FOOD SAFETY CONSIDERATIONS FOR CONSERVATION PLANNERS:

A FIELD GUIDE FOR PRACTITIONERS

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PURPOSE AND USE OF THIS GUIDE

This guide presents a review of scientific literature on environmental sources and pre-harvest contamination of fresh produce (focusing on leafy greens, lettuce, and vegetables) with microbial pathogens. This guide covers major sources of human pathogens in the environment and vectors of possible crop contamination associated with leafy greens and fresh vegetables. This guide considers possible risks as well as potential ways to reduce risks of crop contamination in the field through water, air and animal contact related to common conservation practices and environmental features.

This document focuses on the possible pre-harvest sources and vectors of contamination only. It does not include harvesting, washing, processing, packaging, and food service; however, in many cases these are considered likely sources of contamination.

This guide explores the possible connections between the adoption of conservation practices and pre-harvest food safety in two contexts: 1) A review of scientific literature that is relevant and may be used to aid field-level decisions for the planning and design of conservation practices and environmental protection measures; and 2) A series of appendices with practice-specific considerations to identify potential food safety benefits and risks that may be associated with nineteen common conservation practices. This is not intended to be a how-to or design guide for conservation practices.

After an introduction and background, the literature review is organized into three major sections: 1) Sources of pathogens; 2) Vectors for pathogen movement; and 3) Conservation practice benefits and considerations.

The information contained in this guide is not an exhaustive review of all information available, but attempts to provide the most relevant and critical scientific information about the relationships between conservation practices and food safety. Food safety issues with leafy greens and raw vegetables are not a problem unique to California or the United States. In addition to studies on microbial pathogens and food safety in the United States, relevant literature from the European Union and other countries was reviewed and is also included.

This guide is to be used for conservation planning purposes only and provides only general guidelines to help identify possible food safety risks or benefits associated with conservation practices. This guide is not intended to be used to determine on-farm risk of crop contamination. It should not be used in place of a crop-specific food safety program.

When evaluating potential food safety risks associated with conservation practices and when designing or managing conservation practices to minimize risk of contamination, it is best to consult appropriate experts (e.g. hydrologist to minimize flood risk, vertebrate biologist to minimize animal contamination risk).

BACKGROUND

California is a global leader in agricultural production and economic strength, and has some of the world's most expensive land. In addition, the Central Coast of California boasts some of the highest concentrations of biologic diversity in the world. Providing safe, quality produce to consumers is the number one priority for the produce industry. Simultaneously, agricultural producers face increasing environmental demands and have taken a proactive approach to voluntarily improve water quality on the Central Coast of California.

Protecting foods safety is a critical issue being addressed by all stages of the produce industry in California, especially on the Central Coast. Since the late 1990's, government, researchers, and the produce industry have worked to develop and implement voluntary guidelines or "Good Agricultural Practices" to minimize risk of contamination in the produce industry (e.g. FDA 1998, Bihn 2004). Commodity-specific food safety guidelines have been developed by the produce industry for leafy greens, tomatoes and melons. Such efforts have the potential to serve as the basis for national food safety standards.

In early 2007 produce industry representatives, with oversight by the US Department of Food and Agriculture, developed the *California Leafy Green Products Handler Marketing Agreement* (LGMA 2007). The LGMA covers fourteen crops: arugula; butter lettuce; chard; escarole; iceberg lettuce; spinach; red leaf lettuce; baby leaf lettuce; cabbage; endive; green leaf lettuce; kale; romaine lettuce; and spring mix. As signatories to the Marketing Agreement these handlers, representing more than 99% of the leafy green production in California, are obligated to handle leafy green produce only from growers that adhere to the best management practices detailed in the *Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens*, know as the "Metrics" (LGMA 2008). In addition to the Metrics, many companies and retailers who handle or sell leafy greens have developed their own company-specific food safety program requirements affecting farm management practices. Because growers often sell their crops to multiple buyers, most now face meeting at least one if not several different sets of food safety requirements in order to sell their crop.

The coordinated management (co-management) of food safety and environmental protection is easier said than done, and co-management efforts are being challenged by real or perceived incompatibilities arising between these priorities (Beretti and Stuart 2008, Beretti 2009, Stuart 2009). These recent studies show that efforts of agricultural producers on the Central Coast to protect water quality and the environment may be compromised as some food safety guidelines, or interpretation thereof appear to be incompatible with some management practices intended to improve water quality and enhance natural habitat. Growers of fresh produce, particularly leafy greens, are caught in the middle between these competing priorities and in many cases are being put in a position of having to choose between being able to sell their crops or protect the environment

As industry initiatives such as the LGMA are adopted throughout California and the nation, and "…enhancing our food safety laws for the 21st century…" is a goal for the current administration (PFSWG 2009), successful efforts to implement and maintain on-farm practices to protect water quality and enhance the environment must incorporate food safety considerations.

SOURCES OF PATHOGENS IN THE ENVIRONMENT

Microbial pathogens such as *E. coli* 0157:H7 are zoonoses, meaning they originate from animals. It is important to note that while animals are the source of pathogens in the environment, they are not necessarily the most likely vector for crop contamination (see "Vectors for Pathogen Movement in the Environment" section below).

Cattle and domestic animals have been shown to be the largest reservoirs of pathogenic *E.coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). As summarized by Salmon et al. (2008):

> "Extensive research has made it clear that cattle are by far the most common, prevalent, and important reservoir of *E.coli* pathogens such as the 0157:H7 strain. Other ruminants such as sheep and goats can also carry these pathogens. Regarding non-ruminant animals as carriers of pathogenic *E.coli,* however, documented cases occur but are uncommon. The list includes domesticated animals such as cat, chicken, dog, horse, pig, and turkey. Wild animals carriers include deer, feral pig, Norwegian rat, rabbit, and [some] wild birds (goose, gull, pigeon, sparrow, and starling). In many of these studies, the domesticated and wild animal carriers have been associated with dairy or beef cattle facilities; it is apparent that animals such as dogs, pigs, deer, rodents and birds have been feeding on cattle feces or otherwise exposed to *E. coli* from cattle. When rats have tested positive for pathogenic *E. coli,* all the collected animals were living in and around cattle operations. In many of these studies, researchers question whether the non-cattle animals play a significant role in the persistence and spread of pathogenic *E. coli*."

<u>Domestic Animals as Sources of Pathogens</u>

Domestic animals discussed in detail in this paper include the following: cattle, pigs, goats, sheep, horses, cats, and dogs. This is not an exhaustive list of domestic species that could present a potential human health risk, however, they are those thought to be most commonly found near or able to move in cropped fields. Prevalence of pathogens in domestic animals varies by species.

Cattle

Domestic cattle are the primary source of microbial pathogens associated with food borne illness (Nielsen et al. 2004). However, these pathogens often do not cause any signs of illness in cattle. Prevalence can be highly variable among cattle depending on the environment and the time of year. Hancock et al. (1998) studied cattle in the Pacific Northwest and found that 3.6% of feedlot cattle and 2.3% of dairy cattle tested positive for *E.coli* 0157:H7. Chapman et al. (1997) tested cattle at a slaughter facility in England over an entire year. Overall, 13.4 % of beef cattle and 16.1% of dairy cattle tested positive for *E.coli* 0157:H7. However, depending on the time of year (highest in spring and summer), up to 36.8% of total cattle tested positive for *E.coli*. 0157:H7.

Studies indicate that the composition of cattle diets may affect the amount and composition of bacteria in cattle manure. Diez-Gonzalez et al. (1998) found that cattle fed grain had significantly higher levels of acid-resistant *E. coli* than cattle fed hay or grazed on grass pastures. Franz et al. (2005) explored the effects of cattle feeding regimes on *E. coli* 0157:H7 and *Salmonella* on manure from dairy cattle. They found that manure from cattle with a pure straw diet (high fiber content) had reduced levels of *E. coli* 0157:H7 and *Salmonella* compared to manure from cattle fed a mixture of grass silage and maize silage (lower fiber content). They conclude that a high starch/grain diet favors the growth and survival of pathogenic bacteria. Because feeding grain to cattle (especially dairy cows) has become a common practice, manure may now have higher concentrations of pathogenic bacteria than with previous traditional feeding regimes. Diez-Gonzalez et al. (1998) and Franz et al. (2005) both suggest that increasing fiber in the diet, through feeding hay, could reduce pathogen excretion from cattle. These studies suggest that cattle grazing on open rangeland should have lower pathogen concentrations than those in confined operations being fed grain.

Identification of on-farm management practices that would reduce or eliminate food borne pathogens from cattle and other livestock is an active area of research. Some scientists argue that changes in livestock diets to a more traditional high-fiber feeding regime may reduce the presence of microbial pathogens in cattle operations (e.g. Diez-Gonzalez et al. 1998, Franz et al. 2005). At this point there is not yet a consensus among researchers regarding the specific impacts of cattle diets on pathogen prevalence (Hancock and Besser 2006). Other cattle management practices for pathogens are also being explored including the use of probiotics, immunizations, and bacteriophages (Oliver et al. 2008).

Sheep and Goats

E. coli O157 and other food borne pathogens have been found in sheep and goat manure (Oporto et al. 2008). Sheep and goats are ruminants, like cattle. Sheep and goats do not usually show any signs of illness when carrying these food borne pathogens. Orporto et al. 2008 found 8.7% of 122 dairy sheep tested positive for *E. coli* O157:H7 in Spain. In addition, Ogden (2005) discovered that six out of 15 sheep fecal samples tested positive for *E. coli* O157:H7 in Scotland. Lastly, Orden et al. (2008) found that 3 out of 58 goats from two dairy herds in Spain tested positive for *E. coli* O157:H7.

Pigs (*not* feral)

Escherichia coli 0157:H7 is only occasionally isolated form healthy pigs (Cornick and Helgerson 2004). The study by Cornick and Helgerson (2004) suggest that domestic pigs serve as a potential host and potential reservoir of *E.coli* 0157:H7 under suitable conditions. A subsequent study showed that pigs, but not sheep, could be infected with *E. coli* O157:H7 by aerosol transmission (Cornick and Vukhac 2008). Most pig production in the United States is confined to buildings, reducing the opportunities for contamination between other populations.

Dogs and Cats

Dogs and cats have been shown to carry pathogens, but have lower rates of incidence than domestic ruminants. Regarding pathogenic *E. coli*, both dogs and cats can be carriers and may sometimes show signs of illness when infected (Beutin 1999, Osek

2000). A study of hospital visitation dogs in Canada showed that of 102 dogs sampled, 80% were carrying zoonotic diseases (Lefebvre et al. 2006). Of these dogs 1% carried pathogenic *E. coli* and 3% carried *Salmonella*. A study in Argentina found that 4% of 450 dogs and 2.6% of 153 cats were found to carry pathogenic *E. coli* (Bentancor et al. 2007).

Horses
Few studies have looked at the role of horses as carriers of human pathogens associated with food borne illness. One study looked at the prevalence of pathogens in horse manure from pack animals on hiking trails in the Sierra Nevada Mountains of California (Derlet and Carlson 2002). Of 81 fecal samples, none tested positive for *E. coli* O157:H7 or *Salmonella*.

Wild or Non-Domestic Animals as Sources of Pathogens
Non-domestic animals can be distinguished in the following categories when considering their potential risk to food safety: 1) wild or natural animals; 2) wild animals with higher than normal populations or expanded habitat range; and 3) commensal animals. Wild or natural animals are species that are associated with their natural habitats and have populations within normal ranges based on their habitat availability. In some cases otherwise wild animals may be present in an area at abnormally high populations. This effect is typically observed in species with high reproductive rates and fairly non-specific dietary requirements. Increases in populations are most often due to significant changes in the natural environment (e.g. reduction in predators, monoculture vegetation stands). Commensal animals are non-domestic species that are associated with and/or thrive from human activities and waste (e.g. urban areas, livestock operations, garbage dumps). Commensal animals include but are not limited to gulls, some rodents, pigeons, blackbirds, and starlings.

This review presents information found on species thought to be most relevant to issues on the Central Coast. Overall, all non-domestic animals are much less likely to carry *E.coli* 0157:H7 than domestic ruminants. On average less than 1% of all wild animals and up to 12% of commensal species carried *E.coli* 0157:H7 or other human pathogens, according to the studies reviewed. Preliminary results from a joint E. coli environmental study found less than one half of one percent of 866 wild animals tested positive for Escherichia coli O157:H7 in Central California (CDFG 2009). The prevalence of pathogens in animals that eat or live around human and livestock waste, such as rats and seagulls, is higher: closer to 12%. This indicates that limiting the access these animals have to sources of waste (such as manure piles and garbage dumps) would greatly reduce the prevalence of pathogens in such animals.

Pigs (Feral)
A study stemming from the 2006 spinach outbreak confirmed the first known isolation of *E.coli* 0157:H7 from feral pigs in California (Jay et al. 2007). Of 87 samples, 14.9% tested positive. However, a subsequent study of wild pigs conducted on the Central Coast of California in 2007 and 2008 found that one of 184 (0.54%) tested positive for *E.coli* 0157:H7 (CDFG 2009). Feral pigs may also carry other pathogens, such as

Cryptosporidium parvum and *Giardia* (Atwill et al. 1997, Witmer et al. 2003). *E.coli O157* was also isolated from a single wild boar in Sweden (Wahlström et al. 2003).

Deer
Of 311 black-tailed deer sampled on the Central Coast of California in 2007 and 2008, none (0%) tested positive for *E.coli* 0157:H7 (CDFG 2009). Research on deer sharing the range with cattle showed 0% of deer testing positive for *E.coli O157:H7* in Texas (Branham et al., 2005), 0.3 to 1.8% testing positive in Louisiana (Dunn et al., 2004), and 0.3% testing positive in Nebraska (Renter et al., 2001). Fischer et al (2001) found that 0-0.6% of wild white-tailed deer sharing a range with cattle showed signs of *E.coli* 0157:H7. Both Fischer et al. (2001) and Dunn et al. (2004) concluded that wild deer are not a major reservoir of *E.coli* 0157:H7 in the southeastern United States. In another study of white-tailed deer sharing a rangeland with cattle in Kansas, *E.coli 0157:H7* was isolated from 2.4% of deer (Sargeant et al. 1999).

Rodents
According to Meerburg et al. (2004), rodents can be divided into two groups: field rodents and commensal rodents, such as house mice and rats. Whereas commensal rodents may be in closer contact with human and livestock waste, field rodents that are kept separated from these sources of contamination have a much lower prevalence of pathogens.

A recent review of studies by the University of California Cooperative Extension of Monterey County pointed out that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Of 61 rabbits and 24 mice sampled on the Central Coast of California in 2007 and 2008, none (0%) tested positive for *E.coli* 0157:H7 (CDFG 2009). Based on the studies reviewed, it appears unlikely that these rodents will be found to be a common or important source of *E.coli* O157:H7 and other pathogenic strains. This is due to the prevalence of rodent carriers in many of the studies having been associated with dairy or beef cattle facilities. When rats have tested positive for *E.coli*, all the collected animals were living in and around confined cattle operations. (Salmon et al. 2008, Cizek et al. 1999, Rahn et al. 1997). In addition, Hancock et al. (1998) did not find any *E.coli* 0157:H7 from 300 samples of rodents on cattle farms in the Pacific Northwest. Nielsen et al. (2004) found 2 out of 10 rats living in close proximity to cattle and feces sampled to carry other pathogenic forms of *E.coli* on farms in Denmark. Confined livestock operations should be managed to minimize attracting rodents and exposing rodents to livestock (Meerburg et al. 2004).

