

CONSTRUCTION AND OPERATION AND MAINTENANCE GUIDELINE FOR STORMWATER TREATMENT DEVICES

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ABSTRACT

The Auckland Regional Council is reviewing Technical Publication 10 (TP10) Design Guideline Manual for Stormwater Treatment Devices. Experience shows that many stormwater treatment devices are not functioning correctly due to poor design, inappropriate construction methodologies or insufficient maintenance.

Consultation with industry identified a number of issues regarding construction and maintenance. To adequately address these issues, separate volumes have been prepared for construction of devices, and on operation and maintenance (O&M). These new volumes aim to address the shortfalls around evidential construction and maintenance issues, and to increase awareness of construction, operation and maintenance constraints during the design process.

The new volumes provide information to designers and contractors. Initial sections cover generic considerations, consents and other legal compliance, construction specifications, documentation, monitoring and technical guidance. Each volume then provides a chapter for each stormwater device in TP10. The construction volume provides key components, standards, construction considerations and example specifications. The O&M volume provides guidance on O&M manuals, recommended actions and frequency and troubleshooting.

This paper showcases the rain garden chapter from design through to construction including contract documents, specifications and monitoring. This is followed by key issues to consider for operation and maintenance including maintenance schedules and auditing.

KEYWORDS

Stormwater, treatment devices, construction, operation, maintenance, TP10

PRESENTER PROFILE

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1 INTRODUCTION

The Auckland Regional Council (ARC) provides guidance on the design of stormwater treatment devices through Technical Publication 10 (TP10) Stormwater management devices: Design guidelines manual (Auckland Regional Council, 2003). TP10 provides guidance for design of stormwater treatment devices (STD) and also provides design philosophy for stormwater management, a method for evaluating devices not included in TP10, and construction and maintenance checklists. TP10 was first published in 1999, with the current version being the second edition, published in 2003. It is considered timely to review TP10 for several reasons, including new information that has become available since the current version was published, and experience is showing there are problems arising with implementation of design in the field. Problems in the field are arising from design failing to consider construction and maintenance requirements, and construction faults due to a lack of understanding of the functions of stormwater treatment devices.

The revised TP10 will be released as Guideline Document (GD)01, and is being divided into several volumes to allow tailoring of the volumes for the needs of the intended audience, more focused content of the volumes, and ease of future revisions of individual volumes. The proposed volumes are Stormwater Management Principles (Vol. 1), Stormwater Treatment Device Design (Vol. 2), Construction – Specifications (Vol. 3), Operation and Maintenance – Specifications (Vol. 4) and Landscaping (Vol. 5) which includes planting lists, biodiversity guide etc. As an interim measure while the revision of TP10 progresses, sections of the review that are completed will be published by the ARC as Technical Reports. This paper describes the Construction Technical Report and the Operation and Maintenance Technical Report, which will become Vol. 3 and 4 of the revised GD01.

It is intended that having expanded guideline information on construction and operation and maintenance (O&M) will both improve industry knowledge around these factors and improve design by alerting designers to issues that need to be addressed during the design phase. The project brief for these Technical Reports included requirements that international best practice was considered through literature reviews, that local knowledge and learning was captured through consultation with Territorial Authority staff and industry, and that clear, concise and readable guidance was produced.

This paper outlines the process and key findings for the literature review and consultation, followed by an overview of the Technical Report formats and showcases the construction and operation and maintenance chapters on rain gardens.

2 CONSULTATION AND LITERATURE REVIEW

Essential first steps in determining industry needs and understanding solutions to common problems in constructing or maintaining stormwater treatment devices was to undertake a literature review and consultation with industry. These steps identified real world issues and solutions, and advances in technology and management approaches.

2.1 LITERATURE REVIEW

To understand changes in best management practices and technological advances in relation to stormwater treatment devices, a national and international literature review was conducted. In particular, guidelines and standards from municipal authorities

overseas were reviewed and information on construction and maintenance best management practices collated. Published information on site specific studies was also reviewed to gain an understanding on the issues that can be faced when constructing or maintaining a specific device and solutions to common problems.

