Best Management Practices to Protect Water Quality

A Guide for California Strawberry Growers

Maren J. Mochizuki, Lea Corkidi, Oleg Daugovish, Julie P. Newman, Donald J. Merhaut, Darren L. Haver
California strawberry growers employ numerous practices to protect water quality such as releasing the biological control agent *Persimilis*, thereby reducing pesticide use, and using drip irrigation after plant establishment, thereby reducing water use and runoff. *Best Management Practices to Protect Water Quality – A Guide for California Strawberry Growers* was developed to illustrate relatively low-cost practices that have been successfully employed on some farms but are mostly not yet utilized industry-wide. Our goal is to encourage widespread adoption of cost-effective management practices that minimize pollutants in creeks, rivers, and the ocean.

Authors
Maren J. Mochizuki
Lea Corkidi, Ph.D.
Oleg Daugovish, Ph.D.
Julie P. Newman
Donald J. Merhaut, Ph.D.
Darren L. Haver, Ph.D.

The authors thank José F. De Soto, Héctor Gutiérrez, Sonya Webb, Andrew Wiemers, and Dale Zurawski for their review.

Funding for this project was provided by the UC Hansen Agricultural Center and was procured in conjunction with grant partners John Krist (Ventura County Farm Bureau) and Marty Melvin (Ventura County Resource Conservation District).

Special thanks to Scott Osborne and Matthew Kreiger for design expertise, to Jill Pittsford for adaptation of the watershed drawing, to Toan Khoung for technical assistance, and to Cris Johnson for administrative support.

Spanish translation by Lea Corkidi.

Image credit belongs to:
Dawn Afman, Mark Bolda, Mike Cahn, Jack Kelly Clark*, Lea Corkidi, Oleg Daugovish, José F. De Soto, Amy Ellis*, Emmanuel González-Hinojosa, Darren Haver, Chris Martin, Maren Mochizuki, Lora Morandin, Mike Poe*, Cheryl Reynolds*, David Rosen*, and Sonya Webb.

Photographs included herein are for the express purpose of demonstrating proper best management practices. Photographs depicting improper practices were staged and no implication should be made that an operation is not in compliance with regulations.

Cover photo: These intentionally-planted flowering buffers maintain the integrity of the ends of each strawberry bed, reducing sediment movement via water and wind. The buffer minimizes dust damage to the crop and reduces movement of pests such as spider mites. Flowering plantings may also attract beneficial insects.

*Courtesy UC Statewide IPM Program
The University of California Division of Agriculture & Natural Resources (ANR) prohibits discrimination against or harassment of any person in any of its programs or activities on the basis of race, color, national origin, religion, sex, gender identity, pregnancy (which includes pregnancy, childbirth, and medical conditions related to pregnancy or childbirth), physical or mental disability, medical condition (cancer-related or genetic characteristics), genetic information (including family medical history), ancestry, marital status, age, sexual orientation, citizenship, or service in the uniformed services (as defined by the Uniformed Services Employment and Reemployment Rights Act of 1994: service in the uniformed services includes membership, application for membership, performance of service, application for service, or obligation for service in the uniformed services).

University policy also prohibits retaliation against any employee or person in any of its programs or activities for bringing a complaint of discrimination or harassment pursuant to this policy. This policy also prohibits retaliation against a person who assists someone with a complaint of discrimination or harassment, or participates in any manner in an investigation or resolution of a complaint of discrimination or harassment. Retaliation includes threats, intimidation, reprisals, and/or adverse actions related to employment or to any of its programs or activities.

The University is an affirmative action/equal opportunity employer. The University undertakes affirmative action to assure equal employment opportunity for minorities and women, for persons with disabilities, and for covered veterans (including veterans with disabilities, recently separated veterans, Vietnam era veterans, veterans who served on active duty in the U.S. Military, Ground, Naval or Air Service during a war or in a campaign or expedition for which a campaign badge has been authorized, or Armed Forces service medal veterans). University policy is intended to be consistent with the provisions of applicable State and Federal laws.

