Practice Notes

10 Stormwater ponds

Stormwater dam in Brighton, Tasmania
(Source: Y. Barry, Derwent Estuary Program)

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimise impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note gives a general introduction to stormwater pond design, construction and maintenance and the benefits of using stormwater ponds.

Introduction

Stormwater management is a fundamental consideration in the planning and design of urban development. Unfortunately, it is often treated as a subsidiary issue that is not addressed until the final stages of the planning and design process. By considering stormwater management at the initial design phase it is possible to ensure viable stormwater management solutions that are compatible with other design objectives for the site.

Stormwater management ponds can be used for water quantity and quality control. They have been, and are expected to remain, important components in the stormwater effort to minimise adverse impacts associated with urban land use. This practice note reviews ponds that are either normally dry or normally wet. Both forms of pond can and may possibly have an extended detention component to them.

Common Techniques

There are two types of pond; defined as:

Dry ponds: – A permanent pond that temporarily stores stormwater runoff to control the peak rate of discharges and provide water quality treatment, primarily through the incorporation of extended detention. These ponds are normally dry between storm events.

Wet ponds: – A permanent pond that has a standing pool of water. These ponds can, through their normal storage of water, or in conjunction with extended detention, provide water quality treatment. They can, also in conjunction with extended detention, provide protection of downstream channels from frequent storms.

Stormwater ponds are used for three primary purposes:

- Reducing downstream flood potential.
- Providing water quality treatment.
- Minimising, to the extent possible, downstream channel erosion.

It may not be necessary in every situation to address all three purposes, but there will be sites where all three functions can be included in the design.

Water quantity/quality performance

Ponds detain runoff, typically from a rain event, and then discharge it, usually at the pre-development peak discharge rate.

Traditionally ponds, especially dry ones, have been used primarily for flood protection. They normally detain runoff and then discharge it at a

specified rate, reducing the potential for downstream flooding by delaying the arrival of runoff from upper parts of a catchment. More recently, wet and dry pond designs have been modified to extend the detention time of runoff thereby increasing particulate contaminant settling and minimising downstream channel erosion. Wet ponds are normally designed to have a permanent pool for storage of a specified water quality volume. Wet ponds

also have an outlet design that increases residence time and flow path.

Contaminant removal mechanism

The primary contaminant removal mechanism of all pond systems is settling or sedimentation. However, the effectiveness may vary to some degree depending on the type of detention system (dry or wet).

Flood detention ponds have limited effectiveness at providing sedimentation as detention times are often minimal, so only the coarser particles can be removed from the water column.

Extended detention ponds that are normally dry also rely on sedimentation during short periods of live storage only although they typically hold flows for longer than flood detention ponds.

The best approach for particulate removal is the combination of extended detention in conjunction with a normal wet pool. The pool allows for displacement of water previously stored and the extended detention allows for better sedimentation.

Expected performance

Ponds can be effective at reducing peak discharge rates. Depending on their design and their location within a catchment, they may also be effective in reducing downstream channel erosion, downstream flood levels and flooding.

Effectiveness at contaminant removal depends on the type of pond system. In general, they can be ranked, from least to most effective, in their ability to remove stormwater contaminants: dry detention, extended dry detention, and then wet detention.

Unlike dry detention ponds, wet ponds provide mechanisms that promote the removal of dissolved stormwater contaminants, and not just particulates. Table 1 illustrates expected contaminant reduction.

Constraints on the use of ponds

Dry ponds:

- Need fairly porous soils or subsurface drainage to assure that the bottom stays dry between storms.
- Not suitable in areas with high water tables or shallow depth to bedrock.
- Not suitable on fill sites or steep slopes unless geotechnically checked.
- May not be suitable if receiving water is temperature sensitive as detention ponds do not detain water long enough to reduce temperatures from impervious surfaces.

Wet ponds:

- Not suitable on fill sites or near steep slopes unless geotechnically checked.
- May need supplemental water sup-

Table 1

Contaminant	*Dry (flood)*	*Dry (ext. det.)*	*Wet*
Total suspended solids	20-60	30-80	50-90
Total phosphorus	10-30	15-40	30-8-
Total nitrogen	10-20	10-40	30-60
COD	20-40	20-50	30-70
Total lead	20-60	20-70	30-90
Total zinc	10-50	10-60	30-90
Total copper	20-40	20-60	20-80

Expected contaminant reduction range of ponds

ply or liner system to maintain permanent pool if not dug into the groundwater.

