.

Greywater samples were tested on site for pH. Collected samples were refrigerated and sent to a laboratory [4] where they were tested for conductivity (an indicator of salt content), TDS (total dissolved solids), and boron. A subset of 57 samples were also tested for irrigation suitability at Soil Control Laboratory,including pH, total dissolved solids, conductivity, alkalinity (Carbonate and Bicarbonate reported as CO3 & HCO3), chloride, phosphate, boron, sodium, iron, potassium, nitrate (NO3), phosphate (o-PO4), sulfate (SO4) and secondary nutrients (Calcium (Ca), Magnesium (Mg)).

The laboratories analyzed greywater samples following standard methods for examining irrigation water. Samples from the Santa Rosa area were tested in the city's water quality laboratory (ci.santa-rosa.ca.us) following standard methods.

Categorization of Greywater Quality and Soil Test Results

To summarize the results of the greywater and soil testing we categorized samples into "generally safe", "slight to moderate", and "severe" risk levels for soil and irrigation, following guidelines in "Abiodic Disorders of Landscape Plants" and "Water Quality for Agriculture", based on the work of Pettygrove and Asano (1985). Long-term irrigation with water containing levels in the "generally safe" range should have no negative effects on most plants regardless of soil type. Levels in the "slight to moderate" risk may cause harm to sensitive plants and may be more problematic in clay or slow draining soils. Depending on the plant species, and other factors, long term irrigation with the level "slight to moderate" may have no negative affect, or it may reduce plant growth and productivity. Long term irrigation with water containing levels in the "severe" risk category will most likely cause plant growth problems, and reduce yields in most, but not all, plants.

4 Perry Laboratory, Watsonville, CA or Soil Control Laboratory, Watsonville, CA

Soil Quality and Texture

At the time of the site visit two soil samples were collected per greywater system. One sample was collected from soil underneath the greywater outlets, the area directly beneath where greywater entered the soil from the irrigation system. The other sample was collected from soil in the same area of the landscape that had no contact with greywater. Both samples were collected following standard soil sampling procedures. Investigators also conducted on-site soil texture tests following the soil ribbon and soil worm procedures (see Appendix III).

Soil samples were air dried and sent to the soil laboratory at the University of Massachusetts for standardized testing. Samples were tested for soluble salts, pH, extractable nutrients (P, K, Ca, Mg, Fe, Mn, Zn, Cu, B), extractable aluminum and cation exchange capacity. To test for an effect of greywater irrigation on these variables, at each site we subtracted the value for the non-greywater irrigated soil sample from the value for the greywater irrigated soil sample and tested whether the resulting differences were significantly positive (or negative). A positive difference would imply that greywater irrigated soil sample constituents were consistently larger than the non-greywater irrigated samples from the same site.

Plant Health Assessment

At each site several plants irrigated by greywater were visually analyzed for qualitative indicators of health. We observed 127 plants in detail, and briefly observed more than 1,000 greywater irrigated plants at the sites. Any plant that was identified by the respondent as having problems, or any plant that the investigator noticed as being unhealthy was observed in detail (one of the 127). We looked for leaf chlorosis, leaf necrosis, insect presence, other diseases (e.g. mildews, leaf curl, etc.) and abnormal growth. We rated each plant for the variables listed above with a numeric value (1,2, or 3). For example plants were rated for chlorosis by a “1”- signifying no sign of chlorosis, almost all leaves appear healthy, “2”- signifying some signs of chlorosis, multiple leaves show symptoms, or “3”- signifying severe chlorosis, most of the leaves show symptoms. We then categorized them as “fully healthy” (plant showed no symptoms, or one minor symptom, ie. minor insect presence), “mostly healthy” (plant showed two minor symptoms ie. minor insect presence and some chlorosis), or “unhealthy” (plant showed multiple symptoms or one severe symptom ie. disease, and severe chlorosis), depending on their symptoms.

Calculating Water Savings

We used two methods for calculating water savings. First, we looked at water consumption data for 34 sites (52% of study population) provided by one of the water utilities, East Bay Municipal Utility (EBMUD) and compared consumption before installation of the greywater system to consumption after installation. All water data ended in May of 2012. We analyzed average savings, as well as savings per subgroup. We classified study households into subgroups based on survey questions that explored other steps taken in the home that would influence water consumption, such as whether they made other water saving changes (eg. low-flow fixtures or rainwater harvesting systems) and whether they planted new plants at the time they installed the greywater system or irrigated existing plants.

Second, we estimated how much water would be required to irrigate the area at each site that is currently irrigated by greywater using local climate data and standard irrigation requirements. This method attempts to address the challenge of estimating savings for households that added additional plants to measure how much potable water their system potentially offset. Since we do not have information on whether the presence of greywater as an irrigation source affected a households decisions on what type of plants to grow (i.e. high water need plants vs. low water need plants), this estimate will not capture those variables.

Evaluation of Greywater System Costs

We conducted a separate survey of 20 professional greywater installers, mainly landscaping or plumbing contractors, to evaluate costs of greywater installation materials, labor and permitting. These greywater installers owned businesses in the San Francisco Bay area, Monterey Bay area, Sonoma and Marin counties, and Los Angeles county. Collectively, these installers reported that they had installed 259 greywater systems since 2009. 94% of these greywater systems were the same irrigation system types included in our general analysis (see figure 9). Interviews with greywater system installers were conducted over the phone and or using a web form between July and September 2012. See appendix V for the greywater installer survey questionnaire.

Statistical Methods

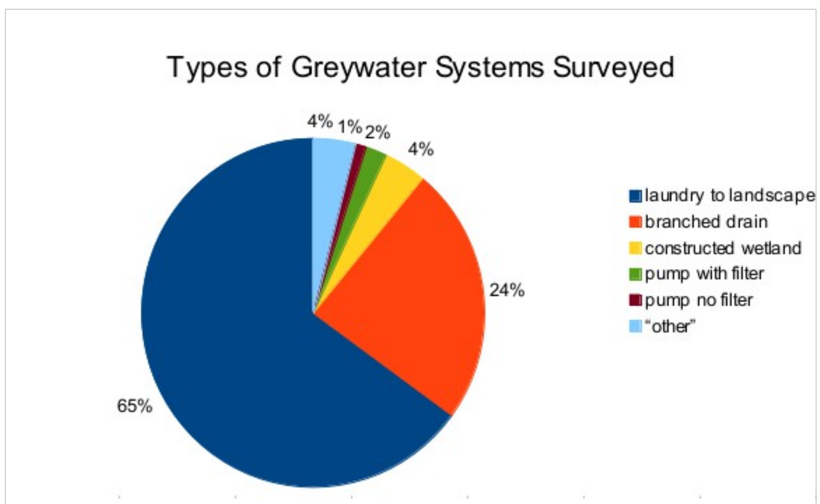
For the soil and greywater test results, many of the variables measured contained a few extreme outliers. To remove their influence and summarize typical values we use medians instead of means and discuss the outliers in detail in the Results.

