TECHNICAL NOTES

USDA-Natural Resources Conservation Service
Boise, Idaho

TN BIOLOGY NO. 22 (revised) March, 2007

CONSTRUCTED WETLAND SYSTEM

GENERAL

A constructed wetland system is a site-specific combination of practices using physical, biological and chemical processes to remove sediment, nutrients, bacteria, pesticides, and organic matter from runoff. The individual components of the system typically include: **Sediment Basin (350), Level Lip Spreader (Waterspreading 640), Primary Grass Filter (Filter Strip 393A), Vegetated Wetland (Constructed Wetland – 656), Deep Pond (Pond 378), and a Polishing Filter (Filter Strip 393, Riparian Forest Buffer 391-A).**

The purpose of a constructed wetland system is to reduce attached and soluble nutrients. Includes phosphorous, nitrogen, some chemicals, sediment, pathogens, and organic matter in runoff water.

This technical note establishes the minimum acceptable quality for the design and construction and management of the constructed wetland system as follows:

1. Failure of the system will not result in: loss of life, damage of homes, commercial or industrial buildings, main highways or railroads, or interruption of public utilities.

2. A constructed wetland system should not be used in lieu of traditional land treatment practices but should be used in conjunction with all reasonable and feasible BMP's. A constructed wetland system should be used when traditional land treatment practices do not meet the goal of the landowner and/or Idaho Water Quality Standards.

Constructed wetland systems can be used on intensively used agricultural or non-agricultural land where traditional structural or additional non-structural practices are not feasible, desirable, or practical, or where protection of the quality of the receiving water is important and additional treatment of runoff is needed to reduce nonpoint source pollution and protect designated beneficial uses.

CONDITIONS WHERE PRACTICE APPLIES

The system may be applied to runoff from cropland, pasture, forestland, urban areas and road systems. This system is to be applied at a point of concentrated flow where the land or water use contributes to an existing or potential water quality problem or when on-site treatment by structural or non-structural conservation practices may not be desirable, practical, or feasible, and additional treatment of runoff often is needed to further reduce nonpoint source pollution.

The treatment of concentrated or continuous flows of animal waste will be planned in accordance with practice standard Waste Management Systems (312).

A constructed wetland system should be used to supplement other soil and water conservation practices that reduce nutrient and pesticide losses and protect the land from erosion.

CONSIDERATIONS

Planning Considerations for Water Quantity and Quality.

1. Water Quantity

   a. This system may reduce downstream peak discharges by partial runoff storage. Consider effects on downstream flows or aquifers that would affect other wetlands, water uses or users.

   b. Evaporation and evapotranspiration are increased and water stored in the system is conserved and available for limited, specified, and allowable uses.

   c. Seepage to groundwater may occur on some sites.

2. Water Quality

   a. This practice is specifically designed to protect and improve water quality by the reduction of large amounts of pollutants. Reported results (NRCS Maine) of systems in non-irrigated areas designed according to this technical note has resulted in the following pollution reductions; suspended solids 90-100%, total phosphorous 85-100%. Similarly substantial reductions can be expected in biological oxygen demand (BOD), nitrogen and potential fecal pathogens.

   b. The temperature of runoff water may be increased in the wetland and pond under some conditions. Consider the effects on temperature of water resources to prevent undesired effects on aquatic and wildlife communities. The deep pond may serve to buffer water temperature changes if groundwater cools the water in the pond. The deeper the pond the greater the cooling effect.

   c. Water leaving the system generally will be well oxygenated due to aeration through the outlet, aquatic plant photosynthesis, and removal of sediment and organic matter by the sediment basin, grass filter, and wetland.

General Planning Considerations

1. An interdisciplinary approach to the design of these systems is essential for site selection and effective design and operation.

2. Grazing is not considered a compatible use on constructed wetland systems.

3. Site conditions will determine the suitability of each component in the system. Conditions may exist where it is impossible to install all components or when available land for the system is limited. An interdisciplinary (e.g. engineer, biologist, agronomist, soil scientist) planning team should determine the applicability of all systems when the designed size of the system cannot be met or when all components cannot be installed because of site conditions.

4. Landowners and/or operators are responsible for obtaining permits, water rights and/or approval from local, state, and federal agencies.

5. Soil and water conservation treatment in the watershed above the system shall be installed to practical and acceptable standards to reduce erosion and the delivery of sediment, nutrients, pesticides, and organic matter. Soil and water conservation practices will be used according to standards in the Field Office Technical Guide.

