

# Hillslope Farming Runoff Management Practices Guide



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Compiled by  
Resource Conservation District of Monterey County  
and  
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Kathleen Robins of the Central Coast Agricultural Water Quality Coalition designed and laid out this guide. All line drawings are by Paul Robins, and all photographs, except where noted in the document, are courtesy of RCDMC and NRCS.

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# ABOUT THIS GUIDE

The Resource Conservation District of Monterey County developed this guide at the request of the Monterey County Agricultural Commissioner's (MCAC) Office to develop guidance for hillside farmland management practices that may be used to prevent erosion and runoff. The MCAC's Office specifically requested that any guidance focus on non-regulatory options that industry could carry forward independently. To that end, the MCAC's office requested that the RCD assist with this effort given the RCD's expertise relative to soil and water conservation assistance and its non-regulatory nature.



To develop this management practices guide, RCD staff met with Monterey County staff, growers concerned with runoff management, and other ag extension and resource professionals. The Guide mostly compiles pre-existing information about approaches and techniques for managing runoff from hillside farmland in Monterey County, and is intended to be improved upon as scientists and practitioners study and trial their own combinations and variations of these and other methods for best stewarding their land.

*This document is intended to serve as a tool for voluntary, self-implementation of soil and water conservation and should not be misapplied as recommendations for regulatory requirements or mitigation.*

## How to Use this Guide

To properly address runoff, a land manager must be able to anticipate the runoff a field will produce and be knowledgeable about appropriate management techniques. The Guide provides a brief overview of how to approach your land to anticipate runoff, but this is always best done with the assistance of an engineer or hydrologist and, ideally, the seasoned perspective of someone who knows the plot of land under consideration.

Management practices in this guide are organized in three categories:

1. Enhancing rainwater infiltration and holding soil and water in place in the field. For example:
  - Row/furrow arrangement for as little 'slope' as feasible without compromising plant or soil health
  - Furrow, ditch, post row (for hoopouses) and road covercrops and filter strips to increase surface 'roughness' and enhance infiltration
2. Temporary means of safely transporting water out of production areas. For example:
  - Road seeding
  - Ditch armoring with plastic
  - Waterbars to direct flow off roads
  - Surface-run conveyance pipe

3. Permanent structures for managing water and transported sediment at the bottom of the field. For example:
  - Underground outlets with multiple inlets
  - Water and sediment control basins

Generally, these practices increase in cost and complexity as one moves down the field, as accumulating flows and volumes require appropriately scaled management measures. How a land manager determines the best practice to apply is entirely dependent upon the characteristics of the site and farming operation. To ensure their most effective application, a qualified engineer or hydrologist should guide their planning and implementation. RCDMC, NRCS, and private consultants can provide this assistance.

Other associated activities such as crop variety selection, timing of cultural practices, and routine maintenance of existing structures on the ranch or downstream conveyance improvements (in coordination with adjacent property owners and county Public Works) are a necessary complement to these practices but not discussed further in this Guide.

It is critical to acknowledge that growers have to address a variety of factors within and outside of their control that impact their ability to protect their resources. These can include permit delays, internal business issues, and access to equipment. And always, unusual timing and intensity of rainfall tests even the best-laid plans.



# ANTICIPATING RUNOFF AND EROSION

In order to select and design the most effective management methods for controlling runoff and erosion, it is critical to understand the factors that influence those conditions and to have a reliable method to anticipate what runoff a given field or landscape will produce under different conditions. This section provides a brief review and overview of the steps a land manager can take to develop the most appropriate suite of integrated runoff management practices for a given ranch.

## Introduction to Water Erosion (*adapted from McCauley, 'Managing for Soil Erosion'*)

The mechanics of water erosion often involve a two-fold process. Raindrops falling on the soil surface can cause particles to detach and splash upward. Upon returning to the soil, splashed particles disperse and clog soil pores, causing surface crusting and a reduction in the soil's infiltration rate. The pounding action of rain may also compact the soil, further decreasing infiltration. When the precipitation or irrigation rate is larger than the soil's infiltration rate, water will puddle and run off, leading to additional detachment and transport of particles by the force of flowing water.

Water erosion is affected by precipitation patterns, soil properties, slope and vegetative cover. In general, the most severe erosion occurs when rains are of relatively short duration, but high intensity. Heavy raindrop action coupled with more water falling than the soil can infiltrate can lead to high surface runoff and large losses of soil.



Soil properties affecting water erosion include those that influence infiltration and soil stability, such as texture, organic matter, aggregation, soil structure and tillage. Runoff is influenced by the amount and velocity of the flow, which in turn, is dependent on the slope of the land. Because fast moving water can carry more sediment than slow moving water, there is a greater potential to lose a larger amount of material on steep slopes than gradual slopes. Vegetative cover reduces detachment by intercepting raindrops and dissipating their energy. In addition, surface vegetation and residue can slow water flow overland and promote deposition.

## Estimating Peak Runoff Rate

Rainfall will infiltrate initially into the soil. When the rate of rainfall exceeds the rate at which water infiltrates into the soil, the water will fill the surface depressions, pond, and then runoff will occur. The design of channels or structures to handle natural surface flow or runoff should be informed by the determination of peak rates of runoff and runoff volume. The factors affecting runoff may be divided into those associated with precipitation and those associated with the watershed or landscape. Precipitation factors include rainfall duration, intensity, and distribution of rainfall over an area. Watershed factors affecting runoff include size and shape of the watershed, topography, soils, and surface of the watershed area (Schwab et al, 1957)

There are a variety of methods for estimating peak runoff rate at varying levels of sophistication. For the type of small watershed that sloped agricultural fields represent, the most commonly-used tool employed by the USDA on the Central Coast is the ‘Rational Method’, as described later in this guide on page 37. In that article, an example is used to illustrate the different volumes of runoff a land manager might anticipate under different soil cover scenarios. (See also pages 42-46 “Technical Paper: Stormwater Erosion...” for additional examples.)

The challenge for the land manager preparing to convert a field to annual crop production in the examples referenced above is to employ a combination of management practices to keep that peak runoff rate (and its potential to erode soil) as close to the natural level associated with the pre-existing land use (such as pasture) as possible. The summaries of management measures that follow in this Guide are intended to provide an overview and reference information for assisting with that decision process.

**Definition:**

A watershed is defined as the area of land that drains out to a single point. From the perspective of the land manager, that is typically understood as a field or cluster of fields with a common drainage point.



One example of an approach would be to increase the opportunity time for infiltration by slowing the movement of water across the field by arranging furrows for minimum slopes, adding cover crops, and adding grass in the furrows and roads. Because this alone may not mitigate for the runoff increase created by cultivation and/or plastic mulch, other measures such as a water control basin may be needed to detain

water at the bottom of the field so water can be released slowly and sediment captured. Additional practices to protect field roads and ditches may also be needed to prevent erosion and reduce the volume of sediment that would either collect in a pond or at level ground below or at the bottom of the field.

**References:**

- Chin, D. A. 2006. *Water-Resources Engineering*. 2nd Edition. Prentice Hall. Upper Saddle River, NJ.
- Fangmeier et al. 2006. *Soil and Water Conservation Engineering*. 5th Edition. Thomson Delmar Learning. Clifton Park, NJ.
- McCauley, A. and C. Jones. 2005. *Managing for Soil Erosion*. Publication 4481-3. Montana State University Extension Service. Montana.
- North Carolina State University. 2013. *Rainfall-Runoff*. Biological and Agricultural Engineering, Erosion and Sediment Control Workshop. Raleigh, NC.
- Oregon Department of Transportation. 2011. *Hydraulics Manual*. State of Oregon.
- Resource Conservation District of Monterey County. 2003. “Stormwater Erosion and Runoff on Salinas and Pajaro Valley Farms.” Salinas, CA. Schwab, G.O., Frevert, R.K., Barnes, K.K., Edminster, T.W. 1957. *Elementary Soil and Water Engineering*. John Wiley and Sons, Inc. New York, NY.

# PREVENTING RUNOFF AT THE SOURCE

## The 4-D Formula

When considering your options for runoff management at any site, the key modes of action are to Decrease (volume and velocity), Detain, Dissipate, and Divert. When at all possible, diversion should be the action of last resort, as diverting the water may simply be ‘diverting’ the problem and not treating it. The practices in this guide are arranged accordingly.

## Other Approaches and Considerations

As noted in the introduction, this guide provides an overview of key practices rather than a comprehensive listing of methods for managing runoff. The following is a short list of other actions and approaches for addressing soil stabilization and runoff concerns that should also be considered in developing a strategy for a piece of land.

- **Good Neighbors:** Work with neighboring property owners or managers to address increased or concentrated runoff from their properties that might be impacting the cropland and surface runoff volumes.
- **Soil Quality Management:** Consider implementing soil quality practices that improve the soil’s ability to hold and make water available for crop use such as composting, reduced tillage, crop residue use, cover crop incorporation, crop rotations with fallowing and/or with green manure crops, etc.
- **Conservation Cover:** Consider permanent cover crops instead of annual cover crops where they can fit within or around a production system.
- **Plant-based Mulch:** Mulching in and outside of crop-growing areas can reduce runoff, help retain moisture, and enhance infiltration.



- **Conservation Tillage:** Reduction of and/or disruption of tillage pans by reducing tillage operations and/or varying the depth of tillage equipment, especially on soils with clay and/or when soils have a significant amount of moisture.
- **Irrigation Water Management and Scheduling:** Timing is especially important in early fall prior to the first rains. If the soil is already saturated from irrigation before the onset of winter, then runoff will be more immediate. If runoff begins early in the season because crop land is already saturated from irrigation then the chance of

soil erosion is higher because cover crops and other grass related practices are still trying to get established and are less effective.

- **Crop and Variety Selection:** Sometimes changing the crop or even the variety can have a profound effect on the amount of runoff coming from the field, or it can affect the timing or practices (such as plastic cover) that influence runoff.
- **Other' Low-tech' Practices:** Straw wattles, mulch strips, rolling dips, and protecting existing buffer vegetation can help slow runoff and reduce concentrations of flow where needed.

## References:

Casale, Richard, CPESC #3. 2013. Personal Communication. USDA NRCS District Conservationist, Capitola, CA

# ROW ARRANGEMENT

## Description and Benefits

Gently sloped furrows help the water to soak into the soil. The water that leaves the field flows slowly, leaving the soil in place.

Benefits of row arrangement include: more uniform irrigation, fertigation and drip fumigation; less ponding of water in furrows; ease of harvest; professional looking fields; and reduced erosion control and clean-up expenses.



## When Row Arrangement can help your situation

The goal in row arrangement is to make the furrows as close to level as possible without causing water to pond in the furrow. A good target to shoot for is 1.5% to 2% sloped rows, but slopes closer to .15% can be more desirable without causing ponding. Avoid slopes steeper than 4% or 5%. Row arrangement is a technique that requires practice and experience to master, and for some parcels it can be difficult to achieve low slope furrows throughout the block. Other considerations are soil type and existing hard pans that may create sloughing of the beds. Flat furrows are not a problem unless water collects in them which can damage beds or crops. Modify these methods as needed to best fit the land you farm and your own methods of listing beds.

## Implementation

### Tools needed

- *Instruments that measure slope, such as an abney level, clinometer or hand level*
- *Leveling rod or pole with foot markings*
- *Measuring tape or wheel*
- *Several hundred feet of string (depending upon block length and width)*
- *Wooden stakes or small sacks with sand*

### Approach

Make a map of the field and the furrow line slope measurements as you take them. This map will help you make decisions about how to lay out the furrows and adjust the guide line for best results.