In the water savings section, however, we used averages rather than medians because data was not influenced by large outliers. The average saving we found, therefore, reflects actual water savings a water district would see if more of their customers with similar water usage patterns as those in our study installed greywater systems.

Statistical analyses and plots were produced in R 2.7 (rproject.org).

Results

Here we report aspects of user experience, the results of the soil and water tests, plant health, water savings, and system costs.



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Greywater Users

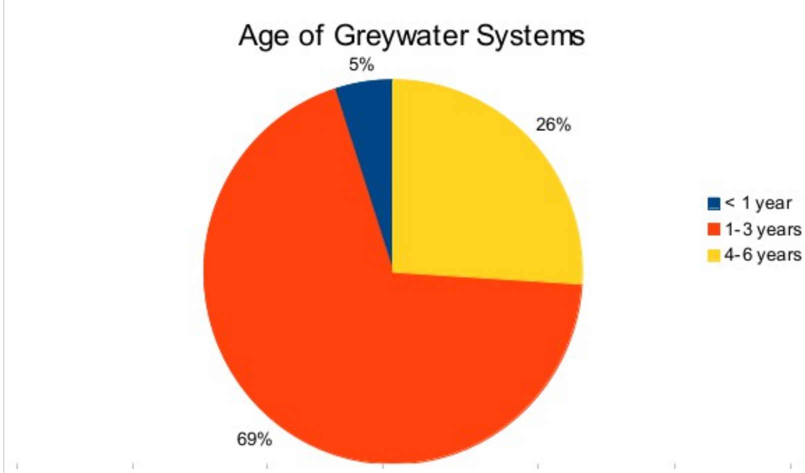
The vast majority, (95%), of participants were homeowners, the remainder rented their homes.

Participants in our study produced an estimated average of 11 gallons/person/day from shower/baths and 7 gallons/person/day from washing machines, (compared to the California code estimate of 25 gallon/person/day for showers/baths and 15 gallons/person/day for washing machines). These numbers were based upon testing the flow of the shower head nozzle, the make and model of washing machine, and reported usage of fixtures from the structured interview.

User Experience

We surveyed these aspects of the user experience:

- how people learned about greywater
- reactions to their system from the larger community
- motivations for installing a system
- perceived benefits
- problems
- user satisfaction
- maintenance and repair needs
- opinions on health risks



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Overall, respondents reported positive experiences with their greywater systems. Most people felt they had benefited from their systems, were satisfied with how the system worked.

We found that participants first learned about greywater reuse from multiple sources. The most common source was friends or colleagues, classes or workshops, and/or the media (eg. article or news coverage). 71% of respondents reported installing their system within three years of learning about greywater, with 35% of people installing the system within one.

We asked what kinds of comments people recalled hearing when they talked to friends, neighbors, and relatives about their greywater system. All respondents reported hearing positive comments of some sort, including “good idea”, “excited”, “want to do it too”, and “interested”. Only 6% of respondents heard some type of negative comment in addition to positive comments. 33% of respondents reported that a friend or family member installed a greywater system after learning about theirs.

Where People First Learned about Greywater*	
Friend or colleague	34%
Media	24%
Workshop	23%
Book	12%
Other	35%
*Multiple responses were recorded	

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Respondents were mainly motivated to install the system by a workshop, or a concern for saving and reusing water. Most households received no incentives or rebates for installations. Participants had a variety of goals for their greywater system, most commonly to save water or a general desire to make their home more ecologically sound . Most people, (68%), felt their system saved water, and almost half felt their plants benefited. People also reported their systems made them feel good about having a more ecological option for their greywater other than sending it down the drain with the rest of the sewage.

User Satisfaction Findings

Overall, greywater users felt overwhelmingly positively about their greywater systems. All respondents but one were either “very satisfied” or “satisfied” ; only one felt “neutral” about their greywater system. They also felt positively about their system's reliability or need for maintenance: 92% reported they were either “very satisfied” or “satisfied”. People felt slightly less satisfied regarding how well their greywater systems waters the plants, with 90% of users reported they felt either “very satisfied” or “satisfied”.

User Satisfaction with Greywater System					
	% Very satisfied	**% Satisfied**	% Neutral	% Dissatisfied	% Very dissatisfied
Overall satisfaction	**75**	**24**	1	0	0
Reliability (need for maintenance)	**69**	**23**	7	1	0
Irrigation performance	**55**	**40**	5	0	0

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86% of system users said they would recommend their systems to others, and 13% said they would recommend the system with modifications. Only one person said they were “not sure” if they would recommend their system, and no one said they would not recommend it.

Maintenance, Repairs, and System Use

The majority of households reported no operations problems with their systems. 12% reported clogging problems, mostly at the greywater outlet (see figure 2), and for most it was a single occurrence that they fixed themselves. The single household that had the most frequent clogging issues had a pump with filter system and reported that the filter clogged every 1-2 months. 8% reported that the system was not irrigating properly, due to a clog, or a valve that had come detached. Pests occasionally disturbed the systems. At one site, slugs congregated inside of the greywater outlets, while at another gophers dug up the mulch basins.

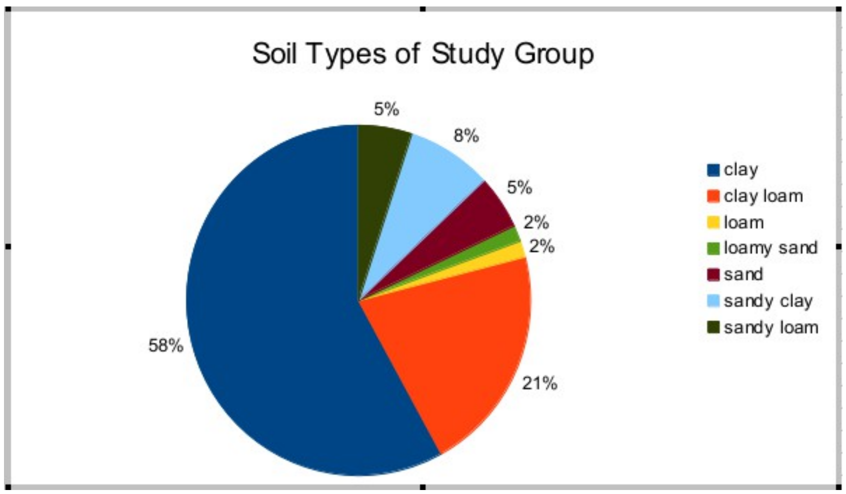
84% of households reported no broken parts up to the date of the interviews with their greywater systems. Of the eleven households that reported a broken part, the tubing caused a problem for nine, one the filter, and one a valve. The typical reason for the tubing to break was through damage during gardening, for example, by accidentally putting a shovel through it. Though not technically part of the greywater system, the “mulch shield” which protects the greywater outlet from root intrusion, was often damaged when it had been made out of a plastic polyethylene nursery pot (instead of using a rigid irrigation valve box or hard plastic container).