Other Mammals
Of 16 striped skunks and 17 opossums sampled on the Central Coast of California in 2007 and 2008, none (0%) tested positive for *E.coli* 0157:H7 (CDFG 2009). Of 51 coyote sampled on the Central Coast of California in 2007 and 2008, one (2%) tested positive for *E.coli* 0157:H7 (CDFG 2009). Of 58 tule elk sampled on the Central Coast of California in 2007 and 2008, two (3.4%) tested positive for *E.coli* 0157:H7 (CDFG 2009).

Birds

Scientific studies reference the role of wild birds as possible, but unlikely reservoirs of pathogens. Most studies have looked at pathogens carried by gulls, which are often associated with a dependence on human waste for food, and fewer studies have looked at other types of wild birds. However, the literature reviewed suggests that commensal birds living in proximity to human or domesticated animal activity/waste have higher incidence of carrying pathogens than other wild birds, such as woodpeckers, chickadees, and nuthatches.

A study conducted on the central coast of California found that none (0%) of 73 birds sampled in 2007 and 2008 tested positive for *E.coli* 0157:H7 (CDFG 2009). Brittingham et al. (1988), studied passerines and woodpeckers in Wisconsin, finding that of 364 birds 0% showed signs of *Salmonella* and 1% showed signs of *E.coli* 0157:H7. Hancock et al. (1998) found that 0% of wild birds tested on cattle farms in the Pacific Northwest showed signs of *E.coli* 0157:H7. Converse et al. (1999) sampled feces from Canada Geese in Massachusetts, New Jersey, and Virginia and found no signs of *E.coli* 0157:H7. Although low frequencies of *Salmonella* and *Listeria* were found, the authors indicate that the risk of geese spreading disease is minimal.

In another study in Sweden, Palmgren et al. (1997) found that, of 50 gulls sampled, 4% contained *Salmonella* isolates and of 151 birds (including both gulls and wild passerines) none contained *E.coli* 0157:H7 isolates. In a survey of wild birds in England, mostly gulls, an average of 2% of isolates from birds contained *E. coli*. 0157:H7 (Wallace et al.1997). In England, Fenlon (1981) showed that of 1,241 seagull feces samples, 12.9% contained *Salmonella*, most likely from nearby sewage outfalls. Studies of European starlings on dairy farms show a 1.1% to 3% incidence rate of *E. coli* 0157:H7 (Wetzel 2005, LeJeune et al. 2008). On Ohio dairy farms *E. coli* 0157:H7 was detected in starlings during the fall but not during the winter, suggesting seasonal variation in carriage rates (Wetzel 2005). Wetzel (2005) also found starlings carry *Campylobater* (25.3%) and *Salmonella* (2.8%) on Ohio dairy farms. The starling is a diversified and opportunistic feeder, having more exposure to possible sources of contamination (Morishita et al. 1999).

Amphibians and Reptiles

Amphibians and Reptiles have been referenced as possible, but unlikely reservoirs of human pathogens, but data is limited and no local data currently exists. The Center for Disease Control (CDC) lists amphibians (such as frogs, toads and salamanders) and reptiles as possible carriers of S*almonella* and other pathogens (CDC 2003). While Grey et al. (2007) demonstrated that amphibians can carry food borne pathogens at some stages of their lifecycle, the study was conducted in an artificial laboratory setting where amphibians were inoculated with pathogens at much higher levels than would be found in the environment. Richards et al. (2004) completed a study of free-living reptiles in Virginia. Of 75 reptiles surveyed, none (0%) tested positive for *Salmonella*.

Invertebrates

Scientific studies reference the role of invertebrates as possible, but unlikely reservoirs of pathogens but no local data currently exists. Generally, the prevalence of human pathogens in invertebrates is very low. Sproston et al. (2006) looked at slugs in Scotland and found that of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7. A 1999 study (Iwasa et al.) conducted on a cattle ranch in Japan found that 2% of commensal flies tested positive for *E.coli* 0157:H7.

VECTORS FOR PATHOGEN MOVEMENT IN THE ENVIRONMENT

Pathogens can be transferred to crops through contaminated water, contaminated soil particles that become airborne, or direct contact with infected animal feces (wet or dry). While efforts to reduce the overall prevalence of human pathogens in the environment (as discussed above) are important, minimizing the risk of crop contamination involves the identification, treatment and/or control of likely vectors for contamination.

Most microbial contamination of leafy greens and fresh vegetables is stated to be associated with improperly composted manures, irrigation water containing manure or sewage, contact with domestic animals, contact with wild animals, contaminated wash water, human handling, contaminated ice during storage, or contamination during packaging, slicing or shredding, and food preparation (Beuchat and Ryu 1997, Beuchat 2006, Tauxe 1997, Francis et al. 1999, Rangel et al. 2005).

Pathogens have been shown to be transferred from manure to the surface of crops on contaminated soil particles. Once on the surface of the crop, pathogens may persist for long periods of time. Islam et al. (2005) found that *E. coli* 0157:H7 could survive on planted carrots contaminated by manure for over 150 days. Beuchat (1999) inoculated harvested lettuce with bovine manure and found that *E. coli* 0157:H7 persisted for over 15 days during cold storage.

Vector: Water

While crop contamination can result directly from manure application and feces from domestic livestock operations, water may be a more likely vehicle of contamination (Suslow et al. 2003). Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations, (Hager et al. 2004, CCRWQCB 2002 and 2004) and diverting these waterways for irrigation could lead to crop contamination. Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). However, growers in the central coast of California typically use groundwater and not surface water diversions. Still, wells should be inspected for possible contamination, especially older and shallow wells (Suslow et al. 2003).

Water draining from open lot cattle/grazing operations or concentrated animal feeding operations can contain contaminated runoff (Koelsch et al. 2006). Vinton et al. (2004) show that leaching between fields can occur through field drains and/or surface run-off. In some cases, runoff from open lot (pipe drained) sheep grazing areas has been shown to result in more contamination than runoff from concentrated sheep facilities with slurry application (Vinton et al. 2004). Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). However, due to the possibility of water contamination from run-off, it is recommended that food crops not be irrigated with water of unknown sources and microbial content (Solomon et al. 2002b).

Lastly, flooding of nearby contaminated water bodies onto fields could also result in contamination of crops.

The majority of studies indicate that contamination most likely occurs through direct contact between crops and contaminated water; however, recent studies have investigated the possibility for *E. coli* 0157:H7 to enter plant tissue through the root system. While these studies used *E. coli* 0157:H7 concentrations in irrigation water far exceeding any that would be found on an agricultural field, they did show that if concentrations are very high, it is possible for *E. coli* 0157:H7 to enter plant tissue through the root system. Solomon et al. (2002a) inoculated irrigation water with extremely high concentrations of *E. coli* 0157:H7. In this situation, lettuce was contaminated without direct surface exposure to the pathogen, but rather by uptake of the pathogen through the root system. However, the authors of the study do concede that the concentrations of *E. coli* 0157:H7 used far exceed any that would be found on an agricultural field. Wachtel et al. (2002a) also found that contamination can occur through plant roots at exceedingly high concentrations. They state that the ability for contamination to occur through the root system is dose dependent, although the specific thresholds are unclear. Again, the authors state that the presence of such high levels of contamination on agricultural fields is very unlikely. In a more realistic scenario, Wachtel et al. (2002b) investigated cabbage that was irrigated with creek water contaminated with sewage from a recent spill. Here, they found that although the roots were contaminated with serotypes of *E. coli*, the edible portions of the plant were not. In the absence of experimental inoculation of water with very high concentrations of pathogens, root uptake is an unlikely route of contamination.

Studies have also investigated the effects of different methods of irrigation as well as how long fields can remain contaminated after exposure to pathogens. Methods of irrigation have been shown to affect the chances of contamination. Solomon et al. (2002b) found that lettuce exposed to *E. coli*. 0157:H7 were more likely to test positive for pathogen presence if they were sprayed by sprinklers with the inoculated water than if they were exposed through surface irrigation. Solomon et al. (2003) also found that repeatedly spraying crops with contaminated irrigation water increases chances of crop contamination. Fields which have been exposed to contaminated water may result in the contamination of the soil for extended periods of time. Islam et al. (2005) treated fields of vegetable crops with irrigation water contaminated with *E. coli* 0157:H7. While the levels of *E. coli* 0157:H7 used in the study were far greater than any that would be likely to exist on an agricultural field, the researchers found that *E. coli* 0157:H7 survived for at least 154 days in the soil.

A review of studies indicates that diverse microbial organisms in soil may reduce the potential for pathogen contamination (Suslow et al. 2003). Suppression of pathogens can occur through the antagonistic capacity of the resident microbial flora. Johannessen et al. (2005) illustrate how naturally occurring bacteria in soil reduce the abundance in *E. coli* 0157:H7 and inhibit the pathogen from uptake into lettuce tissue through the roots. Soil with diverse microorganisms may contain *Pseudomonas fluorescens*, a bacterium known to compete with and inhibit the growth of *E. coli*. 0157:H7. In their study, Johannessen et al. (2005) discovered that transmittance of *E. coli*. 0157:H7 from inoculated soil to lettuce did not occur and suggest that the presence of *Pseudomonas fluorescens* in the soil or on the plant roots may be responsible for preventing transmittance. This study indicates that microbial pathogens may flourish in soils that lack a balance of natural microbial diversity, and that soil management should aim to encourage the diversity of microbial organisms.

Fields with more organic matter have been shown to foster an increased abundance and diversity of soil microbes (Gunapala et al. 1998, Lundquist et al. 1999, Bulluck et al. 2002). Organic fields have been shown to host higher diversity and biomass of soil microbial and faunal communities and have been correlated with higher suppression of soil-borne plant pathogens (Van Bruggen 1995). This pattern may also hold for the suppression of pathogens such as *E. coli* 0157:H7.

E.coli has been shown to persist in soil for days to months and in some cases for years depending on site environmental conditions (e.g. Crane and Moore 1986, Unc et al. 2006, NRCS 2007). Studies have also shown that *E.coli* bacteria can persist in sediment in drainage and irrigation canals (NRCS 2007). The environmental variables that seem to have the strongest effect on fecal source bacteria survival in soil are pH, temperature, moisture, nutrient supply, and solar radiation (Crane and Moore 1986).

Studies have shown that generic *E. coli* can increase in numbers and persist longer in soil that has been amended with chemical or organic fertilizers (Estrada et al. 2004, Pourcher et al. 2007, Unc et al. 2006). The Canadian study of Unc et al. (2006) conducted 20 day trials investigating generic *E.coli* population responses to biosolid applications to soil that had been without agriculture, irrigation or significant wildlife activity for 10 years. After the addition of fresh biosolids to fresh soil, the *E.coli* rose immediately then decreased but did not return to original levels after 20 days. The researchers also found that when fresh biosolids were added to sterile soil, there were no significant changes in *E.coli* numbers over the 20 days of testing. Unc et al. (2006) indicated that the addition of organic nutrients to soil may result in an increase in the numbers of *E.coli* bacteria independent of the addition of *E. coli* in the waste material.

Estrada et al. (2004) monitored the behavior and evolution over time of enterobacteriaceae (faecal coliforms and *E.coli*) in Spain. After 80 days of experimentation the populations of fecal coliforms and *E. coli* had decreased considerably and were undetectable in assays. Over the same period, however, mixtures containing chemical fertilizer (calcium ammonium nitrate) observed a considerable increase in the micro-organism populations studied (Estrada et al. 2004). Pourcher et al. (2007) investigated the survival of enteric micro-organisms in sewage sludge following direct land-spreading in Europe. Sludge was spread at a rate of 80 m^3/ha and the concentration of fecal indicators fell slowly with an observed decrease of 1.2-1.8 logarithmic units over 2 months (but without initial levels in the soil being reached). Enteroviruses were not detected after 2 weeks and *Clostridium perfringens* remained stable during the study period (Pourcher et al. 2007). Though studies were not found that investigated these patterns with pathogenic *E.coli*, it is possible that this pattern may hold for pathogenic strains*.*

Contaminated soil and water should be prevented from moving into cropped fields or it should be treated and cleaned prior to coming into contact with cropland or directly onto crops. While more research is needed to specifically identify effective means to reduce risks of crop contamination, certain practices may reduce the spread of microbial pathogens through water.

Vector: Air

Pathogenic bacteria can also be transferred through the air attached to dry manure, dry soil, or dust. Many studies have looked at the bacterial content of air in confined animal operations and have found significant levels of airborne pathogenic bacteria (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001). These studies and others focused on the impacts of airborne pathogens on worker respiratory health. Spaan et al. (2006) looked at airborne pathogenic bacteria found in three different agricultural sectors: the grains, seeds and legumes sector, the horticulture sector, and the animal production sector. They found that workers in the grains, seeds, and legumes sector were exposed to the highest levels of airborne pathogens. Lee et al. (2006) also looked at airborne pathogens in grain operations and found that exposure to dust and microorganisms after grain harvest exceeded levels found in animal confinements. All of these studies focused on the health effects on humans through direct inhalation. No studies were found that looked at the transport of airborne pathogens onto cropped fields. However, these studies do indicate that pathogens may be airborne and could reach crops if they are in close proximity to confined animal operations or grain harvesting operations.

Although less is known about the risks of airborne contamination through dry manure, soil, and dust, measures may be taken to reduce the likelihood of airborne pathogen transport. Airborne contaminated soil and dust should be prevented from moving into cropped fields or directly onto crops. More research is needed to identify the risks of airborne crop contamination and the best methods to reduce possible risks. Some measures may include, but are not limited to, the installation of vegetated barriers such as windbreaks or hedgerows to limit the movement of dry soil and manure particles as well as provide dust management. Plastic covers or concrete blocks may be used to contain sources of airborne contamination, such as drying manure piles.

Vector: Animals

Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

Domestic Animals

Most studies documenting human illness associated with domestic animals involved cases of direct animal-human contact (CDC 2003, Sato et al. 2000).

Generic and pathogenic forms of *E. coli* are found in fecal material which can contaminate soil in cropped fields (Francis et al. 1999). The most important reservoir of cerocytoxin producing *E. coli* (such as *E. coli* 0157:H7) are domesticated ruminants, primarily cattle (Nielsen et al. 2004). In cases where domesticated animals or livestock reside in close proximity to cropland, measures to prevent wandering animals are recommended. Physical barriers such as fences and vegetated buffers may be effective barriers to prevent movement of livestock onto fields.

Due to the vast quantities of manure created by cattle in the United States and subsequent issues with disposal, applying manure to fertilize soil has traditionally been a common method of disposal. Manure is a source of macro and micronutrients and is an effective fertilizer, often used as an alternative or supplement to applying synthetic fertilizers to soil. However, manure can incubate pathogens and subsequently contaminate crops in the field (Natvig et al. 2002). It is important to note that raw manure application in the Central Coast Region has already been largely phased out and is strictly regulated for organic growers.

