Best Management Practice Effectiveness on Phosphorus Removal from Field Surface Irrigation Return Flows

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Introduction

The purpose of this report is to review available research data and determine Best Management Practices (BMPs) effectiveness on phosphorus removal from surface irrigated cropland return flows. It also describes a process to estimate total phosphorus trapped through the application of a BMP on an individual field or farm. An average range of 40% to 60% of the irrigation water applied to cropland within the south-central and south-west areas of Idaho flows off of surface irrigate fields. This runoff carries varying amounts of sediment and nutrients, which can impact adjacent farm fields and water bodies. Determining what improvements BMPs have on impacted water bodies is difficult when there is great variability between irrigated crop fields. Irrigation systems, soils, slopes, and management practices all vary within Idaho, especially in Canyon and Ada counties, where there over 50 different crops grown. Each of these crops requires unique management, with farmers applying various water amounts, fertilizers, and cultivation practices. Idaho has incorporated a list of BMPs suited for sediment and nutrient containment on farmlands, whether keeping them within the their original source material, within the area of the field, or prior to entering a waterway. Each of these BMPs has variable effectiveness on sediment and nutrient containment because of the previously mentioned reasons. This report explores available data on sediment and nutrient, phosphorus specifically, fate characteristics, and BMP containment of sediment and phosphorus generated from irrigated croplands.

Background

The Environmental Protection Agency, and State environmental agencies from Idaho, Oregon, and Washington, are examining how effluent trading can: (1) help improve water quality in the region; (2) promote pollution prevention; and (3) help meet specific water quality objectives. They are helping to promote the Lower Boise River Watershed Effluent Trading Demonstration Project in implementing actual trades between two or more pollutant sources, specifically phosphorus. The project has a few objectives in order to identify what is actually needed to implement trading, one of which is to investigate ways of reducing costs while improving water quality.

The Lower Boise River was scheduled to have a Total Maximum Daily Load developed by the end of 1998, including load reductions on sediment, and a no-net increase on phosphorus. Agricultural surface irrigation return flows contribute a large proportion of river sediment load during April through October. Nutrient loads coming from point, nonpoint, and ground water sources seem sufficient enough to cause algae problems every year, but only seem to impact the river during drought periods or low river flow years.

Through the trading project, cost ratios are to be developed between the trading sources based on the effectiveness of practices and their phosphorus reductions to the river. In order for a point source, such as a treatment facility, to willfully supply dollars to a nonpoint source for BMP installation, they will supply dollars based on specific practices' performance. It is necessary to explore and determine, based on available data, what the practices' effectiveness is on phosphorus reductions.

Evaluation and Discussion

The objectives of this report are to:

1. Explain the local irrigation systems, agronomic characteristics, and sediment and phosphorus movement on irrigated fields.

2. Identify practical field BMPs with the capability of reducing total phosphorus (TP).

3. Present research literature on the effectiveness of sediment and TP reductions from each of the identified practices.

4. Estimate potential TP reductions by each identified BMP.

5. Estimate on-site installation and maintenance costs for identified BMPs.

6. Estimate typical soil and TP losses from surface irrigated croplands in the Boise Area.

7. Estimate the costs of TP reductions.

8. Discuss additional data needed for better estimating BMP TP reduction capabilities and costs.

Objective #1 Explain the local irrigation systems, agronomic characteristics, and sediment and phosphorus movement on irrigated fields.

Defining the typical characteristics of the irrigated crop fields is difficult given the complexities of the irrigation systems, crops grown, cultivation practices, field size, soil types and slopes, and cultural and management differences between each of the farmers. Besides the differences on these fields in the Boise River watershed, extreme physical alterations exist in the natural drainage patterns. Canals were created to transport water from the Boise River to fields over the two counties, on both sides of the river. Among these canals are man-made surface drains and creeks that have been developed or altered to function within the delivery system. Often a canal will deliver water to a field, then that water is reused by a field below the first or spilled back into a lower canal. In some locations where canals and surface drains intersect, canal water is spilled to maintain constant water elevation.

Surface Irrigation Systems:

Many different surface irrigation systems exist in the valley, including earthen ditches with siphon tube or cut-outs, concrete ditches with siphon tubes, and gated pipeline. Water is turned out of a canal through a gate, sometimes measured with a weir blade. The water is then turned into an earthen ditch or water control structure and pipeline, transporting water to another structure or directly into an earthen, concrete ditch or gated pipe system. This water is then checked downstream of a number of siphon tubes, usually ½ to 1 ½ inches in diameter, about 5 ½ to 7 feet long. These tubes are bent in a fashion to allow water to flow out the ditch, over the side and then down to a corrugate. Priming a tube is not difficult for practiced irrigators, often setting 100 tubes in a few minutes. The water is turned into corrugates or furrows created by the farmer, specifically for directing the water's flow through the field uniformly. The irrigation corrugates generally range from 22" to 44" spacing across the field, depending on the crop, often irrigated on alternate rows (every other one).

The flow rates from these siphon tubes range from about 3 to 20 gallons per minute (gpm), depending on the tube diameter, length, and head elevation above the outlet end of the tube. The variability in the stream sizes among furrows averages about 25% (Trout, et al. 1988 & Trout et al. 1983). Irrigation set time is often on a 12 or 24 hour flow period to simplify irrigation, using large tubes to ensure watering of the lower portion of the field. When these flow rates are large, excessive erosion generally takes place.

Slopes:

Typical surface irrigated field slopes range from 0.7 % to 3%, not necessarily consistent through the entire length of the field. Often the lower ends of the fields drop off at a greater slope than the field's entire slope, described as a convex end. A convex end is an increasing slope beginning approximately 15 to 45 feet upslope from the lower end of the furrow. This pattern occurs because farmers generally maintain drainage ditches deeper than the furrows along the lower end of the fields to allow unrestricted runoff. This practice results in eroding head-cuts that begin at the drainage ditch and move up the furrows. Brown (1985) determined that sediment losses increased almost tenfold on fields with convex-end furrows, compared to a flat-end-furrow field.

Soils:

Soils in the valley are generally deep, with some having a hard, calcareous layer 30" to 40" below the surface. The texture of the soils are excellent for the crops grown in the valley, but most having very little organic matter, often as low as 0.5%. High levels of organic matter, upwards of 4%, have been recorded in fields that have had animal wastes applied for many years. The majority of the soils are silt loam soils, having infiltration rates generally ranging from 0.2 to 1.6 inches per hour. Water holding capacity is generally dependent on texture, ranging from .04 to .21 inches per inch, with silt loam soils within the .16 to .20 inches per inch range. Percent of clay ranges 5% to 32%, with silt loam soils generally around 15% to 20%.

Crops:

The most common are alfalfa hay, alfalfa seed, winter and spring wheat, barley, dry beans, pinto beans, sugar beets, potatoes, commercial onions, onion seed, grain corn, silage corn, sweet corn seed, peppermint, and spearmint. Crops either are planted in the fall or in spring, often as early as late February, such as in 1992, a drought year. Generally, crops are planted around early March through early June. Harvest starts with onion seed, winter wheat, and alfalfa seed as early as July 15, running into December with sugar beets and grain corn, depending on the fall weather.

Cultivation Practices:

Most farmers use moldboard plows, tandem disks, harrows, and cultivators. Soils are generally disked and plowed in the fall, left rough over winter. The field preparation for spring planting of potatoes is generally done in the fall. Conventional tillage often requires a wide assortment of tillage equipment for cultivation, planting, and corrugating. Conservation tillage is a practice not readily adopted by farmers because of the weed control required on certain crops where there are few pesticides available for use after the crop is growing. Lighter tillage implements and fewer trips into the field are part of the management under conservation tillage. This tillage does occur frequently in the northwest part of Canyon County when going from wheat to potatoes. It's common to bed up a wheat field without tilling in the residue to help improve irrigation uniformity of potatoes, which are generally irrigated with portable sprinkler systems.

Crop Water Requirements:

Every crop grown in the Boise River area requires different water amounts to for optimum production (Table #1).

Table #1 Estimated Seasonal Consumptive Use of Various Crops For Climatic Boise Area

Crop	Consumptive Use in Inches	Number of Irrigations per Season
Alfalfa Grass	34	5-8
Alfalfa Seed	16	2-4
Beans	18	10-12
Corn, Field (grain)	23	10-14
Corn, Field (Silage)	22	8-12
Corn, Sweet	18	8-12
Grain, Small Spring	16	4-6
Hops	34	12-15
Mint	19	4-6
Onions	20	15-20
Pasture	29	4-8
Potatoes	24	8-12
Sugar Beets	30	12-16

The ranges of irrigation do vary substantially between crops, and fields. Soil conditions, such as texture requires flexibility irrigation timing to meet the crops' needs. The sandier the soil, the more frequent water needs to be applied to compensate for the lower water holding capacity. If there is substantial percent of clay in a soil, runoff may increase due to a lower infiltration rate, forcing the farmer to run irrigation longer to ensure adequate watering.

Sediment Erosion and Nutrient Fate and Transport:

Tracking nutrients from where they enter a field to where they exit is difficult. Soil characteristics, field conditions, nutrient availability, crop types, irrigation water quality, fertilizer combination, fertilizer application method, timing, and climate are a few factors that impact nutrient fate.

Nutrients in surface irrigation runoff either are in soluble form or attached to soil and residue particles being carried with the water. It has been shown that little soluble nutrient pickup could be expected to result from nutrient diffusion out of the soil into the passing water (Bondurant, 1971). It was found that soluble nutrient and salt concentrations in surface irrigation return flows were essentially the same as those in the applied water.

Carter, et al. (1974) and Carter, et al. (1976) has shown that phosphorus can be tightly held by the soil. These authors reported that sediment concentrations in surface runoff can be closely related to TP and unfiltered orthophosphate concentrations. No relationship between sediment concentrations and filtered sample soluble orthophosphate was found. A regression equation was developed relating sediment and TP concentrations as follows: $Y = 140.52 + 0.72X$ (with correlation coefficients $r^2 = 0.89$ and $r = 0.94$), where Y is nonfiltered TP concentration in ppb, and X is the nonfiltered sediment concentration in ppm. Their data were collected from two large irrigation tracts, 82,030 and 65,350 ha, and therefore represent a wide range of conditions. Data reported by Carlile (1972) also show a close relationship between sediment and TP concentrations in return flows.

Brown (1985) found that sediment and P losses were about twice as great in the wheel rows as a result of wheel compaction and increased water flow velocities were upwards of 1.6 times greater than that of non-wheel rows. Brown (1985) also found on a bean field trial that 49 percent of the erosion took place within the first two irrigations, 62 percent by the third irrigation, and 77 percent by the forth. Only 23 percent of the total eroded sediment was lost during the last four irrigations.

Carter, et al. (1974) found that phosphorus (P) can be conserved by removing sediment from irrigation return flow. They found high P concentrations on smaller particles and aggregates than on larger particles and aggregates. Sediment analyzed from the K lateral drain, as an example, contained 550, 1,150, and 1,285 ppm tp (mostly representing pp), on the sand, silt, and clay fraction, respectively. Average tp concentrations on particle sizes taken from many drain samples show silt particle averaging around 1,000 ppm tp (pp). This gives a sediment-phosphorus ratio of .001. Sediment-phosphorus ratios ranged from .0006 to .002 in the Carter, et al. (1974) study. Surface silt loam soils in the Twin Falls area are very similar to the Boise area silt loam soils.

Objective #2 Identify practical field BMPs with the capability of reducing TP

Some applicable BMPs for the Boise area that have potential for sediment and phosphorus containment are listed in Table2, with a brief description included.

Table #2 Field Applied Best Management Practices with Sediment and Phosphorus Removal Capabilities for Surface Irrigated Croplands Within Southwest Idaho

BMP	Description
Conservation Tillage (Residue Management)	The minimal tillage required to produce agricultural crops grown while maintaining good soil tilth and minimizing soil erosion.
Drip Irrigation Systems	A structural system that provides water to plants specifically directed through small emitters
Filter Strips	Vegetative strips planted at the top and bottom end of crop fields which filter runoff of sediment and reduce erosion within the strip.
Mulching	The practice of applying plant residue to the soil surface to reduce soil erosion and improve water infiltration.
Polyacrylamide (PAM)	A chemical substance used to treat irrigation water and soil to stabilize soil particles under the sheer forces of water and improve infiltration rates.
Pump-back Ponds	The structural system to collect, settle out sediment, and redistribute runoff for reuse.
Sediment Basins	The structural system to collect and settle out sediment, nutrients, and chemicals associated with land uses.
Sprinkler Systems	The structural system that provides water to plants through nozzles, pressurized to distribute water in the similar fashion as natural precipitation.
Surge Irrigation Systems	The structural system that provides water to plants through gated pipe in a surging fashion, reducing erosion and leaching.
Underground Outlets	The structural system designed to collect, filter, and reduce water erosion and sedimentation associated with land use activities.