Most households did very little general maintenance on their systems. Of the 89% of households with mulch basins, about half had done nothing to the basin, and the other half had dug out the area under the outlet and replaced the mulch. Through most respondents indicated they did not notice greywater pooling or running off the soil surface, continued lack of maintenance could lead to this problem. Participants did not believe that system clogs had exposed residents to pooled greywater (97%). Only two participants reported that possible direct contact with greywater had occurred (not including maintenance), both incidents were from greywater runoff onto a path. Though most respondents in the survey were not public health professionals, we asked about their perception on safety, specifically if they thought anyone could get sick from their greywater system. From their personal experience no one believed their system could cause illness.

Even though few people reported pooling or runoff, investigators noticed several additional sites that had some pooling when water was run through the system, indicating these people were not checking the outlets frequently enough to notice the problem. In fact, 25% of people reported they never checked the outlets. After the interview several participants asked questions about maintenance, indicating there was not a good understanding of maintenance needs, even though most people reported they had a good understanding of how the system functioned in general.

Soil Testing Results

Our soil test results suggest that irrigation with greywater did not affect soil salinity, boron, or other nutrient levels. We can be quite confident that if there is an effect it is quite small, since we compared soils irrigated with greywater to soils not irrigated with greywater at each site, thus controlling for most other sources of variation.



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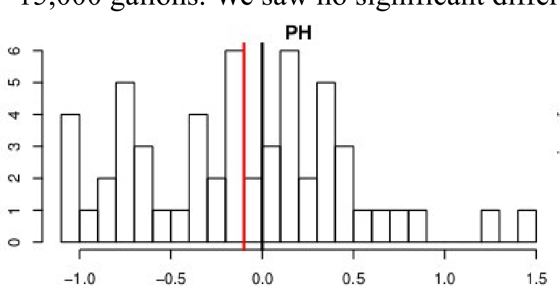
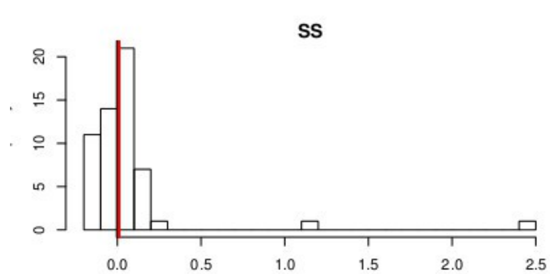
We compared the difference between greywater and non-greywater irrigated soils for the variables of soil pH, soluble salts, boron, as well as other nutrients (P, K, Mg, Ca, S) and micronutrients (Zn, Mn, Cu, Fe, Cd, Pb, Al, Cr, Ni). We analyzed the differences between variables at each site (See figure 7). We also compared differences by soil type to see if some soils could be more impacted by greywater irrigation, since heavy clay soils are known to be more susceptible to accumulation of salts and other ions, whereas sandy soils are more easily leached. However, we saw no significant differences between greywater and non-greywater irrigated soils for any of the soil types (Wilcoxon signed-rank tests). Most of our sites were in clay, clay loam, or sandy clay soils, so these results are more informative than the soil types of loam, loamy sand, sand, and sandy loam that had few samples.

Additionally, we looked for correlations between the age of the system and the difference between greywater and non-greywater irrigated soils, as well as quantity of greywater produced, since older systems might have had more time to accumulate salts or boron. Systems were grouped into less than 1 year old, 1-3 years old, 4-6 years, and more than 6 years. The only variable we found to be significantly different (Wilcoxon signed-rank test) between age categories was a lower pH (relative to the paired non-greywater irrigated soil sample from the same site) in systems older than four years. Since the greywater samples in our study were typically more acidic than the average pH of the municipal water, the reduction of pH could be due to the long term irrigation of a more acidic water. (Note that the pH range of the soils was still with in the safe range for soil pH). Systems were also grouped according to how much estimated greywater had been discharged: less than 5,000 gallons, 5,000 -10,000 gallons, 10,000 -15,000 gallons; or greater than 15,000 gallons. We saw no significant difference for any variable between these groupings.





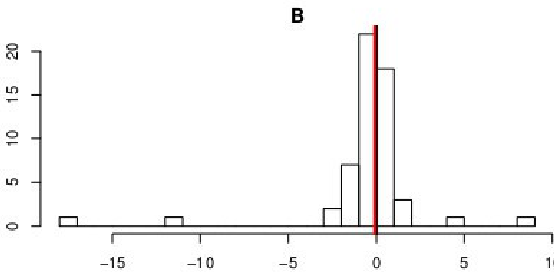


Figure 7

Difference between GW and non-GW

soil tests for pH, suspended salts (SS),

and boron (B) at the same site. Gray

Salts and boron are two constituents commonly found in greywater of most concern for plant health. We found no significant difference between the greywater irrigated soils, and the non-greywater irrigated soils in their level of salts (the EC), or boron levels. Additionally, the difference between greywater and non-greywater soil variables (soluble salts and boron) wasn't correlated with the amount of the salts or boron found in the greywater samples from the same site (EC, B, Na, and Cl).

Guidelines for Interpreting Soil Test Results			
	Generally safe	Slight to moderate risk	Severe risk
Soluble salts (EC) mmhos/cm	0.5-2.0	2.0-4.0	>4.0
Boron (ppm)	0.1-0.5	1 – 5	>5

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We found large variation in the non-greywater irrigated soil samples for the variables we tested, much larger than the typical differences between greywater and non-greywater irrigated soils due to variability in original soils, imported soils, use of fertilizers, etc. Table 4 below illustrates these variations for soluble salts, pH, and boron.

We found the median pH of the greywater irrigated soils to be 6.5 with a range of 5.3 to 7.5, whereas the non-greywater irrigated soils also had a median of 6.5 , with a range of 5.2 to 7.6. The median pH difference between greywater irrigated and non-greywater irrigated soils was -0.1. These results indicate that the greywater irrigated soils were slightly more acidic than the non-greywater irrigated soils, although the difference is not statistically significant and much smaller than the natural range of variation. Range in pH common for arid region mineral soils are 6.5-9. Range in pH common for humid region soils is 5-7 (Brady, Weil, 1999).

