

Sediment Accumulation Monitoring Techniques

2010

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Revision Schedule

Rev. No	Date	Description	Prepared by	Reviewed by	Approved by
Draft	17.06.10	Draft for Client Comments	C. Allen	S. Khareedi	P. Mitchell
Final	08.11.10	Final	C. Allen	S. Khareedi	P. Mitchell

Glossary

AMA	Auckland Motorway Alliance
Silt	Earthy matter, fine sand, or the like carried by moving or running water and deposited as sediment.
AEP	Annual Exceedance Probability
ARC	Auckland Regional Council
IL	Invert Level
NZTA	New Zealand Transport Agency
Operator	Personal undertaking silt measurement
Opus	Opus International Consultants Ltd
Stormwater Devices	Ponds, storage tanks, sediment chambers etc
SW	Stormwater
TP10	ARC's Technical Publication 10: March 2003
WL	Water Level

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Executive Summary

NZTA currently has a myriad of treatment devices that need regular monitoring and maintenance to help meet water quality improvement objectives. These include ponds, wetlands, sediment chambers and sand filters etc., which all need regular sediment depth monitoring and maintenance to prevent the treatment devices from becoming ineffective over time due to excessive sediment built-up.

Typically, the requirement for a device cleaning is based on observations of obvious failure, or as a reactive approach based on a perceived need for cleaning. With no defined method of measuring sediment accumulation, the results recorded and perceived need for cleaning could have inconsistencies. A consistent and convenient method of measuring the depth sediment accumulation in a stormwater device, and hence an ability to determine the actual need for device cleaning will assist in the asset management optimisation, and improved water quality outcomes.

The goal of this investigation is to identify the most reliable and effective tools and techniques based on the review of the local and international best practice for adoption by NZTA.

Auckland Motorway Alliance (AMA) and local network operators were consulted to collate and review current monitoring techniques used in the region. Review of common national and international practices was also undertaken, using different resources viz., internet, local network operators and Regional Council Operation and Maintenance manuals.

Based on the review 10 designs that could be suitable for adoption by the NZTA in their monitoring regimes were also conceptualised. These design concepts included disc and rod designs, pulley systems, electronic systems and suction pumps. A desktop multi-criteria review of each concept was then undertaken to shortlist three preferred ideas namely the stick (e.g. flax stick, push probe style), dip stick style and jagged tooth scoop.

It is recommended that NZTA now undertake stage two of this investigation to include the fabrication and field trials of these devices. Depending on the outcome of the field trials, final fine tuning of the tested designs maybe necessary to verify the best techniques for NZTA's use in the future.

This water quality improvement initiative reinforces NZTA's commitment to being socially and environmentally responsible and to improving the contribution of its networks to the environmental and social well being of New Zealand. This also helps NZTA'S goal under the Environmental Plan to, *"improve the contribution of state highways to the environmental and social well being of New Zealand and prioritise and address environmental and social issues"* by developing approaches and implementation of plans for various categories of the environmental and social impact.

The outcomes of this investigation will also help AMA in the five Key Result Areas namely, Positive Legacy, Value for Money, Maximising Network Efficiency, Customer and Stakeholder Driven Organisation and Healthy Organisation.

Introduction

NZTA currently has a myriad of treatment devices that need regular monitoring and maintenance to help meet water quality improvement objectives. These include ponds, wetlands and sand filters etc. which all need regular sediment depth monitoring and maintenance to prevent the treatment devices from becoming ineffective over time due to excessive sediment built-up.

Currently there is no standard method of measuring the sediment build-up in stormwater treatment devices. Operators are using a range of methods, including staffs or sticks to measure the general depth of sediment over random sections of stormwater devices. This can result in inconsistencies as these current techniques are generally based on individuals' observations of obvious failures or function as a reactive approach based on a perceived need for cleaning.

This study reviews the common national and international best practices with the objective of identifying the best techniques for NZTA's use (i.e. economical, reliable and efficient). The objective of this exercise is to assist operators in adopting a consistent and convenient method of measuring the depth of sediment accumulation in stormwater devices. The scope of works includes:

1. Review of national and international best practices.
2. Identification of the most likely solutions (i.e. reliable, and effective techniques) that will be applicable to NZTA network situation
3. Recommendations to trial the likely solutions for consistency and ease of measurement ('boots to suits'),
4. Identification of the preferred option
5. Summary Reporting (including options, trial findings, and recommended preferred option)

Review of national best practices was done through consultation with Local Authorities/Local Network Operators. Review of international best practices by collating published papers and articles from overseas studies and practices.

Careful consideration was given to the following aspects while selecting the three tools and techniques for trial:

1. They are suitable for use in a range of Stormwater Management Assets,
2. They are portable and easy to use and can be read and recorded by unskilled or semi-skilled maintenance staff
3. They provide flexibility for use under different site conditions (pond/treatment device dimensions and geometry),
4. They are flexible to measuring depths of sediments of varying size (from clay to gravel) and possibly allow for collection of samples
5. Ability to allow for collection of samples as a desirable factor but not a mandatory requirement
6. Ability to reduce health & safety risks for operators

Background / Objective

Background

NZTA currently has a significant number of stormwater treatment devices that need regular monitoring and maintenance to help meet their specified water quality objectives. These devices include stormwater ponds – wetlands, dry ponds, sand filters, sediment chambers and other proprietary devices. Some of these devices need to be monitored regularly for sediment build up; these devices include small ponds, sand filters and other proprietary devices.

Operators monitor SW devices regularly and this includes measuring the depth of sediment accumulation, this is used to determine timing for maintenance intervention. Once the depth of sediment reaches a defined level the SW device will need to be cleared of sediment to ensure the devices continue to work to their potential and to maintain a high water quality standard.

Standard and consistent sediment monitoring techniques are under developed, with many operators using staffs or sticks to measure the general depth of sediment over random sections of stormwater devices. This causes many inconsistencies in the results as these current techniques are based on individuals' observations of obvious failures or function as a reactive approach based on a perceived need for cleaning.

A consistent and convenient method of measuring the depth in a sediment accumulation stormwater device, and hence an ability to determine the actual need for device cleaning will assist in the asset management optimisation and improved water quality outcomes.

