ANNEX 2 MAINTENANCE

AX2.1 INTRODUCTION

This Section, Annex 2, provides a general maintenance procedures/requirements for each of constructed stormwater infrastructure covered in this design workbook; quantity control, quality treatment BMPs and conveyance facilities. The asset owner of a stormwater drainage system is responsible for the lifecycle maintenance of the built system.

A maintenance activity should be prepared and included in the detailed design submission. It is a set of operating instructions for future property owners and/or occupiers. It should be clearly and simply set out and include the necessary information.

AX2.2 ON-SITE DETENTION

AX2.2.1 General

On-site detention (OSD) systems are intended to regulate flows over the entire life of the facilities. This cannot be achieved without some regular periodical maintenance to ensure they are kept in good working order and operate as designed. The task is to optimise the frequency of maintenance and make the job as simple as possible.

The majority of OSD systems, particularly those where a large proportion of the storage is located above-ground, will be able to be maintained by property owners, residents, or handymen. Larger below-ground systems, particularly those with limited access and/or substantial depth, may require the owner to engage commercial cleaning companies with specialised equipment.

The type of routine maintenance necessary to keep OSD facilities in good working order must be clearly and simply specified. Some of the issues that need to be addressed are:

- where the storages are located
- which parts of the system need to be accessed for cleaning and how access is obtained
- a description of any equipment needed (such as key and lifting devices) and where they can be obtained
- the location of screens and how they can be removed for cleaning

AX2.2.2 Maintenance Scheduling

The owner should be provided with advice on how frequently the system needs to be inspected and approximately how often it will require cleaning. The frequencies of both inspections and maintenance will be highly dependent on the nature of the development, location of the storage, and the occurrence of major storms. Suggested frequencies are provided in Table AX2.1.When inspecting OSD facilities, if any of following items are noticed, cleaning and/or repair should be undertaken:

- clogged outlet and obstructed inlets
- excessive deposits
- corrosion of metal parts
- deterioration of concrete
- any other damage or visible problems

Table AX2.1: Suggested Frequencies for Inspection and Maintenance

Premise	Frequency
Residential	Inspect system every 3 months and after heavy rainfall. Clean system as required, generally at least every 6 months
Commercial and Industrial	Inspect system every 2 months and after heavy rainfall Clean system as required, generally at least every 4 months

AX2.3 RAINWATER HARVESTING

Maintenance is generally involving regular inspection and cleaning of tanks, gutters and downpipes. Maintenance typically consists of the removal of dirt, leaves and other accumulated material. Cleaning should take place bi annually or before the start of the major rainfall season. Filters in the inlet should be inspected every about three (3) months. Cracks in storage tanks can create major problems and should be repaired immediately. Below are other maintenances in rainwater harvesting system.

AX2.3.1 Gutters

Every month, check for rusting or leaks in gutters. Use sandpaper and aluminum gloss paint to fix the rusting areas, and use silicon glue to repair leaks in the gutters. Make sure the gutters are secured to the wooden flashings and that the wood has not begun to rot (Figure AX2.1).

Figure AX2.1: Gutter Maintenance

If gutter screens installed, make sure the gutter screens are not damaged or clogged with leaves or dirt (Figure AX2.2). If the gutter screens are clogged, water will not flow into the gutter. Sweep the screens to clean them out. If the screens have been damaged, replace them. The screens are made of wire fly mesh that is cut into pieces and are long enough to cover the length of the gutter.

Figure AX2.2: Partially Clogged Gutter Screen

AX2.3.2 First Flush

After every rainstorm, the first flush must be cleaned out. Unscrew the end cap slowly and drain water from the pipes. Remove any debris that has collected at the bottom of the pipe. Screw the end cap back on, but not all the way so as to allow for the pipes to drain slowly during a storm. The slow drain prevents a build-up of pressure in the pipes.

AX2.3.3 Downpipe

Downpipe and outlets located in landscape areas should be inspected every six months to ensure that splash pad placement is correct and that there is positive drainage away from the outlet and adjacent buildings maintain a minimum of 2 percent slope for the first 1.5 m. Check for animal inhabitations and clogs. Check landscape growth every two weeks during growing periods to protect from overgrowth, which could obstruct

positive drainage. Flush gutters and downpipe once all debris is removed to wash away any remaining dirt or materials. Downpipe shall be checked if any leaking then fix it (Figure AX2.3).