- Minimum contributing drainage area of 2 - 3 hectares is needed to maintain the permanent pool.
- Not feasible in very dense urban areas or areas with high land costs due to large surface area needs.
- May not be suitable if receiving water is temperature sensitive due to warming of pond surface area.
- Safety issues need to be addressed, depending on normal pool depth.

Dry flood detention ponds are not normally recommended for stormwater management systems. They have ongoing maintenance needs because standing water in areas where positive drainage is impeded may cause mosquito problems, and their overall performance for water quality treatment is less than that provided by wet ponds. Also, dry ponds tend to have less aesthetic appeal than wet ponds.

Design Considerations

Objectives

Water quantity objectives

Urbanisation has dramatic impacts on the amount of stormwater runoff that is generated from a catchment. Various Australian and overseas studies indicate that peak rates of discharge were increased from seventy to ninety percent from pre-development to post-development and the total annual volume of runoff increased approximately 300 percent. Ponds, when properly sized, can be a primary quantity control practice.

Criteria for water quantity control depends on the receiving environment. If the receiving environment is a piped stormwater reticulation system with adequate capacity for the increased runoff or tidal (either estuarine or marine), then water quantity control is not an issue and a number of practices can be used to achieve water quality goals. If the receiving environment is a stream, then control of peak rates of runoff may be a requirement, and ponds become a primary option for controlling discharge rates.

Where there are downstream flooding issues, peak discharges for the post-development 100 year 1% Annual Recurrence Interval (ARI) flood may need to be managed to ensure that downstream flood levels are not increased.

Depending on the catchment, the number of tributaries and the location of the project in a catchment, timing of flow, discharges may be an issue. If so, a catchment wide study may be necessary to ensure that downstream flood risks are not increased. If there is no catchment-wide study, work done in Australia and overseas has indicated that limiting the peak discharge of the 100 year flood to not exceed 80% of the pre-development 100 year flood will reduce downstream flood increase concerns. The 80% peak discharge rate reduces potential for coincidence of elevated flow downstream by extended release of the flows.

Water quality objectives

Water quality objectives aim for 75% removal of TSS. Ponds are not as appropriate for dissolved contaminants. They are more appropriate where sedimentation can achieve stated goals. Where possible, water quality ponds need a bypass for larger flows. Because all flows travel through the pond, water quality performance during larger events will be reduced as first flush contaminants are carried through it. Ideally, larger flows should bypass the pond in order to avoid a drop in water quality performance, albeit at the expense of its ability to provide peak flow reduction for larger storms. In those situations, it may be best to use a treatment train approach to stormwater where other practices provide primary water quality treatment while the pond is primarily used for water quantity control. Although often desirable, this treatment train approach may not always be possible due to site constraints.

Channel protection objectives

Urban development has the effect of increasing the frequency and magnitude of floods, particularly during frequent heavy rain events. As a consequence streams can suffer an increase in erosion, as channels enlarge

to cope with the increased water.

The objective of criteria related to channel protection is to maintain or improve the in-stream channel stability to protect ecological values of the stream and reduce sedimentation downstream.

Pond outlets should be designed to convey the volume generated by the initial first flush runoff over the total catchment area, which has been stored and released over a 24 hour period to minimise potential for stream channel erosion. This provision is additional to normal stormwater quality and flow attenuation requirements.

Ponds in series

The use of ponds in series is not generally recommended instead of a single pond with an equivalent surface area. If the single pond were divided into two ponds in series then each of the two ponds would have approximately one half the surface area of the single one.

Each pond then has half the detention time, so the first pond takes out the coarser sediment. The flow is then remixed in the channel between ponds, and the second pond is too small to take out the finer fractions. Therefore ponds in series may be less efficient than single large ponds of equivalent volume.

However, sometimes site constraints make it necessary to use two or more treatment ponds in series rather than one larger single pond. To offset the reduction in sediment removal, where two or more ponds in series are necessary they should be sized at 1.2 times the volume specified for a single pond. Where there are no specific site constraints, a single pond is preferred.