### Step 1: Block layout and planning.

- Determine the ideal locations for your roads and planting block boundaries. In general, place roads in the highest and lowest parts of the field, namely, along to tops of ridges

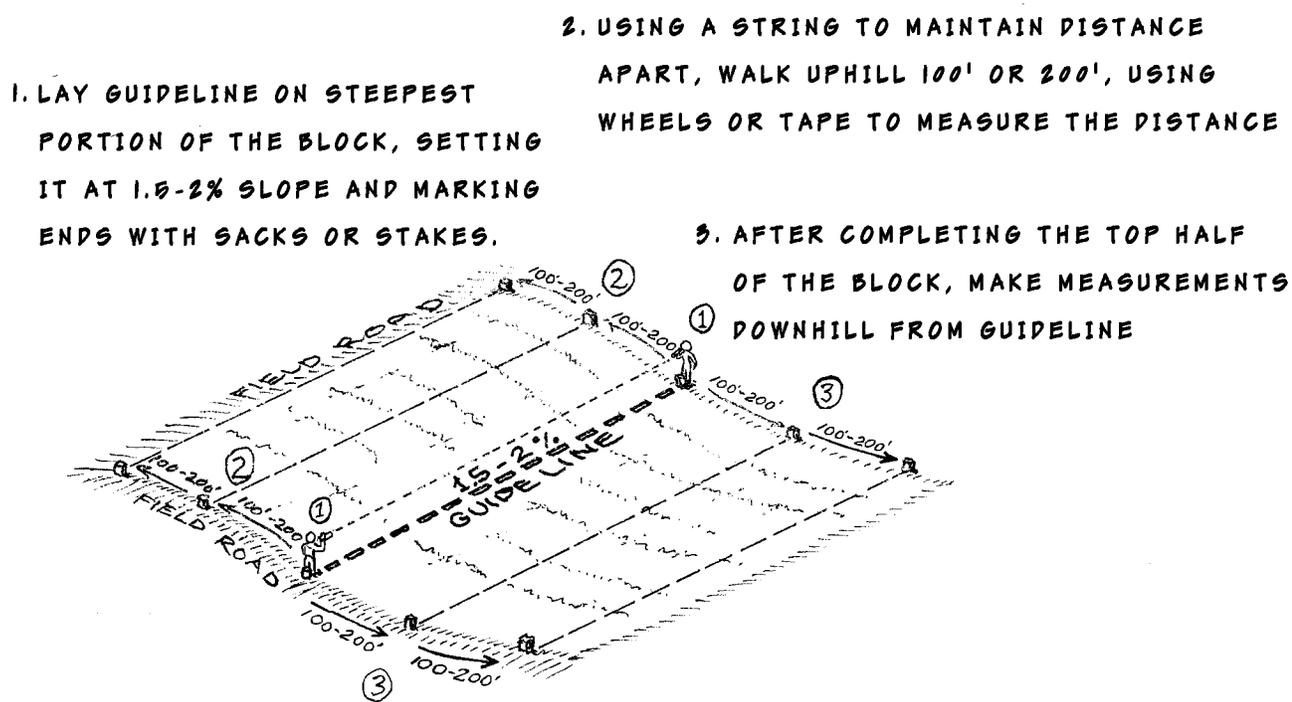


and bottoms of swales or draws.

- Do not direct water to roads that cannot handle it, and plan to incorporate appropriate methods of drainage management along field roads that carry water, as described later in this Guide.
- Plan for ditches or your row arrangement to direct water away from heavily traveled roads. Otherwise, direct traffic away from roads that cannot be kept dry.
- Leave steep areas and those that carry substantial water in natural vegetation.

**Step 2: Lay out the guide line. The guide line marks the alignment of the furrows for the entire block.**

- Go to the largest, most difficult part of the block (e.g. with the most uneven terrain) to lay out the guide line.
- Set out a line with maximum 1.5% to 2% slope using an instrument for measuring slope (see related fact sheet), marking that guide line with paper bags or stakes.



Row Arrangement Figure A: Laying Guidelines

**Step 3: Copy the guide line both up and down the block to mark furrow lines.**

- To do this, one person stands at each bag or stake, holding a string tightly between them. Each person uses a measuring wheel or tape to walk 100' or 200' uphill to the next place where the furrow slope is to be checked. The distance will be determined by how complicated the slope of the block is. As they walk at the same speed, the string between them remains taught, which helps them stay the same distance apart. A compass can be useful for confirming the exact alignment of the previous furrow checked.
- Now, Check the slope of the new furrow line. If the furrow line is less than 4% and has no low points that will pond, then mark the line and continue to move uphill and lay out furrow lines until the top half of the block is complete.
- Go back to the guide line and measure downhill to lay out additional furrow lines. If any of the furrow lines are steeper than 4% or have low points that will pond, then go back to guide line, adjust it, and repeat steps 1 through 4. Don't forget to check at various points throughout the furrow to

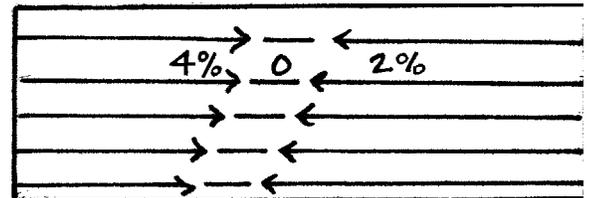
identify low points or high points that will pond or change the direction of the flow respectively.

- If the furrows in the block cannot be arranged so that all are less than 4%, align the furrows so that the steepest ones are at the bottom of the block, where the fast flowing water will do the least amount of damage.

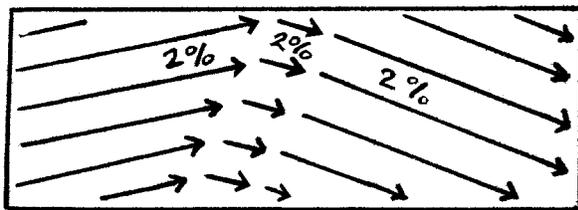
## Challenges

If a field has a low spot that collects water (Fig. B), possible options are to:

- Curve the furrow to drain the low area;
- Divide the block in two by putting a road through the low spot;
- Drain them with one inch PVC pipes to a furrow that will carry water out to a road;
- Use land leveling to fill low area of block and eliminate ponding.



Row Arrangement Figure B: Low spot

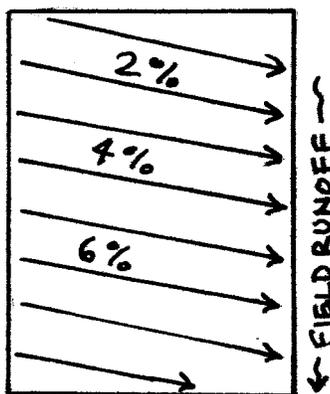


Row Arrangement Figure C: Curved Furrow

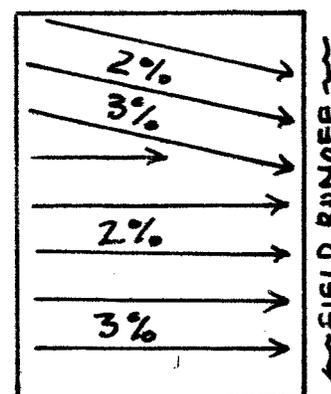


Row Arrangement: Curved Furrows

If the slope of the block changes so that the furrows become too steep (Fig. E), a solution could be to add point rows to compensate (Fig. F).



Row Arrangement Figure E: furrows are too steep



Row Arrangement Figure F: With Point Rows

## References:

Resource Conservation Districts and NRCS of Santa Cruz and Monterey Counties. 2003. Brochure: "Furrow Alignment." <http://www.rcdmonterey.org/pdf/FINALEnglishFurrow.pdf>. Accessed 10/4/13.

USDA-NRCS. 2008. *Field Office Technical Guide*. Conservation Practice Standard. Row Arrangement. Code 557. Davis, CA.



# HOOP HOUSE ANCHOR ROW PROTECTION

## Description and Benefits

Plastic hoophouses as used on the Central Coast provide valuable production benefits and a challenge for runoff management, especially on sloped lands. As conventionally configured, plastic covers can reduce the available permeable surface of a field's production area by over 90%, dramatically increasing the volume of water likely to run off a field in a storm event. Also, rainfall impact on the soil is concentrated along the roof edges of hoophouse anchor (or 'post') rows. Methods that have been used to address these challenges range from soil armoring and cover crops on anchor rows, weather-responsive



**Hoop house Figure A: Filter fabric along roofline**

placement of plastic covers, gutter and drain systems for diverting and directing 'roof' runoff, and increased spacings between hoophouse rows at intervals planted with grass or other vegetative cover. Filter fabric and cover crops in these rows provide the additional benefit of weed suppression.

## When to use Hoop House Anchor Row Protection

Oleg Dugovishi, UCCE Ventura



**Hoop house Figure B: Anchor-row barley cover crop**

a land manager anticipates a field set with hoophouses will experience rainfall while the plastic sheeting is up, anchor row protections will protect the soil from 'drip line' impacts, reducing maintenance and erosion risks along anchor rows. The degree to which these measures can be taken will depend on the land manager's resources, the acreage and density of hoophouses to be placed, the erosive potential of the field (soil texture and slope), the number of acres draining to individual collection points, and the manager's capacity to

manage accumulated runoff through the field and at the field bottom (or low, collection point).

## Implementation

There is very little guidance currently available regarding hoophouse runoff management in the United States. Hoophouse manufacturers and university extension guidance documents understandably focus almost exclusively on crop production factors. That said, for small, semi-permanent structures there are gutter systems available (Figure C., next page), although we have not observed them adapted for the predominant style of hoophouses in use for large-scale production on the Central Coast. Other novel approaches for using in-field drain-pipe to manage drainage of runoff collected along anchor rows are under investigation by growers but not yet verified in terms of effectiveness in a production context.



**Hoop house Figure C: Gutter drains to tank**

While USDA NRCS provides runoff management guidelines for the ‘high tunnel’ (hoop house) practice, it is intended for application on less than 10% of a given farm’s acreage. Those guidelines are incorporated into this section

When setting anchor rows, minimize vehicle traffic if possible in the anchor furrow to maintain maximum infiltration capacity.

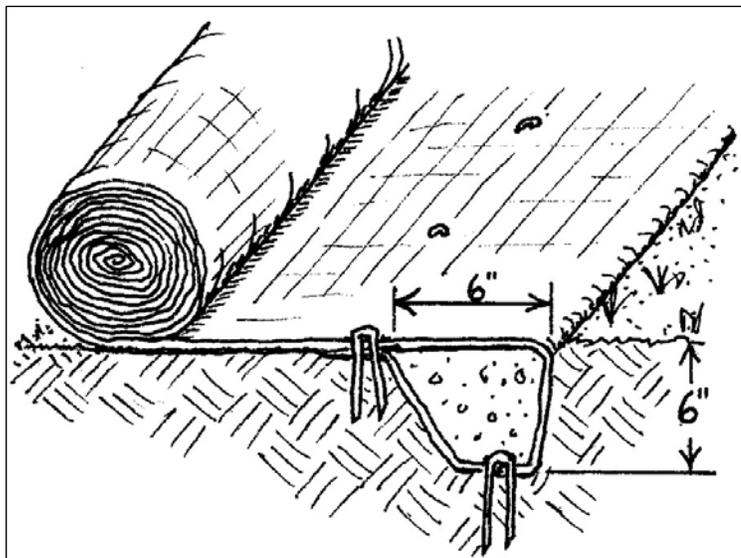
Armoring can be made with a permeable material such as filter fabric, straw or fiber mulch or crushed rock (only for permanent installations). The outlet of each anchor row should be further armored to protect

from erosion of collected runoff water as it spills into the field end ditch or road. See “Ditch Plastic and Grass for Road Protection” (page 27) and “Underground Outlets” (page 33) for treatments to protect roads and ditches carrying water off field. Where possible, drain anchor rows to lightly sloped, densely vegetated areas.

The California Storm-water BMP Handbook recommends covering the soil surface with geotextiles to reduce erosion from rainfall impact and hold soil in place. Woven and nonwoven materials with minimum tensile strength of 80 lbs can be used in anchor rows. The materials must be resistant to degradation by



*Oleg Daugovishi, UCCE Ventura*



**Hoop house Figure D: Geotextile Anchor Trench**

ultraviolet (UV) radiation (70% retained after 500 hours) and to biological and chemical environments normally found in soils. Geotextile mats should extend at least 2 feet under the anchor rows and cover the length of the hoop house. The mat must be secured in place with wire staples and the ends and sides should be anchored in a 6 in. deep by 6 in. wide trench (Figure D). Backfill the trench and tamp the earth firmly to secure the mat.

UC Cooperative Extension researchers in Ventura County are still investigating the runoff and sediment attenuation benefits of grass cover crops planted along hoop house post rows, but their preliminary results indicated a definitely observable benefit.

