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Farm Water Quality Planning

A Water Quality and Technical Assistance Program for California Agriculture

This Reference Sheet is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.

UC PEER REVIEWED

Reference:

Nonpoint Sources of Pollution in Irrigated Agriculture

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WHAT IS POLLUTION?

By legal definition, *pollution* is an alteration of the quality of the State waters by contaminants to a degree that unreasonably affects their beneficial uses or facilities that serve their beneficial uses (see box, *Beneficial Use of Water*). Sewage, sewage sludge, garbage, solid waste, chemical wastes, biological materials, radioactive materials, heat, soil, and agricultural waste all can be pollutants of water. In the Federal Clean Water Act, pollution is categorized by its source as *point* or *nonpoint*.

Point source pollution is an observable, specific, and confined discharge of pollutants into a surface or underground water body. Examples include surface water discharges from feedlots, food processing plants, and agrichemical processing plants, and groundwater contamination from chemical spills.

In contrast, *nonpoint source pollution* (NPS) is defined as diffuse discharges of pollutants throughout the natural environment. It occurs over extensive areas. As water from rainfall, snowmelt, irrigation, or human activities moves over and through the ground it can pick up and carry away natural and synthetic pollutants, eventually depositing them into lakes, rivers, wetlands, coastal waters, and underground sources of drinking water. Agricultural storm water discharges and return flows from irrigated agriculture are included as nonpoint sources even though they may have a single point of discharge. Other examples of nonpoint source pollution are sediment loading in streams, phosphorus pollution of lakes from seepage of lakeshore septic tanks, and nitrate pollution of groundwater from feedlots or from fertilizer applications to fields. Nonpoint source pollution is generally associated with agriculture, forestry, mining, construction, and urban storm water runoff.

BENEFICIAL USE OF WATER

California's State Regional Water Quality Control Board lists 23 beneficial uses of water. Among these are the use of water for the following purposes: domestic (homes, motels, human consumption, etc.), irrigation (crops, lawns), power (hydroelectric), municipal (water supply of a city or town), mining (hydraulic mining, drilling), industrial (commerce, trade, industry), fish and wildlife preservation, aquaculture (raising fish, etc. for commercial purposes), recreational (boating, swimming), stock watering (for commercial livestock), maintaining water quality, frost protection (misting or spraying crops to prevent frost damage), heat control (watering crops to prevent heat damage), groundwater recharge, and agriculture.

NPS FROM IRRIGATED AGRICULTURE

Irrigated agriculture is a significant source of surface water and groundwater NPS pollution in California (see box, *Water Quality*). In a 1994 report to the State Water Quality Control Board, the Irrigated Agriculture Technical Advisory Committee noted the following potential sources of NPS pollution associated with irrigated agriculture:

- sediment (surface water quality impacts only)
- nutrients
- pesticides
- salinity
- trace elements
- pathogens
- temperature (surface water quality impacts only)

Activities that can cause NPS pollution from irrigated agriculture are new land development, cultural practices for production, pest management strategies, and irrigation practices.

SEDIMENT

Soil erosion and sediment deposition are primary causes of adverse impacts to surface water quality. Erosion is a natural process that can be accelerated by human activities. Slopes erode naturally, especially when vegetation is artificially removed. Sediment deposition occurs when the amount of sediment (solid material that has been transported from its site of origin by air, water, or gravity) exceeds the carrying capacity of the force that is moving it. Farmlands generally become a nonpoint source of pollution when farm operations remove a substantial amount of the vegetative cover, exposing the soil surface to the erosive action of water and wind. Eroded soil subsequently becomes sediment, creating the potential for water degradation.

Sources of erosion sediment may be classified as *upland* (*sheet* and *rill*) or *gully*. In areas with steep slopes, highly erodible soils, and intense stormy weather, sediment delivery from farmlands can be relatively high.