There are several ways to reduce the possible contamination of crops from soil via manure. Composting is an effective way to treat manure and decrease risks to food safety. The heat that occurs during composting kills bacteria, including harmful pathogens (Jiang et al. 2003). Non-composted or improperly composted manures are much more likely to harbor pathogens. Another more passive way to reduce pathogen populations is to store or age manure before application (Ingham et al. 2005), or to wait substantial lengths of time before harvesting from fields where manure was applied. The National Organic Standards require at least 120 days between non-composted manure application and crop harvest for crops where edible portions are in direct contact with soil (NOP 2006). Islam et al. (2004) and Islam et al. (2005) explored how long pathogens from non-composted manure can survive in the fields of different vegetable crops in Georgia. They found that depending on the type of crop planted, *E. coli*. 0157:H7 can survive for more than six months in the soil. Because this variation exists, the 120-day interval may need to be reevaluated to incorporate regional climate and the type of crop planted (Islam et al. 2005). Ingham et al. (2005) also studied fertilization-to-harvest intervals and recommended that the interval should not be shortened less than 120 days. Extreme caution should be used when using non-composted manure. Again, the use of non-composted manure has been largely phased out of the lettuce and leafy greens sector in the Central Coast.

As discussed above, diverse microbial organisms in soil may reduce the potential for pathogen contamination (Suslow et al. 2003). Suppression of pathogens and inhibition of pathogen uptake can occur through the antagonistic capacity of the resident microbial flora.

Wild (Non-Domestic) Animals

Studies investigating different wild animals as possible vectors for food-borne pathogens are limited in the types of species and geographic areas being investigated. Existing research suggests that wild animals associated with natural habitats and occurring at natural population levels are unlikely vectors for crop contamination. Accordingly, animals such as invertebrates, field rodents, deer, and birds associated with natural environments should pose a minimal risk to food safety.

At very high population levels occurring at a particular location, however, wild animal species with low incidence of human pathogens may pose an increased threat for crop contamination due to their sheer numbers. In general, greater plant species and structural diversity of non-crop vegetation near cropped fields will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species. Deterring or limiting access that animals with high population densities have to crops would help reduce the risk of contamination from direct animal contact.

Some commensal species, animals typically associated with human or livestock waste, have been found to have higher rates of human pathogens (up to 12%) than wild animals associated with natural environments. It is important to reduce the presence of trash or human waste in and around cropped fields, as well as restricting animal access to the waste. Deterring or limiting access animals associated with human or livestock waste have to crops would help reduce the risk of contamination from direct animal contact.

Deer

Though deer are currently listed by the Leafy Green Marketing Agreement Board accepted Commodity Specific Food Safety Guidelines for Lettuce and Leafy Greens (June 13, 2008) as an animal of significant risk, existing research suggests and many expert biologists consider deer to pose a relatively low risk for possible crop contamination. However, if large populations of deer are known to frequent a ranch, management measures may be considered to limit access.

Pigs (Feral)

Feral pig are also listed by the Leafy Green Marketing Agreement Board accepted Commodity Specific Food Safety Guidelines for Lettuce and Leafy Greens (June 13, 2008) as an animal of significant risk. Since some of the largest mainland feral pig populations occur on the Central Coast of California and feral pigs have been implicated by officials as a potential source of contamination in the 2006 spinach outbreak (CDHS and FDA 2007), growers may want to limit access by these animals to cropland. According to expert biologists, feral pigs are highly mobile and may be attracted to sources of water or food in or near cropland. Accessible sources of food and water can be minimized or enclosed with wire fences to reduce chances of attracting feral pigs. Other management measures such as fencing, hunting and trapping may be needed if large populations of feral pigs are known to frequently visit fields.

Other Animals

As stated above, animals such as invertebrates, field rodents, deer, and birds associated with natural environments should pose a minimal risk to food safety. Based on the studies reviewed, Salmon et al. (2008) suggest that unless future research findings indicate otherwise, it is hard to justify extensive trapping, baiting, fencing, and vegetation clearing for the specific purpose of reducing [field rodent] vectoring of *E. coli* 0157:H7.

Although Sproston et al. (2006) found that slugs in Scotland can carry *E.coli* 0157:H7 on their external surface for up to 14 days, their very low incidence *E.coli* 0157:H7 makes them an unlikely vector for crop contamination.

ENVIRONMENTAL AND HUMAN HEALTH BENEFITS OF CONSERVATION

Conservation practices used on or adjacent to cropped fields to improve environmental quality include but are not limited to: cover crops, basins, hedgerows, irrigation water management, grassed waterways, filter strips, nutrient management, contour buffer strips, and constructed wetlands. Many of these practices, when properly designed and maintained, may also help minimize the presence, persistence and movement of pathogens in the environment.

Constructed wetlands are also a recommended conservation practice to improve water quality. They can be used to treat surface runoff and wastewater from livestock operations and agricultural fields. Constructed wetlands are applied to reduce the concentrations of metals, pesticides, nutrients, fertilizers, and animal wastes in effluent waters and also provide wildlife habitat (NRCS 2008). Constructed wetlands have been shown to effectively reduce the presence of pathogenic bacteria and are used in sewage and agricultural wastewater treatment (Mallin et al. 2001, Hench et al. 2003, Greenway 2005, Oliver et al. 2007). In a wetland, pathogens are removed through filtration in dense vegetation, sedimentation of particles carrying pathogens, microbial competition and predation, high temperatures, and UV disinfection (Hench et al. 2003, Nokes et al. 2003, Greenway 2005). Nokes et al. (2003) show that large, as well as small-scale, constructed wetlands in Arizona can reduce fecal coliforms by up to 97%. Hench et al (2003) tested the effectiveness of constructed wetlands in West Virginia at removing specific pathogenic bacteria. They show that within a 23-52 hour wetland residence time *Salmonella* can be reduced by 93-96%. They also found that wetlands which contain vegetation remove significantly more pathogens than un-vegetated wetlands.

Hill and Sobsey (2001) also report a 96% reduction in *Salmonella* in wastewater from a pig farm after passing through a constructed wetland in North Carolina. Decamp and Warren (2000) found that wetlands reduced between 96-99% of *E. coli* in the influent water. Lastly, studies in Australia show that constructed wetlands can remove 95% of pathogens and indicator organisms (Greenway 2005). Through their literature review, Greenway (2005) conclude that surface-flow constructed wetlands with a high diversity of macrophytes can reclaim water and produce effluent meeting microbial standards for agricultural irrigation. Again, although most of these studies did not test for *E. coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. With the development of additional design standards specifically targeted to reduce pathogenic bacteria, constructed wetlands may provide a highly effective and reliable means to reduce water-borne pathogens.

Burton (2003) found that restoration of native wetland and associated native dry upland plant communities and ponds at two sites in north Monterey County resulted in a very significant reduction of pest rodent problems along farm edges, thereby reducing and in most areas eliminating the need for rodent control adjacent to these restoration sites. Pest rodent populations were reduced through the establishment of large areas of native stands of vegetation and ponds, attracting a greater diversity of small mammals and not supportive of unusually large populations of rodents. They also removed stands of non-native vegetation that supported high number of rodents or repeatedly mowed the non-native vegetation to increase predatory bird hunting efficacy.

Vegetated Treatment Systems (VTS) have also been shown to reduce the presence of pathogens. A Vegetated Treatment System is a planted area that water is directed through to improve water quality. Common practices in these systems include grassed waterways, vegetated ponds or basins, and constructed wetlands. Koelsch et al. (2006) reviewed studies and found approximately 40 field trials indicating that vegetative systems with a settling basin can achieve significant pollution reductions, including pathogenic bacteria. Collection ponds, diversion berms, or vegetated buffers can be used to divert contaminated run-off away from other water sources (Suslow et al. 2003). Settling basins and collection ponds near concentrated livestock operations may be used to contain contaminated runoff (Koelsch et al. 2006).

Other studies indicate that fecal coliform reductions greater than 90% are regularly observed from vegetated treatment systems (Kadlec and Knight 1996). Fecal coliform is readily used as an indicator of possible pathogenic bacteria. These practices can reduce the presence of pathogenic bacteria in waterways near fields and significantly reduce the possibility of contamination if flooding occurs. In general, the literature stresses the importance of knowing the sources of irrigation and flood water and to be aware of possible sources of contamination.

Grassed waterways are natural or constructed channels with established vegetation. The purpose of grassed waterways is to convey runoff, to reduce overall erosion, and to improve water quality (NRCS 2008). Filter strips are areas of vegetation for removing sediment, pollutants, and organic matter from run-off water. This occurs through filtration, deposition, infiltration, and decomposition of materials before they enter the effluent water flow. Filter strips are recommended along field edges, waterways, and around livestock areas to reduce pollution (NRCS 2008). Contour buffer strips are narrow strips of permanent vegetation on sloped cropland aimed to reduce erosion, reduce the transport of contaminants, and provide wildlife habitat (NRCS 2008).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Contamination in overland flow may also be reduced by filtration through perennial forage and/or grasses. Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. They used known quantities of *E. coli* and measured transport in surface water run-off. Although the efficiency of filtration depends on water flow, soil type, and slope, they found that vegetative buffers are an effective way to reduce inputs of waterborne *E. coli* into surface waters. Although this study did not focus specifically on *E. coli* 0157:H7, generic *E. coli* is an indicator of potential pathogen contamination (Suslow et al. 2003, Tate et al. 2006). Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002).

According to the USDA Natural Resources Conservation Service Field Office Technical Guide standards (NRCS 2008), hedgerows are created by planting woody plants or perennial bunchgrasses that are at least 3 feet tall in a linear design. Possible functions of hedgerows are to create living fences, provide food and habitat for wildlife, barriers for odors and dust, and to improve the landscape appearance. Improvements in water quality may also occur through reduced erosion and sediment trapping (NRCS 2008).

Practices that keep phosphorus on the land and in the root zone, such as cover crops, should also keep pathogens on the land (NRCS 2007). Utilizing cover crops also improves organic matter content of soil and may therefore inhibit pathogen presence by fostering a diverse microflora (NRCS 2007). Good irrigation and nutrient management can minimize excess water and nutrients in the soil, prevent contaminant movement into surface and groundwater, and maintain or improve chemical and biological condition of soil (NRCS 2008), which can help reduce pathogen populations, persistence and movement in the environment.

The literature in this review indicates that certain conservation practices, when properly designed, may be useful in addressing current food safety problems. Although the goal of many conservation practices is to reduce erosion and pollution from fertilizers and pesticides, these practices can also remove and control harmful microbes. Many of the ways to address waterborne pathogens described earlier are conservation practices already being promoted to improve water quality and protect wildlife. As detailed earlier, vegetated buffers, vegetative treatment systems, and constructed wetlands have been found to be effective ways to reduce waterborne pathogens. These practices may be designed specifically to increase effectiveness in reducing certain bacteria. For example, constructed wetlands can be designed to maximize the removal of pathogens (Greenway 2005). Although most of these studies did not test *E. coli* 0157:H7 specifically, bacteria such as fecal coliform and generic *E. coli,* which were tested, are often used as indicators for pathogens. With further research, design standards tailored specifically to pathogen removal, including *E. coli* 0157:H7, could be created for several conservation practices.

Ways to make the adoption of these practices more feasible can also be explored. For example, Nokes et al. (2003) show that small-scale vegetated wetlands can be equally effective and efficient in the removal of harmful bacteria as large-scale constructed wetlands. With current land values in California and the costs associated with construction, these small-scale wetlands as well as vegetated buffers and treatment systems may be easier to apply throughout the region.

Many of the same conservation practices have multiple objectives and include enhancing the abundance and diversity of wildlife in agricultural settings. With significant numbers of endangered and threatened species in California and over a third of the total land in agriculture, integrating wildlife habitat onto agricultural landscapes (especially in riparian zones) may be critical for species preservation. Planting non-crop vegetation and creating waterways is likely to attract wildlife. There are concerns that adopting conservation practices will therefore increase the spread of food-borne pathogens. Food safety guidelines often recommend removing non-crop vegetation or anything that may attract wildlife. Given suggested conservation practices and Endangered Species Act requirements, growers are therefore receiving conflicting messages regarding wildlife. However, as the studies reviewed in this paper indicate, wildlife associated with natural environments have a very low likelihood (around 1%) of carrying pathogens such as *E. coli*. 0157:H7. Efforts to keep animals which are associated with human waste (such as gulls) and especially cattle away from croplands are more likely to reduce risks of contamination. Conservation practices aim to attract the types of wildlife that studies indicate are unlikely to cause contamination. In addition, habitat provided by conservation practices could also attract and harbor natural predators, such as birds of prey, which can function to control the growth of small wildlife populations.

There is a concern that conservation practices will increase the chances of flooding on agricultural fields and contaminate crops with pathogens. Whether water bodies introduced or modified through conservation projects will affect the likelihood of flooding depends on site specific conditions and project design. Some conservation practices could actually reduce the chances of flooding. According to Zedler (2003), wetlands not only provide water quality improvement but also provide flood abatement. When designed properly, wetlands can moderate and prevent floods: flood peaks are reduced and delayed due to temporary water storage in the wetlands and either downstream or groundwater drainage (Potter 1994). However, how well water bodies function to mitigate flood events can be limited if capacity is constrained. Although having ponds or canals around fields could result in flooding, if mitigation measures are taken, flooding can be avoided. The USDA standards for grassed waterways state that “all grassed waterways shall have an outlet with adequate capacity to prevent ponding or flooding damages.” (NRCS 2008). Flooding is a valid concern regarding food safety and should be avoided when possible. If flooding of agricultural waterways does occur, the studies presented in this review indicate that highly vegetated waterways should have lower levels of microbial pathogens than non-vegetated waterways. Again, it is the source of flood water that determines whether a flood event presents a significant contamination risk.

It is interesting to compare the food safety and good agricultural practice guidelines between the United States and the European Union. Although there have been similar problems with outbreaks of food-borne illness in Europe, their guidelines do not call for the removal of non-crop vegetation and wildlife from the agricultural environment. “Good farming practice” is common sense farming which cares for the environment and meets minimum hygiene and animal husbandry practices, according to the European Union Department of Agriculture, Food, and Rural Development (2001).

It is evident from the literature that efforts to implement and maintain on-farm practices to protect water quality and enhance the environment must incorporate food safety considerations, considering possible factors that could serve to decrease or possible increase pathogens and their movement in the farm environment. These potential food safety benefits and risk factors will vary depending on the conservation practice under consideration, the environmental setting, as well as the farming operation and characteristics. Practice-specific information is available in the “Food Safety Considerations for Conservation Planning” fact sheets located in Appendix 1.

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APPENDIX 1
Food Safety Considerations for Conservation Planning Fact Sheets

1. **Cattle Trough (614)**
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Food Safety Considerations for Conservation Planning
CATTLE TROUGH - Standard Practice Code 614

PRACTICE DESCRIPTION

Definition: A trough or tank, with needed devices for water control and wastewater disposal, installed to provide drinking water for livestock.

Purpose: To provide watering facilities for livestock at selected locations that will protect vegetative cover, streams and wetlands. Troughs serve as an alternative water source and reduce the impact of livestock on natural waterways.