Objective #3 Present research literature on the effectiveness of sediment and TP reductions from each of the identified practices.

There are numerous BMPs with sediment and nutrient trapping capability. Phosphorus removal capability depends on management, structural design, retention time, filtering processes, soil particle selectivity, temperature, salt concentration and other factors. It is important to understand that sediment is much easier to trap than soluble phosphorus unless the BMP is capable of reducing or eliminating runoff from the field. Flow related BMPs will be more effective in reducing soluble phosphorus than do passive BMPs such as filter strips, sediment basins, and conservation tillage. On a field-scale BMP application however, controlling sediment will generally provide the largest total phosphorus reduction.

Conservation Tillage (Residue Management)

One of the first recommendations to irrigators to reduce erosion is to avoid excessive pulverization of soil by tillage. Tillage affects surface roughness through its effect on residues. When moldboard plows are used, residues are almost completely eliminated from soil surfaces, allowing more erosion to takes place compared to where residues are left to increase the resistance of water flow and shear forces (Carter, et. al 1990). Generally, the less tillage, the greater positive effects on erosion and sediment loss.

Carter et al.(1989) found through more than 70 comparisons of traditional tillage verses conservation tillage systems that conservation-tilled, furrowed land can be successfully irrigated and erosion reduced by 47% to 96%. Carter et al. (1989) also found a high correlation between the number of tillage operations and the amount of sediment loss but did not generally have an effect on crop yields. Wide application of conservation tillage on surface irrigated cropland has the potential to reduce erosion and sedimentation by 80% to 90% (Carter, 1990).

Drip Irrigation Systems (Irrigation System, Trickle)

The drip or trickle irrigation system is specifically designed to place water to root zone of a plant, usually on the soil surface or just beneath. The amount of water flowing from the emitters or drip tubes is at or below the soil infiltration rate, eliminating water leaching and runoff. With no water leaching or runoff, nutrients and sediment are unaffected and not displaced by water movement.

Filter Strips

Most vegetative filters are planted with cereal grains seeded along the lower ends of fields and some on the top ends. Carter, (1985) found that fall seeded cereals or perennial plants, such as grass or alfalfa left along the lower end of the field when alfalfa was plowed out in the normal rotation were most effective. Generally, farmers within the Boise valley plant filter strips with wheat in the spring, to be tilled under during fall tillage.

Sediment removal efficiency was documented by Carter (1985) as variable, ranging from 0% to 70%. When furrows are pulled all of the way through the strips, efficiencies are low. Carter (1985) found when furrows are pulled to the upper edge of the strip or slightly into it, sediment settles at the upper end of the strip and runoff erodes a new channel just upslope of the filter. Those filter strips with the highest efficiencies were found to be installed on fields with convex ends, with furrows pulled about 6 feet in. Carter (1985) also stated that the filter strips could reduce erosion along the lower ends of fields and correct convex. Properly installed filter strips will remove 40% to 60% of the sediment from the field even after being mowed or shredded off.

Mulching

Small quantities of straw or other crop residue in irrigation furrows reduce soil erosion and increase infiltration. Aarstad, et al. (1981) showed that as little as 60-kg straw/ha placed in clumps along the furrow greatly reduced sediment loss from irrigation furrows along a 3% slope. Even on steep slopes of 1.9% to 3.9%, straw mulching reduced sediment losses by 69% to 90% (Brown, et al. 1987). Berg (1984) applied small amounts of straw uniformly along 4% slope sections of furrows in a corn field to reduce erosion on that portion of the field and to reduce sedimentation downstream where the slope decreased to about 1.5%. This decreased erosion and increased corn silage yields.

Brown (1985b) placed 1.5-kg straw/100m of furrow and measured infiltration and sediment loss for six irrigations with two stream sizes. Infiltration increased by 50% and decreased sediment loss by 52% on the higher inflow rate furrows. Practical application of straw is done with straw mulchers, machines attached to a tractor and driven through a field, applying straw at uniform rates. However, straw is generally not applied to row cropped fields until after all cultivation is completed, generally after the first few irrigations. Season long sediment control under mulching does not occur in the Boise area because of the delayed application of the straw. Cultivation practices delay the application of straw to the furrows because it can clog tillage implements and cause damage to the crop.

Polyacrylamide (PAM)

A new technology has been widely adopted by farmers throughout Idaho that is cost-effective and easily managed. PAM, a chemical additive to irrigation water for soil stabilization and enhanced water infiltration, has been extensively researched. Common erosion control and infiltration results have been found on many fields where PAM has been used. One study by Lentz, et al. 1998 showed soil losses in a non-PAM applied control yielded 3,140 kg/ha soil loss, whereas other PAM-applied furrows yielded only 345 and 250 kg/ha soil loss, a 89% and 92% reduction. In another study that monitored irrigations on several different fields and soils PAM applications of 1 to 2 kg/ha reduced furrow irrigation-induced soil losses by 94% (Lentz, et al. 1992; Sojka, et al. 1993; Lentz, et al. 1994).

Lentz, et al. 1998 found that runoff from control furrow streams contained five to seven times greater TP and ortho P concentrations from PAM furrows. PAM treated furrows had 40% less runoff than controls, which helped reduce sediment and phosphorus losses. Across 4 irrigations, where PAM reduced soil losses by 91%, TP was reduced by 86% over control furrow losses and ortho-P losses by 77% (Lentz, et al. 1998). Lentz, et al. (1998) concluded that nutrient concentrations in runoff except NO_3-N were positively correlated with sediment concentration.

The linear relationship between sediment and nutrient runoff concentration variables under the Pearson Correlation (Snedecor, et al. 1980) was examined. Pearson's correlation between sediment concentration and TP, and ortho P were found to be highly significant and ranged from 0.5 to 0.66. Lentz, et al. 1998 found that runoff sediment concentration, however, was only moderately positively correlated with TP and ortho-P concentrations under this PAM trial. PAM certainly seems to affect soil and nutrient concentrations differently than does other erosion control practices but does generally provide good sediment and phosphorus control.

At rates and concentrations employed by this technology, the anionic PAM had demonstrated no known toxic effects for mammalian and aquatic organisms, or plants, though a slight and apparent shift in some soil organism population densities has been observed (Barvenik, 1994).

Pump-back Ponds (Irrigation System, Tailwater Recovery)

A recirculating or pump-back pond, described by Bondurant (1969), is also called a Tailwater Recovery System. This system simply turns runoff back into irrigation water, to be used again on the same field or other adjacent fields. A sediment pond is installed at the lower portion of a field to catch runoff, settling out sediment prior to the water being pumped back up to an irrigation system. Field erosion is not eliminated on the field by this system, but sediment and nutrients in the runoff are reclaimed and not allowed to enter a water body.

Sediment Basins

One sediment retention basin installed to treat a 117-ha cropland area was evaluated by Carter (1976). The area consisted of highly erodible Portneuf silt loam soils, with slopes ranging from < 1% to 15% on surface irrigated beans, sugar beets, cereal grains, alfalfa and some pasture. A total of 2,390 metric tons of sediment was deposited in the .45-ha basin during two irrigation seasons (Robbins, et al. 1975). Average erosion loss was calculated at 20.5 metric tons/ha over a 2-year period from the 117 ha area. The sediment removal efficiency exceeded 80% when sediment concentration exceeded 0.1% and was never below 65% during the period of operation.

The efficiency of one specifically designed district drainway basin in southern Idaho averaged about 70% over a three irrigation seasons (Carter, 1976). The trapping efficiency of sediment basins is directly related to the forward velocity, settling depth and particle size of the sediment. Basins can be designed to remove given particles sizes if the flow volume is known so that velocity relationships can be established. Sediments remaining in suspension are mostly in the clay fraction, although much clay settles in aggregates because dispersion is not complete (Carter, et al., 1977). Dispersion is greater in waters with very low salt concentration, thus more clay remains suspended (Robbins et al, 1978). The clay size fraction is richer in phosphorus, so passing surface runoff through a sediment basin may give a greater phosphorus-to-sediment ratio. Carter, et al, 1974 has shown that sediment basins conserve phosphorus because most of the sediment is removed by the basins. Phosphorus was removed by 55% to 65% in a sediment basin that removed 65% to 75% of the sediment. The ratio phosphorus per unit of sediment was 0.9.

Sprinkler Systems

Sprinkler irrigation is an efficient means of applying water and nearly eliminates runoff during irrigation. New technology has improved center pivot, wheel-line, portable, and linear move operations and have reduced runoff flows to minimal when designed, installed and managed properly. These systems are recommended where the land is too steep for surface irrigation and lands with undulating topography. Of the majority, wheel-line and portable hand-line systems are used in the valley, with greater irrigation efficiency than center pivots and linear move systems.

Many cropland fields within the Boise River area are shaped in such a manner that does not allow for a feasible installation of center pivot systems. Linear moves also fall into the center pivot category and are generally not feasible to install on odd shaped and small acre fields. Wheel-line and portable hand-line systems are generally installed on small to 80-acre fields within the Treasure Valley.

Center pivots and linear move systems have been found to produce runoff where tillage management is not adjusted for the overhead irrigation and water application rates are greater than soil infiltration rates. Kincaid et al (1990) reported an average range of 9 to 25% runoff under conventional tillage management and a range of 1 to 9% under well managed reservoir tillage systems. Many local farmers within Treasure Valley use reservoir tillage or straw mulching equipment under center pivot and linear move systems when in row crops. When legume crops are in rotation, reservoir tillage and straw mulching is generally not be needed because of the crop's soil holding capability and restricts water movement.

Wheel-line and portable hand-line systems are dominantly used in the Treasure Valley and are generally more efficient than center pivot and linear move systems. Some farmers with center pivots on soils with low infiltration rates may irrigate non-legume crops with wheel-line and portable sprinkler systems. Legume and small grain crops may then be irrigated with the center pivot system.

Based on limited data, using Kincaid et al (1990) show a maximum of 25% runoff. However, the experience of the NRCS field offices show less runoff occurring in the Boise area because of design requirements and advanced systems. A realistic runoff estimate of 15% is to be used for the area. Using a typical runoff under surface irrigated cropland is 40% in the Boise area. A conservative reduction in water runoff when cropland is converted to sprinkler would be 25%. Sediment losses will be reduced even more because of the sprinkled water application on soils is less destructive, more uniformly applied than under surface water application, where water is channeled throughout the length of the field.

Surge Irrigation Systems (Irrigation Water Conveyance, Rigid Gated Pipeline)

Siphon tubes deliver water amounts varying with head pressure, which generally does not change significantly within a ditch unless check tins are adjusted or the tubes are tipped back or forward. Gated pipe consists of gates that can be manually adjusted to control flow, but the irrigator must provide themselves time to frequently come back to the irrigation set an adjust gates according to each furrows flow rate. With gated pipe and siphon tubes, much care is needed to ensure uniformity and that little erosion takes place. Under good water management, furrow stream sizes are adjusted for crop needs and erosion control, and irrigation frequency and duration.

Under surface irrigation, devices that control the amount of water from the ditch or pipeline to each furrow are essential to effective erosion control and efficient irrigation. To overcome the problems with siphon tube and gated pipe flow adjustments, Humpherys (1971) developed several systems for reducing flows in furrows after the water reaches the ends. One system splits the set, applying all of the water alternately to half the set until the water reached the end, then switches the water over to the other half until it reaches the end. At that time water is delivered to both halves, at half the rate to each furrow, advancing the water at a greater rate towards the end, subbing water to the plants much more adequately than under standard surface irrigation. This system has been developed further since then and is now automated with a solar charged battery and butterfly valve for switching water between halves. It better irrigates a field because of the multiple surging that occurs on each half, rather than only two surges each, as in Humpherys (1971) earlier design.

Under surge irrigation, runoff and sedimentation is reduced on well-managed systems. Because surge irrigation is new and few systems installed in the area, few irrigation trials have been done locally. Little system efficiency data is available to support sediment and nutrient control effectiveness. However, of those systems installed locally, it has been shown to virtually eliminate runoff when designed and managed properly. The system was developed to reduce deep percolation and runoff, but improve irrigation efficiency.

