Tailwater Return Systems

LAWRENCE J. SCHWANKL, UC Cooperative Extension Irrigation Specialist; **TERRY L. PRICHARD,** UC Cooperative Extension Water Management Specialist; **BLAINE R. HANSON,** UC Cooperative Extension Irrigation and Drainage Specialist

UNIVERSITY OF CALIFORNIA
Division of Agriculture and Natural Resources
http://anrcatalog.ucdavis.edu

INTRODUCTION

The California State Water Code requires those discharging waste that could affect the waters of the state to obtain a permit or coverage under a waiver. Agricultural runoff, whether from irrigation or rainfall, that leaves a property has been determined to likely contain waste (sediment, nutrients, chemicals, etc.).

Compliance under the Irrigation Lands Conditional Waiver is available to agricultural growers of irrigated lands who have runoff from their property caused by irrigation practices or winter rainfall. If no runoff leaves a property, the California Water Code does not impact the property owner.

TAILWATER RUNOFF COLLECTION AND REUSE

Water running off the lower end of a field as part of normal irrigation practices is referred to as tailwater. Tailwater is most often associated with surface irrigation (furrow and border-strip irrigation), since well-designed and well-managed sprinkler and microirrigation systems rarely produce tailwater runoff. Tailwater is necessary, especially in furrow irrigation, to adequately irrigate the lower end of a field since a sufficient infiltration time is required to allow the desired amount of water to infiltrate the soil.

To achieve a good uniformity (evenness) of applied irrigation water across the field, it is recommended that the inflow rate to the border or furrows be kept high. This advances water across the field quickly and minimizes the differences in infiltration time (and thus the differences in the amount of infiltrated water) between the top and bottom of the field. A high flow rate tends to generate greater tailwater unless cutback irrigation (reducing the inflow rate when water reaches the end of the field) is practiced. Even when cutback irrigation is used, it is a good management practice to collect the tailwater for reuse.

Tailwater collection systems (fig. 1) have been used most frequently in row and field crop systems and are not as commonly used in surface-irrigated trees and vine crop systems. Yet there is no reason tailwater collection and reuse systems cannot be used in permanent crop systems, and their use is an excellent management practice for improving irrigation efficiency and minimizing the impact of tailwater runoff.

Tailwater return systems are generally not designed to store winter rainfall runoff. The rainfall runoff volumes are so large that storing them in a pond is seldom practical. For more information, see the companion publication *Storing Runoff from Winter Rains* (ANR Publication 8211).

METHODS OF DEALING WITH TAILWATER

Tailwater runoff is generally handled in one of the following ways.

- The ends of the furrows or borders are blocked with earthen dams or berms, and water is allowed to pond on the tail end of the field. This practice may lead to crop damage due to standing water (fig. 2). If irrigations are managed to minimize ponded water, the tail end of the field may be underirrigated.
- Tailwater from an irrigation set is allowed to flow into the tail end of adjacent unirrigated furrows or border checks. This is most frequently done with fields that have minimal slope.

UC PEER REVIEWED

Figure 1. Tailwater collection system. *Photo:* Lawrence J. Schwankl.

Figure 2. Alfalfa stand loss at end of field due to standing water. *Photo:* Lawrence J. Schwankl.

- Tailwater is allowed to run off the field, collected, and discharged to a natural water body or to the supply system for use by downstream water users.
- Tailwater is collected and placed in a pond with no provision for reuse. The tailwater in the pond is allowed to infiltrate or evaporate. With this method, irrigations are usually managed to minimize tailwater, since a pond has a limited storage capacity. Tailwater ponds often leak, and mobile chemicals in the pond water may leach to the groundwater. It is strongly recommended that tailwater in a pond be recycled back to lands being irrigated.
- Tailwater is collected and reused for irrigation. Most often, a pump and a ditch or pipeline conveyance system move the reused tailwater to where it will be applied. Such a system, when well operated, maximizes irrigation efficiency and minimizes environmental impacts.

ADVANTAGES AND DISADVANTAGES OF USING A TAILWATER RETURN SYSTEM

Advantages

- Minimizes environmental impacts of tailwater leaving the property.
- Improves irrigation efficiency, since tailwater is beneficially reused as irrigation water.
- May reduce water costs, which may be especially important where water costs are high.
- Simplifies irrigation water management for flood systems that do not have a ready outlet for tailwater, since irrigations, especially at night, are more easily managed.
- Removes standing water, which can result in crop loss and weed and mosquito infestations (this advantage is commonly seen in border strip-irrigated alfalfa and furrow-irrigated corn).

