Integrated Stormwater Retention System

A Demonstration of Innovative Stormwater Management Solutions for Rural Landowners at the Occidental Arts and Ecology Center

WATER INSTITUTE

OCCIDENTAL ARTS & ECOLOGY CENTER

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Photographs by Brock Dolman and Jim Coleman

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ACKNOWLEDGEMENTS:

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OAEC's WATER Institute was established to offer positive responses to the crisis of increasingly degraded water quality and diminishing water quantity. We promote a holistic and multidisciplinary understanding of healthy watersheds through our four interrelated program areas — ***W***atershed ***A***dvocacy, ***T***raining, ***E***ducation, and ***R***esearch. For more information please visit **www.oaecwater.org.**

The Occidental Arts and Ecology Center (OAEC) is a nonprofit education and organizing center and organic farm in Northern California's Sonoma County. Since 1994, OAEC has explored, implemented, and provided education for innovative and practical approaches to the pressing environmental and economic challenges of our day. For more information please visit **www.oaec.org.**

INTRODUCTION

Stormwater is water flowing on land surfaces during or within 24 hours of a precipitation event that is not infiltrated into the soil. Historically it has been viewed as a problem primarily of urban areas to be solved by the outmoded engineering practice of "pave it and pipe it." This method fails to properly manage stormwater in the uplands, leading to disastrous consequences: large, powerful volumes of water moving too fast, resulting in severe erosion and flooding in low-lying areas. This excessive runoff requires expensive engineered systems that simply move the problem downstream until the runoff enters a stream and ultimately the ocean, leaving the ecosystem to absorb the excess volume and pollution.

Instead of a problem, water can more accurately be viewed as an enormously valuable resource to be sequestered and re-used whenever possible. Slowing, spreading and sinking stormwater generated by impervious surfaces as high as possible in the uplands of any watershed will increase infiltration and ensure that any water discharged will be clean and moving slowly enough to avoid erosion and sedimentation problems.

In many California coastal communities, reliable access to fresh water is limited and water quality and quantity are growing concerns. Current trends toward longer droughts and more severe storms render traditional methods of stormwater management even less effective. In response, development of a robust, scalable, de-centralized stormwater management strategy is critical for addressing watershed health and water security.

Implementation of effective stormwater management measures results in many benefits which address both human needs and total watershed health, including:

- Increasing upland water infiltration and retention capacity improves water security by recharging groundwater aquifers and improving the productivity of wells.
- Slowing down stormwater runoff decreases topsoil loss, erosion, flooding and stream flow variance by reducing the volume and rate of peak flow events.
- Removing pollutants in runoff improves water quality in streams and aquifers.

To demonstrate the effectiveness of innovative stormwater management practices, OAEC designed and installed an Integrated Stormwater Retention System in 2011. This unique system integrates various techniques, including: head cut mitigation, infiltration swales, sediment basins, multifunctional hedgerows, and native bunch grasses sown by drilling along keylines.

The system was installed below parking lots, a large greenhouse complex and a former horse pasture. Previously, these land uses generated significant increases in stormwater runoff volumes and velocities, resulting in increased erosion, gully head cutting and direct sediment delivery to our natural waterways. As a demonstration center for sustainability practices, OAEC has a responsibility to provide an effective example of mitigating these stormwater impacts. By improving water quality and infiltration, this new system demonstrates a rural residential approach to integrated stormwater management that moves away from *drainage*-based solutions and towards *retainage*-based solutions that also promote increased biodiversity.

This project is our most ambitious and integrated system to date and has been part of our land management visioning process for many years. Located in a highly prominent area of our land, the system is visible to thousands of visitors and students that annually visit OAEC's site. While most low-impact development (LID) techniques have been well demonstrated as effective tools in the suburban and urban sectors, this Integrated

Stormwater Retention System serves to address the community's need for a complementary rural demonstration.