Runoff quantity and quality data for surge irrigation systems is not abundant because of this practice being new. Some data has been collected locally by the Malheur Experiment Station near Ontario, Oregon. Shock et al (1993) reported that surge irrigation resulted in a lower percent runoff than conventional furrow irrigation on 12 one-half acre plots, 13.7% vs. 22.7%. In addition, total estimated sediment loss was reduced from 1231 lbs/acre to 316 lbs/acre, a 71% reduction.

Underground Outlets

A common practice in irrigated areas is to keep the drain ditch at the lower end of the field clean, well enough below and deeper than the furrows, steep enough to get the runoff quickly away. This causes severe erosion at the furrow ends and as it continues, causes a greater slope at the field end. Many tons of soil are lost from this erosion occurring on these convex ends, only to be corrected by land forming to reshape it to its original slope. One management tool used today to control field end erosion and correct the convex end is a buried underground outlet. The first system of its kind was installed in 1978 (Carter, 1985).

The system is comprised of buried pipe that replaces the runoff ditch. At 40 to 60 foot intervals, riser pipes collect runoff from the field after filtering out sediment. Minibasins are formed around each riser to allow for sediment containment. Once sediment has filled these minibasins, the convex ends have been repaired and excessive erosion is eliminated at the field end.

Carter (1985) states that the sediment removal efficiencies for these systems range from 80% to 95%, with few exceptions. After the minibasins are filled with sediment the efficiency drops to about 70% to 90%, but with sediment concentration in runoff much lower than before because convex ends have been corrected.

Objective #4. Estimate potential TP reductions by each identified BMP.

Based on available data and research as described in the previous section, the estimated sediment and TP reductions for specific field scale BMPs are listed in Table 3. These estimated reductions are specific to surface irrigated cropland within the south central and southwestern Idaho region only, using the available research and local conditions. The estimates on Conservation Tillage, Mulching, and Polyacrylamide are conservative where little data exists or where there are management variables, that affects their sediment and/or TP reduction capability.

Conservation tillage estimates will vary with each crop rotation and will not be readily accepted because of mechanical weed control practices. Some conservation tillage is practiced on crop rotations from alfalfa to small grains, small grains to alfalfa, and small grains to potatoes.

Mulching probably will not be applied early enough in the irrigation season on row crops, unless cultivation is replaced with pesticides for weed control. Typical mulching practices today consist of placing straw in the furrows after all cultivation is done on row crops. Some mulching is done on high residue crops to improve infiltration, but has nominal effects on erosion because of the crops soil holding capacity. However, in the sediment and phosphorus control estimate, it is assumed that straw is placed in the furrows prior to the first irrigation.

Polyacrylamide is typically applied starting with the first irrigation and cultivation. The amount applied per acre will vary, but similar results should occur when the amount adjusts to the field conditions. These sediment and phosphorus control estimates will be conservative because of the nature of this chemical and its local management. Farmers within the Notus (city) area were found to have been putting on rates less than recommended on their row crop fields and often applied PAM later in the irrigation set because of the irrigators workload priorities (Ferguson, 1997a). The effectiveness of the PAM may be reduced after a few hours into the irrigation set period. Based upon these findings, a 10% reduction of the researched effectiveness of PAM is used because of the local management.

Based upon much research within south central and southwest Idaho, the ratio of TP loss to sediment loss seems to fall around 0.9. Therefore, TP reductions will be about 10% less than the sediment reduction capability of these BMPs.

Table #3 Surface Irrigated Cropland Field Best Management Practice Estimated Seasonal Effectiveness on Sediment and TP Reductions

BMP	Sediment Reduction Capability	Average Surface TP Reduction Capability	Sediment Reduction Range of Capability
Conservation Tillage	60%	50%	47 – 90%
Drip Irrigation Systems	100%	100%	100%
Filter Strips	40%	30%	30 – 70%
Mulching *	20%	10%	50 – 90% per irrigation *
Polyacrylamide (PAM)	80%	70%	50 – 94%
Pump-back Ponds	100%	100%	100%
Sediment Basins	70%	60%	55% - 80%
Sprinkler Systems	90%	80%	75 – 99%
Surge Irrigation Systems	90%	80%	71 – 90%
Underground Outlets	70%	60%	70 – 95%

* Mulching does not occur until after cultivation's have been completed, typically after 3 or 4 irrigations, therefore reduces the seasonal sediment and TP control effectiveness greatly.

Objective #5. Estimate on-site installation and maintenance costs for identified BMPs.

Current installation and annual operation and maintenance costs have been derived from local suppliers, contractors, Natural Resources Conservation Service, and the Soil Conservation Commission. Table #4 lists costs for BMP installation and annual operation and maintenance costs per unit.

Table #4 Average Installation and Annual Operation and Maintenance Costs per Acre of Identified BMPs .

BMP	Installation Costs per Acre	Annual O & M Costs per Acre
Conservation Tillage	$35/acre	$35/acre
Drip Irrigation Systems	$1000/acre	$10/acre
Filter Strips	$200/0.35acre strip	$200/0.35acre strip
Mulching (straw)	$35/acre	$35/acre
Polyacrylamide (PAM)	$30/acre	$25/acre
Pump-back Ponds	$250/acre	$12/acre
Sediment Basins	$20/acre	$10/acre
Sprinkler Systems	$750/acre	$15/acre
Surge Irrigation Systems	$350/acre	$5/acre
Underground Outlets	$200/acre	$2/acre

Objective #6. Estimate typical soil and TP losses from surface irrigated croplands in the Boise area.

As described in previous sections of this report, sediment and phosphorus loss from surface irrigated cropland varies. Soil types, field slopes, crop types, cultivation practices, and water management are the main factors that determine how much soil and phosphorus is lost. In this section, estimates of soil erosion and phosphorus losses will be established based on the common soil types, field slopes, crop rotations, and water management within the Boise area, specifically Ada and Canyon counties.

There are approximately 169,157 surface irrigated cropland acres within the Boise area that have direct or indirect impacts to the Boise River. Approximately 26,008 acres actually drain into canals (Ferguson, 1997b), which is generally reused by croplands within the watershed or in the Snake River watershed. Of these surface irrigated acres impacting the river, slopes typically range from 0.5% to 3%, with few ranging up to 12%. The steeper sloped surface irrigated lands are generally in pasture because they are not as farmable.

Slope was recognized as an important factor in furrow irrigation erosion in the1930s. Kemper, et al. (1985) concluded that erosion is approximately a two- to three-power function of average furrow slope. Carter, et al. (1983) reported higher sediment losses on fields with convex ends than from those with similar average slopes. Kemper et al. (1985) also concluded that erosion is commonly about a 1.5-power function of stream size. Variability between furrow stream sizes ranges up to about 25% and infiltration rates vary between wheel rows (Trout et al. 1988, and Trout et al. 1983). Residue, surface roughness, tillage practices, and crop rotations are also important factors in erosion.

Berg et al. (1980) conducted detailed investigations of water and sediment inflows and outflows from 50 furrow-irrigated fields. Many more fields have been evaluated and used in soil estimates. They found that an average of 50% of the water applied ran off the fields. This data has been used to develop estimated sediment losses for different crops on various slopes (Everts, et al. 1981). This work was done on soils similar to the Boise area, consisting of mostly silt loam soils. The only major difference between soils in these two areas may be depth of topsoil, which does not seem to warrant any significant adjustments in estimates of soil erosion in the Boise area derived from Everts, et al (1981) data.

The Surface Irrigation Soil Loss (SISL) model has been developed by Dr. Carter and his associates, based on over 200 investigated surface irrigated fields. The SISL model is based on the equation:

$$SISL = BSL \times KA \times PC \times CP.$$

- SISL is the surface irrigation soil loss from a field in tons/acre/year.

- BSL is the base soil loss rate average from Carter's investigations on over 200 fields in the Rock Creek, Twin Falls, Idaho area.

- KA is the soil erodibility adjustment for the soil in relation to the soil on which the base soil data was obtained. (Portneuf silt loam with K factor of 0.49)

- PC is the prior crop impacts on reducing soil erosion.

- CP is the conservation practice impacts on reducing soil erosion.

From the data collected from those 200 fields and the formula developed to estimate erosion rates, Table #5 was developed to estimated erosion rates on typical surface irrigated crop fields using siphon tubes. Two other tables were also created for gated pipe field systems and earthen ditches with cutouts but give similar erosion rates as in Table #5.

Table #5 Estimated Soil Loss (tons/acre/year) for Siphon Tube Irrigation Systems

Average Field Slope		< 1%			1 - 1.9%			2 - 2.9%			> 3%		
Convex End Condition		n	M	s	n	m	s	n	m	s	n	m	s
Crop Field Length	660	0	0	0	0.7	0.9	1.2	2.3	2.9	4.1	5.6	7	9.8
Alfalfa Hay	1320	0	0	0	0.6	0.7	1	1.8	2.3	3.3	4.5	5.6	7.8
	660	1.1	1.3	1.8	3.2	4	5.6	6.4	8	11.2	10.4	13	18.2
Grain & Peas	1320	0.9	1	1.4	2.6	3.2	4.5	5.1	6.4	9	8.3	10.4	14.6
	660	2.5	3.1	4.4	8.7	10.9	15.3	18.4	23	32.2	28	35	49
Beans & Corn	1320	2	2.5	3.5	7	8.7	12.2	14.7	18.4	25.8	22.4	28	39.2
	660	3.2	4	5.6	12.1	15.2	21.2	26.4	33	46.2	44	55	77
Sugar Beets	1320	2.6	3.2	4.5	9.7	12.2	17	21.1	26.4	37	35.2	44	61

The convex end conditions of n, m, and s represent nominal, moderate, and severe. Moderate convex ends have ditch bottom less than 6" from field level, and severe convex ends have ditch bottom greater than 6" from field level. In the Boise area, the moderate convex end is common, therefore will be used in estimating typical erosion rates.

Crop rotations vary from field to field, and often change every year. Farmers don't always hold to a rotation because of crop contracts, expected price drops, and so on. However, there is a common percentage of crops grown on most farms within a 12 year period. Alfalfa seed or hay is grown for about 4 years in 12, wheat and barley 2 years in 12, corn and beans 2 years and 12, and onions, sugar beets, and potatoes 4 years in 12. Given these typical crop percentages, average soil loss can be derived. For the Boise area, in a 12 year rotation, alfalfa similar crops are grown 33% of the time, small grains are grown 18%, corn and beans 16%, and onions, sugar beets and potatoes 33%. Associating these percentages with BSL rates, a weighted BSL can be derived for the 12 year rotation.

Field lengths are generally greater than 660 feet, more often having been leveled to ¼ mile in length, 1320 feet with the Boise area. So the 1,320 foot field length will be used in the typical sedimentation estimates.

The majority of soil types in the Boise area are of the sandy loam, silt loam, and loam soils. The most common K factors, which represents the erodibility of soils, range within 0.28 to 0.49. Everts, et al (1981) data from 200 fields mostly consisted of Portneuf silt loam soils, with a K factor of 0.49, which was suggested to be the most erosive soil types. The majority of the surface irrigated cropland soils within the lower Boise River watershed are summarized in Tables #6. The table shows percent of K factor soils within each slope range.

Table #6 Percentage of Lower Boise River Surface Irrigated Cropland by Soil K factor/Slope Class

K Factor / Slope	0-1%	1-3%	3-7%	7-12%	Total
0.05	14.78%	0.45%	0.00%	4.45%	4.92%
0.1	0.09%	0.06%	0.66%	0.44%	0.31%
0.15	0.85%	10.15%	29.31%	0.68%	10.25%
0.17	0.00%	1.23%	0.01%	0.00%	0.31%
0.2	1.46%	1.88%	0.47%	3.04%	1.71%
0.24	1.99%	2.50%	0.64%	2.80%	1.98%
0.28	7.13%	5.38%	3.46%	12.80%	7.19%
0.32	21.17%	3.55%	1.41%	0.00%	6.53%
0.37	16.68%	18.52%	22.20%	3.56%	15.24%
0.43	31.41%	43.62%	36.20%	30.12%	35.34%
0.49	4.06%	12.51%	2.61%	42.12%	15.33%
0.55	0.39%	0.14%	3.02%	0.00%	0.89%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

In every slope range, the majority of the soils have a K factor between 0.28 and 0.49. Typically, surface irrigation on soils with K factors less than 0.32 are in pasture or have been converted to sprinkler. The data used to create the table was from 1994 landuse data from Idaho Department of Water Resources (IDWR) and 1997 watershed data from the Soil Conservation Commission. Sprinkler irrigated cropland was not separated out of this IDWR landuse data, therefore the table includes soils that have had sprinkler systems installed on them. A K factor of 0.43 will be used to estimate typical sediment losses because of the highest percentages of soils seem to fall within this average range.