Depending on the type of hoop house

or cover, any increase in the spacing between houses with the addition of vegetated cover will have a corresponding benefit in erosion and runoff reduction. Any such spacing should be made to accommodate mowing or weed trimming, depending upon the scale of the operation. In the example shown to the left,



**Cover crop planted along hoop house post rows by Wayne Gularte**

the hoop house 'buffers' are also tied into a field drainage system. The inclusion of buffers or gaps between houses is dependent upon professional consultation, the limitations of hoop house construction or form, the need relative to slope and soil type, and crop production needs. The Rational Method, as described earlier in this Manual, could potentially be very useful for gauging potential runoff rates of different arrangements of hoop houses for the sake of field planning relative to the site's capacity for handling that runoff.

## Resources

- Basler and Daugovish. 'UC introduces a new way to manage weeds in caneberry growing tunnels.' Ventura County Blog. 8/2/2013. <http://ucanr.org/blogs/blogcore/postdetail.cfm?postnum=11040>
- California Stormwater Quality Association. 2003. *California Stormwater BMP Handbook Construction*. Menlo Park, CA.
- USDA-NRCS. 2012. *Field Office Technical Guide*. Conservation Practice Standard. Seasonal High Tunnels for Crops. Code 798. Davis, CA.
- USDA-NRCS. 2011. *Field Office Technical Guide*. Conservation Practice Standard. Lined Waterway or Outlet. Code 468. Davis, CA.



# COVER CROPS

## Description and Benefits

Cover crops as used in perennial and annual cropping systems are associated with soil benefits such as improved tilth and fertility, reduced erosion and crusting, runoff reduction, and increased water-holding capacity. Cover crops can also host beneficial insects and suppress weeds. A specific application of furrow cover crops has been shown to provide significant reduction in runoff in sloped strawberry and vegetable production fields on the Central Coast.

A variety of perennial and annual grasses and broadleaved plants can be used for cover crops as either single- species or multi-species mixes depending on the farmer's needs. Fast-growing grass species provide high biomass for boosting organic matter in the soil, while some species of legumes can provide high volumes of nitrogen for the following



cash crop. Mixed cover crops can be used to provide a combination of biomass and crop nutrient production. Low-statured grasses are likely best for furrow cover crop applications. "Green manure" cover crops are typically incorporated into the soil before a cash crop is planted. In a multi-year crop setting, many annual cover crops can be managed to self-seed, minimizing needs for replanting and soil disturbance. Perennial grass cover crops can provide basic soil cover, and are typically selected to minimize water and sunlight competition with adjacent trees and vines.



## When to use Cover Crops

Cover cropping is useful in a variety of agronomic situations where either rainfall or adequate irrigation are available. Furrow cover crops are helpful on sloped strawberry fields if seeded at the time of transplanting to take advantage of winter rains and crop establishment irrigations.

## Implementation

Ideal planting time is mid-October to allow for germination and maximum plant growth before soil and air temperatures cool down as fall progresses. Before a cover crop is planted, a suitable seedbed should be prepared. This is usually started after the post-harvest irrigation for perennial crops or after seedbed preparation for annual crops. On farmland, light disking or some other form of tillage is usually sufficient for most cover crops. Disking should be followed by some smoothing operation such as floating or planing so that larger clods are broken and the seedbed is smooth. This is particularly important for smaller seeded cover crops such as clovers.

Unless non-leguminous or grass-only cover crops are used, additional fertilizer is not usually required for cover crops. Otherwise, follow your seed company representative's recommendation for fertilizer type and

rate. Excess nitrogen fertilizer may actually reduce overall nitrogen fixation and give weedy species a competitive edge.

Prior to planting, mixes including large-seeded legumes should be inoculated with the appropriate rhizobial bacteria. Host-specific bacteria work in combination with special root structures to bind or ‘fix’ nitrogen into plant tissues. Some seed is sold pre-inoculated, but large-seeded legumes such as vetch, peas and beans should be inoculated immediately before planting at a rate of about 8 oz. of inoculum per 100 lb. of seed and layering it into the planter hopper. If the seed is broadcast rather than drilled, it should be wet-inoculated to provide better adhesion of the inoculum to the seed.



For planting, the cover crop seed can be broadcast or drilled in. Drilling may require less ground preparation, and is the method of choice for first-time plantings. For single species or larger seeded types, an alfalfa drill can be used. Broadcasting seed is faster and less expensive, but will require a light harrowing to incorporate the seed followed by a final floating or rolling to finish the seedbed. In established perennial cover crops, supplemental seeding may be needed every two to five years.

On sloped ground, an application of straw over newly-seeded ground can provide temporary slope protection until the cover crop germinates and grows large enough to provide substantial cover. If fall rains are not expected immediately, a light irrigation will settle soil around the seed and hasten germination. Summer annual cover crops will require regular irrigations just as any other warm season crop.

**Table 1. Suggested Grasses and Seeding Rates**

Seed Varieties	Life Cycle & Planting Time	Grass Characteristics	Lbs. of seed per 100 ft. by 10 ft. of roadway	Lbs. of seed per acre	Estimated cost per acre for seed
*Cereal Rye “Merced” Variety Secale cereal  *Don’t confuse cereal rye with annual rye <i>Lolium multiflorum</i> , potentially an invasive weed	Annual  early season Sept-Nov.	Good on dry, sandy slopes, excellent roots	2	80	52 (a)
Common Barley “UC 937” Variety <i>Hordeum vulgare</i>	Annual late season Nov. & Dec. or for emergencies	Good on all soils, fair roots	4.5	180	63 (b)
Trios “102” Tricale	Annual early season Sept. -Nov.	Good on all soils, good roots & low growth pattern	1.5	60	57 (c)
California Brome <i>Bromus carinatus</i> (nurse crop, fast germ. rate, short lived - 3 yrs.)  Creeping wild rye <i>Leymus triticoides</i> (long lived, slow germ. rate)	Perennial Native Mix early season Sept. & Oct.	Good on dry, sandy slopes, good roots  Good on dry sandy slopes, and loam/clay soils, excellent roots	0.3  1	25  25	174 (d)  750 (e)

- (a) Price based on \$52/80 lb bag, Snow Seed Co., August 2013
- (b) Price based on \$17.50/50 lb bag of “UC 937” Barley, Snow Seed Co., August 2013
- (c) Price based on \$47.50/50 lb bag of organically grown triticale, Snow Seed Co., August 2013
- (d) This price is based on a blend of California brome, meadow barley and blue wild rye: \$7.65/1.1 lb in quantities over 50, Harmony Farm Supply, August 2013.
- (e) Price for *L. triticoides* can be \$20-\$40/lb. or more depending on the year and the source.

## Maintenance

In annual crop fields, the cover crop height can be maintained with line trimmers or mowers, and the cover crop ‘knocked down’ with herbicide or mowing by February or March to not interfere with cash crop production. If self-seeding is desired, mowing should be delayed until the cover crop has matured seed. When mowing a cover crop mix that includes legumes, care should be taken to not cut below the growing point, or re-growth will be hindered. Mowing, spot-spraying or hand-hoeing may be needed to keep sprinkler or drip emitters clear, but using low-growing cover crops or extending sprinkler risers could reduce the need for such maintenance.

Incorporation of the cover crop (if necessary) should be timed to allow at least two weeks of decomposition in the soil before planting. Timing of incorporation should also be made in consideration of adequate soil moisture for decomposition, otherwise additional irrigation may be necessary to adequately break down the organic matter for proper seedbed preparation for the following crop. In spring, care must also be taken not to enter a field with excessive soil moisture, which would obviously hinder equipment access and also damage the soil with excessive compaction and clodding. The simplest scenario for cover crop incorporation involves “knocking down” the cover crop with either mowing or herbicide, followed by disking the plant material into the soil. After a period of decomposition, the soil surface would then be reshaped and smoothed, as needed.

## References

- Ingels, C. 1995. *Cover Crop Selection and Management in Orchards and Vineyards*. UC Davis Sustainable Agriculture Research and Education Program. Davis, CA.
- USDA-NRCS. Lockeford Plant Material Center. Conservation Plant Releases. <http://plant-materials.nrcs.usda.gov/capmc/releases.html>
- Robins, P., R. Bresnick Holmes, and K. Laddish, ed. 2001. *Bring Farm Edges Back to Life!* 5th edition. Yolo County Resource Conservation District.



# VEGETATED FILTER STRIPS

## Description and Benefits

A filter strip is an area of grass or other permanent vegetation used to “filter” sediment, organics, nutrients, pesticides, and other contaminants from farm sheet flow runoff in order to maintain or improve water quality in local waterbodies, such as streams and ponds. Filter strips slow the velocity of water, allowing the settling out of suspended soil particles, infiltration of runoff and soluble pollutants, adsorption of pollutants on soil and plant surfaces, and plant uptake of soluble pollutants. Filter strips are typically no narrower than twelve feet, and increased width



typically increases the filtering or water quality benefit. Filter strips can be an aesthetic means of stabilizing field border soil and can also serve as forage (on-farm use or cash crop), turnrows and headlands, and field access. Filter strips can enhance wildlife objectives depending on the vegetative species used and management practiced. When planted with native or adapted vegetative species they can provide food and cover for important wildlife.



## When to use Vegetated Filter Strips

Filter strips are most effective and useful on land with less than 10% slope at the lower edge of crop fields, sacrifice areas, or hardened footing areas where there is sheet or uniform shallow flow, especially adjacent to streams, ponds, lakes, and drainageways. They can also serve as part of a riparian forest buffer system.

## Implementation

- The filter strip should be designed to accommodate anticipated flows, slope and soil type to maximize the potential benefit. To determine the optimum width of a filter strip, consult with an NRCS engineer who will evaluate the individual site.
- Before a filter strip is planted, a suitable seedbed should be prepared. On farmland, light disking or some other form of tillage is usually sufficient. Disking should be followed by some smoothing operation such as floating or planing so that larger clods are broken and the seedbed is smooth. This is particularly important for smaller seeded species such as clovers.
- For non-leguminous or grass-only plantings, additional fertilizer may be needed to aid establishment.

Fertilize and amend the soil according to soil test results from the site and the needs of the species to be planted. Excess nitrogen fertilizer can be washed or leached out of the site (causing a water quality concern) or even give weedy species a competitive edge over the planted species.

- If legumes are to be included in the planting, make sure that they are either pre-inoculated or that you inoculate them with the appropriate rhizobial bacteria prior to planting at a rate of about 8 oz. of inoculum per 100 lb. of seed.
- For planting, the filter strip seed can be broadcast or drilled in. Drilling may require less ground preparation, and is the most desirable planting method. For single species or larger seeded types, an alfalfa or legume drill can be used. Broadcasting seed is faster and less expensive, but will require a light harrowing to incorporate the seed followed by a final floating or rolling to finish the seedbed. If necessary, mulch the newly-seeded area with straw for soil protection during germination. Supplemental seeding may be needed every 2-5 years.
- If fall rains are not expected immediately, a light irrigation will settle soil around the seed and hasten germination.
- Mow (and harvest if possible) filter strip grasses several times a year to encourage dense vegetative growth. For ground nesting wildlife, care should be taken to avoid mowing during nesting periods. If self-seeding is desired, mowing should be delayed until the desired filter strip species have matured seed. When mowing a planting that includes legumes, care should be taken to not cut below the growing point, or re-growth will be hindered.
- Be careful to maintain original width and depth of the planted area in order to maintain the intended benefits of the filter strip. Inspect and repair after storm events to fill in gullies, remove flow disrupting debris and sediment accumulation, reseed disturbed areas, and take other measures to prevent concentrated flow in the filter strip.
- Suppress weeds with well-timed mowings, which are preferable to herbicide in a filter strip. If herbicide is needed, it should be applied at low rates or in spot treatments and with adequate time for degradation before anticipated storms or irrigations (runoff events).
- Take care to exclude livestock and vehicular traffic from the filter strip during wet periods of the year since filter strips rely on infiltration for reducing contaminants. It is recommended that this type of traffic be excluded at all times to the extent that is practical.
- Restoration of the filter strip will be required once it has accumulated so much sediment that it is no longer effective.