WATER QUALITY

California surface water quality. Four water quality problems—siltation, metals, nutrients, and bacteria—impair the most river miles in California. The leading sources of degradation in California's rivers and streams are agriculture, unspecified nonpoint sources, forestry activities, urban runoff and storm sewers, and municipal point sources. In lakes, the most common pollutants are siltation, metals, and nutrients. Hydrologic/habitat modifications pose the greatest threat to lake water quality, followed by urban runoff/storm sewers, construction/land development, and atmospheric deposition.

Groundwater quality. Salinity, total dissolved solids, and chlorides are the most frequently identified pollutants impairing the use of groundwater in California, followed by nutrients and pesticides. Leading sources are disposal of *septage* (residual wastes and water removed from septic tanks during maintenance), agriculture, and dairies. The State of California also reports that trace inorganic elements, flow alterations, and nitrates cause the continuing degradation of over 1,000 square miles of groundwater aquifers.

Source: EPA/SWRCB Water Quality Summary for California; http://www.epa.gov/owow/305b/96report/ca.pdf

Roads and other areas of disturbed ground can be major contributors to sedimentation of streams and lakes. Roads located alongside streams, where muddy runoff from the road is discharged directly into the stream, are especially important. Roads within farming areas, however, often have the greatest degree of rill and gully erosion. Streambank erosion may be another farm-related sediment source where riparian areas are susceptible to damage from high flow rates.

As one example of the significance of erosion, previous studies of hillside vineyards in Napa and Sonoma Counties conducted by the USDA Natural Resource Conservation Service (NRCS) estimated that soil losses from these vineyards were up to 350 tons per acre per year, and averaged 50 tons per acre per year (USDA, 1985). The highest rates of soil erosion generally occurred during the first few years of vineyard development. The vulnerability of many Central Coast vineyard soils to erosion makes it all the more important that growers identify and implement appropriate land management practices that will prevent and mitigate sediment movement. These issues are similar to the potential water quality impacts identified by rangeland producers, generally those associated with stormflow events.

NUTRIENTS

The leaching of nutrients from watersheds into streams, lakes, and groundwater is a natural part of nutrient cycling. When growers manipulate the soil-water-plant system to increase agricultural production, they can change the natural balance of nutrient cycling. Nutrient sources associated with agricultural production practices include fertilizers, biodegradation of crop residues, agricultural and municipal wastes applied to land, and waste generated directly by animals. Nutrients from these sources become pollutants when they are transported off site into nearby streams and lakes or when they percolate in excessive amounts to groundwater.

Nutrients, whether dissolved or attached to soil particles, are transported by water. Soluble forms of nutrients leave their source sites by dissolving in water and traveling in solution with the runoff water or percolating soil water. Other forms of the nutrients that are attached to the soil, such as organic material, must be detached by erosion (surface water pollution only) before they can be transported.

Nutrients are transported to groundwater by deep percolation of irrigation and rainfall waters. Deep percolation occurs when the amount of water infiltrating and percolating through the soil exceeds the soil's water-holding capacity together with the uptake of water by plant and crop roots.

The two most significant nutrients affecting water quality are nitrogen (in the form of nitrate) and phosphorus (as phosphate). Nitrate and phosphate loading in surface water bodies contributes to a nutrient-rich environment, a condition called *eutrophication*. This process of increasing nutrients leads to increases in aquatic plants and algal blooms, which in turn deplete dissolved oxygen and so affects aquatic organisms. Nitrate pollution of groundwater is widespread and is a serious problem throughout California because of its impact on drinking water for humans and livestock. Between 10 and 15 percent of California's water supply wells exceed nitrate standards for drinking water. In contrast, pesticides and industrial pollutants are found in much fewer than 1 percent of California's wells. Expensive treatment (costing about $700 per acre-foot), dilution with high-quality water, abandonment of wells, or deepening of wells is required if high-nitrate or high-salt water is to be used in a public drinking water supply. Many domestic well users buy bottled water (in relatively small quantities but at a cost equivalent to $200,000 to $500,000 per acre-foot) for actual drinking water use.