The percentage of surface irrigated acres with 1, 3, 7, and 12% slopes in the Boise area are reported in Table 7. Again, most of those fields on the 12% slope range are in pasture or sprinkler.

Table #6 Percentage of Lower Boise River Surface Irrigated Cropland by Soil K factor/Slope Class

K Factor / Slope	0-1%	1-3%	3-7%	7-12%	Total
0.05	94.62%	2.51%	0.00%	2.87%	100.00%
0.1	24.22%	14.74%	49.37%	11.67%	100.00%
0.15	4.67%	49.23%	45.71%	0.38%	100.00%
0.17	0.00%	99.64%	0.36%	0.00%	100.00%
0.2	41.12%	46.51%	3.73%	8.64%	100.00%
0.24	42.76%	47.28%	3.89%	6.07%	100.00%
0.28	50.47%	33.47%	6.92%	9.14%	100.00%
0.32	85.76%	12.63%	1.61%	0.00%	100.00%
0.37	42.14%	41.11%	15.84%	0.91%	100.00%
0.43	37.86%	46.17%	12.32%	3.66%	100.00%
0.49	20.27%	54.85%	3.68%	21.20%	100.00%
0.55	28.83%	8.80%	62.37%	0.00%	100.00%
Total	39.39%	38.08%	17.15%	5.38%	100.00%

The bulk of the soils are within the 1% and 3% slope ranges. Taking the average Base Soil Loss (BSL) between these slope ranges would give an average soil loss to use in the typical soil loss estimate for the Boise area.

Using a weighted BSL of 13.44 (33% of alfalfa, 18% of grains, 16% of corn, 33% of sugar beets) for the typical crops grown; the average slope range of 2 – 2.9% (between 1 and 3% slopes); a moderate convex end; an adjustment rate of 0.87 for a K factor of 0.43, which was determined by Carter; a PC factor of 1, using a conservative assessment; a CP factor of 1 for conventional tillage which typically occurs in the Boise area, the formula for determining SISL would follow:

- BSL (13.44) x KA (0.87) x PC (1.0) x CP (1.0) = SISL (11.69)

The typical average soil loss for the area would then be 12 tons/acre/year. This estimate is certainly not specific to any one field, but gives a good average based on the above factors for the Boise area. This rate will be used to determine typical TP losses from these fields.

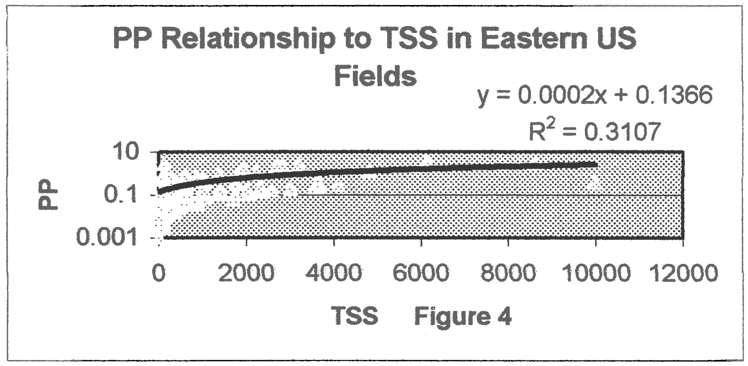

Figure 4

Fitzsimmons et al. (1972) found average total suspended solid concentrations at 1,550 ppm in surface runoff from 79 field and drain sites in the Canyon and Ada county area. They attributed most of the solids to sediment. Using the Carter et al. (1974) and Carter et al. (1976) regression equation from irrigation and drainage waters in the Twin Falls area, an average TP loss/acre/year can be estimated for the area. The equation again is: Y = 140.52 + 0.72X (with correlation coefficients r^2 = 0.89 and r = 0.94), where Y is nonfiltered TP concentration in ppb, and X is the nonfiltered sediment concentration in ppm.

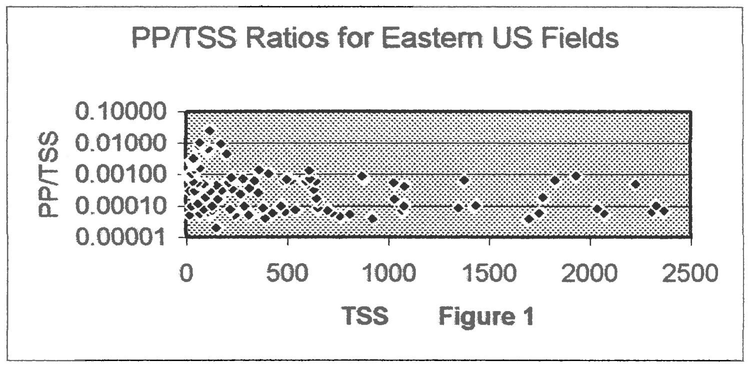

Figure 1

If we use the average of 1,550 ppm sediment concentration that Fitzsimmons et al. (1972) determined, the average TP concentration would be 1,257 ppb or 1.3 ppm or 1.3 mg/l. This sediment to TP ratio is 0.0008 (1.3/1550), thus if the average sediment loss volume of 12 tons/acre/year is used, then an estimated TP loss is 18 lbs/acre/year (0.009 t/a/yr). If there is a need to determine actual soil and TP losses, then intensive water monitoring has to occur throughout a season for any specific crop.

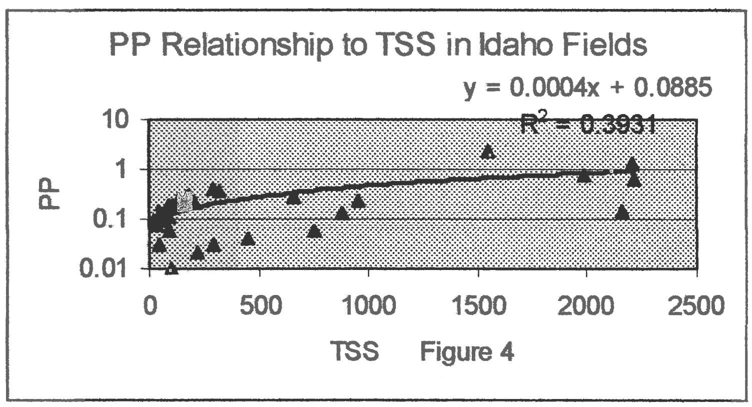

Figure 4

Brown (1985a) measured TP volume losses from potatoes plots to be at 7 lbs/acre/year, with sediment to TP loss ratios ranging from 0.0006 to 0.0012. Sharpley et al. (1991) determined a ratio of sediment concentration of runoff under natural precipitation to particulate P of r^2 = 0.79, giving the predictive formula of $Y = 0.72X^{-0.30}$. Average TP/TSS ratios in Sharpley et al. (1991) field trials from Texas and Oklahoma ranged from 0.0002 to 0.001.

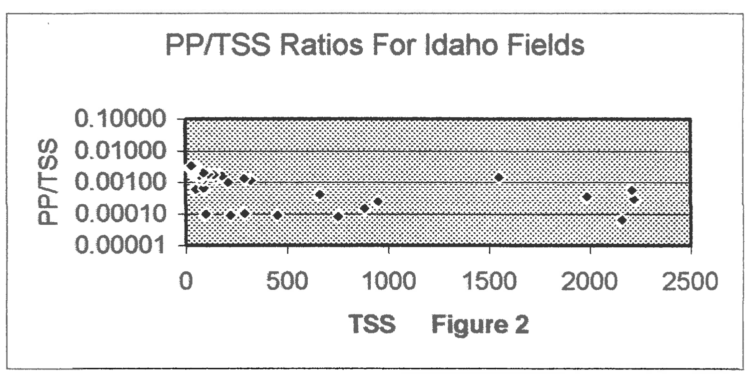

Figure 2

Lentz et al (1998) showed through PAM trials on dry bean fields that treated and untreated furrows yielded an average ratio of sediment to TP loss of 0.0005.

This ratio showed up in both runoff concentrations and volume losses. Sediment loss for untreated furrows yielded 2724 lbs/acre cumulative sediment loss and a TP loss on this trial after irrigations was 1.3 lbs/acre. Data collected by Lentz et al. (1994) also showed average sediment to TP ratios on PAM and non-PAM treated fields to range from 0.0005 to 0.0007.

Thus far, TP has been the focus in its relationship to sediment. Typically, the major portion of TP that has a strong relationship to sediment is the particulate phosphorus (PP). Realizing that the majority of TP captured in sediment ponds, filter strips, and other sediment related BMPs, is dependent on the amount of sediment captured, PP may be the appropriate portion of TP that we can only capture effectively with sediment and erosion BMPs. From this point on, PP will be evaluated as the main portion of sediment BMP controllable TP. It is important to understand that every BMP will have different sediment reduction capabilities, trapping differing amounts as well as particle sizes. As mentioned before, the smaller the particle size the greater amount of phosphorus is likely attached. The farther away sediment travels from its source of origin, the greater selectivity occurs and the majority of particles are of the silt and clay fraction. Another important factor in selectivity is that the closer sediment particles are to its source, the more likely they are in aggregate form, including a greater portion of all particle sizes. On a field scale, it is likely that sediment trapped with BMPs include clay and silt fractions containing greater amounts of phosphorus because a great amount of selectivity has not occurred. A sediment pond may then have a greater sediment and phosphorus trapping capability the closer to the sediment's source material, being able to trap larger aggregates better than fine particles.

Figure 1 shows a graphic relationship between TSS (Total Suspended Solids) in Eastern US field runoff to PP/TSS ratios. These data are from a number of research plots and fields from eastern and midwestern states ranging in size from .5 to 150 hectares. The data sources for Figure 1 are listed in the references. Figure 2 reflects the same relationship from data gathered by researchers around the Snake River area from Twin Falls through the Parma Idaho area. Data collected from Mason Creek drainage waters in Canyon county Idaho show a very strong relationship of PP to TSS (Figure 3).

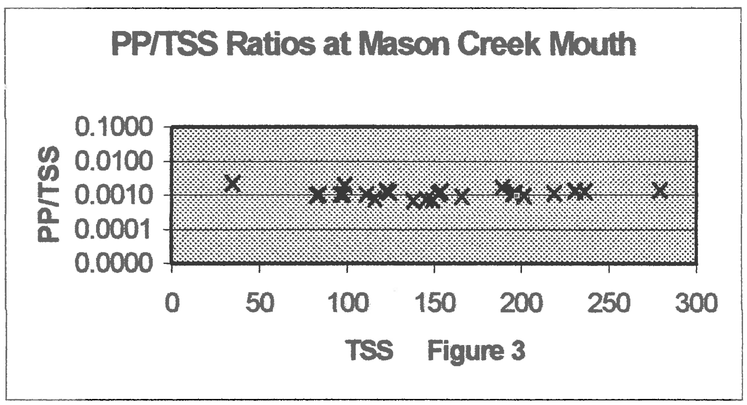

Figure 3

Objective #7 Estimate the costs of TP reductions

Using the 18 lbs/acre/year TP loss estimate, the cost per pound of TP reduction for each BMP was estimated in Table #8, in reference to the costs noted in Table #4. The local Boise area costs associated with each BMP to reduce one pound of TP is dependent on BMP effectiveness, current TP losses from fields, and installation, annual maintenance, and operation costs.

