Voluntary Clean Water Guidance for Agriculture Chapters

A phased approach is being used to develop these guidelines. During the first phase an overview of the guidance was produced along with its initial chapter which examines tillage and residue management practices. Additional chapters not completed though anticipated for inclusion in the overall guidance are listed below. These chapters will be completed in the following several years. Producers who are interested water quality guidance related to practices not yet addressed can contact Ecology's Agriculture and **Water Quality Planner Ron Cummings at ron.cummings@ecy.wa.gov or (360) 407-6600.**

Chapter 1 Cropping Methods: Tillage & Residue Management-Completed (December 2022)

Chapter 2 Cropping Methods: Crop System-***In development***

Chapter 3 Nutrient Management-***In development***

Chapter 4 Pesticide Management-***In development***

Chapter 5 Sediment Control: Soil Stabilization & Sediment Capture (Vegetative) -***In development***

Chapter 6 Sediment Control: Soil Stabilization & Sediment Capture (Structural)-Completed (December 2022)

Chapter 7 Water Management: Irrigation Systems & Management-***In development***

Chapter 8 Water Management: Field Drainage & Drain Tile Management-***In development***

Chapter 9 Water Management-Stormwater Control & Diversion-***In development***

Chapter 10 Livestock Management-Pasture & Rangeland Grazing-Completed (December 2022)

Chapter 11 Livestock Management-Animal Confinement, Manure Handling & Storage-***In development***

Chapter 12 Riparian Areas & Surface Water Protection-Completed (December 2022)

Chapter 13 Suites of Recommended Practices-***In development***

This report is available on the Department of Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2010008.html

Chapter 6

Sediment Control: Soil Stabilization & Sediment Capture (Structural)

Voluntary Clean Water Guidance for Agriculture

Prepared by:
Washington State Department of Ecology
Water Quality Program

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Recommendations for Sediment Control: Soil Stabilization & Sediment Capture (Structural) to Protect Water Quality

The Voluntary Clean Water Guidance introduction[1] provides overall goals and objectives, as well as information on how the guidance will be used. Readers are encouraged to read the overall introduction before this chapter.

Introduction

This chapter focuses primarily on the capture of sediment from moderate to large flows of concentrated runoff occurring on cropland, orchards, pastures, and rangelands. It does not apply to animal confinement/ heavy use areas or structures, which are addressed by other BMP chapters. For the purpose of this guidance, a moderate to large flow of concentrated runoff is one which exceeds roughly 0.5 cubic feet per second (cfs). In this regard, the guidance focuses on the use and effectiveness of sediment basins, which are a primary structural means of capturing sediment transported by moderate to large concentrated runoff flows. Other types of structural practices that can be used to control sediment transport (such as terraces, level spreaders, and silt fences) may be addressed in future guidance.

Lastly, general sediment basin design considerations are presented in this guidance, but the guidance does not delve into quantitative characteristics such as the dimensions of embankments, basins, inlets, and outlets since these aspects are highly site specific and may require engineering services to determine.

Photo 1. An aerial image showing four sediment basins designed to hold a permanent pool of water in a dryland agricultural area of the Palouse region along the Washington-Idaho state border

[1] https://apps.ecology.wa.gov/publications/documents/2010008.pdf

Definitions of Sediment Control Practices as Used in this Document

The terminology used to describe structural sediment control practices is highly variable. This guidance uses the terms water and sediment control basin (WaSCoB) and sediment control basin (SCoB) to describe two of the main types of structural sediment control practices employed on agricultural lands.

This guidance evaluates the two types of sediments basins that are most commonly addressed in agricultural science literature.

Water and Sediment Control Basin (WaSCoB)

A water and sediment control basin (WaSCoB) is an earthen embankment or a combination ridge and channel constructed across the slope of a minor drainageway (i.e., a raised earthen barrier constructed parallel to the topographic contour in order to impede the flow of downhill runoff) (NRCS, 2018).

Sediment Control Basin (SCoB)

A sediment control basin (SCoB) is a structure created in a drainageway through excavation or building an embankment (NRCS, 2017).

These are the terms used to describe these practices in agricultural science publications. In other literature, such as that concerning urban stormwater, similar practices may be referred to as retention ponds, detention ponds, wet-ponds, or dry-ponds. This document uses the term “sediment basin” to refer to both WaSCoBs and SCoBs when addressing considerations that apply to both practices. In most instances though, it wasn’t appropriate to lump these practices together under the general term of “sediment basin” because: there are differences in their functions; and much of the effectiveness-related research is focused on WaSCoBs and the associated findings may not extend to other types of sediment basins with slightly differing structures and functions.

Photos on the following page depict sediment basins in differing types of settings.

Photo 2. An in-field WaSCoB.

Note the embankment and rise pipe in left of photo. (Photo credit: Fairfield SWCD, Ohio)

Photo 4. A below field WaSCoB.

(Photo credit: NRCS)

Photo 3. A series of infield WaSCOBs.

(Photo credit: Benton SWCD, Minnesota)

Photo 5. A below-field SCoB in a drainageway.

(Photo credit: NRCS)

Primary Recommendations for Sediment Basins

The following presents the main findings and recommendations of the effectiveness evaluation, with further detail provided throughout the rest of the document.

Function/Purpose

- The primary purpose of WaSCoBs and SCoBs is to capture sediment in runoff. WaSCoBs can also be used to prevent gully erosion since they are designed to dampen peak flows.

Applicability

- Typically, WaSCoBs may be placed in-field, edge-of-field, or in a drainageway (e.g. swales, rills, gullies) depending on site-specific conditions.
- ScoBs are typically located as the terminal practice in a series of BMPs before runoff is discharged from a drainageway into a waterway.
- Neither WaSCoBs nor ScoBs should be placed within perennial, intermittent, or natural ephemeral stream channels, or within the riparian areas of such channels.

Effectiveness

- Appropriately designed and located sediment basins can consistently capture over 90% of the total sediment load in runoff. This typically involves an "enhanced" outlet design that targets removal of fine silt and clay particles and can hold a pool of water at low and high stages.
- In contrast, the maximum sediment removal effectiveness for unimproved sediment basins is likely to be in the range of 50 to 70% of the suspended sediment load; however, the percentage of the total sediment load removed may be greater than 70% if the sediment size distribution in runoff is skewed towards larger silt and sand particles. The lower removal rate for non-enhanced basins is largely because resuspension of deposited fine particles often occurs due to turbulence and the outlet draws water containing fine sediment that hasn't settled out of suspension.
- Sediment removal can be enhanced by: installing a "floating skimmer" to drain water containing less suspended sediment from the top of the pool; installing a perforated riser with a gravel jacket that helps "filter" out silt and clay; providing storage in both low and high stages, which helps to reduce the resuspension of deposited sediments during runoff events.
- Ecology does not recommend the use of flocculants (used to increase aggregation of fine particles in order to inhibit transport in runoff and accelerate settling in basins) due to the risk of certain types of flocculants causing harm to aquatic organisms.

Design, Construction and Maintenance

Design and Construction

- Ecology recommends working with a farm planner and licensed engineer to determine the appropriate location and design specifications for a sediment basin.
- In general, the design of sediment basins should be consistent with Ecology's stormwater BMP manual specifications and comply with NRCS FOTGs.
- Sediment basins of a certain size are subject to WA State dam safety requirements. See WAC 173-175-020(1).
- It is recommended that an enhanced basin design be implemented when the silt and clay fractions combined are expected to exceed 20% of the sediment load (see Ward et al. 1977b).
- Current research indicates that the most effective basin design enhancements are to install a "floating skimmer" or a perforated riser with a gravel jacket, and to provide storage in both low and high stages (see Center for Watershed Protection, 2000). Floating skimmers sit on the surface of the sediment basin as it fills and drains releasing the cleanest water in the basin instead of draining from the bottom.
- Sediment basins should only be installed where appropriate upslope erosion and runoff control BMPs (e.g., reduced/no-till, cover crops, field borders, etc.) are implemented and maintained, but have not achieved runoff and sediment management objectives.
- It is recommended that landowners couple WaSCoBs in sequence with down-gradient practices that infiltrate runoff, such as grassed waterways, riparian buffers, and critical area plantings wherever permitted by site conditions; where a non-enhanced basin design is to be employed, it is still recommended that landowners install a series of sediment basins to maximize effectiveness.

Maintenance

- Inspection is recommended after significant runoff events to ensure that the basin components are intact and will function properly during subsequent runoff events.
- Periodic vegetation maintenance and removal of accumulated sediment is needed to ensure that a basin remains functional and effective. Excavated sediment should be applied and graded into the contours of the upgradient field(s) from which it was eroded; sediments should be applied in fields at locations and/or during times of the year in which it is unlikely to be eroded by runoff and should be seeded or mulched as soon as possible. If the excavated sediment contains any contaminants, such as pesticides, disposal at any other location besides the field from which it eroded may be subject to WA State solid waste handling regulations (see WAC 173-350).
- The maintenance schedule should be tailored to site specific conditions and basin design, following NRCS guidance, Ecology stormwater manual guidance, and/ or recommendations from a farm planner and/or engineer.

Function and Purpose of Sediment Control Basins

WaSCoBs and SCoBs are constructed similarly, each with an embankment and a stable outlet used to detain runoff and cause sediment to settle out of suspension. Their primary difference is that a WaSCoB is typically designed to reduce peak runoff flows for a specified time period, whereas a SCoB is usually not designed to detain peak runoff flows (NRCS, 2017, 2018; Rutledge, 2014). Additionally, SCoBs are typically larger than WaSCoBs. WaSCoBs and SCoBs are not specifically designed to infiltrate runoff within the basin (i.e., they are not intended to promote water seepage into the soil), although a minor amount of infiltration often occurs (Fiener et al, 2005).

Water and Sediment Control Basins

WaSCoBs evolved from terraces with underground tile outlets for drainage (Seibel, 1983). The primary functions of WaSCoBs are to control runoff, reduce gully erosion, and trap sediment. They are often used to control erosion by concentrating runoff in areas where the terrain is not amenable to terracing (Seibel, 1983).

The WaSCoB practice may be used where (NRCS 2018; Seibel, 1983):

- Topography is irregular
- Gully erosion is a problem
- Practices to control sheet and rill erosion are in place
- A stable outlet can be provided

WaSCoBs are intended to be used as part of a broader suite of BMPs to control erosion and runoff. According to Czapar et al. (2005), "water and sediment control basins perform very similarly to terraces with underground outlets, but do not reduce slope length or erosion losses in the field. It is very important to have soil erosion control on the watershed above the sediment control basin to ensure a long effective life of the basin."

WaSCoBs can be used to provide limited flood protection for farmland (but not structures) down gradient of small contributing areas, e.g. 30 to 50 acres (Ohio State University Extension, 2020; Rutledge, 2014; Seibel, 1983).

Sediment Control Basins

SCoBs are designed to detain the flow of runoff for enough time to cause sediment to settle within the basin. SCoBs are commonly larger than WaSCoBs. Rather than being used to control erosion, a SCoB is used to capture sediment from erosion that has already occurred upgradient. They are used where physical conditions or land ownership make erosion-control measures impractical or ineffective. However, it is recommended that they be used as the terminal BMP in a series of erosion control and sediment capturing practices when necessary to capture sediment from runoff before it is discharged to surface waters (NRCS, 2017; Ohio State University, 2020; Rutledge, 2014).

Water Quality Parameters Addressed

Sediment is the primary pollutant addressed by WaSCoBs and SCoBs. Sediment-adsorbed nitrogen, phosphorus, pesticides, and pathogens may also be removed by sediment basins, although the removal of these pollutants should be considered a secondary function since it tends to be significantly less than the amount of sediment removed.

Applicability

Where sediment basins are applicable:

Sediment basins can be used to capture sediment in runoff from croplands, rangelands, and orchards in western and eastern Washington. Sediment basins are probably most suitable for croplands within the Palouse and Columbia Plateau regions of eastern Washington whose soils have a high potential for erosion by surface runoff, as well as western Washington croplands that have soils of a low infiltration capacity.

Placement of WaSCoBs is appropriate within fields, edge of field, or below fields where concentrated flows tend to originate and/or are conveyed. This includes features such as: topographic depressions in fields; swales within or below fields; and management-induced ephemeral channels (such as rills or gullies). Because ScoBs are designed to retain sediment from erosion that has occurred upgradient, they are likely going to be placed at or near the downstream end of a sediment transport channel such as a gully or a ditch used for irrigation or drainage.

As a rough estimate, one should consider the practicality of installing sediment basins if concentrated flows on a site tend to exceed 0.5 cubic feet per second. Lesser runoff flows are likely to be more appropriately addressed by other vegetative and/or structural erosion control practices.

Sediment basins may be applicable in some settings where runoff can be diverted into an “off-channel” basin. For example, limited research suggests that sediment control basins may be suitable for removing sediment from irrigation or drainage ditch runoff in some situations (Bjorneberg and Lentz, 2005; Brown et al. 1981). However, the sediment removal effectiveness for irrigation runoff may vary widely depending on the basin design and sediment size distribution in the runoff, among other factors (refer to the section on sediment removal effectiveness for more information).

Mielke (1985) asserted that WaSCoBs could be used instead of grassed waterways on lands with steeper slopes that deter the use of terrace systems. Grassed waterways are channels whose grade and vegetation are designed to convey surface runoff at a non-erosive velocity. WaSCoBs have been used in Iowa as a substitute for grassed waterways due to concerns about reductions in farmable land and damage to vegetation in the grassed waterway by herbicides- thereby impacting their effectiveness.

(Seibel, 1983). Alternatively, Fiener et al. (2005) recommended using WaSCoBs in concert with grassed waterways- installing a grassed waterway downslope of sediment basins in order to promote runoff infiltration and increase the removal of fine silts and clay.

The following photographs depict examples of management-induced ephemeral channels in eastern Washington where WaSCoBs may be appropriate.

Figure 2: management induced ephemeral channel

Photo Credit: Dept. of Ecology Eastern Regional Office.

Figure 3: management-induced rills in conventionally tilled slope

Photo Credit: Dept. of Ecology Eastern Regional Office.