Figure AX2.3: Leaking Downpipe

AX2.3.4 Tank

Every six (6) month, clean and disinfect tank to prevent slime, algae, bacterial growth, and the build-up of sediments. This will allow the tank to last longer and for the water to remain clean. When cleaning, do not enter the tank. To clean the tank, first drain all the water from the tank and close the tap. It is preferable to wait until the tank is almost empty (at the end of the dry season), to clean the tank. Wash and remove dirt from inside surfaces of the tank with water. Drain the wash water and sediment from the bottom of the tank by opening the spigot.

Use chlorination to disinfect the inside surfaces of the tank. Once the water inside the tank is chlorinated, let the chlorine solution sit in the tank for 3-5 hours, and then drain the tank completely. Now, fresh water can be added to the tank. Run the water from the spigot until there is no smell of chlorine, and then continue normal usage of the tank.

AX2.4 DETENTION POND

A detention pond, in common with other methods of stormwater quantity control, will prove effective only if it is maintained regularly. This requires a sound understanding of operational and maintenance requirements.

AX2.4.1 Consultation

It is important that lines of communication and contacts be established during the planning period and maintained thereafter, so that any problems regarding the operation, maintenance, or use of the detention pond can be brought to the notice of operational staff quickly and prompt action taken. It is also very important that the person or team responsible for the design liaises closely with and seeks the advice of the staff who will be responsible for its future operation and maintenance. A schedule of points covering operational, inspection, and maintenance requirements should be drawn up and agreed. This should cover questions of safety, access for personnel and plant, and methods of dealing with blockages and the possible failure of equipment or power supplies. Inquiries should be made about any problems experienced with previous installations and the design amended where necessary to devise improvements. On completion, the works must be handed over formally after ensuring that operational staffs are fully conversant with the installation, have been trained in the operation of special equipment, and are aware of all maintenance requirements.

AX2.4.2 Planned Maintenance and Inspection

The design storm for most detention ponds is a relatively rare occurrence and the pond and its outlet structures must be kept in good working order in the intervening period so that it performs satisfactorily when required. It is essential, therefore, that all detention ponds are subject to regular inspection and maintenance. In some circumstances, failure to carry out routine maintenance could result in blockage of the primary outlets and premature filling of the pond under normal flow conditions, leaving no storage available for flood control. It is

essential that the responsibility for future maintenance should be clearly established and formal arrangements should be drawn up for inspection and maintenance. In addition to basic engineering requirements, the arrangements must cover the amenity of the pond wherever recreational usage of the pond is provided. Inspection and maintenance must be carried out on a regular basis in order to minimise risks. The frequency and requirements for routine inspection will depend on the type and size of the pond, the local circumstances, and the type and complexity of the primary outlets. The frequency of inspections and maintenance visits may vary widely and should be reviewed continually in the light of any problems experienced on site and any long-term changes in maintenance requirements. A formal inspection and maintenance programme should be drawn up, staff allocated, and the duties and responsibilities confirmed in writing.

AX2.4.3 Grass Maintenance

Where embankments and/or spillways are subject to scour caused by high velocities of flow, regular mowing (at once a month) is required to keep the grass sward in good condition and discourage woody growth (Figure AX2.4). The depth of the grass for dry pond should be maintained 50 mm to keep the pond in better condition. Similar treatment is necessary in areas used for formal recreation.

Maintaining turf quality, where hydraulic protection is to be provided, requires a good supply of nutrients, which may require the use of fertilisers. The frequency of application depends on the quality of the soil. Normal soils may only require fertilising in the first year of growth while poor ones may demand annual treatment for a number of years. Some weeds can break up the turf cover and have serious effects on its ability to withstand erosive forces and must be controlled. Such weeds can be eradicated by using selective weed-killers.