Disadvantages

- Increases costs, not only for the installation, maintenance, and operation of the tailwater return system but also because land must be taken out of production for the pond and other system components.
- Requires timely recycling of tailwater pond contents to prevent groundwater pollution by chemicals in the tailwater. Tailwater should be returned to land being irrigated and not allowed to simply infiltrate from the pond.

TAILWATER RETURN SYSTEM MANAGEMENT

The management of tailwater return systems is often dictated by the design of the return system. For new tailwater return systems, management must be a key factor in the design. For an existing tailwater return system, management options may be constrained by the return system's capabilities. Factors such as the pond size and the return pump discharge rate limit the ways in which the return system can be managed. For more information on tailwater return system design, see the next section.

Growers manage tailwater return systems in a wide variety of ways to address site-specific needs and conditions. There is no "best" way to manage a tailwater return system, but a few useful guiding principles and considerations for tailwater system management do exist.

Recirculating tailwater back to the top of the irrigation set from which it came is generally not a good practice. The recirculated tailwater would be applied to wet soil that has a low infiltration rate, and it may add to the tailwater volume that must be handled. A better strategy is to apply the tailwater to an area that has not been irrigated. Tailwater return flows are often used to supplement the irrigation water of another irrigation set on the same field or on another field.

Another management or design strategy is to make the tailwater pond and return pump large enough to irrigate a set using tailwater alone. The return flow pump must be of adequate size to provide the desired irrigation flow rate. While this may aid management, it may increase the expense of return system hardware and also increase the size of the pond.

Another approach that saves cost and reduces the land taken from production involves reducing the size of the pond to handle only the runoff from one or two irrigation sets. The tailwater is then used to supplement the primary irrigation supply of an irrigation set other than that which generated the tailwater. The tailwater pump and pipelines can be made large enough to empty the pond quickly (a few hours) or smaller to empty it more slowly. Emptying the pond quickly temporarily increases irrigation flow and may require setting more siphons or opening more valves, which may not be convenient. Emptying the pond more slowly has the advantage of requiring a smaller pump or a smaller conveyance pipeline, and the return flow rate is less likely to require temporary changes in the number of siphons, gates, or valves operated to handle the extra flow.

TAILWATER RETURN SYSTEM DESIGN

Tailwater Pond

Most frequently, tailwater ponds are excavated below ground level, allowing gravity flow to fill the pond. The major tailwater pond design decision is determining its size. As mentioned in the section on tailwater return system management above, proposed management of the system often determines the pond size. In general, a larger pond allows more operational flexibility, but the size of the pond must be balanced with the cost of constructing the pond and the land taken out of production.

Figure 3. Cantilevered pipe discharge into tailwater pond. *Photo:* Lawrence J. Schwankl.

As a rule of thumb, expect the tailwater volume to be 15 to 25 percent of the water applied to an irrigation set. For example, if an irrigation set has a flow rate of 1,500 gallons per minute and is 8 hours long, the expected tailwater discharge (15% of inflow) would be 108,000 gallons (1,500 gal/min × 60 min/hr × 8 hr × 0.15 = 108,000 gal). (For metric conversions, see the table at the end of this publication.) This would be 14,440 cubic feet or 0.33 acre-feet of water. A tailwater volume of 25 percent of the irrigation set applied water would be 180,000 gallons (2,060 cubic feet, or 0.55 acre-feet).

The next decision in sizing the pond is choosing how often the pond will be emptied. After every set? After 2 sets? More often? A small pond, such as one needing to be emptied after each irrigation set, may be difficult to manage since it must be monitored closely to make sure it does not overfill. Even with an automated pump system, there is a risk of overfilling the pond. The estimated tailwater runoff per irrigation set and the frequency of pond "pump-down" will determine the pond storage capacity. Seldom is it possible to pump the pond completely dry. It is usually not acceptable to have the pump intake at the bottom of the pond due to sediment accumulation, so this should be accounted for when determining the size of the pond.

The tailwater pond should be at least 5 feet deep to control aquatic weed growth. Most ponds are deeper than this to attain the desired storage while minimizing the field area devoted to the pond.