According to the NRCS (2018) SCoBs are applicable where:

- Physical conditions or parcel ownership boundaries prevent installation of erosion-control practices to treat a sediment source. In other words, they are used to capture large quantities of sediment over time when upgradient erosion control BMPs are either impractical to implement or are not fully effective at controlling erosion.
- Failure of the basin will not result in loss of life, damage to homes, commercial or industrial buildings, highways or railroads, or public utilities.

With rare exception, sediment basins should be implemented as part of a series of in-field, edge-of-field, and edge of waterway agricultural practices intended to control erosion and sedimentation. (NRCS, 2018, 2017a; Seibel, 1983). For example, Makarewicz et al. (2009) found that a combination of strip cropping, grass buffers, and WaSCoBs resulted in a 71% reduction in total suspended solids in watershed runoff within New York State. The evaluation of WaSCoBs by Czapar et al. (2005) suggests that water and sediment control basins should be reserved for situations in which:

1. there is a higher relative risk of pollutant delivery to a stream channel due to proximity of fields to stream channels (e.g., fields are adjacent to a channel and/or are hydrological connected by rills, gullies); and
2. alternative/ complementary BMPs will not be effective at reducing sediment, nitrogen, and phosphorous loads to the degree necessary to protect water quality.

In summary, the reason for implementing a sediment basin along with other practices is not only so that erosion and sediment transport can be appropriately controlled, but also because sediment basins have a higher cost per unit of pollutant removal relative to other practices such as contouring, strip cropping, terraces with vegetative outlets, and no-till (Czapar et al., 2005; Chen, 1975).

Similar to crop production techniques, planning for a suite of BMPs to address erosion and runoff is not a matter of selecting preferred BMPs from a list that seems feasible to implement on a parcel. It is critical to carefully consider land management practices in the context of the site-specific environmental conditions, including the types and forms of pollutants likely to be generated (Czapar et al., 2005). For example, according to Czapar et al. (2005):

> Erosion control practices can substantially reduce particulate phosphorus and nitrogen loss from fields, but may increase dissolved phosphorus losses if fertilizer or manure is not effectively incorporated into the soil. Erosion control practices have relatively little impact on inorganic nitrogen losses. The fraction of the nutrient and sediment losses delivered to surface water are affected by practices in the field as well as the distance and path traveled between the field and stream. For example, a field with high concentrations of phosphorus in the soil surface adjacent to a stream and eroding at half the T value may have greater impacts on water quality than a field with low phosphorus levels eroding at >3T, but four miles from the stream.

Where sediment basins are not applicable:

Sediment basins should not be implemented within perennial, intermittent, or natural ephemeral channels; they should also not be placed within the riparian areas of these channels.

Since WaSCoBs do not reduce sheet and rill erosion they are not recommended for areas in which a terrace system can be implemented (Seibel, 1983).

Liu (2017) suggested that since WaSCoBs tend to have one of the highest costs per pound of phosphorus removed, they should not be used in situations which it is feasible or economical to use other BMPs to control pollutant transport associated with gully erosion. This suggestion, however, was narrowly based on phosphorus and does not take into account that WaSCoBs are far more effective at capturing sediment than phosphorus.

Design, Construction, and Maintenance Considerations

There are many design, construction, and maintenance considerations and specifications that are not included here; refer to the NRCS Conservation Practice Standard for Practice Codes 350 and 638 (NRCS, 2018, 2017a), WA State Dept. of Ecology (2019a, 2019b), and Steward (2006) for further information on these aspects.

Most sediment basins constructed in WA State are likely to have a relatively small basin volume (e.g. less than 10 acre-feet of storage) and be shallow in depth. Nevertheless, it is important to note that WA State dam safety requirements apply to sediment basins that meet or exceed certain storage capacity and/or embankment height criteria. Dam safety requirements apply to sediment basins with a maximum storage capacity of at least 10 acre-feet (435,600 cubic feet; 3.26 million gallons) as measured at the embankment crest, and/or basins that have an embankment height greater than six feet, even if water storage is intermittent and infrequent (WAC 173-175-020(1). For more information about dam safety requirements, visit Ecology's Dam Safety Office webpage[2].

Tomer et al. (2020) discusses how geographic information systems (GIS) mapping can be used to locate appropriate locations for sediment basins within a watershed. A brief tutorial on using GIS to perform spatial analysis[3] for WaSCoB placement in a watershed can be watched at this link.

NRCS (2017a) recommends selecting a location for SCoBs that will maximize the interception of runoff from the eroding lands and will minimize the number of runoff inflows into the basin. For WaSCoBs, NRCS (2018) recommends locating the basin where it will fit the topography, maximize storage, and will not encroach on property boundaries. For both SCoBs and WaSCoBs, NRCS recommends (2018, 2017a) placement of basins in locations that will minimize interference with farm equipment or operations. The placement and design of basins should accommodate access by equipment that will be needed to periodically remove accumulated sediment.

WaSCoBs can be placed in series down a slope to increase erosion control effectiveness (NRCS, 2018; Rutledge, 2014). In situations where grade control is needed, several smaller basins in sequence may be preferable over a single larger basin at a gully outfall (Seibel, 1983).

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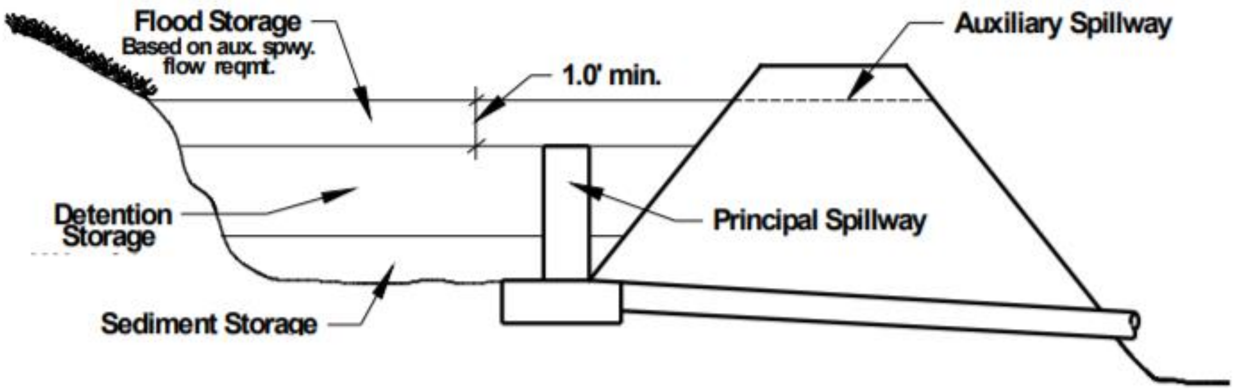
[2] https://ecology.wa.gov/Water-Shorelines/Water-supply/Dams

[3] https://www.youtube.com/watch?v=ZEVFelN4Gi8

Figure 4: Generalized basin design employed by the NRCS



Both SCoBs and WaSCoBs may be designed to retain a permanent pool of water, which increases their sediment retention effectiveness (NRCS, 2017). Long, narrow basins may capture coarser sediment more effectively, while more circular and rectangular basins capture finer sediment more effectively. Basins may be sized for the expected amount of sediment deposition for the design life (or between cleanouts) or basins may be designed to detain the total runoff from individual storms. For the former, the outflow is uncontrolled and for the latter, the outflow is controlled. Choosing between the two involves considerations of costs, amount of sediment retention needed, and the soil particle size distribution to be captured (Chen, 1975).

The hydraulic design for WaSCoBs is usually a 10-year frequency, 24-hour duration storm. (NRCS 2018; Rutledge, 2014; Seibel, 1983). The 10-year frequency, 24hr duration storm in agricultural areas of eastern Washington generally ranges from 1.2 in the driest portion of the Columbia Plateau up to 2.5 inches in the Palouse and mountain foothills surrounding the Columbia Plateau. In western Washington, the 10-year frequency, 24hr duration precipitation amount ranges from about 2.0 in the Olympic Mountains rain shadow to 4.0 in most of the agricultural areas from the Canadian border down to the Columbia River, except along the Pacific coast where it generally ranges up to 5.0 inches (NOAA, 1973).

In terms of maximum contributing areas for a sediment basin, Ecology was unable to find estimates specific to Washington State. In Midwestern states, maximum contributing areas for a WaSCoB or SCoB of 30 or 50 acres have been recommended (Ohio State University Extension, 2020; Seibel, 1983).

For reference, the 10-year frequency, 24hr duration storm in Ohio generally ranges from 3 to 4 inches and 4 to 5 inches in Iowa (NOAA, 2004-Current). Therefore, maximum contributing areas in wetter regions of Washington State may be similar to those in Midwestern states, while in the driest regions, maximum contributing areas may be significantly greater.

Ecology recommends that landowners work with an engineer and/or farm planner to ensure that the basin is designed, located and sized appropriately. The size and location design aspects depend upon hydrological calculations based on contributing area, precipitation and runoff analyses, and expected sediment loading. Note, however, that different methods for determining the size and location would be needed for certain types of situations, for example, where an irrigation return flow ditch is routed through a sediment basin prior to discharging to a stream.

In some versions of the NRCS guidance (NRCS, 2010) for sediment basins (practice 350), the basin storage requirements are: a minimum of 900ft^3 per contributing acre of sediment storage (with the total sediment storage volume equal to 10 years of expected sediment accumulation); a minimum of 3600ft^3 per contributing acre for water detention storage; and a flood storage volume that is calculated based on site specific outflow rates corresponding to the expected runoff for the maximum storm event (e.g. the 10-year frequency, 24-hour duration precipitation amount). In general, though, Ecology recommends that sediment basins be constructed to have storage volumes and embankment heights that are lower than the thresholds to which dam safety regulations apply (see notes on dam safety regulations earlier in this section).

Flocculants such as anionic polyacrylamide (ionic polyacrylamide is toxic to aquatic organisms) are sometimes added to irrigation furrows within fields to increase upgradient irrigation furrows to increase P retention in downslope basins, but this appears to work only if surface runoff from fields is concurrently reduced. Ecology does not recommend the use of flocculants due to their risk of harming aquatic organisms.

The basin and embankment should be vegetated with perennial, non-invasive herbaceous vegetation. (NRCS, 2017). Rutledge, 2014 recommended installing filter strips/ field borders around the basin to prevent flow channelization and “short-circuiting” of the hydraulic design.

The effectiveness of sediment basins requires routine maintenance. Basins and embankments should be periodically inspected (e.g., after each significant runoff event). Repair or replacement of damaged components should occur as soon as possible. Periodic mowing should occur to prevent trees and shrubs from growing on berms/embankments and may also be needed within the basin. (NRCS, 2017)

Basins require periodic sediment removal and grading/shaping, dependent on sediment loading rates (NRCS, 2017; Rutledge, 2014). If the excavated sediment contains any contaminants, such as pesticides, transport or disposal to any other location besides the field from which it eroded may be subject to WA state solid waste handling regulations (see WAC 173-350). However, there is an exception in the solid waste handling regulations to allow for contaminated soil to be placed at or near the location of generation within a site (see WAC 173-350-020(2)(y).

It is therefore recommended that excavated sediment be applied and graded into the contours of the upgradient field(s) from which it was eroded. Sediments should be applied in fields at locations and/or during times of the year in which it is unlikely to be eroded by runoff and should be seeded or mulched as soon as possible.

The proper design of a sediment control basin may necessitate consultation with a licensed engineer. Improperly designed structures may be ineffective at trapping sediment, may worsen runoff and sediment problems, and/ or may result in a catastrophic failure of the structure. **Therefore, Ecology recommends that a landowner consult with a licensed engineer when designing and constructing any sediment basin. This will help ensure that the structure is constructed appropriately based on site geology, soils, climate, topographic, hydrology, vegetation, land management, etc.**

Related NRCS Practices

- Sediment Control Basin- SCoB (NRCS practice code 350)
- Water and Sediment Control Basin-WaSCoB (NRCS practice code 638)
    - Brief NRCS video on WASCoBs[4]

Commonly Associated Practices:

- Cover Crop
- Conservation Crop Rotation
- Critical Area Planting
- Filter Strip
- Mulching
- Nutrient Management
- Grassed Waterway
- Residue and Tillage Management, No Till
- Residue and Tillage Management, Reduced Till
- Riparian Buffer
- Water Control Structure
- Pond
- Terraces
- Level spreader

[4] https://www.youtube.com/watch?v=F2tiivKf8a0

Chapter 6 Appendix Part A: Effectiveness Synthesis (Sediment Control: Soil Stabilization & Sediment Capture (Structural))

Effectiveness

Basins designed to temporarily detain runoff from cropland significantly reduce loads of sediment and sediment-adsorbed nitrogen, phosphorus, and pesticides to surface waters (Fiener et al, 2005; Schepers et al., 1985). However, sediment basins may cause slight increases in leaching of soluble pesticides, nitrogen, and phosphorous (The University of California Cooperative Extension, undated publication).

There are a fair number of field studies that have examined the pollutant removal effectiveness of WaSCoBs and SCoBs. Most of the effectiveness research has evaluated sediment and nutrient removal; limited research has evaluated pesticide removal and no research was located that examined the removal of pathogens. The following provides a synopsis of literature that was reviewed concerning the effectiveness of sediment basins at removing sediment, nutrients, and pesticides from surface runoff.

Sediment

Many factors influence the effectiveness of sediment control basins (NRCS, 2017; Rutledge, 2014; Chen, 1975) including:

- basin size
- basin shape
- water detention time
- the permanence of water pooled in the basin
- the type of drainage outlet
- the degree to which the design reduces flow turbulence
- sediment particle distribution in runoff

Sediment trapping efficiency of a SCoB or WASCoB increases exponentially as the ratio of basin volume to basin inflow increases (i.e., larger basins with smaller inflows trap sediment more effectively than smaller basins with larger inflow) (Chen, 1975). Additionally, as basin volume increases and outflow rates decrease, the retention of finer sediment particles increases. In general, however, sediment retention curves suggest that sediment basins used on agricultural lands are not likely to be large enough to prevent a significant amount of clay and fine silt particles from being discharged in the outflow (Chen, 1975).