The median soluble salts in the greywater irrigated soil was 0.17 mmhos/cm (dS/m), with a range of 0.05 mmhos/cm to 2.6 mmhos/cm. The median for non-greywater irrigated soils was 0.16 mmhos/cm with a range of 0.05 mmhos/cm to 1.85 mmhos/cm. The median difference between greywater and non-greywater irrigated soils was 0.01. All but two of the greywater irrigated samples were in the "generally safe" range, and 3% were in the "slight to moderate" risk range for soluble salts, whereas 100% of non-greywater irrigated samples were in the "generally safe" range.

Greywater and Non-greywater Irrigated Soil Testing Results

		Median	Min	Max	Samples in "generally safe" range	Samples in "slight to medium" risk range	Samples in "severe" risk range	median difference btw. GW and non-GW samples
Soluble salts (mmhos/cm) or dS/m	greywater	0.17	0.05	2.6	97%	3%	0%	0.01
	non-GW	0.16	0.05	1.85	100%	0%	0%	
pH	greywater	6.5	5.3	7.5				
	non-GW	6.5	5.2	7.6				-0.1
Boron (ppm)	greywater	1	0.2	9.3	55%	42%	3%	
	non-GW	0.8	0.2	19.3	65%	32%	3%	0

able 4

The two greywater soil samples with salt levels outside of the "generally safe" range (2.03 and 2.6 mmhos/cm) did not have high salt levels in the greywater we tested. Greywater from the first site tested low in salts (EC 0.31 mmhos/cm and TDS 198 ppm) and greywater from the second site had salt levels slightly above the "generally safe" range. (EC of 0.78 mmhos/cm, TDS of 504 ppm, and SAR of 5.4). Soap used at this second site listed no sodium products in its ingredients list, and other sites that used the same detergent did not have levels of salts out of the "generally safe" range. Since this was a one time sampling, it is possible the higher level of salts could have come from the clothing, or residue from other detergents. This site also reported that manure had been added within the month, possibly another source of salts to the soil since manures have been found to have salts ranging from 12.0 to 23.0 mmhos/cm (Costello et. al 2003). We did not see any problems with plants at either site.

The median level of boron in the greywater irrigated soils was 1.0 ppm, with a range of 0.2 to 9.3 ppm; while the median for non-greywater irrigated soils was 0.8 with a range of 0.2 to 19.3. The greywater from the site with the highest levels of boron in the greywater irrigated soil (9.3 ppm) had very low levels of boron in the greywater, 0.18 ppm, indicating the source of boron in the soil was from elsewhere. Even though the greywater irrigated soils had a higher median boron level, the difference is not attributed to greywater. The median difference between boron levels in greywater and non-greywater irrigated soil samples from the same site was 0.00 and the distribution was not significantly positive (wilcoxon signed-rank test).

Guidelines for Interpreting Greywater Test Results

	Generally safe	Slight to moderate risk	Severe risk
EC (mmhos/cm)	<0.7	0.7-3.0	>3.0
TDS (ppm)	<450	450-2,000	>2,000
SAR	<3	3 – 9	>9
Boron (ppm)	<0.5	0.5-1.0	>1.0
Chloride (ppm)	<140	140-300	>300
Sodium (ppm)	<70	70-200	>200

Table 5

Greywater Testing Results

In this section, we report our findings for each variable we tested for, where we found most samples to be in the generally safe range for irrigation water, and provide details on outlier samples. Only one site used powdered detergent and was the source for many of the outliers results. A few sites occasionally used powdered cleaning products.

Municipal water contains some amounts of salts and bo ron, Table 6 s hows ranges found in tap water from the municipalities of the study area. Note that the reported maximum levels of salts (EC, TDS, Na, and Cl) found in tap water from some municipalities in our study area are in the “slight to moderate” risk category for irrigation, hence, results from those districts will most likely have higher salt content than from municipalities with lower salt content in the tap water. Although we lack data on the specific salt levels of tap water in our greywater samples, we suspect some of our samples were influenced by this, particularly the samples that tested on the low-end of the “slight to moderate” risk category for EC, TDS, SAR, chloride, and sodium, came from sites using products that tested “generally safe” at other sites, and did not contain any salt compounds in their ingredients.

See appendix I for information about each variable and its effect on soils and plants and table 5 (above) for the ranges for each category of “generally safe”, “slight to moderate”, and “severe” risk for long term irrigation.

The median pH was 6.5, with a range of 5.5 to 9.7[5].

The median EC was 0.31mmhos/cm, with a range of 0.07 to 4.82 mmhos/cm. 85% were in the “generally safe” range for irrigation water, 14% were on the low end of the “slight to moderate risk” (0.704, 0.74, 0.78, 0.79, 0.91, 0.92, 1.15, 1.21, 1.3, 1.35 mmhos/cm), and one sample was in the “severe” risk range- 4.82 mmhos/cm. This site used powdered laundry detergent.

We found the median TDS to be 198 ppm, with a range of 47 to 3133 ppm. 84% were in the “generally safe” range, 15% in the “slight to moderate” risk range, and only one in the “severe” risk range. This site used powdered laundry detergent.

The median sodium absorption ratio (SAR) (adjusted Rna) level was 1.8 with a range of 0.35 to 64. 80% of the samples had a SAR rating in the “generally safe” range, 18% in the low range of the “slight to moderate” risk, and two samples in the “severe” risk category (SAR 14 and SAR 64). The sample with the highest SAR rating, SAR 64, used powdered laundry detergent, and the sample with the second highest rating, SAR 14, used many different commercial brands (like Suave).

We found the median boron level to be 0.05 ppm, with a range of 0.003 to 4.55 ppm. 92% of the samples were in the “generally safe” range, 5% were in the “slight to moderate risk” range, and two samples were in the “severe” risk range, with levels of 2.81 and 4.55 ppm. The site with the highest boron levels in the water used a detergent that lists itself as “greywater safe”, though boron is an ingredient (7th Generation). The second site used Arm and Hammer Oxy Clean Power Gel, which does not list all ingredients.

We evaluated the boron levels in the soil at the sites with high boron levels in the greywater. It was not obvious that boron levels were increasing, though they could over more time. The soil from the two sites with highest levels of boron in the greywater did have more boron in the greywater irrigated soil than in the non-greywater irrigated soil. However, soil from the three greywater samples that showed a “slight to moderate” risk had only one site with an increase in boron levels and two sites with no increase compared to the non-greywater irrigated soil sample. Since most of the greywater samples did not contain elevated levels of boron, we do not have many sites that could experience a build up of

5 There was some discrepancy between the on-site pH tests and the laboratory, we used the average between the two results.

boron.

The median chloride level was 24 ppm, with a range of 4 to 210 ppm. 94% of samples had levels in the "generally safe" range, with most samples lower than 50ppm. Six percent of samples had levels in the "slight to moderate" risk range. No sites had chloride levels in the severe risk range.