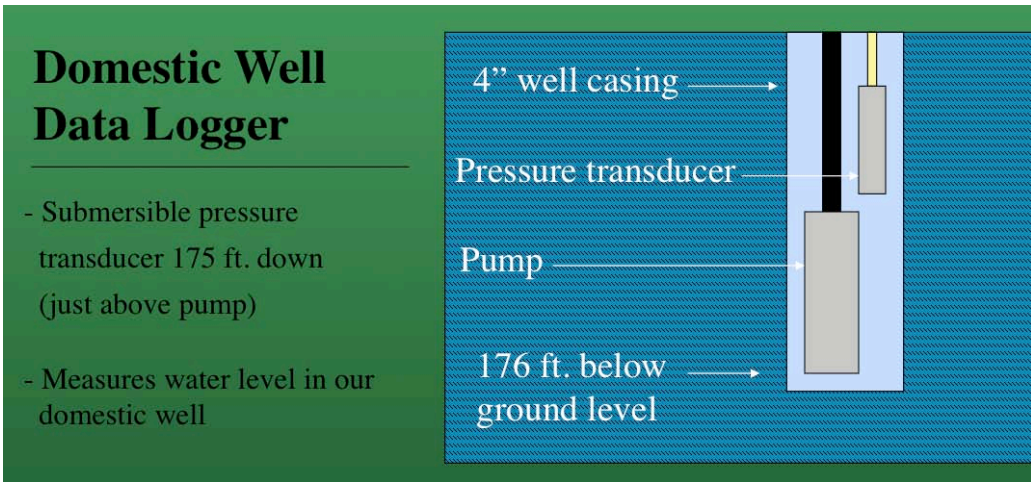
SYSTEM DESCRIPTION

Since 2004, OAEC's WATER Institute has been implementing an on-site Conservation Hydrology Adaptive Management Plan (CHAMP) that employs and demonstrates renewable energy technologies and best management and conservation practices for water, in addition to the energy associated with its use. These practical solutions include: graywater systems, micro-hydro generated electricity, roof water catchment systems, a rainwater harvesting pond that supplies 100% of our irrigation needs, a solar thermal hot water system, bio-filtration to improve water quality in a koi-pond, numerous swales and rain gardens, fish-friendly rural road improvements and a 10-kilowatt solar photovoltaic system (see page 17 for project reports).

In the spring of 2011, we consulted with Restoration Ecologist, Jim Coleman, M.S to design a new, enhancing element for our CHAMP – an Integrated Stormwater Retention System. With regard to physical function, the two primary design goals were to improve water quantity through increasing our well water production and improve surface water quality of our streams that drain into our salmonid bearing creek. The design needed to offset the run-off associated with the new greenhouse roofs, the existing road and the compacted soil of the former horse pasture, all of which were accelerating the rates of surface erosion and gully head cut migration that were contributing sediment to nearby creeks. Additionally, this rapid run-off prevented optimal infiltration of rainwater into our adjacent water supply well.

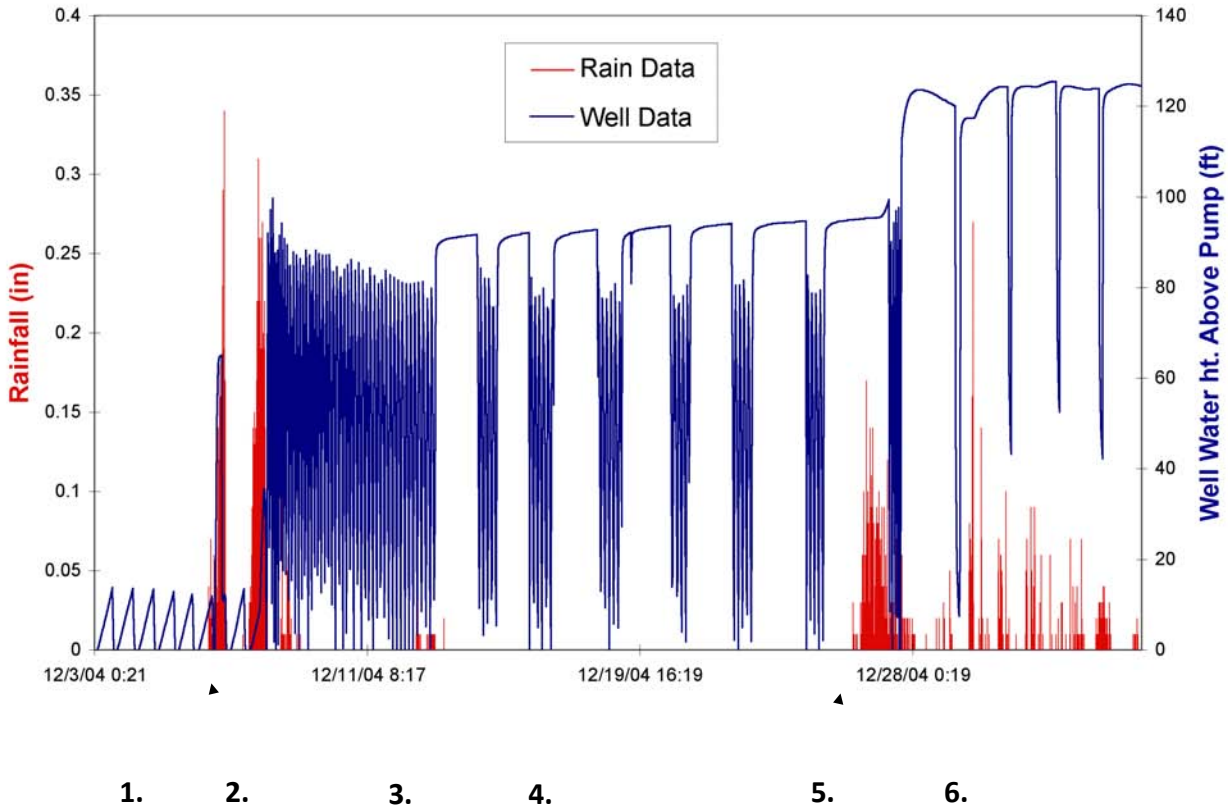
This system includes two different excavated sediment basins that double as wildlife habitat 'raingardens' and are associated with two long swale systems that have been planted with a multi-functional hedgerow. On the slopes above the swales, we utilized a keyline plow to improve infiltration and simultaneously sow keyline strips of native bunch grasses to improve erosion control, recharge groundwater and build soil. By design, the system elements are strategically located near the only water well on site, which serves as the property's sole source of potable water. The design incorporated information from previous research on the relationship between stormwater infiltration and groundwater levels in our well. The research was conducted as follows.