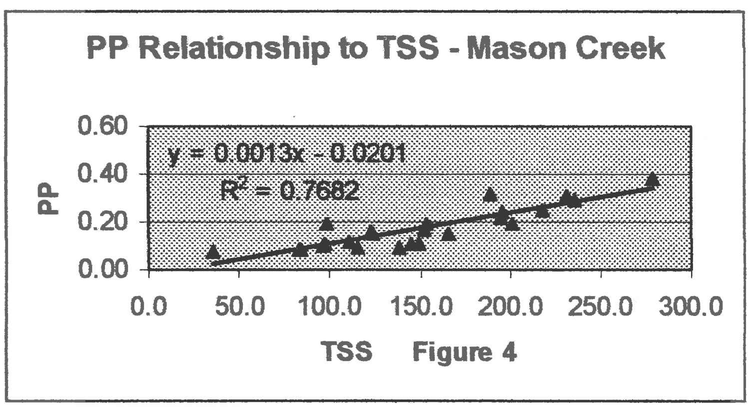

Figure 4

Table #8 Estimated Costs of TP Reduction per Pound by Various BMPs in Boise Area

BMPs	TP Reduction Capability	TP Reduced/Ac (18xTPRC)	Cost /lb of TP in installation or 1[rst] year (Install cost/TP reduced)	Annual Cost /lb of TP (Annual cost/TP reduced)
Conservation Tillage	50%	9.0	$3.89	$3.89
Drip Irrigation Systems	100%	18.0	$55.56	$0.56
Filter Strips	30%	5.4	$37.04	$37.04
Mulching (straw)	10%	1.8	$19.44	$19.44
Polyacrylamide (PAM)	70%	12.6	$2.38	$1.98
Pump-back Ponds	100%	18.0	$13.89	$0.67
Sediment Basins	60%	10.8	$1.85	$0.93
Sprinkler Systems	80%	14.4	$52.08	$1.04
Surge Irrigation Systems	80%	14.4	$24.30	$0.35
Underground Outlets	60%	10.8	$18.52	$0.18

Objective #8 Discuss additional data needed for better estimating BMP TP reduction capabilities and costs

The analysis done in this report is based on available erosion and sedimentation data and the relationships of TP to sediment. If better costs estimates and BMP effectiveness are to be determined, then an analysis could be done on field basis with actual soils, slopes, crop rotations, and water management factors determined. Field water quality monitoring during every irrigation, over the entire crop rotation period, would also be needed to determine actual TP losses. This sort of monitoring may not be feasible under effluent trading or within the TMDL implementation of BMPs within the Boise River watershed. Some important factors need addressed as the Boise area effluent trading progresses:

1. Improve typical nonpoint source phosphorus loss estimates from agriculture fields in southwest Idaho
2. Improve the sediment to phosphorus relationship on irrigated fields in southwest Idaho
3. Explore the relationship of phosphorus and sediment movement from fields to drains and the Boise River.
4. Improve upon existing BMP effectiveness data regarding phosphorus and sediment reductions.
5. Establish a better understanding of in-stream sediment and nutrient movement within southwest Idaho.
6. Update on-site BMP installation and maintenance cost lists from contractors, suppliers, and farmers.

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Watershed-Scale and Field-scale Sediment Basin Phosphorus Reduction Effectiveness

Prepared for: Lower Boise River Watershed Effluent Trading Demonstration Project
The Environmental Protection Agency, Region 10
The Idaho Soil Conservation Commission

Prepared by: David F. Ferguson, Water Quality Resource Conservationist with the Idaho Soil Conservation Commission

Date Prepared/Revised: 9/16/99

Introduction

The purpose of this report is to discuss the effectiveness of a sediment basin on sediment and phosphorus removal. There are two classes in which these sediment basins will fall, the watershed-scale and field-scale sediment basin. The general difference in the two is defined by the size of the treatment area, where field-scale basins usually treat less than 100 acres. What effect these basins have on a drain, stream, river, or lake is difficult to estimate when there arenumerous factors within the basin design and within the natural and man-caused sediment and phosphorus sources, erosion characteristics, and transport processes.

Irrigated agriculture is a dominant landuse in the Lower Boise River watershed, of which surface irrigated cropland is dominant. A large proportion of sediment and phosphorus reaching the Boise river comes from these lands and is addressed in the Idaho's Agricultural Pollution Abatement Plan (APAP). A list of national and state adopted Best Management Practices (BMPs) engineered to reduce sediment and nutrient contamination to a water body is included in the APAP. The BMPs listed for irrigated cropland vary in their effectiveness on sediment and nutrient containment because of the complexities mentioned before as well as farm management. The intent of this report is to establish the average sediment and phosphorus trapping efficiencies that can be expected when sediment basins are installed in southern Idaho and maintained according to the Natural Resources Conservation Service (NRCS) standards and specifications as stated in the National Handbook of Conservation Practices (NHCP).

Background

The Environmental Protection Agency, State environmental agencies from Idaho, Oregon, and Washington, and local interests are examining how effluent trading can: (1) help improve water quality in the region; (2) promote pollution prevention; and (3) help meet specific water quality objectives on the Lower Boise River. They are supporting the Lower Boise River Watershed Effluent Trading Demonstration Project by implementing actual trades between two or more pollutant sources, with phosphorus as the tradable element. The project has a few objectives to identify what is actually needed to implement trading, one of which is to investigate ways of reducing phosphorus loads while minimizing source reduction costs.

The Lower Boise River has a Total Maximum Daily Load (TMDL) developed for sediment sources. Load reductions for phosphorous are not currently required in the Lower Boise River TMDL, but are likely to be set under the Snake River-Brownlee Reservoir TMDL. Nutrient loads coming from point, nonpoint, and ground water sources may be sufficient enough to cause algae problems in the Boise River in the summer months, specifically during drought periods and at low river flows. The portion of phosphorus that is critical to algae growth is soluble phosphorus, which seems to be the majority of the total phosphorus.

It is not entirely understood where the majority of this soluble phosphorus comes from; however, local water sampling seems to point towards groundwater leachate. Fitzsimmons et. al, (1972) noted that the ground water in the Boise area contained a relatively large concentration of both forms of dissolved and total phosphorus (average TP at .58 ppm and DP at .11 ppm). Some 1998 winter groundwater samples taken by the Idaho State Department of Agriculture (ISDA) in the Sand Hollow tributary area have shown levels up to .26 ppm soluble phosphorus and .36 ppm total phosphorus. Other sources include wastewater runoff from agricultural fields, wastewater discharge from public treatment facilities, storm event runoff from multiple landuses, and desorped phosphorus from sediment and plant materials.

Through the trading project, reduction ratios are to be developed between the trading sources based on the practice phosphorus removal effectiveness and their potential phosphorus reductions to the river. It is necessary to explore and determine, based on available data, what the practices' effectiveness is on phosphorus reductions.

An Effective Phosphorus Reduction BMP

The BMP initially selected here for phosphorus reductions is characterized in two scales of treatment: field-scale and watershed-scale. The sediment basin is not the only BMP capable of reducing phosphorus, but by evaluating this BMP's effectiveness on sediment and phosphorus removal, it will help conservationists begin to understand the complexities of other BMP effectiveness on sediment and phosphorus.

The field-scale sediment basin is installed at a collection point of a small watershed or field (< 100 acres) to settle out sediment and sediment attached phosphorus. A watershed-scale sediment basin is installed at a collection point of a large watershed (> 100 acres) to settle out sediment and sediment attached phosphorus.

Field-scale Sediment Basins

Sediment Basin Description

The sediment basins installed on irrigated cropland fields are generally rectangular shaped, approximately 3 to 6 feet deep, 15 to 25 feet wide with 1:1 side-slopes, and ranging from 80 to 200 feet long. These ponds can be built by large earth movers, backhoes, or front-end loaders (commercial or a farm tractor attachment). There is usually at least a 4 foot wide berm around the pond, with at least a 1 foot freeboard height above existing ground surface. Water from the irrigated field or fields can enter the pond through 10 to 12 inch corrugated metal pipes or over very shallow, non-erosive grades. Steel pipe inlets are preferred because of bank protection and water control is greater than earthen inlets. Basin outlets generally have to be either a horizontally installed metal pipe like the inlet or a "glory hole" style outlet, where water drops into a vertical pipe, then transported through a horizontal pipe through the basin's bank and into another drainage.

The basin is shaped to meet the farmers desire and the basins inlet and outlet conditions are designed to meet Stokes Law. The trapping efficiency of sediment basins is directly related to the Stokes Law (Stokes, 1851), including a forward velocity factor. It is possible to determine the time it takes for a given particle size and density to drop a given distance within a water body, given some constants. Basins can be designed to remove given particles sizes if the flow volume is known and velocity relationships are established. NRCS requires a minimum trap efficiency of 65% and a storage capacity of 80% of expected annual sediment load when the basin is to be cost-shared.

Sediment Basin Life Span

The life span of a sediment basin is not discussed in the current standards or specifications of the NHCP, but field-scale sediment basins constructed to treat agricultural runoff are generally designed to last for an indefinite period. Sediment basins are designed to capture the maximum annual sediment load and require cleaning every year when there is sediment in the basin. Basin life span is generally dependent on how well maintenance occurs on bank integrity, inlet, and outlet structure replacement because of metal deterioration.

Applicability of Sediment Basin

These basins can be installed where land is available for construction and will collect the desired amount of water runoff from a specified acreage. These field-scale sediment basins are generally installed on croplands where erosion occurs and sedimentation is a problem downstream of the field. The basins are often considered as a "band-aid" BMP, not addressing the source of the sediment problem, where soil erosion occurs. However, these basins are a tool in which landusers can judge their effectiveness on erosion control methods and feasibly reduce sediment losses. Other landuses, such as subdivisions, construction sites, and parking lots, can benefit by the installation of these basins.

Initial Cropland Field Phosphorus Loss Calculation

There are few sediment and phosphorus models for irrigated agriculture, but they are limited in their ability to predict phosphorus losses. Two models exist that may be the most appropriate for irrigated croplands, the Environmental Policy Integrated Climate (EPIC, formally known as the Erosion Productivity Impact Calculator) and the Surface Irrigation Soil Loss (SISL). There has been some adjustments done on the EPIC model through the NRCS to better predict soil and phosphorus losses. This model has been adjusted to better represent nutrient and sediment losses under irrigation. Phosphorus-sediment ratios can be used where there is some understanding of the areas soils and land management with the SISL model to estimate phosphorus losses.

The SISL model (Soil Conservation Service, 1989) was developed by the Agricultural Research Service in Kimberly Idaho from over 200 surface irrigated field evaluations and can estimate soil losses on similar croplands. Having estimated soil loss, phosphorus losses may be estimated with a phosphorus-sediment relationship. With a high degree of certainty, most of the phosphorus losses from surface irrigated croplands occur with sediment losses (Carter, et. al 1976). Berg et al., 1980 wastewater analysis on 49 surface irrigated fields within the south-central and south-western portions of Idaho, showed there was a significant relationship between total phosphorus and sediment losses. <u>The median percent of dissolved phosphorus to total phosphorus was only 3%, with an average of 11%! The median total phosphorus-sediment ratio in pounds-per-ton of soil was 1.6 and the particulate phosphorus-sediment was 1.5.</u>

North American field-scale and watershed-scale studies on sediment and phosphorus losses show phosphorus-sediment ratio of 0.0002 to .002 (0.4 to 4 lbs./ton soil). The phosphorus-sediment ratios in the Boise area drains will generally fall within .0005 to .001 (1 to 2 pounds per ton soil), however; the closer eroded soil is to its source, the higher the phosphorus-sediment ratios may be due to lessor aggregate dispersion. A larger percent of silt and clay particles will still be in aggregate form, dropping out into ditches and basins quicker than individual silt and clay particles staying in suspension in drainage waters. <u>Average field-scale total phosphorus losses would be about 2 pounds for every ton of soil with particulate phosphorus losses just slightly less, generally depending on the residue cover.</u>

Phosphorus Reduction Period

The majority of the phosphorus loads originate from irrigation induced soil erosion, anytime during the irrigation season. Some storm events can produce soil and phosphorus loads, but are minimal compared to the irrigation season loads. Pollutant reductions with sediment basins will occur throughout the year, trapping the highest percentage of the sediment and phosphorus in June and July due to irrigation frequencies.

Sediment Basin Maintenance

Maintenance on sediment basins generally occurs after the crop has been harvested, prior to the next planting. This maintenance includes annual sediment excavation, stockpiling, and spreading. Deteriorated pipe structures may need to be reinstalled or replaced after some years. Sediment basins installed for urban landuses runoff may need only minimal cleaning, depending on the sediment losses from the watershed. However, where pipe culverts exist, clogging can occur from litter, especially near urban areas and when adjacent to highways. NRCS requires vertical pipes to have covers or trash screens to reduce the risk of clogging and risk to children and small animals.

Excavated sediment will need to be disposed, whether transported back onto its source of origin or used as fill material for other purposes. The trucking distance is generally within a mile of the basin. Sediments are generally stockpiled near to the basin to allow for drying and increased microbial activity. Soils cleaned out of the basin can have little oxygen content because of water saturation but will regain microbial activity once dried and spread out.