The median sodium level was 32 ppm, with a range of 7 to 1024ppm. 85% of samples were in the "generally safe" range, 13% were in the "slight to moderate" risk range. One sample was in the "severe" risk range, with a level of 1024 ppm. This site used powdered detergent.

Greywater Testing Results

		Median	Min	Max	Samples in "generally safe" range	Samples in "slight to medium" risk range	Samples in "severe" risk range
EC (mmhos/cm)	greywater	0.31	0.07	4.82	85%	14%[2]	1%
	municipal water[1]	0.38	0.04	1.64			
TDS (ppm)	greywater	193	47	3133	84%	15%[2]	1%
	municipal water[1]	240	29	846			
SAR[3]	greywater	1.8	0.35	64	80%	18%[2]	2%
	municipal water[1]	no data available					
pH	greywater	6.5	5.5	9.7			
	municipal water[1]	8.3	6.7	9.7			
Boron (ppm)	greywater	0.04	0.003	4.55	92%	5%[2]	3%
	municipal water[1]	0.31	ND	0.88			
Chlorine (ppm)	greywater	24	4	210	94%	6%[2]	0%
	municipal water[1]	24	3	394			
Sodium (ppm)	greywater	32	7	1024	85%	13%[2]	2%
	municipal water[1]	23	3	140			

1- We averaged the quality of municipal water for the seven water districts of the study area. Since there was not an even distribution of sites in each water district, the averages show above do not reflect an accurate estimate of constituents preexisting in the water, rather they shows levels that can be found in municipal water.

2- Most samples were at the low end of range, see results section for details

3- SAR- We used the adjusted Rna calculation

able 6

Plant Health Results

Our detailed observations of greywater irrigated plants found 95% to be fully healthy. We found seven cases of disease, none of which appeared to be attributed to greywater. Of the plants identified as unhealthy, half had been identified by the household as unhealthy prior to greywater irrigation, while the remaining unhealthy plants showed

Health of Greywater Irrigated Plants

	No signs	Some signs	Severe signs
Leaf necrosis	95%	5%	0%
Leaf chlorosis	94%	5%	1%
	Fully healthy	Mostly healthy	Unhealthy[1]
Overall health	95%	2%	3%

1- Of the unhealthy plants, half were identified to be unhealthy before greywater irrigation began.

able 7

symptoms of common diseases that did not appear to be directly related to greywater (such as peach leaf curl).

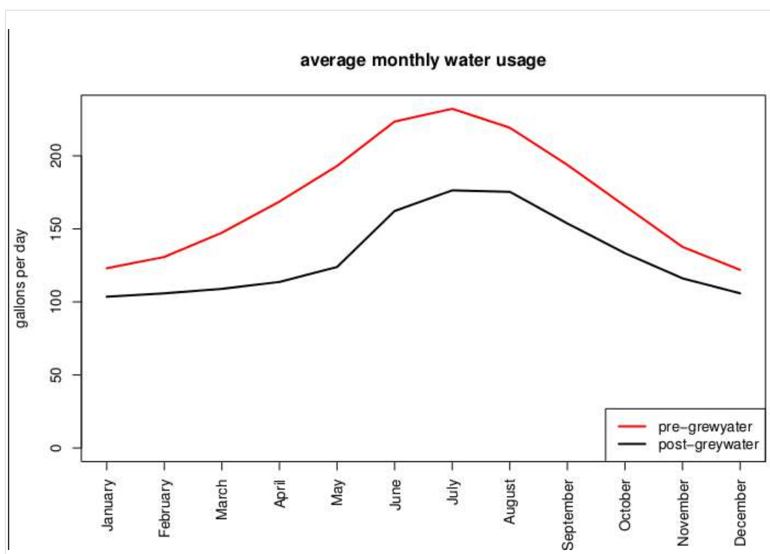
Leaf chlorosis and necrosis are common symptoms of salt and boron toxicity, but can also indicate nutrient limitations and other stresses. 95% of the plants observed showed no signs of necrosis, 5% of plants showed minimal signs of necrosis, and no plants showed severe signs of necrosis. 94% of plants showed no signs of chlorosis, 5% showed minimal signs of chlorosis, and two plants showed extreme signs of chlorosis. Of the two plants with severe chlorosis, one was grossly over-watered (all greywater was being directed to one tree) with poor drainage, and the other was a lemon tree, which often suffer from chlorosis due to nutrient deficiencies.

We observed plants in good health under a large range of irrigation regimes. For each household, we estimated weekly greywater production and plant water requirements. We found that some plants were being under-watered, some appropriately watered, and some over-watered. This demonstrates that the common landscape plants included in this study can tolerate and thrive under many different soil moisture conditions.

Water Savings Results

In this section we provide results for estimating water savings, as well as water consumption findings for various subgroups of households, for example, separating results from households that planted new plants with their greywater system vs. those that did not.

From the water consumption data we found an average water savings of 17 gallons per person per day after installation of the greywater system and people used 48 gpd (down from 65 gpd before greywater system installation).



igure 8

Average annual household water savings was 14,565 gallons each year after installation of the system. Average savings varied by season, with higher savings in spring and summer, (nearly 10,000 gallons), and lower in fall and winter, (close to 5,000 gallons). Since these systems were used for outdoor irrigation we would expect to see higher savings during the irrigation season.

Average Water Usage and Savings Pre and Post Greywater System				
Month	**Pre-greywater gpd**	**Post-greywater gpd**	**Daily savings**	**Monthly savings**
January	123	104	19	589
February	131	106	25	700
March	147	109	38	1178
April	169	114	55	1650
May	193	124	69	2139
June	223	162	61	1830
July	232	176	56	1736
August	219	175	44	1364
September	194	154	40	1200
October	166	133	33	1023
November	138	116	22	660
December	122	106	16	496
		Annual average household savings (gal)=		**14 565**

able 8

Though the average per capita daily savings was 17 gallons per day (gpcd), (68 gallon/day for a family of four), some households actually used more water after installing greywater, (up to 32 gallons/day), while others saved much more than this (up to 122 gallons/day). For households that reported they had adopted other water-saving practices in addition to their greywater system the average savings was 23 gpcd. Of the households that did not make any water saving changes, those that planted new plants when they installed their greywater system used an average of 4 more gallons per person per day, while households that did not plant new plants saved an average of 11gpcd. Some households had a change in the number of people living in the house before and after installing the greywater system. We will discuss the implications of this and affects on our results in the Discussion.