Criteria: Adequate capacity to meet the water requirements of the livestock. Include the storage volume necessary to carry over between periods of replenishments. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 614).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Cattle troughs can reduce the likelihood of surface water contamination and movement of pathogens through waterways by reducing or eliminated cattle/animal presence in natural waterways. Cattle troughs can also reduce flooding.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto nearby cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including livestock, wildlife, and storm water runoff (NRCS 2007). Troughs provide a water source that aids in maintaining livestock in predetermined upland locations and reduces the presence of livestock around waterways and thereby lessens the risks of surface water contamination. Proper placement (away from natural waterways and cropland) and maintenance of cattle troughs will significantly reduce the presence and movement of pathogens though the landscape and natural waterways.

Rivers, creeks, and streams can contain pathogenic bacteria from upstream

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. Proper placement of cattle troughs can reduce impacts to vegetated cover, streams and wetlands (NRCS 2008). By reducing the input of sediment into waterways, cattle troughs may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Design and Management Considerations to Reduce Food Safety Risk:
Cattle trough placement should reduce access of livestock and animals to waterways and proximity to cropland; upland sites away from waterways, swales and fields that grow fresh produce are ideal. Include a vegetated filter strip or protect naturally-vegetated grassland downslope of the trough to intercept overland flow from areas of concentrated manure around trough.

FOOD SAFETY CONSIDERATIONS: *AIR*
General Considerations: Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), cattle troughs may increase the potential for air-born movement of pathogens by increasing animal densities. High numbers of animals damage vegetation immediately surrounding the trough, and their associated feces may become pulverized and air-born.

Design and Management Considerations to Reduce Food Safety Risk:
If a trough is located up-wind or near produce fields, consider placing gravel or other ground protection to minimize wind-borne movement of pulverized manure and dust.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Cattle troughs have the potential to attract wild and domestic animals for watering and possibly breeding (amphibians and insects, only). Water residence time and the quantity of water present in the trough may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to certain habitats and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to a water source such as a cattle trough.

According to wildlife biologists, wild and commensal birds, amphibians, and small and large mammals may utilize cattle troughs for watering. Amphibians and insects may potentially, but rarely utilize the trough for breeding.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Cattle troughs do not serve as primary habitat for any of these species, however, these species can be attracted to cattle troughs as a water source.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive fo *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:
Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with cattle troughs include amphibians, wild and commensal birds, small and large mammals, and insects. As stated above, studies suggest that wild animals (not domestic nor commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities.

Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have shown to have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Cattle troughs are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the trough.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Cattle trough placement should reduce access of livestock and animals to waterways and proximity to cropland; upland sites away from waterways, swales and fields that grow fresh produce are ideal. Troughs should be cleaned regularly to reduce transmission of disease and/or pathogens within or across species.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
CONSTRUCTED WETLAND - Standard Practice Code 656

PRACTICE DESCRIPTION

Definition: A constructed shallow water ecosystem designed to simulate natural wetlands.

Purpose: To reduce the pollution potential of runoff and wastewater from agricultural lands prior to release to water.

Criteria: Practice shall be designed as surface flow system consisting of adequate seepage control, a suitable plant medium, hydrophytic vegetation, and the structural components needed to contain and control flow. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 656).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Constructed wetlands can effectively capture and treat water that contains pathogens and reduce flooding.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003), and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed constructed wetland can be used to effectively reduce the movement of potentially contaminated soil as well as capture and treat potentially contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Runoff prevention and diversion structures including vegetated buffer areas can be used to divert contaminated run-off from irrigation away from other water sources (Suslow et al. 2003).

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of sediment into waterways, constructed

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

wetlands may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005). According to Zedler (2003), wetlands not only provide water quality improvement but also provide flood abatement. When designed properly, wetlands can moderate and prevent floods (Potter 1994), thereby reducing the risk of crop contamination from adulterated flood waters.

Constructed wetlands have been shown to effectively reduce the presence of pathogenic bacteria and are used in sewage and agricultural wastewater treatment (Mallin et al. 2001, Hench et al. 2003, Greenway 2005, Oliver et al. 2007). Pathogens are removed through filtration in dense vegetation, sedimentation of particles carrying pathogens, microbial competition and predation, high temperatures, and UV light disinfection (Hench et al. 2003, Nokes et al. 2003, Greenway 2005). Constructed wetlands have been shown to reduce fecal coliforms (up to 97%), *E.coli* (up to 96-99%), and *Salmonella* (up to 93-96%), and general pathogens and indicator organisms (up to 95%), depending on size, water residence time, and vegetation (Nokes et al. 2003, Hench et al. 2003, Hill and Sobsey 2001, Decamp and Warren 1999, and Greenway 2005). Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. None of these studies took place in California. With the development of additional design standards specifically targeted to reduce pathogenic bacteria, constructed wetlands may provide a highly effective and reliable means to reduce water-borne pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for constructed wetland design and placement. Pathogens of concern should be identified and the wetland designed to target the capture and treatment of these constituents of concern, as feasible. A constructed wetland should be situated in a location that does or can receive potentially contaminated surface drainage or flood waters. A constructed wetland should be designed to have no effect on or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*
General Considerations: Constructed wetlands can reduce wind-borne erosion and because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), may reduce the movement of sediment-associated pathogens when they incorporate bank or only intermittently wetted plantings.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for constructed wetland design and placement. Constructed wetlands should be designed to incorporate dense ground cover on banks or intermittently wetted areas to minimize on-site dust movement (when dry).

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*

Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Constructed wetlands have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in constructed wetlands can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the wetland may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to constructed wetlands. Wildlife attraction to wetlands is strongly determined by the type of vegetation used and proximity to other open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, constructed wetlands do not serve as primary habitat for any of these species. However, because of its potential as a food source and shelter, vegetation used in constructed wetlands may attract animals. According to experts, deer do not typically forage on short grasses. Expert opinions from wildlife biologists indicate that vegetation used in constructed wetlands is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive fo *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as

Cryptosporidium parcum and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurance, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>*Other Animals*</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with constructed wetlands include amphibians, wild/song and commensal birds, small mammals and insects. According to wildlife biologists, waterfowl and amphibians may use the constructed wetlands as habitat, reproduce in or nearby them, and/or utilize them when migrating. Waterfowl and amphibian presence depends largely on the aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals may also be associated with a constructed wetland. All of these species may use constructed wetlands as habitat, reproduce in or nearby them, and/or utilize them when migrating. Birds (excluding waterfowl) and small mammal presence depends largely on the emergent aquatic vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to constructed wetlands for feeding, watering and migrating; their presence is largely determined by the quantity of water present as well as emergent aquatic vegetation characteristics and adjacent upland habitat.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Seagulls, which seek open water to land on, are the most well-studied commensal bird possibly attracted to constructed wetlands. Studies have found gulls have a low incidence (0 to 2%) of *E. coli*. 0157:H7 (Wallace et al.1997; Palmgren et al. 1997), but a moderate to high incidence (4 to13%) of *Salmonella* (Palmgren et al. 1997; Fenlon 1981). Seagulls are not attracted to water with aquatic plant cover. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have shown to have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Burton (2003) found that restoration of native wetland and associated native dry upland plant communities and the removal or mowing of non-native vegetation in north Monterey County resulted in a very significant reduction of pest rodent problems along farm edges. Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Constructed wetlands are most likely to attract the low-risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the wetland.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Evaluate animals that may be attracted to constructed wetland based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the constructed wetland site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for constructed wetlands should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, a greater variety of plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

When larger woody vegetation is prescribed for a constructed wetland and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the wetland area that is more attractive than the farm crop to prevent animal movement into the fields. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals. Maintaining a low-growing perennial or mowed buffer between the wetland area and the crop may likewise reduce large animal movement into the cropland.

If birds attracted to open water are a concern, such as seagulls, they may be deterred by planting diverse aquatic vegetation with a varied plant structure. If upland or terrestrial animals are of concern, you may avoid upland planting and focus on establishment of aquatic vegetation essential to the water quality function of this practice. If pest rodent populations are a concern they may be reduced through the establishment of native stands of upland vegetation and removal and/or mowing of non-native stands of upland vegetation, attracting a greater diversity of small mammals and increasing predatory bird hunting efficacy, respectively. If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the constructed wetland or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
COVER CROP - Standard Practice Code 340

PRACTICE DESCRIPTION

Definition: Grown in row crop systems and vineyards where seasonal benefits of a cover crop are needed. They control erosion, add organic matter and nutrients to the soil, capture and recycle or redistribute nutrients in the soil profile, improve soil tilth and increase infiltration and aeration of the soil. Cover crops have a filtering effect on movement of sediment, pathogens, and pollutants attached to sediment.

Purpose: Control erosion when the major crops do not furnish adequate cover. Add organic material to the soil and improve infiltration, aeration, and tilth.

Criteria: Includes temporary cover crops as well as long term, perennial or reseeding annual cover crops. Selected species must be compatible with the planned management system. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 340).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Cover crops can effectively reduce the transport of pathogens, inhibit their presence in the soil, treat water that may contain pathogens and reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed cover crop can be used to effectively reduce the movement of potentially contaminated soil as well as capture and treat potentially contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Runoff prevention and diversion structures including vegetated buffer areas can be used to divert contaminated run-off from irrigation away from other water sources (Suslow et al. 2003).

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

contamination of crops. By reducing the input of sediment into waterways, cover crops may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Guber et al. (2006) concludes that pathogens move off the land in a similar manner to phosphorus. Practices that keep phosphorus on the land and in the root zone, such as cover crops, should also keep pathogens on the land (NRCS 2007b). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetative buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002). Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Cover crops may also inhibit pathogen presence by fostering a diverse microflora. A review of the literature by Suslow et al (2003) indicates that diverse microbial organisms in soil may reduce the potential for pathogen contamination. Suppression of pathogens can occur through the antagonistic capacity of the resident microbial flora. Johannessen et al. (2005) illustrate how naturally-occurring bacteria in soil reduce the abundance of *E.coli* 0157:H7 and inhibit the pathogen uptake into lettuce tissue through the roots. Soil with diverse microorganisms may contain a bacterium (*Pseudomonas fluorescens*) known to compete with and inhibit the growth of *E.coli* 0157:H7. In their study, Johannessen et al. (2005) discovered that transmittance of *E.coli* 0157:H7 from inoculated soil to lettuce did not occur and suggest that the presence of *Pseudomonas fluorescens* in the soil or on the plant roots may be responsible for preventing transmittance. This study indicates that microbial pathogens may flourish in soils that lack a balance of natural microbial diversity, and that soil management should aim to encourage the diversity of microbial organisms. Utilizing cover crops improves organic matter content of soil (NRCS 2007b). Fields with more organic matter have been shown to foster an increased abundance and diversity of soil microbes (Gunapala et al. 1998, Lundquist et al. 1999, Bulluck et al. 2002). Additionally, organic fields have been shown to host higher diversity and biomass of soil microbial and faunal communities and have been correlated with higher rates of suppression of soil-borne plant pathogens (Van Bruggen 1995). This pattern may also hold for the suppression of pathogens such as *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:

Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for cover crop design and placement. Pathogens of concern should be identified and the cover crop designed to target the capture and treatment of these constituents of concern, as feasible. A cover crop should be situated in a location that has or potentially has contaminated soil and/or that does or potentially receives contaminated water. A cover crop should be designed to have no effect on or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*

General Considerations: Cover crops can reduce wind-borne erosion and may reduce the movement of sediment-associated pathogens. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), planting bare ground with a cover crop could prevent possible transport of dust-born pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for cover crop design and placement. Cover crops should be designed to incorporate dense ground cover to minimize on-site dust movement.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*

Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Cover crops are designed using temporary vegetation consisting of a single species or a mixture of grasses, legumes and/or other forbs adapted to the soil and climate (NRCS 2008). Cover crops have the potential to attract wild and domestic animals for feeding, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in or near the cover crop can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the cover crop may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to cover crops. Wildlife attraction to cover crops is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, cover crops do not serve as primary habitat and are unlikely to be an attractant for these species. According to experts, deer do not typically forage on short grasses. Expert opinions from wildlife biologists indicate that vegetation used as a cover crop is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with cover crops include amphibians, wild and commensal birds (particularly ground nesting birds), small mammals and their predators, and insects. According to wildlife biologists, wild and commensal birds (particularly ground nesting birds), amphibians, small mammals and their predators such as coyotes or fox, and insects may be associated with a cover crop. All of these species may use cover crops as habitat, reproduce in or nearby them, and/or utilize them when migrating. Animal presence in cover crops is largely determined by vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies have shown that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Cover crops are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated area.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Evaluate animals that may be attracted to a cover crop based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the cover cropped site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for cover crops should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

According to expert biologists, low-growing grasses provide less cover and are therefore less likely to attract large animals. Selecting low-growing plants or mowing may reduce the cover crop's attractiveness as use for shelter. If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the cover crop or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons, predatory bird perches). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
CRITICAL AREA PLANTING - Standard Practice Code 342

PRACTICE DESCRIPTION
Definition: Planting vegetation, such as grasses, shrubs and trees on highly erodible slopes.

Purpose: To stabilize the soil, reduce damage from sediment and runoff to downstream areas, and improve wildlife habitat and visual resources.

Criteria: Use on erodible or critically eroding areas that if left untreated can cause severe erosion or sediment damage. Seeding recommendations can be obtained from your local RCD or NRCS office. Adjust seeding rates to ensure the required amount of pure live seed. Use straw mulch on plantings to anchor seeds in place during germination. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS FOTG 2008, Standard Practice Code 342).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*
The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Critical area plantings can effectively reduce pathogen transport in overland flows as well as reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed critical area planting can be used to effectively reduce the movement of potentially contaminated soil as well as capture and treat potentially contaminated water prior to reaching crop land or other water bodies.

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could result in contamination of crops. By reducing the input of sediment into waterways, CAPs may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetative buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002). Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for critical area planting design and placement. A critical area planting project should be designed to have no effect or reduce the likelihood of flooding on the ranch by reducing sediment movement.

FOOD SAFETY CONSIDERATIONS: *AIR*

General Considerations: Critical area plantings can reduce wind-borne erosion and may reduce the movement of sediment-associated pathogens. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), planting bare ground with a CAP could prevent possible transport of dust-born pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for critical area planting design and placement. CAPs should be designed to incorporate dense ground cover to minimize on-site dust movement.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*

Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Critical area plantings have the potential to attract wild and domestic animals for feeding, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in the CAP project can determine the amount and type of wildlife attracted. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to CAPs. Wildlife attraction to CAPs is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, critical area plantings do not serve as primary habitat and are unlikely to be an attractant for these species. According to experts, deer do not typically forage on short grasses. Expert opinions from wildlife biologists indicate that vegetation used in critical area plantings is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with CAPs include amphibians, wild/song and commensal birds, small and large mammals, and insects. According to wildlife biologists, passerine (song) birds and commensal birds, amphibians, small and large mammals, and insects may be associated with a CAP. All of these species may use critical area plantings as habitat, reproduce in or nearby them, and/or utilize them when migrating. Animal presence in CAPs is largely determined by vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic nor commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies show that song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Critical area plantings are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated bank.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Evaluate animals that may be attracted to a critical area planting based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the CAP site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for CAP projects should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

Dense, low growing perennial grasses are typically preferred vegetation for stable critical area plantings; these species provide less cover and are therefore less likely to attract large animals. When larger woody vegetation is prescribed for a critical area planting and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the CAP that is more attractive than the farm crop to prevent animal movement into the fields. Maintaining a low growing perennial or mowed buffer between the CAP and the crop may likewise reduce animal movement into the cropland.

