INSTREAM SEDIMENT DETENTION BASINS

1 DESCRIPTION OF TECHNIQUE

This technique describes the design and construction of instream sediment detention basins, or gravel traps, to capture excess sediment within the stream and store it for later removal. The user of this manual should have arrived at this technique only after developing a thorough understanding of sediment sources and depositional patterns, and only after exhausting all other alternatives to deal with an undesirable abundance of sediment in a particular reach. This technique addresses only the symptom of excessive sediment accumulation, not the root cause, and should be used only as a last resort to provide a short-term solution while a long-term solution is being implemented. Sediment detention basins can provide an alternative to chronic widespread dredging. This discussion of in-channel sediment detention is intended to supplement the Aquatic Habitat Guidelines' Freshwater Gravel Mining and Dredging Issues white paper[1].

Stream sediments range from very fine-grained materials carried in suspension as turbidity, to large boulders. In-channel sediments may come from mass wasting directly into the stream (colluvial sources), they may mobilize from the bed and banks of the stream as the channel migrates in response to high flows (alluvial sources), or they may wash into the stream from the uplands and tributary streams.

A river in equilibrium can be viewed conceptually as a conveyor belt moving sediment downstream. All stream systems transport a characteristic range of sediment sizes as a natural geomorphic function. These sediments make up the streambed and bar forms, define much of the channel morphology, and provide many aquatic habitat elements[2,3]. Sediment transport in streams occurs within a dynamic range, from low flows to seasonal high flows and episodic floods. When viewed in a watershed context at a particular point in history, a given stream reach is either in equilibrium, sediment limited, or transport limited[4]. Equilibrium reaches transport the majority of their bedload over the course of time, but transport-limited segments aggrade. It is in these aggrading reaches that sediment traps are considered when channel processes interfere with land use. Note that channel aggradation may result from natural or anthropogenic disturbance to the dynamic balance between sediment input volumes and the stream's capacity to transport sediments. These causes are described in the Application section below. Refer to the *Sediment Transport* appendix for further discussion of sediment transport dynamics.

Other complementary or alternative techniques described in this manual that can address the root cause of channel aggradation include *Bank Protection Construction, Modification, and Removal* (to stabilize banks undergoing excessive levels of erosion; this technique has limited application for the purpose of stream habitat restoration), *Riparian Restoration and Management* (to stabilize banks and intercept the transport of sediment to the stream), *Channel Modification* (where sedimentation and aggradation occurs due to historic local or reach-length channelization practices), and *Large Wood and Log Jams* (where sedimentation and aggradation occurs as a result of decreased upstream sediment detention or channel stability due to historic channel cleaning and timber harvest activities). Other methods to consider, including upland sediment and erosion control and flow regime restoration are discussed in Chapter 4.5.6, *Restoring Aggrading Channels*, of the Stream Habitat Restoration Guidelines.

2 PHYSICAL AND BIOLOGICAL EFFECTS

Instream sediment detention results in a significant disruption of existing channel dynamics and related natural functions, habitat, and passage. While the intent of detention is to address problems associated with excess sediment (such as bank erosion and flooding in the vicinity of infrastructure), allowing an “appropriate” amount and type of sediment to continue downstream should be a key consideration. This technique can have far-reaching effects - sediment detention may result in benefits or impacts to all downstream resources. The effects, whether positive or negative, will last as long as the structure remains in place and is maintained (regularly dredged). The amount of time before effects are realized is dependent upon site-specific conditions, design of the structure, and the essentially random nature of timing and volume of sediment transport. Sedimentation basin projects will impact a number of stream processes including:

- Impacts to stream hydrology and hydraulics including flooding.
- Impacts to sediment continuity and budget at the project and along downstream reaches.
- Impacts to stream geomorphology, which might include downstream incision.
- Impacts to streambed and streambank stability.

Sediment detention requires the installation of structures in a channel. Any in-channel construction will necessarily result in temporary turbidity impacts and disruption of habitat on a local scale. The *Construction Considerations* appendix provides further discussion of construction impacts and practices to reduce impacts. Routine maintenance is required as the trap fills so that it continues to function as designed. Cleanout activities require the use of heavy equipment and have a host of effects including; increased turbidity, the potential for fuel or hydraulic oil leaks or spills, stranding fish in the trap and dewatered sections downstream, physical injury to fish in the trap and other disturbances.

Sediment detention basins are intended to trap excess sediment that exists within the stream system. As such, they can be useful short-term tools employed in the recovery of sediment-laden systems. However, even properly designed detention basins must be used with care, for their potential negative effects. Large traps act as dams and create a discontinuity in sediment and debris flow. Interruption of this flow may affect downstream habitat value, particularly for spawning. Segregation of bedload into a coarse fraction (which is trapped) and a fine fraction (which may pass through the trap) may cause downstream scour and incision, potentially leading to alteration in stream-floodplain interaction downstream[5]. There is considerable discussion of the downstream effects of dams in the literature. The following references are from a survey of the current literature and are recommended reading[6] [7] [8]. Outlet structures and grade control may act as barriers to upstream and downstream passage of aquatic organisms.