Per Capita Savings Per Category (GPCD)			
	Average	Minimum	Maximum
Per capita	**17**	-32	122
GW + other water saving changes in home	**23**	-18	81
Planted new plants with GW, no other changes	**-4**	-19	8
No new plants, no other changes	**11**	-32	122

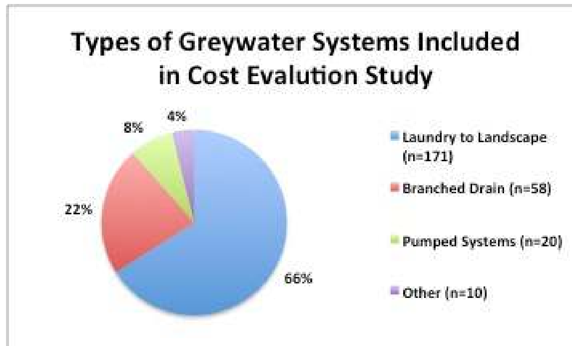
able 9

To account for the amount of water potentially offset by a greywater system that was installed with new landscaping, we looked at the total area irrigated with greywater at each site and then estimated how much irrigation water it would require during an eight month irrigation season. We found that on average 325 square feet was irrigated with greywater at each study site, offsetting an estimated 5,200 gallons of potable water a year per site. Landscaped areas irrigated with greywater ranged from 36 to

1,380 square feet, offsetting an estimated 576 to 22,080 gallons a year. These calculation assume that all new landscape area irrigated by greywater would have been irrigated with municipal water [6]. The estimated savings found with this method were significantly lower than the actual savings we observed from water consumption data, suggesting that actual savings associated with greywater systems may be influenced by factors other than just landscape irrigation needs.

Greywater System Cost Results

Results show that homeowners that hire a professional plumber or landscaper to install a greywater irrigation system can expect to pay a range of costs depending on the system type, size and complexity of the system installed. Table 10 documents the low, average, and high range of system costs including materials, labor, and permitting fees for systems installed by the 20 professional installers in the study group. Table 11 reports the low, average, and high range of costs for homeowners who install their own greywater systems.



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Professional-Installed Greywater System Cost Range

MATERIALS + LABOR + PERMIT	L2L (no permit)	Branched Drain	Pumped Systems
Low	$350.00	$500.00	$1,800.00
Average	$750.00	$1,740.00	$3,790.00
High	$2,000.00	$4,250.00	$5,750.00

Table 10

Homeowner Installed Greywater System Cost Range

MATERIALS + PERMIT ONLY	L2L (no permit)	Branched Drain	Pumped Systems
Low	$100.00	$250.00	$800.00
Average	$250.00	$715.00	$1,790.00
High	$500.00	$1,750.00	$2,750.00

Table 11

<u>Materials Costs</u>

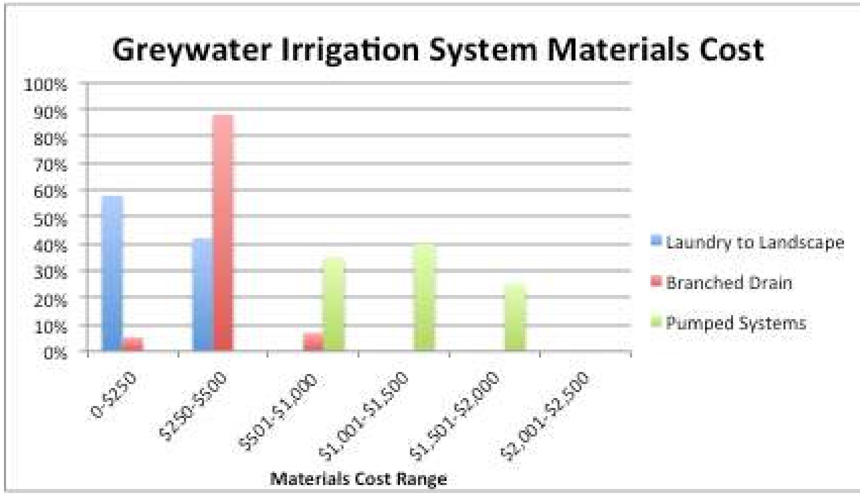
Laundry-to Landscape

58% of laundry to landscape systems had material costs between $0-$250. 42% these installations had material costs between $250-$500.

6 We used the estimate of 0.5 gallons/square foot of planted area per week for irrigation need

Branched Drain
88% of branched drain systems had material costs between $250-$500.

Pumped Systems
Contractors reported the widest range of costs for pumped systems, with a total of 75% of installations costing between $500 and $1,500.



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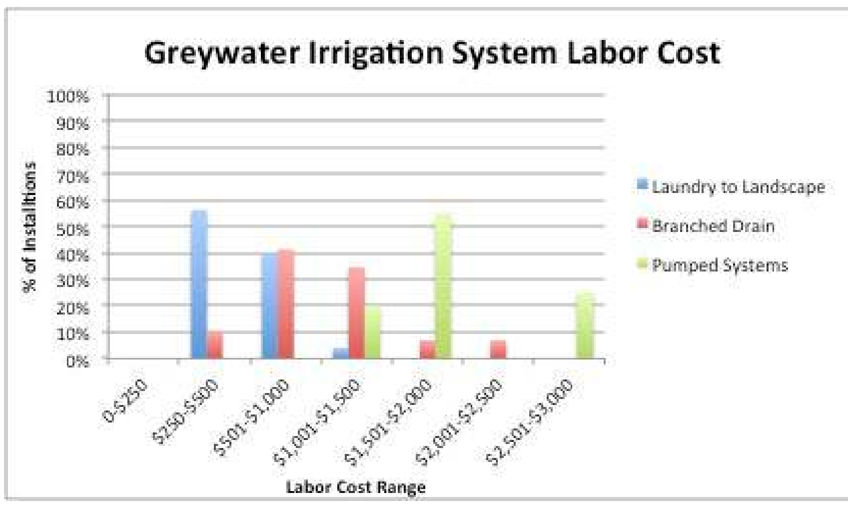
Labor Costs

Laundry-to Landscape
56% of laundry to landscape systems had installation labor costs between $250-$500. Another 40% of these systems had labor costs in the $501-$1,000 range.

Branched Drain
41% of branched drain systems had installation labor costs between $501-$1,000. 34% of these systems had labor cost between $1001-$1,500. 10% of systems had lower labor costs in the range of $250-$500, while 14% of systems had labor costs over $1,501.