Retaining a permanent pool of water in a basin increases sediment retention because it inhibits resuspension of already settled particles (NRCS, 2017; Rutledge, 2014). For very large basins with a long water residence time, applying a chemical flocculation aid to the pool of water increases retention of clay and fine silt (Brown et al., 1981). A flocculation aid is basically a chemical such as polyacrylamide that causes silt and clay particles to stick together so that they will settle to the bottom faster. Note that polyacrylamide is generally considered non-toxic, although it can break down into acrylamide, which is considered toxic/ carcinogenic for certain doses and exposure rates. Limited research on the use of flocculants in combination with sediment basins found that applying a chemical flocculation aid to upgradient irrigation furrows reduced sediment load generation, but the percentage of sediment retained by the basin was unchanged (Bjorneberg and Lentz, 2005).

According to the Center for Watershed Protection (2000), simple sediment basin designs typically have a sediment removal effectiveness below 70%. They assert that sediment removal can be improved through key design elements such as:

- adequate basin sizing which helps reduce turbulence
- providing for water storage during wet and dry periods, which helps prevent re-suspension of sediments
- installing a floating skimmer or a perforated riser outlet with a gravel jacket
- placing multiple basins in series, where feasible

Table 1: Estimated effectiveness of sediment basins for sediment removal

Reference	Sediment Removal Effectiveness	Notes
Bjorneberg and Lentz, 2005	86%	Suspended sediment. Removal rates among treatments using polyacrylamide (PAM) and controls without PAM showed no significant difference, although the use of PAM in irrigation furrows significantly reduced sediment loading into the basins.
Brown et al. (1981)	65 to 76%	Suspended sediment. Very large ponds receiving continuous irrigation runoff in ID.
Center for Watershed Protection (2000)	60 to 70%	Total suspended solids. Unimproved sediment basins for urban stormwater. Variation based on water retention time.
Center for Watershed Protection (2000)	>90%	Total suspended solids. Urban stormwater basins with improved inlet, basin, and outlet design.
Czapar et al. (2005)	95%	Total sediment. For runoff from conventionally tilled fields in Iowa.
Fiener et al. (2005)	54 to 85%	Total sediment. Non-enhanced basins with an underground outlet.
Her et al., 2016	<1%	Modelled reduction in watershed scale sediment load attributed to WaSCoBs.
Her et al. (2017, 2016)	47 to 55%	SWAT Modeled reductions at the field-scale, Midwest U.S.
Mielke (1985)	97 to 99%	Total sediment. WaSCoBs in Nebraska.
USDA, 1979	60%	Total sediment. Estimated reduction in cumulative sediment load from gully erosion at the watershed scale from sediment basins.

In a review of effectiveness studies, Rutledge (2014) reported that SCoBs with water retention times between 1 and 2.7 hours have sediment removal rates ranging from 65 to >97%. Ward et al. (1977b) asserted that the sediment particle fraction greater than 20 microns (silt is approx. 2 to 50 micron) has an insignificant effect upon trapping efficiency except where inflow velocity is very high. This means that the percentage of sediment retained is largely driven by how much silt/clay is in the runoff vs. how much silt/clay can be settled out by the basin design. Brown et al. (1981) found that very large ponds receiving irrigation runoff at rates higher than the design flow (and with no flocculation aid) retained 65 to 76% of sediment loads. Mielke (1985) found that WaSCoBs in Nebraska reduced sediment loads by 97 to 99%, and that after a pool forms in the basin, the vast majority of sediments not retained were clay particles.

Czapar et al. (2005) estimated the effectiveness of WaSCoBs relative to sediment loads from conventional tillage operations on ten different soil types in Iowa. WaSCoBs were estimated to reduce sediment yields (tons/acre/yr) in runoff by 95%. Fiener et al. (2005) evaluated sediment basins that were constructed using farm machinery to raise the height of field borders and in which an underground outlet was installed. They found that the sediment retention rates for the basins ranged from 54 to 85%. In some arid areas, it may be possible to size a basin such that no release of water is necessary, resulting in a 100% sediment retention rate (Rutledge, 2014).

Modeling suggests that WaSCoB sediment removal effectiveness varies across spatial scales. Using the SWAT model in the Midwestern U.S., Her et al. (2017, 2016) estimated that WaSCoBs decrease sediment loads by an average of about 47 to 55% at the field scale. For watersheds in central California, USDA estimated that grade stabilization structures in gullies (e.g., water and sediment control basins) could result in a 60% reduction in sediment loading from gullies at the watershed scale (USDA, 1979). However, in terms of total sediment loading at the watershed scale, modelled sediment load reductions for WaSCoBs have been estimated to potentially comprise only a fraction of the load reductions achieved from other BMPs (Her et al., 2016). This suggests that although WaSCoBs may be important for achieving significant sediment load reductions at the field-scale, their combined load reductions at a watershed scale are likely to be minor in comparison to the cumulative effect of other practices that reduce the generation of sediment such as conservation cover, conservation crop rotation, conservation tillage, cover crops. The reason for this is that each WaSCoB is used to address a small drainage area, such that the combined acreage addressed in a watershed is likely to be insignificant in comparison to the watershed scale acreage that can be covered by BMPs addressing in-field sediment generation (Her et al., 2016).

In summary, sediment removal effectiveness varies based on the design of a particular sediment control basin and the spatial scale at which effectiveness is examined (e.g., individual basin vs. a cumulative effect at a watershed scale). Improved basins designs with large volumes can retain more than 90% of sediment in runoff because they are engineered to retain more fine silt and clay, while smaller basins and/or basins with more rudimentary designs are more likely to have a sediment removal rate closer to 50 to 70%, depending on how much fine silt and clay is in the runoff. No studies reviewed examined the effectiveness of sediment basins placed in series or coupled with a grassed waterway, although these practices are recommended in the literature for improving sediment trapping effectiveness. Where runoff contains a large proportion of suspended fine silt and clay, the literature suggests that the use of a flocculant aid (e.g., polyacrylamide) can improve the sediment retention rates in smaller or rudimentary basins to achieve removal rates that approach those of much larger and/ or more highly engineered basins. Although flocculation is probably not practical in many settings, it may be reasonable for situations in which large-engineered basins are not feasible, and runoff containing large loads of fine silt and clay are a chronic occurrence, e.g., summer long return flows from irrigated crop fields.

The limited information available suggests that the cumulative effect upon watershed scale sediment loads from multiple sediment control basins is likely to be insignificant relative to the potential cumulative load reductions that can be achieved by other practices that reduce in field soil erosion. Therefore, higher priority should be given to implementing BMPs that reduce sediment load generation, and SCoBs and WaSCoBs should be reserved for situations in which those BMPs are not able to adequately diminish erosion and runoff.

Nitrogen (N) and Phosphorus (P)

Table 2: Estimated effectiveness of sediment basins for nitrogen and phosphorus removal (sediment-bound and soluble forms)

Reference	Nutrient Removal Effectiveness	Notes
Rutledge (2014)	Total P: 25 to 98%	Review of studies with water retention times between 1 and 2.7 hrs.
Czapar et al. (2005)	Total N: 82% Total P: 88% Ammonia + Nitrate: -33% Phosphate: -50%	For runoff from conventionally tilled fields in Iowa, majority of N and P was soil-bound.
Brown et al. (1981)	Total P: 25 – 33%	Very large ponds receiving continuous irrigation runoff in ID.
Smith et al. (2015)	Soluble P: 80% Total P: 79%	Surface runoff
Smith et al. (2015)	Soluble P: -60% Total P: -24%	Tile drain runoff
Her et al. (2017)	Total P: approx. 46% Total N: approx. ~32%	SWAT model, field-scale
Her et al. (2016)	Total P: 16.8% Total N: 39.5%	SWAT model, field-scale; effect upon total N and P loading at the watershed scale was insignificant

Sediment-bound N and P

The amount of sediment-bound nitrogen and phosphorus retained in a sediment control basin varies with the proportion of fine sediment deposition that occurs (Fiener et al., 2005). In a review of effectiveness studies, Rutledge (2014) reported that SCoBs with water retention times between 1 and 2.7 hours have been found to have total phosphorus removal rates ranging from 25 to 98%. This wide variation in removal rates is due to significant differences in the amount of fine sediment retained among the basins examined. Czapar et al. (2005) estimated the effectiveness of WaSCoBs relative to conventional tillage on ten different soil types in Iowa. WaSCoBs were estimated to reduce both total N and total P losses in eroded soil by 92%. Total N and P losses (lb/acre for water and soil combined) were estimated to be reduced by 82% for N and 88% for P. Even though there was an increase in soluble N and P loads in runoff, the total amount of N and P retained was large because the vast majority was bound to settled soil particles. Brown et al. (1981) found that very large ponds (analogous to WaSCoBs) receiving irrigation runoff at rates higher than the design flow (and with no flocculation aid) retained 25 to 33% of total phosphorus loads. Where soils contain a significant proportion of clay and fine silts, increasing the effectiveness of phosphorus removal can be achieved through use of a flocculation aid to remove these fine sediment particles from suspension (Bjorneberg and Lentz, 2005; Brown et al., 1981).

Removal of soluble N and P

As one would expect, WaSCoBs and SCoBs are much more effective at removing sediment-bound N and P than they are at removing soluble N and P from runoff (Smith et al, 2015; Czapar et al., 2005; Paul, 2003; Crites, 1994; Schepers et al., 1985). Smith et al. (2015) estimated that WaSCoBs reduced soluble P and total P in surface runoff by 80 and 79% on average. In contrast, WaSCoBs used to treat tile drainage runoff were estimated to increase soluble P by 60% and increase total P by 24%. Since these estimates were based on blind inlets (analogous to WaSCoBs) installed to treat surface runoff and tile drainage from the same fields, it is notable that the net reduction in soluble P for surface and subsurface runoff combined was estimated to be 10%. Czapar et al. (2005) estimated that WaSCoBs increased ammonia + nitrate in runoff by 33% and increase phosphate in runoff by 50%. Schepers et al. (1985) found that although soluble N and P comprised less than 15% of the total N and P losses in runoff treated by SCoBs, the amount of these solutes discharged was still high enough to cause water quality problems in downstream receiving waters. One of the primary reasons for the ineffective capture of soluble nutrients is that the water retention time is rarely long enough for biochemical processing to occur within a sediment control basin (Paul, 2003; Crites, 1994). Secondarily, any infiltration of water within the basin will carry with it dissolved N and P, which in turn may be transported as subsurface flow and may eventually reach surface waters.

Similar to the findings for sediment, modelling suggests that WaSCoB effectiveness varies across spatial scales. Using the SWAT model in the Midwestern U.S., Her et al. (2017) estimated that WaSCoBs decreased total P loads by roughly 46% and total N by roughly 32% at the field-scale; this is in spite of minimal decreases in soluble P loads and an increase in soluble N loads. (Note that a decrease in modelled soluble loads may be associated with subsurface leaching, which may deliver the pollutants to groundwater and thus not actually be a load reduction.) In a prior study using the SWAT model, Her et al. (2016) estimated that WaSCoBs resulted in modelled field-scale load reductions for N and P of 16.8% and 39.5%, respectively. At the watershed scale however, WaSCoBs had an insignificant effect upon total N and P loading. This suggests that although WaSCoBs reduces sediment-bound N and P loads at the field scale, other practices that reduce the generation and transport of pollutants such as conservation cover, conservation crop rotation, conservation tillage, and cover crops should be given higher priority for reducing N and P loading (Her et al., 2016).

In summary, SCoBs and WaSCoBs can remove significant amounts of nitrogen and phosphorus, yet the amount removed will vary considerably with the design of the basin and how much N and P is sediment-bound. The amount of sediment-bound N and P may vary spatially among soil types as well as temporally among seasons or runoff events. Soluble N and P loads (which are more bioavailable) may be increased through the use of SCoBs and WaSCoBs. For these reasons, the removal of N and P from runoff should be considered as a secondary benefit of SCoBs and WaSCoBs rather than a primary function or intended use.

Pesticides and Pathogens

No studies were located that evaluated pathogen removal and only one study was found that examined pesticide retention by sediment control basins. Fiener et al. (2005) evaluated sediment basins that were constructed using farm machinery to raise the height of field borders and in which an underground outlet was installed. They found that the basins reduced *maximum* concentrations of a moderately soluble pesticide (Terbutylazin) by approximately 50%. As with nutrients, sediment basins are likely to preferentially retain sediment-adsorbed pesticides while being ineffective at retaining dissolved pesticides (The University of California Cooperative Extension, undated publication). Potential removal of pesticides should therefore be considered an ancillary benefit and not a primary function of a sediment basin.

Summary of references reviewed in developing the guidance for sediment control basins.

Note: In cases where a reference was not acquired, the article abstract is presented instead.

1) Bjorneberg, D.L., and Lentz, R.D. (2005). Sediment Pond Effectiveness for Removing Phosphorus from PAM-Treated Irrigation Furrows. Applied Engineering in Agriculture, 21(4), 589-593.

   Abstract: Polyacrylamide (PAM) greatly reduces erosion on furrow-irrigated fields and sediment ponds can be constructed to remove suspended sediment from irrigation runoff. Both practices are approved for reducing phosphorus (P) loading in the Lower Boise River Pollution Trading Project in southwest Idaho, but information is not available about using both practices on the same field. The objective of this study was to measure the combined effects of PAM application and sediment ponds on sediment and P losses from a furrow-irrigated field. Small sediment ponds (5.8 m^2) with a 60-min design retention time were installed on two fields to receive runoff from PAM-treated or control furrows. Pond inflow and outflow were monitored during a total of 11 irrigations on the two fields. Three crop years of data showed that applying PAM to furrows reduced sediment and total P mass transport to the ponds 50% to 80%, which reduced the mass of sediment and total P retained in the ponds. However, PAM application did not change the percentage of sediment (86%) and total P (66%) retained. The PAM-sediment pond combination reduced average total P loss by 86% to 98%, based on the difference between untreated inflow and PAM-treated outflow. PAM and sediment ponds had little or no effect on dissolved reactive P (DRP) concentrations. The mass of DRP retained in sediment ponds was directly related to the amount of water that infiltrated within the ponds. Applying PAM to irrigation furrows and installing sediment ponds at the end of the field can be an effective combination for

reducing sediment and total phosphorus losses from furrow-irrigated fields, but these practices only reduced soluble P losses by decreasing the volume of water that ran off the fields.