A significant effect in some sediment traps is described as follows. Fine-grained sediment is deposited in the sediment trap during a storm event. As flow recedes, the water cuts down into the fine sediment, transporting it through the trap and depositing it in the downstream channel in areas where flows are insufficient to keep it moving. (This phenomenon is similar to heavy sediment runoff from a construction site, where runoff cuts down into disturbed soil, transporting it offsite and depositing it in lower gradient sections.) This fine sediment can foul spawning gravel, endangering incubating eggs (a significant concern for ESA species) and eliminating productive habitat.

Naturally aggrading reaches are part of normal valley building and the construction of a sediment trap precludes these processes. In the sense that many organisms are dependent upon ecologies supported by normal geomorphic systems, sediment traps interfere with their survival requirements for a variety of life-history stages.

3 APPLICATION

The movement of sediment to and within the stream channel is a natural and necessary process in order to maintain stream stability and habitat (see Chapter 4.5.1, *Restoring Sediment Supply*, of the Stream Habitat Restoration Guidelines for further discussion). It's only when the supply of sediment exceeds the ability of the stream to transport it that it may be considered a problem. Both supply and sediment transport capacity may be altered by humans as a result of land use activities and associated channel or flow regime modifications. The general causes of excessive sediment supply to a reach include: excessive supply from upstream or upland sources, accelerated stream bank and bed erosion and mass wasting events, channelization, loss of vegetated riparian zone capable of retaining sediment, loss of upstream sediment detention, upstream channel incision or other factors. Excessive localized sediment deposition may be caused by a channel constriction (such as an undersized bridge or culvert), general channel bed aggradation and many other factors. Upstream channel incision is a significant source of high sediment volumes to downstream reaches[9] and is discussed in detail in Chapter 4.5.5, *Restoring Incised Channels,* of the Stream Habitat Restoration Guidelines. Additional discussions on the causes of excessive sediment supply and on the causes of channel aggradation are provided in Chapter 4.5.6, *Restoring Aggrading Channels,* of the Stream Habitat Restoration Guidelines.

Excess sediment within a stream system often leads to deposition within the channel and resultant aggradation. Aggrading reaches, or reaches with excessive in-channel deposition, tend to widen as sediment accumulates, leading to high bank erosion rates. Reduction of sediment supply or trapping and removal of sediment in these reaches can slow or arrest the rate of lateral expansion and erosion in these reaches. Many stream reaches in Washington are naturally depositional and form braided channels or deltas at confluences or grade breaks. While these features are unpredictable and may interfere with land use, they provide important ecological functions[10] and play a role in disturbance that has been found to contribute to salmonid restoration[11]. Reach or watershed assessment should be used to determine whether a channel is naturally braided, or whether it is aggrading due to anthropogenic disturbances before initiating sediment control treatments.

Channel aggradation problems are best addressed by treating the source of the problem, whether it be supply or sediment transport-related, to provide the best long-term sustainable solution. Sediment traps merely address the symptoms of excessive aggradation and do not treat the cause of the problem. The goal of instream sediment detention is to remove excess sediment from the stream system before long-term measures can be implemented or before they become effective.

Sediment traps are a temporary technique or a technique of last resort when source control is not possible or must be deferred and can limit the length of reach affected by sedimentation. Traps can limit the reach of stream affected by excessive sedimentation and provide an alternative to widespread and chronic dredging. Sediment traps do not constitute natural channel restoration or rehabilitation, nor do they constitute creation of habitat. As a temporary feature, it can be used to address a single catastrophic or major input of sediment supply (e.g., a landslide triggered by human causes occurred upstream and a sediment slug is working its way through the system with undesirable side effects). Instream sediment detention basins can be applied in transport or depositional reaches along alluvial or non-alluvial reaches.

Sediment detention is most effective for sediment that is categorized as gravels, cobbles and boulders, and less effective for finer grained material, including sand. In-channel sediment detention is rarely appropriate for detaining materials finer grained than sand.

Instream sediment detention basins have typically been applied on small to medium size streams. On larger streams, sediment is often removed from the channel without employing sediment detention basins (i.e., from gravel bars). The size of the detention basin and its efficiency in trapping stream sediments may be limited by available land on which to access, construct and maintain the trap.

In some cases, particularly in smaller streams, wood can be used to retain sediment (creating step pools along steeper gradient reaches), promote bed and bank stability, and thereby reduce the volume of sediment delivered to downstream reaches. Various studies have researched the role of wood in storing sediment in source and transport reaches[12] [13] [14] [15] [16] [17] [18] [19]. Although not used as a technique to control sediment routing, it may be applicable in some cases. Refer to the *Large Wood and Log Jams* technique and the referenced citations for additional information.