One key theme regarding construction found in the literature review was the need for site investigations to be carried out to ensure that the design meets site specific requirements prior to construction and also at critical points during the construction process. This allows for design issues to be addressed immediately and rectified before the device goes live.

Maintenance issues tend to arise from lack of knowledge regarding the function of the device. For example many stormwater treatment devices end up being maintained as landscape features (e.g. rain garden maintained as civic flower bed). Budget constraints and lack of formal hand over procedures of devices to owners (particularly Council) also mean that devices do not get put on maintenance schedules and ultimately fail in the function they were designed to deliver.

2.2 CONSULTATION

Consultation was undertaken with a broad spectrum of industry professionals to gain an understanding of the level of knowledge and gaps in knowledge regarding construction and operation of stormwater treatment devices and to identify the key issues faced in constructing or maintaining a device.

During the process of consultation, it became apparent that the gap in information relating to the construction, operation and maintenance of the devices was only one portion of the issues relating to stormwater treatment in the Auckland region. Key points that were raised during consultation included:

- The need for clarification of the regulatory role of the ARC and Territorial Authorities. It is anticipated that this need will remain following formation of the Auckland Council, with different departments having different responsibilities.
- The need for continuation of increased consultation and communication between Council departments.
- General lack of understanding across all stakeholders as to how stormwater treatment devices work and a general need for training across all aspects of stormwater treatment.
- It is perceived that there are too many documents that are required to be followed for the design (e.g. both TP10 and local Council guidelines).
- The level of audience's understanding changes depending on the type of device and was therefore tailored in the guidelines.
- Generally, construction is not problematic when adequate plans and specifications are provided.
- Operation and maintenance, particularly in relation to ponds and wetlands, is problematic, with limited guidance on maintenance issues.
- It is important that the guidelines do not duplicate existing information and it is important that design, review and approval are carefully considered.

3 TECHNICAL REPORTS FORMAT

The Technical Reports followed similar formats for ease of use and were written for the target audiences as determined through consultation. The first sections of the construction, and operation and maintenance reports discuss generic information applicable to all types of devices. Each device has a chapter which outlines specific information related to the device.

The device specific chapters use language that is most suitable for the target audience. For example larger devices (e.g. wetlands) or manufactured devices (e.g. sand filters) tend to be constructed and maintained by experienced contractors who have a strong understanding of good construction and maintenance practices while smaller devices (e.g. rain gardens or swales) may often be constructed by contractors not used to dealing with stormwater treatment devices (e.g. landscapers) or maintained by residential home owners. The devices addressed by the specific chapters are listed in Table 1.

Table 1: Stormwater treatment devices included in the Technical Reports.

Stormwater ponds	Oil and water separators
Wetlands	Permeable paving
Rain gardens	Rain tanks
Tree pits	Green roofs
Swales and filter strips	Infiltration dry wells and trenches
Sand filters	

3.1 CONSTRUCTION TECHNICAL REPORT

The Construction Technical Report starts with generic sections relating to the construction of stormwater treatment devices. These include:

- Construction considerations (e.g. sequencing, seasonal constraints, health and safety, geotechnical conditions)
- Requirements for construction drawings and as-built drawings
- Consent, permits and approvals (e.g. resource consents, building consents and other permits like road opening notices)
- Construction contracts (e.g. types of documents, responsibilities, legal considerations)
- Construction specifications (e.g. how to prepare, applicable standards or regulations, what to include)

- Completion documentation (e.g. final inspections, as-built drawings, operation and maintenance manual)
- Construction monitoring (e.g. roles, critical success factors, remote monitoring and compliance)
- Contractor compliance (e.g. evidence or information to request from contractors to demonstrate compliance).

Following the generic front section are chapters specifically discussing each management device, as listed in Table 1. These chapters build on the generic information and offer specific device information for construction. Each device chapter is structured in a similar format for ease of use. Each chapter provides the following information:

- Device description which identifies how the device functions, key components of the device and their function, a 'typical' device diagram showing components and information on device varieties;
- Applicable guideline documents, standards and codes of practice specific to the device;
- Specific construction considerations for the device;
- Items to consider when developing construction specifications with an example provided in the appendix as a 'starter specification';
- Critical points during construction where inspections and monitoring should be completed to ensure the device is installed correctly and any design issues can be addressed; and
- A photo gallery which showcases good and bad examples of device construction (particularly those with underground components not normally seen).