NZTA is committed to being socially and environmentally responsible and to improving the contribution of its networks to the environmental and social well being of New Zealand. NZTA's goal under the Environmental Plan is to, *"improve the contribution of state highways to the environmental and social well being of New Zealand and prioritise and address environmental and social issues"* by developing approaches and implementation of plans for various categories of the environmental and social impact. This project fulfils the Water Resources, Social Responsibility, Spill Response and Contamination and Resource Efficiency objectives under the Transit New Zealand Environmental Plan of 2008.



Photo 1: SH1 Papakura Int Pond

Stormwater Treatment Devices – Brief Description

The NZTA manage a variety of stormwater treatment devices. These devices are used to hold the stormwater and treat it before it is discharged back into the environment. The stormwater treatment devices that require assessment of sediment accumulation to determine any maintenance needs include:

- Ponds
- Sandfilters/Sediment Chambers
- Wetlands

Ponds

Stormwater ponds improve discharge water quality by removing sediments and other contaminants from stormwater before discharging it to a receiving open water body or piped stormwater system. Ponds have a long life span if maintained correctly.

The sediment forebay makes up 15% of the main pond area; this is where most contaminants are collected by settlement processes, and is the primary area that will need to have sediment monitoring and maintenance to ensure a good water quality outcome. The main pond area also needs to have sediment accumulation monitoring and maintenance. This main pond area retains water for longer allowing finer sediments to settle out.

The sediment forebay typically needs to be cleared every 5–10 years. This frequency varies with the different sizes of the ponds and depends on the findings of the sediment accumulation depth monitoring. The main pond area is typically cleared every 20–50 years but this also depends on findings of the sediment accumulation depth monitoring.

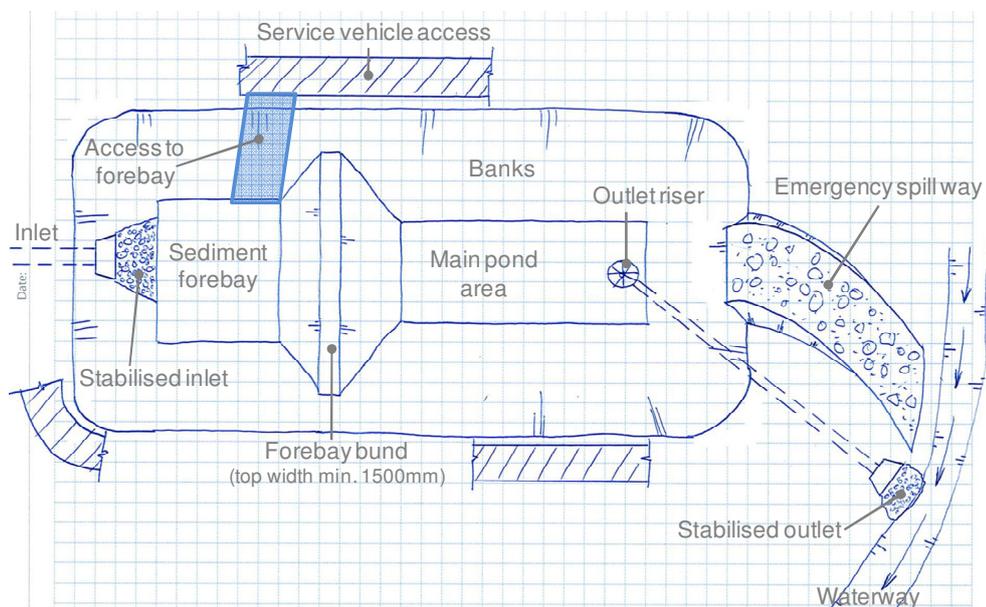


Figure 1: Typical stormwater pond



Photo 2: A typical NZTA Pond

Wetlands

Wetlands provide a number of ecosystem benefits, such as improving water quality and flood attenuation. Constructed wetlands mimic the processes found in natural wetlands and provide an important water treatment system.

In a wetland the sediment settles in the forebay (if it has one) and also the main wetland area. The forebay needs to be cleared of sediment generally every 5–10 years; unless the sediment depth monitoring indicates otherwise.

The main pond area generally needs to be cleaned of any accumulated sediment about every 20–50 years. Maintenance can be very resource, cost, time consuming. Too frequent maintenance will cost too much relative to the water quality benefits, and too infrequent maintenance will not deliver the necessary water quality improvement benefits.

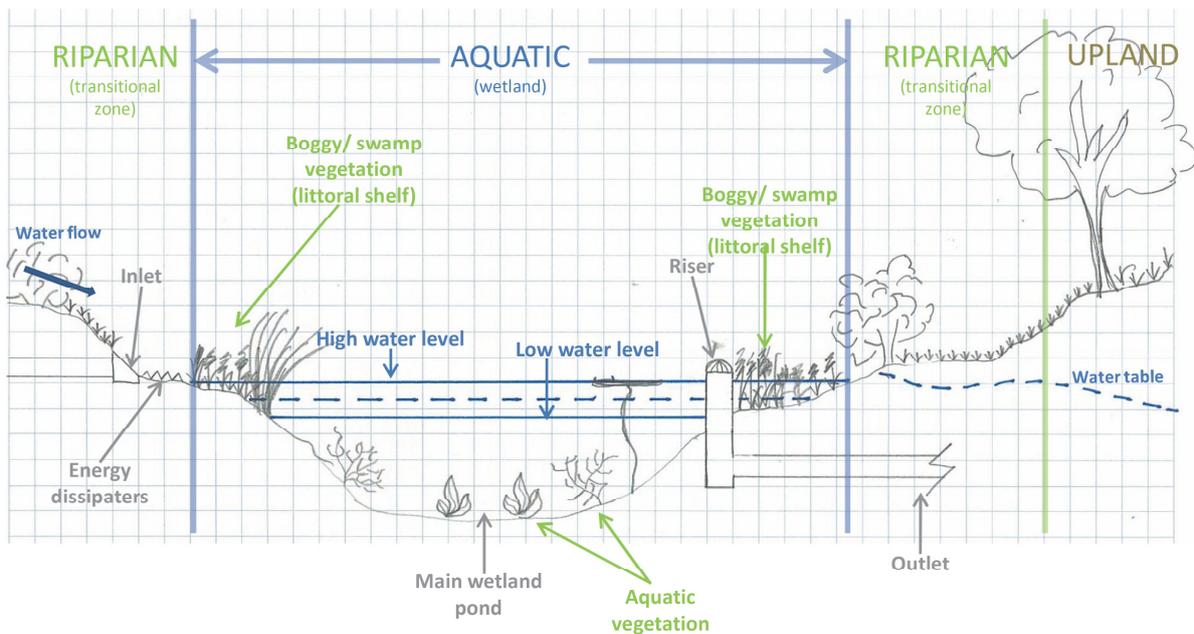


Figure 2: Typical stormwater wetland



Photo 3: A typical NZTA Wetland Pond

Sand Filters & Sediment Chambers

Sand filters and Sediment Chambers are usually multi-chamber structures designed to treat stormwater runoff through sedimentation (settling of heavier particles from the water column) and filtration (runoff passes through the sand to filter out pollutants).