If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the CAP or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons, predatory bird perches). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
FENCE - Standard Practice Code 382

PRACTICE DESCRIPTION
Definition: A constructed barrier to animals or people.

Purpose: Practice is applied to facilitate the application of conservation practices by providing a means to control movement of animals and people.

Criteria: Fences shall be positioned to facilitate management requirements. Height, size, spacing, and type of materials used will provide the desired control and management of animals and people. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 382).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*
The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Fences can reduce the likelihood of surface water contamination and possible flooding associated with loss of riparian vegeation by reducing or eliminating domestic animal presence in waterways.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Proper placement of fences can reduce animal access and impacts to vegetated cover, streams and wetlands (NRCS 2008). Direct contamination of surface waters can be reduced by limiting domestic animal access to waterways. By reducing animal impacts to vegetation in and adjacent to waterways, fences likewise result in reduced pathogens in waterways.

Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of sediment into waterways, fences may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

Design and Management Considerations to Reduce Food Safety Risk:
Fence design and placement should reduce access of livestock and animals that pose a potential threat to food safety to waterways and proximity to cropland. Fence design and placement should consider the potential for soil erosion and concentrated animal impacts along the fence line; minimizing the possibility that soil, fecal material, and accelerated runoff (and associated pathogens) will arrive, untreated to waterways or cropland. Consider establishing a vegetated filter area or protect naturally vegetated grasslands downslope of the fence to intercept overland flow from areas of concentrated animal impact and manure. Fence design and placement should consider its potential to cause flooding or scour, and fence placement through waterways or within floodplains should be avoided.

FOOD SAFETY CONSIDERATIONS: *AIR*
General Considerations: Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), fences may be used to reduce the potential for air-born movement of pathogens to cropland and waterways. Fences may prevent or minimize vegetation loss due to animal impacts as well as physically impede dust movement. Conversely, livestock have the tendency to walk along fence lines, potentially generating a strip of bare, pulverized soil with concentrations of feces or manure, which likewise may become pulverized and air-borne.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for fence design and placement. Consider establishing a hedgerow/windbreak or protect naturally vegetated areas downwind of the fence to intercept pulverized, air-borne feces from areas of concentrated animal impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Fences have the potential to limit access of wild and domestic animals to cropland, waterways, conservation practices, and other natural features. Alternately, since livestock have the tendency to walk along fence lines, fences may attract some domestic and wild animals taking advantage of livestock trails for migration. As with all conservation practices, its location in the landscape and proximity to certain habitats and land use types will influence the type, quantity, timing and frequency in which animals may be present or controlled by the fence. Time of year also plays a large role in determining the type and quantity of animals present or controlled by a fence.

According to wildlife biologists, livestock trails along fence lines may attract large wild and domestic mammals for migration. Fences may be effective barriers to prevent movement of amphibians, small and large mammals, and some insects.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Fences, properly designed for the target species, may be effective barriers to prevent movement of all species listed as animals of significant risk. Likewise, livestock trails along fence lines may be used for migration by all of these species.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive fo *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially contained within or behind fences include amphibians, small and large mammals, and some insects. Some large mammals not considered significant risks may also use livestock trails along fence lines for migration. As stated above, studies suggest that wild animals (not domestic nor commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities.

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998).

Only one study was found that investigated amphibians or reptiles in the wild.

This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:

Fence design and placement should reduce access of livestock and other high risk animals to waterways and to cropland. Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. The height, composition, and placement of fencing should be considered for its effect on: the safety and management of livestock, wildlife movement, location and adequacy of water facilities, the development of potential grazing systems, and stream crossings (NRCS 2008).

If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern. Fencing for food safety should be designed to block access to crop land and/or water sources by animals that are considered high risk for contamination. Unintended consequences of trapping animals and creating landscape-level barriers to migration for wildlife should be avoided. Fence design should also consider potential unintended population and community-level impacts of limiting movement of non-target species. For example, exclusion of predators (e.g. coyotes and foxes) may result in a population expansion of rodents inside the cropped field.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
FILTER STRIP - Standard Practice Code 393

PRACTICE DESCRIPTION

Definition: A strip or area of vegetation for removing sediment, organic matter, and other pollutants.

Purpose: To remove sediment and other pollutants from sheet flow runoff by processes such as filtration, deposition, infiltration, absorption, and volatilization, thereby reducing pollution and protecting the environment.

Criteria: Apply this practice on cropland at lower edge of field, in areas requiring filter strips as part of a system to treat polluted runoff. Appropriate filter strip size is related to the type of pollutants being filtered, the filter strip slope and the drainage area being treated. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 393).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Filter strips can effectively reduce the transport of pathogens, treat water that may contain pathogens and reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003), and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed filter strip can be used to effectively reduce the movement of potentially contaminated soil as well as capture and treat potentially contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Runoff prevention and diversion structures including vegetated buffer areas can be used to divert contaminated run-off from irrigation away from other water sources (Suslow et al. 2003).

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing excessive runoff and the input of sediment into

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

waterways, filter strips may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetated buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002).

Treatments utilizing vegetation have been shown to have significantly lower levels of microbial pathogens compared to non-vegetated waterways (Kadlec and Knight 1996, Nokes et al. 2003, Koelsch et al. 2006). Vegetation within waterways can therefore reduce chances of pathogen presence and possible contamination of nearby crops during flood events. These studies suggest that filter strips are likely to reduce the transport and presence of pathogens in agricultural environments. Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for filter strip design and placement. A filter strip should be situated in a location that does or can receive potentially contaminated surface drainage. A filter strip should be designed to have no effect or reduce the likelihood of flooding on the ranch. Pathogens of concern should be identified and the filter strip designed to target the capture and treatment of these constituents of concern, as feasible

FOOD SAFETY CONSIDERATIONS: *AIR*

General Considerations: Filter strips can reduce wind-borne erosion and may reduce the movement of sediment-associated pathogens. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), planting bare ground with a filter strip could prevent possible transport of dust-born pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for filter strip design and placement. Filter strips should be designed to incorporate dense ground cover to minimize on-site dust movement.

<u>FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*</u>

Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Filter strips are designed to accommodate sheet flow using permanent vegetation typically consisting of a single species or a mixture of grasses, legumes and/or other forbs adapted to the soil and climate (NRCS 2008). Filter strips have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in the filter strip can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in or near the filter strip may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to filter strips. Wildlife attraction to filter strips is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, filter strips do not serve as primary habitat and is unlikely to be an attractant for these species. According to experts, deer do not typically forage on short grasses. Expert opinions from regional wildlife biologists indicate that vegetation used in filter strips is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive fo *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>*Other Animals*</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with filter strip include amphibians, wild and commensal birds (including waterfowl), small and large mammals and insects. According to wildlife biologists, waterfowl and amphibians may use the filter strips as habitat, reproduce in or nearby them, and/or utilize them when migrating. Waterfowl and amphibian presence depends largely on the nearby aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals may also be associated with a filter strip. All of these species may use filter strips as habitat, reproduce in or nearby them, and/or utilize them when migrating. Birds (excluding waterfowl) and small mammal presence depends largely on the any emergent aquatic vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to filter strips for feeding, watering (if present) and migrating; their presence is largely determined by the quantity of water present or nearby as well as any emergent aquatic vegetation characteristics and adjacent upland habitat.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Filter strips are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated bank.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, only 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:

Evaluate animals that may be attracted to filter strips based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the constructed wetland site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for filter strips should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals.

If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the filter strip or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
GRADE STABILIZATION STRUCTURE - Standard Practice Code 410

PRACTICE DESCRIPTION

Definition: A structure used to control the grade and head-cutting in natural or artificial channels.

Purpose: To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, to enhance environmental quality and to reduce downstream sedimentation and flooding problems.

Criteria: The structure must be designed for stability. The outlet must be designed and built to prevent damage to the structure or downstream areas. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 410).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations:

Grade stabilization structures can effectively reduce the transport of pathogens and reduce flooding by controlling water and sediment movement over land.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed grade stabilization structure can be used to effectively reduce the movement of potentially contaminated soil prior to reaching crop land or other water bodies.

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of sediment into waterways, grade stabilization structures may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for grade stabilization structure design and placement. A grade stabilization structure should be designed to have no effect or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Practice has no known significant impact.

Food Safety Considerations for Conservation Planning
GRASSED ROADS - Standard Practice Code N/A

PRACTICE DESCRIPTION

Definition: Roads are one of the most vulnerable areas to erosion on the farm. Road seeding throughout the winter months can help protect roads. The practice is similar in form and impact to a critical area planting (NRCS Practice Code 342) and heavy use area protection (NRCS Practice Code 561).

Purpose: To stabilize soil, reduce damage from sediment and runoff to downstream areas, and improve visual resources.

Criteria: Seeding recommendations can be obtained from your local RCD or NRCS office. Adjust seeding rates at the field site to insure the required amount of pure live seed. Use straw mulch on plantings to anchor seeds in place during germination. Irrigate seed to establish grass before winter rains. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 342 & 561).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Grassed roads can effectively reduce the transport of pathogens and reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed grassed road can be used to effectively reduce the movement of potentially contaminated soil as well as capture and treat potentially contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Runoff prevention and diversion structures including vegetated buffer areas can be used to divert contaminated run-off from irrigation away from other water sources (Suslow et al. 2003).

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in

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contamination of crops. By reducing the input of sediment into waterways, grassed roads may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetated buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002). Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for grassed road design and placement. A grassed road should be designed to have no effect on or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*
General Considerations: Grassed roads can reduce wind-borne erosion and may reduce the movement of sediment-associated pathogens. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), grassing bare roads could prevent possible transport of dust-born pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for grassed road design and placement. Grassed roads should be designed to incorporate dense ground cover to minimize on-site dust movement.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Grassed roads are designed using temporary or permanent vegetation consisting of a single species or a mixture of grasses adapted to the soil and climate (NRCS 2008). Grassed roads have the potential to attract wild and domestic animals for feeding, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in the grassed road can determine the amount and type of wildlife attracted. If open water is nearby, water residence time and the quantity of water present near the grassed road may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to grassed roads. Wildlife attraction to grassed roads is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

<u>*Animals of Significant Risk (as defined by LGMA Board accepted Metrics)*</u>: The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, grassed roads do not serve as primary habitat and are unlikely to be an attractant for these species. According to experts, deer do not typically forage on short grasses. Expert opinions from wildlife biologists indicate that vegetation used in grassed roads is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>*Other Animals*</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with grassed roads include amphibians, wild and commensal birds (particularly ground nesting birds), small mammals and their predators, and insects. According to wildlife biologists, wild and commensal birds (particularly ground nesting birds), amphibians, small mammals and their predators such as coyotes or fox, and insects may be associated with a grassed road. Insects and small mammals are the most likely animals to utilize grassed roads. All of these species may use grassed roads as habitat, reproduce in or nearby them, and/or utilize them when migrating. Animal presence in grassed roads is largely determined by vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Grassed roads are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated area.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

<u>Design and Management Considerations to Reduce Food Safety Risk:</u>

Evaluate animals that may be attracted to grassed roads based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the grassed road site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for grassed roads should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species. Seasonal grass plantings as opposed to permanent grassed roads may reduce its habitat function and ability to support wildlife reproduction.

According to expert biologists, low-growing grasses provide less cover and are therefore less likely to attract large animals. Selecting low-growing plants or mowing may reduce the grassed roads attractiveness as use for shelter. If attraction of seed-eating rodents or birds is a concern, select non-seeding grass varieties or implement a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the grassed roads or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons, predatory bird perches). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
GRASSED WATERWAY - Standard Practice Code 412

Practice Description

Definition: A constructed channel that is shaped or graded to the required dimensions and planted with suitable vegetation for the stable conveyance of runoff.

Purpose: To convey runoff without causing erosion or flooding and to improve water quality.

Criteria: Amount of water conveyed will not exceed vegetated channel design with respect to erosion and flooding. Grading and seedbed preparation may result in some short-term soil loss prior to establishment of vegetative cover. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 412).

Food Safety Considerations[1]: *Water*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Grassed waterways can effectively reduce pathogen transport, treat water that contains pathogens and reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed grassed waterway can be used to effectively reduce the movement of potentially-contaminated soil as well as capture and treat potentially-contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Runoff prevention and diversion structures including vegetated buffer areas can be used to divert contaminated run-off from irrigation away from other water sources (Suslow et al. 2003).

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

contamination of crops. By reducing the input and movement of sediment in waterways, grassed waterways may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetative buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002).

Treatments utilizing vegetation have been shown to have significantly lower levels of microbial pathogens compared to non-vegetated waterways (Kadlec and Knight 1996, Nokes et al. 2003, Koelsch et al. 2006). By reducing the flow of sediment, vegetation along waterways may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005). Vegetation within waterways can therefore reduce chances of pathogen presence and possible contamination of nearby crops during flood events. These studies suggest that grassed waterways are likely to reduce the transport and presence of pathogens in agricultural environments. Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for grassed waterway design and placement. Pathogens of concern should be identified and the grassed waterway designed to target the capture and treatment of these constituents of concern, as feasible. A grassed waterway should be situated in a location that does or can receive potentially contaminated surface drainage. A grassed waterway should be designed to have no effect on or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*

General Considerations: Grassed waterways can reduce wind-borne erosion and may reduce the movement of sediment-associated pathogens when they incorporate bank or only intermittently wetted plantings. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), planting bare ground with a grassed waterway could prevent possible transport of dust-born pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for grassed waterway design and placement. Grassed waterways should be designed to incorporate dense ground cover on banks or intermittently wetted areas to minimize on-site dust movement (when dry).

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Grassed waterways typically are designed using permanent vegetation consisting of a single species or a mixture of grasses, rushes and/or sedges adapted to the soil and climate (NRCS 2008). Grassed waterways have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the species composition used in the grassed waterway can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the grassed waterway may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to grassed waterways. Wildlife attraction to grassed waterways is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, grassed waterways do not serve as primary habitat for any of these species. Because of its potential as a food source and shelter, vegetation used in grassed waterways may attract animals, however, according to experts, deer do not typically forage on short grasses. Expert opinions from wildlife biologists indicate that vegetation used in grassed waterways is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>*Other Animals*</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with vegetated treatment areas include amphibians, wild/song and commensal birds, small mammals and insects. According to wildlife biologists, waterfowl and amphibians may use the grassed waterways as habitat, reproduce in or nearby them, and/or utilize them when migrating. Waterfowl and amphibian presence depends largely on the aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals may also be associated with a grassed waterway. All of these species may use grassed waterways as habitat, reproduce in or nearby them, and/or utilize them when migrating. Birds (excluding waterfowl) and small mammal presence depends largely on the any emergent aquatic vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to grassed waterways for feeding, watering and migrating; their presence is largely determined by the quantity of water present as well as any emergent aquatic vegetation characteristics and adjacent upland habitat.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies have shown that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Grassed waterways are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated bank.

Only one study was found that investigated amphibians or reptiles in the wild.