Sediment Basin Water Monitoring

Small watershed-scale water sampling throughout the year could be costly and may not be feasible unless outside funds are available and is requested to be carried out by the landowner. An alternative to water sampling would be to analyze the soil trapped in the basin for phosphorus content. Composite samples could help determine an average phosphorus concentration in the trapped soil. Sediment and phosphorus trap estimates can be made to establish initial phosphorus credits, and then finaled with soil testing and quantifying the amount of sediment removed. The most sensible time to do basin soil analysis on agricultural lands would be in the fall, after the majority of the sediment loss has occurred. With non-agricultural landuse sediment basins, soil testing may be done in the late spring or summer, after the majority of soil loss has occurred.

Operation inspections, also known as status reviews can be performed at any time to verify the basin is operating according to design. This would include a visual inspection at the minimum, possibly including dimensional measurements as well. The measurements would then be compared to the design specifications to determine if the basin is in operation compliance.

Initial Estimate of Phosphorus Removal

Surface water

Phosphorus trapped in sediment basins is dependent on the amount of sediment trapped and phosphorus-sediment ratio of those caught in the basin. Soluble phosphorus is not trapped in the basin while it is fully charged with water. However, a small portion may become trapped when the basin inflow is halted. The remaining soil particles settle out in the basin tying up remaining dissolved phosphorus. This amount is not typically accounted for when basin efficiency is determined. Soil analysis would account for most of the trapped phosphorus.

A sediment basin's total phosphorous trapping capability is very dependent on the percent soluble phosphorus of the total phosphorus. Where soluble phosphorus is 10% or less of total (from little or no residue fields), the total phosphorus trap efficiency will be high, similar to the basin's sediment trapping efficiency. But as the percentage of soluble phosphorus increases in the inflowing water, the basin's total phosphorus efficiency decreases.

The sediment trapping efficiency of sediment basins is directly related to the forward velocity, settling depth and particle size of the sediment. Basins can be designed to remove given particles sizes if the flow volume is known so that velocity relationships can be established. Sediments remaining in suspension are mostly in the clay fraction, although much clay settles in aggregates because dispersion is not complete (Carter, et al., 1977).

An initial range estimate for phosphorus removal for field-scale sediment basins is about from 1.5 to 2.5 pounds of particulate phosphorus (pp) per soil ton trapped, but can be greater. Bondurant et al, 1975 presented one basin's effects on sediment retention by particle size distribution. Average sand, silt, and clay percentages caught in the basin were 13, 65, and 22 percent respectively. Utilizing 550, 1,150, and 1,285 ppm tp on sand silt, and clay fractions from Carter, et al. (1974) (1.1, 2.3, and 2.6 lbs/ton soil respectively), the average phosphorus concentration (pp) per ton of soil ratio caught in the basin was 1100 ppm or 2.2 lbs.

When sediment concentrations exceed 250 mg/l, basin sediment removal efficiencies can exceed 80% (Carter 1985). The highest efficiency expected is 95%, with concentrations around 1000 mg/l. However, when concentrations are extremely high, greater than 1000 mg/l, trap efficiency can even exceed 95%.

Dispersion is greater in waters with very low salt concentration, thus more clay remains suspended (Robbins et al, 1978). The clay size fraction is richer in phosphorus, so passing surface runoff through a sediment basin may give a greater phosphorus-sediment ratio. Carter, 1976b stated that sediment basins conserve phosphorus because most of the sediment is removed by the basins. Carter, 1976b also referred to a basin that removed phosphorus by 55% to 65% while removing 65% to 75% of the inflowing sediment. Field-scale basins have the capability to trap these amounts when total phosphorus is mostly of the particulate form and sediment concentrations while most of it is attached to the particles.

Ballard, 1975 studied various sediment basins and found that the trap efficiencies were very high. Most basins averaged greater than 80% sediment trap efficiencies and four basins analyzed trapped over 35 to 78% of the total phosphorus. One basin on a wheat field achieved over 85% sediment trap efficiency and 39% total phosphorus trapped. A bean field's basin trapped over 80% sediment and 50% of the total phosphorus. One potato field basin trapped over 80% of the sediment and 78% of the total phosphorus. The wheat field' soil loss was low, providing a lower concentration of total phosphorus and the potato field's soil and total phosphorus loads were high. This supports the basin's increase in sediment and phosphorus trap efficiency with high concentrations and loads.

Where a low residue crop is surface irrigated and planted on silt-loam soils; and soluble phosphorus is less than 10% of total phosphorus, a field-scale sediment basin with a designed 65% trap efficiency should trap 55 percent of total phosphorus, on average, 1.8 pounds (2 pounds minus 10%) of total phosphorus per ton of soil. If, for example, the percent soluble phosphorus increases to 30% of total phosphorus and where the crop has a greater amount of residue, the basin may only trap 45% of the total phosphorus. Designing field-scale basins with trap efficiencies much greater than 65% may not generally be feasible due to their large size.

From ground water

Field-scale sediment basins are only designed to filter surface water, and on a field-scale, there would seldom be ground water recharge to a drain in which water was diverted into a basin. Sprinkler and drip irrigation systems and nutrient and water management are some BMPs that would address phosphorus leaching on a field-scale basis.

Certainty of total phosphorus removal amount from field runoff

There is uncertainty when estimating BMP removal efficiencies because of nutrient cycling, erosion processes, and field management. There is even greater uncertainty on what BMPs effectiveness is on sediment and phosphorus reductions within a large drain or river. However, when designed, installed, and maintained according to specifications from the Natural Resources Conservation Service, the basin will very likely provide at least a 65% sediment removal on site and an average of 1.8 pounds of phosphorus for every ton of soil. Design of these basins is important but maintenance is a greater factor on these basin's efficiencies. Soil and phosphorus testing and quantifying sediment removal from these basins could provide actual phosphorus removal from the basin's watershed area.

Environmental Impacts

Negative environmental impacts generally do not occur with these field-scale sediment basins. However, there may be problems when water is perched within the basin and the local water table is raised. Adjacent construction sites, homesteads, and cropland fields can become wet unless drainage tile or ditches are installed around basin, providing adequate drainage. To avoid this soil-wetting problem, basin depth and outlet conditions are designed according to local site conditions.

Nutrient leaching below these basins may occur because of ponding and increased water pressures over the basin site. It is not specifically known how much of the phosphorus would be leached or the probability, but likely much less than what was lost to non-treated surface runoff.

Wildlife often utilize these small basins and can contribute nutrients and pathogens. The contribution amounts have not been studied locally but probably would be minimal because of the small number of waterfowl that use one sediment basin.

Watershed-Scale Sediment Basin

System Description

The watershed-scale sediment basin is a structure built in or adjacent to a drainage to intercept, filter, and return water to the drain in a cleaner state. These basins would generally treat a watershed greater than 100 acres, including all landuse pollutant sources within the watershed. These basins only filter solids (mostly sediment) and sediment-attached substances in water. These would not include filtration by vegetation provided through a wetland or sediment & nutrient system.

A watershed-scale sediment basin placed near the mouth of any tributary will generally trap the estimated amount of sediment because of the design criteria. If a good phosphorus-sediment relationship is established for a given watershed, then the estimated amount of phosphorus may be similar to what is actually trapped in the basin.

These sediment basins installed within or adjacent to large drains would generally be rectangular or similarly shaped, approximately 6 to 10 feet deep, up to 60 feet wide with 1:1 side-slopes, and ranging from 200 to 1000 feet long. It may not be feasible to install a larger basin because of installation and maintenance costs in relation to the number of pounds of phosphorus trapped. The size depends on the amount of water and sediment its designed to treat. These ponds can be built by large earth movers, track-hoes, and drag-lines. They would need to have at least a 10 foot wide berm around the pond, with at least a 2 foot freeboard height above existing ground surface. Water from the drain can enter the basin through large diameter corrugated metal pipes or through rip-rapped drainage ways. Basin outlets generally would be either a horizontally installed metal pipe like the inlet or a "glory hole" style outlet, or a wide rip-rapped outlet, transporting filtered water back into the drainage.

Sediment Basin Life Span

Watershed-scale sediment basins constructed to treat surface and ground water should be designed to trap at least one annual sediment load. Life spans are not discussed in NRCS standards or specifications but should be built to bypass large runoff storms such as a 25 year or greater storm events. Maintenance is critical to the life span of these large basins, where after a few years, it may be difficult to tell where the original basin sides were located when soil is stockpiled alongside the basin and then later removed.

Applicability of Sediment Basin

This system can be installed wherever there is land available and there is potential or existing sediment loss from a watershed. Typically, these watershed-scale systems are installed if there is an agreement with many landowners and ditch operators within and upstream of the system. These basins, because of their potential size, may not fit to every drain situation. Where a drain is on a steep grade (>3%), the pond length may not fit to the grade or possibly require higher banks, which may not be allowed near highways or homesteads. Depths to hard layers may increase installation costs or restrict the depth of the pond, requiring wider or longer basins to ensure storage capacity.

Land acquisition, through purchase, lease, or permanent easements, needs to occur through any number of landowners. These basins may need to be located between two landowners properties to best fit the topography near the drain. Private property rights need to be upheld when lands are leased or given to permanent easements.

Initial Watershed Phosphorus Load Calculation

The amount of sediment and phosphorus passing a given point along a drain or stream is best determined with actual water monitoring. A watershed scale basin can be designed to trap a given amount of soil based on inflowing water velocities, cross-sectional area, and soil holding capacity. Initial monitoring needs to take place to estimate the sediment and phosphorus load over an entire irrigation season or expected basin operation period to size the basin accordingly. However, if a basin was installed without knowing inflowing water velocities of sediment loads, the basin could be monitored during or after its operation period to determine the amount of sediment and phosphorus trapped. This would then characterize the basin into a measured BMP.

Phosphorus Reduction Period

Because most of the larger drains in the Boise area flow continuously, these systems may provide phosphorus credits throughout the year. There is a possibility that these systems may divert drain water in the winter for a period of time to allow for maintenance. A portion or all of the drainage water may be diverted around the basin for fish passage if there ever exists the need. Engineering may also allow excessive storm flows to be diverted around the system to bypass large storm flows. Phosphorus credit establishment with a watershed-scale basin would be dependent on landuse types above the system when actual measurements are collected prior to operation or during.

Sediment Basin Maintenance

Operation may generally occur during the winter months. Estimated time needed to clean these basins is less than a month (30 days), while water is diverted around the basin, probably in the original drainage way. Sediment may need to be stockpiled, then later trucked to agricultural fields or other locations needing fill material. Soils excavated out of basins often need time to dry and begin to allow microbial activity to occur prior to it being spread back onto an agricultural field. Soils that are trucked to agricultural fields have to be spread thin and mixed in the parent soils to ensure that good soil texture is maintained. Actual operation and maintenance will vary from system to system, depending on the agreements established between system owners and operators.

Maintenance agreements need to be established prior to installation to ensure cleaning and its costs are covered. Downstream water users may need assurance that they will continue receiving adequate water supply. Soils not spread onto adjacent farm fields need a storage location, whether temporary or permanent.

Sediment Basin Water Monitoring

The systems' inflow and outflow can be monitored to better understand phosphorus removal effectiveness. The frequency of samples may need to be determined prior to installation, and possibly adjusted after the system is functioning. Monthly reductions may best be determined with multiple samples, significant enough to represent the month's flows. Phosphorus trapped in the basin can be determined by quantifying sediment trapped and using a soil-phosphorus analysis.

Monitoring should be representative of the actual seasonal flows occurring in the drain, and when possible, estimating a monthly or bi-weekly load should be done. Sediment and phosphorus concentrations and flow rates can change dramatically throughout the irrigation season.

Operation inspections, also known as status reviews can be performed at any time to verify the basin's operating according to design. This would include a visual inspection at the minimum, possibly including dimensional measurements as well. The measurements would then be compared to the design specifications to determine if the basin is in operation compliance.

Initial Estimate of Phosphorus Removal

From surface water

Initial estimates of removal rates are difficult to determine within watershed-scale areas. The larger the source area and length of watershed, the greater the dispersion, and phosphorus sorption and desorption. When groundwater influences the drainage waters with high levels of phosphorus, as it does in the Boise area, estimating phosphorus loads at the end of a drain is difficult.