## References

- USDA-NRCS. 2011. Field Office Technical Guide. Conservation Practice Standard. Filter Strips. Code 393. Sacramento, CA.
- Robins, P., R. Bresnick Holmes, and K. Laddish, ed. 2001. *Bring Farm Edges Back to Life!* 5th edition. Yolo County Resource Conservation District.

# ROAD SEEDING

## Description and Benefits

Roads are some of the most vulnerable areas on the farm for erosion. With a few simple techniques, your roads can be protected. Seeding grass on winter roads provides a large root mass that protects roads from washing out, protects bed ends from slumping, inhibits the growth of weeds, and enhances the water quality of runoff into adjacent streams.

Road seeding is a good idea when you are working with sloped farmlands with roads running directly downslope between planting blocks that capture and transport winter runoff downslope.



## Implementation

Before laying out or modifying your road, evaluate the key areas of the farm that will either drain to or receive runoff from your road. If possible, redirect uphill runoff to a sediment basin or to a well-protected road. Protect non-cropped areas with vegetation such as a cover crop or perennial grasses. Where furrows convey heavy storm runoff, consider modifying them by creating longer furrow blocks with shallower (1-3%) slopes to slow down the rate of runoff reaching your road. (See 'Row Arrangement') Furrows and plastic mulch on beds concentrate and speed up runoff of

winter rains. Manage that water before it reaches your roads.

In general, if you are laying out field on raw ground, look at the natural low spots in the field and place roads there. Then arrange your planting blocks and furrows according to the drainage that those roads can handle. For roads with protection such as underground pipe systems, flow can be collected from blocks on either side of the road (Fig. A). However, for roads with minimal protection such as grass and plastic-lined ditches (Fig. B), a better approach is to break up that flow by orienting furrows to drain adjacent blocks to individual roads or ditches.

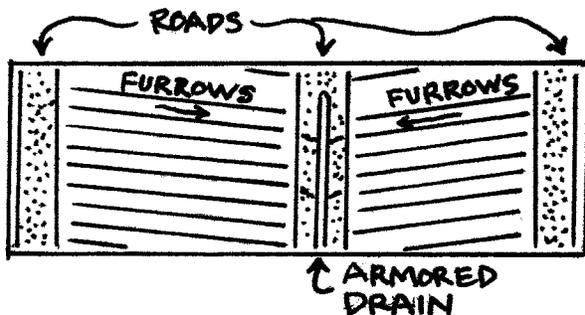


Figure A.

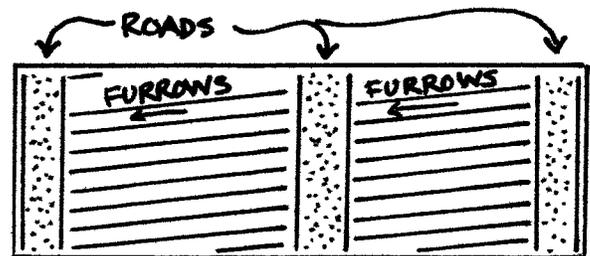
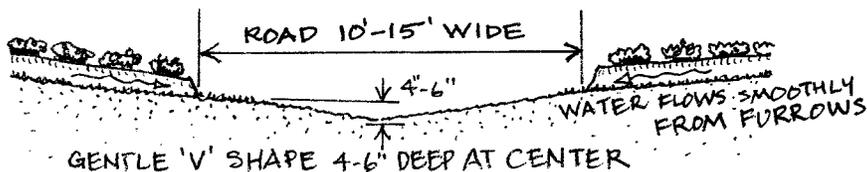


Figure B.

If a road is steeper than 20%, runoff from the furrow blocks should be spread out evenly to less steep roads. If those areas carry a lot of runoff, the road design should include a reinforced channel as described in a later section of this Guide.

A road can be configured to carry some water by either shaping it as a broad 'v' (as described below) or with a ditch along a low side (or both sides) using plastic to protect or 'armor' it, as pictured on the prior page. The latter method is described in "Ditch Plastic & Grass for Steep Road Protection" on page 27.



**Steps for shaping a road with a broad channel in the center to protect bed ends from erosion:**

1. Cultivate fields and chisel if necessary to increase water infiltration.
2. Cut roads with scraper to form a gentle "V" shape, 6" deep in center.
3. Spread soil in low parts of field.
4. List beds across roads.
5. Cut roads again with scraper to form a gentle "V" shape.
6. Use leftover soil to make water bars or shape beds; don't leave it on the road.
7. Roads at the edge of a farm can be sloped out to natural vegetation

**Fall Grass Planting on roads to Minimize Winter Erosion**

Plant grasses as soon as roads are cut and irrigate if necessary. If soil on the road is compacted, lightly aerate the soil with a disk, chisel or a rake. (Passing over the soil with a ring shank roller prepares an excellent seed bed.) Broadcast seed over the road by hand or with a seed broadcaster. If you were to throw a baseball cap over the seeds, you should see ten seeds below the hat (see chart for detailed application rates on p. x). Seed more heavily around ends of beds and seed at least 10 feet into each furrow (See 'Cover Crops' for information on full-furrow seeding).

Lightly bury seed about 1/2 inch deep in soil by passing over it with a disk or rake. Cover the seed with straw mulch to protect it and retain moisture, and provide supplemental irrigation if planted before rains. After the grass is grown, mow grass before seeds set. Keep vehicles off roads during winter to avoid tire track creating gullies.

The tables below indicate the maximum number of farmed acres that can be safely drained with grass alone to stop road erosion depending on road slope, use of annual or perennial grasses, and presence or absence of full bed plastic mulch in winter.

**Maximum number of acres that grassed roads can handle:**

With plastic mulched beds:

Road Slope	Acres
4%	2.5
8%	1
16%	1/3
24%	1/4

Road Slope	Acres
4%	5
8%	2
16%	2/3
24%	0.5

Without plastic bed mulch:

Road Slope	Acres
4%	6.5
8%	2.5
16%	0.75
24%	0.5

Road Slope	Acres
4%	13
8%	5
16%	1.5
24%	1

Use these tables above as a guide to estimate the uppermost portion of your roads that can be protected with grass alone and still drain safely. Below these sections, incorporate a ditch or pipeline the rest of the way down your grassed road. In situations with a large amount of water that comes from non-cropped areas, you will be safer to extend the ditch or pipe all the way up the road

### Benefits and limitations of annual vs. perennial grasses for road cover

ANNUAL GRASSES	PERENNIAL GRASSES
Suited for non-permanent roads	Suited for permanent roads & critical areas
Quick to establish in the fall	Slow to establish in the fall
Does not need a nurse crop	Needs a nurse crop for first year establishment
Requires little maintenance	Requires weed maintenance for first two years
Short roots	Deep roots
Need to replant every year	Provides cover & protection through the years
Protects soil in winter	Reduces dust in summer/protects soil in winter

### References

Resource Conservation Districts and NRCS of Santa Cruz and Monterey Counties. *Controlling Erosion on Hillside Farm Roads*. <http://www.rcdmonterey.org/pdf/FINALEnglishRoadsBrochure0301.pdf> Accessed 10/4/2013.



# DITCH PLASTIC AND GRASS TO PROTECT STEEP ROADS FROM EROSION

## Description and Benefits

On steep fields with ditches and roads that run directly down slope with potential to carry highly-erosive runoff during winter rains, one form of temporary protection for the ditch or road is a channel reinforced with plastic. While this protects the conveyance from erosion, it must have a protected outlet or pond to be able to handle those flows at the bottom of the slope. See “Underground Outlets” (page 33) for slopes needing more significant conveyance capacity or “Sediment and Water Retention Basins” (page 35) for bottom of slope runoff management.



## When to use Ditch Plastic and Grass

It is best to consult a qualified professional and an experienced land manager with specific knowledge of a given ranch to assess whether plastic and grass seed will be sufficient to protect a particular road or ditch, and to determine the appropriate treatment for managing the outflow of that ditch. The tables on page xx of the previous article are an additional helpful reference for estimating when grass alone may not be adequate to stabilize a road.

## Implementation

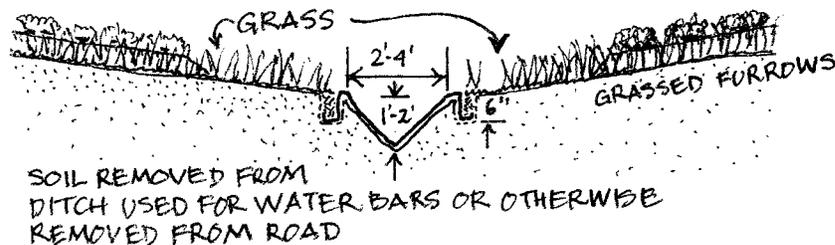


Figure A. Cross-section of plastic road ditch looking 'up road'.

After roads are cut and smoothed, cut a 1' deep x 4' wide ditch in the center or side of the road. (Ditches on either side of a road have also been used effectively.)

Lay out 2 mil embossed plastic or 6 mil smooth plastic for maximum strength. Both can withstand a deer stepping on them without tearing. **Don't reuse plastic from other applications.**

Set plastic in a shingle-style, starting from the bottom of the hill and work your way up, so that the bottom

edge of each additional sheet of plastic overlaps the prior sheet by about 3 feet. (See Fig. B)

Dig a small trench (6" deep) along the outer edge of plastic. Tuck the edges of the plastic into the trench and bury them.

Plant grass on road above and on the sides of the ditch and 10' up into the adjacent furrows that drain into the road.

Consult with an engineer for placement, size and quantity of materials (such as quarried rock) at the bottom of the slope to minimize damage from water flow. Where possible, consider planting willow stakes in the rocked area for additional long term armoring, in a manner that will not impede the flow of the channel.

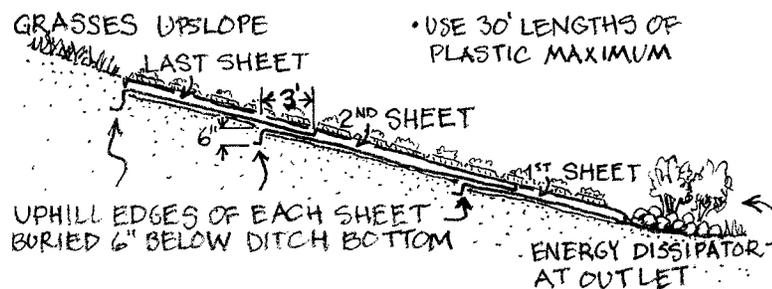


Figure B. Longitudinal cross-section of plastic ditch illustrating specifications for overlay of plastic sheeting

## References

Resource Conservation Districts and NRCS of Santa Cruz and Monterey Counties. *Controlling Erosion on Hillside Farm Roads*. <http://www.rcdmonterey.org/pdf/FINALEnglishRoadsBrochure0301.pdf> Accessed 10/4/2013.

# CROSS-RIPPING ROADS & WATERBARS

## Description and Benefits

A water bar can be used to help redirect water from roads on steep slopes towards structures or lands that can carry or absorb the water safely with minimal erosion. Cross-ripping is a technique that temporarily increases the road's ability to absorb runoff by creating fissures perpendicular to the slope for water to pass into the subsoil.



## When to Cross-Rip roads and place Waterbars

Temporary water bars and cross-ripping are helpful as quick and inexpensive supplemental practices to road seeding when more permanent structures (ditches and underground outlets) are not feasible. Waterbars can also be used to direct road surface flow to existing drainage structures or heavily vegetated areas.

## Implementation

**Table. Water bar spacing recommendations for unpaved roads from Kocher, Gerstein, and Harris. 2007. as adapted from Keller and Sherar 2003. For this table, 'erosive soils' are those with high concentrations of silt or fine sands relative to clay content.**

Road or trail Grade (%)	Soil erodibility	
	Low to non-erosive soils (ft)	Erosive soils (ft)
0-5	250	130
6-10	200	100
11-15	150	65
16-20	115	50
21-30	100	40
30+	50	30

Water bars are used primarily when a road will not receive traffic for the winter or for an extended period of time. Vehicular traffic should be minimized and the water bars should be seeded and fertilized to reduce erosion. A water bar is constructed by excavating a trough at a 30-45 degree angle downslope across the road. The excavated earth should be piled on the downhill side of the water bar. To be sure that no water by-passes the water bar, the uphill end of the

water bar should be tied in to any ditches or furrows. The water bar should have a protected outlet on its downhill end to allow water to be directed safely to an appropriately armored ditch, underground outlet, or naturally-vegetated area (of limited slope).