Grass-cutting costs can be kept to a minimum (in areas used for formal recreation or where grass is used for scour protection) by keeping the slopes of embankments and other areas gentle enough for machine mowing. Equipment can operate on slopes of up to 4(H):1(V) but slopes of 6(H):1(V) or flatter are preferred.

Figure AX2.4: Maintaining Grass on Embankment

Engineered waterways upstream and downstream of a detention pond will require regular attention, particularly in urban districts. Banks below flood level should be mown where necessary to promote good grass growth, thereby providing protection against scour.

AX2.4.4 Thrash and Sediment Removal

All screens on primary outlets should be inspected and cleaned on a regular basis, particularly following a storm event. Particular problems can occur in urban areas where rubbish is often deposited in watercourses by residents. Any rubbish, debris, and silt should be removed in order to prevent the possible blockage of screens and primary outlet structures (Figure AX2.5).

Figure AX2.5: Primary Outlets Clogging

Regular removal of any accumulated silt and sediment from a detention pond is essential, particularly where the pond floor is used for recreational purposes. Removal of accumulated debris, trash, paper, etc. should take place every 6 months or so and vegetation growing within the pond should not grow taller than 0.5 m. No standing water should be allowed in the pond beyond a period of 72 hrs after a storm event. If such conditions occur, corrective maintenance should be undertaken (Figure AX2.6).

Figure AX2.6: Sediment Removal Work

AX2.4.5 Structural Repairs and Replacement

Inlet and outlet devices and riser structures have been known to deteriorate with time, and may have to be repaired and replaced (Figure AX2.7). The actual life of a structural component will depend on site specific criteria, such as soil conditions, type of construction, and frequency of operation.

Figure AX2.7: Structure Failure

AX2.5 INFILTRATION FACILITIES

Infiltration facilities, as with all BMPs, must have routine inspection and maintenance designed into the life performance of the facility. The principal maintenance objectives are to prevent clogging and groundwater contamination. Maintenance and inspection plans should be identified prior to establishment. Infiltration

facilities and any pre-treatment BMPs should be inspected after large storm events to remove any accumulated debris or material. A more thorough inspection should be conducted annually. A summary of inspection and maintenance activities is provided in Table AX2.2

Depending on the specific system implemented, maintenance should include at least the followings:

- inspect and clean pre-treatment devices biannually (i.e. before and after the wet season) and ideally after major storm events;
- once the infiltration system is operational, inspections should occur after every major storm for the initial few months to ensure proper stabilisation and function. Attention should be paid to how long water remains standing after a storm; standing water within the system for more than 72 hours after a storm is an indication that soil permeability has been over-estimated;
- after the first wet season, infiltration systems should be inspected at least biannually (i.e. before and after the wet season). Important items to check and clean or repair if required include: accumulated sediment, leaves and debris in the pre-treatment device, signs of erosion, clogging of inlet and outlet pipes and surface ponding;
- when ponding occurs, corrective maintenance is required immediately.

Table AX2.2: Typical Maintenance Activities

Activity	Frequency
Ensure the contributing drainage area, facility and inlets are clear of debris Ensure that the contributing area is stabilized Remove sediment and oil/grease from pre-treatment devices, as well as overflow structures Mow grass filter strips as necessary. Remove grass clippings	Monthly
Check observation wells following three days of dry weather. Failure to percolate within this time period indicates clogging Inspect pre-treatment devices and diversion structures for sediment buildup and structural damage Remove trees that start to grow in the vicinity of the trench	Semi-annual
Replace peat gravel/topsoil and top surface filter fabric (when clogged)	As needed
Perform total rehabilitation of the trench to maintain design storage capacity Excavate trench walls to expose clean soil	Upon Failure

Source : US EPA, 1999

In infiltration facilities, clogging occurs most frequently on the surface. Ponded water lasting more than 24 hours usually indicates that the facility is clogged. Grass clippings, leaves and accumulated sediment should be removed routinely from the surface. If clogging appears to be only at the surface, it may be necessary to remove and replace the first layer of filter media and the geotextile filter.