PESTICIDES

Pesticides (insecticides, miticides, herbicides, fungicides, and nematicides) that move from their site of application into surface or groundwater can affect the postapplication usefulness of water through their potential to impact organisms other than their primary targets. The presence and bio-availability of pesticides in soil can adversely impact human and animal health, beneficial plants and soil organisms, and aquatic vegetation and animals.

For example, herbicides can damage and destroy vegetation when they enter the aquatic system. Since this vegetation is cover and food for aquatic organisms, herbicides can affect an entire community. Dissolved oxygen levels that support aquatic life are sometimes reduced because of decaying plants killed by the herbicides.

Ideally, a pesticide will stay in the treated area long enough to produce the desired effect and will then degrade into harmless materials. Four major processes affect the environmental fate of pesticides and therefore the risk of NPS pollution:

- *Retention*—the ability of the pesticide to stick (adsorb) to soil particles rather than leach away with soil water
- The *leaching rate* of water in the soil
- The ability of the pesticide to *degrade* over time
- The pesticide's potential for *volatilization* into the atmosphere

There are three main modes of degradation in soils: biological degradation (by means of microorganisms), chemical breakdown (by means of chemical reactions such as hydrolysis and redox reactions), and photochemical breakdown (by means of ultraviolet or visible light).

Pesticide retention in the soil is the soil's ability to hold a pesticide in place and prevent it from being transported off site or to groundwater. *Adsorption*—the accumulation and adhesion of a pesticide onto the surface of soil particles—is the primary means by which a soil retains a pesticide. Pesticide adsorption to soil particles depends on the chemical properties of the pesticide (i.e., its water solubility and polarity) and the soil properties (i.e., organic matter and clay content, pH surface charge characteristics, and permeability). For most pesticides, organic matter is the most important soil property determining the degree of adsorption.

Pesticides, like nutrients, may be transported by water depending on their retention properties. Wind erosion or drift from pesticide applications may also contribute to the movement of pesticides away from their target area. Pesticides may enter surface waters in irrigation return flows and tile drainage either dissolved in the water or adsorbed to waterborne sediments. Groundwaters in agricultural areas may also be subject to pollution from pesticides when deep percolation from irrigated land carries water-soluble pesticides to the groundwater.

SALINITY

Irrigation water is essential for crop production in the arid and semiarid regions of California. Irrigation water naturally contains a certain amount of dissolved minerals (salts). The amount of salt in the water depends on its source: Rivers flowing from the Sierra Nevada are generally very low in salts (the granitic and gneissic rocks of the Sierra Nevada leach very few minerals). Groundwater leaching through alluvial sediments derived from marine sedimentary rocks, which often occur along California's coast range, collects many minerals. Irrigation waters pumped from such aquifers have much higher salt content.

When irrigation water, regardless of its salt content, is applied to crops, the salts accumulate in the soil while the applied irrigation water is consumed by plants or lost to evaporation. To maintain the productivity of irrigated lands, accumulated salts must be leached below the root zone. For this reason, irrigation is always scheduled to exceed the anticipated crop consumption. The leached salts may permeate groundwater aquifers or migrate with groundwater flows into other water bodies. In some places, such as the west side of the San Joaquin Valley, irrigation may also leach naturally occurring salts in the soil profile into tile drains or groundwater.

In some coastal areas, increased groundwater pumping has resulted in salt water intrusion from the ocean, threatening the overall groundwater quality. In addition, in areas such as the Salinas Basin high salt levels in irrigation return flow have degraded the quality of surface water in ponds and sloughs.