6. Component practices shall be designed according to the standards and specifications for each practice, incorporating specific design criteria as outlined by this technical note.

7. The system is intended to function during irrigation runoff or storm events which result in the greatest transport and delivery of pollutants. Pollution will be reduced during all seasons although some seasonal variation may occur.

8. The constructed wetland system is designed to supplement the effectiveness of on-farm land treatment measures to meet water quality objectives.

9. The functioning of the pond is enhanced when water levels are maintained throughout the year. This can be done by constructing the pond in a high water table or seasonal groundwater area. Sealing or lining the pond and wetland may be needed in some cases on highly permeable sites.

10. When phosphorous is the primary water quality concern, retention time should be one of the major concerns in the design of the wetland. The size of the pond and storage capacity should be increased and the size of the wetland decreased proportionally as far as practical. (e.g. using design criteria below if the size of the deep pond is increased to 51% then the wetland is decreased to 13% of the total area.) Design criteria listed below will be used to size a typical system for phosphorous removal.

11. Where nitrates, ammonia, BOD, and fine sediments are primary concerns, and phosphorous is not, the wetland should be increased (at least doubled) in total size, and the size of the pond may be decreased. The biological activities responsible for the reduction of the pollutants listed above are associated with shallow water wetland areas and associated wetland vegetation. A larger shallow wetland will remove more of these pollutants.

12. Wildlife may utilize the wetland, grass filter, pond and vegetation around the pond. The system should be managed to protect wildlife habitat and other uses where feasible.

13. Consider other limited economic uses of the deepwater pond. Emergency fire protection, baitfish culture, spray water, etc. The ponds are not to be used for irrigation because the extreme amounts of water used may drain the constructed wetland and pond.

DESIGN CRITERIA

Non-Irrigated Runoff

The system shall be designed for a minimum four-day retention time and flow through time through the system for the peak discharge of no less than a 2-yr/24-hr storm. Provisions will also be made to bypass a storm of the larger of a 10-yr/24-hr storm or as required by practice standard for specific components. This may be done with emergency spillway or inlet control structures.

Site conditions often dictate limits on the construction of the components, size, and position. The four-day flow through design will be sized according to the following criteria:

a. Sediment Basin - 3% of the system.
b. Primary Grass Filter - 23% of the system.
c. Vegetated Wetland - 23% of the system.
d. Deep Pond - 41% of the system.
e. Polishing Filter - 10% of the system.

When the size of the filters, wetland and pond is reduced due to unavoidable site limitations, the sediment basin should be increased. This will help compensate for the change in system effectiveness.

When a low water situation exists consider enlarging the sediment basin to regulate the accumulated waters.

Irrigated Runoff/Continuous Flow Runoff

On irrigated areas or in continuous flow situations, the total system will be designed to have a four-day flow through retention time. Phosphorous and nitrogen loading rates shall not exceed 3g/m2/year and 15 g/m2/year respectively. The four-day flow through design will be sized according to the following criteria:

a. Sediment Basin - 3% of the system.
b. Primary Grass Filter - 23% of the system.
c. Vegetated Wetland - 23% of the system.
d. Deep Pond - 41% of the system.
e. Polishing Filter - 10% of the system.

Component Descriptions and Design Criteria

Refer to Exhibit 1 and 2 for a typical constructed wetland system layout.

Sediment Basin (350)

The sediment basin is designed to collect larger sediment particles, insoluable phosphorous which attaches to the particles and organic matter from runoff water prior to routing through the treatment system. It provides pre-treatment which protects the functions of the other components. It also serves to regulate flow which minimizes excessive flushing of the pond and constructed wetland.

The sediment basin buffers peak flow and often stores 100 percent of the water from small runoff events. This protects the pond and wetland from frequent turbidity, which would reduce biological activity.

Sediment Basin (350) will be designed in accordance with practice standard 350 incorporating the following design criteria for constructed wetland systems.

The sediment basin consists of a trapezoidal trench located across the slope. The bottom width shall be a minimum of 8 to 10 feet to accommodate standard equipment used for maintenance. Side slopes shall not be steeper than 2/1.

The length of the sediment basin should be at least equal to the width of the grass filter. Depth will be a minimum of 4 feet. Excavate as deep as practical to accommodate slopes and dimensions. A ramp shall be provided on one or both ends to provide access for sediment removal. The ramp shall not be steeper than 4/1.