Channel incision or chronically unstable hill slopes can supply an endless stream of bedload that may deposit in ways that interfere with developed lands and must lead to long term solutions. Schumm[20] describes the formation of natural alluvial fans, a study that can aid planners in developing patterns found in nature into engineering solutions. In two papers, Parker *et al.*[21] [22] develops the theory and application of alluvial fan formation for optimizing a tailings basin. This model could help designers engineer alluvial fans as solutions to aggradation at grade breaks (high to low stream slope transitions at valley floors and elsewhere) or channel expansions (confined to unconfined valleys) for a long term, environmentally responsible alternative to dredging or sediment basins. An area is set aside with the proper slope and dimensions and is left to aggrade naturally. As sediment deposits in one area, the main flow channel moves to another location that is lower in elevation. This pattern continues, forming a complex network of abandoned and new channels and layers of deposited materials[23]. Maintenance of the delta trap is accomplished by excavating a shallow area on one side of the delta and allowing flow to reclaim the lowered area. It is likely that a project like this would take up more area than a conventional sediment trap, but retain some of the ecological benefits of a natural alluvial fan.

4 RISK AND UNCERTAINTY

4.1.1 Risk to Habitat

Sediment detention traps interrupt the transport of sediment and therefore affect sediment sizes and quantities delivered to downstream reaches. The ability of the sediment basins to trap bedload material is more efficient for coarse sediments than for smaller sized sediments.

The sedimentation basin structure will alter stream flow and hydraulic conditions. Traps can impede both upstream and downstream passage of fishes and other aquatic organisms. The traps will detain debris. The pools may act as an attractive nuisance, associating rearing fish with a maintenance structure and possibly stranding them during low flow or no flow periods. Cleanout operations require fish relocation, resulting in stress, injury or death to fish and other aquatic organisms within the trap.

Trapped sediment is susceptible to re-mobilization in the event of structural failure or, in some cases, simply due to the occurrence of a large runoff event. Failure to monitor and maintain sediment traps may also lead to unanticipated lateral channel migration subsequent to aggradation resulting from filled sediment traps.

Bank failure and water quality impacts may also result from use of heavy equipment for periodic maintenance of sediment traps. Grade controls installed as part of a sediment trap may also fail or create aggradation and associated lateral channel movement, if improperly designed and constructed.

4.1.2 Risk to Infrastructure and Property

Most sediment traps incorporate flow control devices that alter stream flows. Infrastructure and property adjacent and upstream of the project may be subject to increased flood levels caused by normal trap operations or debris accumulations on the trap. Failure of the trap may cause a dam-break flood and sudden release of water and sediments, impacting downstream properties. As mentioned above, failure to monitor and maintain sediment traps may also lead to unanticipated lateral channel migration subsequent to aggradation, possibly threatening nearby property and infrastructure. Risk to property and infrastructure can be minimized by accounting for it during the design process.

4.1.3 Risk to Public Safety

The consequences of a trap failure pose higher risks to public safety and infrastructure in urban areas than in non-urban areas. Sediment basins are deep pools when cleaned out and pose a risk of drowning. Restricting access may be necessary in urban or other areas where children are present. In the past, sediment basins have been built on smaller streams. If the technique is applied to a larger stream it may pose a risk to recreational river users, since many designs require diversions or channel-wide structures that could block or hang up watercrafts.

4.1.4 Uncertainty of Technique

Due to high natural variability in sediment transport conditions and individual stream conditions, there is inherent uncertainty in predictions of trapping efficiency and the size of particle trapped by detention structures. This is particularly true with small traps where it is likely that smaller sediment sizes will pass through the trap.

Sediment transport analysis provides an estimate of sediment transport potential, but does not provide accurate predictive results, particularly where the sediment supply is constrained by bed or bank armoring or for other reasons (refer to the *Sediment Transport* appendix for a discussion of sediment transport analyses and their limitations). Predictions of the size and volume of sediment transported using various transport equations can differ by orders of magnitude. And these predicted rates of transport could vary from actual conditions by orders of magnitude, especially in the absence of comprehensive bedload measurements over the range of design flows. . Due to the inaccuracies of theoretical predictions, the estimated minimum size for a sediment detention basin may be larger or smaller than what is necessary to accommodate actual transport conditions. Even when adequately sized, a single flood event in excess of design flows can prematurely fill a trap that was expected to function for several years before cleanout operations became necessary. .