The discharge to the tailwater pond should minimize bank erosion. A cantilevered pipe inlet (fig. 3) or some other form of protected inlet, such as riprap, should be used.

Removal of sediment and trash (weeds, crop residue, etc.) will be necessary, so the design should provide access for equipment. Steep pond wall slope (a 1:1 slope is usually the steepest acceptable) minimizes the area required for the pond and may reduce weed growth problems, but a more gentle slope (e.g., 3:1) makes access easier, may reduce erosion, and are often safer. More gentle slopes also encourage the establishment of desired plant species to reduce erosion, compete against unwanted weeds, and provide wildlife habitat.

Consideration should be taken in choosing the width of the tailwater pond. Two important considerations favoring a narrower pond are that the pond may need to be cleaned of sediment using machinery located on the pond embankments, and that control of mosquito larvae may be required. Check with your local mosquito abatement district for pond size restrictions.

An alternative design is to construct a two-stage pond. A first smaller pond acts as a sediment trap and is designed for easy cleaning. The second larger pond provides the primary tailwater return storage. Sediment trap recommendations include having the trap length be at least 3 times its width and designing its volume to be sufficient to trap a season's worth of sediment while maintaining capacity to provide adequate settling. The flow velocity through the sediment trap should be 1 foot per second or less to allow large soil particles to settle out before they enter the larger storage pond.

Currently, tailwater return ponds in California do not require lining. However, the seepage from tailwater ponds can allow water-soluble chemicals to leach into shallow groundwater (see Prichard et al. 2005). Lining ponds with synthetic liners or clay may prevent this but would significantly increase the cost. As an alternative, pond management ensuring that the tailwater pond is emptied after the final irrigation set and that the remaining tailwater is not simply allowed to infiltrate from the pond will minimize the movement of water-soluble chemicals to the groundwater.

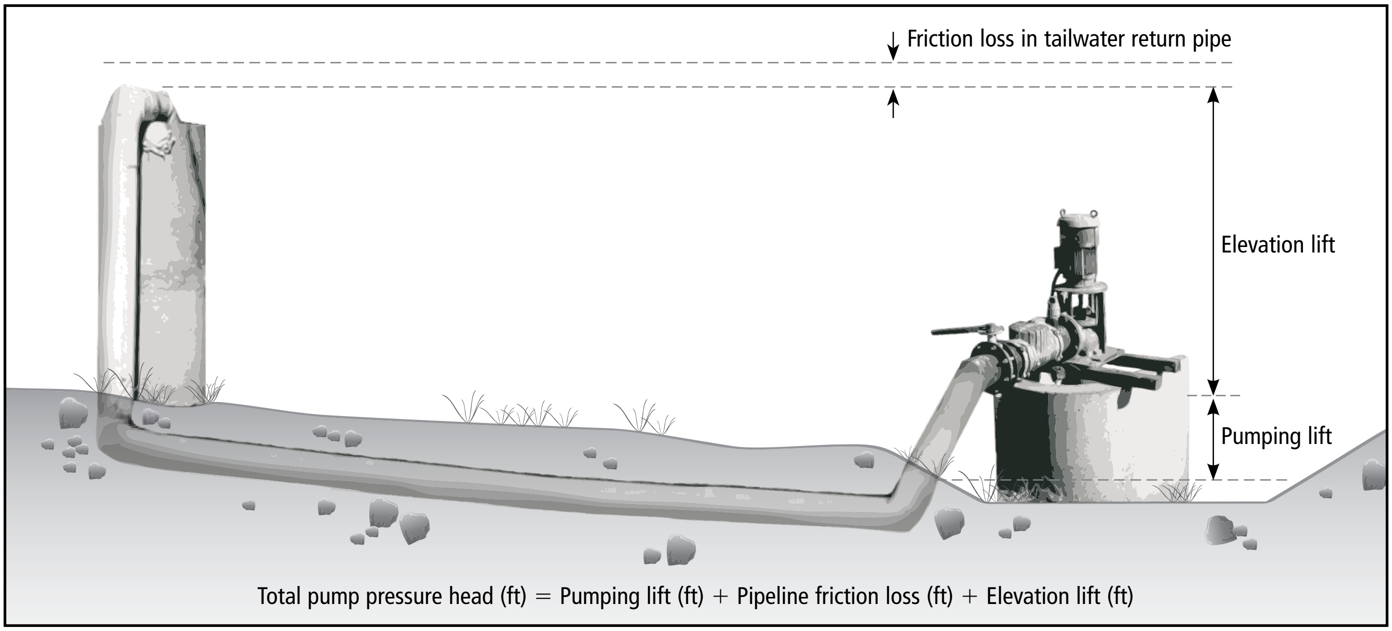

Figure 4. Total pump pressure head requirement.