Spacing of water bars should be determined with the guidance of a qualified professional, although general guidance for water bar spacing on established unpaved roads can be helpful as a reference. The table below is an example of such a resource from the UCANR Rural Roads Construction and Maintenance Guide. It is important to note that such information is intended for permanent roads and may assume standard road

construction methods such as gravelling and compaction.

## References

Keller, G., and Sherar, J. 2003. *Low Volume Roads Engineering: Best Management Practices Field Guide*. USDA Forest Service/USAID.

Kocher, Gerstein, and Harris. 2007. *Rural Roads. A Construction and Maintenance Guide for California Landowners*. University of California DANR. Publication 8262. Davis, CA.

Resource Conservation Districts and NRCS of Santa Cruz and Monterey Counties. *Controlling Erosion on Hillside Farm Roads*, <http://www.rcdmonterey.org/pdf/FINALEnglishRoadsBrochure0301.pdf> Accessed 10/4/2013.

# TEMPORARY SLOPE DRAIN

## Description and Benefits

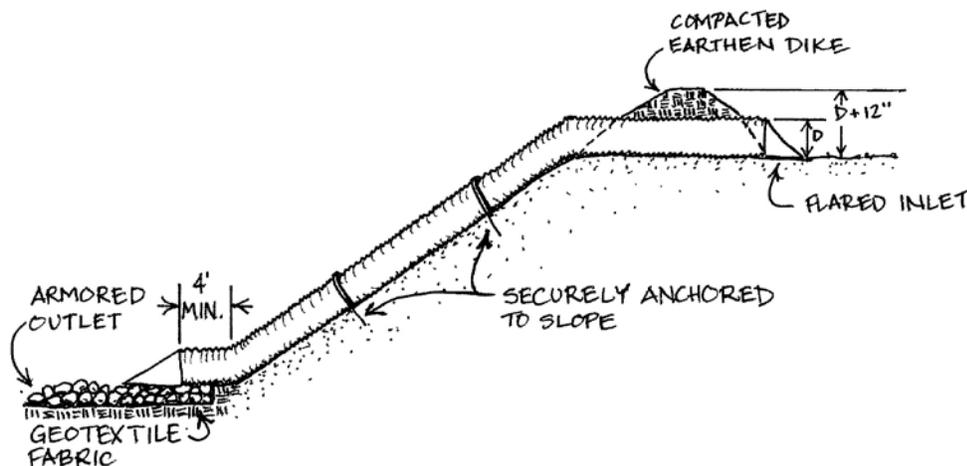
A temporary slope drain is a flexible pipe that runs overland and is designed to carry concentrated runoff from the top of a slope to the base of the slope without causing erosion. Runoff is intercepted upslope of a disturbed area and is routed to the slope drain, which carries the runoff to a stable outlet, where it is released at a non-erosive velocity into a sediment trap or basin. While it is simpler and quicker to install a temporary slope drain than an underground outlet, it only functions with a single inlet at its uppermost point.



## When to use Temporary Slope Drains

Temporary slope drains may be a short-term alternative drainage management tool for fields with limited tenure and dramatic runoff management needs. Temporary slope drains are applicable on sites with a maximum drainage area of 10 acres and on slopes 3 percent or steeper that have not yet been stabilized. Larger areas should have runoff split between multiple drains. This practice is used in conjunction with several other BMPs such as temporary diversions, stone outlet protection, and sediment traps and basins. Always consult a qualified professional for proper application of this technique.

## Implementation



The slope drain may be a rigid pipe, flexible plastic corrugated pipe or even layflat hose with secure, watertight joints and a flared inlet portion. The size of the pipe will vary depending upon the drainage area of the site, but should not have a diameter that exceeds 30 inches. To prevent failure of the device during large storm events, the soil surrounding the pipe must

be hand compacted, with the portion of the diversion or berm above the pipe at least one foot higher than the height or diameter of the pipe.

To prevent erosion of the diversion structure, the inlet of the slope drain should be underlain with geotextile filter fabric. The type of filter fabric that is selected will vary upon the individual characteristics

of the site, but should extend at least 5 feet from the inlet, with the edges keyed at least 6 inches into the ground.

The pipe should be anchored to the slope according to the manufacturer's installation instructions. However, regardless of the model selected, it must be secured to the slope with grommets in at least 2 places spaced no more than 10 feet apart. At the base of the slope, a minimum of 4 feet of pipe should have slope of 1% or flatter before discharging in order to reduce the velocity of the runoff. The slope drain should outlet to a protected surface and a sediment trap or basin

## Maintenance

Slope drains should be inspected after each rainfall event. Inspect outlets for erosion and downstream scour. If eroded, repair damage and install additional energy dissipation measures. If downstream scour is occurring, it may be necessary to reduce flows being discharged into the channel. Inspect the inlet for clogging and undercutting and remove debris from inlet to maintain flows. To repair any undercutting, it may be necessary to install a flared section or riprap around the inlet.

## References

- California Stormwater Quality Association. *California Stormwater BMP Handbook*. 'EC-11: Slope Drains'. 2007.
- Dane Count Land and Water Resources Department. 2007. *Dane County Erosion Control and Stormwater Management Manual*. Slope Drain (Temporary). Madison, WI.
- Minnesota Pollution Control Agency. 2000. *Protecting Water Quality in Urban Areas, A Manual*. St. Paul, MN.
- U.S.D.A. Natural Resources Conservation Service. 1996. *National Catalog of Erosion and Sediment Control and Storm Water Management. Guidelines for Community Assistance*. Washington, D.C.
- U.S.D.A Natural Resources Conservation Service and Mississippi Department of Environmental Quality. April 1994. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater*. Washington, D.C.
- USDA-NRCS. 2011. *Field Office Technical Guide*. Conservation Practice Standard. Surface Drain, Main or Lateral. Code 608. Sacramento, CA.
- USDA-NRCS. 2011. *Field Office Technical Guide*. Conservation Practice Standard. Pipeline. Code 516. Sacramento, CA.

# UNDERGROUND OUTLETS

## Description and Benefits

Storm water that reaches your farm roads can be directed into an underground outlet (or pipe) and transferred down the slope without taking sediment and crops along with it. An underground outlet generally needs to be coupled with a sediment basin at its outlet to effectively handle the high flow volumes that underground outlets are designed to accommodate. An inadequate downstream conveyance can result in extreme erosion, sedimentation and/or flooding. When the concentrated water conveyed by the underground outlet are caught in a sediment basin, the outflow of water can be metered out gradually. This system is a permanent and highly effective solution.

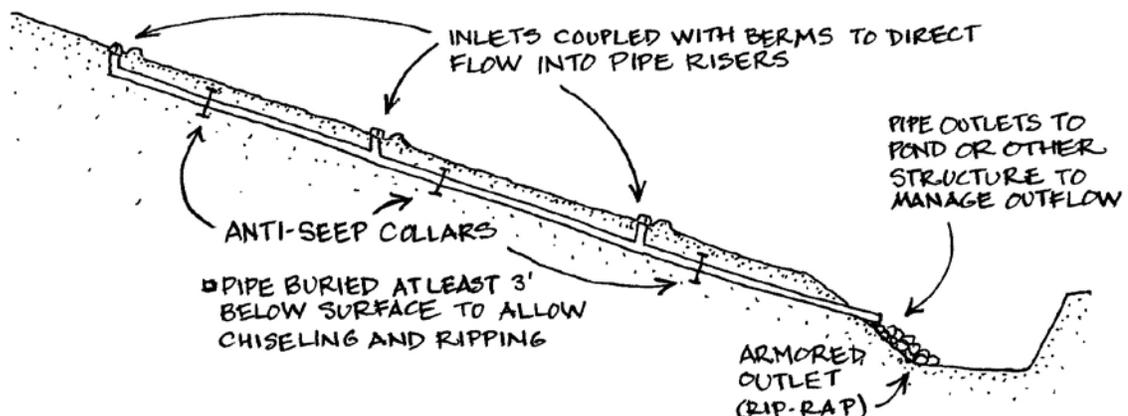


## When to use Underground Outlets

Underground outlets are cost-effective in settings with a permanent field configuration and should only be planned and implemented with guidance from a qualified professional. In general, such pipelines and their inlets are placed underneath permanent roads running through 'low' collection areas on slope steep enough to generate high concentrated runoff volumes. An underground outlet should be designed with a safe downstream outlet.

## Implementation

The design capacity of the underground outlet is based on the requirements of the structure or practice it serves. The capacity of the underground outlet for natural or constructed basins needs to be adequate for the intended purpose without causing inundation, damage to crops, vegetation, or works of improvements. Underground outlets may be designed for either pressure or gravity flow.



**Inlet** An inlet can be a collection box, a perforated riser, or other appropriate device. For perforated risers, use durable, structurally sound material that is resistant to damage by rodents or other animals. Inlets need

an appropriate trash guard to ensure that trash or other debris entering the inlet passes through the conduit without plugging.

Design collection boxes large enough to allow maintenance and cleaning operations. Use blind inlets where the installation of an open or above ground structure is impractical. Design the blind inlet with a graded granular filter around the conduit. Design the filter based on the particle size of the surrounding soil and the desired flow rate.

**Materials** Plastic, concrete, aluminum, and steel pipe shall meet the requirements specified in the applicable ASTM standard. Materials must meet applicable site specific design requirements for leakage, external loading, internal pressure or vacuum. Underground outlet conduits can be perforated or nonperforated, depending on the design requirements. Use a filter fabric wrap (sock) or appropriately designed granular filter if migration of soil particles into the conduit is anticipated. Design the filter based on the particle size of the surrounding soil to prevent rapid clogging of the filter. Protect all exposed plastic materials from degradation due to exposure to sunlight.



**Outlet** The outlet must be stable for anticipated design flow conditions from the underground outlet. Design the underground outlet for water surface conditions at the outlet expected during the design flow conditions. The outlet must consist of a continuous 10 foot section or longer of closed conduit or a headwall at the outlet. If a closed conduit is used, the material must be durable and strong enough to withstand anticipated loads, including those caused by ice. Do not design outlets to be placed in areas of active erosion. Use fire resistant materials if fire is an expected hazard. All outlets must have animal guards to prevent the entry of rodents or other animals. Design animal guards to

allow passage of debris while blocking the entry of animals that cannot easily escape from the conduit.

## Operation And Maintenance

A written operation and maintenance plan needs to address the following minimum requirements:

- Periodic inspections, especially immediately following significant runoff events, to keeping inlets, trash guards, and collection boxes and structures clean and free of materials that can reduce flow
- Prompt repair or replacement of damaged components
- Repair or replacement of inlets damaged by farm equipment
- Repair of leaks and broken or crushed lines to insure proper functioning of the conduit
- Periodic checking of the outlet and animal guards to ensure proper functioning
- Repair of eroded areas at the pipe outlet
- Maintenance of adequate backfill over the conduit
- To maintain the permeability of surface materials on blind inlets, periodic scouring or removal and replacement of the surface soil layer may be necessary

## References

USDA-NRCS. 2012. *Field Office Technical Guide*. Conservation Practice Standard. Underground Outlet. Code 620. Sacramento, CA

# SEDIMENT AND STORMWATER CONTROL BASINS

## Description and Benefits

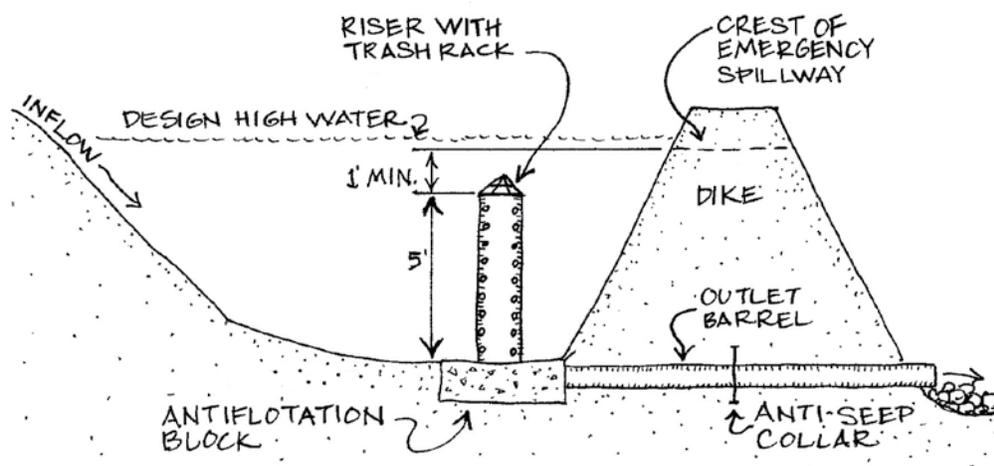
Storm water flows are often so intense that they overwhelm on-farm drainage systems and flood into public ditches, drains and roads. These high flows of water can carry large amounts of soil which increase risk of flooding and damage to the affected farm and downslope lands. Detention basins help reduce the volume, intensity, and sediment load of storm water runoff by slowing the water down, allowing more water to infiltrate, drop out most of the sediment load and cause water leaving the field to be cleaner, slower, and lower volume.