3.2 OPERATION AND MAINTENANCE TECHNICAL REPORT

The O&M Technical Report has a slightly different audience from the Construction Technical Report. Those who carry out maintenance often come from wider backgrounds that include horticulture and roading maintenance and may not be familiar with stormwater management approaches and specific treatment devices.

The generic sections of the operation and maintenance Technical Report include:

- Identification of relevant regional technical guidelines, which may include requirements for operation and maintenance manuals;
- Role and benefits of operation and maintenance manuals including recommendations for information to be included in manuals; and
- Legal compliance requirements which lists relevant legislation, standards and information of compliance auditing and monitoring (often consent and or contact requirements).

The device specific chapters follow the same format for ease of use and referencing different sections. Each chapter contains:

- A description of the device, how the device functions, key components of the device and their function, a 'typical' device diagram showing components and information on device varieties;
- Discussion on how the location of a device can impact on maintenance, for instance all weather access and upstream catchment activities (e.g. earthworks);
- Specific content and format of a device operation and maintenance manual (e.g. log book, list of maintenance procedures and how to carry out common maintenance tasks);
- A typical maintenance schedule, including recommended actions in easy to understand instructions, frequency for maintenance and information on unplanned or emergency maintenance;
- Troubleshooting advice on common problems, as identified during consultation and in the literature review, including possible causes and remedies;
- Specific auditing and or monitoring requirements related to the device which may be a requirement of consent or a maintenance contract; and
- A photo gallery which shows good and bad examples of device operation and maintenance and effects of improper maintenance.

4 RAIN GARDENS

Rain gardens have been steadily applied across the region to meet stormwater quality requirements. Most Councils have some in public civic areas and reserves to treat stormwater from impermeable surfaces and on private properties. Issues surrounding rain gardens usually occur during construction because plans are not detailed enough nor do the designs consider site specific requirements. There is also a general lack of understanding among contractors regarding the function of a rain garden, which contributes to the problems that arise during construction and ongoing maintenance.

Perhaps the biggest problems reported by those consulted are related to the soil, specifically the soil mix required for permeability and treatment, the level of the soil to ensure a live storage volume within the rain garden, and clogging due to lack of protection or improper sequencing during construction. Many people spoken to had numerous stories of rain gardens having to be dug up and re-constructed due to incorrect construction and use of materials. Maintenance activities can also change the function of the rain garden particularly if those carrying out the maintenance do not understand its function, particularly that of the ponding area.

Rain gardens can either be used to treat stormwater before discharge to the reticulated stormwater network or discharge to surrounding soil and soakage. Auckland, Rodney and Franklin all identify soakage and lack of aquifer recharge as a particular issue for their regions and rain gardens have been identified as a management approach to achieve aquifer recharge.

4.1 RAIN GARDEN CONSTRUCTION TECHNICAL REPORT

The rain garden chapter of the Construction Technical Report provides guideline information directly related to the construction of rain gardens.

4.1.1 DEVICE DESCRIPTION

This Device Description section is essential for educating readers on the core functions of a rain garden and how each component comes together and provides overall treatment. The primary rain garden functions are:

- To filter stormwater runoff to remove pollutants;
- To retain runoff to alleviate flooding;
- To provide aesthetic value; and
- If appropriate, to recharge aquifers or discharge treated runoff directly to open water bodies.