Figure 5. Trash screen on a concrete sump intake box. *Photo:* Lawrence J. Schwankl.

Return Flow Pump

The tailwater return flow pump removes water from the tailwater pond and moves it to the discharge point where it will be reused for irrigation. The pressure (head) the return pump must supply is determined by the sum of the pond depth (lift), the pressure lost to friction in the return flow pipeline, and any elevation differences between the pump and its discharge point (fig. 4).

Final pump selection must be based on the desired tailwater return flow rate and pressure. The pump should have a high efficiency under the planned operating conditions. Since the pond level will be changing, the pump operating conditions (flow rate and pressure) will also change. Select a pump with high efficiency across the range of expected operating conditions.

The tailwater return pump is frequently automated using a float system or an electric probe sensor to operate when the pond has reached a preset height and then shut off when the pond has been pumped down to a desired level. Automation can help ensure that the pond does not overfill. Even when automated, the tailwater return system can always be operated manually. Some operators choose manual operation to assure that additional siphons are started or sufficient valves are opened to accommodate the additional flow rate.

A screen should be installed at the return flow pump intake to protect the pump from trash and debris. The screen may be a vertical screen on a concrete sump (fig. 5) or a self-cleaning rotary screen (fig. 6).

A control valve (e.g., a butterfly or gate valve) should be installed downstream of the pump to control the tailwater return flow rate (fig. 7). There should also be appropriately placed air and vacuum relief valves, or open vents, to protect the return flow pipeline (see fig. 7).

A check valve should be installed downstream of the pump (see fig. 7). This is especially important if the return system is connected to the irrigation supply, which could allow irrigation water into the tailwater pond. The check valve also keeps the return flow pipeline full, protecting from excessive power loads and pressure surges associated with an empty pipeline at pump start-up.

Figure 6. A rotary pump intake screen and diesel engine used for tailwater return. *Photo:* Lawrence J. Schwankl.

Figure 7. Control (butterfly) valve, air-vacuum relief valve, and check valve located downstream of tailwater return pump. *Photo:* Lawrence J. Schwankl.

Tailwater Return Pipeline

The design of the tailwater return pipeline depends primarily on the return flow pump discharge rate. Pressure loss (frequently called friction loss) tables are readily available for selecting the appropriate pipe size. A maximum pipe flow velocity of 5 feet per second is often used to ensure that pressure losses are limited. Pipe flow velocities from 2 to 3 feet per second are more acceptable and are commonly used. The choice of pipe size involves balancing cost versus pressure loss. Greater pressure loss means increased energy costs for pumping. Saving money on the initial pipe cost by selecting smaller pipe may cost more in long-term operating costs.

PVC pipe is the most common choice for return flow pipelines. The PVC pipe class should match the expected pressure requirements. Steel pipe should be used for exposed sections. Portable aluminum pipe is also used as a return flow pipeline; this pipeline is removed for equipment access at harvest or for land preparation. The discharge point for the return flow pipeline depends on the design of the irrigation system. It may be a standpipe connected to the irrigation system, a supply ditch, or some other point. While not required, installation of a flow meter in the return flow pipeline permits the operator to adjust the return flow rates and also allows the operator to keep records of return flow volumes. A flow meter is a good water management tool.

Power Unit

Most commonly, either an electric motor or a diesel engine is the power unit for the return flow pump. Electric motors (see fig. 7) have the advantage of being easily automated, available on demand, and having low maintenance costs. They also have a low pollution impact, which is important in areas where air quality regulations are a factor.

A diesel engine (see fig. 6) can also be used as the power unit for the pump. Their selection is usually based on cost. Diesel fuel prices, engine maintenance costs, and air quality regulations must be weighed against electric energy costs, meter and service charges, and other electric motor expenses. With electric energy costs and diesel fuel prices constantly changing, the decision can be difficult. Most pumps driven by diesel engines are operated on a manual start and shutdown basis. Automated diesel starting and shutdown systems are available but add to the overall cost.