TRACE ELEMENTS

The discovery of a connection between embryonic deformities and deaths of aquatic birds and the accumulation of a trace element (selenium) at Kesterson Reservoir in 1983 significantly altered public perception of the pollution threat of irrigated agriculture. Unlike nutrients and salts, trace elements typically do not originate from agricultural chemical applications. Rather, irrigation mobilizes naturally present trace elements. Trace elements are found at very low concentrations in all waters. Many trace elements are—at a low concentration—essential for human, animal, and plant health. At higher concentrations, however, they may become toxic to organisms. Trace elements may be mobilized in high concentrations along with other salts from marine sediments or soils with a naturally high salt content. They dissolve in percolating drainage water or groundwater and are discharged into wells or drainages, or in seepage into streams and lakes. The principal impact of trace element pollution is its adverse impact on animal life through biomagnification (the concentration of an element as it moves up the food chain) and on the degradation of water quality when used for human consumption.

Trace elements of concern to irrigated agriculture include selenium, molybdenum, arsenic, vanadium, and boron. The water quality control requirements for trace elements are stringent and water quality objectives are usually prescribed in parts per billion. Because of its ability to impact beneficial uses of water at very low levels, the control of trace elements is complex and difficult. Trace element pollution must be examined on a case-by-case basis.

PATHOGENS

Pathogens are microorganisms and parasites that can cause illness in humans and in animals. A small subset of all pathogens, the *zoonotic pathogens*, are shed in the feces of livestock and many wildlife species and can infect other animals as well as humans. These include *Salmonella*, *Giardia*, and *Cryptosporidium parvum*, and are the pathogens that cause concern with regard to food safety and water quality. The potential for pollution of surface waters increases when flows resulting from irrigation or rainfall come from land that has received untreated human or animal waste or when irrigation water contains animal manure. Localized contamination of surface water, groundwater, and the soil itself can result from animals in feedlots, corrals, exercise yards, pastures, and rangelands. Other nonpoint sources of pathogens include wildlife and septic tanks.

Regulatory agencies generally rely on tests for fecal coliform bacteria to indicate pollution in streams and in shallow groundwater. Although fecal coliforms themselves are not pathogenic, they indicate that pathogens could exist and possibly flourish. Ratios of fecal coliform to fecal streptococci concentrations may be used to distinguish human from animal waste pollution.

The extent and concentration of pathogens in surface water depends largely on livestock density, timing and frequency of grazing, and access to streams and lakes. Pollution can occur when the daily rate of fecal deposition exceeds the ability of vegetated buffers, soil, and solar radiation (sunshine) to either filter out or inactivate the pathogenic microorganisms. Fecal coliform levels tend to increase as the intensity of livestock use increases. Maintaining the health of livestock is critical, as is proper management of the herd, its byproducts, and exposed land areas.

The occurrence of pathogens in groundwater depends on manure application rates, the amount of rainfall and irrigation, the efficiency and uniformity of irrigation, the depth of groundwater, and the type of soil and aquifer. Shallow groundwater is very vulnerable to pathogen contamination. High levels of pathogens are particularly common in well-drained soils (sands and sandy loams) and where aquifer sediments are predominantly gravelly or sandy or otherwise highly permeable (for example, in volcanic soils and rocks). Where groundwater is deeper underground or shallow groundwater is several hundred feet from the pollution source, many pathogens are filtered out or have died off before the polluted water can reach the groundwater. Groundwater seldom travels laterally more than a couple of feet per day, and researchers have found that most pathogens die off within a few months. Only in very sandy to gravelly, shallow aquifers, can pathogens travel a considerable distance, particularly those pathogens such as *Cryptosporidium parvum* that survive groundwater travel over extended periods of time.

TEMPERATURE

Thermal pollution of surface waters has three basic sources that relate to farmlands:

- Development and subsequent cultural operations in irrigated agriculture can result in the loss of streamside vegetation that shades streams and helps to maintain the cool water temperatures required by many cold water fishes, especially trout, salmon, and steelhead.
- Drainage of irrigation water that has warmed while crossing a farm field can raise the temperature of a cold water stream.
- Streamwater diversions for irrigation and wetland management can lower overall stream flows.

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