This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Evaluate animals that may be attracted to grassed waterways based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the constructed wetland site. To help evaluate site-specific food safety risk, note population densities (e.g. normal versus high), frequency in area, animal type (wild, commensal, domestic), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for grassed waterways should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

When larger woody vegetation is prescribed adjacent to the grassed waterway and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the grassed waterway that is more attractive than the farm crop to prevent animal movement into the fields. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals. Maintaining a low-growing perennial or mowed buffer between the grassed waterway and the crop may likewise reduce animal movement into the cropland.

If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the grassed waterway or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
HEDGEROW - Standard Practice Code 422

PRACTICE DESCRIPTION

Definition: Establishing a living fence of shrubs or trees in, across, or around a field.

Purpose: To delineate field boundaries, attract beneficial insects, serve as fences or wind and dust barriers, establish contour guidelines, provide wildlife food and cover, provide visual screens, or improve landscape aesthetics.

Criteria: Species selection should be given careful consideration to minimize possible conflict between plantings and crops to be grown. Use local native or known plant sources whenever possible. Consideration should be given to flowering and otherwise attractive species as well as those providing food and cover for desired wildlife. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 422).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Hedgerows can effectively reduce pathogen transport in overland flows (when they incorporate a dense herbaceous understory) as well as reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed hedgerow with a dense herbaceous understory can be used to effectively reduce the movement of potentially-contaminated soil as well as capture and treat potentially-contaminated water prior to reaching crop land or other water bodies

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could result in contamination of crops. By reducing the input of sediment into waterways, hedgerows with dense herbaceous understories may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et

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[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetated buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002). Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for hedgerow design and placement. A hedgerow project should be designed to have no effect on or reduce the likelihood of flooding on the ranch by reducing sediment movement. Hedgerows should be designed to incorporate dense ground cover to increase infiltration, minimize erosion, and provide adequate water filtering and possible treatment.

FOOD SAFETY CONSIDERATIONS: *AIR*
General Considerations: Hedgerows can reduce wind-born erosion and may reduce the movement of sediment-associated pathogens. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), constructing barriers or windbreaks with fences or vegetation could impede transport of pathogens through wind and dust.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for hedgerow design and placement. Hedgerows should be designed to incorporate dense ground cover to minimize on-site dust movement as well as tall, dense vegetation to provide wind protection and to capture dust-born pathogens from nearby sources.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Hedgerows have the potential to attract wild and domestic animals for feeding, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in the hedgerow project can determine the amount and type of wildlife attracted. If open water is nearby, water residence time and the quantity of water present near the hedgerow may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to hedgerows. Wildlife attraction to hedgerows is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

<u>*Animals of Significant Risk (as defined by LGMA Board accepted Metrics)*</u>: The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, hedgerows do not serve as primary habitat for any of these species. Because of its potential as a food source and shelter, however, vegetation used in a hedgerow may attract animals. Expert opinions from wildlife biologists indicate that vegetation used hedgerow is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>*Other Animals*</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with hedgerows include amphibians, wild/song and commensal birds, small and large mammals, and insects. According to wildlife biologists, passerine (song) birds and commensal birds, amphibians, small and large mammals, and insects may be associated with a hedgerow. All of these species may use hedgerows as habitat, reproduce in or nearby them, and/or utilize them when migrating. Animal presence in hedgerows is largely determined by vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies show that song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Hedgerows are most likely to attract the low-risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the practice.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

<u>Design and Management Considerations to Reduce Food Safety Risk:</u>
Evaluate animals that may be attracted to a hedgerow based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the hedgerow. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for hedgerow projects should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

Dense, low growing perennial grasses provide less cover and are therefore less likely to attract large animals. When larger woody vegetation is prescribed for a hedgerow and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the hedgerow that is more attractive than the farm crop to prevent animal movement into the fields. Maintaining a low growing perennial or mowed buffer between the hedgerow and the crop may likewise reduce animal movement into the cropland.

If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the hedgerow or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons, predatory bird perches). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
IRRIGATION WATER MANAGEMENT - Standard Practice Code 449

PRACTICE DESCRIPTION

Definition: Irrigation Water Management is the process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner.

Purpose: Manage soil moisture to promote desired crop response, optimize use of available water, minimize irrigation-induced soil erosion, decrease nonpoint source pollution of surface and groundwater resources, manage salts in the crop root zone and manage the air, soil or plant microclimate.

Criteria: Address proper irrigation scheduling, in both timing and amount, the control of runoff, and the uniform application of water. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 449).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Irrigation water management can reduce the movement of pathogens, prevent or reduce the likelihood of crop contamination as well as reduce flooding both on-farm and downstream.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003), and potential sources of water contamination (via irrigation or flood waters) should be considered. Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Fields which have been exposed to contaminated water may result in the contamination of the soil for extended periods of time. Islam et al. (2005) treated fields of vegetable crops with irrigation water contaminated with *E.coli* 0157:H7. While the levels of *E.coli* 0157:H7 used in the study were far greater than any that would be likely to exist on an agricultural field, the researchers found that *E.coli* 0157:H7 survived for at least 154 days in the soil.

Certain changes in irrigation management can impact chances of crop contamination. Methods of irrigation have been shown to affect the chances of crop contamination. Solomon et al. (2002) found that lettuce exposed to *E.coli* 0157:H7 were more likely to test positive for pathogen presence if they were sprayed with inoculated water by sprinklers than if they were exposed through surface irrigation. Solomon et al. (2003) also found that repeatedly spraying crops with contaminated irrigation water increases chances of crop contamination. Therefore, surface irrigation and drip systems are less likely to lead to crop contamination in cases where water sources are

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

contaminated.

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing excessive tailwater runoff and the input of associated sediment into waterways, irrigation water management may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Design and Management Considerations to Reduce Food Safety Risk:
Potential water and soil-born sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for irrigation water management. Irrigation water may be tested to determine the probability of pathogen presence or absence, prior to application. Irrigation water management should include methods designed to increase irrigation efficiency and decrease excessive water application and subsequent tailwater runoff. Selection of an irrigation system (e.g. surface, drip, sprinkler) should consider likelihood of crop contamination; contamination may occur through direct application of contaminated water and potential to move soil-associated pathogens to the crop. If a field does become contaminated it should be cultivated and allowed to dry to increase aeration and help decrease the persistence of *E.coli* in the soil.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Practice has no known significant impact.

Food Safety Considerations for Conservation Planning
NUTRIENT MANAGEMENT - Standard Practice Code 590

PRACTICE DESCRIPTION

Definition: Managing the amount, source, form, placement and timing of nutrient applications.

Purpose: To supply plant nutrients for optimum forage and crop yields, minimize entry of nutrients to surface and groundwater, and to maintain or improve chemical and biological condition of soil.

Criteria: Develop a crop nitrogen use budget for each crop in the proposed cropping sequence. Utilize tools such as the Pre-Sidedress Soil Nitrate Quick Test to maintain consistency with the predetermined budget. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 590).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Nutrient management can effectively inhibit pathogen presence in the soil. Proper nutrient management may increase the presence of diverse microbial organisms in the soil, thus inhibiting pathogen presence by fostering a diverse microflora.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and pathogens in the soil could be transferred to crops via water. A review of the literature by Suslow et al (2003) indicates that diverse microbial organisms in soil may reduce the potential for pathogen contamination. Suppression of pathogens can occur through the antagonistic capacity of the resident microbial flora. Johannessen et al. (2005) illustrate how naturally occurring bacteria in soil reduce the abundance of *E.coli* 0157:H7 and inhibit the pathogen uptake into lettuce tissue through the roots. Soil with diverse microorganisms may contain a bacterium (*Pseudomonas fluorescens*) known to compete with and inhibit the growth of *E.coli* 0157:H7. In their study, Johannessen et al. (2005) discovered that transmittance of *E.coli* 0157:H7 from inoculated soil to lettuce did not occur and suggest that the presence of *Pseudomonas fluorescens* in the soil or on the plant roots may be responsible for preventing transmittance. This study indicates that microbial pathogens may flourish in soils that lack a balance of natural microbial diversity, and that soil management should aim to encourage the diversity of microbial organisms. Utilizing cover crops improves organic matter content of soil (NRCS 2008). Fields with more organic matter have been shown to foster an increased abundance and diversity of soil microbes (Gunapala et al. 1998, Lundquist et al. 1999, Bulluck et al. 2002). Additionally, organic fields have been shown to host higher diversity and biomass of soil microbial and faunal communities and have been correlated with higher

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

rates of suppression of soil-borne plant pathogens (Van Bruggen 1995). This pattern may also hold for the suppression of pathogens such as *E.coli* 0157:H7.

E.coli has been shown to persist in soil for days to months and in some cases for years depending site environmental conditions (e.g. Crane and Moore 1986, Unc et al. 2006, NRCS 2007). Studies have shown that generic *E. coli* can increase in numbers and persist longer in soil that has been amended with chemical or organic amendments (Estrada et al. 2004, Pourcher et al. 2007, Unc et al. 2006). Though studies were not found that investigated these patterns with pathogenic *E.coli*, it is possible that this pattern may hold for pathogenic strains.

Design and Management Considerations to Reduce Food Safety Risk:
Efficient nutrient management should be used to avoid applying more than the crop is able to utilize. Where feasible, management alternatives that increase soil organic matter to increase the abundance and diversity of soil microbes should be encouraged. To help reduce pathogen persistence in the soil, fertilizer or nutrient applications should not exceed the minimal amount needed for the crop. To help reduce pathogen survival in the soil when using animal-based compost or biosolids, it is important to insure the material has been properly composted prior to application and is well mixed and aerated in the soil.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Practice has no known significant impact.

Food Safety Considerations for Conservation Planning
ROW ARRANGEMENT - Standard Practice Code 557

PRACTICE DESCRIPTION

Definition: Establishing a system of crop rows on planned grades and lengths primarily for erosion control and water management.

Purpose: To establish crop rows in direction, grade, and length that provide adequate drainage and erosion control and permit optimum use of rainfall and irrigation water.

Criteria: Facilitate the use of applicable field machinery. Provide for surface drainage, erosion control, and water conservation. Conditions where practice applies: 1) on sloping land, where control of the length, grade, and direction of rows can reduce soil erosion; 2) to facilitate the optimum use of water in drip or graded furrow irrigation systems; and, 3) on a surface drainage system where the rows are planned to carry excess water to surface drains (NRCS 2008, Standard Practice Code 557).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations:

Row arrangement can effectively reduce the transport of pathogens within cropped fields and reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed row arrangement can be used to effectively reduce the movement of potentially-contaminated soil as well as divert potentially-contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Suslow et al. (2003) indicates that runoff prevention and diversion structures can help divert contaminated run-off from irrigation away from other water sources. Row arrangement aims to improve irrigation efficiency and minimize tailwater runoff from the farm (NRCS 2008) and has the potential to be an effective type of runoff prevention and diversion

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

treatment.

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing excessive runoff and the input of sediment into waterways, row arrangement may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for row arrangement design and layout. Row arrangement should be designed to direct potentially-contaminated surface drainage away from cropped areas and waterways, directing potentially-contaminated water to a stable location where sediment, nutrients, or pathogens can be captured or filtered before entering waterways. Row arrangement should be designed to have no effect or reduce the likelihood of flooding on the ranch. Row arrangement should be designed to achieve optimal irrigation efficiency to minimize tailwater runoff.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Practice has no known significant impact.

Food Safety Considerations for Conservation Planning
SEDIMENT BASIN - Standard Practice Code 350

PRACTICE DESCRIPTION

Definition: A basin constructed to collect and store debris or sediment. A sediment control basin has less storage capacity for peak runoff than a Water & Sediment Control Basin (638).

Purpose: To prevent undesirable deposition on bottom lands and developed areas.

Criteria: 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. Sediment Basins will not be constructed in a stream channel or other permanent water bodies. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 350).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations:

Sediment basins can effectively reduce the movement of pathogens and reduce flooding by capturing sediment and debris.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed sediment basin can be used to effectively divert and capture potentially-contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Because sediment basins can slow the flow of surface water and collect runoff, they can be used to capture and divert contaminated run-off and potentially prevent it from entering other fields, water supplies, and surface or ground water (Suslow et al. 2003, NRCS 2007).

If contaminated runoff water is not controlled as it leaves the field it can flood

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

nearby fields and could result in crop contamination (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005). Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of water and associated sediment into waterways, sediment basins may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

E.coli has been shown to persist in soil for days to months and in some cases for years depending on site environmental conditions (e.g. Crane and Moore 1986, Unc et al. 2006, NRCS 2007). Studies have also shown that *E.coli* bacteria can persist in sediment in drainage and irrigation canals (NRCS 2007). If *E. coli* bacteria have been trapped in the basin, they may persist in the sediment and application of sediment captured in sediment basins to cropland may then pose a food safety risk.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for sediment basin design and placement. A sediment basin should be designed to have no effect or reduce the likelihood of flooding on the ranch. Increased water residence time will enable more sediment to be captured and slower water release, thereby reducing possible downstream flooding. Alternatives for sediment clean out, disposal and/or possible treatment to prevent the introduction of sediment-borne pathogens onto cropland should also be incorporated in the sediment basin design and management. If contaminated, basin sediment should be cultivated and allowed to dry to increase aeration and help decrease the persistence of pathogens such as *E.coli* in the soil prior to or after spreading on fields.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Sediment basins have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the presence, absence and/or type of vegetation present in the sediment basin can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the basin may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. A properly designed and maintained sediment basin is not designed to hold water except during storms or immediately after storms; therefore conditions are rarely adequate for long-term vegetated cover establishment or wildlife breeding. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to sediment basins.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

<u>Animals of Significant Risk (as defined by LGMA Board accepted Metrics)</u>: The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. A properly designed and maintained sediment basin does not serve as primary habitat for any of these species, however, these species can be attracted to sediment basins as a potential water source during migration.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>Other Animals</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with sediment basins include amphibians, wild/song and commensal birds, small and large mammals and insects. According to wildlife biologists, wild and commensal birds (including waterfowl), amphibians, small and large mammals, and insects may use a properly designed and maintained sediment basin as a source of temporary habitat (especially if vegetation is present), as well as for migration. Waterfowl and amphibian presence depends largely on any aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals presence depends largely on any emergent vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to sediment basins for feeding, watering and migrating; their presence is largely determined by the quantity residence time of water and any emergent and upland vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Seagulls, which seek open water to land on, are the most well studied commensal bird possibly attracted to ponds. Studies have found gulls have a low incidence (0 to 2%) of *E. coli*. 0157:H7 (Wallace et al.1997; Palmgren et al. 1997), but a moderate to high incidence (4 to13%) of *Salmonella* (Palmgren et al. 1997; Fenlon 1981). Seagulls are not attracted to water with aquatic plant cover. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Sediment basins are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the basin.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Evaluate animals that may be attracted to sediment basins based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the constructed wetland site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management

alternatives for animals.

If animal attraction is a concern, sediment basins may be designed for reduced water detention time (typically they drain within 48 hours) which should prevent establishment of permanent aquatic vegetation and reduce attraction. When vegetation is present and/or desirable, selection or management of plants in the sediment basins should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. If vegetation is present, in general the greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

When larger woody vegetation is present and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the sediment basin that is more attractive than the farm crop to prevent animal movement into the fields. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals. Maintaining a low growing perennial or mowed buffer between the basin and the crop may likewise reduce large animal movement into the cropland.