## When to use Sediment and Water Control Basins

A detention basin can be effective when placed at the low end of a field in which runoff has been collected by ditches and underground outlets, and where the potential intensity or volume of that runoff will overwhelm downstream structures. A basin constructed solely for sediment management is generally designed for smaller capacity than a stormwater control basin. Do not construct them in stream channels or other permanent water bodies.

## Implementation



A stormwater detention or sediment basin should be designed and developed in consultation with a qualified engineer to ensure the stability and function of the berm or dike and outlet structures. A basin and its outlet must be correctly sized for sufficient

capacity to accommodate the anticipated rate and volume of runoff so that the outlet is not overwhelmed while reducing and delaying the flow out of the structure to downstream properties or waterways.

An overwhelmed structure will eventually fail, posing a liability in terms of safety, maintenance, and environmental impacts. The capacity of the sediment basin shall equal the volume of sediment expected to be trapped at the site during the planned useful life or intended maintenance interval of the basin or the improvements it is designed to protect. To reduce construction costs and save space, most basins are designed to be cleared out annually.

One example of a convenient location for siting a basin is inside the field road at or around the low corner of a field using the road embankment as a berm, provided that it is (or can be) adequately laid and compacted in lifts (or layers) to ensure stability. The sides of the berm or embankment can be further protected from erosion if covered with vegetation or armored with rock (depending upon the intensity of flow exerted upon the site).

The first step in designing a basin is to determine the anticipated peak flow of runoff and desired outflow rates. While a skilled land manager with years of experience on a given ranch might be able to anticipate this, such information is best generated with the assistance of a qualified engineer. A brief description of this process is provided at the beginning of this Guide.

Critical design features of any basin should include:

1. A protected inlet to prevent bank erosion when water enters the pond.

2. A carefully sized and anchored outlet pipe (see “Principal Spillway Design” on page 40). Outlets can be slotted pipe or flash board risers. While a flashboard riser is more expensive, it allows more flexibility for setting water level or outlet flows. With a slotted pipe riser, the water is allowed to gradually exit the basin through slots in the side of the pipe. If runoff increases then the water exits through the top of the pipe. Pipelines should be designed with a minimum velocity of 1.4 ft/sec to prevent sediment from collecting inside the pipe (CPS 620). The pipe should have an anti-seep collar to prevent ‘piping’ or seepage from degrading the compacted fill surrounding the outlet pipe. The riser should be anchored in concrete. Anti-seep collars are often made of concrete or sheet metal with mastic coating. If an anti-seep collar is not installed, saturated conditions will gradually cause the berm to fail.



3. A berm and excavated area with adequate capacity for the desired volume with at least one foot of berm height (‘freeboard’) above the top of the outlet pipe riser. Berm and basin bank slopes should not exceed 2:1 if they are constructed of compacted soil. In general, any fill should be carefully compacted in layers or ‘lifts’ of less than x” for ideal stability and to minimize potential erosion of the slope.

4. An emergency spillway is a portion of the berm that is lower than the majority of the berm and appropriately armored with rock or concrete to withstand the erosive force of the water cascading over and down it. This is a ‘fail safe’ feature to protect the primary water

retention structure so that under maximum runoff conditions (those that exceed the pipe outlet capacity), water will exit through the secondary or emergency spillway rather than over the top of the berm.

## References:

- USDA-NRCS. 2010. *Field Office Technical Guide*. Conservation Practice Standard. Sediment Basin. Sacramento, CA.
- USDA-NRCS. 2009. *Field Office Technical Guide*. Conservation Practice Standard. Water and Sediment Control Basin. Code 638. Sacramento, CA.

# ESTIMATING PEAK RUNOFF USING THE "RATIONAL METHOD"

A simplified tool that engineers and hydrologists use to predict the watershed peak runoff rate is known as 'The Rational Method'. A project designer has to know the peak runoff ( $Q_p$ ) rate in order to properly design channels, culverts, slope drains, and sediment basins. The Rational Method is a simple formula often referred to as the Rational formula:

$$Q_p = CiA$$

Where  $Q_p$  is the peak runoff in cubic feet per second (cfs),  $C$  is the runoff coefficient (defined further below), " $i$ " is the design (or anticipated peak) rainfall intensity in inches per hour, and  $A$  is the watershed area in acres. The Rational Method should be limited to areas smaller than 200 acres, where the entire area is contributing to the runoff to be managed. The information presented in this section is intended for educational purpose and not for the design of erosion control structures. Each farm should be evaluated by a professional engineer prior to the design and installation of structures to control runoff and erosion.

**1 cfs = 449 gallons per minute**

The watershed characteristics that affect the peak runoff rate are incorporated in the runoff coefficient ( $C$ ). The runoff coefficient varies between 0.0 and 1.0 depending on the watershed soil's infiltration rate, the land use, the land cover and the land slope. Soils with rapid infiltration rates, such as sands, have low runoff coefficients (eg. 0.0 to 0.30), while soils with slow infiltration rates, such as clays have much higher runoff coefficients. Impermeable areas such as those covered with pavement, buildings or plastic have runoff coefficients of 1.00 or nearly 1.00. The influence of vegetation on infiltration rate is two-fold. First, the denser and larger the vegetative cover, the more rain will be intercepted and not reach the soil surface. Second, the presence of deep-rooted vegetation tends to improve soil structure and increase infiltration. Typical runoff coefficients are shown on Table 1, below. It is common practice to use the fraction of impervious area of a watershed as an estimate of runoff coefficient. For example, plastic mulch and roofs will have a larger fraction of impervious area compared to pasture and woodlands.

**Table 1. Rational Method Runoff Coefficients**

Land Use	Runoff Coefficient, C	Land Use	Runoff Coefficient, C
Bare packed soil:		Woodlands	0.05-0.25
Smooth	0.30-0.60	Pasture:	
Rough	0.20-0.50	Heavy soil	0.15-0.45
Cultivated rows:		Sandy soil	0.05-0.25
Heavy soil with crop	0.20-0.50	Drives and walks	0.75-0.85
Sandy soil with crop	0.10-0.25	Roofs	0.75-0.85
Crop with plastic mulch	0.50-0.70		

The rainfall intensity, " $i$ ", in the Rational Method is often referred to as the 'design' rainfall intensity, which is the uniform rainfall intensity that has duration equal to the watershed's response time (or the time it would take during a runoff event for a droplet of water to travel from the top of the watershed to the collection

point at the bottom: the ‘time of concentration’). This design rainfall intensity is a function of three parameters: (1) the watershed’s time of concentration, (2) the watershed’s location and (3) the return period (storm frequency) for which the peak runoff rate is desired. To determine the design rainfall intensity for use in the Rational Method, first determine the watershed’s time of concentration,  $t_c$  which is based on the watershed or field length, cover and slope. For example, fields with a larger fraction of impermeable area (i.e. plastic mulch) will have a faster runoff (shallow concentrated) flow velocity and a shorter travel time or time of concentration. Second, determine the return period (or storm frequency) for which you want to anticipate maximum runoff. (In this context, the less frequent or likely a storm, the larger it will be. Depending on the level of runoff ‘protection’ you need, that could be for a 10-year or 100-year storm ‘return period’.) Third, read the design rainfall intensity from the best available Intensity-Duration-Frequency (IDF) information to determine the design rainfall intensity for the rainfall duration and return period. The NOAA National Weather Service has a public website that provides this information at <http://hdsc.nws.noaa.gov/hdsc/pfds/>.

The land cover will influence the peak runoff in two ways. First, the time of concentration will be smaller for areas with a larger impervious fraction, which directly influences the storm intensity. Second, the runoff coefficient will be larger for areas with a larger impervious fraction. This dual effect will produce a larger peak runoff for areas with larger impervious fraction (Table 2). The units of peak flow presented in Table 2 are in cubic feet per second per acre (cfs/ac) of land. The peak runoff in cubic feet per second can be easily calculated by multiplying the peak flow per unit area (cfs/acre) by the farm acreage.

**Table 2. Peak Runoff influenced by Time of Concentration ( $t_c$ ) and Runoff Coefficient (C).**

Time of Concentration (Minutes)	10-year Frequency Storm Intensity (inches/hour)	Runoff Coefficient	Peak Runoff per Unit Area (cfs/acre)	Runoff Coefficient	Peak Runoff per Unit Area (cfs/acre)
5	2.30	0.25	0.58	0.85	2.00
10	1.65	0.25	0.41	0.85	1.40
15	1.33	0.25	0.33	0.85	1.13
30	0.92	0.25	0.23	0.85	0.78
60	0.63	0.25	0.16	0.85	0.54

For example, we will compare the peak runoff rate for three scenarios: a row-cropped farm with and without plastic mulch and that of native pasture land in the same location (Table 3). The runoff coefficient (C), based on the same farm area, slope and soil, is larger for the row crop production than the native pasture (Table 1), and larger with plastic-mulched than without it. The plastic mulch ( $C=0.60$ ) will reduce the amount of water that can infiltrate into the soil, thus increasing the proportion of the rainfall that will run off from the field. The time of concentration will be a lot shorter in the cropped field ( $t_c = 5$  & 10 minutes) than in the native pasture because a large proportion of the area is covered by plastic and the presence of furrows allows faster movement of water in the field. Because a shorter  $t_c$  corresponds with a higher potential rainfall intensity, based on a 10 year storm frequency, the factor for rainfall intensity will be correspondingly larger for the cultivated land than the land in pasture. Using the Rational Method in this example, then, estimates that the peak storm runoff will be three to twelve times greater for the row cropped land (without and with plastic mulch, respectively) as compared to the native pasture land.

**Table 3. Example Calculation of the Storm Peak Runoff Rate**

	<b>Site A</b>	<b>Site B</b>	<b>Site C</b>
	Row crop with plastic mulch	Row crop	Native Pasture
<b>Farm Size (A)</b>	18 acres	18 acres	18 acres
<b>Farm Slope</b>	10 %	10%	10 %
<b>Soil</b>	Sandy Loam	Sandy Loam	Sandy Loam
<b>Runoff Coefficient (C)</b>	0.60	0.18	0.15
<b>Time of Concentration (assume)</b>	5 minutes	10 minutes	120 minutes
<b>Storm Frequency</b>	10 years	10 years	10 years
<b>Rainfall Intensity (i)</b>	2.3 in/hr	1.65 in/hr	0.46 in/hr
<b>Peak Runoff Rate (<math>Q_p=CiA</math>)</b>	<b>25 cfs</b>	<b>6 cfs</b>	<b>2 cfs</b>

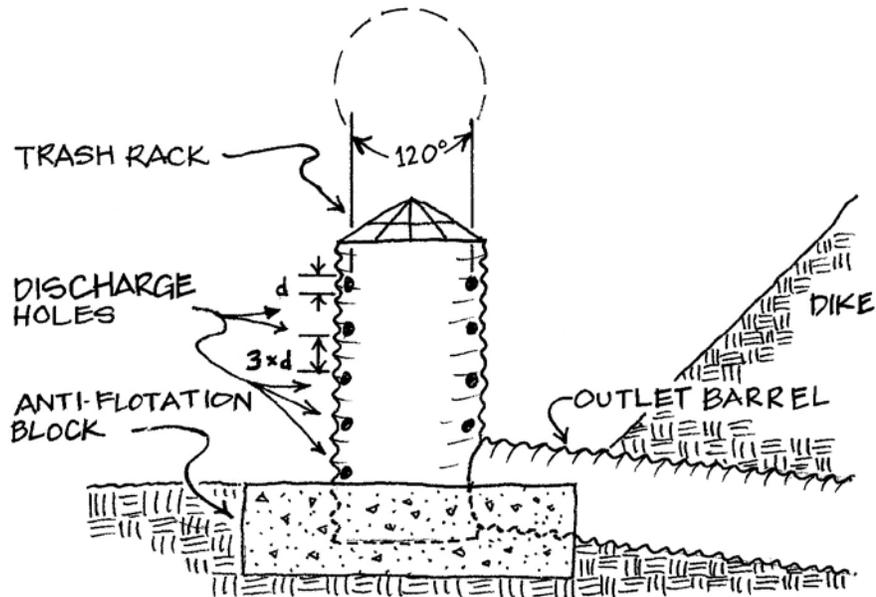
## References

- Chin, D. A. 2006. Water-Resources Engineering. 2nd Edition. Prentice Hall. Upper Saddle River, NJ.
- North Carolina State University. 2013. Rainfall-Runoff. Biological and Agricultural Engineering, Erosion and Sediment Control Workshop. Raleigh, NC.
- Oregon Department of Transportation. 2011. Hydraulics Manual. State of Oregon.