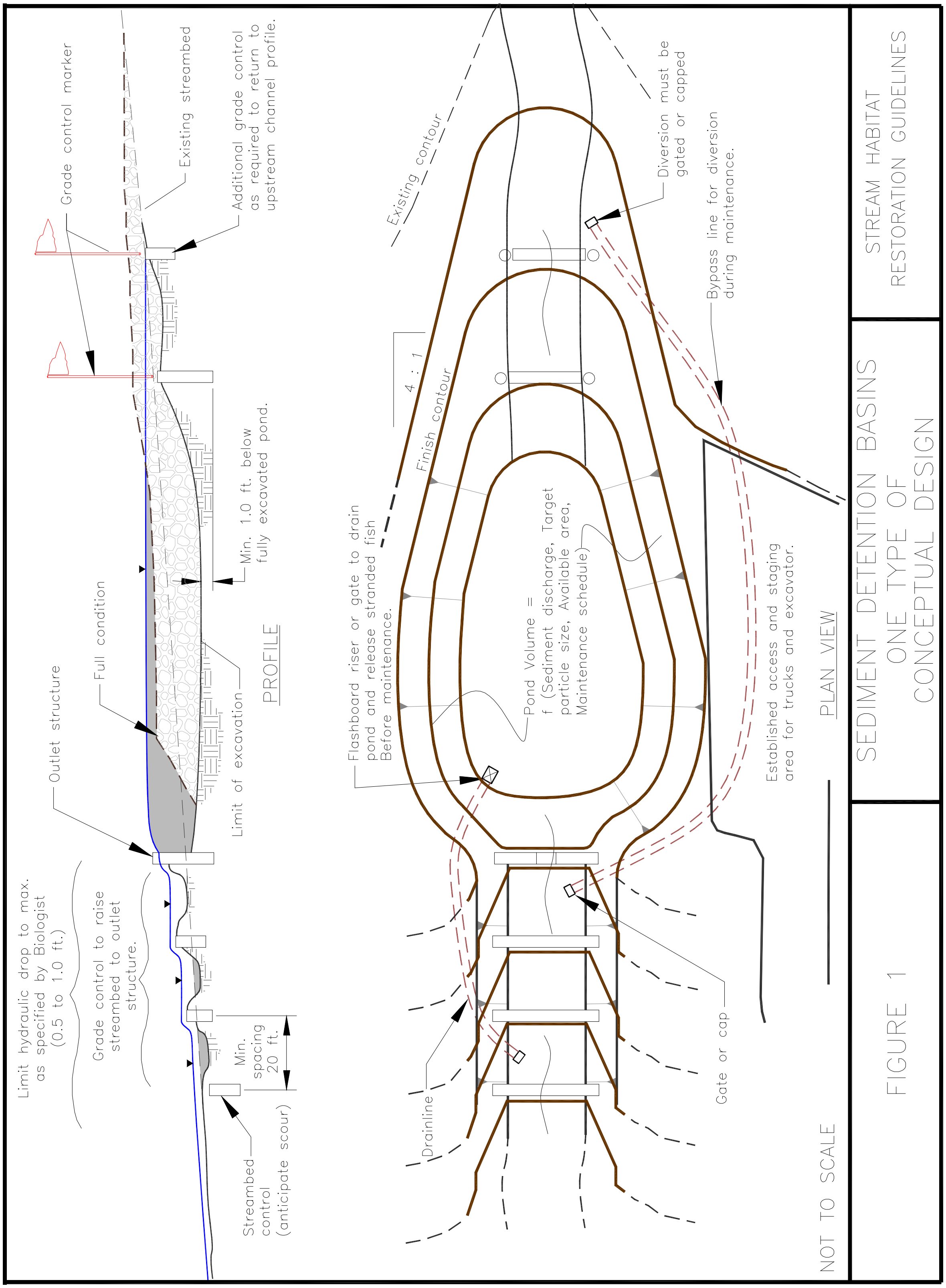
5 METHODS AND DESIGN

The basic concept involved in sediment detention is to create an area of relatively low velocity in order to induce sediments to settle out of the flow. Sediment basins are typically designed with a downstream flow control in the channel that creates an upstream pool, and may include an excavated basin to enlarge the cross sectional area (see **Instream Sediment Detention Basin Example Figures 1 through 6** for examples). Long term, instream storage of sediment is less desirable than regularly scheduled removal. Sediment traps function only while they fill. Depending on sediment source conditions, site conditions and trap design, once the basin is full, sediment may pass downstream as before.

Effective design of sediment detention systems is dependent upon prediction of the volume and size gradation of sediment moving through the system. Methods to estimate sediment transport are provided in the *Sediment Transport* appendix. Dredge records are the first source for volume estimates. Sediment size can be determined by sieve analysis of dredge spoils.

Prior to undertaking a sediment detention method, a feasibility assessment is advised to justify that a sediment detention basin is the best solution. Early discussions with regulatory and resource agencies and other stakeholders are encouraged to determine if implementing a sediment detention basin is an acceptable option. Sediment traps should not be employed without first asking the following questions during data collection, assessment and design:

1. Could the sediment deposition problems experienced at the site be solved in a different way than a sediment basin? Make sure there is no alternative before designing the basin.
2. What sort of mitigation will be required for the installation of the sediment basin? Might mitigation obligations offset the benefits of the sediment basin?
3. Would a sediment trap starve downstream spawning habitat of gravel? It has been suggested that loss of spawning habitat cannot be mitigated. If good spawning habitat is limiting in the stream system, then loss of spawning habitat may be a very important consideration.