To ensure positive water quality outcomes, Sediment Chambers typically need to be cleared when the accumulated depth of sediment exceeds the design sediment storage depth. Typically Sediment Chambers need cleaning about every 2–3 years. Maintenance can be costly and it is important that an optimal maintenance intervention period can be identified to ensure value for money operations are delivered.

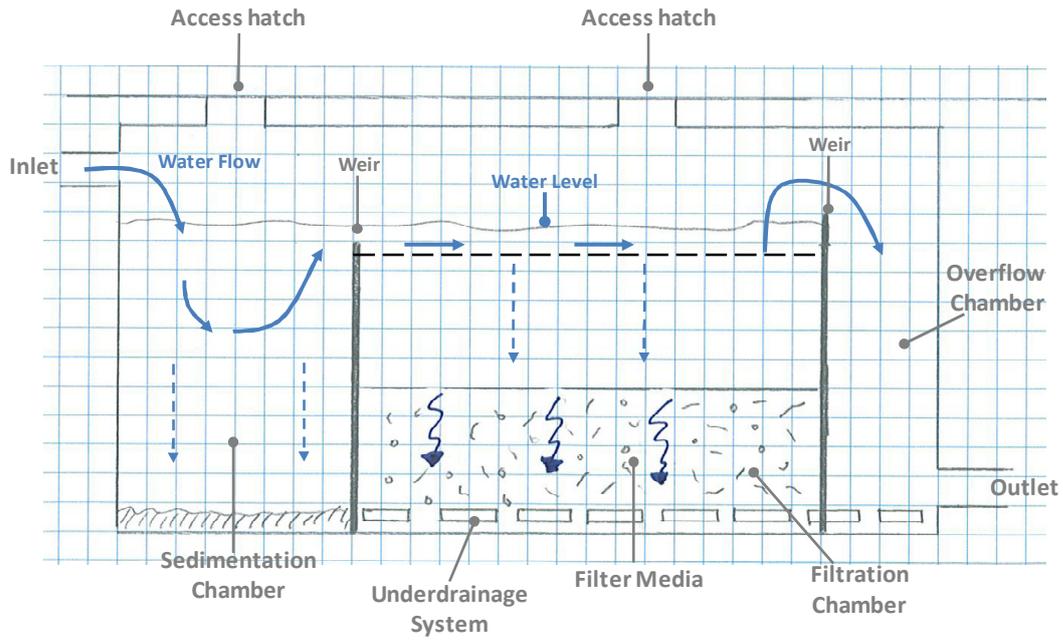


Figure 3: Cross section of sand filter



Photo 4: A typical NZTA Sand Filter/Sediment Chamber

Objectives

A regular monitoring programme and standard monitoring and measurement tools will help ensure that the depth of accumulated sediment in stormwater treatment devices is being accurately measured. This minimises the risk of SW devices from becoming ineffective over time due to excessive sediment built-up. Inconsistent and inaccurate readings of sediment accumulation could result in too frequent maintenance adding to the costs.



Photo 5: A sediment Chamber full of Sediments

The ultimate goal of this investigation is to identify the most reliable and effective sediment accumulation monitoring and measurement tools and techniques for use by NZTA based on the review of the local and international best practice.

AMA and local network operators were consulted to review current monitoring techniques used. Research and review of other national and international practices was also undertaken (internet, local network operators and Regional Council Operation and Maintenance manuals).

- Careful consideration has been given to the following operational aspects while identifying the preferred tools and techniques:
- Suitability for use in a variety of Stormwater Management Assets
- Portability, easy to use and convenient to read and record by unskilled or semi-skilled maintenance staff
- Flexibility for use under different site conditions (pond/treatment device dimensions and geometry)
- Flexibility to measure depths of sediment of varying size (from clay to gravel), and possibly
- Ability to allow for collection of samples as a preferable factor but not a mandatory requirement
- Ability to reduce health & safety risks for operators

Stormwater devices must function effectively to ensure that the water runoff from the motorways is treated properly to maintain a good water quality outcome. The tools identified by this study are intended to improve the monitoring and maintenance of these devices to best deliver positive water quality outcomes.

NZTA Benefits

This investigation is to help with NZTA's commitment to being socially and environmentally responsible and to improving the contribution of its networks to the environmental and social well being of New Zealand. This work also helps towards NZTA'S goal under the Environmental Plan to, "*improve the contribution of state highways to the environmental and social well being of New Zealand and prioritise and address environmental and social issues*" by developing approaches and implementation of plans for various categories of the environmental and social impact. This project also helps towards the Water Resources, Social Responsibility and Contamination & Spill Response objectives under the Transit New Zealand Environmental Plan of 2008. Specific objectives that are fulfilled by this investigation are listed below:

Water Resources Objectives

This investigation helps towards the following Water Resources objectives:

W1: Ensure run-offs from state highways complies with the RMA requirements – One of the obligations that NZTA has in relation to complying with the RMA requirements is to comply with the Resource Consent Conditions for Stormwater Diversion and Discharge. This includes ensuring that the stormwater run-offs from the network comply with ARC's TP10 guidelines as it is often a standard condition of a Resource Consent. This investigation is focused on optimising the asset condition by indicating when a device is due for cleaning. This ensures the treatment devices are functioning satisfactorily to comply with the Consent conditions.