Preferences

Wetlands verses Ponds

Constructed wetlands are preferred to open water ponds because they provide better filtration of contaminants, including dissolved ones due to densities of wetland plants, incorporation of contaminants in soils, adsorption, plant uptake, and biological microbial decomposition. In addition, wetlands, being shallow water bodies do not have the safety issues associated with deeper water ponds.

On-line versus off-line

'Off-line' placement of ponds is preferred to 'on-line' placement. Off-line ponds are considered to be those ponds not physically located in perennial watercourses. They can be in gullies or upland areas. On-line ponds are located on streams having perennial flows and their impact to the stream itself can be significant. On-line ponds alter geomorphic and biological character of streams and these alterations may adversely impact on the streams natural character and function.

However, while off-line ponds are preferred, it is not a hard and fast rule. Within metropolitan urban limits, on-line ponds may be the only option to provide downstream benefits if there is already a high level of development that exists in a catchment. In those areas, on-line ponds would have to be considered on a case-by-case basis to determine suitability.

There may be mitigation requirements placed on on-line ponds to compensate for the loss of stream habitat when an on-line pond is accepted for a specific location.

Dry ponds versus wet ponds

Dry ponds are not normally recommended. They need more maintenance and have a lower water quality performance than wet ponds. In terms of preference when ponds are the selected options, constructed wetlands are a first choice, followed by wet ponds, and finally dry ponds.

Maintenance responsibility

Maintenance issues will be discussed below in detail, but the issue of ensuring an entity is responsible for maintenance must be considered as an issue to determine whether ponds are applicable in a given situation. Ponds are expensive and require routine and non-routine maintenance to ensure proper long-term performance, or failure of the pond system can occur. While a swale can fill in or a sand filter clog, pond failure can

have significant effects, such as property damage and potential loss of life. Ponds must, therefore, be regarded as small dams, and evaluated in the context of best practice for dam operation. If maintenance responsibility cannot be defined during the design phase, ponds should not be selected for a given site.

Pond safety

The most important concern of stormwater management detention and retention ponds is safety. Failure to act in some situations may cause structural failure. Inspections must be made at least annually to ensure the safety of a stormwater pond. If there is any concern that the facility is unsafe, the pond owner must seek advice from a dam safety expert. Failure to take action when confronted with potential problems can increase liability if a failure occurs.

Complete failures of stormwater management ponds generally do not occur overnight. They start as small problems and increase gradually, hence the importance of regular maintenance.

Ponds are unique among stormwater practices. If filtration, biofiltration, or infiltration practices fail or clog, their reduced performance generally will not result in downstream safety concerns. Ponds provide effective water quality performance, but that performance is gained at the cost of increased safety concerns. They must be designed correctly, built satisfactorily and actively maintained. A failure in any one of these three aspects of ponds could result in significant problems. Ponds are a valuable tool in controlling stormwater runoff, but care must be taken to ensure their long-term effectiveness.

Safety features to consider include:

Depth

Deeper ponds can be attractive to children who like open water. Historically, ponds have been 1 - 3 metres deep, sometimes over anyone's head. Stormwater ponds should not be deeper than 2 metres, if at all possible. If water quality volume requirements and site limitations limit pond area, then use a wetland and extended detention live storage to achieve the water quality volume.

Benches

A reverse slope bench or slope break should be provided 300 mm above the normal standing water pool (where there is a normal pool) for safety purposes. All ponds should also have a shallow bench 300 mm deep that extends at least three metres from the shoreline, before sloping down to the pond floor. This shallow bench will facilitate the growth of emergent wetland plants and also act as a safety feature.

In addition to the benches, the steepness of the pond slope down to the invert of the pond should not exceed 4 horizontal to 1 vertical. Steeper slopes will make it very difficult for someone who is in the pond to get out of it.

The reverse slope above the waterline has at least three functions. It:

1. Reduces erosion by rilling that normally would be expected on longer slopes.
2. Intercept particulates traveling down the slope and conveys them to the pond inflow.
3. Provides an additional safety feature to reduce the potential for children running or riding uncontrolled down the slope and falling into the pond.

Fences

For safety reasons fencing of ponds will generally be required. The use of natural features such as reverse benching, dense bank planting, and wetlands buffers (which consists of a dense stand of vegetation) can provide a similar level of protection.

Aesthetics

Aesthetics must be considered as an essential pond design component. Ponds can be a site amenity if properly designed and landscaped, or can be a scar on the landscape. The developer and designer should consider the pond as if they themselves were to be living in the development. Small items can have a big influence on the

livability of a given area to residents and the best time to consider the issue is during the design phase.