The most reasonable method initially estimating phosphorus removal with a sediment basin is relating it to the phosphorus-sediment relationships, representing only the phosphorus attached to sediment particles. Phosphorus removal may initially be calculated using a current sediment and phosphorus inflow and the design effectiveness of the basin. The 0.0005 (1 lb./ton soil) phosphorus-sediment trap ratio and sediment trap efficiencies can be used to initially estimate the percent of total phosphorus removed. The reason for a lower trap efficiency for phosphorus is because of the greater amount of soil dispersion and higher percentage of soluble phosphorus of the total. The Lower Boise River tributaries typically transport high loads of phosphorus to the river with 60 to 80 percent of the total phosphorus in soluble form. This will significantly decrease a basin's total phosphorus trap efficiency, reducing the pounds of phosphorus per ton of sediment because of the reduction of clay soils it could trap.

A sediment retention basin installed to treat a 117-ha cropland area was evaluated by Carter (1976). The area consisted of highly erodible Portneuf silt loam soils, with slopes ranging from < 1% to 15% on surface irrigated beans, sugar beets, cereal grains, alfalfa and some pasture. A total of 2,390 metric tons of sediment was deposited in the .45-ha basin during two irrigation seasons (Robbins, et al. 1975). Average erosion loss was calculated at 20.5 metric tons/ha over a 2-year period from the 117 ha area. The sediment removal efficiency exceeded 80% when sediment concentration exceeded 0.1% of the inflowing water and the removal efficiency was never below 65% during the period of operation.

Brown et. al, 1981 found that a sediment basin installed near the mouth of the K-lateral drain near Jerome Idaho in 1972, reduced sediment by an average of 70% and total phosphorus by an average of 29% over a 5 year study (range 25 - 33%). The total phosphorus in the Jerome area consists mostly of sediment attached phosphorus in the drains, providing reasonable phosphorus trapping efficiencies, however, the percent soluble phosphorus of the total phosphorus was around 15 to 30 percent. This is greater than field-scale losses, but much less than Lower Boise River tributary percentages. The basin was originally designed to catch only 54% of the sediment load coming through the K-lateral. Average in-flowing phosphorus-sediment ratios were around 0.001 (2 lbs./ton soil), with average phosphorus-sediment trapped ratios near 0.0006 (1.2 lbs./ton soil)

Watershed-scale basins installed to treat water from the Lower Boise River tributaries will not be as efficient in trapping sediment and phosphorus as field-scale basins. This is due to greater aggregate dispersion and greater proportions of soluble phosphorus in the total phosphorus. The sediment concentrations often fall below 100 mg/l in the tributaries, which will lower basin trap efficiencies. Ground water phosphorus loading to the tributaries also influences this proportion of soluble phosphorus. Clay and silt particles are not as likely to be in aggregate form, but transported through slow velocity basins. Clay particles can begin to flocculate together with substances of opposite charges, but they would still be of such small size they would not likely be trapped in a basin. The phosphorus-sediment ratio of soil settled out in a watershed-scale basin would be less than the soil settled in a field-scale basin.

The watershed-scale basin treating Boise valley tributary water would trap on average, 1 pound of phosphorus carried with every ton of soil (0.0005). These basins would generally only trap an average of 5% of the total phosphorus entering the basin because of the high percentage of soluble phosphorus and clay particles passing through the basin, and the low phosphorus-sediment ratio of sediment retained. No soluble phosphorus would generally ever be trapped in a watershed-scale basin, however, instantaneous inlet and outlet monitoring may show a reduction in soluble phosphorus.

From ground water

Phosphorus entering the tributaries through the shallow, irrigation induced recharge aquifer would mix and enter into a basin installed to treat surface drainage water. The basin would not likely trap any phosphorus derived from the shallow recharge aquifer because of it being in soluble form.

Certainty of removal amount from surface water

When designed, installed, and maintained according to NRCS specifications, the basin will very likely provide at least a 65% sediment load reduction to the watershed/stream segment and an average of 1 pound of phosphorus for every ton of soil. However, it may not be feasible to install a basin at a 65% trap efficiency, but rather 50%, which would significantly reduce the size of the basin. Design of these basins is important but maintenance is a greater factor on these basin's efficiencies. Soil and phosphorus testing and quantifying sediment removal from these basins could provide actual data on phosphorus removal from the basin's watershed area.

Environmental Impacts

The positive impacts of these watershed-scale sediment basins are in sediment and phosphorus reductions in the downstream water body of concern. There are some potential negative impacts that we must be aware of prior to installation:

- Ponding water may influence shallow ground water movement near the basin. Increased water pressures around the basin may cause excessive soil wetting within a few feet, up to hundreds of feet. Nearby lands may become flooded and unmanageable for cropping, construction, and other uses.

- Wildlife habitats may be formed around the basin which may then be destroyed during maintenance. A large number of waterfowl may use the basin and contribute pathogens and nutrients to the basin's outflow.

- Fencing may be needed for public protection, but does not necessarily remove the potential of humans, wildlife, and livestock from entering the basin. Liabilities need to be addressed and should be carefully weighed in terms of project feasibility.

- Identified watershed fisheries may need to be addressed and prevented from entering the basin and their passage to and from the river must not be interrupted.

- Large storm flows should be prevented from entering the basin to reduce the risk of structure and basin damage.

Summary

Field-scale sediment and total phosphorus losses from surface irrigated, low residue crops are greatest and typically lose 2 pounds of total phosphorus per ton of soil. The percent soluble phosphorus of the total phosphorus is generally less than 10%. A field-scale basin installed to treat row crop fields should trap at least 65% of the soil and 55% of the total phosphorus, at 1.8 pounds of phosphorus per ton of soil.

The Lower Boise River tributaries average soluble phosphorus portion of the total phosphorus ranges from 60 to 80%. The total phosphorus per son of soil ratio is usually higher in the drainages then in wastewater from irrigated croplands. Sediment concentrations often fall below 100 mg/l, often associated with lower flows in late-season irrigation return flows (August through October) or low sediment losses during early-season months (April and May).

Watershed-scale basins are not nearly effective as the field-scale basins in the Boise valley because of lower sediment and phosphorus trapping efficiencies. However, unlike the field-scale basins (which may only be implemented on a handful of farms within a watershed), watershed-scale basins will treat runoff from the *entire* watershed. The watershed-scale basin should be designed to trap a minimum of 50% of the inflowing sediment, unless under NRCS specifications, then 65% of the sediment. The total phosphorus trapping efficiency will only be about 5%, at 1 pound of phosphorus per ton of soil.

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BEST MANAGEMENT PRACTICE (BMP) LIST FOR THE LOWER BOISE RIVER POLLUTION TRADING PROGRAM

THE LOWER BOISE RIVER POLLUTION TRADING PROJECT

This Pollution Trading project has been established and supported by many agencies and local interests to assist the point and nonpoint phosphorus sources in reducing their phosphorus loads and implementation costs in meeting a Total Maximum Daily Load (TMDL) at the mouth of the Boise River near Parma, Idaho. A "trading market" should enable point and nonpoint sources reductions to be achieved at lesser costs.

The trading that occurs between point and nonpoint sources will be due largely to high point source reduction costs. The point sources that cannot immediately meet their permitted discharges would be permitted to discharge in excess of their permit as long as there is an equal reduction at another point or nonpoint source location. In-stream water quality problems due to discharges in excess of what is permitted will not be allowed under this trading program. Water quality improvements are still to be achieved, regardless of the activity within the trading program.

DOCUMENT PURPOSE

Selected nonpoint source BMPs can be used to offset a point source's discharge, in which are described here. The procedure for generating credits, as well as other trading program requirements, are described as well. This document will be updated periodically and new BMPs added to the list of those currently eligible for trading.

CALCULATED AND MEASURED PHOSPHORUS CREDITS

To offset a given amount of phosphorus at one location from a point source, there must be an equal and beneficial reduction from another point or nonpoint source location. The term "credit" has been established to represent that equalized portion of phosphorus considered in the trading market. The reduction is calculated or measured in pounds of phosphorus, determined by one of two methods. These reductions are then converted to credits for trading purposes.

To estimate what a BMP's capability is in reducing phosphorus losses, local sampling data is needed in order to make that estimate. Where there is adequate data for a specific BMP's reduction capability, a calculation can be made with fair certainty of it actually occurring. Where data is limited, "measuring" for phosphorus removal is necessary. For this trading program, participants may use either the calculated or measured approach to generate credits. The calculated approach will utilize exiting data to estimate an average reduction for a particular BMP, with a slight discount in its effectiveness due to potential uncertainty in the data and other management factors. For measured credits, grab samples will be taken during the BMP's operation to quantify the actual reductions. An inflow and outflow condition will be necessary to sample a BMP.

GENERAL BEST MANAGEMENT PRACTICE (BMP) REQUIREMENTS FOR THE POLLUTION TRADING PROJECT

Agricultural landowners participating in the pollution trading program are highly encouraged to develop a conservation plan with one of two Soil Conservation Districts (SCD). The Ada Soil Conservation District resides at 132 SW 5th Ave., Meridian, ID 83642 (208-888-1890 x3) along with the Natural Resource Conservation Service (NRCS), the Soil Conservation Commission (SCC), and the Farm Services Agency (FSA). Ada county participants will utilize this office for technical and trading program assistance. For Canyon county participants, the Canyon Soil Conservation District is located at 2208 E. Chicago St. Caldwell, ID 83605 (208-454-8684), which also includes NRCS, SCC, and FSA.

The conservation plans are cooperatively developed among the landowner, NRCS and the SCC. These conservation plans are developed to address existing natural resource concerns as well as meeting the landowner's objectives. Through the conservation planning process, BMP installation and other planned activities are evaluated to ensure that they do not have significant negative impacts on natural resources and other landowners.

The BMPs typically used to address water quality concerns are listed in the Agricultural Pollution Abatement Plan (APAP), which is kept at the SCC. BMPs originate in the USDA-NRCS National Handbook of Conservation Practices (NHCP, 2000), which can be found in either of the SCD offices.

Upon installation, after being incorporated into this document, it is to be certified as installed according to NRCS and this document's criteria, as well as meet any applicable local, state, and federal laws and regulations. Upon certification and at the start of BMP operation, credit generation can begin. Most agricultural BMPs within the Lower Boise River watershed will provide reductions primarily within the irrigation season as designed and operated. All BMPs are to function according to the appropriate criteria throughout their operating period.

All BMPs are to be inspected after installation or application, prior to their seasonal period operation. Some BMPs will require a greater number of inspections as outlined in the monitoring section.

CURRENT ELIGIBLE BMPS FOR TRADING

The program eligible BMPs are listed in Table 1, which are also discussed in Carter 2002. The NRCS practice code and typical lifespan are included here.

Table 1. BMPs Currently Eligible for Trading.

BMP	NRCS Code[1]	Lifespan
Sediment basins	350	20 years
Filter strips	393	1 season
Underground outlet	620	20 years
Straw in furrows	484	1 season
Crop sequencing	328, 329	1 season
Polyacrylamide	450	1 irrigation
Sprinkler Irrigation	442	15 years
Microirrigation	441	10 years
Tailwater Recovery	447	15 years
Surge Irrigation	430HH	15 years
Nutrient Management	590	1 year
Constructed Wetland	656	15 years

(1) Refer to http://id.nrcs.usda.gov/practices.htm Additional components for the BMP may incorporate other practice codes.

BMP EFFICIENCY AND UNCERTAINTY DISCOUNTS

Listed in Table 2 are the effectiveness and uncertainty discounts for the currently eligible types, field, farm, and watershed scale. The sediment basin is categorized into 3 types, which, are due to differences in the size of treatment area and duration of flow in the basins.

Nutrient management does not have a phosphorus reduction efficiency due to numerous complexities. This practice is, however, a necessary long-term practice that will benefit water quality if applied properly. Though this practice does not have an efficiency associated with it, it is a valuable BMP for this trading program and will be marketable in relation to other applied BMPs. If nutrient management is applied in addition to other eligible BMPs, the uncertainty factor for those other BMPs will reduced by 50%, thereby, increasing their market value.

Table 2: BMP Effectiveness and Uncertainty Discounts

BMP	Effectiveness	Uncertainty[(1)]
Polyacrylamide	95%	10%
Filter Strip	55%	15%
Sprinkler	100%	10%
Microirrigation	100%	2%
Tailwater Recovery	100%	5%
Mulching	90%	20%
Crop sequencing	90%	10%
Sediment Basin Field scale	80%	10%
Sediment Basin (farm scale)	75%	10%
Sediment Basin (watershed scale)	65%[(4)]	15%[(4)]
Underground Outlet	85% (65%)[(2)]	15% (25%)[(2)]
Surge Irrigation	50%	5%
Nutrient Management	NA[(3)]	NA[(3)]
Constructed Wetland (farm scale)	90%	5%
Constructed Wetland (watershed scale)	NA[(4)]	NA[(4)]

(1) This is to be subtracted from the efficiency.
(2) This BMP's effectiveness drops after 2 years.
(3) Data unavailable for efficiency estimate. If applied with other eligible BMPs, their uncertainty discounts will be reduced by 50%.
(4) Not recommended for calculated credit.