W2: Limit the adverse effects of run-off from state highways on sensitive receiving environments – Large sections of the Auckland Motorway Network is close to sensitive receiving environments. Cleaning a stormwater treatment device at the right time will ensure the stormwater being discharged into these sensitive receiving environments best manages any adverse effects.

W3: Ensure stormwater treatment devices on the network are effective – a consistent and convenient method of measuring the depth of stormwater device sediment accumulation will assist in the optimised functioning of a treatment device. This will in turn ensure that the device is effective throughout its functional lifetime.

W4: Optimise the value of water management through partnership with others – This investigation included consultation and information sharing with other network operators and local authorities in New Zealand and overseas. The recommendations outlined draws from the industry best practice bringing in benefits similar to those that can be expected from partnerships.

Social Responsibility Objectives

This study fulfils the social objective **SR1 – Enhance and contribute to community cohesion** by considering social cost alongside technical, safety and economic issues associated with stormwater treatment devices. This is achieved by reducing the cost from unforeseen environmental damages due to poor functioning of these devices.

Spill Response and Contamination Objectives

This study fulfils both the Spill Response and contamination objectives namely,

S1 – Design stormwater control and retention devices that can accommodate spills in areas of high environmental risks, and

S2, ensure the removal, placement and disposal of contaminated soils achieved in accordance with best practice.

Minor spills consisting of hydrocarbons and other material adhere to sediment and silt which eventually get discharged and accumulated in stormwater treatment devices. Ensuring that these devices function satisfactorily and ensuring that the sediments are collected and disposed off in accordance with the best practice, which this study does, enables NZTA comply with the two above mentioned objective.

AMA Benefits

The objectives of the AMA as outlined in their alliance Charter are,

- Maximising network efficiency e.g. less time monitoring and maintaining assets.
- Delivering a positive legacy for future generations e.g. standard best practice tools identified.
- Delivering enhanced value for money e.g. improved water quality outcomes for less cost.
- Creating and maintaining a healthy and enthusiastic organisation e.g. safe tools.
- Customer and Stakeholder driven organisation.

AMA values include putting people first, seeking innovation, open and honest dealings, importance of economic health and positive results.

This investigation helps towards all of the above objectives by providing the following:

- Assurance that the SW devices are operating satisfactorily and at optimal levels
- Assurance that the Resource Consent Compliance is being achieved
- Encouraging regular monitoring by providing tools and techniques that are simple, reliable and accurate
- Standardising monitoring techniques for all devices and operators
- Optimising maintenance that results in cost savings
- Ensuring safety of the operators

It is anticipated that the final 'refined' tool for monitoring and measuring sediment accumulation will provide all of this by creating a new, innovative design that is efficient, cost effective, easy to manufacture, easy to use and be a product that will withstand the test of time.

This research/design will also help NZTA by.

- Ensuring the technique is aligned with the prescribed stormwater management guideline (ARC TP10).
- Providing a positive link to the NZTA Environmental Management Plan.
- Ensuring that the work ties into institutional knowledge of monitoring SW devices on the NZTA research.
- Reducing work by external contractors on the network.



Photo 6: SH16 Newton Pond

Sediment Monitoring Practices

Monitoring Techniques used in New Zealand

The following section summarises the common sediment accumulation monitoring techniques used in New Zealand. Some of these techniques are more commonly used on large SW devices i.e., ponds/lakes and may not be applicable for use in medium to small devices that NZTA is responsible for. This information has been included for research and background purposes. Many of the Local Authorities in the Auckland region are using a combination or modified versions of the tools and techniques listed below. For the purpose of this report, we have kept our discussions to the generic aspects of each tool/technique.

The common techniques currently being used in New Zealand are:

- Boat and Staff
- Dipstick with Disc
- Endress & Hauser Device
- Stick or Gum Spear
- Bathymetry

Boat and Staff

This method is used for larger devices such as lakes and ponds, which is a minority of the NZTA's SW devices. Many operators use the simple method of rowing around the lake or pond in a boat and taking silt depth measurements by measuring from the known permanent WL to the top of silt as best they can.

Safety of the operators is the single biggest concern of this approach, and the accuracy of this device and technique is subject to the skills of the operation. The readings of sediment build-up could be inconsistent and at time not reliable as exact top of sediment is hard to feel. However, if this technique can produce relatively reliable readings of the sediment depth when is used with other devices outlined further in this report. A boat will only service as a means getting around the pond to take readings at required locations. This technique is expensive and not suitable for small or shallow ponds. The measurements are taken at random points in the pond therefore past results cannot be compared as surveyed locations could vary.

Dipstick with Disc

This option is currently used for both sludge monitoring in wastewater ponds and sediment monitoring in stormwater ponds. It consists of a rod with a flat disc mounted on the end. The rod and disc are lowered into the water to settle on top of the sludge. The measurement is then read off the graduations on the rod. The operator needs to know the permanent water level to work out up to what level the sediment is built up to.

This is a good approach. However, the ease of access will depend on the type of SW device being monitored. It may be hard to access all parts of a large pond unless the network operator gets into the water or uses a boat. This option could work well on smaller SW devices where the operator can easily access all parts of the device i.e. without getting into the device, and where a 'permanent' design water level is known and benchmarked.

Endress & Hauser Devices

Endress & Hauser, in Christchurch manufacture and supply level measurement equipment for solids and liquids. They have a range of products with these two options being relevant to our research:

- Guided Radar Level- Continuous level measurement of liquids, powdery or granular bulk solids. Reliable in liquid tanks with turbulent (foamy) conditions, unaffected by dusty conditions.
- Ultrasonic Level- Continuous, non-contact level measurement of fluids, pastes, sludge and powdery to coarse bulk materials. Measuring range up to 70 m (depending on sensor and material measured) Level

limit detection (up to 6 relays) and pump control. Full featured remote sensor line for control and inventory monitoring. Compact unit for level measurement in liquids and coarse bulk materials. Flow measurement in open channels and measuring weirs. System integration via HART®, PROFIBUS, FOUNDATION FIELDBUS.

The review of these options is purely of academic interest as the SW devices that NZTA operates are all very small in relation to the large Lakes/Ponds that the above two devices are manufactured for.