Pond and site design

Pond shape

The design of pond shape should consider engineering constraints, design parameters to achieve treatment, and the existing topography. For a given catchment the design parameters include water volume, surface area, depth, water flow velocity and detention period. In addition, it is recommended that the length to width ratio be 3 horizontal to 1 vertical or greater to facilitate sedimentation. These parameters should be considered in light of the existing topography. Generally, a pond will look more natural and aesthetically pleasing if it is fitted into existing contours.

Pond contours

Pond contour profiles are critical to the design of a pond. They determine available storage, the range of plants that can be grown and the movement of water through the pond. The safety features of shallow slopes and reverse slopes will help provide areas suitable for a variety of plants.

Edge form

Edge form influences the appearance of a pond, increases the range of plant and wildlife habitats and has implications for pond maintenance. Edges can include sloping margins where water level fluctuations cause greater areas of wet soils. Generally, sloping margins require a more sophisticated management approach to ensure growth of plants. Areas of gradually varied wetness should be identified and specific planting strategies

should be developed for these areas. Such gradually sloping areas can appear a more natural part of the landscape than steep banks, and they provide opportunities for a greater range of plants and habitat.

Islands

Islands, properly located, can be used to manipulate flow characteristics, to increase the distance that water travels and to help segregate first flush inflow from later flows within a rainfall event. They also increase the extent of planted margin and can provide a wildlife habitat that offers some protection from domestic animals or people, as well as offering additional aesthetic appeal.

Landscaping

Design of a stormwater pond system should ensure that the pond fits in with the surrounding landscape. General landscape design principles will apply. The area should develop a strong and definite theme or character. This might be generated from particular trees, or views from the site, topographical features, or the cultural character of the surrounding neighbourhood. The landscape design for the area will provide a setting for the pond so that the pond will appear a natural component of the overall setting.

Maintenance Issues

Maintenance falls into a number of different categories:

Aesthetic maintenance

Aesthetic maintenance primarily enhances the visual appearance and appeal of a stormwater pond. An attractive stormwater pond will more easily become an integral part of a community. Aesthetic maintenance is obviously more important for those ponds that are very visible. The following activities can be included in an aesthetic maintenance program:

- **Graffiti removal:** The timely removal of graffiti will improve the appearance of a stormwater pond. Timely removal will also tend to discourage further graffiti or other acts of vandalism.
- **Grass trimming:** Trimming of grass around fences, outlet structures, hiker/biker paths, and structures will provide a more attractive appearance to the general public. As much as possible, the design of stormwater ponds should incorporate natural landscaping elements which require less cutting and/or trimming. However, there often are areas where mowing will be necessary to maintain attractiveness.

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- **Control of weeds:** In situations where vegetation has been established, undesirable plants can be expected. These undesirable plants can adversely impact the aesthetics of a stormwater pond and send the wrong signals to the public about weed control. This can also apply to wet detention littoral zones, which may be invaded by undesirable aquatic plant species. These undesirable plants can be removed through mechanical or chemical means. If chemicals are used, the chemical should be used as directed and according to any Council requirements and left over chemicals disposed of properly.
- **Miscellaneous details:** Careful and frequent attention to performing maintenance tasks such as painting, tree pruning, leaf collection, debris removal, and grass cutting (where intended) will allow a stormwater management pond to maintain an attractive appearance and help maintain its functional integrity.

Functional maintenance

Functional maintenance is necessary to keep a stormwater management system operational at all times. It has two components – preventive and corrective maintenance.

Preventive maintenance: Is done on a regular basis. Tasks include upkeep of any moving parts, such as outlet drain valves or hinges for grates or maintenance of locks. It can also include maintenance of vegetative cover to prevent erosion. Examples of preventive maintenance include:

- **Grass mowing:** Actual mowing requirements at a pond should be tailored to the specific site conditions and grass type.
- **Grass maintenance:** Grass areas require limited periodic fertilising and soil conditioning in order to maintain healthy growth. Provisions may have to be made to re-seed and re-establish grass cover in areas damaged by sediment accumulation, stormwater flow or other causes.
- **Vegetative cover:** Trees, shrubs, and other landscaping ground cover may require periodic maintenance, including fertilising, pruning, and weed pest control.
- **Trash and debris:** A regularly scheduled program of debris and trash removal will reduce the potential for outlet structures, trash racks, and other pond components from becoming clogged and inoperable during storm events. In addition, removal of trash and debris will prevent possible damage to vegetated areas and eliminate potential mosquito breeding habitats. Disposal of debris and trash must comply with all local and regional control programmes. Only suitable disposal and recycling sites should be used.
- **Sediment removal and disposal:** Accumulated sediments should be removed before they threaten the operation or storage volume of a stormwater management pond. Disposal of sediments also must comply with local and regional requirements especially if they are contaminated. Only suitable disposal areas should be used.
- **Mechanical components:** Valves, sluice gates, pumps, fence gates, locks and access hatches should remain functional at all times. Regularly scheduled maintenance should be performed in accordance with the manufacturers' recommendations. All mechanical components should be operated during each maintenance inspection to assure continued performance.
- **Elimination of mosquito breeding habitats:** The most effective mosquito control programme is one which eliminates potential breeding habitats, or, in the case of open water ponds, ensures that optimal conditions are maintained for the survival of mosquito control organisms. Any stagnant pool of water can become a mosquito breeding area within a matter of days. Ponded water in open cans, tyres, and areas of sediment accumulations or ground settlement can become mosquito breeding areas.
- **Pond maintenance programme:** A maintenance programme for

monitoring the overall performance of the stormwater management pond should be established. Wet detention ponds are especially complex environments. They require a healthy aquatic ecosystem to provide maximum benefits and to minimise maintenance. It is important to remember that potentially large problems can be avoided if preventive maintenance is done in a timely fashion.

Corrective maintenance

Corrective maintenance is required on an emergency or non-routine basis to correct problems and to restore the intended operation and safe function of the pond. Corrective maintenance is done on an as required, not on a scheduled basis. Failure to promptly address a corrective maintenance problem may jeopardise the performance and integrity of the pond. It may also present a potential safety problem to those living by or below it. Corrective maintenance activities include:

- **Removal of debris and sediment:** Sediment, debris, and trash which threaten the ability of the pond to store or convey water should be removed immediately and properly disposed of in order to restore proper pond function. A blocked inlet or outlet means that stormwater will travel in an area that was not normally designed as a flow path. In the case of an inlet, the stormwater could travel over a kerb onto a grassed area and scour it. If the outlet is blocked, water will back up in the pond and may travel through the emergency spillway. These areas are not designed for frequent flow and may become eroded. If sediments are clogging a pond component, the lack of an available disposal site should not delay removal of the sediments. Temporary arrangements should be made for handling the sediments until a more permanent arrangement is made.
- **Structural repairs:** Repairs to any structural component of the pond should be made promptly. Equipment, materials, and personnel must be readily available to perform repairs on short notice. The immediate nature of the repairs depends on the type of damage and its effects on the safety and operation of the pond. Where structural damage has occurred, the design and conduct of repairs should be undertaken only by qualified personnel.
- **Dam, embankment and slope repairs:** Damage to dams, embankments, and slopes must be repaired quickly. Typical problems include settlement, scouring, cracking, sloughing, seepage and rilling. A common concern in embankments with outflow pipes through them is seepage around the outside of the barrel. This can also cause movement of embankment soils, which can weaken the embankment. Repairs need to be made promptly. Other temporary activities may be needed, such as drawing down the water level in the pond in order to relieve pressure on a dam or embankment or facilitate repairs. Crack repair in a concrete structure may necessitate draining the pond and cleaning before repair. If the pond is to be dewatered, pumps may be necessary if there is no drain valve.
- **Elimination of mosquito breeding areas:** If neglected, a stormwater pond can become a mosquito breeding area, especially where normally dry ponds do not completely drain and dry out. Corrective action may be needed if a mosquito problem exists and the stormwater pond is the source of the problem. If mosquito control in a pond becomes necessary, the preventive maintenance programme for mosquitoes should be re-evaluated, and more emphasis placed on control of mosquito breeding habitats.
- **Erosion repair:** Vegetative cover is necessary to prevent soil loss, maintain the structural integrity of the pond and maintain its contaminant removal benefits. Where a reseeding program has been ineffective, or where other factors have creat-

ed erosive conditions (such as pedestrian traffic, concentrated flow or the like), corrective steps should be taken to prevent further loss of soil and any subsequent danger to the performance of the pond. Corrective action can include erosion control blankets, riprap, sodding or reduced flow through the area.