Inquiries regarding the University’s equal employment opportunity policies may be directed to Linda Marie Manton, Affirmative Action Contact, University of California, Davis, Agriculture and Natural Resources, One Shields Avenue, Davis, CA 95616, (530) 752-0495.
Table of Contents

Water Quality and Potential Agricultural Pollutants ................................................................. 4

Which management practices will be most effective to protect water quality? ...................... 6

Best Management Practices to Protect Water Quality

Soil Management ......................................................................................................................... 8
Irrigation Management ................................................................................................................ 10
Fertilizer Management .................................................................................................................. 12
Pest Management ....................................................................................................................... 14
Fertilizer and Pesticide Storage ................................................................................................... 16
Non-production and Maintenance Areas .................................................................................. 18
Roads and Parking Areas ......................................................................................................... 20

Acronyms and Glossary .............................................................................................................. 22

Additional Resources ............................................................................................................... 24

References .................................................................................................................................. 25

Best Management Practices Record-Keeping ............................................................................. 26
Agricultural pollutants have contributed to impaired water quality in California.

Runoff, leaching, drift, evaporation and wind erosion are some ways that pollutants move from agricultural areas in a watershed.

Over 9,000 miles of rivers and streams and over 500,000 acres of lakes and reservoirs in California are considered impaired by levels of nutrients, pesticides, sediment, trash, metals, salts and pathogens that exceed established thresholds (SWRCB, 2012a).

- High concentrations of nitrate in drinking water pose human health risks.
- Excess nitrogen and phosphorus in surface waters stimulate growth of aquatic plants and algae.
- Excess pesticides contaminate food and water sources for fish, wildlife, and humans.
- Excess sediment causes flooding and turbidity, degrading habitat and recreation.
Some strawberry production practices may contribute to water quality impairments:

- Bare soil during tillage and formation of planting beds is susceptible to wind erosion.
- Overhead irrigation over plastic mulch during plant establishment may carry pollutants with water.
- Nutrient and water uptake is limited by the shallow root system of the crop.
- Pollutants may enter the environment through improper amount, placement or timing of fertilizers, pesticides or irrigation; improper storage of fertilizers and pesticides; and improper equipment calibration and maintenance.

Implementation of best management practices adapted to local conditions can prevent or reduce pollutant discharges.
Which management practices will be most effective to protect water quality?

Answer three key questions to determine whether a management practice is right for your operation.

1. **What materials in my operation have the potential to become pollutants?**
   - Nitrogen or other nutrients
   - Pesticides in current use
   - Legacy pesticides (materials no longer in use that persist in the environment) adhered to soil
   - Salts
   - Trash
   - Fuel

2. **Which water bodies are potentially at risk and where are they located relative to my operation?**
   Identify type (creek, river, lake, groundwater) and proximity.

3. **What are my regulatory obligations?**
   - Identify which Regional Water Quality Control Board (RWQCB)* regulates your location(s).
   - Review the appropriate RWQCB Basin plan(s)*.
   - Familiarize yourself with the Total Maximum Daily Loads (TMDLs)* adopted in your area.
   - Identify and join a Conditional Waiver discharger group*, if available.

*Refer to the Acronyms and Glossary (pages 22-23) for more information.
Which management practices will be most effective to protect water quality?

Use your answers to guide management practice decisions and implementation of new practices.

**Example:** Your operation is 50 acres of organic berries on land that was previously orchard.

1. **What materials in my operation have the potential to become pollutants?**
   - Nutrients: Compost applied prior to creating planting beds and liquid fish fertilizer
   - Legacy pesticides adhered to soil
   - Sediment
   - Salts
   - Trash
   - Fuel

2. **Which water bodies are potentially at risk and where are they located relative to my operation?**
   The property is adjacent to a creek that drains to a river.

3. **What are my regulatory obligations?**
   The RWQCB has established nitrogen and legacy pesticide TMDLs for the river in your region.

Precise irrigation (page 10) and nutrient management (page 12) to prevent leaching and sediment movement may be the most cost-effective management practices with the greatest impact on water quality for this example operation.
Vegetative buffers are intentionally-planted areas that can filter any excess nutrients and pesticides and intercept sediment from water runoff.

- Know your soil series and erosion hazard potential (see Additional Resources, p. 24).

- Develop a soil conservation plan in consultation with USDA-NRCS or other local agency (see Acronyms and Glossary, p. 23).

- Install vegetative buffers, straw wattles or other means of reducing sediment movement from the production area.

The USDA-NRCS Web Soil Survey provides access to maps and detailed soil descriptions for any area of interest in the U.S.

This grassed buffer reduces movement of pests such as spider mites.
Soil Management

- Install permanent hedgerows, windbreaks or other means of reducing off-site sediment movement.