The primary components in a rain garden design should include the following; however site specific constraints or issues should take precedence and dictate the design parameters:

- Grass buffer strip (not always included) to provide interface between impermeable surface and the rain garden. They often provide the first stage of filtration and promote sheet flow.
- Ponding area is the holding area for stormwater to seep into rain garden soil mix.
- Mulch layer to prevent weed establishment and keep plants from drying out.
- Rain garden soil mix, a special mix of sand, topsoil and compost (no clay), that allows for a particular rate of filtration and treatment.
- Sand layer (if included) provides additional filtration and assists in confining rain garden soil mix within the rain garden.
- Underdrain system which collects filtered stormwater and discharges it to a reticulated stormwater network or receiving water body. Underdrains are not usually used if the rain garden is designed for infiltration into surrounding soil.
- Overflow system removes excess runoff from the ponding area and discharges directly to the stormwater network.
- Plant selection is particularly important in rain gardens as they are exposed to both extreme wet and dry conditions so must be resilient. Native species are often well suited to these conditions.

4.1.2 GUIDELINES, STANDARDS AND TECHNICAL DOCUMENTS

The guidelines, standards and technical documents listed are particularly relevant to the construction of rain gardens. These lists are not exhaustive and the documents are subject to change, however it shows the breadth of relevant information that may need to be reviewed when constructing a rain garden. Tables 2 and 3 show selected documents from the rain garden chapter of the Construction Technical Report.

Table 2: Sample of guidelines relevant to rain garden construction in Auckland

Publisher	Title	Description
ARC	TP90 Erosion and Sediment Control Guidelines for Land Disturbing Activities in the Auckland Region	These guidelines outline the principals of erosion and sediment control and control measures that should be used.
LTSA	Integrated Stormwater Management Guidelines for the New Zealand Roding Network	Provide guidance on a range of issues relating to the management of stormwater run-off from state highways and local roads in New Zealand.
NSCC	LB204 Rain Gardens	Practice note describing the benefits and site considerations for rain gardens used to treat stormwater from small catchment areas.
NZWWA	On Site Stormwater Management Guideline	Provides guidance on the design of on-site stormwater management devices for the majority of applications in New Zealand.
WCC	Stormwater Solutions for Residential Sites	Document providing guidance on management practices applicable to developments on individual residential lots (<1000m ²). For use by engineers and applicants for stormwater control building permits for developments of this size.

Source: AECOM, 2009a

Table 3: Sample of standards and technical documents relevant to rain garden construction in NZ

Title	Description
AS/NZS 2566.2:2002 Buried Flexible Pipelines – Installation	Specifies requirements for the installation, field testing and commissioning of buried flexible pipelines with structural design in accordance with AS/NZS 2566.1.
NZS 7643:1979 Code of Practice for the Installation of Unplasticized PVC Pipe Systems	Details requirements for the installation of uPVC pipes.
SNZ HB 2002:2003 Code of Practice for Working in the Road	This Handbook deals with aspects of the roles and responsibilities of Road Controlling Authorities, principal providers, utility operators and contractors; consents and work approvals; and details of construction requirements; for the purpose of installation and maintenance of utilities within the road corridor.

Source: AECOM, 2009a

4.1.3 RAIN GARDEN CONSTRUCTION CONSIDERATIONS

Knowledge on how a rain garden functions and clear construction plans can prevent many of the problems that arise once the rain garden is operational as they can be rectified during construction. There are many considerations throughout the construction process; a selection have been identified here.

Perhaps one of the first considerations is the physical location of the rain garden. A rain garden should be located close to the source of runoff (e.g. adjacent to a road) and away from steep slopes. If the location is not suitable this should immediately be discussed and confirmed with the Project Engineer and client. Retaining walls and edge beams may need to be added depending on site constraints.

The rain garden should not be installed whilst other works are still underway within the catchment unless they will be protected from potential debris and siltation (refer 2010 Stormwater Conference

Photograph 1) as they are sensitive to clogging. Most importantly, rain garden media should not be placed before the carriageway is hot mixed and chip sealed. Depending on the location of a rain garden, safety fencing may be necessary to exclude the public and prevent vehicles from driving over it during construction. Many rain gardens have had to be rebuilt as a result of uncontrolled discharges of sediment laden runoff from surrounding construction and earthworks activities clogging the soil media in the rain garden.

Photograph 1: Constructed rain garden showing sand bags blocking inlets for protection.