# PRINCIPAL SPILLWAY DESIGN FOR A WATER CONTROL BASIN

## Step 1: Peak Runoff Rate Estimation

The peak runoff rate will be influenced by the slope, soils, and percent of impermeable area. Based on the results in Runoff Table 3 in the previous article (page 39) and past NRCS projects, the common peak runoff is 1.5 cfs/acre for a 10-yr frequency storm on cultivated hillslope lands of Northern Monterey County.



Spillway Figure A: Configuration of discharge holes on outlet pipe.

## Step 2: Principal Spillway Riser Sizing

Based on the peak runoff determined in Step 1 and Table A1, determine the size of the pipe riser. For the example shown in Runoff Table 3 on page 39, the peak flow rate is 25 cfs and the pipe riser size selected is 36". The top of the riser should have a trash rack to prevent debris from clogging the structure.

Table A1. Discharge Table for a Corrugated Metal Pipe Riser (Head= 1.0 ft) and Size of Concrete Required for Anti-floatation Block.

Riser Diameter (inches)	Discharge (cfs)	Size of Concrete for Anti-floatation Block (cu.ft)
12	4.1	4.2
18	6.7	9.4
24	10.1	16.8
30	21.4	26.2
36	25.7	37.7
42	30.0	51.4
48	34.2	67.1
54	38.5	84.9
60	42.8	104.8

## Step 3: Anti-floatation Block Sizing

The amount of concrete needed for the anti-floatation block is presented in Table A1 and depends on the diameter of the riser pipe. The riser should be securely fastened to the block by placing two bars through it and embedded within the concrete block.

#### Step 4: Principal Spillway Barrel Sizing

It is recommended that the pipe barrel size be equal to or one size smaller than the pipe riser size. Based on the peak runoff determined in Step 1 and Table A2, determine the size of the pipe barrel. For the example shown in Runoff Table 3 (page 39), the peak flow rate is 25 cfs, so the appropriate pipe barrel size should be 30”.

Table A2. Discharge Table for a Corrugated Metal Pipe Barrel Flowing Full with a Head of 5.0 ft (K = 1, L = 70 ft).

Barrel Diameter (inches)	Discharge (cfs)
12	4.5
18	12.2
24	24.7
30	42.1
36	64.5
42	91.9

#### Step 5: Multiple-Orifice Outlet Riser Sizing

The number and size of the orifices will depend on the drainage area (Table A3). The surface area of the basin was calculated using 3600 ft<sup>3</sup>/acre of drainage area and average depth of 6’. The orifices will be located in the riser evenly distributed on two columns and separated vertically by 3 times the hole diameter and 120 degrees horizontally (see Figure. A, previous page). The orifices are designed to drain the basin in 24 hrs.

Table A3. Hole Size Required to Drain Basin within 24 hours

Hole Diameter (inches)	Drainage Area (Acres)
1.0	1 - 18
1.5	19 - 27
2.0	28 - 36
2.5	37 - 45
3.0	46 - 54

#### References:

- California Stormwater Quality Association. 2003. *California Stormwater BMP Handbook Construction*. Menlo Park, CA
- City of Knoxville. 2001. *Knoxville BMP Manual Erosion and Sediment*. Sediment Basin. Knoxville, TN.
- USDA-NRCS. January 2012. *Engineering Field Handbook*. Chapter 6 - Structures. Washington D.C.
- USDA-NRCS. 2010. *Field Office Technical Guide*. Conservation Practice Standard. Sediment Basin. Code 350. Sacramento, CA



# *Resource Conservation District of Monterey County*

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## TECHNICAL PAPER

### STORMWATER EROSION AND RUNOFF ON SALINAS AND PAJARO VALLEY FARMS

#### **PURPOSE**

The purpose of this document is to characterize the typical rates of stormwater runoff and soil erosion under different cropping patterns for Salinas and Pajaro valley farms.

#### **METHODS**

Peak and total runoff rates were calculated using the hydrology model presented in the Natural Resources Conservation Service Engineering Field Manual, Chapter 2, which was calibrated using limited field data collected locally during storms. Erosion estimates were made based on field measurements made by the Natural Resources Conservation Service, the Resource Conservation Districts of Monterey County and Santa Cruz County, and the California State University at Monterey Bay in addition to calculations using the Unified Soil Loss Equation modified to include concentrated channel erosion. Input parameters were selected based on historic rainfall data, typical soil types and farm sizes.

#### **LIMITS OF THIS ANALYSIS**

This paper is intended for general educational purposes and not for design. Farm facilities including ditches, sediment basins and pipes should be designed on an individual basis. Using the values presented here for design may result in massive erosion, flooding, dam failure, injury and death. Each farm should be evaluated by a professional engineer prior to the design and installation of structures to control water or sediment. The Resource Conservation District of Monterey County and the Natural Resources Conservation Service offer this service free of charge, and capable local engineering businesses are available as well.

The analysis presented here is based on specific hypothetical examples. We discourage extrapolating this information beyond these examples. Each farm is unique and should be evaluated on an individual basis. The combination of soil management, soil type and cropping pattern can increase or decrease runoff and erosion rates substantially. Two farms that appear similar to the untrained observer can vary in their runoff and erosion rates by several hundred percent.

This analysis is based on mathematical models that, while calibrated to observed conditions on Central Coast farms, contain numerous assumptions and simplifications. As such, the full range of conditions is not examined here. Typical values are provided as a general indication of how much runoff and erosion can be expected from different types of land management.

This document is intended to be informational purposes and not intended to promote or guide any regulation on land use restriction. The variability between farms is an important reason why this data should not be used for such purposes.

#### **EXAMPLE FARM BLOCK**

The farm block considered for this analysis was 10 acres, square and sloped at four percent. For the case of a strawberry field with full bed plastic mulch, 50 percent of the soil surface was assumed to be covered with plastic. A strawberry field without plastic mulch will behave similarly to the vegetable crop case. For the hoop houses, 80 percent of the soil surface was assumed to be covered with plastic. In all cases it was assumed that runoff flows off the farm down roads or through ditches. Spreading runoff water over large flat areas reduces peak runoff and erosion rates. (Such areas are typically unavailable as they are used for production.)



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With respect to runoff rates, it is assumed that no practices have been used to increase infiltration, such as incorporating organic material into the soil, chiseling, or planting cover crops in furrows, on farm roads or in other areas. These practices may reduce runoff rates significantly.

### **RESULTS: RUNOFF RATES**

Table 1 presents approximate stormwater runoff rates, reported as cubic feet per second (cfs), resulting from different agricultural operations. There is a wide spectrum of runoff rates for different types of crop cover. Undisturbed soil with perennial pasture cover infiltrates large quantities of water, resulting in very low runoff rates. Both soil covered with plastic and bare soil are effectively sealed to infiltration, resulting in substantial increases to runoff rates. (Rain impact on bare soil rapidly clogs soil pores.)

The increase factor presented in table 1 relates the cropping situation to pasture. An increase factor of five indicates that the peak runoff rate of the cropping situation is five times that of pasture. The increase factor is the highest for frequent storms because most of the rain associated with these smaller storms will infiltrate in a pasture setting while some runoff will be generated on cropland.

While the percent increase in runoff between certain types of irrigated agriculture and pasture is high, whether that amount of runoff poses a problem depends largely on the capacity and erodibility of downstream ditches, culverts and channels. If those channels have sufficient capacity, the excess runoff may not be a problem. If the channels lack sufficient capacity, flooding or downstream erosion will result. Downstream erosion is discussed in the following section. Water that infiltrates into the soil leaches salts, is available to plants and can recharge groundwater if geologic conditions permit. Runoff is less available for groundwater recharge unless it is captured and detained for infiltration.

Many parts of these two valleys have heavier soils such as clays and clay loams. These soils will yield more runoff under all conditions, including pasture. The runoff increase factor for these soils will be less than for sandy soils.

To help interpret these results, table 2 shows the capacity of culverts of different sizes. In order to estimate the cumulative impacts of more than one farm block, additional analysis is required. Generally, as the total acreage increases the peak runoff per acre decreases.

### **RESULTS: EROSION**

Field erosion is affected by many factors, including the amount of soil protected from rainfall by plants, mulch or other covers, and the amount of runoff, which is largely determined by soil texture and management related to permeability. Steeper slopes, longer runs and areas of more intense rainfall will generally also have more erosion. This analysis is limited to sandy loam soils. Heavier soils are generally less erosive. While fields partially covered with plastic have less area exposed to rainfall, the runoff rate is much higher than for fields without plastic and this generally causes the overall erosion rate to be higher.

The Soil Surveys of the US Department of Agriculture, Soil Conservation Service lists rates of erosion that are tolerable from the perspective of maintaining long term crop production. Those rates typically range from two to five tons per acre per year. Erosion at these rates is nearly invisible. Field erosion averaging 1/16<sup>th</sup> of an inch in depth amounts to 11 tons per acre. Tolerable rates of erosion with respect to maintaining channel capacity and other beneficial uses of receiving waters have not been determined for our area. Similarly, site specific assessments are required to determine the amount of increased runoff that can be accommodated by existing channels and ditches without excessive erosion.



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Table 1. Peak runoff rates for a 10 acre block of Pajaro and Salinas valley cropland on sandy loam soil at four percent slope. One cubic foot per second (cfs) is equal to 7.3 gallons per second.

Farm Site: Pajaro Valley, East of Watsonville, West of foothills.

Storm Size Frequency (years)	Rainfall 24 hours (inches)	Pasture	Row Crops		Strawberries		Hoop Houses	
		Peak Flow (cfs)	Peak Flow (cfs)	Increase Factor	Peak Flow (cfs)	Increase Factor	Peak Flow (cfs)	Increase Factor
2	3.5	0.3	7	22	15	47	19	60
10	4.6	1.5	12	8	21	14	26	17
25	6.0	4.3	18	4	29	7	35	8
100	8.0	10	28	3	41	4	48	5

Farm Site: Castroville to Greenfield, Salinas Valley

Storm Size Frequency (years)	Rainfall 24 hours (inches)	Pasture	Row Crops		Strawberries		Hoop Houses	
		Peak Flow (cfs)	Peak Flow (cfs)	Increase Factor	Peak Flow (cfs)	Increase Factor	Peak Flow (cfs)	Increase Factor
2	1.6	0.0001	0.7	5,400	4.3	35,000	7.1	57,000
10	2.5	0.06	3.2	51	9.2	150	13	200
25	3.0	0.15	5.0	34	12	80	16	110
100	3.8	0.5	8.2	16	17	32	21	41

Table 2. This table is intended to illustrate how runoff affects downstream drainage facilities. This table is not intended for design purposes. The culvert size required to pass a certain flow rate is presented. Assumptions: The top of the culvert at the inlet is submerged by 2 feet. The culvert outlet is free flowing. The culvert is sloped at two percent, is made of corrugated steel, and is kept free from debris and sediment.