- After production, plant subsequent cash or cover crops.

Wind, irrigation and storm runoff may transport sediment, nutrients and pesticides from bare fields.

Potential pollutants with TMDLs:
- Nitrogen, pesticides
Irrigation Management

- Use crop rooting depth, soil texture and an estimate of the available water content of your soil or a calculated crop coefficient (if available) to determine how much water to apply.

- Use soil moisture-sensing equipment installed at the level of the crop root zone or track evapotranspiration values (ETo) from local weather stations to determine when to water (soil water depletion).

- Annually test the distribution uniformity of your irrigation system by monitoring water delivery and pressure differences within a block.

- Perform regular maintenance on your irrigation system to maintain distribution uniformity and prevent runoff from leaks and clogged lines.
Irrigation Management

- Use drip irrigation as early as possible in the production cycle.
- Inject liquid emulsified formulations of polyacrylamide to reduce sediment movement with surface runoff.

Reduce or even eliminate the use of overhead sprinklers to establish transplants: test a small area using one line of drip tape for each plant row, and actively monitor salinity in the transplant root zone using a handheld probe.

Reserve overhead sprinklers to leach salts from the transplant root zone (in absence of rain) or for frost protection.

Runoff from untreated sprinkler irrigation (left) compared to 5 ppm polyacrylamide treatment (right). Suspended sediment in treated runoff was reduced by more than 90% (Cahn, 2010).

Sediment, nutrients and pesticides move with irrigation and storm runoff during windy conditions, when spraying unpaved roads or when backfill for irrigation trenches is not compacted.

Potential pollutants with TMDLs: Nitrogen, pesticides, salts
Conduct soil tests to determine if pre-plant or early-season fertilizer is needed.

Apply the minimum amount of fertilizer based on test results from soil or plant tissue.

Consider nitrate present in irrigation water when calculating fertilizer application (see Additional Resources, p. 24).

If fertigating, inject fertilizer toward the end of the irrigation run.

Inspect backflow prevention devices annually.
Fertilizer Management

Seasonal nitrogen uptake for strawberry at Watsonville and Santa Maria, California (Bolda, 2012)²

<table>
<thead>
<tr>
<th>Total uptake during early growth (planting-March)</th>
<th>Average daily uptake during active growth (April-August)</th>
<th>Total nitrogen uptake for the season²</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 lb/A</td>
<td>1 lb/day</td>
<td>180-220 lb/A</td>
</tr>
</tbody>
</table>

² Growing conditions in Oxnard and Irvine promote active growth and nutrient uptake earlier in the season compared to Watsonville and Santa Maria. There is likely less nutrient uptake overall in southern California, however, because the growing season is typically shorter than in northern California.

³ Seasonal uptake for phosphorus (P₂O₅) and potassium (K₂O) in northern California is 90-110 lb/A and 270-330 lb/A, respectively.

- Time fertilizer application to maximize plant uptake. Consider how plant growth and development is affected by length of season, plant variety, transplant chill hours, weather at the production site, mulch (black vs. clear), and the use of tunnels.

- Maintain fertilizer use records.

Fertilizer applied prior to the active growth stage of the plant may be leached with irrigation or storm water.

Potential pollutants with TMDLs:
Nitrogen, salts, trash
When selecting plant varieties, use available guides on variety disease resistance or tolerance (see Additional Resources, p. 24) as well as disease and vector history in your field to reduce pesticide use.

Apply pesticides only when justified by pest population and crop damage thresholds.

Choose pesticides that are most selective for the target species (see Additional Resources, p. 24).

Use databases such as UC IPM WaterTox to evaluate the water quality risk of applying a specific pesticide (see Additional Resources, p. 24).
Use the lowest effective application rate according to the product label and the most current recommendations from UC, local agencies, and industry.

If using chlorpyrifos or other water-soluble organophosphate pesticides, consider applying a commercial enzyme product (e.g., Landgard™) to runoff capture ditches to hasten pesticide degradation.

Maintain pesticide use records.

Pesticides may move with wind, storm or irrigation runoff or when applicator nozzles are not closed during turns.

Potential pollutants with TMDLs:
Pesticides, salts, trash
Accurate measurements ensure the labeled rate is applied and may reduce or eliminate any excess requiring disposal.