2) Brown, M.J., Bondurant, J.A, & Brockway, C.E. (1981). Ponding Surface Drainage Water for Sediment and Phosphorus Removal. *Transactions of the American Society of Agricultural Engineers,* 1478-1481.

Summary: This is a case study of a very large sediment retention pond (3400 m3 capacity) in Idaho designed to filter irrigation runoff from 4050 hectares of land. The scale of the pond makes it mostly irrelevant to sediment control basin Ag BMP guidance, however, it is useful in that it related sediment retention to phosphorus retention. Sediment retention rates of 65 to 76% were associated with phosphorus retention of 25 to 33%.

Phosphorus not retained was either in soluble form or was associated with soil particles (i.e., clay) that did not settle out of suspension. It was noted that the inflow rate for all 5 years was greater than the design flow, which inhibited settling of silt and clay, and also noted that no flocculation aid was utilized to settle out particles.

3) CA Dept. of Transportation. 2003. Construction site best management practice (BMP) field manual and troubleshooting guide. CTSW-RT-02-2007. Sacramento, CA.

This manual provides guidance on using various practices to control runoff and erosion on construction sites, including guidance on troubleshooting some of the BMPs.

4) Center for Watershed Protection. 2000. Improving the Trapping Efficiency of Sediment Basins, Article 58. *The Practice of Watershed Protection: Techniques for Protecting and Restoring Urban Watersheds.* Ellicott City, MD.

Summary: This paper reviews sediment basin performance and modifications to improve effectiveness. The context is urban stormwater and construction sites, but the principles can be applied more broadly. The article asserts that an often-used construction site basin design (rectangular hole, corrugated metals riser, and truckload of riprap at the outlet) often does not consistently remove 70% or more of incoming sediment loads. 95 to 99% sediment removal is needed to achieve a "relatively clear water discharge." Factors that reduce trapping efficiency are noted below (taken directly from the text):

- Large storm events (greater than two-year storm)
- Moderate to low incoming TSS concentrations
- Sediment deposits on bottom are re-suspended, or sides erode
- Fine particle sizes in incoming runoff (silt and clay particles 40 microns or less)
- Advanced stage of construction, with storm drains and paved roadways increasing runoff volume/velocity
- Low intensity, long duration rainfall events

- Length-to-width ratio of 1:1 or less
- Multiple inlets, particularly if not stabilized or if their invert is more than a foot above basin floor
- Steep side-slopes, particularly in non-growing season or poor vegetative cover
- Turbulent energy in runoff
- Cold water temperatures (below 40 degrees F)
- Absence of standing water in basin
- Upland soils are in C and D hydrologic soil groups, or highly erodible soils

Adding a perforated riser alone for drainage instead of a pipe with a large opening at the top can achieve sediment removal of 60-70%; testing showed that fine silt and clay were typically not removed from runoff. Adding a gravel jacket or polystyrene chips to a perforated riser has been found to increase sediment removal by 15 to 18%.

Adding filter baric to a perforated riser is not recommended because it doesn't effectively increase silt and clay trapping, but does become clogged, making it a barrier to flow. Placing silt fences as baffles (in series perpendicular to flow) in a basin is also not recommended unless the basin is poorly shaped or has multiple inlets. The silt fences reduce short-circuiting of a basin, but have no significant effect on storage time, and increase the volume of dead storage, which decreases detention time for incoming flow. A floating skimmer that is designed to drain water from less turbid water at the surface as it rises with the rising water stage has been shown to boost sediment removal; however, if turbulent flow exceeds 0.3ft/second- which is typical, then their utility is negated. Dual detention basins in series significantly increase sediment removal by increasing storage time. The following design criteria are recommended (taken directly from the text):

- Provide a minimum storage of at least 3,600 ft3 per acre.
- Provide storage in wet and dry stages.
- Silt fence barriers required if length to width ratio is less than two.
- Evaluate all proposed inlets for stability.
- Employ a floating skimmer, or at least a perforated riser w/ gravel jacket.
- Incorporate storage in multiple cells, where possible.
- Limit side-slopes to no greater than 3:1.
- Check water table to determine if basin can/should fully de-water.
- Paint depth markers on principal spillway to measure sediment deposition to better
- trigger cleanouts.
- Stabilize side-slopes and basin bottom with mulch or hydro-seeding within one week.

5) Chen, C. 1975. Design of sediment retention basins. *In Proceedings, National Symposium on Urban Hydrology and Sediment Control, University of Kentucky: Lexington, KY, 285–298.*

Summary: This article addresses the hydraulic design of sediment retention basins. Multiple equations and graphs are provided related to sediment transport and hydraulics. One curve shows that sediment trapping efficiency increases exponentially as the ratio of the basin capacity to the inflow rate increases; i.e., larger basins with smaller inflows trap sediment more effectively than smaller basins with larger inflows. Additionally, it is shown that as basin area increases and outflow rate decreases, basin capture of smaller and smaller soil particles increases. One take home message here is that most sediment control basins used on farmlands will probably not be large enough to retain clay and maybe even some portion of the fine silt load. Basins can be sized for the expected amount of sediment deposition for the design life (or between cleanouts) or basins may be designed to store the total runoff from individual storms. For the former, the outflow is uncontrolled and for the latter, the outflow is controlled. Choosing between the two involves considerations of costs, amount of sediment retention needed, and the soil particle size distribution to be captured.

The following steps are suggested in the basin design process: estimate the sediment yield for the contributing area; estimate the soil particle size distribution; determine the rate and size fraction of sediment to be retained; estimate the capture efficiency needed to retain the target sediment load; estimate the basin surface area to outflow rate that matches the target efficiency; estimate the spillway capacity; estimate the range and average outflow rates; develop draft basin dimensions; compute average outflow velocity; estimate volume of sediment to be captured for a target time-span; estimate storm runoff volume; verify or adjust basin design outflow rate; finalize outlet dimensions; if examining a range of sediment capture efficiencies, then develop alternative basin and outlet dimensions and select the final design based on costs and maintenance vs. amount of sediment capture. Lastly, the author suggests that implementing additional sediment control practices along with sediment control basins is likely to be more cost-effective than implementing sediment basins alone.

6) Crites, R.W. (1994). Design criteria and practice for constructed wetlands. *Water Science and Technology 29(4), 1-6.*

Summary: This paper addresses constructed wetland design and has little relevance to the sediment control basin BMP. It does, however, suggest that water retention time would need to be 8 to 14 days or more to remove a significant amount of nitrogen through denitrification and 5 to 10 days to remove TSS.

7) Czapar, G., Laflen, J., Mcisaac, G., and McKenna, D. 2005. Effects of Erosion Control Practices on Nutrient Loss. *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop.* American Society of Agricultural and Biological Engineers, St. Joseph, MI.

Summary: This is an unpublished comparison among common erosion control practices vs. typical conventional tillage in Iowa in terms of their effect upon sediment and nutrient loss. “Water and sediment control basins perform very similarly to terraces with underground outlets, but do not reduce slope length or erosion losses in the field. It is very important to have soil erosion control on the watershed above the sediment control basin to ensure a long effective life of the basin."

> "Erosion control practices can substantially reduce particulate phosphorus and nitrogen loss from fields, but may increase dissolved phosphorus losses if fertilizer or manure is not effectively incorporated into the soil. Erosion control practices have relatively little impact on inorganic nitrogen losses. The fraction of the nutrient and sediment losses delivered to surface water are affected by practices in the field as well as the distance and path traveled between the field and stream. For example, a field with high concentrations of phosphorus in the soil surface adjacent to a stream and eroding at half the T value may have greater impacts on water quality than a field with low phosphorus levels eroding at >3T, but four miles from the stream."

Effectiveness estimates are based on average for 10 Iowan soils, a 72.6ft long, 9% slope and a 300ft long, 5% slope. Compared to typical conventional tillage, water and sediment control basins, reduce sediment yields (tons/acre/yr) in runoff by 95%, increase ammonia + nitrate in runoff by 33%, increase phosphate in runoff by 50%, reduce total N losses in eroded soil by 92%, and reduce total P losses in eroded soil by 92%. Total N and P losses (lb/acre for water and soil combined) are reduced by 82% for N and 88% for P.

In this regard, even though there is an increase in soluble N and P loads in runoff, the total amount of N and P retained reduced by the water and sediment control basins is large because the vast majority of the N and P is bound to soil particles that are captured in the basins.

Water and sediment control basins were estimated to cost $600/acre of contributing area and have a lifespan of 10 years. The estimated annual cost for pollutant reductions was estimated to be $8.10 per ton of sediment per year, $2.05 per pound of nitrogen per year, and $5.22 per pound of phosphorus per year. In this regard, although water and sediment control basins reduce sediment, N, and P loads significantly more so than contouring, stripcropping, terraces with vegetative outlets, and no-till, the cost per pound of N, P, and sediment captured is higher than those other BMPs.

The information in the paper suggests that water and sediment control basins should be reserved for situations in which there is a higher relative risk of pollutant delivery to a stream channel due to proximity of fields to stream channels (e.g., fields are adjacent to a channel and/or are hydrological connected by rills, gullies) and alternative BMPs will not effectively reduce N, P, and sediment loads to the degree necessary to protect water quality.

This paper also contains a very useful summary of field conditions that affect nutrient loss.

8) Fiener, P, Auerswald, K., and Weigand, S. 2005. Managing erosion and water quality in agricultural watersheds by small detention ponds. *Agriculture, Ecosystems, and Environment 110* pp.132-142.

Summary: This study evaluated the performance of four sediment control basins over a period of 8 years. The type of basins studied were described as being cheap and easy to construct using farm machinery. Basically, they were created by raising the height of field borders and installing underground outlets in areas where terrace countering systems are appropriate- on slightly undulating lands with slopes between 6.5 and 9.5% (not in fields with steep/complex topography). Field sizes ranged from 1.9 to 6.5 hectares. The sediment storage capacity of the basins was 30 to 260 m^3/hectare. The basins were designed to have a water retention time of less than 3 to 4 days. Peak runoff during heavy precipitation was reduced by threefold. Infiltration and evaporation in the basins accounted for less than 10% of delivered runoff. Maximum concentrations of pesticides (Terbutylazin- moderately soluble) in the outflow was reduced by one-half. It was estimated that the long-term sediment retention effectiveness of these ponds ranges between 50 and 80%. "The ponds increased the enrichment due to a selective sedimentation of the coarse incoming sediments and a preferential loss of the dispersed fines. Residence time within the ponds (roughly 1 d) and water column height (roughly 1/3 of the maximum water level, 0.4 m) allows only for a complete settlement of particles >2.3 mm if Stokes law is applied under the assumption of negligible turbulences. Hence, due to this enrichment of fine particles in the delivered sediments, the sediment trapping of the ponds was more efficient (54–85%) than nutrient trapping (35–70%)." The ponds also prevented downslope linear erosion of drainage ways. A significant dampening of peak runoff rates was also observed, although total runoff volume is not significantly reduced. The authors recommend installing a grassed waterway downslope to promote runoff infiltration.

9) Gupta, A. K., Rudra, R. P., Gharabaghi, B., Daggupati, P., Goel, P. K., and Shukla, R. 2019. CoBAGNPS: A toolbox for simulating water and sediment control basin, WaSCoB through AGNPS model. *Catena, 179, 49-65.*

Abstract: A WaSCoB constituting a modest detention pond (berm), surface inlets and tile drains; designed to capture the flow and release it gradually into the drainage system is an efficient watershed BMP. Henceforth; a toolbox, CoBAGNPS for the AGNPS model, is developed to simulate WaSCoBs through the AGNPS model. The toolbox utilizes the inputs from AGNPS, through the launching of an application for execution of the WaSCoB module. Finally, the output files are generated after routing flow through WaSCoBs. The toolbox was applied with a case study in the Gully creek watershed and one of its sub-basins (DFTILE sub-basin) located in Ontario, Canada. The toolbox reproduced the required outputs successfully. Henceforth, significantly enhancing the capability of the AGNPS model to simulate flow through a WaSCoB and a network of WaSCoBs. Furthermore; the efficiency of the drainage system is also analyzed under different scenarios of pipe risers and tile drains. Also, few scenario analyses were considered in which different diameter drainage pipes were considered to route flow for extreme events for WaSCoB3 in the DFTILE sub-basin. A 375-mm diameter drainage pipe is efficient in routing flow for a 10-year 24-h design storm without it overtopping the berm. Finally, another component of the toolbox was tested, where the flow from the DFTILE sub-basin was directly routed to the outlet of the Gully creek watershed (GULGUL5) through a drainage pipe of 200 mm with 1% slope, assuming a lag time. The hydrograph at the watershed outlet increased marginally due to the small size of the DFTILE sub-basin.

Summary: This study modeled the effectiveness of different water and sediment basin (WaSCoB) configurations at routing flow. The study did not model sediment or nutrient transport. This modelling effort is different than others in that it simulated flow through surface inlets whereas other models, such as SWAT, do not. WaSCoBs consist of a system of berms, surface inlets, and tile drains. WaSCoBs slowly divert captured runoff through surface inlets into an underground drainage outlet, thereby controlling drainage rate and retaining sediment and nutrients within the basin. Perforated pipe risers (tile risers) are the most frequently used surface inlet. Some studies have found that "traditional surface inlets" (surface tile inlets) are less effective at inhibiting sediment and phosphorus transport to downstream waterbodies than blind inlets. The modelling results suggested that pipe riser type does not have a significant effect upon peak discharge from a basin. Further research is needed to evaluate how different basin areas, types of pipe riser, and drainage systems influence sediment and nutrient transport.