If birds attracted to open water, such as seagulls, are a concern they may be deterred by planting diverse aquatic vegetation with a varied plant structure (although again, a properly designed and maintained sediment basin rarely has conditions adequate for long-term vegetated cover establishment). If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through water management and vegetation selection and management alone, other methods may be considered as well to deter animal movement into the sediment basin or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons, predatory bird perches). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
STREAMBANK AND SHORELINE PROTECTION - Standard Practice Code 580

PRACTICE DESCRIPTION

Definition: Treatments used to stabilize and protect banks of streams or constructed channels, and shorelines of lakes, reservoirs, or estuaries.

Purpose: To prevent the loss of land or facilities adjacent to banks; to maintain the flow or storage capacity of the water body; to reduce the offsite or downstream effects of sediment resulting from bank erosion; to improve or enhance the stream corridor for fish and wildlife habitat, aesthetics and recreation.

Criteria: Measures must be installed according to a site-specific plan that considers anticipated stream flows, soil stability, and wildlife protection concerns. Protective measures must be used to minimize disturbance to wildlife and water quality during construction. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 580).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Streambank and shoreline protection projects can effectively reduce pathogen transport, treat water that contains pathogens and reduce flooding through reduced erosion and sediment movement. The individual practices that comprise bank protection treatments can vary significantly, but can include the use of vegetation. Streambank and shoreline protection projects that incorporate vegetation may provide treatment of contaminated upland surface flow prior to entering the waterway as well as providing treatment of contaminated water moving through the waterway.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depends on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed streambank and shoreline protection project can be used to effectively reduce the movement of potentially-contaminated soil as well as capture and treat potentially-contaminated water prior to reaching crop land or other water bodies.

Rivers, creeks, and streams can contain pathogenic bacteria from upstream

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input and movement of sediment in waterways, bank protection projects may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetative buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002).

Regarding vegetation for stream stabilization within a waterway, treatments utilizing vegetation have been shown to have significantly lower levels of microbial pathogens compared to non-vegetated waterways (Kadlec and Knight 1996, Nokes et al. 2003, Koelsch et al. 2006). Vegetation within waterways can therefore reduce chances of pathogen presence and possible contamination of nearby crops during flood events. These studies suggest that bank protection practices using vegetation either along or within waterbodies may reduce the transport and presence of pathogens in agricultural environments. Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for streambank and shoreline protection project design. Pathogens of concern should be identified and the bank protection project designed to target the capture and treatment of these constituents of concern, as feasible. For potentially treating contaminated surface flow prior to reaching a waterway, a bank protection should be situated in a location that does or can receive potentially contaminated surface drainage. For potentially treating contaminated surface flow within a waterway, a bank protection project should include vegetation within the waterway. A bank protection project should be designed to have no effect on or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*

General Considerations: Streambank and shoreline protection projects can reduce wind-borne erosion and may reduce the movement of sediment-associated pathogens when they incorporate bank or only intermittently wetted plantings. Because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), planting bare ground with a bank protection project could prevent possible transport of dust-born pathogens.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for streambank and shoreline protection project design and placement. Bank protection projects should be designed to incorporate dense ground cover on banks or intermittently wetted areas to minimize on-site dust movement (when dry).

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Vegetated banks (riparian areas) have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in the vegetated bank project can determine the amount and type of wildlife attracted. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to streambank and shoreline protection projects. Wildlife attraction to bank protection areas is strongly determined by the type of vegetation used and proximity to open water sources.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, streambank and shoreline protection projects do not serve as primary habitat for any of these species. Because of its potential as a food source and shelter, however, vegetation used in bank protection projects may attract animals. Expert opinions from wildlife biologists indicate that vegetation used for stream bank stabilization is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurance, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with vegetated bank protection projects include waterfowl, amphibians, wild/song and commensal birds, small and large mammals, and insects. According to wildlife biologists, waterfowl and amphibians may use the vegetated bank protection project as habitat, reproduce in or nearby them, and/or utilize them when migrating. Waterfowl and amphibian presence depends largely on the aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals may also be associated with a vegetated bank. All of these species may use riparian areas as habitat, reproduce in or nearby them, and/or utilize them when migrating. Birds (excluding waterfowl) and small mammal presence depends largely on the emergent vegetation and adjacent riparian habitat. Some larger mammals and other animals may be attracted to vegetated bank projects for feeding, watering and migrating; their presence is largely determined by the quantity of water and emergent and riparian vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Vegetated bank project projects are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated bank.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

<u>Design and Management Considerations to Reduce Food Safety Risk:</u>
Evaluate animals that may be attracted to streambank and shoreline protection project based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the bank protection site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for vegetated bank protection projects should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

When larger woody vegetation is prescribed for stream bank stability and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the riparian area that is more attractive than the farm crop to prevent animal movement into the fields. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals. Maintaining a low growing perennial or mowed buffer between the riparian area and the crop may likewise reduce animal movement into the cropland.

If birds that are attracted to open water, such as seagulls, are a concern, they may be deterred by planting diverse aquatic vegetation with a varied plant structure. If upland or terrestrial animals are of concern, you may avoid upland planting and focus on establishment of riparian and aquatic vegetation essential to the water quality function of this practice. If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the vegetated bank project or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
TAILWATER RECOVERY SYSTEM - Standard Practice Code 447

PRACTICE DESCRIPTION

Definition: Facility to collect, store and transport irrigation tailwater for reuse in farm irrigation distribution system.

Purpose: Capture and store irrigation runoff for reuse as well as acting as a sediment and nutrient detention basin.

Criteria: Must predict irrigation runoff rate and sediment load to design sediment storage reservoir and determine pump capacity. Outlet must be designed and built to handle emergency overflow. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 447).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations:

Tailwater recovery systems can effectively capture tailwater that may contain pathogens as well as reduce flooding.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed tailwater recovery system can be used to effectively divert and capture potentially-contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Because tailwater recovery systems can stop the flow of surface water and collect runoff, they can be used to capture and divert contaminated run-off and prevent it from entering other fields, water supplies, and surface or ground water (Suslow et al. 2003, NRCS 2007).

If contaminated runoff water is not controlled as it leaves the field it can flood nearby fields and could result in crop contamination (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005). Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

(CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of water and associated sediment into waterways, tailwater recovery systems may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

However, reuse of drainage water from contaminated fields poses a potential risk for onsite crop contamination (NRCS 2007). *E.coli* has been shown to persist in soil for days to months and in some cases for years depending on site environmental conditions (e.g. Crane and Moore 1986, Unc et al. 2006, NRCS 2007). Studies have also shown that *E.coli* bacteria can persist in sediment in drainage and irrigation canals (NRCS 2007). If *E. coli* bacteria have been trapped in the tailwater recovery system, they may persist in the sediment and application of sediment captured in the system to cropland may then pose a food safety risk.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for tailwater recovery system design and placement. A tailwater recovery system should be designed to have no effect or reduce the likelihood of flooding on the ranch. The design and management of a tailwater recovery system should allow for possible filtering, treating, and testing of recovered tailwater prior to applying it to crops. Alternatives for sediment clean out, disposal and/or possible treatment to prevent the introduction of sediment-borne pathogens onto cropland should also be incorporated in as well. If contaminated, tailwater system sediment should be cultivated and allowed to dry to increase aeration and help decrease the persistence of pathogens such as *E.coli* in the soil prior to or after spreading on fields. Tailwater recovery systems may also be designed to include pathogen-reducing features such as vegetated treatments (see Vegetated Treated Areas, Grassed Waterways).

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Tailwater recovery systems (or tailwater ponds) have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the presence, absence and/or type of vegetation present in the tailwater recovery system can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the tailwater system may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to tailwater systems.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, unnaturally high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high, unnatural population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Tailwater recovery systems do not serve as primary habitat for any of these species, however, these species can be attracted to tailwater systems as a potential food and water source. Expert opinions from wildlife biologists indicate that vegetation present in tailwater systems is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with tailwater recovery systems include amphibians, wild/song and commensal birds, small and large mammals and insects. According to wildlife biologists, waterfowl and amphibians may use the tailwater recovery system as habitat, reproduce in or nearby them, and/or utilize them when migrating. Waterfowl and amphibian presence depends largely on any aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals may also be associated with a tailwater system. All of these species may use tailwater recovery systems as habitat, reproduce in or nearby them, and/or utilize them when migrating. Birds (excluding waterfowl) and small mammal presence depends largely on any emergent vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to tailwater systems for feeding, watering and migrating; their presence is largely determined by the quantity of water and any emergent and upland vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Seagulls, which seek open water to land on, are the most well-studied commensal bird possibly attracted to ponds. Studies have found gulls have a low incidence (0 to 2%) of *E. coli*. 0157:H7 (Wallace et al.1997; Palmgren et al. 1997), but a moderate to high incidence (4 to13%) of *Salmonella* (Palmgren et al. 1997; Fenlon 1981). Seagulls are not attracted to water with aquatic plant cover. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). Tailwater recovery systems are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the wetland.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

<u>Design and Management Considerations to Reduce Food Safety Risk:</u>
Evaluate animals that may be attracted to tailwater system based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the tailwater recovery system site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type

and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection or management of plants in the tailwater recovery system should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. If vegetation is present, in general the greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

When larger woody vegetation is present and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the tailwater system that is more attractive than the farm crop to prevent animal movement into the fields. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals. Maintaining a low-growing perennial or mowed buffer between the tailwater system and the crop may likewise reduce large animal movement into the cropland.

If birds attracted to open water, such as seagulls, are a concern they may be deterred by planting diverse aquatic vegetation with a varied plant structure. If vegetation is desired and upland or terrestrial animals are of concern, you may avoid upland planting and focus on establishment of aquatic vegetation essential to the water quality function of this practice. If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the tailwater recovery system or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons). Blocking animal access to tailwater systems may reduce the likelihood of water contamination from animals. Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planning
UNDERGROUND OUTLET - Standard Practice Code 620

PRACTICE DESCRIPTION
Definition: A structure used to control the grade and head-cutting in natural or artificial channels.

Purpose: To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, to enhance environmental quality and to reduce downstream sedimentation and flooding problems.

Criteria: The structure must be designed for stability. The outlet must be designed and built to prevent damage to the structure or downstream areas. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 620).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*
The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations:
Underground outlets can effectively prevent potential water contamination, reduce the transport of pathogens and reduce flooding through reduced erosion and sediment movement.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed underground outlet can be used to effectively reduce the movement of potentially contaminated soil as well as divert potentially contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Suslow et al. (2003) indicates that runoff prevention and diversion structures can help divert contaminated run-off from irrigation away from other water sources. An underground outlet has the potential to be an effective type of runoff diversion treatment and may safely transport surface runoff past isolated contaminated areas (NRCS 2008).

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

Rivers, creeks, and streams can contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of sediment into waterways, underground outlets may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for underground design and placement. An underground outlet should be designed to have no effect on or reduce the likelihood of flooding on the ranch. An underground outlet should outlet in a stable location where sediment, nutrients, or pathogens can be captured or filtered before entering waterways. Underground outlets should not contribute to any overland flow on adjacent cropland.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Practice has no known significant impact.

Food Safety Considerations for Conservation Planning
VEGETATED TREATMENT AREA - Standard Practice Code 635

PRACTICE DESCRIPTION

Definition: A component of an agricultural waste management system consisting of an area of permanent vegetation used for agricultural wastewater treatment.

Purpose: To improve water quality by reducing the loading of nutrients, organics, pathogens, and other contaminants associated with animal manure and other contaminated runoff and process water generated from livestock, poultry, and other agricultural operations.

Criteria: Base the total treatment area for the Vegetated Treatment Area (VTA) on the soil's capacity to infiltrate and retain runoff within the root zone and the vegetation's nutrient requirements. Permanent vegetation consisting of a single species or mixture that is adapted to the soil and climate shall be established in the treatment area. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 635).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations: Vegetated treatment areas can effectively reduce the transport of pathogens and treat water that may contain pathogens.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto nearby cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed VTA can be used to effectively reduce the movement of potentially-contaminated soil as well as capture and treat potentially-contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Runoff prevention and diversion structures including vegetated buffer areas can be used to divert contaminated run-off from irrigation away from other water sources (Suslow et al. 2003).

Rivers, creeks, and streams can contain pathogenic bacteria from upstream

[1] A more detailed discussion of studies referenced in this fact sheet and a list of citations can be found in *Food Safety Considerations for Conservation Planning: A Field Guide for Practitioners* (RCDMC, July 2009)

activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing excessive runoff and the input of sediment into waterways, VTAs may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

Vegetated landscapes have been shown to significantly reduce pathogen transport as compared to bare ground (Tate et al. 2006, Kouznetsov et al. 2006, Collins et al. 2007). Tate et al. (2006) tested the effectiveness of *E. coli* filtration through vegetated buffers on cattle grazing lands in California. While the efficiency of filtration depends on water flow, soil type, and slope, researchers have found that vegetative buffers are an effective way to reduce inputs of waterborne *E.coli* into surface waters. Other scientists especially recommend the use of short grasses for filtration of pathogens because they effectively reduce transport while allowing for more UV exposure, which reduces pathogen populations (Trevisan et al. 2002).

Treatments utilizing vegetation have been shown to have significantly lower levels of microbial pathogens compared to non-vegetated waterways (Kadlec and Knight 1996, Nokes et al. 2003, Koelsch et al. 2006). Vegetation within waterways can therefore reduce chances of pathogen presence and possible contamination of nearby crops during flood events. Constructed wetlands have been shown to effectively reduce the presence of pathogenic bacteria and are used in sewage and agricultural wastewater treatment (Mallin et al. 2001, Hench et al. 2003, Greenway 2005, Oliver et al. 2007). These studies suggest that vegetated treatment areas are likely to reduce the transport and presence of pathogens in agricultural environments. Although most of these studies did not test for *E.coli* 0157:H7 specifically, they did test for common indicator bacteria associated with pathogens. Only one of these studies (Tate et al. 2006) took place in California.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for vegetated treatment area design and placement. Pathogens of concern should be identified and the VTA designed to target the capture and treatment of these constituents of concern, as feasible.A vegetated treatment area should be situated in a location that does or can receive potentially-contaminated surface drainage. A vegetated treatment area should be designed to have no effect or reduce the likelihood of flooding on the ranch.

FOOD SAFETY CONSIDERATIONS: *AIR*
General Considerations: Vegetated treatment areas can reduce wind-borne erosion and because pathogenic bacteria can be transported as dust (Chang et al. 2001, Lee et al. 2006, Whyte et al. 2001), may reduce the movement of sediment-associated pathogens when they incorporate bank or only intermittently wetted plantings.

Design and Management Considerations to Reduce Food Safety Risk:
Potential air-borne sources of contamination, both on-farm and upwind, as well as direction of predominant winds and proximity to cropland should be considered for vegetated treatment area design and placement. VTAs should be designed to incorporate dense ground cover on banks or intermittently wetted areas to minimize on-site dust movement (when dry).