- Accurately measure all fertilizers and pesticides and calibrate application equipment.
- Mix and load fertilizers and pesticides on an impermeable surface (e.g., concrete floor) or in an area with low potential for runoff.
- Store fertilizer and pesticide application equipment in a covered or enclosed location.
- Store fertilizers and pesticides in a structure that complies with local, state and federal guidelines and is located at least 100 ft. downslope from water sources.
- Seal any open or torn bags containing granular or powder formulations.

Store fertilizers and pesticides atop an impermeable surface with secondary containment.

Pesticide storage must be labeled and should be kept locked.
Clean any spills immediately according to a pre-determined protocol and dispose of material as required by law.

- Provide cleanup materials for liquid and granular spills in a readily-accessible location.

- Enclose open containers of liquid formulations in a tray, sealed plastic bags, or other form of secondary containment.

- Use covered disposal containers for empty fertilizer and pesticide containers.

- Contact your local Agricultural Commissioner's Office for a list of approved disposal sites (see Additional Resources p. 24).

Improper disposal of empty bags in a full or uncovered dumpster may lead to off-site movement.

Potential pollutants with TMDLs: Nitrogen, pesticides, salts, trash
Non-production and Maintenance Areas

- Use permanent hedgerows, straw wattles or other runoff capture devices around property perimeter and especially adjacent to critical locations such as drainage areas, creeks or paved streets.

- Surround maintenance areas with landscape, vegetative buffers or gravel.

- Minimize use of fertilizers and pesticides in landscaped areas.

- Apply polyacrylamide to runoff capture ditches prior to storm events.

- Inspect culverts, roadside ditches, waterbreaks and outlets, cleaning them after major rain events.
Non-production and Maintenance Areas

- Use tight-fitting lids on all dumpsters and trash cans and secure them upright.

- Store equipment and spare parts under tarps or other cover.

- Place fuel tanks at least 100 ft. downslope from water sources.

- Assess the potential for spills (fuel, vehicle fluids, cleaning products) and provide cleanup materials in a readily-accessible location.

Covered dumpsters and trash cans prevent off-site movement of trash.

Provide secondary containment for fuel tanks.

Trash may move off-site via roadside ditches, especially during and after storms.

Potential pollutants with TMDLs: Nitrogen, pesticides, salts, trash
Roads and Parking Areas

- Grade roads to direct runoff to ditches, vegetated areas or a sediment trap. If crops are grown immediately adjacent to roads, direct runoff toward the center line of the road.

- On roads with gradients exceeding 8% slope, create and regularly maintain waterbreaks (waterbars).
Roads and Parking Areas

- Apply mulch to moderately-used, unpaved road surfaces and other bare soil traffic areas prior to winter rains or seed with annual or perennial grasses and mulch until grass is established.

- Use corrugated steel plates, shaker plates, or other devices to keep sediment and gravel on the property, especially in high-traffic areas such as entrances and exits.

Mulched or seeded roads reduce sediment movement and may increase water infiltration.

A grid of rubber rings helps stabilize gravel in this parking area.

Without stabilization measures, gravel can move with irrigation or storm runoff, carrying sediment and adsorbed nutrients and pesticides.

Potential pollutants with TMDLs:
- Trash
Acronyms and Glossary

**Basin Plan**  a “master planning document” and “regulatory tool” for each RWQCB that includes water quality objectives, implementation programs to achieve the objectives, time schedules for actions and determination of compliance (SWRCB, 2012b). Visit your RWQCB website (see RWQCB, below) to view its Basin Plan.

**BMP**  best management practice, an on-farm procedure or method based on scientific research or testing and adapted to local site conditions that achieves the objectives of productivity, profitability and an additional goal such as minimization of pollutant movement off-site.

**Conditional waiver** or **Ag waiver**  shortened name for a regulatory program requiring owners and operators of irrigated land used for commercial crop production to measure and control discharges from their property, instead of applying for a waste water discharge permit (full name: Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands).

**Discharge group**  a membership-based collective of agricultural landowners and growers created to comply with the conditional waiver; e.g., VCAILG (Ventura County Agricultural Irrigated Lands Group).

**Distribution uniformity**  (abbreviated DU) the degree to which irrigation water is evenly applied to a field, expressed as a percentage. Higher DU values indicate more uniform application of water; ideal system performance is greater than 80%. Irrigation evaluations to determine DU can be conducted by RCDs (see RCD below).