In 2004, the WATER Institute installed both a weather station with a rain gauge and a pressure transducer (see photo below left) with associated data logger into the well (see diagram below right). This equipment allows us to monitor rainfall and the change in ground water elevation on a daily basis.



Over a two-year period, we were able to determine how rainfall and human use affect changes in groundwater elevation as observed in the well (see Figure 1.).

Figure 1. OAEC rainfall compared with the level of the OAEC domestic well from December 3, 2004 through January 6, 2005. Rainfall measured in inches, well water level measured in ft. above submersible pump 176 ft below ground level.



1. **Ground water low, well recharging slowly**
2. **First big rain event**
3. **Ground water rises, pump works to fill tank**
4. **Pump intermittently fills tanks as community use pattern emerges**
5. **Second big rain event**
6. **Ground water levels rise further after additional rainfall**

In summary, this research demonstrated how, in the rock formation surrounding our well (fractured Franciscan), stormwater from small rain events (2 inches or less) raised the groundwater level in our well nearly 75 feet within 1-2 days. This is a rapid increase in groundwater elevation that appears to indicate the surface water and groundwater are highly connected.

With low productivity throughout the dry season, we attribute this inability to hold water to the fractured nature of this geologic formation surrounding the well. Based on this research, we determined that to improve dry season water security, it would be best to enhance water storage performance in the soils and underlying geology by implementing the following design elements.

During the design process, we determined that immediate mitigation of existing erosion was a high priority and needed to be addressed first. In the spring of 2011, the WATER Institute enlisted 28 Permaculture Design Course students to cut invasive woody Scotch Broom (*Cytisus scoparius)* and overcrowded Douglas fir *(Pseudotsuga menziesii*) from surrounding grasslands and forests to mitigate the eroding gully. Removing the broom gives native grasses a chance to flourish, while the fir removal reduces the potential for catastrophic fires in the forest. These materials were installed in the eroded gully to trap soil and prevent further head cut migration and the associated erosion (see photos below).

Eroded gully to be filled with freshly cut invasive Scotch Broom (Cytisus scoparius)

Students filling gully

To make this kind of erosion control work, one must be certain the brush and woody material is firmly placed in the gully. This can be achieved by stabbing the butt ends into the soil and subsequent layers of branches, weaving brush together into a dense matrix, and stomping brush to compact it and ensure thorough contact between brush and the gully walls. It is most effective to place branches with the tips pointing uphill and the cut ends downhill to increase filtration surface area. It is important to fill all voids so water cannot concentrate in volume and undermine the structure. The end result should be a densely packed but porous matrix that disperses the flow of water while trapping soil and leaf litter particles.

It is best to use fresh green material so that the leaves from the drying branches can fall and fill in the voids. If you must use dry, leafless or large woody materials (logs), you must also include a weed-free source of carbon (such as straw) to infill the micro spaces.

Over time, this material composts and results in a fertile and water-holding sponge into which the adjacent tree roots grow. These roots further stabilize the gully, restore the slope to its original grade, and support a stable soil profile that is resistant to erosion. The removal of the gully elevates the surrounding shallow groundwater, making it available to adjacent plants and improving soil moisture conditions during drought.