Grade control marker
Existing streambed
Additional grade control as required to return to upstream channel profile.
Min. 1.0 ft. below fully excavated pond.
Full condition
Outlet structure
Limit of excavation
PROFILE
Limit hydraulic drop to max. as specified by Biologist (0.5 to 1.0 ft.)
Grade control to raise streambed to outlet structure.
Min. spacing 20 ft.
Streambed control (anticipate scour)
Existing contour
4 : 1
Finish contour
Diversion must be gated or capped
Bypass line for diversion during maintenance.
Flashboard riser or gate to drain pond and release stranded fish Before maintenance.
Pond Volume = f (Sediment discharge, Target particle size, Available area, Maintenance schedule)
Established access and staging area for trucks and excavator.
PLAN VIEW
Drainline
Gate or cap
NOT TO SCALE
STREAM HABITAT RESTORATION GUIDELINES
SEDIMENT DETENTION BASINS ONE TYPE OF CONCEPTUAL DESIGN
FIGURE 1

4. Would a sediment trap in a given location cause downstream incision or scour? In a metastable stream small changes in external conditions can result in a major change in channel evolution.
5. How often would the sediment trap require inspection, maintenance and cleanout? Identify the individual or organization responsible for maintenance and make sure that funds are budgeted for this purpose for the life of the project.
6. Where will removed sediments be dumped? Will the spoils site be available for the duration of the basin's predicted life? Is the spoils site large enough for the anticipated volume over the life of the project? Could the spoils be used in restoration projects requiring gravel?
7. How and when will the trap be decommissioned and natural stream function restored? A set date for decommissioning is recommended, with clear conditions and consequences for failure to decommission on time. A funding source or responsible party should be identified that will pay for the decommissioning.

5.1 Data Collection and Assessment

Planning and designing instream sediment detention basins should be preceded by careful assessment of sediment conditions within the stream, including evaluation of the natural forces at work and the biological impacts of the sediment.

- *Watershed assessment* Since sediment detention basins exert significant impacts on stream systems they should be considered a "last resort" technique to be used only when other options are not feasible. Prior to implementing instream sediment detention, sediment sources should be identified and alternatives to control these sources should be evaluated.
- *Fluvial Geomorphic Assessment.* A geomorphic analysis of the natural stream processes, human influences affecting the reach, and historic conditions, should be conducted in order to assess the appropriateness of a detention basin in the geomorphic and historic context. Refer to the *Fluvial Geomorphology* appendix for details on geomorphic principles. The effects of channelization are often what drive landowners to feel they need sediment traps. One half of the sediment basins in Western Washington are there because of channelization. Channels that have been straightened and cut off from their floodplains lack the sediment storage and transport characteristics of natural channels that have configured themselves to efficiently handle their sediment discharge. Other naturally depositional stream reaches often have adjacent infrastructure that need sediment traps for protection until a long-term solution can be implemented.
- *Biological habitat Impacts.* Planning for instream sediment detention should include a biological assessment of the impacts of the project. Particularly important in this regard are impacts to downstream spawning and macroinvertebrate habitats and other discontinuity effects associated with dams[8 10]. Operations and maintenance represent continuing impacts to habitat.
- *Sediment Transport Analysis.* Planning for instream sediment detention will require estimation of sediment volume being transported through the stream. This will typically require hydrologic, hydraulic, and sediment transport assessment and/or analyses that are

detailed in the *Hydrology, Hydraulics*, and *Sediment Transport* Appendices respectively.

- *Hydrology.* In order to estimate sediment volumes using some methods, detailed hydrologic statistics, including a flow duration curve derived from mean daily flows over the period of record, will be needed.
- *Hydraulics.* Additionally, a hydraulic model will have to be developed to determine flow velocity, energy slope, depth, effective width and shear within the channel at varying flows. This typically requires detailed surveying of cross-sections throughout the channel.
- *Sediment supply and volume* The simplest method to estimate the average annual sediment yield is to integrate the stream flow duration curve with the sediment discharge rating curve at the inlet to the trap[24 25 26 27]. The U. S. Army Corps of Engineer's SAM[26] at-a-section sediment transport model can be used for these calculations. Often, this method gives an overestimate of sediment volumes when the bed substrate is armored, as transport does not occur to predicted levels until a flow threshold is reached that breaks the armor layer. The average annual sediment yield can be used for an initial planning level estimate of frequency of maintenance.

  More complex analyses may include the use of the U.S. Army Corps of Engineer's HEC-6[28] one-dimensional sediment transport model. HEC-6 is capable of modeling armoring effects in sediment transport processes. Estimates of sediment volumes transported by a specific event can be estimated with a known flood hydrograph, enabling estimates of event-based deposition.

  Estimates of sediment yield are difficult to make and may have little to do with actual yield in any given year. Sediment flux is episodic due to failure of channel bank and bed features as well as variable colluvial process. Sediment volumes are also highly dependent upon the magnitude and duration of flow; a single low frequency flood may fill the trap. Monitoring and maintenance should include documentation of prior stream flow conditions, sediment yield (volume collected), and size distribution of bedload material collected in the trap. Records of dredge volumes may give an indication of sediment discharge.