Figure 4: Picture of Endress & Hauser level measurement equipment

Stick/Gum Spear

These options are currently the preferred options by many operators to use in the field. The device consists of a stick or a probe (similar to the Gum Spear) which gets pushed into the sediment at a number of random spots in the SW device being monitored. The operator then gets an average idea of the depth of sediment around the SW device by measuring from the known permanent water level to the top of sediment, or from the known level at the base of the pond to the top of sediment.

The best way to choose points to survey is based on the typical behaviour of sediment in the SW devices.

The accuracy of this device and technique is subject to the skills of the operation. However the ease of access will depend on the type of SW device being monitored, it may be hard to access all parts of a large pond unless the network operator gets into the water or uses a boat.

This option would work very well on the smaller SW devices where the operator can easily access all parts of the device i.e. without getting into the device. This technique is preferred by many operators because it is cheap, easy and convenient.

Bathymetry

Some Local Authorities in Auckland region engage a topographical survey companies to complete a pond bathymetry using topographical survey equipment viz., a Total Station, GPS. The surveyors use a small boat if the SW device is a large pond or measure depths standing within or next to the SW device if they are small.

This provides the most accurate measurement of sediment build-up. However, it is very expensive and warrants external contractors on NZTA's networks.

Monitoring Techniques used Around the World

In addition to the common monitoring techniques used in New Zealand (see section 4.1), the following summarises some additional common sediment/sludge accumulation monitoring techniques used around the world.

Manual Blanket Level Detector

This product is from a company in Canada called Markland Speciality Engineering LTD. This product consists of a gun like shape with a probe on the end of a cable. The probe gets lowered down and beeps as soon as it hits the sludge surface. The user can then read the depth off the increments on the cable. The permanent water level must be known to calculate the exact depth of sludge.

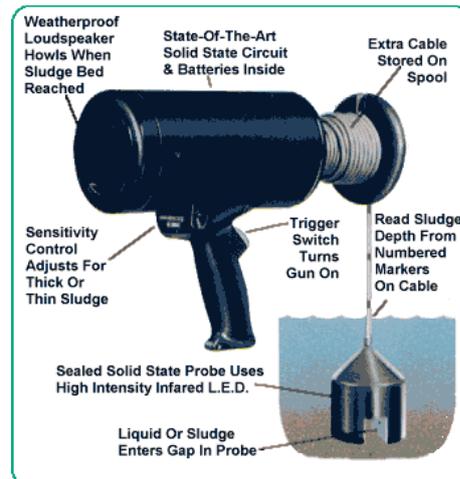


Figure 5: Picture of manual blanket level detector

Liquid Sediment Detection Pole

The main purpose for this instrument is to measure sedimentation in ponds, reservoirs and ditches. It works in a way similar to the blanket level detector above in the sense that it beeps when it is lowered into the sediment level. It has an accuracy of 2cm, can measure to a max depth of 2.4m.

This is an expensive but a good accurate option but it does not take core samples. This device will however require the operator to walk into the pond or use a boat if it is large.

GPS

Large reservoir surveys in New Delhi, India have been using GPS to carry out their sediment surveys; it is much faster than the traditional theodolite, boat and rod techniques. Using the GPS on a boat the depth and position measurements are taken. As GPS picks up a position measurement you can always survey the same spots and compare your results.

This essentially the same of the Bathymetry technique used in New Zealand. This option is suitable for very large/deep reservoirs. This technique gives the most accurate measurement of sediment build-up. However, it is very expensive and warrants external contractors on NZTA's networks.

Echosounders

Echosounders are mainly used in marine environments to measure marine life and bottom classification. It uses sonar to map out the sea floor and produces a report showing each different layer depending on its density.

This would be accurate but very expensive and suitable for large projects. The review of these options is purely of academic interest as the SW devices that the NZTA operates are all small.

Dipstick and Disc

Rod and disc explained in the previous section (Section 4.1.2) is being used in a number of other countries in addition being used in New Zealand.

Boat and Staff

The boat and staff method outlined in the previous section (Section 4.1.1) is being used overseas as well.

Discussion of Current Techniques

Most of the techniques and devices currently being used in New Zealand are the same of as those around the world. This could be because of New Zealand adopting the best practice at the time around the world or vice versa.

There are a myriad of tools and techniques available the range from costing almost nothing viz., a stick to expensive viz., Ecosounders and Endress & Hauser Devices. Some are suitable for small devices viz., sand filters, and small and/or elongated ponds and other are suitable for large lakes and ponds.

A complete Bathymetry survey is the most accurate of all techniques being used. This is one of the most expensive techniques and not warranted for the stormwater treatment devices that NZTA is responsible for. NZTA requires a device and technique that can be used by is field operators with little training, is inexpensive, convenient and provides a reliable consistency of measure.



Photo 7: Picture of Titoki Pond Forebay

Potential Sediment Accumulation Monitoring Options for NZTA

After collating and reviewing national and international practices of sediment monitoring, we have combined the practices to create 10 designs that could be suitable for the NZTA to incorporate into their monitoring regimes. When the Operators go to a SW device to monitor/maintain, they undertake a range of other activities. Sediment Accumulation monitoring is only a very small part. In short-listing suitable options for use by AMA operators, consideration has been given to convenience for carrying and the device being quick and easy to use. The list of 10 designs are:

- 1 Half Tube with Disc
- 2 Piston Suction Pump
- 3 Jagged Tooth Scoop
- 4 Dipstick with Disk
- 5 Fishing Rod Style
- 6 Permanent Cable and Pulley
- 7 Tower Crane System
- 8 Gantry Pulley System
- 9 Manual Blanket Level Detector
- 10 Stick/Gum Spear

Half Tube with Disc

This design consists of a PVC or a metal tube cut in half (at least below WL) and permanently positioned in the pond. The sediment settling in the pond will get caught within the half tube to same sediment level as the area around the half tube. The operator will then come along and, using a disc attached to a rod arrangement, will slide the disc down the tube until it reaches the top of the sediment. The depth can then be measured off the graduations on the rod. This will then be used to find the actual sediment depth by subtracting the measured depth from the actual pond depth (water level to pond base).