The presence of ponded water inside the trench after an extended period indicates clogging at the base of the trench. Remediation includes removing all of the filter media and geotextile envelope, stripping accumulated sediment from the trench base, scarifying to promote infiltration and replacing new filter media and geotexile. Vegetation can assist in prevention of clogging as the root network breaks up the soil and thereby promotes infiltration.

In the case of infiltration basins, sediment should be removed when it is sufficiently dry so that the sedimentation layer can be readily separated from the basin floor.

Maintenance responsibility for an infiltration facility should be assigned to a responsible jurisdiction or authority through a legally binding and enforceable maintenance agreement completed as a condition of the site plan approval.

AX2.6 BIORETENTION SYSTEM

Routine inspection and attention to maintenance needs are required if bioretention basins are to continue to function correctly. High maintenance levels are required for new systems, but once established and correctly operating maintenance requirements are expected to decline. The property's normal landscaping contractor, when provided with appropriate training, can be expected to successfully maintain an established bioretention basin.

AX2.6.1 Checklist

This checklist notes the key features to be inspected and maintained during operation of a bioretention basin.

- Sediment accumulation at inflow points
- Litter within basin
- Erosion at inlet or other key structures
- Traffic damage
- Dumping (e.g. building waste)
- Vegetation condition (density, weeds etc.)
- Watering of vegetation
- Replanting
- Mowing/ slashing
- Clogging of drainage points (sediment or debris)
- Evidence of ponding
- Damage/ vandalism to structures
- Surface clogging
- Drainage system
- Resetting of system

AX2.6.2 Frequency

Inspections should occur every 1 - 6 months, depending on the size and complexity of the system. The followings are suggested maintenance frequencies:

- Project completion: Water plants daily for at least two weeks

- As Needed
  - Re-mulch void areas
  - Mow turf areas
  - Treat plant diseases
  - Water plants throughout periods of persistent drought.
  - Removal of top two to three inches of discolored planting medium and its replacement with fresh mix, when ponding of water lasts for more than 48 hours.

- Monthly
  - Inspect basin to evaluate condition and problems needing maintenance attention.
  - Remove litter and plant debris.
  - Repair eroded areas.

- Twice per year: Remove and replace dead and diseased plants.

- Once per year
  - Add new mulch.
  - Replace tree stakes and wires if needed.

AX2.7 GROSS POLLUTANT TRAPS

AX2.7.1 General Maintenance

Appropriate maintenance is essential to ensure the long-term pollutant trapping efficiency of all GPTs. It is important in planning a catchment wide strategy for installing GPTs pollution control devices to make adequate provision for maintenance. A written maintenance plan should be prepared.

(a) "Soft" Trash Racks/ Litter Collection Devices (LCDs)

The "soft" trash racks/ LCDs are cleaned by removing each sock in turn, undoing the tie at the base of the sock and dumping the collected material into a truck. The base of the sock is then re-tied and it is slotted back into place. Due to the effectiveness of the socks it has been found that during periods of rainfall the LCDs may need to be cleaned every two to three days.

(b) Modified Trap Gullies

Modified trap gullies are suited to cleaning using eduction. While modified trap gullies can be maintained as part of a regular maintenance program particular attention should be given to assessing the need to clean trap gullies after storm events to ensure that trapped material is not flushed from the trap gully during a subsequent storm event. Experience to date suggests that trap gullies should be maintained on average monthly in urban areas and or more frequently in commercial areas.

(c) 'SBTR' Gross Pollutant Traps

The SBTR-type GPTs can be cleaned out using front-end loaders, backhoes and standard tip trucks. Eductor shall be carried out trucks, if available, can also be used to clean SBTR Type GPTs. A review of the maintenance issues including maintenance equipment, de-watering, access for maintenance equipment and cleaning, inspection program and cleanout frequency, costs and safety.

(d) Proprietary Traps

The appropriate cleaning frequency for proprietary traps should be discussed with the trap suppliers and where possible the experiences of operators should be reviewed to gain an understanding of the plant, manpower requirements and the likely frequency of cleaning required.

AX2.7.2 Maintenance Provisions

Maintenance provisions should be considered at the design phase of the GPTs as follows:

(a) Frequency

GPTs should be inspected monthly, as well as after every major rainfall event, to ascertain whether clean-out is required.