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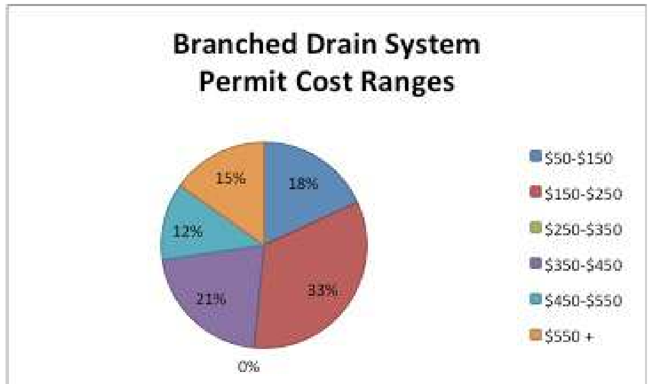
Pumped Systems
A total of 75% of pumped system had labor costs between $1,001-$2,000. The remaining 25% of installations had labor costs in the range of $2,501-$3,000. Pumped systems often combine flows from more than one greywater fixture. Higher labor costs reflect the increased complexity of designing pumped systems, which involves sizing, selecting, and siting an appropriate pump, preparing more complex permit applications and drawings, as well as installing additional electrical outlets and other site specific overflow requirements.

Permitting Costs
Installers who reported the lowest permit fees ($50-$150 range) were from the Monterey Peninsula and the San Francisco Bay area. Higher permit fees were defined as >$550. Installers from the Los Angeles area reported the highest permit fees of the study group.

The average permit fee for a branched drain system was $340, although the most common permit fee reported (33% of systems) was between $150-$250.

The average permit fee for a pumped system was $540, although the most common permit fee reported (50% of systems) was greater than $550.

When installed by a professional installer, average greywater system permitting costs were 20% and 14% of the total installation cost for branched drain and pumped systems respectively. Homeowners who have the training and skills necessary to install their own greywater irrigation systems will experience lower overall average costs because they are contributing their own labor: $250 for a laundry-to landscape system, $715 for a branched drain system, and $1790 for a pumped system. For homeowners who act as their own contractors, average permitting costs are 48% and 30% of the total installation cost for branched drain and pumped systems respectively.



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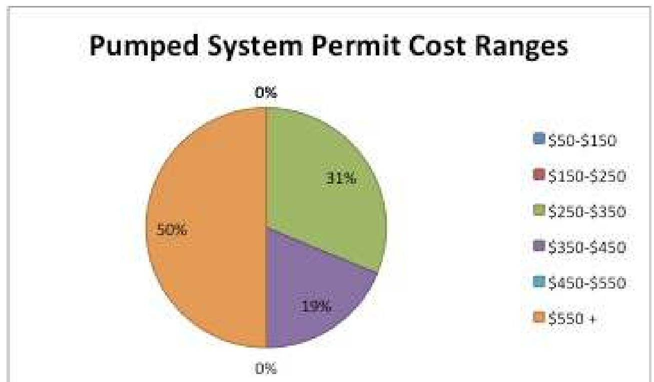

igure 13

<u>Total Average Costs for Three Most Common Types of Greywater Irrigation Systems</u>

igure 14

igure 15

Average materials and labor costs were lowest for laundry to landscape systems. Pumped system had the highest average materials, labor, and permitting costs.

igure 16

Discussion

Overall, the greywater systems in our study saved water and had few problems. Key findings include:

- Per capita water consumption decreased by an average of 17 gallons per day after greywater system installation, at least half of which is directly attributable to water savings from greywater reuse.
- Greywater did not negatively affect soil or plant health.
- Quality of greywater was typically suitable for long-term irrigation of plants, so long as households used products without sodium or boron compounds.
- System users were overwhelmingly satisfied with their systems.
- Though people did very little maintenance on their system, no major problems developed. However, more education and a few changes in design can improve greywater systems to avoid potential problems.

Relationship to Other Studies

Other studies have found the quality of greywater for irrigation to be much lower than ours (Al-Hamaidedeh and Bino, 2010; Alifya, et al., 2012; Misra and Sivongxay 2009). We believe this difference is due to the fact that most of the households in our study changed their products after installing their greywater system, or were already using plant friendly soaps and detergents prior to irrigation with greywater. For example, an Australian a study found the average EC value three times higher than our results, SAR seven times higher, sodium five times higher, and pH 2.7 units higher (Howard, et al., 2005).

It is clear that we cannot form conclusions about the quality of greywater as a source of irrigation without considering the types of products used in the systems, since the quality of greywater is dependent upon what products are used in the home. For example, many people and organizations (Greenplumbers, Duttle for New Mexico State University) report that greywater is alkaline or basic, when, as seen in our study, greywater can actually be acidic depending on what products are used.

Water Savings

Overall water usage decreased after households installed greywater systems by an average of 17 gallons per capita per day (gpcd), which represents an average reduction of 26% (48 gpcd down from 65 gpcd). It is interesting to note that the average reduction of 26% that we found is higher than the target reduction of 20% in the 2020 plan for the state of California.

The range in water savings was large, with maximum savings reaching 122 gpcd. Measuring water savings is not as straight forward as simply looking at water consumption data. Increased water use associated with new landscaping or young children in the home are important considerations when assessing actual savings from a greywater system. Also, behavior factors, such as continued irrigation of plants that are also irrigated with greywater, can negatively affect potential water savings. In our study group most homes (27 households) decreased their total usage. Ten of our study sites increased, with four of the increases explained by an increase in landscaped area, and two by an increase in water use associated with a new baby in the home. We observed some additional trends with water savings:

- Households that used more water to begin with were more likely to see reductions than households that used less water to start with.
- Many households implemented additional water saving techniques after installing their greywater system; these homes saved more water than those that reported they made no other changes in water use, 23 gpcd vs. 11 gpcd.
- There was a wide range of savings, as some households saw reductions seven times higher than the average, and in contrast, some used more water after installing their system then before.

These trends suggest that while greywater systems can save water on their own, they can be effectively incorporated into a wider suite of water saving techniques.

Cost of Greywater Systems

The installation and maintenance of greywater irrigation systems has the potential to create quality green jobs in the water sector. Early adopters of greywater reuse (such as those included in this study) reported investing in a greywater system because of a general concern for saving and reusing water. However, many consumers may be genuinely interested in greywater reuse but will be motivated to actually install a system if there are economic savings over a reasonable period of time.

Our evaluation of average system costs and corresponding payback period under a range of residential water rate scenarios shows that for professionally-installed systems, the payback period for the greywater irrigation system may exceed the period of time the homeowner actually owns the home. As conservation water rates increase, the return on investment of a greywater system becomes more attractive. The calculation does not include other potential benefits of the greywater system that are more difficult to quantify economically, such as “drought insurance” for landscapes during water restrictions, extending the life of septic systems, delaying the need to drill deeper wells, time savings on watering, or increasing a home’s resale value.

Average permitting fees that amount to between 20-48% of the total cost of the system may negatively impact a homeowner’s decision to move forward with a greywater irrigation system installation. Regions with higher permit fees and/or time-consuming permit processes may experience an increase in unpermitted installations by uneducated homeowners and unlicensed contractors. Regions who use inexpensive, over-the-counter permits and streamlined inspections for simple greywater systems will have more opportunities to educate residents about best practices at the permit counter.