10) Her, Y., Chaubey, I., Frankenberger, J., and Jeong, J. 2017. Implications of spatial and temporal variations in effects of conservation practices on water management strategies. *Agricultural Water Management* 180, pp. 252-266.

Summary: This study used the SWAT model to estimate field-scale effectiveness of agricultural BMPs at reducing sediment and nutrient loads in a Midwestern watershed. Water and sediment control basins WaSCoBs were treated similarly to terraces in the model, with adjustments made by reducing curve number, P-factor, and slope length. The model indicated that WaSCoBs increase soil moisture content, which increases leaching of soluble N. Sediment loads were estimated to decrease by an average of about 55%, total P by roughly 46% and Total N by roughly 32%- this is in spite of minimal decreases in soluble P loads and an increase in soluble n loads. Note that a decrease in soluble loads according to the model may just be associated with subsurface leaching, which may deliver the pollutants to groundwater and thus not actually be a load reduction. The authors found that effectiveness of the various BMPs varied seasonally and with the timing of activities such as tillage, planting, harvesting, fertilizer application. Authors "suggest that conservation practice planning should be designed to separately consider controlling nutrients in particulate form or in soluble form with a practice to improve its reduction efficiency."

11) Her, Y., Chaubey, I., Frankenberger, J., and Smith, D. 2016. Effect of conservation practices implemented by USDA programs at field and watershed scales. *Journal of Soil and Water Conservation 71 (3) 249-266.*

Summary: The authors used modelling (SWAT model) to estimate pollutant load reductions for agricultural BMPs at the field and watershed scale in a Midwestern U.S. watershed (area = 1,084mi^2). The BMPs addressed included: conservation crop rotation, no-till, conservation cover, mulch-till, field border, filter strip, biomass planting, nutrient management, WaSCoB, and split N application. Conservation cover had the greatest effect at the field scale, resulting in modelled sediment, N, and P load reductions of 99.4, 85.7, and 99.6%, respectively. WaSCoBs resulted in modelled field-scale load reductions for sediment, N, and P of 47%, 16.8%, and 39.5%, respectively. At the watershed scale, WaSCoBs resulted in modelled load reductions for sediment, N, and P of 0.02%, 0.01%, and 0.02%.

This indicates that although WaSCoBs may be important for achieving significant pollutant load reductions in individual fields, they are unlikely to have a significant effect at a watershed scale. Conservation crop rotation and cover crops had the greatest modelled effect upon sediment, N, and P at the watershed scale- although no watershed scale load reduction was greater than 2%. The fact that all BMPs combined were modelled to have watershed scale cumulative load reductions of <5% makes the accuracy of the modelling effort suspect – especially when considering that cropland comprised 43.3% of the watershed.

12) Lenhart, C., Gordon, B., Peterson, J., Eshenaur, W., Gifford, L., Wilson, B., Stamper, J., Krider, L, and Utt, N. 2017. Agricultural BMP Handbook for Minnesota, 2nd Edition. St. Paul, MN: Minnesota Department of Agriculture.

    Summary: Provides a description of agricultural BMPs used in Minnesota.

13) Liu, Y. 2017. Economic Costs and Environment Tradeoffs: A meta-analysis of farm-level abatement costs of agricultural beneficial management practices in mitigating excess phosphorus loss in Ontario. M.SC. Thesis. The University of Guelph.

    Summary: This is a cost-benefit analysis regarding the efficacy of different agricultural BMPs at preventing the export of phosphorus to surface waters. It found that WaSCoBs can remove a relatively high level of sediment bound and organic P, but because they tend to be one of the most expensive BMPs in terms of dollars per kg of P removed, Liu suggests that their use should be reserved to situations in which nutrient transport via gullies cannot be feasibly or economically addressed by other BMPs.

14) Makarewicz, J.C., Lewis, T.W., Bosch, I., Noll, M.R., Herendeen, N., Simon, R.D., Zollweg, J., and Vodacek, A. 2009. The impact of agricultural best management practices on downstream systems: soil loss and nutrient chemistry and flux to Conesus Lake, New York, USA. *Journal of Great Lakes Research*, 35 pp., 23-35.

    Summary: This study evaluated the effectiveness of agricultural BMPs, including sediment control basins, at reducing nutrients and sediment in multiple watersheds. In one watershed, a combination of strip cropping, grass buffers and water/sediment control basins resulted in a 71% reduction in total suspended solids concentrations and a 32% reduction in nitrate + nitrite (and no significant P decrease); however, the latter reduction was attributed to a conversion of a large proportion of cropland to alfalfa-grass hay fields during the study. Pollutant reductions for sediment basins were not evaluated separately from other BMPs.

15) Marin Resource Conservation District. 2007. Groundwork: a handbook for small scale erosion control in coastal California. 2nd edition. Marin County, CA.

- This is a handbook developed to help guide landowners with selecting and apply techniques to control soil and streambank erosion problems on their lands that are of a low to moderate severity and can be addressed without professional assistance.

16) Mielke, L.N. 1985. Performance of water and sediment control basins in northeastern Nebraska. *Journal of Soil and Water Conservation.* 40 (6) 524-528.

Abstract: Water and sediment control basins formed with discontinuous, parallel terraces using riser inlets and underground pipe outlets were evaluated for soil erosion and sediment control on a loess-derived association of Ustorthents and Haplustolls in northeastern Nebraska. The structures, parallel to existing field boundaries, provided straight rows as well as erosion protection on severely dissected landscapes that were too undulating to farm using conventional terrace systems. With clean-cultivated corn, sediment trapping efficiency exceeded 97%, and the basins retained sediment near its point of origin. The small quantity of sediment discharged from the outlet contained 12% silt and 88% clay after about 2 hours of runoff. Based on sediment trapped in the basins, an 86-mm storm transported about 40 t/ha of sediment into the basins. A smaller storm (50 mm) deposited about 17 t/ha. Sediment discharged during the initial runoff from a storm was high in silt and low in clay particles.

Summary: Over a period of several years, Mielke examined sediment removal by water and sediment control basins designed for 2, 5, or 10 year 24-hr rain events on deep, highly dissected loess soils (Ustorthents and Haplustolls). Soils had less than 20% residue cover remaining after cultivation in most of the years. Sediment trapping efficiency was found to range from 97 to 99%. Water discharged from the basins initially contained about 60% silt and 40% clay, but after a pool formed in the basins, the discharge contained about 12% silt and 88% clay. The author asserted that water and sediment control basins can be used instead of grassed waterways on lands with steeper slopes that deter the use of terrace systems, and may be the only feasible erosion control option in some situations when terrace systems are not feasible. Installation costs were noted to be higher than other practices, but the practice was favorably viewed by farmers due to its effectiveness and ability to be integrated with farming operations.

17) *NOAA, 2004- Current. Precipitation-Frequency Atlas of the United States. Atlas 14 Vols. 1-9.*

- Reference for precipitation frequency numbers.

18) *NOAA, 1973. Precipitation-Frequency Atlas of the United States, Washington. Atlas 2, Vol. IX.*

- Reference for precipitation frequency numbers.

19) *NRCS-NHCP 2010. Field Office Technical Guide (FOTG), Section IV, Conservation Practice Standard - Sediment Control Basin, 350. Washington. January 2010. Downloaded from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025942.pdf on 8/20/21*

20) *NRCS. 2018. Field Office Technical Guide (FOTG), Section IV, Conservation Practice Standard - Water and Sediment Control Basin, 638. Washington. September 2018.* Downloaded on 8/28/2020 from *https://efotg.sc.egov.usda.gov/#/details.*

Summary: Provides NRCS practice considerations and specifications for water and sediment control basins. The following text was directly taken from the reference:

Definition: An earth embankment or a combination ridge and channel constructed across the slope of a minor drainageway.

This practice may be applied for one or more of the following purposes:

- Reduce gully erosion
- Trap sediment
- Reduce and manage runoff

This practice applies to sites where:

- The topography is generally irregular.
- Gully erosion is a problem.
- Other conservation practices control sheet and rill erosion.
- Runoff and sediment damages land and works of improvement.
- Stable outlets are available.

- Do not use this standard in place of a terrace. Use Conservation Practice Standards (CPS) Terrace (Code 600) or Diversion (Code 362) where the ridge and/or channel extends beyond the detention basin or level embankment.
- Install a water and sediment control basin as part of a conservation system that addresses resource concerns both above and below the basin. Where land ownership or physical conditions preclude treatment of the upper portion of a slope, a water and sediment control basin can separate this area and permit treatment of the lower slope.
- Locate the water and sediment control basin to reduce erosion in a drainageway. Install a basin singly or in series as part of a system to fit site conditions. Adjust the location to—
    - Fit the topography.
    - Maximize storage.
    - Accommodate farm equipment and farming operations.
    - Accommodate property lines.
- Water and sediment control basins can be spaced at intervals down a slope, similar to terraces, in order to control erosion. Refer to CPS Terrace (Code 600) for methods to determine spacing. Install additional conservation measures in the watercourse between basins to prevent erosion as necessary.
- An underground outlet from a water and sediment control basin can provide a direct conduit to receiving waters for contaminated runoff from cropland. To reduce the impact of this runoff, install the water and sediment control basin as part of a conservation system that includes such practices as grassed waterways, contouring, a conservation cropping system, conservation tillage, nutrient and pest management, crop residue management, and filter areas to reduce or mitigate contaminated runoff.

21) *NRCS. 2017b. Field Office Technical Guide (FOTG), Section IV, Conservation practice overview. Water and Sediment Control Basin, 638.* Washington. October 2017. Downloaded on 8/28/2020 from https://efotg.sc.egov.usda.gov/#/details

The following text was directly taken from the reference:

A water and sediment control basin (WASCOB) is an earth embankment or a combination ridge and channel constructed across the slope of a minor drainageway.

The purpose of this practice is to reduce gully erosion, trap sediment, and reduce and manage runoff. WASCOBs are constructed across small drainageways where they intercept runoff. The basin detains runoff and slowly releases it allowing sediment to settle. WASCOBs generally use an underground outlet to control the release and carry the runoff in a pipe to a receiving stream or ditch.

This practice applies to sites where—

- The topography is generally irregular.
- Gully erosion is a problem.
- Other conservation practices control sheet and rill erosion.
- Runoff and sediment damages land and works of improvement.
- Stable outlets are available.

WASCOBs alone may not be sufficient to control sheet and rill erosion on sloping upland areas. In addition, outlets from water and sediment control basins can provide a direct conduit to receiving waters for contaminated runoff from cropland. For these reasons, additional practices may be needed to adequately protect sloping upland areas from erosion and to protect down-slope water quality.

The Conservation Practice Standard (CPS) Water and Sediment Control Basin (Code 638) is frequently associated with CPSs Conservation Crop Rotation (Code 328); Residue and Tillage Management, No Till (Code 329); Residue and Tillage Management, Reduced Till (Code 345); Cover Crop (Code 430); Critical Area Planting (Code 342); Filter Strip (Code 393); and Nutrient Management (Code 590).

22) NRCS. 2017a. *Field Office Technical Guide (FOTG), Section IV, Conservation Practice Standard - Sediment Control Basin, 350. Washington. July 2017.* Downloaded on 8/28/2020 from https://efotg.sc.egov.usda.gov/#/details.

Summary: Provides NRCS practice considerations and specifications for sediment basins.

The following are excerpts directly taken from the reference:

Practice definition: A basin constructed with an engineered outlet, formed by constructing an embankment, excavating a dugout, or a combination of both.

Purpose: To capture and detain sediment-laden runoff, or other debris for a sufficient length of time to allow it to settle out in the basin

Conditions where the Practice applies:

This practice applies to urban land, construction sites, agricultural land, and other disturbed lands where-

- Physical conditions or land ownership preclude treatment of a sediment source by the installation of erosion-control measures.

- Failure of the basin will not result in loss of life, damage to homes, commercial or industrial buildings, main highways or railroads; or in the use of public utilities.
- The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the reservoir below the elevation of the crest of the auxiliary spillway.
- The effective height of the dam is 35 feet or less. The effective height of the dam is the difference in elevation between the auxiliary spillway crest and the lowest point in the cross section taken along the centerline of the dam.
- The dam is classified low hazard according to section 520.21(E) of the NRCS National Engineering Manual (NEM).

Location: Sediment basins provide the last line of defense for capturing sediment when erosion has already occurred. When possible construct the basin prior to soil disturbance in the watershed. Choose the location of the sediment basin so that the basin intercepts as much of the runoff as possible from the disturbed area of the watershed. Choose a location that minimizes the number of entry points for runoff into the basin and interference with construction or farming activities. Do not locate sediment basins in perennial streams.

General considerations: To work most effectively, the sediment basin should be the last practice in a series of erosion control and sediment capturing practices installed in the disturbed area. This incremental approach will reduce the load on the basin and improve effectiveness of the overall effort to prevent offsite sedimentation problems.

Many factors influence the efficiency of sediment removal in a basin. These include the detention time of runoff, the type of dewatering device, the presence of a permanent pool in the basin, a decrease in turbulence in the basin, and soil particle size.

23) Ohio State University Extension. 2020. Water and sediment basin (NRCS 350 & 638). Accessed online 10/8/2020.

- "A water and sediment basin should be installed to control the stage, discharge, distribution, delivery, or direction of flow of water in open channels or water use areas. NRCS Conservation Practice Standard 638 is used to reduce watercourse and gully erosion; trap sediment; reduce and manage onsite and downstream runoff; improve downstream water quality; and improve the ability to farm sloping land. A water and sediment basin is usually small enough that the sediment can be excavated and placed back on fields."
- "NRCS Conservation Practice Standard 350 is used where physical conditions or land ownership preclude treatment of a sediment source by the installation of erosion control measures to keep soil and other material in place, or where a sediment basin offers the most practical solution to the problem. A sediment basin is often larger than a water and sediment basin. Typically, it has legal size requirements and is not commonly used in Ohio as an agricultural sediment management practice."