Level Lip Spreader (Water Spreading - 640)

This component provides the necessary sheet flow of water from the sediment basin to the primary grass filter. The spreader can be gated pipe or a leveled stable earthen berm or buried rock dike capable of delivering sheet flow to the primary grass filter.

Primary Grass Filter (Filter Strip – 393A)

This area shall be level side-to-side to provide sheet flow. It shall be designed to receive uniformly distributed flow from the sediment basin and maintain sheet flow to the wetland. Criteria in Filter Strip (393) will be followed incorporating the following design criteria for constructed wetland systems. The recommended slope should be 0.5 to 0.8 percent, but shall not exceed 3%.

Grasses will be planted to establish a dense sod. Filter Strip (393) shall be used to determine suitable sod forming vegetation for the filter. Herbaceous hydrophytic vegetation may be used when continuous wet soil conditions exist. Constructed Wetland (656) will be used to plan and design hydrophytic plantings. Mowing and removal of grass shall be done after critical nesting periods to maintain a dense sod for the effectiveness of the filter as well as nutrient removal.

Where feasible, the filter may be constructed with a subsurface tile drain system to: increase infiltration, maintain the root zone in an aerobic condition, prevent the area from being saturated for extended periods, and improve access for mowing. Spacing shall be in accordance with criteria in Subsurface Drain (606) or a minimum 20 feet, whichever is closer. Depth of tile should be a minimum of 24 inches below the ground surface. Grass filters with subsurface tile will probably not be suitable for planting of hydrophytic vegetation.

The minimum pipe size shall be four-inch diameter perforated pipe drain tile. The tile shall outlet into the wetland if nitrates are at unacceptable levels or into the deepwater pond if nitrogen levels are not elevated. If the tile intercepts clean groundwater, other than grass filter infiltration, divert the water around the pond to a stable outlet.

No tile will be placed under the water spreader. First line of tile shall be at least 20 feet downslope of the spreader.

Vegetated Wetland (Constructed Wetland - 656)

The vegetated wetland shall be constructed to maintain shallow water and saturated soil conditions. The wetland usually results in a combination of anaerobic and aerobic conditions in the soil and organic matter layer. These conditions are important in the removal of nitrates, ammonia, and pathogens. The conditions are suitable for growth of a dense stand of emergent aquatic plants and habitat for important micro and macro organisms.

Vegetation of the wetland will occur through direct planting. It is recommended to directly plant the wetland to reduce the chances of unwanted vegetation from getting established and to expedite the functioning of the system.

Criteria listed in Constructed Wetland (656) will be used to develop a vegetation plan and design the vegetated wetland.

The wetland may receive water from the primary grass filter by sheet flow sloping down to the wetland or from a point source (e.g. pipe or structure). When entering from a point source the wetland should receive water from the primary grass filter at a point farthest from the inlet to the deep water pond. This will create the longest route for the water to travel before entering the deep water pond.

Water in the wetland shall range in depth from the zone of saturation near the primary grass filter to a maximum depth of 18 inches near the pond. When a level vegetated wetland is constructed, the design depth shall be 12 inches.

The outlet of the wetland into the pond shall be protected from erosion by riprap or vegetation. The outlet of the wetland shall be located as far from the pond outlet as possible to create the longest route for the water to travel before exiting the system.

Onsite soil investigations will be required for all constructed wetland systems. Soils with an infiltration rate of 0.6 inches/hour or greater, may require lining to reduce the chances of ground water pollution and enhance the efficiency of the wetland system.

Wetland Minimum Design Criteria:

Minimum berm width - 4 ft.
Minimum side slopes - 2:1
Maximum side water depth - 1.5 ft.
Minimum freeboard depth - 1 ft.

Consider widening the berm width to facilitate maintenance with truck or tractors.

Berms and other non-wetland disturbed areas will be vegetated using Practice Standard 342 (Critical Area Planting).

The wetland should be capable of being drained to allow for maintenance and vegetative establishment if necessary.

Deep Water Pond (Pond 378)

The pond is designed to provide a limnetic biological filter for nutrient and fine sediment removal, depending on available nutrients. Benthic algal communities may flourish in the pond, thus utilizing these nutrients.

The pond can be stocked with selected species of fish, which feed on plankton and other microorganisms. Indigenous species will be used.