5.2 Site Selection for Sediment Basins

If possible, basins should be located where the channel has a natural grade break or constriction that increases the natural tendency for sediment to accumulate. The site should be readily accessible to equipment such as front-end loaders, excavators, and dump trucks. Areas immediately upstream from road culverts may make good sediment basin locations, provided the basin and associated sediment deposits will not impair the function or structural stability of the culvert. If such a culvert is not large enough to pass floodwater, sediment and debris, or is a barrier to fish passage, then it should be replaced before the sediment pond is installed. Don't let an existing culvert determine pond characteristics - design the outlet to accomplish the goals of the project. It is possible that increasing culvert capacity may change the deposition pattern in such a way that a sediment trap is not necessary.

The profile of the entire reach should be considered when designing a sediment basin. Fish passage must be maintained up to the ten percent exceedance flow for periods when fish migrate through the reach, according to the Revised Code of Washington (RCW) 75.20.060. Many organisms move up and down the channel using means that are not often identified. Designing sediment traps to resemble natural channels is the best insurance for maintaining this movement. Transitions between the various elements should be smooth, both horizontally and vertically. No abrupt water surface changes greater than one foot at all flows and pond conditions. Grade control should be established downstream for a smooth transition as well as scour protection at the outlet of the flow control device. At least one grade control should be installed 25 to 50 feet downstream of the basin outlet to maintain the bed elevation. Grade control upstream will be necessary to prevent headcut when the pool is excavated. The first grade control immediately upstream of the pond must extend down to at least 1 foot below the maximum depth of excavation to prevent failure from undermining or sloughing. When the pond is empty, this control acts as a dam supporting the upstream channel.

5.3 Flow Control Structures

Flow control devices are required to create and operate the sedimentation basin. These controls include outlet controls to create a damming effect, inlet controls to divert low or high flows from the stream to the basin and gates to isolate the trap and create a bypass during maintenance operations. Flow control devices include weirs, slots, gates and flashboard risers. For detailed guidance on the design of hydraulic structures, refer to these or similar manuals:

- *Handbook of Hydraulics,* E. R. Brater and H. W. King[29],
- *Fluid Mechanics*, J. A. Roberson, J. J. Cassidy, and M. H. Chaudhry[30].

5.3.1 Weirs

Discharge through a weir is controlled by the shape, elevation and length of the weir crest. Flow passes over the crest of the weir. A weir used as an outlet structure to backwater a basin, collect gravel, and provide grade control may be constructed out of a variety of materials, including rock, wood, or concrete. See **Instream Sediment Detention Basins Figure 5**.

5.3.2 Slots

Slots are configured in a vertical orientation with flow passing through the slot. They are used as an outlet structure. Flow through a slot is conveyed less efficiently than over a weir, increasing water levels in the upstream pool higher than a weir. Slots form a more concentrated jet that may scour the downstream channel. Slots are susceptible to accumulations of debris and the design must account for this. See **Instream Sediment Detention Basins Figure 3**.

5.3.3 Flashboard Risers and gates

A flashboard riser is one method to drain and allow fish to escape the trap during cleanout operations. Gates allow isolation of the active working area from the stream while the stream is shunted to a bypass.

It is important to consider the hydraulic conditions for each component of the structure. The stage-discharge relationships for the various flow control structures involved in the project (e.g.

slots and weirs) and channels may all have different flow depths for a given flow. Changes in flow depths through the various components of the structure will result in changes in water surface elevations. Changes in water surface elevations between these structures should not be greater than one foot to provide fish passage and discourage deep scour.

5.4 Detention Basin Design

Detention basins function by providing a lower energy zone that enables sediment to deposit within a constructed basin. The size and shape of a sediment detention basin depends on the stream size, stream hydrology, sediment load, available site area, access, and impacts to upstream and downstream reaches. As sediment is deposited in the basin, trapping efficiencies for the range of sizes of particles changes. This is particularly important for trapping smaller sized particles since the settling velocity is slower and residence time in the basin decreases as it fills[30]. Design typically focus on providing trapping of critical particle sizes at the pool volumes expected under normal circumstances. Other design factors may prove to be important including: pool length, expansion rate, depth and shape. Methods to calculate sediment deposition and trapping in reservoir-type conditions can be found in Hann[31], Lopez[32], and Raudkivi[33] and primarily consider settling velocity and residence time.

Sediment detention basins are typically located on the mainstream channel. Width, depth, length and shape of the basin should work with existing site constraints and allow for efficient gravel removal. An example of one type of sediment basin is shown in **Instream Sediment Detention Basins Figure 5** where the effects of expansion of the channel width and backwater by the downstream hydraulic control combine to promote the deposition of streambed material. Expansion rates of 1:2.6 to 1:4 have been tried. These traps are successful, although expansion as an independent variable has not been thoroughly evaluated. Another trap has been designed to take advantage of the hydraulic characteristics of a meander bend. The trap is configured to look like a bend; sediment is deposited on the "point bar" of the trap and a pool is maintained around the outside of the bend (the pool drain is located along the outside and is not buried by errant deposits). Aesthetic and habitat concerns are less important since the basin is temporary. Habitat enhancement should not be a part of trap design and features that attract fish or encourage spawning should be eliminated. Since the pool is deep after cleaning, many fish are attracted to it.