24) Paul, L. 2003. Nutrient elimination in pre-dams: results of long-term studies. *Hydrobiologia 504, 289-295.*

Summary: This paper discusses the use of pre-dams for reducing sediment and nutrient inputs into reservoirs. Pre-dams are like very large water and sediment control basins. The article is not particularly relevant for evaluating AG BMP effectiveness. It does provide some information that may be useful when thinking about WaSCoB effectiveness. It suggests that small pre-dams are not effective at retaining soluble reactive phosphorus (SRP) or nitrate because retention requires enough time for biological processes to occur (e.g. uptake by of SRP phytoplankton and subsequent settling of cells in the bottom of the basin, or denitrification of nitrate by sediment dwelling bacteria).

25) Rutledge, J. 2014. An evaluation of three types of water retention structures in the Red and Assiniboine watersheds. Unpublished. Prepared for Agriculture and Agri-food Canada.

Summary: This report includes an evaluation of nitrogen and phosphorus retention by sediment control basins and water and sediment control basins. The paper states that *sediment control basins* are designed to trap sediment from a target magnitude runoff event (either small or large), but are not designed to reduce peak flows, although water may be retained for indefinite time periods in order to achieve sediment retention objectives. It is stated that *water and sediment control basins* are typically designed to reduce peak flows during larger runoff events, with sediment capture being a secondary design objective.

Regarding sediment control basins:

Sediment control basins are a terminal BMP (last line of defense before discharge to surface waterways) and should be employed along with complementary upslope practices to address erosion and runoff. They should not be placed in perennial streams, but rather in places that are usually dry, but have surface flow during distinct runoff events.

A table of previously published study results for sediment controls basins indicates that for water retention times between 1hr and 2.7hrs, sediment removal was found to vary between 65 to >97%, while total phosphorus retention ranged from 25 to 98%.

"Efficiency of sediment removal is affected by a number of factors:

a) Effective detention time (and therefore sediment trapping) will increase as the basin size increases;
b) The presence of a dewatering device or skimmer that removes cleaner water above sediment storage and increases quality of water exiting the basin;
c) The presence of a permanent pool in the basin will reduce suspension of sediment in the basin;
d) The presence and degree of basin turbulence is also a factor."

In arid areas, it is possible that up to 100% of sediment is captured because it may be that no water release is necessary. In humid areas, it is unlikely that all water and sediment can be captured because the basin may fill and drain multiple times a year. Some information suggests that long, narrow basins capture coarser sediment more effectively, while more circular and rectangular basins capture finer sediment more effectively. Non-toxic flocculants can be added to irrigations furrows to increase P retention in the basins, but this appears to work only if surface runoff from fields is concurrently reduced. Periodic mowing of basins should occur to prevent trees and shrubs from growing on berms/embankments. Filter strips/field borders should be employed around the basin to prevent flow channelization and “short-circuiting” of the hydraulic design. Basins require periodic sediment removal, grading/shaping. Embankments require periodic inspection and maintenance.

Regarding water and sediment control basins (WaSCoBs):

WaSCoBs can provide some flood protection for low-intensity land uses, but the contributing area needs to be small so that the basins can handle the runoff. The hydraulic design for WaSCoBs is usually a 10 yr frequency, 24hr duration storm. The capacity is designed to store 10 years of excepted sediment accumulation. Several WaSCoBs in succession can be used for grade control in areas probe to gully formation. It is estimated that WaSCoBs can remove up to 90% of sediment from runoff.

26) Schepers, J. S, Francis, D. D, & Mielke, L. N. 1985. Water Quality from Erosion Control Structures in Nebraska. *Journal of Environmental Quality,* 14, 186

Abstract: Runoff collected from terrace and sediment-control basins having tile-outlet systems was compared with runoff water quality from Maple Creek in northeastern Nebraska. This study was part of a Model Implementation Project (MIP) initiated in 1978 to accelerate land treatment for erosion control and development of best management practices (BMPs). Soils in the area are very erosive (Nora-Crofton complex) when subjected to high-intensity rainfall in the spring and summer. Sediment concentrations in runoff from the terraces and sediment basins were initially high and comparable to stream concentrations until a pool of runoff water formed around the riser inlet of the tile discharge system. Formation of a pool allowed sediment to settle out away from the riser inlet, thus reducing sediment losses from the field. Sediment-borne N and P accounted for 85 to 98% of total N and P losses from the land. Because tile-outlet terraces and sediment basins effectively reduced sediment and nutrient concentrations in runoff, they proved to be an effective BMP for use by producers.

Summary: This study occurred in the same area as Mielke (1985) and compared suspended solids, nitrogen, and phosphorus in discharges with a stream, a tile-outlet terrace, and a sediment control basin. The authors concluded that the sediment control basins significantly reduced sediment and sediment-associated nitrogen and phosphorus in cropland runoff. General quantitative estimates of load reductions were not made. It was noted that although soluble N and P comprised less than 15% of the total N and P losses in runoff, the amount of these solutes remaining in the sediment control basin discharges was still high enough to cause concern for downstream waterbodies.

27) Seibel, D.C. 1983. Use of water and sediment control basins in Iowa. For Presentation at the 1983 Winter Meeting. *American Society of Agricultural Engineers. 5pp.* fiche no. 83-2552.

Summary: This article provides a summary of the function and application of water and sediment control basins (WaSCoBs). WaSCoBs evolved from terraces with underground tile outlets for drainage. They can be used to control erosion by concentrated flows in areas where the terrain is not amenable to terracing. WaSCoBs have been used in Iowa in place of grassed waterways, which are noted to reduce farmable land and whose vegetation was frequently being damaged by herbicides- thereby impacting their effectiveness. WaSCoBs are used to control gully erosion and stabilize the grade of drainageways. Several basins in sequence can be used in some places instead of a single larger and expensive grade control structure at the gully outfall. The basins are typically designed to handle a 10-yr frequency 24-hr duration precipitation event (2 -3 inches in Iowa) and can provide flood protection for farmland downgradient of small drainage areas. They are not intended to provide flood protection for structures. It is asserted that the basins can capture as much as 90% of sediment eroding from farmland and can also retain chemical attached to soil particles. It is noted that they can also trap organic wastes form small feedlots, although the water needs to be diverted to a holding pond or filter strip rather than through a subsurface drain system. WaSCoBs do not provide protection from sheet and rill erosion as terrace systems do. Therefore, they are not recommended where contour farming can employ terraces. They are to be used in combination with additional practices that control sheet and rill erosion. The following design specs were noted: construct to handle the storm intensity noted above; spacing should be 35 to 100 meters, depending on soil slope, cover, and erodibility; maximum basin height should not exceed 4.5m; minimum top width of the embankment needs to vary based on embankment height (example numbers provided in article); basin sideslopes should be no steeper than 2:1 horizontal to vertical; uncontrolled drainage area should not exceed 50 acres; minimum outlet capacity should be 1 acre-inch/acre/day. WaSCoBs may be constructed using a bulldozer and possibly a scraper.

28) Shields, F.D., Smiley, Jr., P.C., and Cooper, C.M. 2002. Design and management of edge-of – field water control structures for ecological benefits. *Journal of Soil and Water Conservation. Vol. 57, No. 3.*

Summary: This study evaluated wildlife habitat use of water and sediment control basins in Mississippi. The study found that basins that were designed to hold a permanent pool of water provided habitat for greater species diversity. This suggests that in some locations, landowners may benefit by constructing sediment control basins that retain a permanent pool of water.

29) Smith, D.R., Francesconi, W., Livingston, S, Huang, C. 2015. Phosphorus losses from monitored fields with conservation practices in the Lake Erie Basin, USA. *AMBIO*, 44(suppl. 2): S319-S331.

Summary: This study evaluated the effect of multiple agricultural conservation practices upon soluble and total P. Practices included residue and tillage mgmt., no-till, conservation crop rotation, grassed waterways, water and sediment control basin, and underground outlets. States that no study has evaluated the effect of grassed waterways on subsurface

phosphorus transport. The estimated average reductions for water/sediment control basins for soluble P and total P in surface runoff were 80 and 79%. The estimated average effect for water/sediment control basins for soluble P and total P in tile drainage runoff were -60% (an increase) and 24%. Soluble P loads in surface runoff were significantly reduced, but note that these loads were much less than total P loads. The main effect of the water and sediment control basins was upon total P loads in surface runoff.

30) Stang, C., Gharabaghi, B., Rudra, R., Golmohammadi, G., Mahboubi, A.A., and Ahmed, S.I. 2016. Conservation management practices: Success story of the Hog Creek and Sturgeon River watersheds, Ontario, Canada. *Journal of Soil and Water Conservation* 71 (3): 237-248.

Summary: The article contains a table summarizing agricultural BMP sediment removal effectiveness based on a literature review. Sediment control basins are listed as having a mean sediment removal efficiency of 76% and a median removal rate of 75%. Modelling and monitoring were used to develop sediment rating curves and evaluate BMP effectiveness for two study watersheds. For both watersheds, stream bank fencing most effectively reduced sediment loading (note that no-till had the highest efficiency, but had not been widely adopted). Vegetative buffer strips resulted in the second highest load removal in one watershed and third in the other. Ditch bank/gully stabilization resulted in third highest removal in one watershed and second highest in the other.

31) Steward, D.G.M, coordinating editor. 2006. Handbook of western reclamation techniques. 2nd Ed. University of Wyoming.

Summary: The section on hydrology provides useful design considerations and techniques for constructing sediment control basins for mine reclamation, which are also applicable to agricultural lands. Hay/straw bales (staked into the ground, along a contour, with double row being more effective) may be used as a temporary check dam (with ends of the dam pointed uphill) in drainages with slopes less than 20%; for example, this technique may be useful during springtime tillage, when there is a temporary period during which exposed soils coincide with precipitation events. Straw bales can be used where runoff is unlikely to overtop the bales such as swales up-gradient of gullies. They are not appropriate for narrow, steep channels and ditches or where flow is highly concentrated. Shallow basins may be created in conjunction with bale placement in order to provide sediment storage. Rock check dams may be used to control runoff velocity and trap some sediment in narrow, steep channels on steep terrain (where hay bales won't work). A geotextile sediment fence may be used in place of a hay bale dam where sediment control is needed for one year or more; they may be placed in series. They must be constructed using high quality fabric that is wired to a sturdy support structure (wooden snow fence wired to braced steel posts is recommended) that will be able to withstand hydrostatic pressure, sediment load pressure, and wind. It is also recommended that vegetative filters be used downgradient of silt fences to capture finer particles by infiltrating shallow overland flow. Rock gabion baskets work better for high velocity, high volume, and/or long duration situations.

32) Tiessen, K.H.D., Elliott, J.A., Stainton, M., Yarotski, J., Flaten, D.N., and Lobb, D.A. 2011. The effectiveness of small-scale headwater storage dams and reservoirs on stream water quality and quantity in the Canadian Prairies. *Journal of Soil and Water Conservation* 66(3): 158-171

Summary: This is a study of sediment and nutrient retention effectiveness for two small dams constructed in agricultural lands in Manitoba, Canada that had contributing areas of approximately 500 acres. One dam (designed to retain 15-20% of volume during summer) had a storage capacity of ~2.6 million gallons (~13 million gallon total capacity) before drainage through an uncontrolled drop outlet occurred; max outflow through the outlet was ~7.4 cfs. The other dam (a dry dam designed for full drainage) also had an uncontrolled drop outlet and storage of 130,000 gallons before outflow began (~12 million gallon total capacity); max outflow through the outlet was ~6.4cfs). Between the two dams, 66 to 77% of sediment loads were retained. Most N and P was in the dissolved form. Total N loads were reduced by 15 to 20%. Total P loads were reduced by 9 to 12%. The dams are not especially comparable to the effectiveness of SCoBs and WaSCoBs described in NRCS practice standards.

33) Tomer, M.D., Van Horn, J.D., Porter, S.A., James, D.E., and Niemi, J. 2020. Comparing agricultural conservation planning framework (ACPF) practice placements for runoff mitigation and controlled drainage among 32 watersheds representing Iowa landscapes. Journal of Soil and Water Conservation 75(4): 460-471.

Summary: This article describes an effort to evaluate how ArcGIS could be used in combination with an Ag BMP planning framework to determine where BMPs could be sited on the landscape. Placement of water and sediment control basins is addressed by the study, but the study does not evaluate the effectiveness of this BMP.

34) Tosakana, N.S.P., Van Tassell, L.W., Wulfhorst, J.D., Boll, J., Mahler, R., Brooks, E.S., and Kane, S. 2010. Determinants of the adoption of conservation practices by farmers in the Northwest Wheat and Range Region. *Journal of Soil and Water Conservation*. 65 (6): 404-412.

Summary: This paper summarizes a study of the adoption of BMPs in northern Idaho and eastern Washington. The BMPs addressed were buffer strips and “gully plugs”- which is a regional term used to represent a water and sediment control basin, sediment basin, or grade stabilization structure. Survey respondents estimated that 28% of their land had slopes 0 to 5%, 49% was estimated as 6 to 15%, and 32% was estimated to have >15% slopes. The majority of farmers did not use gully plugs and viewed them as generally having low effectiveness, but higher effectiveness for steep slopes. This reference is better suited for the implementation evaluation than the effectiveness evaluation.

35) University of California Cooperative Extension and NRCS. Undated. Farm water quality planning management practice. Water and sediment control basin, 638. Oakland, CA.

- From the text:
    - This practice applies to sites where field runoff rates are high and where erosion and control in the fields and ditches is not feasible. Basin size can be reduced when combined with infield erosion prevention practices such as Row Arrangement #557 or Cover Crops #340. Sediment Basins #350 are not designed to detain peak runoff water in addition to sediment.