BMP MONITORING: EVALUATION AND MEASUREMENT REQUIREMENTS

To ensure that a BMP is operating properly and actually reducing phosphorus losses, an evaluation is necessary. An evaluation will consist of at least 1 annual field inspection to ensure proper application and operation. Table 3 provides the minimum inspections needed for each BMP, and provides a minimal level of measurement requirements, though not applicable to all BMPs.

Some BMPs do not allow for true "inflow-outflow" comparisons utilizing flow and nutrient measurements, therefore it is not recommended for measurement. Also, a measurable BMP's inflow conditions only represent the instantaneous condition, not reflective of the 1996 baseline condition. In essence, these instantaneous measurements would provide a pretreatment load different than that of the baseline average load, misrepresenting the average 1996 loads. Therefore, no measurements will be allowed for field-scale BMPs to generate credits.

Watershed-scale BMPs, such as the sediment basin and constructed wetlands, where they are not easily calculated, will be measured to generate credits. The schedule for measurements will be set within the buyer-seller contracts for specific watershed-scale BMPs.

Table 3. BMP Evaluation Requirements

BMP	Evaluation
Sediment basin - field scale	before & middle of all irrigations
Sediment basin - farm scale	before & middle of all irrigations
Sediment basin - watershed scale	before & middle of season of use
Filter strips	before & middle of all irrigations
Underground outlet	before & middle of all irrigations
Straw in furrows	before & middle of all irrigations
Crop sequencing	before & middle of all irrigations
Polyacrylamide	evaluate 2 irrigations & review application records
Sprinkler Irrigation,	evaluate 1 irrigation
Microirrigation	evaluate 1 irrigation
Tailwater Recovery	before irrigations & evaluate 1 irrigation
Surge Irrigation	evaluate 1 irrigation
Nutrient Management	evaluate records annually
Constructed wetland	before & middle of season of use

CREDIT PRODUCTION METHOD

Calculated Credits

To calculate a total phosphorus credit, a reduction estimate is determined prior to the sale of the credits, utilizing BMP effectiveness data and other applicable factors.

In the case of calculated credits, specifically to a cropland field, the phosphorus losses in 1996 (TMDL baseline) must be estimated. The Surface Irrigation Soil Loss (SISL) tool is currently the most accurate and simple method available for the program area to estimate soil losses from surface irrigated croplands. SISL losses are then converted to phosphorus losses by multiplying tons soil loss by 2, which provides pounds of phosphorus. Typically, there is on average, 2 pounds of phosphorus loss per ton of soil loss within the program area. This tool is described in USDA-NRCS Agronomy Technical Note No. 32.

There is a great amount of variability in soil and phosphorus loss from one year to the next because of crop rotations, as the SISL shows when used according to its design. This variability would cause a great deal of fluctuation from year-to-year in credits generated from one field. This fluctuation may is not greatly desired in a trading program. Also, because there does not exist data for all fields within the program area for 1996, the crop specific SISL estimate cannot be derived for a number of fields.

An average subwatershed Base Soil Loss (BSL), a necessary factor in SISL, has been determined for each the major Lower Boise River subwatersheds (Table 4). Numerous field crop records from 1996 were evaluated to establish baseline 1996 soil losses with SISL. By utilizing the average subwatershed BSL, crop rotations will have no effect on credit calculation because the pretreatment load of 1996 will not change. A change in credits will only be due to switching from one BMP to another.

Where the SISL-BSL represents seasonal sediment losses, monthly losses may be estimated utilizing numerous irrigation records, which can be used to provide an average number of irrigations per month. Another critical factor to be considered in determining an average sediment and phosphorus loss on a monthly basis, is the percent soil loss of total per irrigation. The first three irrigations typically produce the majority of the annual sediment loss, whereas, with each additional irrigation, less erosion takes place due to increasing soil stability and some crop foliage protection where it lies within the furrow later in the growing season.

Table 4. SISL BSL (tons/ac/yr soil loss[1]) per Subwatershed

Slope of field	<1%		1-1.9%		2-2.9%		>3%	
Drain/Field length	660	1320	660	1320	660	1320	660	1320
Eagle Drain	2.0	1.6	7.3	5.8	15.5	12.4	25.2	20.2
Thurman Drain[2]	NA	NA	NA	NA	NA	NA	NA	NA
Fifteenmile	1.6	1.3	5.8	4.6	12.5	10.0	21.0	16.8
Mill Slough	2.0	1.6	7.3	5.8	15.5	12.4	25.2	20.2
Willow Creek	1.9	1.5	6.8	5.5	14.7	11.7	24.0	19.2
Mason Slough	2.0	1.6	7.3	5.8	15.5	12.4	25.2	20.2
Mason Creek	1.7	1.4	6.4	5.1	14.1	11.2	23.7	18.9
East Hartley	2.0	1.6	7.3	5.8	15.7	12.5	25.6	20.5
West Hartley	2.0	1.6	7.3	5.8	15.7	12.5	25.6	20.5
Indian Creek	1.9	1.5	6.9	5.5	14.9	11.9	24.7	19.8
Conway Gulch	2.0	1.6	7.3	5.8	15.7	12.5	25.6	20.5
Dixie Drain	1.7	1.4	6.4	5.1	13.9	11.1	23.0	18.4
Boise River	2.0	1.6	7.3	5.8	15.5	12.4	25.2	20.2

(1) Multiple BSL by 2 to obtain pounds of phosphorus
(2) Thurman drain currently does not have any cropland fields within it drainage area.

Based on numerous irrigation records and local input, average number of irrigations per crop type per month was established, then one average for all crops per month. The average number of irrigations per month is shown in Table 5.

Table 5. Average Number of Irrigations per month, based on a 181-day irrigation season.

Month	Irrigations	Days/month
April	0.4	15
May	1.2	31
June	2.4	30
July	3.0	31
August	1.9	30
September	0.5	31
October	0.2	15
Total	9.5	181

The average number of irrigations per month was not rounded to the whole number because it would exclude any irrigation that does occur in April and October. The irrigation season is assumed to start on start on April 15 and end October 15, providing a 181 irrigation day season.

Based on numerous runoff studies on surface irrigated cropland, percent soil loss per irrigation was determined. These percent losses per irrigation were then lined up with the average 9-10 irrigations per season to estimate average percent loss per irrigation (Figure 1).

Figure 1. Average Percent Soil Loss per Irrigation per Total Season Loss

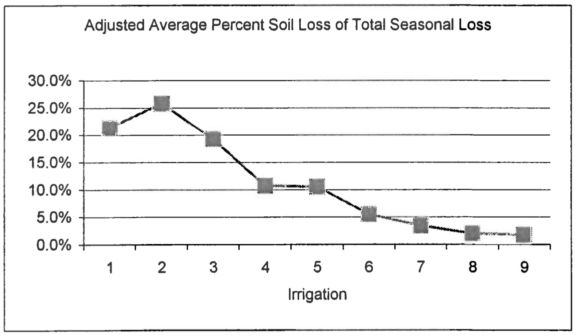

Table 6 shows the percent loss per month, which was derived from the average irrigations per month (Table 5) and percent loss per the 9-10 irrigations per season (Figure 1).

Table 6. Percent Soil Loss per Month

Month	Percent Loss
April	8.5%
May	28.1%
June	39.9%
July	19.4%
August	3.6%
September	0.4%
October	0.1%

Recent water quality samples taken throughout the Lower Boise River tributaries reflect similar loss characteristics, where the months of May, June, and July show the largest in-stream sediment loads. Once the seasonal SISL losses are determined, which represents the pretreatment load, a monthly estimate can be estimated with the values from Table 6.

River Location Ratios

Upon establishing a monthly or irrigation season phosphorus reductions, with a BMP applied, pounds reduced are to be converted into "Parma Pounds" or credits. The current adopted method utilizes a simple mathematical calculation to convert pounds into credits. The amount of phosphorus retained by a BMP on a field within a subwatershed does equal the amount of phosphorus reduced at the mouth of the drainage. There are River Location Ratios (DEQ, 2000) that attempt to account for the river's phosphorus transmission losses and are set at the various locations within the river system, primarily at the mouths of the major tributaries, as shown in Table 7. Those river adjacent lands that impact the river directly will receive the next downstream tributary river location ratio.

Table 7. River Location Ratios

Subwatershed	River Location Ratio
Eagle Drain	0.63
Thurman Drain	0.51
Fifteenmile Creek	0.75
Mill Slough	0.75
Willow Creek	0.75
Mason Slough	0.75
Mason Creek	0.75
East Hartley Gulch(1)	0.80
West Hartley Gulch(1)	0.80
Indian Creek	0.89
Conway Gulch	0.95
Dixie Drain	0.96

(1) East & West Hartley Gulch merge before confluence at Boise River

Site Location Factors

Transmission losses may occur between the point where the reduction takes place and the subwatershed's channel due to wastewater being water reuse and natural sediment-phosphorus relationships. Canals may intercept wastewater runoff from fields, which may or mat not impact the drainage in which the field is located. The greater the travel distance and the chance of reuse, the less likely the total phosphorus amount lost at the field will reach the channel. Site Location Factors are developed to account for some of this transmission loss, shown in Table 8.

Table 8. Site Location Factors

Land runoff flows into a canal, likely to be reused by downstream canal users	0.6
Land runoff does not flow directly to a drain, but through or around other fields prior to entering a drain	0.8
Land runoff flows directly to a drain or stream through a culvert or ditch	1.0

Drainage Delivery ratios

Drainage Delivery Ratios were also developed to account for the phosphorus transmission losses in the subwatershed's main channels. Recent water quality samples collected from within some of these subwatersheds do show however, upstream to downstream, an increase in phosphorus concentrations. This increase in phosphorus concentration is likely due to increasing surface and ground water flows and phosphorus loads from increasing numbers of sources. Due to no available research data or locally developed transmission models, a simple linear calculation is made that represents this potential loss, which is:

(100 - distance in miles to mouth of the drain from the project's point of discharge on the drain)/100.

A measurement, in miles, is made from the mouth of the channel on the river to the point where the wastewater enters the channel. This measurement is to be made with the use of computer based Geographic Information Software (GIS).

Example Credit Calculation

The following is an example of the current method of calculating credits:

Given: 30 acre surface irrigated field with a sediment basin capable of trapping 80% of the sediment. The uncertainty discount associated with this basin is 10% (subtracted from BMP efficiency). Assuming the annual SISL load calculation is 7.3 tons/acre soil loss per irrigation season, calculated to be 229 total tons diverted into the basin. Estimated phosphorus loss from the field is calculated to be 438 pounds (229 x 2 lbs/t), which is diverted into the basin. The Site Location Factor is 0.8, because of potential reuse but not through a canal. The distance from the river to the entry point at the channel is 2.5 miles, which gives a 0.975 Drainage Delivery Ratio. The River Location Ratio is 0.75.

Credits (Parma Pounds) =
438 lbs P x
0.80 trap efficiency - 0.10 uncertainty x
0.8 site location factor x
0.975 drainage delivery ratio x
0.75 river location ratio =
179 credits (Parma Pounds) for sale for irrigation season (annual).

By month:	*April*	*15.2*
	May	*50.3*
	June	*71.4*
	July	*34.7*
	August	*6.4*
	September	*0.7*
	October	*0.2*

Note: A TMDL reduction requirement will need to be met first, therefore, a percentage of these credits will not be tradable.

INCLUSION OF NEW OR EXISTING PHOSPHORUS CONSERVATION MEASURES TO THE BMP LIST

There may be other conservation measures not specifically characterized within the NHCP or APAP that can reduce phosphorus losses from agricultural lands or treat wastewater. These conservation measures can be added to this list at any time, once they have been reviewed and approved by the BMP technical Committee potentially undergo a public review process to fulfill the trading program requirements.

Proposed conservation measures to be considered for the purpose of establishing credits not contained within this list are to be forwarded to the Idaho Soil Conservation Commission, BMP Technical Committee, Pollution Trading, P. O. Box 790, Boise, Idaho 83701 at (208) 332-8650.

REFERENCES

Carter, D. L. 2002. Proposed Best Management Practice (BMP) list and application criteria for the Lower Boise River Pollution Trading Demonstration Project, Unpublished report.

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