As with most restoration projects, these repairs need to be monitored and maintained. As the repair materials decompose, you may need to add new material over the years to bring the level up to grade until a stable level has been achieved.

Students tightly stuffing and stomping fir into the gully

The finished gully, ready for the rainy season

A broom stuffed gully one year after installation.

Digging the swale and sediment basin

Finished sediment basin and swale with overflow

Rockwork for overflow prevents erosion

Overflow goes through culvert to second sediment basin on other side of the road

In summer 2011, the WATER Institute installed the next phase of the Integrated Stormwater Retention System, which was comprised of two swales and associated sediment basins. We placed sediment basins in two locations where sediment-laden water was most likely to first enter the structure. These basins are both accessible from the road so, if needed, they can be cleaned out with a backhoe in the future. The sediment basins are deeper than the swales and can hold a greater volume of water for a longer period while the sediment drops out of the water. In small storm events, these basins will tend to be the first and only place that fills with water. The area immediately surrounding these basins will get more water and allow planting of more water-loving vegetation around its perimeter, thus functioning like the raingardens found in urban areas.

Once the upper sediment basins are full, they then begin to flow into the adjacent swales. By swale, we mean an infiltration trench dug on contour whose berm is built with the soil excavated to make the trench. Digging them on contour retains the greatest amount of water over the longest possible length of slope, resulting in optimal groundwater infiltration. The swales were laid out using an A-Frame leveling device to locate the contour line to be excavated on the slope. We mulched the berm with straw to prevent erosion and protect the soil. We have intentionally sized the capacity of the system in anticipation of less frequent but wetter storm events as predicted by climate change models. We have also designed and installed robust rock-lined spillways to safely manage large water overflows when the system has reached capacity.

In Fall/Winter 2011, the all-native hedgerow was planted by students attending a Designing Edible Food Forests course taught by Eric Toensmeier at OAEC (see plant list on page 12). The former horse pasture was keyline plowed and sown with native grasses using the No-Till-Drill (see photos below). The seed drill was rented from our local Gold Ridge Resource Conservation District and is specifically designed to dispense native grass seeds. We chose to keyline plow off contour to evenly disperse the sheet flow from the pasture away from the road and towards the forest edge to optimize the recharge capacity and support the growth of native grasses. These long-lived and deep-rooted native grasses help to enhance water infiltration and sequester carbon.

By planting both the hedgerow and the slope with California native plants and bunch grasses, we were able to highlight the use of native plants as part of wildland restoration concepts described in the seminal work *Tending The Wild by K*at Anderson (2006). Many of the plants were selected for their cultural, medicinal and material value to the Coast Miwok and Southern Pomo tribes in the area. The plowing and seeding demonstration was open to the public. Land managers, contractors and landowners attended.

Students learn how to place native California plants so they benefit one another

Having planted the lower swale with native starts, we gather students to sow native grass seed in the upper swale

Using the keyline plow to cut keylines just off contour to direct water away from road and towards the forest in the background

Close-up of the special blade and rotating tines on the keyline plow

Setting up the cogs on the No-Till-Drill with bags of seed waiting in the foreground

Putting the native grass seeds into the special hopper designed for native seeds – a feature unique to this particular style of No-Till-Drill

Using the No-Till-Drill between the keylines to seed the pasture with native California grass seeds

Many hands full of native seeds make light work

Now that the system has been in place for one season, we have made the following observations. As predicted with climate change, our 2011-2012 rain year was below average. Nearly 75% of the rain we received, however, arrived during four large rain events that delivered heavy precipitation in a short period of time. This water quickly saturated the soil and delivered significant runoff to our Integrated Stormwater Retention

System. Since we had designed oversized swales for this type of large flow, we were able to harvest and retain almost all of the water in the system. All sediment produced was captured and retained within the sediment basins. The small percentage of water that overflowed the system was free of sediment. The two primary goals of the system were achieved – dramatically improved water quality and recharge quantity. The headcut has ceased to migrate and the erosion gully has stabilized. The water quality below the gully has dramatically improved, and we have ceased delivering sediment to nearby Calypso Creek.

The plants are all flourishing. Of the three blue elderberries we planted in different locations along the top of the swale, the one closest to the first sediment basin (which receives water first from the greenhouse roof downspout) is three-five times larger than the ones planted 25-50 feet further from the basin, an area that receives standing water only during large storm events (see Figure 2.). This suggests that the first elder may be taking advantage of and benefiting from the extra water infiltrating its root zone. This supports the concept that planting perennial vegetation adjacent to seasonal water is effective and that plantings located in areas less frequently inundated may require supplemental irrigation.