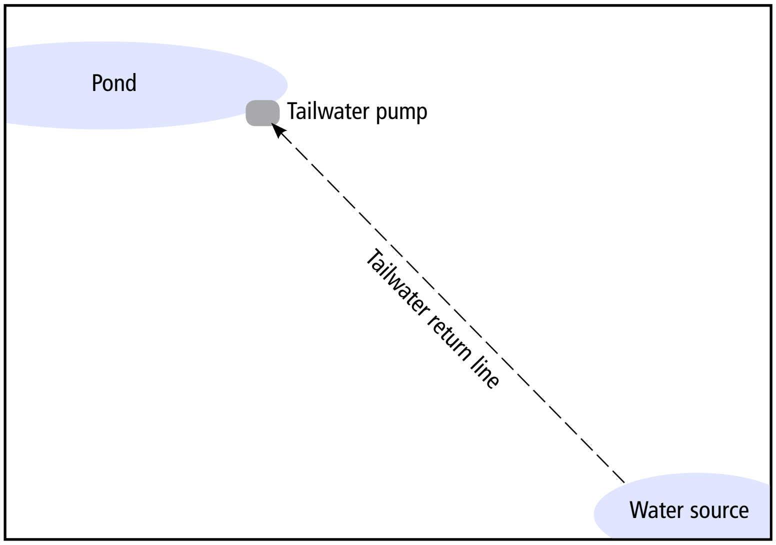

Figure 8. Sample tailwater return system.

SAMPLE COSTS OF CONSTRUCTING AND OPERATING A TAILWATER RECYCLING POND

Scenario

Tailwater return systems consist of water ditches to collect runoff, drainage ways to convey water to the collection pond, a sump pump and power unit, and a pipeline to conduct water to the point of redistribution (fig. 8). The point of redistribution is often the top of the field being irrigated, but it can be an adjacent field. The following example for a border-irrigated alfalfa field near Tracy, California, outlines common design criteria and costs for tailwater return systems in the area. Table 1 summarizes the results of these examples.

Design Criteria

In the Tracy area, cracking clay soils are typical and require about 15 percent tailwater runoff to maximize uniformity. A water supply of 2,200 gallons per minute operated for 12 hours produces a tailwater volume of 240,000 gallons (2,200 gal/min × 60 min/hr × 12 hr × 0.15 = 240,000 gal). The return flow pump should generally produce a volume of one-third of the irrigation supply flow rate, which would be equal to 733 gallons per minute; however, other considerations such as irrigation set length and pond volume can influence the decision. The size of the pump and the power unit is determined by the pumping rate (in gpm) and the total dynamic head. Most growers prefer to discharge from the pond during daytime irrigation sets, so off-peak power use was not considered.

Alfalfa Field and Irrigation Summary

- Field size: 80 acres, 1,320 feet wide by 2,640 feet long
- Irrigated field: Two fields 1,320 feet by 1,320 feet, each with a drain at bottom of field
- Water source location: Top (north) side of field
- Pond dimensions: 220 feet long, 50 feet wide
- Pond wetted depth: 8 feet
- Pond slope (sides): 2:1
- Pond volume at maximum: 1.8 acre-feet, or about 600,000 gallons; 2.5 sets required to fill pond when 15 percent of onflow is runoff
- Pond location: Bottom (south) side of field
- Pond displacement: 3,000 cubic yards of soil
- Distance from irrigation source to pond: 2,900 feet on the straight-line shortest distance
- Irrigation system: Open ditch with siphons
- Irrigation set: One set of 12 checks; check width = 27 feet, check length = 1,320 feet, for a coverage of 9.8 acres
- Set flow: 2,220 gallons per minute
- Gross irrigation: 6.0 inches
- Trash removal screen on concrete sectional sump