- Advantages
    - Reduced runoff
    - Slowly meters out peak flows so peak runoff load to nearby waterbodies is reduced
    - Reduced gully erosion downstream
    - Reduces sediment leaving property
    - Retains some fine-grained sediment that may contain adsorbed pesticides and nutrients
- Disadvantages
    - Loss of farmable acreage
    - May cause pollutants to leach into the groundwater

  The reference cites the *Conservation Practice Physical Effects* from USDA Natural Resource Inventory and Analysis Institute as determining that WaSCoBs have the following qualitative practice effectiveness for reducing nonpoint source pollution effects upon water quality:

    - Erosion- sheet & rill: negligible effectiveness
    - Erosion- streambank: slight effectiveness
    - Pesticides-leaching: potential for slight increase in leaching
    - Pesticides- dissolved in runoff: moderate effectiveness
    - Pesticides- adsorbed to sediment: significant effectiveness
    - Nutrients- leaching: potential for slight increase in leaching
    - Nutrients- surface waters: slight to significant

36) USDA, SCS. 1979. Recommended plan of best management practices for reduction of agricultural sediment. 168p.

    Summary: This is a lengthy publication that provides case studies of erosion control in central California. It was estimated that grade stabilization structures (e.g. sediment control basins) would reduce sediment loads from gully erosion by an average of 60% across the multiple study areas. A snapshot of the grade stabilization practice summary is shown below.

- The beneficial economic effects are listed as:
    - Reduces need for channel stabilization
    - Protects productive land from loss by stream and gully erosion
    - May provide water for other uses
    - May trap sediment that would impact other waterworks

  The adverse economic effects are listed as:

    - General requires sizable installation investment

- Annual maintenance costs
- Potential loss of productive land due to inundation

Beneficial environmental effects are listed as:

- Prevention of erosion and sedimentation
- Potential fish and wildlife habitat

The adverse economic effects are listed as:

- May not be aesthetically pleasing
- May serve as reservoir of weed seeds
- May become muddy and/or provide mosquito habitat

Social well-being effects are listed as:

- May provide recreational opportunities

37) Virginia Dept. of Environ. Quality. 2017. Guidance Manual for Total Maximum Daily Load Implementation Plans.

Summary: This is a guidance manual for developing TMDL implementation plans. An appendix contains estimated pollutant removal efficiencies for agricultural BMPs.

38) Ward, A. J., Haan, C. T., and Barfield, B. J. 1977b. Simulation of the Sedimentology of Sediment Detention Basins. *KWRRI Research Reports*. 98.

Summary: This publication discusses the DEPOSITS model for sediment retention basins and compares predicted with observed basin performance.

From pg 12:

> It can be seen that the deposition of sediment in reservoirs will be dependent on the soil characteristics, the detention time in the basin, the depth of fall and the sediment concentration of the flow. The detention time and depth of flow in the basin are dependent on the geometry of the basin, the inflow and outlet design and the inflow hydrograph. The sediment concentration variation with flow is dependent on the intensity of the rainfall, the vegetative cover on the watershed, the permeability and characteristics of the soil, and the slopes and distances of transport on the watershed. Turbulence will tend to keep particles in suspension or will resuspend them by removal from the reservoir bed (Sayre, 1969). Turbulence will occur depending on the inflow geometry and design and the shape of the basin.

The sediment retention basin results presented are all for larger structures (ponds) that may not be accurate for smaller agricultural sediment control basins. Nevertheless, the estimated sediment trapping effectiveness for five basins ranged from 90 to 97%.

It is asserted that particle fraction greater than 20 microns (silt is approx. 2 to 50 micron) has an insignificant effect upon trapping efficiency except where inflow velocity is very high (meaning that the retention amount is largely driven by how much silt and clay is in the runoff vs. how much can be settled out by the basin design).

Figure 5: From the paper – Effect of particle size on trap efficiency

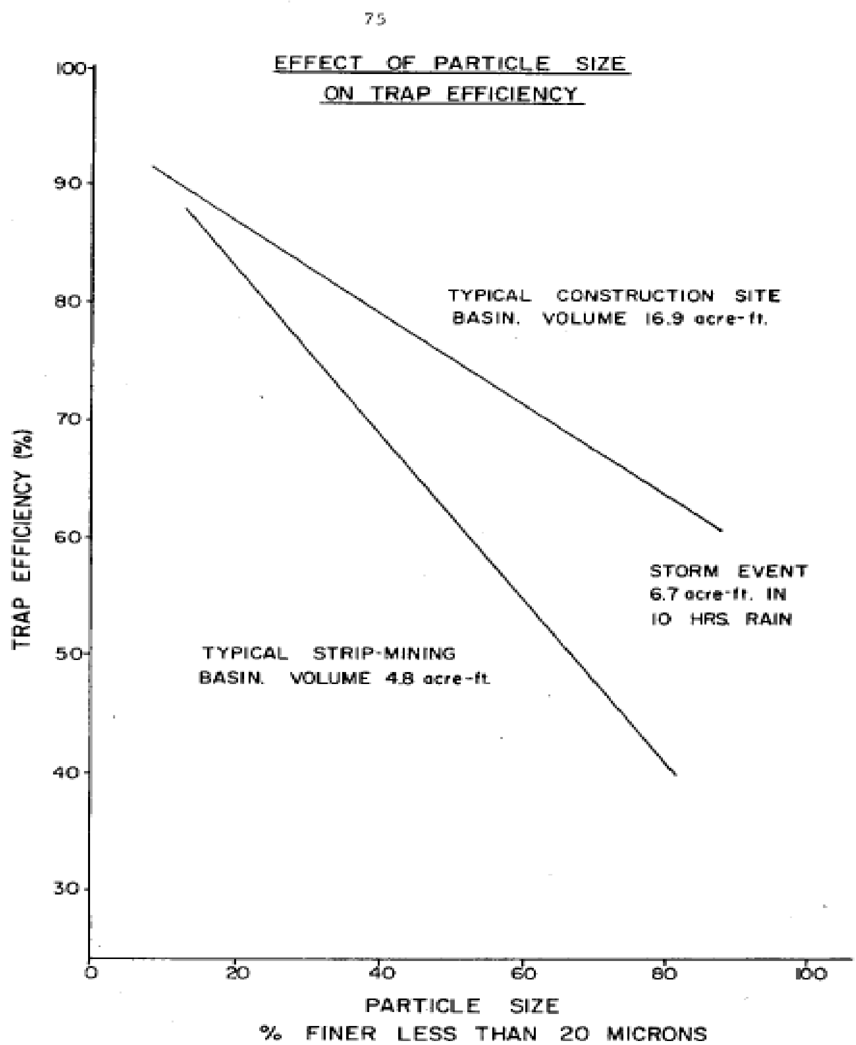


Figure 22: Effect of particle size on trap efficiency

39) Ward, A.D., Haan, C.T., & Barfield, B.J. 1977a. The performance of sediment detention structures. In Proceedings of the International Symposium on Urban Hydrology, Hydraulics and Sediment Control, University of Kentucky, 58–68.

Summary: This paper discusses a model (DEPOSITS) that can be used to design sediment retention basins as an improvement to design based on empirical curves and "rules of thumb". It seems to be a boiled down version of Ward (1977b). It does not contain information that is particularly useful for the structural sediment control effectiveness evaluation.

40) WA State Dept. of Ecology. 2019a. *2019 Stormwater management manual for eastern Washington*. Olympia, WA.

Summary: This document contains design considerations and specifications for stormwater BMPs including detention ponds, infiltration basins, wet ponds, and biofiltration swales- which have more or less applicability to the design of sediment control basin and water and sediment control basins on agricultural lands. The document does not contain pollutant removal effectiveness estimates for the various BMPs.

41) WA State Dept. of Ecology. 2019b. 2019 Stormwater management manual for western *Washington*. Olympia, WA.

Summary: This document contains design considerations and specifications for stormwater BMPs including detention ponds, infiltration ponds, infiltration basins, wet ponds, and biofiltration swales- which have more or less applicability to the design of sediment control basin and water and sediment control basins on agricultural lands. The document does not contain pollutant removal effectiveness estimates for the various BMPs.

42) Washington State Dept. of Transportation, 2015. Hydraulics Manual. M 23-03.04. Environmental and Engineering Programs Hydraulics Office. Olympia, WA.

Reference for runoff coefficients.

43) WA State Dept. of Transportation. 2014. Temporary erosion and sediment control manual. Engineering and Regional Operations. Development Division, Design Office. Olympia, WA

Summary: This document addresses the planning and implementation of temporary erosion control practices, with an emphasis on their application and design considerations.

44) Zech, W.C., Fang, X., and Logan, C. 2012. State of the practice: evaluation of sediment basin design, construction, maintenance, and inspection procedures. Research report No. 1. Project No. 930-791. Highway Research Center. Harbert Engineering Center. Auburn University. Auburn, AL.

Chapter 6 Appendix Part B: Implementation Considerations (Sediment Control: Soil Stabilization & Sediment Capture (Structural))

Introduction

This section describes factors related to the implementation of sediment control basins in Washington State (WA). The section is focused on factors that apply to the design, construction, and maintenance of sediment control basins and is meant to guide producers when deciding if sediment control basins are appropriate for their land. General information is provided below on costs and benefits along with a discussion of the barriers and incentives for practice adoption. The *Implementation Information Synthesis* section (Table 1) provides specific information organized by sediment control basin type. This information is provided to support producers in adopting best management practices to protect water quality. Information was gathered through literature review and interviews with conservation districts (CDs).

Adoption of Sediment Control Basins in Washington State

Water and sediment control basins (WaSCoB) can be earthen embankments, or a combination ridge and channel constructed across the slope of a minor drainageway (i.e., a raised earthen barrier constructed parallel to the topographic contour to impede the flow of downhill runoff) (NRCS, 2018). Sediment control basins (SCoB) are typically created in a drainageway through excavation or by building an embankment (NRCS, 2017). WaSCoBs and SCoBs are often implemented as a final attempt to control sediment. Other practices to promote rainfall infiltration, impede runoff, implement channelization, or manage upstream conditions are often adopted *before* constructing sediment control basins. These basins can provide protection for lower lying areas that are prone to soil saturation and ponding and be a form of secondary support to other erosion control and protection activities. They can also help protect from major snow or rain events. SCoBs and WaSCoBs can remove significant amounts of nitrogen and phosphorus, yet the amount removed will considerably vary and the removal of nitrogen and phosphorus from runoff should be considered as a secondary benefit rather than a primary function or intended use. Overall, sediment control basins alone are insufficient for sediment control and should be paired with other practices. Other practices that may need to be implemented along with sediment control basins to address site-specific concerns include critical area planting, mulching to prevent erosion following construction activities, structures for water control if using a dewatering device, and pond sealing or lining (NRCS, 2021).

No-tillage or low-tillage practices can help reduce runoff and with more landowners implementing these types of practices, the need for sediment control basins has declined over the past decades. Minimal tillage systems help reduce the need for multiple sediment control basins. Whereas more conventional systems can cause sediment to move off the field and increase the need for larger sediment control basins. Pairing sediment control basins with ephemeral gullies can be useful but landowners should initially consider reducing tillage before developing sediment control basins. Additionally, landowners would benefit from evaluating how potential sediment control basins would fit in their suite of practices and management styles when planning.

Benefits and Costs Associated with Switching to Sediment Control Basins

One producer in Spokane, WA near Lake Coeur d'Alene shared insights about sediment control basins on their land that were implemented roughly fifteen years ago. After reaching out to their local CD, Spokane CD supported the costs to develop and implement sediment control basins. After a contractor constructed the basins, the producer found that they were costly to maintain since soil would need to be cleaned out every seven years and redistributed on the land. However, producers saw this as a benefit since the basins saved soil. Even though the basins are fifteen years old now, the producers saw that they fulfilled their purpose in the first five years. This was mainly due to bluegrass that the producers planted around the basins, and they did not constantly plow the land.

Sediment control basins can be beneficial in settings with various conditions including croplands, rangelands, and orchards in western and eastern WA. They may be applicable where runoff can be diverted into an "off-channel" basin and are suitable for croplands in regions of eastern WA where soils have a high potential for erosion by surface runoff or western WA croplands that have soils of a low infiltration capacity. The reason for implementing a sediment control basin along with other practices is not only so that erosion and sediment transport can be appropriately controlled, but also because sediment control basins have a higher cost per unit of pollutant removal relative to other practices such as contouring, strip cropping, terraces with vegetative outlets, and no-till (Czapar et al., 2005; Chen, 1975).

Barriers to Implementation

A major barrier to implementing sediment control basins is capacity. A producer, from the Valley Ford area shared that larger farms may be limited by time constraints, staff, and other resources that are necessary to maintain sediment control basins since they are operating on many more acres. Given land conditions, some limitations exist with implementing either WaSCoBs or SCoBs. WaSCoBs may be placed in-field, edge-of-field, or in a drainageway depending on site-specific conditions. SCoBs are typically located as the terminal practice in a series of best management practices before runoff is discharged into a waterway. Neither WaSCoBs nor ScoBs should be placed within perennial, intermittent, or (lowland) ephemeral stream channels or within the riparian areas of such channels.

Construction and Design

There are various factors to consider when designing and constructing a sediment control basin. Typically, most sediment control basins constructed in WA are likely to have a small basin area and shallow depth. The typical sediment control basin is constructed by excavating 1200 cubic yards and spreading the spoil outside the pool area using a dozer or similar excavation equipment. The sediment storage capacity is about 700 cubic feet per acre of disturbed area and the detention storage is about 3000 cubic feet per acre of drainage area. State dam safety requirements apply to sediment control basins that meet certain storage capacity and/or embankment height criteria. Critical areas of planting are necessary for disturbed soil after implementing a basin.

If landowners lack a suitable location for the basin's outlet and there is a steep slope, then this could lead to erosion occurring down the land's hillside. As a result, terraces should be considered when constructing basins.

To maximize sediment control basin effectiveness, current research indicates that the most effective basin design enhancements are to install a "floating skimmer" or a perforated riser with a gravel jacket, and to provide storage in both low and high stages.

Basins should be constructed to the necessary capacity and landowners should determine if multiple basins or other interventions are needed since these basins could be considered a stopgap.