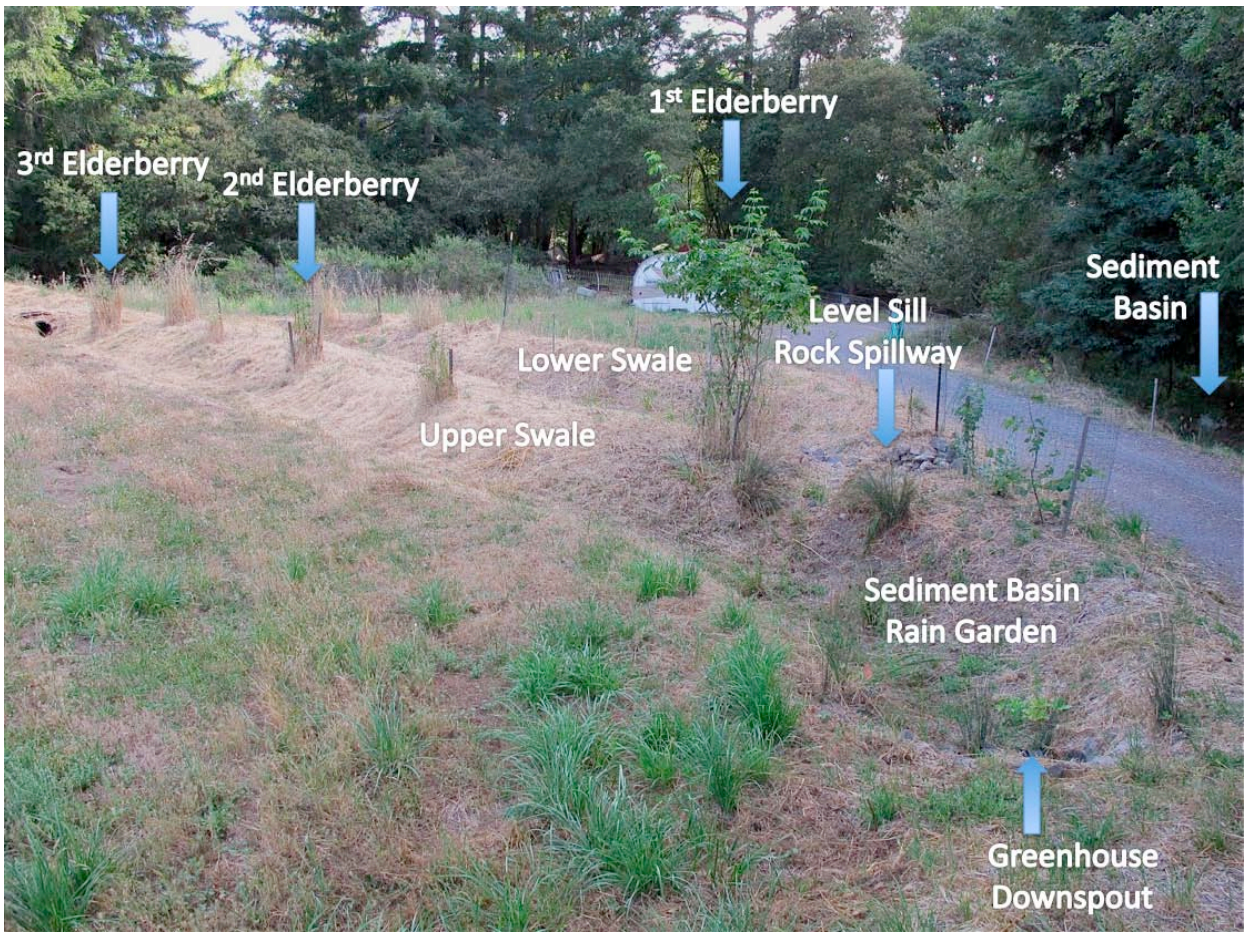


Figure 2. Image of the sediment basins and swales planted with California natives as of July 2012

In sum, as we witnessed problems with this section of the property, we also began noticing opportunities. Most notably, the excess runoff could help us solve the problem of the low production well nearby. We lead with the perspective of seeing constraints as opportunities. If form follows function and we envisioned multiple functions, then we needed to create a system comprised of multiple forms (road drainage, sediment basins, swales, stacked spillways, keyline plowing and native vegetation). Each of these elements provides different, specific roles within the system and support one another.