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Vegetated treatment areas are designed using permanent vegetation consisting of a single species or a mixture of grasses, legumes and/or other forbs adapted to the soil and climate (NRCS 2008). VTAs have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the type of vegetation used in the VTA can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the VTA may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to VTAs. Wildlife attraction to vegetated treatment areas is strongly determined by the type of vegetation used and proximity to open water sources

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. Of the wild (non-domestic) animals, deer and feral pigs, vegetated treatment areas do not serve as primary habitat for any of these species. Because of its potential as a food source and shelter, vegetation used in VTAs may attract animals. According to experts, deer do not typically forage on short grasses. Expert opinions from wildlife biologists indicate that vegetation used in VTAs is not likely to attract feral pigs, which are more likely to be drawn to already present water or food sources..

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive fo *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

<u>*Other Animals*</u>:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with vegetated treatment areas include amphibians, wild/song and commensal birds, small mammals and insects. According to wildlife biologists, waterfowl and amphibians may use the vegetated treatment areas as habitat, reproduce in or nearby them, and/or utilize them when migrating. Waterfowl and amphibian presence depends largely on the aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals may also be associated with a vegetated treatment area. All of these species may use vegetated treatment areas as habitat, reproduce in or nearby them, and/or utilize them when migrating. Birds (excluding waterfowl) and small mammal presence depends largely on the characteristics of any emergent aquatic vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to vegetated treatment areas for feeding, watering and migrating; their presence is largely determined by the quantity of water present as well as emergent aquatic vegetation characteristics and adjacent upland habitat.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). VTAs are most likely to attract the low risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the vegetated bank.

Only one study was found that investigated amphibians or reptiles in the wild.

This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

Design and Management Considerations to Reduce Food Safety Risk:
Evaluate animals that may be attracted to a vegetated treatment area based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the VTA site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) should also be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, selection of plant materials for VTAs should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. In general, greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals.

If birds attracted to open water are a concern, such as seagulls, they may be deterred by planting diverse aquatic vegetation with a varied plant structure. If upland or terrestrial animals are of concern, you may avoid upland planting and focus on establishment of aquatic vegetation essential to the water quality function of this practice. If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through vegetation selection and management alone, other methods may be considered as well to deter animal movement into the VTA or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program at (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

This is not intended to be a how-to or design guide for conservation practices. Individual practices must meet minimum standards and comply with local laws and regulations. When designing or managing conservation practices and environmental features to minimize food safety risk, please consult the appropriate experts. This guide is not intended to be used to determine on-farm risk of crop contamination and should not be used in place of a crop-specific food safety program.

Food Safety Considerations for Conservation Planning
WATER AND SEDIMENT CONTROL BASIN - Standard Practice Code 638

PRACTICE DESCRIPTION

Definition: A sediment basin or off stream pond constructed to capture sediment as well as handle excess runoff and sediment from farmed or developed parcel.

Purpose: Detain water and retain sediment that is associated with runoff from a developed parcel where sufficient area is available for temporary storm runoff storage capacity.

Criteria: Must be sized to accommodate the sediment load and excess runoff above natural predicted runoff. In addition, a primary spillway and an emergency spillway must be installed to prevent basin failure. All applicable federal, state, and local laws, rules and regulations must be followed (NRCS 2008, Standard Practice Code 638).

FOOD SAFETY CONSIDERATIONS[1]: *WATER*

The majority of studies indicate that crop contamination most likely occurs through direct contact between crops and contaminated water.

General Considerations:

Water and sediment control basins (WSC Basins) can effectively capture water and associated sediment that may contain pathogens as well as reduce flooding.

Water is a likely vehicle of contamination of crops (Suslow et al. 2003) and potential sources of water contamination (via irrigation or flood waters) should be considered. Abu-Ashour and Lee (2000) show that pathogenic *E. coli* can migrate through run-off on sloped surfaces, potentially increasing risks to crops down slope. Nearby sources of pathogens (e.g. confined livestock facilities) could result in movement of E. coli onto cropped fields through field drains and/or surface run-off (Vinten et al. 2004). It is important to note that the extent of pathogen movement over land can depend on various factors including soil type, infiltration, and soil moisture (Trevisan et al. 2002, Roodsari et al. 2005, Lang and Smith 2007). A properly designed WSC basin can be used to effectively divert and capture potentially contaminated water prior to reaching crop land or other water bodies.

Contaminated irrigation water can be a source of crop contamination, with potential sources of contamination including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff (NRCS 2007). Because WSC basins can slow the flow of surface water and collect runoff, they can be used to capture and divert contaminated run-off and potentially prevent it from entering other fields, water supplies, and surface or ground water (Suslow et al. 2003, NRCS 2007).

If contaminated runoff water is not controlled as it leaves the field it can flood nearby fields and could result in crop contamination (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005). Rivers, creeks, and streams can

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contain pathogenic bacteria from upstream activities, such as livestock operations (CCRWQCB 2002 and 2004, Hager et al. 2004). Flooding of nearby contaminated water bodies onto fields could also result in contamination of crops. By reducing the input of water and associated sediment into waterways, WSC basins may also reduce the risk of downstream sediment accumulation and flooding, a potential food safety risk if contaminated water comes into contact with crop surfaces (Solomon et al. 2002a, Solomon et al. 2002b, Wachtel et al.2002, Islam et al. 2005).

E.coli has been shown to persist in soil for days to months and in some cases for years depending on site environmental conditions (e.g. Crane and Moore 1986, Unc et al. 2006, NRCS 2007). Studies have also shown that *E.coli* bacteria can persist in sediment in drainage and irrigation canals (NRCS 2007). If *E. coli* bacteria have been trapped in the basin, they may persist in the sediment and application of sediment captured in WSC basins to cropland may then pose a food safety risk.

Design and Management Considerations to Reduce Food Safety Risk:
Potential water or soil-borne sources of contamination and pathways for introduction, both on-farm and upstream, should be considered for WSC basin design and placement. A WSC basin should be designed to have no effect on or reduce the likelihood of flooding on the ranch. Increased water residence time will enable more sediment to be captured and slower water release, thereby reducing possible downstream flooding. Alternatives for sediment clean out, disposal and/or possible treatment to prevent the introduction of sediment-borne pathogens onto cropland should also be incorporated in the WSC basin design and management. If contaminated, basin sediment should be cultivated and allowed to dry to increase aeration and help decrease the persistence of pathogens such as *E.coli* in the soil prior to or after spreading on fields.

FOOD SAFETY CONSIDERATIONS: *AIR*
Practice has no known significant impact.

FOOD SAFETY CONSIDERATIONS: *ANIMALS (WILD AND DOMESTIC)*
Due to the animal origins of zoonoses pathogens, contamination can occur through contact directly with contaminated animal feces (wet or dry).

General Considerations: Water and sediment control basins have the potential to attract wild and domestic animals for feeding, watering, breeding, and/or migration. Those experienced in implementing conservation practices agree with wildlife biologists that the presence, absence and/or type of vegetation present in the WSC basin can determine the amount and type of wildlife attracted. Water residence time and the quantity of water present in the basin may also be a determining factor for the timing and frequency in which animals may be present in or near the practice. A properly designed and maintained WSC basin is not designed to hold water except during storms or immediately after storms; therefore conditions are rarely adequate for long-term vegetated cover establishment or wildlife breeding. As with all conservation practices, its location in the landscape and proximity to other types of habitat and land use types will influence the type, quantity, timing and frequency in which animals may be present. Time of year also plays a large role in determining the type and quantity of animals attracted to WSC basins.

In general research suggests that wild animals are much less likely to carry *E. coli* 0157:H7 than domesticated and commensal animals. On average around 1% of all wild animals in studies (excluding those in close contact with animal and human waste) carried *E. coli* 0157:H7. On the central coast of California less than 0.5% of wildlife tested in 2007 and 2008 were found to carry *E.* coli 0157:H7 (CDFG 2009). The prevalence of pathogens in commensal animals such as rats and seagulls that eat or live around human and livestock waste is higher (closer to 12%). In addition, high densities of a species can increase the risk to food safety, even of species with a very low prevalence of the pathogen. Accordingly, evidence suggests that domestic animals, commensal species and any animal with extremely high population densities are likely to pose the greatest risk to food safety.

Animals of Significant Risk (as defined by LGMA Board accepted Metrics): The Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens (LGMA accepted June 13, 2008) currently lists cattle, deer, goats, pigs (wild and domestic), and sheep as animals of significant risk. A properly designed and maintained WSC basin does not serve as primary habitat for any of these species, however, these species can be attracted to WSC basins as a potential water source during migration.

Cattle and domesticated animals have been shown to be the largest reservoirs of pathogenic *E. coli* (Chapman et al. 1997, Nielsen et al. 2004, Khaitsa et al. 2006). Up to 36.8% of cattle have been found to carry *E. coli* 0157:H7 (Chapman et al. 1997). Between 8.7% and up to 40% of sheep sampled have tested positive for *E. coli* O157:H7 (Orporto et al. 2008, Ogden 2005). Three out of 58 goats sampled tested positive for *E. coli* O157:H7 (Orden et al. 2008).

Between 0.54% and 14.9% feral pigs have been found to carry *E. coli* 0157:H7 (CDFG 2009, Jay et al. 2007). Feral pigs also carry other human pathogens such as *Cryptosporidium parcum* and *Giardia* (Atwill et al. 1997, Witmer et al. 2003).

Studies have found that wild deer associated with rangeland typically have low rates of *E. coli* occurrence, between 0 to 2.4% (CDFG 2009, Sargeant et al. 1999, Fischer et al. 2001).

Other Animals:

Animals *not* considered of Significant Risk (as defined by the LGMA Board accepted Metrics June 13, 2008) potentially associated with WSC basins include amphibians, wild/song and commensal birds, small and large mammals and insects. According to wildlife biologists, wild and commensal birds (including waterfowl), amphibians, small and large mammals, and insects may use a properly designed and maintained WSC basin as a source of temporary habitat (especially if vegetation is present), as well as for migration. Waterfowl and amphibian presence depends largely on any aquatic habitat and vegetation available. Passerine (song) birds and commensal birds, insects and small mammals presence depends largely on any emergent vegetation and adjacent upland habitat. Some larger mammals and other animals may be attracted to WSC basins for feeding, watering and migrating; their presence is largely determined by the quantity residence time of water and any emergent and upland vegetation characteristics.

As stated above, studies suggest that wild animals (not domestic or commensal animals) are less likely to carry *E. coli* 0157:H7 and other human pathogens and present relatively low food contamination risk when found at natural or low population densities. Seagulls, which seek open water to land on, are the most well studied commensal bird possibly attracted to ponds. Studies have found gulls have a low incidence (0 to 2%) of *E. coli*. 0157:H7 (Wallace et al.1997; Palmgren et al. 1997), but a moderate to high incidence (4 to13%) of *Salmonella* (Palmgren et al. 1997; Fenlon 1981). Seagulls are not attracted to water with aquatic plant cover. Studies show that waterfowl (Canada geese) and other/song birds (passerines, woodpeckers, nuthatches, chickadees, others) have very low incidence of human pathogens: 0 to 1% for *E. coli* 0157:H7 and 0% for *Salmonella* (Palmgren et al. 1997, Converse et al. 1999, Brittingham et al. 1988, Hancock et al. 1998).

Rodents can be divided into two groups: field rodents and commensal rodents (Meerburg et al. 2004). A recent review of studies reported that rodents in coastal California agricultural fields have not been found to harbor pathogenic *E.coli* (Salmon et al. 2008). Rats, a commensal species often living in close proximity to cattle or human waste, were found to have a high (20%) incidence of pathogenic *E. coli* (Nielsen et al. 2004). No *E. coli*. 0157:H7 (0%) was found in field rodents (Hancock et al. 1998). WSC basins are most likely to attract the low-risk field rodents unless human or domestic animal waste is allowed to accumulate in or near the basin.

Only one study was found that investigated amphibians or reptiles in the wild. This study found none (0%) of the 75 free-living reptiles surveyed tested positive for *Salmonella* (Richards et al 2004).

The prevalence of pathogens in invertebrates is very low: 2% of flies and 0.21% of slugs were found to carry *E. coli*. 0157:H7 (Spronston et al. 2006). Sproston et al. (2006) found that *E. coli* 0157:H7 can live on the slugs for up to 14 days, however, of 474 slugs collected, 0.21% were found to carry *E.coli* 0157:H7.

<u>Design and Management Considerations to Reduce Food Safety Risk:</u>

Evaluate animals that may be attracted to water and sediment control basins based on local conditions. Following is a suggested list of possible, but not the only, considerations. Additional information may be relevant on a site-specific basis. Consider proximity and connectivity to known habitats and existing animal populations to evaluate the likelihood that certain animals may be able to migrate to the constructed wetland site. To help evaluate site-specific food safety risk associated with animal species note the population abundance (e.g. normal versus high) and frequency of occurrence, extent to which they may enter fields, access to human and livestock waste, animal type (wild, commensal, domestic), incidence rate for carrying pathogenic organisms (use local data if available), Animals of Significant Risk as defined in the Leafy Green Marketing Agreement Board accepted guidelines (if applicable), and possible at-risk or protected species. Crop type and harvest method (e.g. manual vs. machine) shouldalso be considered when determining the potential food safety risk and resulting management alternatives for animals.

If animal attraction is a concern, WSC basins may be designed for reduced water detention time (typically they drain within 48 hours) which should prevent establishment of permanent aquatic vegetation and reduce attraction. When vegetation is present and/or desirable, selection or management of plants in the WSC basins should consider the potential to deter or attract animals that present significant food safety risk in relation to its importance for practice design and function. If vegetation is present, in general the greater plant species and structural diversity will result in a greater diversity of animals attracted, thereby reducing the likelihood of getting large populations of any single species.

When larger woody vegetation is present and large animals posing significant risk are anticipated, certain mitigation measures may be applied. It may be desirable to plant a wildlife food plot along the edge of the WSC basin that is more attractive than the farm crop to prevent animal movement into the fields. According to expert biologists, low-growing perennial grasses provide less cover and are therefore less likely to attract large animals. Maintaining a low-growing perennial or mowed buffer between the basin and the crop may likewise reduce large animal movement into the cropland.

If birds attracted to open water are a concern, such as seagulls, they may be deterred by planting diverse aquatic vegetation with a varied plant structure. If upland or terrestrial animals are of concern, you may avoid upland planting and focus on establishment of aquatic vegetation essential to the water quality function of this practice. If attraction of seed-eating rodents or birds is a concern, you may consider selecting non-seeding grass varieties or implementing a regular mowing schedule to reduce seed production. Note, ground squirrels need open areas to detect predators, and the removal, absence or mowing of upland vegetation may create more favorable conditions for ground squirrels.

If animal concerns cannot be addressed through water management and vegetation selection and management alone, other methods may be considered as well to deter animal movement into the WSC basin or into the adjacent cropland (e.g. bird tape, scarecrows, fencing, noise-cannons, predatory bird perches). Methods to deter or prevent animal movement should target the species of concern while minimizing or avoiding negative impacts to other species and the environment. If fencing is necessary, the fence material, height and buried depth will differ depending on the species of concern.

For more information on wildlife identification and species-specific management methods, refer to the UCCE Wildlife Damage Management Program (http://wfcb.ucdavis.edu/www/Faculty/Desley/programs.htm).

Food Safety Considerations for Conservation Planners:
A Field Guide for Practitioners
July 2009

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