Cleaning frequencies depend on the sediment and litter loading generated in the catchment, generally for SBTR traps are cleaned twice per year, on average. Suggested cleaning frequencies for other types of GPTs are to be determined from operational experience under Malaysian conditions.

More regular cleaning may be required to facilitate ease of removal (i.e. if trapped material becomes compacted and hard to remove; or if specialised equipment is not available), or if litter loads are excessive.

(b) Need for Special Equipment

Designs should be based on cleaning operations being undertaken with plant and equipment including;

- eductor truck;
- backhoe or front-end- loader;

- truck;
- pump and generator; and
- truck mounted crane.

Some designs require more specialised equipment, such as eductor trucks. Such equipment may be introduced into Malaysia during the life of this Manual, subject to discussions and approval by the regulatory authority to suit local conditions and contractor's expertise.

(c) De-watering

GPTs will need to be de-watered from time to time either as part of their general operation or for maintenance purpose. Usually this is done with portable pumps. Water released to stormwater drains or directly to receiving waters should not threaten environmental values and should therefore be consistent with locally applicable water quality objectives.

Prior to pumping out the supernatant water, the SBTR may be dosed with a non-toxic flocculating agent to promote settling of colloidal particles.

The following methods are alternatives that can be used for the disposal of poor quality supernatant water that is retained within the trap:

- *Via Infiltration or Filtration On-site* - The trap may be designed to allow supernatant water to be pumped to a de-watering area on site. The water could either be infiltrated on a grassed area, or filtered through geo-fabric and allowed to drain back to the waterway. An infiltration trench may be included to enhance water polishing and/or permit groundwater recharge.

  Such design shall;

  - have a suitable de-watering and sludge handling or drying area;
  - have stabilised banks to prevent erosion; and
  - not constitute a health hazard.

- *Direct to Sewer* - The SBTR trap may be designed, if necessary, to allow de-watering by pumping supernatant water to a nearby sewer (with the approval of the local sewerage agency). Where there is a sewer line within 200 metres of the facility, the sewer should be extended to provide a manhole with a bolt-down lid adjacent to the SBTR. This will enable the decanted supernatant to be pumped to the manhole and thence to the sewer.

- *Via Tanker* - Where there is no sewer available, provision shall be made for the decanted supernatant to be pumped to tanker for treatment and disposal by a licensed waste management operator.

AX2.8 WATER QUALITY POND AND WETLANDS

AX2.8.1 General Maintenance

As with any constructed facility, ponds require regular ongoing operation and maintenance. General maintenance including lawn mowing, rubbish removal, and inspection should be carried out at regular intervals not exceeding once every two weeks.

Structures such as GPTs, embankments, inlets, outlets, spillways and culverts must be routinely inspected for serviceability, safety, and cleaning and removal of trapped rubbish and sediment. Safety measures such as fences, booms and warning notices must be routinely inspected to ensure that they are in good working order. General guidelines for operation and maintenance of detention ponds are given in earlier section of this Annexure.

AX2.8.2 Aquatic Vegetation

Maintenance during the plant establishment phase is critical because it is during this phase that plants are most vulnerable to damage. Low water level, weed invasion, and damage by animals are possible causes of problems. Plants should be inspected at least weekly during the initial phase in order to detect any damage and allow corrective action. Aquatic plants should be inspected periodically to control pest species and to promote the desired mix of plants for conservation and landscape purposes. Occasional replanting may be necessary to maintain the desired mix of species.

It is not appropriate to regularly harvest macrophytes. The disturbance created by the harvesting process introduces the risk of remobilising sediments and nutrients, and introducing weed species.

AX2.8.3 Eutrophication and Other Problems

Under certain climatic conditions, nutrient enrichment of pond water can cause abundant plant and algal growth. The resulting algal blooms are unsightly and damaging to public health and can cause fish kills and episodes of poor water quality. The following conditions are most likely to encourage eutrophication:

- excessive nutrient loadings in inflows;
- high average temperatures and abundant sunshine;
- still water; and
- clear water (low turbidity).