This design would be good for use in AMA stormwater devices viz., ponds, wetlands and sand filters that are small or narrow enough to be read from the bank. The device can be left in place and only the rod and disc needs to be carried each time for inspection. This design would be easy to manufacture and maintain. The AMA operators can position the half tubes at locations in the stormwater device that would most accurately reflect the level of sediment in the whole device.

Part of the monitoring routine for the AMA includes collecting sediment samples. With a slight modification of disk attached to the rod, this device might allow for the collection of samples. This design amendment is subject to field trials. For the desktop review we have considered that collecting samples from this device is not possible

This design includes installing a permanent structure in the SW device. There is a potential for this sediment measuring device to become an eye sore or for being a target of vandalism. Moreover, it may be necessary to install these devices in multiple locations in the same stormwater treatment device to capture an average depth of sediment build-up.

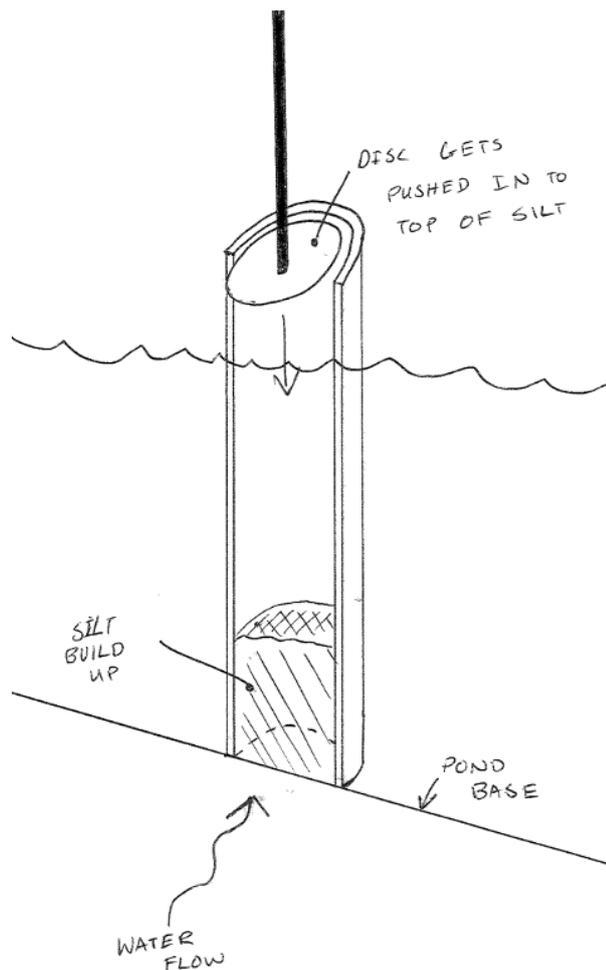


Figure 6: Half Tube with Disc

Piston Suction Pump

This design is similar to a hand piston air pump used to blow up balloons and air mattresses. It consists of a hollow tube with a suction piston (a disc on the end of a rod). The operator will position the tube at chosen locations in the SW device. The probe will get pushed down to the sediment surface. This causes the piston inside the pipe to rise by an amount equal to the sediment depth. The depth of sediment is measured off the graduations on the piston stem. A sample can be retrieved for verification and testing by drawing the piston back before retrieving the probe. A welded lip inside the tube stops the piston from completely coming out of the pipe. The tube is then removed from the stormwater device and the core sample removed for measurement. This allows for the verification of the sediment depth measured before retrieving the device out of the pond.

This idea can be used in the NZTA's small ponds, sediment chambers, sand filters etc. It is portable. It will be cheap to manufacture and will only need minimal maintenance. This design can be used in any SW device without getting into the SW device if it is small and by getting into the SW device if it is big viz., a large pond. It could however be difficult to retrieve a sample if the sediment is coarse i.e., gravelly or silty with less cohesion. NZTA operators may also require some training to retrieve the sediment samples without it washing away in the water.

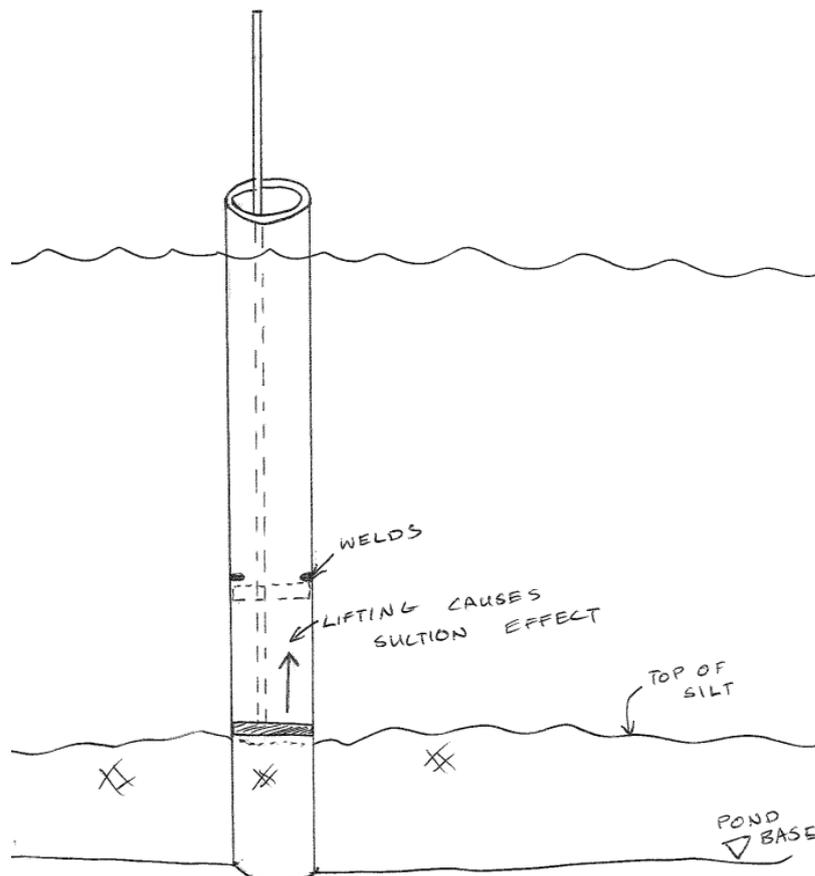


Figure 7: Piston Suction Pump

Jagged Tooth Scoop

This option consists of metal rod or pipe with cup like teeth at preset regular intervals. The rod is pushed into the sediment until it hits the pond base. It is then carefully drawn out of the water with the cup like teeth bring up samples of sediment with them. The accuracy of the depth measurement will depend on the spacing of cup like teeth. This also enables small amount of samples to be obtained. These samples however will not be useful to the NZTA as the samples are too small for testing. The silt that gets caught in cups will be used to determine the depth. The operator will also need to carefully lift so as not to wash the sediment out of the cups when pulling the scoop out of the water.