The NRCS Biologist or IDF&G will be contacted for recommendations on fish species available for stocking. IDF&G will be contacted to obtain needed permits. Stocking rates will be determined by IDF&G or NRCS Biologist recommendations. Idaho is limited in indigenous fish that may be suitable for this purpose.

Where suitable and available, shellfish (fresh water mussels), will be stocked at a rate of 100 per 3000 square feet of surface area 1 year after the pond is constructed.

These shellfish are filter feeders and will enhance the effectiveness of the pond ecosystem. Each mussel filters 10-12 gallons of water per day. Re-stock every 3-5 years, as needed.

The deep pond shall comply with Practice Standard No. 378. In addition, the following criteria shall apply:

Locate the principal and emergency spillways on the same side of the pond. They shall be on the opposite side of the pond from where water enters from upstream component whenever possible. The purpose is to create the longest path of flow.

Where feasible, the pond shall have the capability of being drained to allow for necessary maintenance of the system. This may be accomplished by pumping.

The depth of the pond should be from 4 feet to 12 feet. Where shallow bedrock is a problem or in irrigated areas where the pond may dry up for several months, depths from 4 to 6 feet are a minimum. In cases where the pond may be dry for several months of the year do not stockfish and mussels in the pond.

The principal spillway shall outlet into a level spreader such that the polishing filter will receive sheet flow from the pond.

On sites with soil infiltration rates of 0.6 in/hr or greater, lining may be required to reduce chances of groundwater pollution and enhance the efficiency of the system.

The emergency spillway shall be designed to preclude channelized flow and provide sheet flow at a maximum depth of 2 inches onto the polishing filter.

Route the 2-year to 5 year, 24 hour storm through the principal spillway to set the crest or level of the emergency spillway.

Polishing Filter (Filter Strip 393A, Riparian Forest Buffer 391-A)

This area shall be a stable, vegetated site which is grassland, wetland, or forestland area, either natural or constructed, between the pond outlet and a stream or natural body of water. This area is intended to serve as a final filter or buffer between the deep water pond and the receiving body of water. It will help to remove algae and may remove some additional nutrients during spring runoff.

The water from the deep water pond shall be distributed in sheet flow to the polishing filter with a level spreader. The level lip spreader can be gated pipe or a level earthen or rock spreader.

The vegetation shall be herbaceous and/or woody vegetation capable of sustaining prolonged soil saturation conditions. Follow criteria in Filter Strip (393A), Constructed Wetland (656) or Riparian Forest Buffer (391).

Because of the wet conditions, sod forming hydrophytic vegetation may be planned for the site.

When a level spreader ditch is to be used to provide uniform distribution through this filter, the minimum design criteria shall include:

a. Level spreader ditch
   Minimum width - 3.0 ft.
   Minimum side water depth - 1.6 ft.
   Minimum freeboard depth - 1.0 ft.

Use Critical Area Planting Standard (342) for suitable vegetative planting for the level spreader ditch.

Specialized Installation Procedures

When working in non-irrigated areas, do not bypass the constructed wetland system during major runoff events. These events usually carry the greatest loads of pollutants.

Install necessary water control measures to exclude clean runoff water from the system.

A construction erosion control plan should be developed to prevent and trap soil erosion that occurs during construction until the system is stabilized. This may include the following:

a. Temporary debris basin at the lowest elevation of the site.

b. Silt fence downstream of the site.

c. The topsoil shall be stripped and stockpiled for later use in the grass filter and wetland.

d. Piping and underground tile shall be backfilled and compacted to prevent problems caused by settling.

The erosion control devices and/or any temporary debris basin shall be removed after permanent vegetative cover has been established over 90 percent of the disturbed area or after 6 months, whichever comes first.

Runoff water should be diverted through the sediment basin and then bypass the system until one growing season after the primary grass filter has become established.

Plans and specifications shall be prepared in accordance with criteria described in each practice standard and constructed wetland system technical note and shall describe the requirements for applying the practice for the specific field site. Plans and specifications include engineering plans, job sheets, planting plans, and narrative

statements in conservation plans. Schematic diagrams are shown in the Engineering Field Manual, Chapter 13, "Wetland Restoration, Enhancement, or Creation." Livestock will be excluded from the system.

OPERATION AND MAINTENANCE

A specific plan shall be prepared for each Constructed Wetland System detailing maintenance of each component.

Sediment Basin

Sediment shall be removed from the basin when the accumulation reaches a depth of 12 inches. This is essential in order to prevent overflow of sediment into the grass filter, wetland, or deep water pond. Excess sediment reduces the efficiency of the system. Removal of plant growth in the basin is not needed until sediment is removed.