Rain garden levels must adhere to the plans and specifications. Soil and mulch levels are designed to be lower than the overflow outlet and lower than surrounding ground level so that the required ponding depth can be maintained. The ponding captures the first flush of a rain event and allows the water to percolate through plant roots and soil to remove sediment and pollutants. Levels must be checked during construction.

4.1.4 RAIN GARDEN CONSTRUCTION SPECIFICATIONS

Specifications are an integral part in any construction project and provide the contractors with the information they need in order to construct the rain garden as it has been designed. Example specifications are provided in the Technical Report, which excludes particulars such as site establishment, health and safety, testing, materials, and reinstatement. These are designed to be used as 'starter specifications' for guidance only.

As an example, rain garden specifications must include information on the diameter, size and type of overflow system (suggesting supplier or model may be appropriate). The specification should include details of the underdrain pipe including diameter, type of perforated pipe and whether a filter sock or cloth is required. The exact composition of the rain garden soil mix and or supplier must be documented as this is paramount to the effective operation of the rain garden.

4.1.5 RAIN GARDEN CONSTRUCTION MONITORING

Monitoring and regular inspection during the construction process will ensure the rain garden is installed correctly. The Technical Report identifies critical points during construction where checks should be made and details what needs to be checked. For example, once the rain garden has been excavated the levels should be checked to ensure they match the construction plans. If there are problems either with achieving the levels specified or the levels will not provide the treatment required, it must be discussed with the design engineer or project manager before progressing.

Another critical point to monitor is the installation of the underdrain (where required). Photographs at this stage of construction can be put into the operation and maintenance manual (refer Photograph 2) or used in construction progress reports as it can help with future operation and maintenance troubleshooting. Connections to the stormwater system and overflow structure must be water tight and care must be taken when backfilling not to crush the underdrain. Gravel backfill should be manually placed in the rain garden rather than dropped from height by a digger.

Photograph 2: Excavated rain garden showing underdrain and impermeable liner installed.



4.2 RAIN GARDEN OPERATION AND MAINTENANCE TECHNICAL REPORT

The rain garden chapter of the O&M Technical Report provides guideline information directly related to the operation and maintenance of rain gardens.

4.2.1 DEVICE DESCRIPTION

The description of a typical rain garden, how it functions and the components is very similar to that used in the Construction Technical Report. The language is often adjusted to be better understood by the audience as this can vary from the audience for the Construction Technical Report.

This section provides information on how the location of a rain garden can influence maintenance and the life span of a rain garden. The life span of any rain garden is directly influenced by the contaminant loads being captured and treated and catchment activities which can decrease the effectiveness of a rain garden. A properly maintained rain garden can last upwards of 10 years.

4.2.2 OPERATION AND MAINTENANCE MANUALS

Operation and maintenance manuals are often required as a condition of consent. Even if they are not, an operation and maintenance manual is very useful in documenting design and construction information of the device and providing methodologies for maintenance procedures. Typically an operation and maintenance manual should

contain a section for the log book to record inspections and maintenance activities, technical information on the design and construction of the rain garden, and a section for all the maintenance procedures which detail methodology and frequency.

The technical information can assist in troubleshooting any problems associated with the operation of the rain garden. Typically this section would include contact information and responsibilities of key people (e.g. owner, maintenance contractor), design details (e.g. levels, inverts, contributing catchment), as-built plans and construction photos.

The procedures section should provide a maintenance schedule with instructions on how to carry out tasks. This section can form the basis of a maintenance contract. Any reporting or monitoring requirements, often a condition of consent, should also be identified as a task and scheduled.

4.2.3 MAINTENANCE SCHEDULES

Rain gardens require regular inspection and maintenance to ensure they continue to operate effectively. One year after construction is complete, a full inspection of the rain garden, including all the operational and visual features, should be conducted. As part of the full inspection, a flow test should be performed to confirm that the underdrain is still working properly and that the rain garden drains down within 24 hours. Council may require a CCTV report for the underdrainage for the full inspection. This may coincide with the end of a construction maintenance period.