Uncertainties in design primarily include the structural stability of the weir, and the sediment trapping capability of the basin. The weir should be relatively low and simple. The areas backwatered by the weir should be large and low gradient enough to effectively trap the desired quantity of sediment. In all but the simplest cases, a hydraulic engineer with experience in sediment transport should conduct the hydraulic design. A civil or structural engineer should design the supporting infrastructure. A geotechnical engineer may be required for design of the foundations and mass stability of the structure.

5.5 Fish Passage through Basins

Large drops between the pool exit and the downstream bed elevation may require structures to provide fish passage, sometimes-involving concrete dams and fishways. A guidance document on design of fishways is available from the WDFW at www.wa.gov/wdfw/hab/engineer/habeng.htm. A hydraulic engineer with experience in design of fishways and a civil or structural engineer may be required for design. A geotechnical engineer may be required for design of the foundations and mass stability of the structure.

5.6 Sediment Removal

Basin design should include a bypass ditch or pipe for diverting stream flow during basin maintenance and sediment removal. Both ends of the bypass should be blocked when it is not in use to prevent fish stranding. It the bypass is a channel it can be designed to function as off channel habitat. One such design has been developed for a sedimentation basin in Whatcom County[34]. This same design configured the sediment trap to divert all low stream flows along a habitat bypass channel. Above a threshold stream flow, flow control devices limit the flow diverted into the bypass channel and the bulk of the flow and sediment is conveyed into the sediment trap. This facilitates isolating the trap for cleanout and limits increases in summer time stream temperatures.

A sluice gate or flashboard riser should be included in the bottom of the sediment basin to allow its drainage (in conjunction with fish removal) prior to sediment removal. Locate this drain in a place that is not likely to become overwhelmed with sediment and remains clear prior to excavation. When repeated sediment removal is expected, an access road and work pad should be provided for excavation equipment and truck access.

The Freshwater Gravel Mining and Dredging Issues white paper[1] provides additional information on sediment detention.

5.7 Decommissioning Sediment Basins

Once the sediment basin is no longer required it should be decommissioned to restore continuity of stream processes including flow, sediment, biologic function and riparian function. Decommissioning for smaller basins may be as simple as removing the flow control device. Larger basins will require removal of infrastructure to allow stream flow to pass unimpeded. The stream channel may need to be reconstructed through the pool of the basin by grading trapped sediments and reconstructing streambanks. Refer to the *Channel Modification* technique for guidance on channel reconstruction and the Integrated Streambank Protection Guidelines[35] for design of reconstructed streambanks.

6 PERMITTING

Permitting sediment basins is likely to require a considerable effort in justification and a discussion of the operations and maintenance throughout the life of project as well as decommissioning (nearly all sediment traps are temporary).

As construction and maintenance of instream sediment detention basins involves in-channel work, excavation, and the placement of fill within the channel, required permits and checklists may include, but are not limited to, State Environmental Policy Act (SEPA) and a Joint Aquatic Resource Permits Application (JARPA) (including a Hydraulic Project Approval and possibly a Shoreline Management Act Permit, Section 401 Certification, and Section 404 Permit). A Washington Department of Natural Resources Use Authorization and an Endangered Species Act Section 7 or 10 Consultation may also be required. Refer to the *Permitting Considerations* *for Work In and Around Water* appendix for more information regarding each of these permits and checklists.

7 CONSTRUCTION

A complete discussion of construction considerations for in-channel projects is presented in the *Construction Considerations* appendix. In addition, it is recommended that all weirs and structural elements that can be buried by deposited sediment be marked to avoid damage during sediment removal.

There are two major components of sediment detention construction – excavation of the basin and construction of control structures. Control structures may be constructed from a wide variety of materials and methods. Depending on their size and complexity, they may be constructed in place or may be constructed off-site as units to be installed. The advantage of off-site assembly is that it reduces the amount of time that a stream must be impacted by dewatering. A structural engineer should be consulted for further details on construction considerations for the structural components of the basin.

The excavation of sediment detention basins is typically a very intrusive endeavor and requires the movement of large volumes of material. To reduce impacts and facilitate construction, all construction activity should be conducted in a dewatered environment - the stream should be routed around the basin site during construction to minimize water quality impacts. Dewatering methods are further described in the *Construction Considerations* appendix will be essential for construction of sediment detention systems. As with any channel disturbance, construction should be conducted during a period where impacts to critical life stages of fish and wildlife are avoided and when dewatering for construction is possible (if necessary). Instream work windows vary among fish species, other aquatic organisms, and streams. Contact the Washington Department of Fish and Wildlife's Area Habitat Biologist for information on work windows.

Excavation within stream systems is best accomplished using either a tracked hydraulic excavator or a dragline. The size of equipment will be dictated by the size of the basin, materials to be excavated, and site constraints. Excavated material may need to be hauled off-site in dump trucks. Site conditions will dictate whether these trucks can be loaded directly at the site, if other loading equipment will be necessary, and whether a haul road is necessary. Because most sediment detention basins require maintenance and cleaning out, a haul road constructed for excavation may also be useful for long-term maintenance. Disturbance limits for excavation can be limited by having the majority of operations conducted within the basin’s footprint.