Sediment basin full of precious rainwater after a storm

PLANT LIST

California Native Plants for OAEC WATER Institute's Stormwater Swale/Hedge (aka "Swedge")

Upper Canopy/Shrub

Pacific Wax Myrtle	*Myrica californica*
Grey Willow	*Salix exigua*
Blue elderberry	*Sambucus mexicana*
Redbud	*Cercis occidentale*
Hazelnut	*Corylus cornuta californica*
Red twig dogwood	*Cornus stolonifera*
Western Azalea	*Rhododendron occidentale*
Spicebush	*Calycanthus occidentalis*
Thimble berry	*Rubus parviflorus*
Oso Berry	*Oemleria cerasiformis*
Leatherwood	*Hoita macrostachya*
Silk Tassel	*Garrya eliptica*
Sugar Bush	*Rhus ovata*

Herbaceous

Common Rush	*Juncus patens*
Basket Sedge	*Carex barbarae*
Spike Rush	*Eleocharis sp.*
Mugwort	*Artemisia douglasiana*
Pacific Iris	*Iris douglasii*
Cardinal Monkey Flower	*Mimulus cardinalis*
Coltsfoot	*Petasites frigidus*
Yampah	*Perideridia gairdneri*
Coast Angelica	*Angelica hendersonii*
Foothill Angelica	*Angelica tomentosa*
Celery Weed	*Lomatium californicum*
Common Camas	*Camassia quamash*

Low herbaceous to Groundcover

Meadow Barley	*Hordeum brachyantherum*
Columbine	*Aquilegia formosa*
CA Buttercup	*Ranunculus californicus*
Bleeding heart	*Dicentra Formosa*
Mariposa Lily	*Calochortus luteus*
Yerba Buena	*Satureja douglasii*
Woodland Strawberry	*Fragaria vesca*
Yerba mansa	*Anemopsis californica*
Wild Ginger	*Asarum caudatum*
Yarrow	*Achillea millefolium*

Vines

Ninebark	*Physocarpus capitatus*
Wild grape	*Vitus californica*
Pipestems	*Clematis lasiantha*

Grasses

California Brome	*Bromus carinatus*
Blue Wildrye	*Elymus glaucus*
Idaho Fescue	*Festuca idahoensis*
Meadow Barley	*Hordeum brachyantherum*
California Barley	*Hordeum californica ssp.californicum*
Deer Grass	*Muhlenbergia rigens*
Purple Needlegrass	*Nassella pulchra*
Pine Bluegrass	*Poa secunda*

Purple needlegrass (Nassella pulchra), California's state grass in full bloom

RESOURCES

Note: OAEC's WATER Institute provides this information as a potential resource, not as an endorsement.

BOOKS / ARTICLES / VIDEOS

Conservation Strategy No. 4: Stormwater Management for Coastal California Communities
- A product of the Salmon Creek Water Conservation Program written by Brock Dolman, Kate Lundquist and Kevin Swift. (2010) www.salmoncreekwater.org/cs/Stormwater_Management.pdf

Contour Farming: NRCS Conservation Practice Standard - Specs and support for keyline-related practices. http://efotg.nrcs.usda.gov/references/public/ID/330.pdf

Creating Rain Gardens: Capturing the Rain for Your Own Water-Efficient Garden – by Cleo Woefle-Erskine and Apryl Uncapher. Timber Press (2012).
http://www.timberpress.com/books/creating_rain_gardens/woelfle-erskine/9781604692402

Design For Water: Rainwater Harvesting, Stormwater Catchment and Alternative Water Reuse
by Heather Kinkade-Levario. Publisher: New Society Publishers. ISBN: 9780865715806 (2007)
www.newsociety.com/bookid/3954.

Groundwork: A Handbook for Small Scale Erosion Control in Coastal California (2nd Edition),
Marin Resource Conservation District, Marin County Stormwater Pollution Prevention Program (2007),
http://www.mcstoppp.org/acrobat/groundwork.pdf

Harvest the Rain: How to Enrich Your Life by Seeing Every Storm as a Resource – By Nate Downey. Sunstone Press (2010). http://harvesttherain.com/author.html

Harvesting Water the Permaculture Way - A DVD presented by Geoff Lawton.
"The complete introduction course to constructing a dam and swale on a small acreage farm using the principles of permaculture to harvest water passively."
http://www.permaculture.org.au/store/water_harvesting_dvd.htm