Pond designers should try to avoid these conditions. For example, it may be inappropriate to locate a pond downstream of an oxidation pond discharge, which is rich in nutrients. In many parts of Malaysia the high turbidity of surface waters helps to prevent eutrophication by preventing sunlight penetration.

However, high turbidity promotes another problem, which is water column stratification. Heated surface waters become lighter than the bottom waters, effectively preventing any mixing. The resulting physical barrier prevents oxygen transfer to the bottom layers, which typically become deoxygenated. Deep ponds may be prone to stratification. There is a rapidly increasing body of scientific knowledge of both of these problems and there are methods, such as mechanical mixing, to overcome them. If any ponds are found to be subject to these problems specialised technical advice should be sought.

AX2.9 CONSTRUCTION EROSION AND SEDIMENT CONTROL BMPS

Sediment basin, the most important BMPs facility in construction stormwater quality control, requires routine maintenance to remain effectiveness as sediment traps. When sediment reaches the maximum level assumed in the design, (usually one-third to one-half the basin volume) it must be removed. Excavated sediment must be placed in a location where it will not easily be eroded again. In addition to sediment cleanout, sediment basin should be inspected after storms to determine whether the embankment or spillways sustained any damaged that requires repair. If the outlet becomes clogged with sediments, it should be cleaned to restore its flow capacity.

The structure should be inspected after significant runoff events to check for the damage or operational problems. Once the contributing drainage area has been stabilized, the structure can be removed or if possible, modified to become part of permanent control features.

Below are other BMPs need to be checked and maintained to make sure the sediment control is working effectively:

- Stabilisation
  - Inspect monthly and after significant rainfall;
  - Re-anchor loosened matting and replace missing matting and staples as required;
  - Inspect periodically and after every significant rainfall; and
  - Repair as necessary.

- Water crossing
  - Inspect weekly and after each significant rainfall, including assessment of foundations;
  - Periodically remove silt from crossings; and
  - Replace lost aggregate from inlets and outlets of culverts.

- Road
  - Periodically apply additional aggregate on gravel roads;
  - Dirt construction roads that are in constant use are commonly watered three or more times per day during the dry season;
  - Inspect weekly, and after rainfall; and
  - Repair any eroded areas immediately.

- Diversion Channel
  - Inspect weekly and after each rainfall;
  - Repair any erosion immediately; and
  - Remove sediment, which builds up in the channel and restricts its flow capacity.

- Slope Drain
  - Structure must be inspected regularly and after rain;
  - Inlet must be free of undercutting and water should not circumvent the entry;
  - Outlets should not produce erosion; velocity dissipators must be maintained; and
  - Pipe anchors must be checked to ensure that the pipe remains anchored to the slope.

AX2.10 PAVEMENT DRAINAGE

Inlets shall be checked and cleaned regularly, to prevent an accumulation of litter and debris, which may cause blockage. Sag locations are particularly susceptible to blockage. Curb and inlets should be cleaned at least twice a year to ensure their proper function. If only one cleaning is possible it should occur prior to the rainy season. Water can pond on the outside edge of the travel way surface when debris, particularly aggregate and soil on turf shoulders, builds up. As debris accumulates on the shoulder, it raises the level of the edge, and eventually hinders run-off from flowing into side ditches or inlets.

Water ponding on the edge of the pavement contributes to the deterioration of the pavement edge and the rutting of stabilized soil supporting the pavement edge, which can result in additional safety hazards (Figure AX2.8). Edge drop-offs and shoulder scour are often caused when water is trapped at the pavement edge by the build-up of debris and vegetation growth.

Figure AX2.8: Deterioration of Pavement Edge

Drainage features that fail to remove run-off because they are too small or are clogged and pond water on the roadway can cause hydroplaning or force drivers to leave their lane (Figure AX2.9). Additionally, other

drainage features which do not have anything to do with causing a crash can significantly contribute to the severity of the crash, such as an errant vehicle striking a culvert headwall.