Sediment detention basins are well suited for unit cost or lump sum contracting because excavation quantities, structural components, and dewatering systems, and other construction components can be readily estimated prior to construction.

7.1 Cost Estimation

Costs to construct a sediment basin will include excavation and hauling to construct the basin, construction of infrastructure and flow control devices, and, potentially, construction of any bypass channels. Dewatering, sedimentation and erosion control and restoration of disturbed surfaces will have costs similar to those discussed in *Channel Modification* technique.

Maintenance costs for sediment removal from the sediment trap and removal of debris accumulated on the trap will include labor, excavation and hauling. Rates for these tasks vary by region and by haul distance. Local rates can generally be estimated based on conversations with a few local contractors. The circumstances and location of the work can also affect cost significantly. When working in difficult-to-access sites and/or space-constrained conditions, construction crews and equipment may require twice (or more) as much time as they would to complete tasks under ideal conditions.

Maintenance, operation, and decommissioning costs should be included in cost estimating. Operational costs will include routine inspections. Costs will be dependent on hourly billing rates and expenses for inspection staff to visit, inspect and document site conditions.

8 Monitoring

Sediment detention basin volume requires monitoring to determine when sediment removal is necessary. In addition, structural integrity of basin components, basin effects on local streambanks, and downstream effects (such as increased erosion) should be monitored. Monitoring may include any or all of the following elements:

- Visual inspections (periodic, and after storm events);
- Section and profile data (upstream, through the basin and downstream);
- Document stream flows between maintenance/monitoring operations;
- Record the volume of sediment taken out the trap;
- Record the bed substrate data (e.g. grain size distribution) of sediment removed from the trap. Note any variation in size and relative location in the trap (coarser materials are expected near the inlet with finer materials further from the inlet);
- Photo Points;
- Reach based fish snorkeling to identify impacts to habitat; and
- Spawning surveys, document location of redds (this is often not a part of spawning surveys) to detect impacts to downstream reach.

Visual reference points may simplify monitoring. For instance, a staff gage or pin driven into the bed can indicate maintenance is needed. Scour chains with floating balls downstream can show threat or injury to spawning redds.

9 Maintenance

Operation and maintenance play a major role in successful sediment detention basin application. With the exception of structures intended to be permanent and naturally maintained (e.g., large wood placed in low-order streams to enhance sediment retention), the majority of sediment detention structures will require operation and maintenance efforts. As mentioned previously, detention basin volume should be monitored so that sediment removal can be initiated as they near operating capacity. In addition, structural integrity of basin components, basin effects on local streambanks, and downstream effects (such as increased erosion) should be monitored.

A maintenance schedule and procedures should be a part of the design and contracting documents, and as a provision in the original HPA (the Hydraulic Project Approval permit). The schedule should require the use of a checklist to insure that all procedures are followed, specifically stating who is to perform the maintenance and the details of that activity. Modifications to that schedule should be made in cooperation with all the interested parties. Check at least after each flood since sediment flux is episodic and may vary dramatically from storm to storm and year to year.

In addition to monitoring, repair, and removal of sediment, removal of the basin and associated structures should be included as operation and maintenance duties. Additionally, cleanout operations require careful transplanting of fish from within the basin to upstream or downstream reaches.

10 EXAMPLES

Instream Sediment Detention Basins Figure 2: Coal Creek sediment basin, Skagit County. Looking downstream from basin to slot-type outlet structure. Stream enters on left, deposition shoaling in middle left.

Instream Sediment Detention Basins Figure 3: Coal Creek sediment basin, detail of outlet structure. Downstream weir prevents erosion of channel. A more fish-friendly structure downstream of the slot might be a porous weir. Fish passage is an important consideration in the design of outlet structures.

Instream Sediment Detention Basins Figure 4: Hansen Creek sediment basin, Skagit County. Looking downstream at outlet structure. Outlet is more ad hoc than other basins and can be a passage problem at some flows. Basin is actually many acres with only the outlet shown here.

(a)

(b)

(c)

Instream Sediment Detention Basins Figure 5: Chimacum Creek sediment basin, Jefferson County. (a) Pre-construction, (b) Post-construction, and (c) Looking upstream at control weir and nearly full sediment basin. Log control used as the outlet structure. Machinery pad and access road is off the picture to the right. Bypass pipe starts above the basin and outfalls just below picture.

Instream Sediment Detention Basins Figure 6: Maplewood Creek sediment basin, King County. Looking upstream at sediment basin. High flow overflow structure in on right, inlet stream on right. Low flow outlet structure is a fishway off the picture on the left.

11 Glossary

Colluvial – Material supplied to a river that is not derived from river transport and deposition.

Mass wasting – Geotechnical failure of a bank in response to gravity forces resulting in deposition of a wedge of bank material in the channel bed.

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