Level Lip Spreader

Maintain level conditions in the earthen spreader to provide sheet flow into the primary grass filter. This will be needed in the early years of operation due to settling. Maintain spreader free of brush and trees.

Gated pipe or other structural devices will be maintained to deliver water in sheet flow to the primary filter.

Primary Grass Filter

The vegetation shall be mowed to a 6-inch stubble height and clippings removed at least twice during the growing season where possible. Harvesting should occur between June 25 and July 5th and between September 1-30. Mowing before June 25 may destroy duck nests. At the end of the growing season, the grass shall be at a height of at least 6 inches going into the winter. The vegetation that is removed may be used as mulch, or forage, or be transported out of the drainage area for other purposes.

Regrading, reseeding, and nutrient management shall be done as needed to protect the functions of the filter.

Tile lines under grass filter shall be maintained free flowing.

Constructed Wetland

It is recommended that the vegetation be mowed and removed once in 5 years. This may not be possible due to climate and site conditions. Mowing when wetland is frozen is acceptable. Vegetation can be shredded and used for mulch or forage.

In irrigated areas, the wetland may be without water for up to six months because of a loss of irrigation water from late fall through early spring. Remineralization of nutrients, and subsequent release of nutrients when irrigation water returns to the system may occur under these conditions. When these conditions exist, the wetland and pond components will need to be charged before full flow is directed into the system. To charge system, direct water into the system to the point where the vegetated wetland and pond are at capacity, but NO outflow of water occurs from the deep pond. Continue maintaining water levels at this level for 7 days. After 7 days, the system is considered charged and can accept full flow throughout the season.

Maintenance of the embankments shall be performed to preclude bank erosion and to control all woody vegetation.

Deep Water Pond

Dense floating mats of algae should be removed throughout the year. This material should be taken to upland sites for disposal or composting.

Maintenance of the embankments shall be performed to preclude bank erosion and to control all woody vegetation.

When fish and mussels are used as part of the system, restocking may be needed periodically and should be evaluated by local Idaho Department of Fish and Game personnel and the NRCS biologist.

When fish are used as part of the system, natural harvesting will occur by established food chains. The efficiency of the system can also be enhanced by harvesting fish by netting and physical removal from the pond. No supplemental feeding of fish is to be conducted. No chemical treatment is to be used in the pond without concurrence of the NRCS biologist and applicable permits obtained from Idaho Department of Fish and Game.

If nutrient loads cause advanced eutrophication or extended anaerobic conditions, aeration or other destratification techniques may be necessary.

Polishing Filter

The polishing filter will be maintained free of channel flow and gully erosion. Vegetation will be managed to maintain a herbaceous and/or woody filter.

Maintain level conditions in the earthen spreader by raking, grading, etc., to provide sheet flow into the polishing filter. This will be needed in the early years of operation due to settling. Maintain spreader free of brush and trees.

Gated pipe or other structural devices will be maintained to deliver water in sheet flow to the polishing filter.

Standards applicable for use with Constructed Wetland System are:

Pond (378)
Structure for Water Control (587)
Irrigation Pipelines (430)
Pond Lining (521)
Filter Strips (393A)
Constructed Wetland (656)
Dikes (356)
Critical Area Planting (342)
Riparian Forest Buffer (391A)
Subsurface Drainage (606)
Sediment Basin (350)
Waterspreading (640)

REFERENCES

Wengrzynek, Robert J. Jr., 1991. Unpublished Reports and Interim Standard and Specification (Code I-05) Nutrient/Sediment Control Systems. USDA Natural Resources Conservation Service, Orono, Maine.

NRCS(Natural Resources Conservation Service). 1992. Engineering Field Handbook, Chapter 13: Wetland restoration, enhancement, or creation. 210-EFH, 1/92.

NRCS(Natural Resources Conservation Service). 1994. Riparian/Wetland Project Information Series, No. 8: Constructed wetland system for water quality improvement of irrigation wastewater. Plant Materials Center (PMC), Aberdeen, ID. Unpaged.

NRCS (Natural Resources Conservation Service) and EPA (Environmental Protection Agency) – Region III. 1995. A Handbook of Constructed Wetlands. A guide for creating wetlands for :Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage, and Stormwater in the Mid-Atlantic Region, 5 volumes. Washington, DC.