Culvert diameter (inches)	Flow capacity (cfs)
12	5
24	22
36	53

Downstream erosion frequently occurs in natural areas, ditches and creeks that were built or formed by natural processes to handle less runoff than they currently receive. Gully erosion is a common form of downstream erosion. Ditches and creeks typically adjust to increased runoff by eroding to achieve a lower gradient or slope. This causes the channel to become deeper and wider as bank failure occurs. (Channels subject to increased runoff that become shallower over time are often filling with sediment faster than they erode.) Typically, moderately sized storms such as the two-year storm cause the most erosion over the long term because they are both erosive and relatively frequent.

Downstream erosion is largely determined by the runoff rate and the position of the farm on the landscape. A farm high on a terrace or alluvial fan may contribute significantly to downstream erosion, while a farm that is level with a wide flat area or a lake or slough will probably contribute little to downstream erosion. A low rainfall area will have lower peak runoff rates, but it is also likely to have smaller or less developed channels that are less able to handle additional runoff without erosion.

The potential for downstream erosion is a description of the probability of erosion if the downstream areas are vulnerable. A moderate potential for downstream erosion indicates that erosion is unlikely in dry years but is likely in heavy rain years if downstream areas are vulnerable. The severity of that erosion



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is affected by a number of factors including the geometry and geology of the downstream area in addition to peak runoff rates.

Table 3. Approximate annual erosion rates resulting from different types of agricultural operations.

Farm Site: Pajaro Valley, East of Watsonville, West of foothills.

Crop Type	Without soil conservation practices* or runoff water detention		With soil conservation practices*, but without runoff water detention	
	Annual Field Erosion (tons/acre)	Potential Downstream Erosion due to runoff	Annual Field Erosion (tons/acre)	Potential Downstream Erosion due to runoff
Fallow	16	Moderate	1.5	Very Low
Row Crops	5.5	High	2.2	Moderate
Strawberries	16	Extreme	4.5	High
Hoop Houses	11	Extreme	4.4	High

\* Practices such as row arrangement, cover crops, broad waterways lined with rock or perennial grass, and grassed roads

Farm Site: Castroville to Greenfield, Salinas Valley.

Crop Type	Without soil conservation practices* or runoff water detention		With soil conservation practices*, but without runoff water detention	
	Annual Field Erosion (tons/acre)	Potential Downstream Erosion	Annual Field Erosion (tons/acre)	Potential Downstream Erosion
Fallow	4.5	Moderate	0.3	Very Low
Row Crops	1.5	Moderate	0.6	Low to Moderate
Strawberries	4.5	High	1.5	Moderate to High
Hoop Houses	3.0	Extreme	1.2	High

\* Practices such as row arrangement, cover crops, broad waterways lined with rock or perennial grass, and grassed roads

## RESULTS: MITIGATION

Reducing the impacts of increased runoff and erosion can be accomplished through cultural and structural practices. These include minimizing furrow slope and plastic cover, maximizing vegetative cover, and increasing soil organic matter and tilth. In certain cases these techniques have proven to virtually eliminate increased runoff and erosion from farm fields. These are the most effective practices for reducing erosion of clay particles, which may carry fertilizers and pesticides. Waiting to apply plastic mulch until the storm season has passed will reduce runoff in strawberry fields. However, there may be unintended impacts on water quality and crop production. For example, fertilizer on the bed would be more subject to leaching or erosion.

Erosion can also be controlled using structural techniques such as underground pipes, grade control structures, energy dissipators, and lining ditches and channels with vegetation, plastic sheeting or rock. These practices may prevent downstream erosion from increased runoff along a given reach of channel, but such erosion may resume at the end of the treated reach unless those practices are extended to an area where the water will not accelerate again such as a wide level area or a slough or lake. Each of these techniques has limitations and can cause serious damage, injury or death if not properly planned, installed, or maintained. Consult with an engineer prior to installing such measures.

Where these practices are insufficient, basins that detain runoff and sediment are highly effective at capturing eroded sediment and reducing peak runoff and downstream erosion. The detention basin sizes listed below were determined based on the goal of reducing the current runoff rate to the peak rate for pasture or to 10 percent of the developed rate, whichever is greater. The capacity is listed in acre-feet and



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the footprint in square feet, assuming an average basin depth of 4 feet. Actual basin footprint sizes for a given capacity vary widely based on site conditions. Basins of these sizes will be only somewhat effective at retaining clay particles and associated chemicals.

Table 4. Approximate detention storage required to mitigate effects of increased runoff rates.

10 Acre Farm Site: Pajaro Valley, East of Watsonville, West of foothills.

Design Storm Size (Year)	Rainfall Inches	Row Crops		Strawberries		Hoop Houses	
		Acre-Feet	Square Feet	Acre-Feet	Square Feet	Acre-Feet	Square Feet
2	3.5	0.7	8700	1.1	14,000	1.3	16,000
10	4.6	1.0	12,000	1.5	19,000	1.7	21,000
25	6.0	1.5	19,000	2.1	26,000	2.3	29,000

10 Acre Farm Site: Castroville, Salinas, Spreckles

Design Storm Size (Year)	Rainfall Inches	Row Crops		Strawberries		Hoop Houses	
		Acre-Feet	Square Feet	Acre-Feet	Square Feet	Acre-Feet	Square Feet
2	1.6	0.3	3700	0.5	6200	0.6	7500
10	2.5	0.4	5000	0.8	10,000	1.0	12,000
25	3.0	0.5	6200	0.9	11,000	1.1	14,000

## CONCLUSIONS

Common agricultural land uses have the potential to increase erosion and runoff rates substantially over natural levels in the Pajaro and Salinas Valleys, but common soil conservation practices have the ability to reduce these rates to levels that are sustainable over the long term. Determining acceptable levels of runoff and erosion is a complex and site specific task that is beyond the scope of this analysis. Those levels are likely to be affected more by downstream site conditions than conditions on the farm itself. Despite the potential for increased runoff associated with agricultural land uses, these runoff rates are likely to be substantially lower than urban, industrial or transportation land uses that have higher percentages of impervious surfaces. Similarly, erosion rates for the cropland situations considered here are likely to be much lower than for land uses that result in bare soil or increased runoff on land with slopes over 5 percent. Irrigation that simulates rainfall has the potential to cause erosion in a similar manner to storm events. The intensity of the irrigation is an important factor and is highly variable, therefore such analysis is beyond the scope of this paper.

More information is needed to improve these tables. Specifically, winter runoff data from adjacent fields under different management practices would be helpful to quantify the benefits of non-structural practices that reduce erosion and runoff. Interesting comparisons might include chiseled versus non-chiseled fields, or a field with runoff directed down vegetated roads versus one where runoff flows down earthen ditches, or fields with lots of incorporated organic matter versus ones with little organic matter. If you would like to participate in such a study, please contact the Resource Conservation District of Monterey County. Confidentiality is guaranteed.

# EROSION CONTROL SEED AND PLANT MATERIAL SOURCES

## Erosion Control Seed Sources

Central Coast Wilds  
114 Liberty Street, Santa Cruz  
(831) 459-0655  
[www.centralcoastwilds.com](http://www.centralcoastwilds.com)

L.A. Hearne  
King City & Prunedale  
(831) 663-1572  
[www.hearneseed.com](http://www.hearneseed.com)

Elkhorn Native Plant Nursery  
P.O. Box 270, Moss Landing  
(831) 763-1207  
<http://www.elkhornnursery.com/>

Native Revival Nursery  
8022 Soquel Drive, Aptos  
(831) 684-1811

General Feed & Seed  
1900 Commercial, Santa Cruz  
(831) 476-5344  
<http://generalfeedandseed.com/>

Rana Creek Ranch  
35351 Carmel Valley Road, Carmel Valley, CA  
(831) 659-4851

Snow Seed Company  
21855 Rosehart Way, Salinas  
(831) 758-9869  
[www.snowseedco.com](http://www.snowseedco.com)

## Where to Buy Rice Straw

AGCO Incorporated  
Hollister, CA  
(831) 628-3564

General Feed & Seed  
1900 Commercial, Santa Cruz  
(831) 476-5344  
(minimum purchase - 250 bales of rice straw)

L.A. Hearne  
8525 Prunedale N. Rd.  
(831) 663-1572  
[www.hearneseed.com](http://www.hearneseed.com)

**Note:** We recommend rice straw because it is less weedy on uphill farms.

# MEASURING SLOPE

## Tools to Measure the slope of your fields

Effective use of many of the techniques in this Guide is dependent on measuring and mapping out the slope of the land you're working. Slope can be measured with relatively simple tools and techniques as described below or can be conducted professionally by engineering and land-leveling contractors. The following are brief descriptions of some of the available instruments that measure slope and how to use them

www.forestry-suppliers.com



### Abney Level

An abney level measures slope. Look through the level and aim at an object that is the same height as your eye. For example, if you are one inch taller than your partner, aim at the brim of their hat. Now adjust the abney level until the level bubble is in the center of the view. Then read the percent slope off the side of the instrument.

### Clinometer

A clinometer measures slope. Hold the clinometer up to one eye, while keeping both eyes open. With one eye, look at an object that is the same height as your eye. With the other eye, look at the clinometer dial to read the slope in percent. A very simple clinometer can also be constructed with a straight rod, protractor, string and a washer. Percent numbers are on the right hand side as you read the clinometer.



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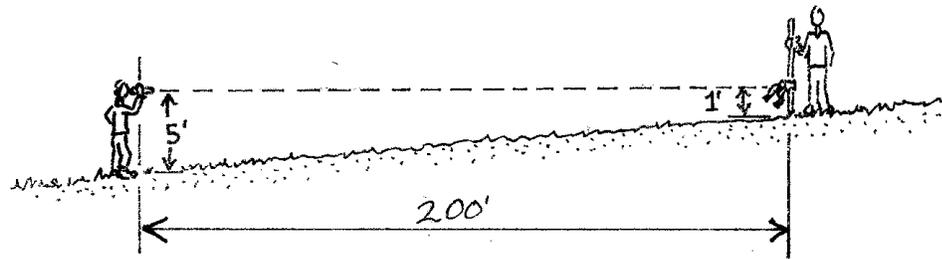


### Hand Level

Looking through a hand level, you see objects at the same elevation as your eye when the bubble is centered. This method can be used by one person alone by pounding a stake into the ground and tying a ribbon to it. You must make the needed measurements to calculate the slope.

## What is 2% slope?

In the sketch below, the user's eye is five feet above the ground. He sights 200 feet across the field to a pole held by a partner. The pole has a ribbon tied to it one foot above the ground. The slope can be found by calculating the rise over the run:



## Other tools used by professional surveyors

**Auto Level**, a tripod-mounted instrument that works like a hand level, but with greater accuracy.

**Total Station**: A tripod-mounted instrument that uses a light beam to measure distances and an internal level to measure slope.

**Global Positioning System Receiver**: A backpack or handheld instrument that uses satellite signals to determine the elevation and position of the receiver.

For assistance from the local Resource Conservation District and Natural Resources Conservation Service for estimating slope, contact the local field office listed in the Technical Assistance section.



# TECHNICAL ASSISTANCE SUPPORT

**Your local RCDs and NRCS** work in partnership to provide conservation technical assistance with staff skilled in soil and water conservation, agricultural engineering, and vegetation management techniques. Depending on funding cycles, they can also provide partial financial assistance for project implementation.

Resource Conservation District of Monterey County	831-424-1036 x124
USDA Natural Resources Conservation Service, Salinas	831-424-1036 x101
Resource Conservation District of Santa Cruz County	831-424-1036 x124
USDA Natural Resources Conservation Service, Capitola	831-424-1036 x101

**UCCE Farm Advisors** are a critical resource for local growers on the whole gamut of regional crop production concerns and bring with them the resources of the University of California. On matters of soil and water conservation, they also work cooperatively with the RCDs and NRCS.

University of California Cooperative Extension, Salinas Valley	831-759-7350
University of California Cooperative Extension, Watsonville	831-763-8040

**The Agricultural Commissioner** is responsible for the promotion and protection of the agricultural industry while also ensuring farm worker health and safety, environmental resource protection, and a fair market place for consumers.

Monterey County Agricultural Commissioner	831-759-7325
Santa Cruz County Agricultural Commissioner	831-763-8080