Figure AX2.9: Clogging Inlet

AX2.11 DRAIN AND SWALES

a) Lined Drain

Lined open drains will require periodical maintenance to remove weed growth, sediment deposits, and debris and litter accumulation to maintain the designed hydraulic capacity of the drain. Damaged linings or displaced joints or strut beams should be repaired as soon as practical to prevent further deterioration or failure of sections of the drain.

b) Swale

Periodical maintenance will be required to maintain the hydraulic capacity of a swale. Grass should be regularly mown and sediment, litter, and debris deposits removed, particularly at flow restrictions such as vehicular crossing points. The suitable depth of grass to remove pollutants is about 150mm.

Bare patches and scoured areas must be repaired by removing dead grass, filling scour holes, and reseeding with a recommended permanent grass seed mix.

AX2.12 PIPED DRAIN

A well-maintained pipe drain system will be ready to convey the runoff from the next storm with minimal damage to the storm drainage facilities. A poorly maintained drainage system may not be able to function at its design conveyance and could be damaged by the runoff.

The owner of the facilities should establish a routine maintenance inspection program once the facility has been completed and placed in service. The inspections should be conducted on an annual or semi-annual basis, as well as following major storms. The inspections may be accomplished by visual means or by using a television camera, where applicable.

The inspection should be documented. Items to be recorded should include size and type of facility, date of inspection, location of facility, minor deficiencies, major deficiencies and areas of possible future problems. The documentation should be kept current and when any repair work has been accomplished, it should be recorded. Right-of-way constraints frequently dictate use of a piped drainage system, which in turn create particular maintenance constraints.

The maintenance shall include the followings:

- Debris control – Trash racks should be cleaned regularly to keep accumulations from forming. In-pipe debris should be removed if it is large enough to create a flow obstruction.

- Overflow channel maintenance – If the pipe system was designed with a surcharge or overflow channel it deserves occasional attention. It must be kept clear of excessive vegetation. In general, it should be maintained as an open channel to be ready to function when called upon.
- Inspection – A regular in-pipe inspection of piped drainage systems will detail long term changes and will point out needed maintenance work such as debris removal or joint patching. Special attention is necessary to insure the safety of the inspection team if the pipe is long. Small pipes that carry continuous flow can be viewed with automated equipment. Inspections should be done following major runoff events. Inlet grates should be checked for clogging and catch basins and pipes for sediment/waste blockage.

Typical problem areas then can signal the need for repair of a piped system include:

- Inlet and outlet structures – Local erosion to high velocities, lack of protection, or transition turbulence.
- Trench backfill – Subsidence of the trench, which can result from poor initial compaction or from pipe or joint failure. Earth settlement around manholes is a frequent indicator of compaction problems.
- Pipe joints – The first sign of problems in the system shows at the pipe joints. Spalled concrete, cracks, distorted pipe geometry, backfill movement and water inflow occur at the joints and are precursors of greater problems to come.

AX2.13 ENGINEERED CHANNEL

The owner of an engineered waterway should establish a routine maintenance inspection program once the facility has been completed and placed in service. The inspections should be conducted on an annual or semi-annual basis, as well as following major storms.

The following guidelines are general requirements for the maintenance of all engineered waterways:

- *Mowing* - Grassed waterways should be mowed often enough to maintain appearance and to control weeds.
- *Debris control* - Debris blockage at drainage structures often contributes to flooding problems. Structures such as inlet pits, headwalls, trash racks, and debris traps should be regularly cleaned. Debris should also be regularly removed along the length of the waterway. This should include trimming and thinning of trees if they encroach on the waterway main channel or if they have become overgrown.
- *Sediment and silt removal* - Some silt accumulation in energy dissipation structures and around waterway obstructions is inevitable and is harmless in limited amounts. Silt should be removed if it is severe enough to alter the water surface or affect the function of structures such as drops and culvert inlets. Silt accumulations can also cause trouble by supporting undesirable or obstructive vegetation.

  Sediment traps will need regular removal of trapped material to protect downstream facilities.
- *Access road and footpath repair* - Damaged access road and footpath sections should be repaired to ensure continued maintenance access and better pedestrian use.
- *Vandalism* - Drainage facilities can be attractive nuisances and can be damaged by those who use the area. Preventive measures may be necessary, to keep graffiti off walls, to keep rock riprap from being relocated, or to keep gabion baskets from being cut open.