This device can be used in the NZTA's ponds, sediment chambers, sand filters etc. It is portable. It will be cheap to fabricate and will only need minor maintenance. This device can be used in any SW device without getting into the SW device if it is small and by getting into the SW device if it is big viz., a large pond.

This design can be used in NZTA SW devices such as small ponds, wetlands, sediment chambers etc. It is portable however it may be an awkward device to store in the vehicle due to the jagged tooth.

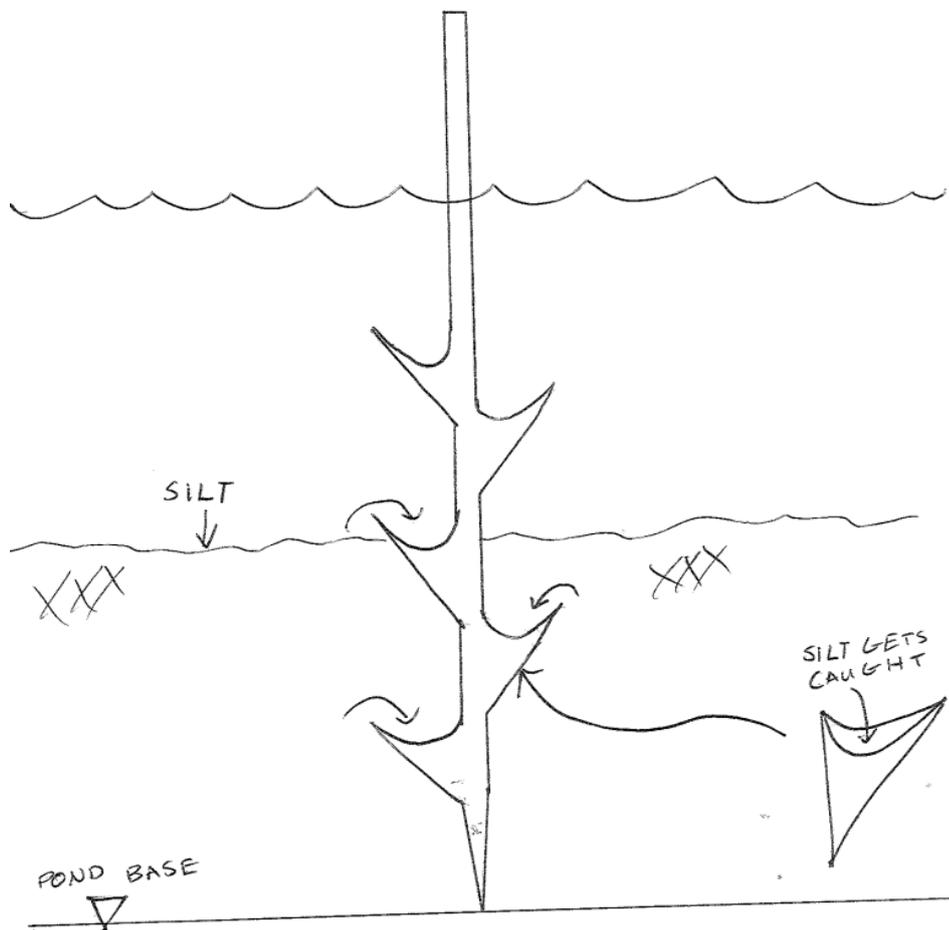


Figure 8: Jagged Tooth Scoop

Dipstick with Disc

This device is being currently used in New Zealand and around the world. This design is simple as it involves a rod with a flat disc welded to its end.

The depth of sediment is measured off the graduations on the rod. This will then be used to find the actual sediment depth by subtracting the measured depth from the actual pond depth (water level to pond base).

This device can be used in the NZTA's ponds, sediment chambers, sand filters etc. It is portable. It will be cheap to manufacture and will only need minor maintenance. This device can be used in any SW device without getting into the SW device if it is small and by getting into the SW device if it is big viz., a large pond.

This device and technique uses water surface level to calculate the sediment depth. Errors could be introduced if the water level is different to the design water level due to evaporation or leakages. If the water level in stormwater treatment device is lower than the design level, the reading on the staff will be higher suggesting higher than actual sediment build-up. This might trigger an un-necessary clean up of the sediments leading to increase in the maintenance costs.