Nicasio Native Grass Ranch (A Case Study) - Through their experiments in preserving native grass species, John Wick and Peggy Rathmann discovered keyline design principles of soil conservation and water harvesting. From the California Institute for Rural Studies report California Water Stewards: Innovative On-Farm Water Management Practices.
http://aginnovations.org/agwaterstewards.org/uploads/docs/Nicasio_Native_Grass_Ranch.pdf

Keyline and Fertile Futures
by L. Spencer - An article providing a good basic introduction to keyline. www.laceweb.org.au/kff.htm

Rainwater Harvesting for Drylands, Volume 1: Guiding Principles to Welcome Rain Into Your Life and Landscape by Brad Lancaster. Publisher: Rainsource Press ISBN: 097724640X (2006)
www.Harvestingrainwater.com

Rainwater Harvesting for Drylands, Volume 2: Water Harvesting Earthworks
by Brad Lancaster. Publisher: Rainsource Press ISBN: 0977246420 (2008)
www.Harvestingrainwater.com

Rx for the Biosphere **-** A lecture by Darren Doherty delivered in Santa Barbara and posted on YouTube. Covers elements of keyline design in Australian context.
http://www.youtube.com/watch?v=QX_6rxVya3I&feature=related

Slow It, Spread It, Sink It: A Homeowner's & Landowner's Guide to Beneficial Stormwater Management By Southern Sonoma County Resource Conservation District and the Resource Conservation District of Santa Cruz County (2010) http://www.sscrcd.org/rainwater.php

Storm Water as a Resource: How to Harvest and Protect a Dryland Treasure
City of Santa Fe, New Mexico (2002) www.santafenm.gov/DocumentView.asp?DID=532

Tending The Wild: Native American Knowledge and the Management of California's Natural Resources
By M. Kat Anderson, University of California Press (2006) – A seminal work on traditional land management practices and native plant uses in California.
http://www.ucpress.edu/book.php?isbn=9780520248519

The Challenge of Landscape: The Development and Practice of Keyline
By P.A. Yeomans - The fundamentals of keyline planning and design.
www.soilandhealth.org/01aglibrary/010126yeomansll/010126toc.html

The Keyline Plan
by P.A. Yeomans - The principles of keyline design and planning.
www.soilandhealth.org/01aglibrary/010125yeomans/010125toc.html

Water for Every Farm – Yeomans Keyline Plan (4th Edition)
by P.A. and K.B. Yeomans, CreateSpace ISBN: 978-1438225784 (2008). A seminal work on keyline systems. Covers core principles, keyline pattern of cultivation, farm dams, ponds, fencing, water harvesting and many other practical aspects of keyline design. www.amazon.com/Water-Every-Farm-Yeomans-Keyline/dp/1438225784

What are Keylines and How Do They Work? by Liza Cowper. A concise article explaining the ideas behind keyline. http://www.keyline.com.au/qasset.htm

The Yeomans Plow in Action - A short video showing the use of a Yeoman's Keyline Plow.
http://www.youtube.com/watch?v=OpAPRlg2Zgs&feature=related

WEBSITES / ORGANIZATIONS

California Agricultural Water Stewardship Initiative (CAWSI) - www.agwaterstewards.org
Great initiative with papers, articles, case studies in their resource center. See their keyline design page at http://agwaterstewards.org/index.php/Resource-Center-Articles/keyline_design/ .

Marin County Stormwater Pollution Prevention Program - www.mcstoppp.org
Great source for information on creek care, regulations and more.

Salmon Protection and Watershed Network (SPAWN) - www.spawnusa.org
SPAWN works to protect endangered salmon in the Lagunitas Watershed and the environment on which we all depend.

Wholly H2O – www.whollyh2o.org
Wholly H2O is a catalyst for sustainable, integrated water management in California.

CONTRACTORS / DESIGN CONSULTANTS

AP Rainwater Harvesting & Graywater Gardens - David Ortiz, (707) 874-9460 in Sebastopol, CA. Provide consultation and design of systems that integrate rainwater harvesting and the latest graywater technologies, reduce storm water runoff, create rain gardens to act as sponges and promote native plant growth, save money on water bills, and replenish the water table. www.aprainwaterharvesting.com

Design Ecology - Josiah Raison Cain, (415) 233-9186 in San Francisco, CA. Provides comprehensive solutions from concept to completion, including consultation, strategy, design, detailing, standards and specifications, construction oversight, and monitoring systems. www.designecology.com

Keyline Designs – Queensland, Australia. A consulting service providing assessments and plans for the sustainable development of land and water resources in agricultural and suburban areas. Lots of great information about keyline is available on this website.
http://www.keyline.com.au