AX2.14 BIOENGINEERED STREAM

Bioengineering is a stream bank stabilization technique that uses natural materials such as grasses, shrubs, trees, roots, and logs to divert water away from eroding banks, and stabilize the bank. Bioengineering is the preferred method of stream bank stabilization, and is permitted without notification where no work is done in stream with mechanized equipment; and where the work is done in accordance with an approved bioengineering plan.

In order to maintain bioengineered stream the following action must be taken into consideration:

- Check banks after every high-water event.
- Fixing gaps in the vegetative cover at once with structural materials or new plants.

- Mulching if necessary.
- Fresh cuttings from other plants may be used for repairs.

AX2.15 PUMP

Pump stations are vulnerable to a wide range of operational problems from malfunction of equipment to loss of power. Monitoring systems such as on-site warning lights and remote alarms can help minimise such failures and their consequences. Telemetry and SCADA system are options that should be considered for monitoring critical pump station. Operating functions may be telemeter from station to a central control unit. This allows the central control unit to initiate corrective actions immediately if a malfunction occurs. Such functions as power, pump operations, unauthorised entry, explosive fumes, and high water levels can be monitored effectively in this manner. Perhaps the best overall procedure to assure the proper functioning of a pump station is the implementation of a regular schedule of maintenance conducted by trained, experienced personnel.

Since major storm events are infrequent, a comprehensive, preventive maintenance program should be developed for maintaining and testing the equipment so that it will function properly when needed. Instruments such as hours-run meters and number-of starts meters should be used on each pump to help schedule maintenance. Regular inspections as well as disassembly inspections should be conducted in conjunction with regular inspections to prevent any accidents from occurring. The following list will explain the basic maintenance procedures as well as detailed explanations regarding inspections and troubleshooting :

- A maintenance reference guide with details regarding the appropriate frequency and time intervals between inspections and part replacements should be created to assist with maintenance activities and smooth accident free operation;
- Create daily and monthly logs, and enter information regarding maintenance inspection etc. Always make note of condition of the machinery;
- Classify each unit and create a log to record detailed information on inspections, maintenance activities, repairs and other problems for future reference; and
- Organise and store special tools used for repairs and maintenance, spare parts and consumables so they will be readily available if needed.

Most of the pump suppliers will provide together with the pump the checklist, maintenance and service manuals for reference during the operation period.

All elements of the pump station should be carefully reviewed for safety of operation and maintenance. Ladders, stairwells and other access points should facilitate use by maintenance personnel. Adequate space should be provided for the operation and maintenance of all equipment. Particular attention should be given to guarding moving components such as drive shafts and providing proper and reliable lighting. It may also be prudent to provide air-testing equipment in the station so maintenance personnel can be assured of clean air before entering. Pump stations should be classified as a confined space. In this case, access requirements along with any safety equipment are all defined by code. Pump stations should be designed to be secure from entry by unauthorised personnel.

AX2.16 CULVERT

Poorly working culverts can cause flooding that significantly damages roads and bridges. A crushed or plugged culvert allows water to back up in roadside ditches, even during normal wet weather. This contributes to road deterioration because standing water prevents drainage from the road base and subgrade. Culverts should be inspected at least once a year. The elements for culvert inspection as listed below:

- Check the accumulation of debris, siltation or other flow impedimentsat inlets and outlets;
- Inspect the culvert barrel, if possible, for tree or other vegetation roots, mineral deposits, trash or silt accumulations and other foreign objects obstructing flow paths;
- Examine inlet and outlet areas for evidence of soil erosion, which generally leads to scour, undermining and caving of adjacent soil supporting the culvert. Soil erosion quickly leads to reduced structural and hydraulic performance;

- Inspect all visible structures such as sumps, headwalls, wing walls, culverts and aprons for sign of wear or breakage;
- Check upstream for evidence of backup or prolonged surface water presence that indicated reduced inflow. Check downstream for evidence of foreign material that indicate reduce filtration of soil or structural degradation of drainage system itself;

Figure AX2.10: Maintenance Work for Culvert