- **Fence repair:** Fences can be damaged by any number of factors, including vandalism and storms. Timely repair will maintain the security of the site.
- **Elimination of trees or woody vegetation:** Woody vegetation can present problems for dams or embankments. The root system of woody vegetation can undermine dam or embankment strength. If the vegetation dies and the root system decomposes, voids can be created in the dam or embankment which weaken the structure. Preventive maintenance can avoid this problem. However, when preventive maintenance programmes are deficient, steps must be taken to eliminate the problem. Vegetation, including root systems, must be removed from dams or embankments and the excavated materials replaced with proper material at a specified compaction (normally 95% of the soil's maximum density).
- **General facility maintenance:** In addition to the above elements of corrective maintenance, general corrective maintenance should address the overall pond and it's associated components. If algal growth becomes a problem for ponds, steps must be taken to re-establish its original performance. Stormwater ponds can be very complex systems. They will work only as long as each individual element functions correctly. If one pond component is undergoing corrective maintenance, other components should be inspected at the same time to see if they also need maintenance. This may yield cost savings if equipment is already on site.

Other maintenance activities

Maintenance activities for dry and wet ponds have many similarities, but there also are some differences in the types of maintenance that are needed. Dry detention systems have more lawn areas, that must be mowed at least once per year to prevent the growth of woody vegetation on the embankment. Monthly or more frequent mowing is necessary if good turf grass cover is expected or desired.

Dry detention ponds frequently have pilot or low flow channels to convey smaller flows. Concrete pilot channels may become undermined, and stone ones may become choked with vegetation and require chemical treatment to reestablish flow conveyance ability. Maintenance efforts for pilot channels will be done on an "as needed" basis. Careful inspection of concrete pilot channels is essential, as their undermining will jeopardise its structural integrity.

Wet detention ponds, with their normal water pool, are effective at converting inorganic nitrogen to organic nitrogen. Consequently, this may create algal problems unless littoral zones are planted and maintained with aquatic vegetation. Wet detention ponds also commonly have forebays to remove heavier sediments. Forebay maintenance is therefore an important issue for wet detention ponds, and must be considered. Frequency of forebay maintenance depends on the incoming contaminant load and the forebay size.

Both dry and wet detention ponds have the potential for debris clogging of inlet and outlet structures. Residential communities generate a surprising amount of debris, while commercial facilities can expect debris of all sorts. Inspections for debris should be made on a monthly basis or after rain events to ensure that all components of the stormwater ponds are operating as required.

Coarser sediments can be expected to be found close to the pond inlet, with finer sediments expected to be

deposited closer to the pond outfall. The coarser sediments will occupy a greater volume and maintenance schedules should include more frequent removal. Forebays can be more easily and more often cleaned out extending the storage life of the rest of the pond.

To remove sediment from a wet pond drain the water down to the lowest possible level, leaving a small pool of water to provide habitat if there is a desirable resident fish population. This avoids disturbing fines and causing significant turbidity downstream. Sediments removed from the pond should be placed where they can dry before final placement. Sediment control provisions must be included in maintenance costs, to prevent downstream increases in contaminant loadings or to prevent removed sediment from re-entering the pond.

Sediment removal from dry detention ponds is more straightforward. Since they are normally dry, sediments can be removed by an appropriate means and disposed of in one operation. Experience has shown that it is easier and more effective to remove sediments when they are dry and cracked, and thereby more easily separated from the vegetation. Sediment control during maintenance is necessary to prevent rainfall mobilizing stockpiled materials or eroding exposed soils.

Erosion problems can occur with either dry or wet detention ponds. For the most part they start as small problems which, if uncorrected, can grow into large problems and possibly threaten the integrity of the detention pond. Inspections to locate erosion problems should be done at least annually or after major storms. Evidence of significant foot or bike traffic in areas where vegetation has died indicate potential erosion areas in the future. These areas should be protected from traffic or provided with a more erosive resistant ground cover.

Periodic maintenance of structural components must be done to ensure their continued operation. This includes inspecting any joints for possible leakage or seepage. Areas should also be checked for corrosion, valves should be manipulated and lubricated when needed, and all moving parts inspected for wear and tear.

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