To overcome these types of financial barriers, the energy efficiency industry employs a multitude of federal, state, and local financing mechanisms and rebates to incentivize residential energy efficiency and alternative energy installations and upgrades (DOE, Database of State Incentives for Renewables & Efficiency, 2012). Expedited permits or reduced permit fees, state and municipal utility rebate programs, tax credits, PACE programs[7], and other low interest financing should all play an important role in lowering economic barriers to investing in greywater systems for the average consumer. Public agency-sponsored hands-on installation workshops for lower cost laundry to landscape systems are an important strategy for increasing adoption of greywater systems, especially in disadvantaged and lower income communities. Increasing water rates throughout the state, combined with financial incentives and peer-to-peer sharing of greywater system satisfaction will help to drive market demand for greywater irrigation systems in the future.

Use and Maintenance

A large number of our respondents did not maintain their greywater systems adequately. Maintenance for the majority of systems in our study would only require annual replacing of decomposed mulch. This is a simple task, in most situations should take approximately one hour or less. This leads us to conclude that greywater promoters, educators and installers should do more to educate people about how to maintain their systems, and installers should create maintenance contracts with their clients who are unwilling or unable to do this work**.**

Furthermore, we believe that a strong emphasis on appropriate choice of soaps, detergents, and cleaning products is important to improve the quality irrigation water from greywater systems. Most people in our study group used products with little or no salts or boron, resulting in a better quality irrigation water. The few samples that were not safe for irrigation came from households that used either powdered detergents, known to be high in salts, or commercial brands not typically considered "greywater friendly" nor listed all ingredients.

System Performance and Design Recommendations

We observed a few minor problems that could be avoided by better design or more frequent maintenance. A few sites had pooling or runoff of greywater, and a few others experienced uneven distribution of greywater to plants. Locating greywater outlets away from pathways can prevent any pooling that results from lack of maintenance or other causes, from creating a route of exposure to the public. In systems where greywater outlets are located near hardscape, such as the cement paths of the two sites with runoff in our study, any of three simple design changes would have prevented runoff and subsequent potential for public exposure:

- Ensure sufficiently large basin sizes.

7 PACE: Property Assessed Clean Energy, formerly known as Special Energy Financing District

- Move the basin farther from the path.
- Create a mound of soil (a "berm") next to the path to prevent greywater from overflowing onto the path.

Irrigation problems are another potential problem related to system design. We observed two system designs resulting in over-irrigation.

- One system had shut-off valves on all greywater outlets. Someone shut off all but one valve, so all greywater was directed to one tree, resulting in massive over-watering. Poor soil drainage and excess water caused the tree to exhibit signs of stress, so the homeowner watered it more, unaware that the problem was too much water.

- One site had an existing irrigation system that the homeowner did not disconnect or turn off, so the plants were being irrigated twice (greywater and drip system). In this situation there was good drainage and the plants were not harmed, but the system design did not result in water savings.

For the most part, plants grew healthily with greywater with no obvious changes from when they received freshwater irrigation. Several sites reported plants that had been unhealthy becoming healthy after greywater irrigation. One bougainvillea vine didn't flower much until it received greywater, a fig tree began to "thrive", and a lime tree that the homeowner thought was going to die began to flower and produce fruit.

Conclusion and Policy Recommendations

Greywater irrigation is an important component of reducing total residential water consumption. Residential greywater systems can work synergistically with other water conservation strategies, such as lawn removal, conversion of non-greywater irrigated landscapes to xeriscaping or native plantings, rainwater harvesting and rain gardens, and installation of water-efficient fixtures and appliances. In preparation for drought-related water shortages and mandates for reduced water withdrawals to help restore our aquatic ecosystems, water districts can encourage deep savings by promoting a suite of options to reduce water demand by increasing incentives to the homeowner as they incorporate all the strategies.

Our findings suggest five policy approaches that can help agencies and other organizations realize residential greywater systems' water savings potential at scale:

- Simple laundry-to-landscape and branched drain systems should be promoted, as these types of systems are more economical, have few problems, and result in high user satisfaction.
- Education programs should also include support for implementation, since most people installed their systems within a year of learning about greywater. For example, installation workshops, subsidized installations, or referrals to local installers could enable people to follow through with their ideas for a home greywater systems.
- Use of plant-friendly products (without salt and boron) should be emphasized, to ensure good

quality greywater for irrigation.

- To increase water savings, greywater systems should be designed to replace other irrigation methods. Drip irrigation should be removed from greywater-irrigated areas, and supplemental hand watering should be discouraged.
- Thoughtful integration of greywater irrigation with rainwater harvesting, rain gardens, and climate-adapted plantings can maximize outdoor water savings by replacing municipal water as an irrigation water source. Such landscapes will be resilient in the face of future water shortages, and should be promoted as a strategy to increase resilience to droughts and adapt to climate change.

Our study should allay concerns about long-term effects on soils and plants, so long as greywater system owners have proper education about the importance of "plant friendly" products, but key questions about the mechanisms to maximize water savings and economic barriers to widespread adoption and sustained use of greywater irrigation systems remain. Most of our respondents are classic "early adopters", who were motivated by environmental concerns and desires for a more "eco-friendly" landscape, and who invested a few hundred or thousands of dollars in their greywater systems. Understanding how to recruit other potential adopters is a key area for future research.

We found significant average water savings in households that installed greywater irrigation systems (17 gpcd), but there was significant variation between households, given that many concurrently adopted other water saving practices, while others increased the amount of landscaped area, and others had changes in household size or composition. (Despite these confounding factors, we estimated that at least half of the 17 gpcd was due directly to greywater.) The adoption of multiple conservation measures is encouraging for scale up, but the variability in water savings suggests that how people use systems, and behavioral practices related to irrigation, are also important.

Follow-up studies can be designed to evaluate the long-term effect (more then 3 years) of greywater irrigation on soil and plant health over the growing season. Such a study conducted in a phased matter (over irrigation seasons, e.g. Spring, Summer and Fall), especially in productive urban gardens, along with documentation of plant species irrigated, yields obtained over the growing season, and detergents used will strengthen the evidence for greywater reuse in residential irrigation. Such studies will also make a case for productivity of greywater irrigation, strengthening the socio economic angle for greywater reuse.

Finally, follow-up studies should be conducted to investigate the lifetime and long-term maintenance needs of these systems. These studies should assess the lifetime of system components, the effects of different maintenance regimes, whether new owners and residents understand and choose to maintain the systems, and how systems fare when new residents undertake major changes to the landscape.

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