Table 1. Costs to install and operate a tail water return pond

	Specifications			Cost ($)		
	System 1	System 2	System 3	System 1	System 2	System 3
Capital Costs						
Return pond	2,999 cu. yd 605,662 gal	2,999 cu. yd 605,662 gal	2,999 cu. yd 605,662 gal	4,500	4,500	4,500
System flow rate	290 gpm	500 gpm	850 gpm			
Pipeline, 2,900 ft	8″	8″	10″	8,031	8,031	8,031
Pipeline installation				14,500	14,500	14,500
Concrete sump installation				3,000	3,000	3,000
Driver (pump motor specs); check valve installation; butterfly valve installation	5 hp	10 hp	15 hp	5,982	6,726	7,054
Power supply and hookup (pole, service panel, mag starter/panel, auto on/off sensor and control)				2,500	2,500	2,500
Total Capital Costs				$38,513	$39,257	$43,991
Annualized Costs						
Annual repairs/maintenance				98	101	125
Energy				444	515	454
Weed control				200	200	200
Silt removal				200	200	200
Total Yearly Operational Costs				$941	$1,016	$979

- Return flow pipeline: PVC Cl 100 IPS gasketed shortest distance
- Electric motor: three-phase driver
- Pump: single stage turbine
- Electric probe type on/off sensors for pump automation
- Butterfly throttle valve
- Check valve

Operation

- **System 1** allows one set's runoff (240,000 gal) to be collected as a result of the night irrigation set, then discharged during the next day set.
- **System 2** allows for collection of runoff from 2 sets (460,000 gal), then discharged during the third set. This provides for the first set being a day set.
- **System 3** allows the pond to fill to the maximum (600,000 gal), then be discharged over a single set.

Costs

Each of these systems requires a different pump and power unit and different-sized pipe. Initial costs include pond excavation, concrete sump, electric power unit and pump, PVC pipe, valves, and electrical hookup and controls. Installation is included in the initial costs. Annualized costs include hardware costs annualized over the useful life of each component minus salvage value, energy costs, tax, and insurance. The study assumed a three-phase energy Ag 1A cost rate, including the price per kilowatt-hour and all current charges via the PG&E service area, which equaled $0.19/kWh.

REFERENCES

Prichard, T., J. Troiano, J. Marade, F. Guo, and M. Canevari. 2005. Movement of diuron and hexazinone in clay soil and infiltrated pond water. Journal of Environmental Quality 34(6).

USDA Natural Resources Conservation Service. 2006. National conservation practice standard, Irrigation system, Tailwater recovery. Standard 447-1. NRCS Web site, http://efotg.nrcs.usda.gov/references/public/NM/447.pdf.

Westland Water District. 2001. Water management handbook, Tailwater Reuse Systems.

METRIC CONVERSIONS

English	Conversion factor for English to Metric	Conversion factor for Metric to English	Metric
foot (ft)	0.3048	3.28	meter (m)
cubic foot (ft^3)	28.317	0.353	liter (l)
cubic yard (yd^3)	0.765	1.307	cubic meter (m^3)
acre (ac)	0.4047	2.471	hectare (ha)
acre-foot (ac-ft)	1,233	0.000811	cubic meter (m^3)
gallon (gal)	3.785	0.264	liter (l)

FOR FURTHER INFORMATION

Storing Runoff from Winter Rains (ANR Publication 8211), 2007.

Understanding Your Orchard's Water Requirements (ANR Publication 8212), 2007.

Measuring Irrigation Flows in a Pipeline (ANR Publication 8213), 2007.

Causes and Management of Runoff from Surface Irrigation in Orchards (ANR Publication 8214), 2007.

Managing Existing Sprinkler Irrigation Systems (ANR Publication 8215), 2007.

Soil Intake Rates and Sprinkler Application Rates in Sprinkler-Irrigated Orchards (ANR Publication 8216), 2007.

To order or obtain printed ANR publications and other products, visit the ANR Communication Services online catalog at http://anrcatalog.ucdavis.edu. You can also place orders by mail, phone, or FAX, or request a printed catalog of our products from:

University of California
Agriculture and Natural Resources
Communication Services
6701 San Pablo Avenue, 2nd Floor
Oakland, California 94608-1239
Telephone: (800) 994-8849 or (510) 642-2431
FAX: (510) 643-5470
E-mail inquiries: danrcs@ucdavis.edu

An electronic version of this publication is available on the ANR Communication Services Web site at http://anrcatalog.ucdavis.edu.

Publication 8225

ISBN-13: 978-1-60107-445-4
ISBN-10: 1-60107-445-X

UC PEER REVIEWED

This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Land, Air, and Water Sciences.

pr-2/07-SB/RW