**Evapotranspiration, reference**  (abbreviated \( \text{ET}_o \) for grass grown in standardized conditions) the loss of water to the atmosphere via evaporation from soil and plant surfaces and transpiration from plant tissues, expressed in inches or millimeters, and available from weather station data. Higher \( \text{ET}_o \) values indicate greater water loss. Cumulative \( \text{ET}_o \) may be used to schedule irrigations (http://wwwcimis.water.ca.gov/).

**IPM**  integrated pest management, an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of control strategies.
Leaching  process in which soluble substances dissolved in water (such as nutrients from fertilizer), percolate from the upper soil horizon to lower soil layers and, in some cases, to groundwater.

Pollutant  discharged contaminant for which a TMDL has been established by the RWQCB.

RCD  Resource Conservation District, non-regulatory, locally-led, not-for-profit organization established under Division 9 of the California Public Resources Code to collaborate with landowners, government agencies and other willing partners to facilitate the conservation and restoration of natural resources. Find your RCD: http://carcd.org/rcd_directory0/aspx

Runoff  Water movement along the soil or ground surface. Runoff that carries sediment and other pollutants may contaminate surface waters.

RWQCB  Regional Water Quality Control Board, develops and enforces water quality objectives and implementation plans to protect state waters (SWRCB, 2012c). Find your RWQCB: http://www.waterboards.ca.gov/waterboards_map.shtml

Sediment trap  a containment area where runoff is temporarily held, allowing sediment to settle before runoff is discharged. (http://www.cabmphandbooks.com/Documents/Construction/SE-3.pdf)

TMDL  total maximum daily load, the qualitative amount of a pollutant a water body can tolerate on a daily basis within established water quality benchmarks (SWRCB, 2012d).

UC  University of California, a public institution providing education, research and extension.

USDA-NRCS  United States Department of Agriculture-Natural Resource Conservation Service, a federal agency with county-based service centers that provide conservation planning and assistance to private landowners. Find your service center: http://www.nrcs.usda.gov/

Waste Discharge Requirements Program  program regulating point-source discharges that are exempt from California solid waste regulations and are not subject to the Federal Water Pollution Control Act. This program includes the Conditional Waiver of Waste Discharge Requirements (see Conditional waiver, above).
Additional Resources

**Soil** (page 8)
Web soil survey for location-specific soil types, erosion potential, etc.:

**Irrigation** (page 10)
Estimating soil moisture by feel and appearance:
(at the bottom of the page, a pdf can be downloaded and printed to take to the field).

Using tensiometers for strawberries (sandy and sandy loam soils):
See also Integrated Pest Management for Strawberries (Strand, 2008) Table 6, p.22.

**Fertilizer** (page 12)
Using the nitrate present in soil and water in your fertilizer calculations:
http://www.valleywater.org/programs/agriculture.aspx (see additional resources on right side of page).

**Pest management** (page 14)
Characteristics of common strawberry cultivars, including susceptibility to pests and disorders:
http://ucipm.ucdavis.edu/PMG/r734900111.html

UC Cooperative Extension weed susceptibility database:
http://info.ucanr.org/weed_sept/

UC IPM WaterTox:
http://ucipm.ucdavis.edu/TOX/

**Fertilizer and pesticide storage** (page 16)
County Agricultural Commissioner contact information:
http://www.cdfa.ca.gov/exec/county/countymap/

**UC Farm water quality planning**
http://anrcatalog.ucdavis.edu/FarmWaterQualityPlanning/
References

http://cesantacruz.ucdavis.edu/Strawberry_Nursery_Plan_Production/Presentations_from_the_2012_Annual_Central_Coast_Strawberry_Meeting/


http://ucanr.org/repository/cao/landingpage.cfm?article=ca.v065n04p197&fulltext=yes

SWRCB, 2012a. Irrigated Lands program and information on Section 303(d) list.
http://www.waterboards.ca.gov/water_issues/programs/agriculture/docs/about_agwaivers.pdf

SWRCB, 2012b. Basin Plan (Region 4).
http://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan


SWRCB, 2012d. TMDL program.
http://www.waterboards.ca.gov/water_issues/programs/tmdl/background.shtml

<table>
<thead>
<tr>
<th>BMP</th>
<th>Installation Date</th>
<th>Notes/Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pest Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer and Pesticide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preparation and Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance and Non-production Areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roads and Parking Areas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>