The Technical Report provides a schedule for maintenance actions for the typical components of a rain garden. The maintenance frequency provided in the TR is the recommended minimum. Rain gardens should be inspected after storms to ensure that any damage is fixed immediately. In most cases an operation and maintenance manual that covers detailed maintenance specific to each rain garden will be produced by the designer / owner of the rain garden. A good maintenance schedule will explain how inspections or certain tasks should be completed. For example, to check the surface of the rain garden for blinding (sealing of the soil surface) look for a crust of fine sediment on the surface of the soil or mulch. If present remove the crust and rework the top layers of rain garden soil mix. If necessary, top up with extra soil mix and mulch ensuring that final level is between 200mm and 300mm below the surrounding hard surfaces.

4.2.4 TROUBLESHOOTING

Through the consultation and literature review a number of common problems were identified when a rain garden is not maintained or surrounding landuse changes. The Technical Report lists common symptoms, the likely causes and possible remedy for the problem. Table 4 is an example of a problem that may arise in the operation of a rain garden.

Table 4: Sample of a common problem associated with operation of a rain garden.

Symptom	Likely Cause	Remedy
Stormwater run-off is bypassing the rain garden.	Earthworks activities in the area can greatly increase the sediment load in run-off hindering the ability of the rain garden to filter the water or raising the surface level of garden.	Ensure that the surface of the rain garden is below the surrounding area. Remove any accumulated sediments and debris from inflow areas and from the top of the rain garden.
	Rubbish and other debris may be blocking the inflow points to the rain garden.	Remove rubbish, leaves and any other debris that could be causing a blockage.

Source: AECOM, 2009b

4.2.5 COMPLIANCE AUDITING AND MONITORING

There can be many requirements for compliance from different regulating sources. These can include performance areas in maintenance contracts, or part of consent conditions. Depending on the requirements for audits and monitoring, reporting of results should be submitted to the owner and the regulatory authority.

Auditing typically implies a compliance requirement while monitoring will tend to refer to performance of the rain garden. An audit checklist can be developed based on the maintenance schedule. One of the first tasks in an audit is to correlate the log book with the maintenance schedule to determine if inspections and planned maintenance are taking place at the required frequencies.

Monitoring of the rain garden would tend to focus on discharge water quality and permeability of the rain garden soil mix. If maintenance frequency for the rain garden is difficult to determine (based on catchment activities and contaminant loads) quarterly sampling of discharge during the first year of operation will provide a good indication of performance and assist in reviewing maintenance frequencies and methods. The permeability of the growing media should be tested within the first month of operation as this should represent optimum permeability. Thereafter, permeability should be tested quarterly for the first year of operation and then annually in subsequent years.

5 ONGOING INFORMATION DEVELOPMENT

These Technical Reports provide guideline information in a bid to improve industry knowledge and stormwater treatment device designs and documentation. The ARC, North Shore City Council and AECOM have worked together to produce Construction and Operation and Maintenance guides for operators in the field which provide more practical and 'how to' guidance. These will be available following completion of graphic design work.

As part of the TP10 review, the design of each device is being reviewed and reported in an individual Technical Report. Once all devices have been reviewed, any changes will be incorporated into the Construction Technical Report and Operation and Maintenance Technical Report prior to their release as part of GD01.

6 CONCLUSIONS

The ARC and AECOM have endeavoured to use a consultative approach combined with sound technical and engineering knowledge to produce these Technical Reports. A 2010 Stormwater Conference

driving requirement has been to produce useable and user-friendly guidance that addresses real-world problems.

The literature review found a relative consistency among best practice activities. Key findings suggest onsite check of design appropriateness is required before and during construction and devices require regular maintenance to operate effectively. The consultation showed that the level of understanding of how stormwater treatment devices function means that many problems are perpetuated through construction and maintenance activities. Indicating that education across all aspects of stormwater treatment is required.

Rain gardens have been featured to demonstrate the type and level of information collated in the Technical Reports and highlight specific real-world problems and solutions. We believe we have produced a valuable resource with these Technical Reports, and invite and welcome feedback on them prior to their release as part of GD01.

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GHD	OPUS International Consultants Ltd	Waitakere City Council
HEB Smithbridge Ltd		Wharehine
Hynds Environmental	Papakura District Council	

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