Case Examples

Case Study: Lake Coeur d'Alene

- **Setting:** One producer described success with sediment control basins in Spokane, WA near Lake Coeur d'Alene. Since the farm was close to Lake Coeur d'Alene, there were concerns about water runoff and the landowners consequently decided to install sediment control basins to mitigate these runoff issues.
- **Construction and Implementation:** Ten sediment control basins were installed in strategic locations with guidance from Spokane CD. A contractor was hired to install a few ponds and dig the basins. The contractor used an excavator to dig a hole on one side, then shaved the berm, and installed a pipe on an uphill side where water would drain down.
- **Challenges:** One challenge was with local elk herd using plastic risers in the basins as scratchers and consequently damaging the risers which hindered the water from properly draining in the basins. With this, steel risers would be more effective for basins depending on surrounding wildlife. Every seven years, the basins are cleaned out and soil is redistributed which was seen as a benefit, but the cost effectiveness of these basins is unclear.
- **Results:** The basins are fifteen years old and have been successful throughout their lifetime. The producers used a fairly no-tillage system and healed many ditches with the sediment control basins. Bluegrass was planted around the basins which significantly contributed to the basins' effectiveness and ability to control soil erosion. These basins fulfilled their purpose in the first five years partly due to the bluegrass and no-tillage system, however severe weather events impacted the basins' success over time.
- **Conclusion:** Based on this experience, the producer advised that other producers will ultimately know if sediment control basins are a suitable option for their land.

Case Study: Valleyford

- **Challenges:** A major barrier to implementing sediment control basins is capacity. A producer from the Valleyford area shared that larger farms may be limited by time constraints, staff, and other resources that are necessary to maintain sediment control basins since they are operating on many more acres. Another challenge was drying out the basins to remove the soil that they caught.
- **Results:** The producer shared that they used sediment control basins on their land for the last fifty years and have seen mixed results. The basins were found to be effective in capturing soil and cleaning them out is more feasible now that equipment is more easily accessible. Basins that were constructed in the field were found to harbor some weeds which should be controlled if they are closer to where crops are raised.

Basins that were in the field were more manageable since they were set upright. A moving scraper was used to redistribute soil in shallower areas.

- **Conclusion:** Overall, the basins fulfilled expectations by improving surrounding areas where the topsoil had been shallow.

Case Study: Palouse

- **Construction and Implementation:** Producers from Palouse, WA shared their experiences with implementing sediment basins roughly ten years ago. They found that estimating how much sediment is coming through the system is necessary when designing the size of the basins and ensuring that the basins met their expected lifespan. The producer contacted their county public works for a grading permit however pre-construction meetings with permitting agencies are now required to ensure that producers understand which permits are needed for installing the basins. Working with NRCS or CD planners were found to beneficial for support with sediment load calculations and basin design. When constructing the basins, ensuring access to the basin was critical for future maintenance activities. The producers learned that there should be an access ramp to the bottom of the basin for cleaning too.
- **Challenges:** If a major runoff event occurred and/or there were poor upland practices from other producers, then the basins collected sediment from these other sources. With this, inserting silt fences inside of the basin to create a wall of curtains was found to be useful with slowing down water and dropping particulates throughout the basins. The producers found that sediment collected by the basins could be reused as soil.
- **Conclusion:** They concluded that basins should not be implemented on their land without grass waterways, since drainage coming into the basin needs to be regraded and seeded to a permanent grass species. The producers also recommended using a complete system of tillage (or conservation/no-tillage), grass waterways, and basins for effective water quality protection.

Implementation Information Synthesis

Table 1 below provides information to support producers in adopting sediment control basin best management practices. Information was gathered through literature review and interviews with CDs and other experts across the state.

Practice: Water and Sediment Control Basins & Sediment Control Basins

Table 1: Implementation Considerations for Water and Sediment Control Basins and Sediment Control Basins

Considerations	Details

Capital Cost	• Sediment control basins have a higher cost per unit of pollutant removal relative to other practices such as contouring, strip cropping, terraces with vegetative outlets, and no-till.
	• Cost rates for sediment control basins were developed by NRCS and other CDs. These estimates are approximately $3.50/cubic yard of movement (NRCS estimate was $3.55/cubic yard of movement in 2019). Cost rates are re-evaluated on a frequent basis for local and regional levels.
	• In 2021, NRCS developed the following cost estimates for sediment control basins. The scenario descriptions vary due to factors including state laws and local ordinances.
	  ○ **Scenario: The estimated cost of a 1,500 cubic yard embankment earthen basin *with* pipe(s) is $11,779.69.** For sediment control basins with pipe(s), additional materials are needed, including steel reinforced concrete, skilled laborers, sand, gravel, galvanized helical corrugated metal piping, and trash guards. This estimate includes equipment installation, labor, materials, and mobilization:
	    ▪ Steel reinforced concrete and cast-in-placed in formed structures such as walls or suspended slabs by chute placement (typical strength is 3000 to 4000 psi), including materials, labor and equipment to transport, place and finish - $1,643.37
	    ▪ Track mounted Dozer with horsepower range of 125 to 160 - $4,055.20
	    ▪ Labor requiring a high-level skill set including carpenters, welders, electricians, conservation professionals involved with data collection,
	monitoring, and record keeping, etc. - $485.50
	    ▪ Heavy equipment operators - $1,951.32
	    ▪ Sand, typical ASTM C33 gradation including materials, equipment, and labor to transport and place - $674.04
	    ▪ Gravel including materials, equipment, and labor to transport and place, includes washed and unwashed gravel - $55.78
	    ▪ 18 and 16 gauge galvanized helical corrugated metal pipe priced by the weight of the pipe materials - $2,027.64
	    ▪ Conical shaped trash guard (fabricated-steel, including materials, equipment, and labor to transport and place) for drop inlet spillway - $361.08

Considerations	Details
	▪ Cost of mobilization equipment with 70-150 HP or typical weights between 14,000 and 30,000 pounds is $525.76 ○ Scenario: The estimated cost of 1,500 cubic yard embankment earthen basin *without* pipe(s) is $6,532.28. This includes equipment installation, labor, materials, and mobilization: ▪ Track mounted Dozer with horsepower range of 125 to 160 - $4,055.20 ▪ Heavy equipment operators - $1,951.32 ▪ Mobilization equipment with 70-150 HP or typical weights between 14,000 and 30,000 pounds - $525.76 ○ Scenario: The estimated cost of a 1,200 cubic yard excavated sediment control basin is $5,053.88. This includes equipment installation, labor, materials, and mobilization: ▪ Track mounted Dozer with horsepower range of 125 to 160 - $3,041.40 ▪ Heavy equipment operators - $1,486.72 ▪ Mobilization equipment with 70-150 HP or typical weights between 14,000 and 30,000 pounds - $525.76 • NRCS cost estimates for labor, equipment, and materials were normalized nationally. There are some adjustments to the costs at the regional level. The specific components are not definitive on how the scenario is applied in WA. They are definitive on how the cost for the scenario was developed.
Operational and maintenance requirements and costs	• Operation considerations ○ SCoBs are typically not designed to detain peak runoff flows. Neither WaSCoBs nor SCoBs are specifically intended to infiltrate runoff (i.e., they are not specifically intended promote water seepage into the soil), although a minor amount of runoff infiltration does occur (Fiener et al, 2005). ○ Sediment control basins should only be installed where appropriate upslope erosion and runoff control best management practices (e.g., reduced/no-till, cover crops, field borders, etc.) are implemented and maintained, but have not already achieved runoff and sediment management objectives.

Considerations	Details
	• Maintenance considerations ○ Maintain the basin by regularly cleaning out sediment to maintain capacity and prevent issues with the basin's outlets. The basin could fill up more frequently if there are major runoff events or other sources that are generating runoff. Some landowners try to pull sediment uphill to gain soil that can be redistributed. ○ Inspection is recommended after significant runoff events. ○ Periodic vegetation maintenance and removal of accumulated sediment is needed. ○ Maintenance schedules should be tailored to site specific conditions and basin design, following NRCS guidance, Ecology stormwater manual guidance, and/or recommendations from a farm planner and/or engineer. • Related operation and maintenance costs ○ Maintenance and operation costs depend on whether the landowner already owns equipment for these types of activities. ○ The most significant cost for basins is related to cleaning the basin. ▪ Cleaning frequency depends on the basin's size, location, land type, and other factors. ▪ The frequency can range from annually to every four to five years, however there is not a recommended cleaning frequency for all basins. ▪ Regularly cleaning the basin will promote the basin's life expectancy.
Technical requirements	• Permitting agencies typically have preconditions that need to be met for implementing a sediment control basin. • According to the NRCS, SCoBs are applicable where: ○ Physical conditions or parcel ownership boundaries prevent installation of erosion-control practices to treat a sediment source. In other words, they are used to capture large quantities of sediment over time when upgradient erosion control BMPs are either impractical to implement or are not fully effective at controlling erosion. ○ Failure of the basin will not result in loss of life, damage to homes, commercial or industrial buildings, highways or railroads, or public utilities.

Considerations	Details

	• Ecology recommends consulting farm planners and licensed engineers when designing the sediment control basin to determine the appropriate location and size specifications.
	• The design of sediment control basins should be consistent with Ecology's stormwater BMP manual specifications and comply with NRCS FOTGs.
	  ○ Dimensions of embankments, basins, inlets, and outlets are highly site specific and may require engineering services to determine.
	  ○ Ensure that the basin's grade is accurate, and compaction is complete. If possible, recruit engineering support with designing and constructing the basin. Common errors in basin design and construction include incorrect overflow height and not correctly releasing water out.
	• Placement and design of basins should accommodate access by equipment to periodically remove accumulated sediment.
	• Sediment load, hydrology, and depth of soil are all essential calculations and factors to consider when designing and constructing the basin.
	  ○ When designing the basin, first estimate the sediment load quantity or how much sediment is traveling through the system. These calculations can be done using erosion modelling tools. This will inform the size and lifespan of the basin and help reduce maintenance and operation practices for the basin.
	  ○ Consider basin size, basin shape, water detention time, the permanence of water pooled in the basin, the type of drainage outlet, the degree to which the design reduces flow turbulence, sediment particle distribution in runoff.
	  ○ Use runoff calculations to assess how runoff events will affect the basin. Designing the basin around these circumstances could then inform maintenance activities.

Lifespan	• The hydraulic design for WaSCoBs is usually a 10-year frequency, 24-hour duration storm. • The lifespan of SCoBs is determined by maintenance activities. • Ensuring that the basin is cleaned when full of sediment and/or water and preventing the spillway from deteriorating will contribute to a longer lifespan.
Land area requirements	• Generally, basins are constructed along an existing flow path that already exists as a low spot in the field. • Basins should not be implemented within any waters of the state, which includes perennial, intermittent, and "lowland" ephemeral channels; they should also not be placed within the riparian areas of state waters.

<table>
<tr><th>Considerations</th><th>Details</th></tr>
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Basins may be applicable in some settings where runoff can be diverted into an “off-channel” basin.
An enhanced basin design can be implemented when the combined silt and clay fractions are expected to exceed 20 percent of the sediment load (Ward et al. 1977b).
Low spots in the field or an area with an ephemeral gully is typically ideal for basin implementation.

Consider the extent of ponding that will occur from the basin when choosing the WaSCoB or SCoB’s location.
Areas with snow drifting that eventually melts is also ideal since the basin can support sediment capture to prevent erosion.

Constructing a basin is challenging if the land contains rock. Basins should not be implemented in steep areas since the flow could then damage the basin.
Larger particles in runoff settle out more readily while clay particles do not
NRCS (2017a) recommends selecting a location for SCoBs that will maximize the interception of runoff from the eroding lands and will minimize the number of runoff inflows into the basin.

Consider weather events that could potentially overflow the basin (e.g., local thunderstorms).
Suitable land types for sediment control basins include cropland, orchards, pastures, and rangelands

Locate WaSCoBs where it will fit the topography, maximize storage, and will not encroach on property boundaries.

WaSCoBs may be used where:

topography is irregular
gully erosion is a problem
practices to control sheet and rill erosion are in place
a stable outlet can be provided

WaSCoBs are not recommended for areas in which a terrace system can be implemented.
WaSCoBs could be used instead of grassed waterways on lands with steeper slopes that deter the use of terrace systems.

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<tr><td>Other implementation factors</td><td>

Sediment control basin construction considerations

The basin’s outlet should be placed on the lower level of the lower elevation side.

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Considerations	Details
	◦ An access ramp for the bottom of the basin is necessary to clean the sediment out of the basin. • Sediment control basins can help capture runoff although fractions of sediment and/or water will be carried through regardless of the basin's size. ◦ Consider inserting silt fences inside the basin to build a wall of curtains that can help slow down water and drop particulates throughout the basin. This could improve the basin's functionality. ◦ As basin volume increases and outflow rates decrease, the retention of finer sediment particles increases. ◦ Sediment control basins on agricultural lands are not likely to be large enough to prevent a significant amount of clay and fine silt particles from being discharged in the outflow. • Typically, a Washington CD or NRCS planning staff will develop a plan for the landowner with alternatives to implementing a sediment control basin. ◦ Other options include using both a grass waterway with a sediment control basin or adopting a no-tillage system. ◦ Options will be provided based on the types of equipment landowners already own and other land conditions. • Sediment control basins should be implemented as part of a series of in-field, edge-of-field, and edge of waterway best management practices that are intended to control erosion and sedimentation. ◦ In some cases, a sediment control basin should be paired with a grass waterway since the drainage coming down into the basin has to be regraded and seeded to a permanent grass species to slow the input of the sediment coming into the basin. ◦ Filter strips should be paired with sediment control basins if there isn't a grass waterway to help slow down nutrients in the water and runoff. • WaSCoBs should be coupled with down-gradient practices that infiltrate runoff (e.g., grassed waterways, riparian buffers, and critical area plantings). ◦ At the watershed scale, modelled sediment load reductions for WaSCoBs have been estimated to potentially comprise only a fraction of the load reductions achieved from other BMPs.
Resources	• Refer to the NRCS Conservation Practice Standard for Practice Codes 350 and 638 (NRCS, 2018, 2017a), WA State Dept. of Ecology (2019a, 2019b), and Steward (2006) for further information on design, construction, and maintenance considerations. • See the NRCS Practice Scenarios for details on cost estimates of different sediment control basin scenarios.

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