Permaculture Artisans - Erik Ohlsen, (707) 824-0836 in Sebastopol, CA. This ecological landscape and farm company creates natural systems that support the health of the surrounding ecosystems by building soil, supporting wildlife, catching rainwater, installing appropriate plant species, and building beneficial human relationships throughout the landscape. They provide keyline plow services. www.permacultureartisans.com

Permaculture.biz – Darren Doherty, This Australian company provides keyline and permaculture design, education and consulting services around the world. Information on keyline courses in the U.S. listed.
www.permaculture.biz

Prunuske Chatham, Inc. – Mike Jensen (707) 824-4601 ext. 107 in Sebastopol, CA. They bring together scientists, planners, designers, and builders to take your project from the first idea all the way through to implementation.
www.pcz.com

Rusty Davis – (707) 321-MUCK in Forestville, CA. Sonoma county large machinery operator who does keyline plowing and other permaculture earthworks.

Sentient Landscape - (707) 829-3655 in Sebastopol, CA. A local landscape company whose methods are based on permaculture principles.
www.sentientlandscape.com

WaterSprout – John Russell, (510) 541-7278 in Oakland, CA. A design/build landscape firm specializing in residential and commercial greywater, rainwater catchment, and irrigation efficiency. www.watersprout.org

MATERIAL AND TOOL SUPPLIERS

California Flora Nursery (707) 528-8813 in Fulton, CA. A small, unconventional nursery devoted to California natives and plants appropriate for our California mediterranean climate. www.calfloranursery.com

Gold Ridge Resource Conservation District (707) 874-2907 in Occidental, CA. This local RCD has a no-till-drill for rent. www.grrcd.org

Le Ballister's Seed and Fertilizers (707) 526-6733 in Santa Rosa, CA. This local seed company sells California native seeds. www.leballistersseed.com

Mostly Natives Nursery (707) 878-2009 in Tomales, CA. A small retail nursery with a wide variety of native and non-native perennials, grasses, shrubs, and trees. www.mostlynatives.com

The North Coast Native Nursery (707) 769-1213 in Petaluma, CA.
Grows a wide variety of California native plants for restoration projects, natural landscapes, bioswales and living roofs. www.northcoastnativenursery.com

Yeomans Plow Company in Australia. Information and specs on the Yeomans plow and related implements. Distributor information is also available at this site. www.yeomansplow.com.au/redbook

Notes:

Occidental Arts & Ecology Center's WATER Institute

This publication was produced by the WATER Institute, a innovative program that provides demonstration, education, capacity building and advocacy leadership to implement Conservation Hydrology: a holistic and multidisciplinary understanding of the importance of healthy watersheds.

OAEC's WATER Institute has developed or contributed to the following publications to help citizens, landowners, agencies and decision makers implement useful techniques to restore and protect the watersheds we live in. Most of these publications include extensive resource lists and are free to download. For a list of all our publications, see below or go to: www.oaecwater.org/publications.

- **Basins of Relations - A Citizen's Guide to Protecting and Our Watersheds**

  A 20-page WATER Institute booklet for individuals to educate themselves and for those working to educate others about the myriad issues facing our watersheds and the steps we can take to preserve them. (2nd Edition 2008).

- **Garden Koi Pond With Bio-Filtration System**

  A 19-page WATER Institute how-to on building a bio-filtered koi pond (2007).

- **Heating Water With The Sun: A Thermal Drainback Solar Hot Water Heater Demonstration**

  A 10-page WATER Institute how-to on solar hot water heating (2009).

- **Legal Graywater Design For Small Scale Applications in California: A Demonstration of Laundry to Landscape and Branched Drained Systems at the Occidental Arts and Ecology Center**

  An 11-page WATER Institute how-to on two legal graywater designs for residential applications (2010).

- **Low Cost Roofwater System For Agricultural Supply: A Demonstration of Our Flexible "Wonder Gutter" System at the Occidental Arts and Ecology Center**

  An 11-page WATER Institute how-to on this simple agricultural roofwater catchment design (2011).

- **Roofwater Harvesting for a Low Impact Water Supply**

  A 27-page WATER Institute how-to on simple residential roofwater harvesting systems at OAEC (2008).

- **Roofwater Harvesting In California: Obstacles and Opportunities - Supporting statewide adoption of this valuable water conservation strategy to increase community water security and stream flows for salmonid recovery**

  A 23-page WATER Institute report on roofwater harvesting in California (2011).