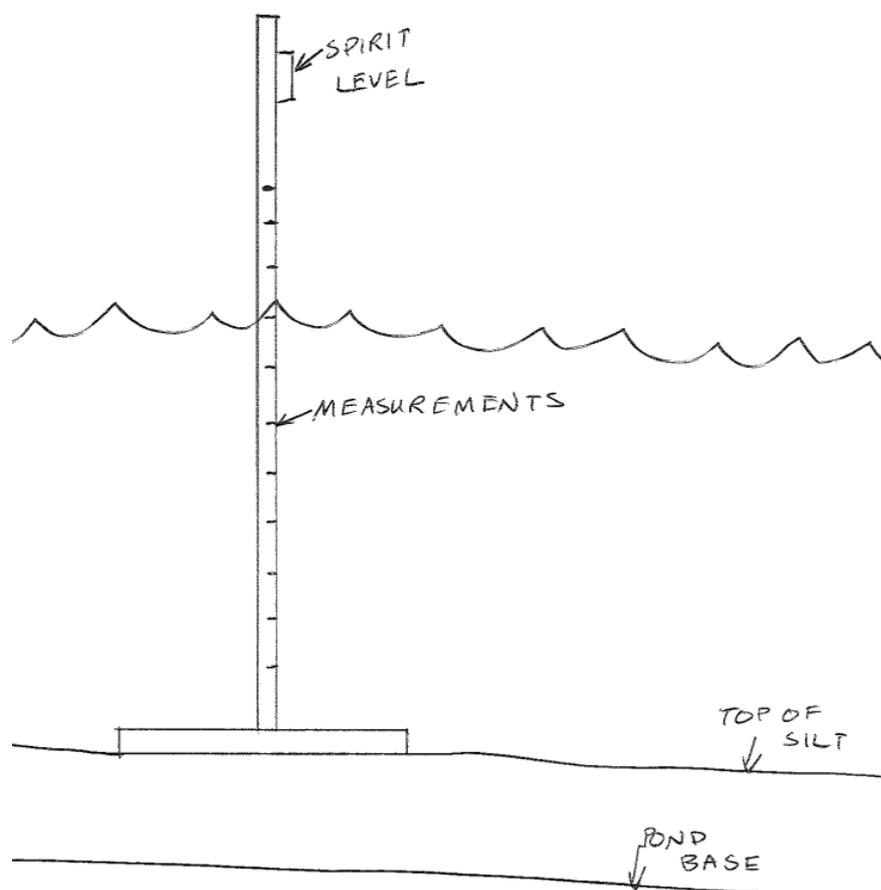


Figure 9: Dipstick with Disc

Fishing Rod Style

This concept device is similar to a fishing rod with a disc on the end of a reel near the handle. The operator can stand on the edge of the pond and lower the disc into the water. The depth of sediment is then read off the graduations on the cable/tape taking readings once when the disk touches the water surface and once when it rests on the sediment. This measurement is then subtracted from the known permanent depth of pond (water level to base). This device will need to be used with a spirit level attached to the handle to keep it level for accurate measurements.

This design is complicated to use and would need operator training. However it can be used in many of NZTA's small and medium sized SW devices including ponds, wetlands, sediment chambers. It also will be very good for health and safety as the operator will not have to get into SW device to take readings.

This is one of the more expensive designs and may need maintenance to retain its accuracy. This device does not collect sediment samples.

This device and technique uses water surface level to calculate the sediment depth. Errors could be introduced if the water level is different to the design water level due to evaporation or leakages. If the water level in stormwater treatment device is lower than the design level, the reading on the staff will be higher suggesting higher than actual sediment build-up. This might trigger an unnecessary clean up of the sediments leading to increase in the maintenance costs.

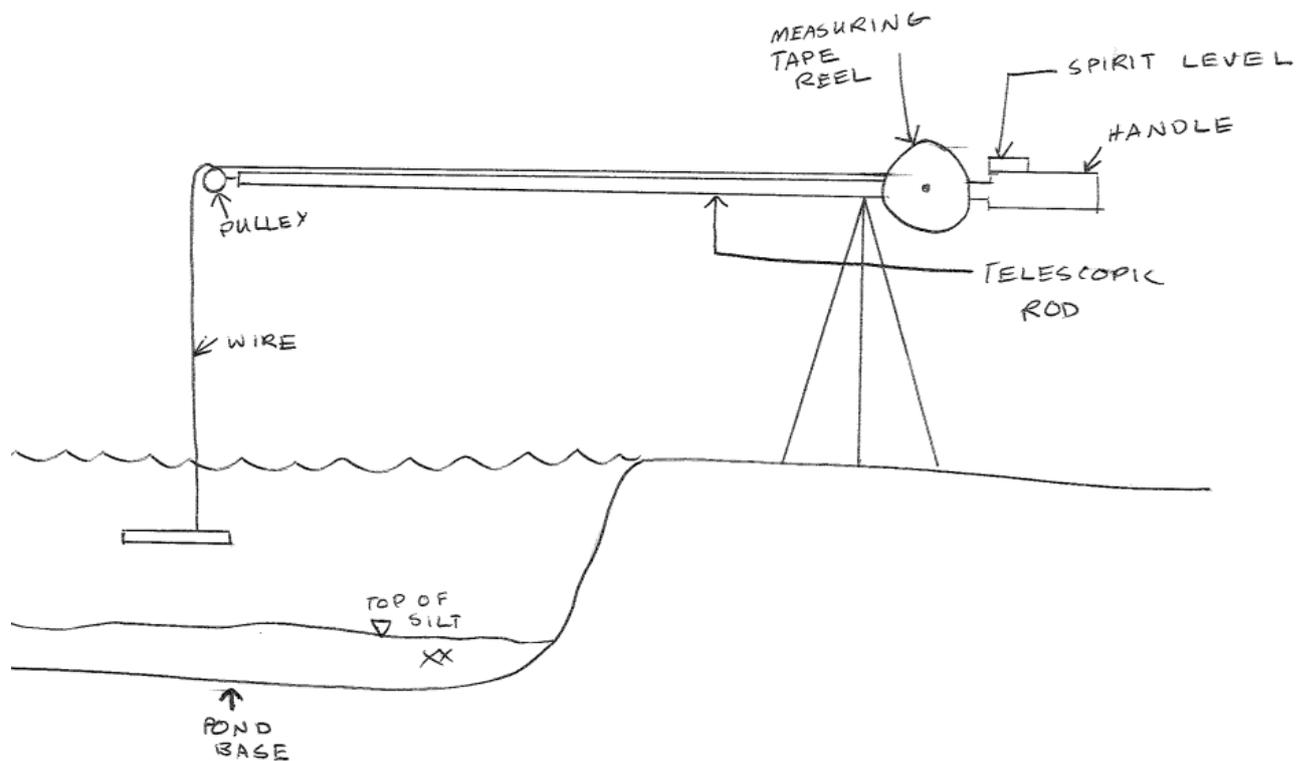


Figure 10: Fishing Rod Style

Permanent Cable and Pulley

This device consists of a column with a pulley at the top permanently mounted in the pond. A cable with a probe weight attached at its end runs from the pulley down the column, and along the bottom of the SW device on to the edge. The operator can then stand on the edge of the SW device and lower the probe weight up and down. The depth of sediment is then read off the graduations on the cable/tape taking readings once when the probe touches the water surface and once when it rests on the sediment. This measurement is then subtracted from the known permanent depth of pond (water level to base).

This device can be used in all of NZTA's SW devices including ponds, wetlands, sediment chambers. It also will be very good for health and safety as the operator will not have to get into SW device to take readings. The operator will be able to test the same spot each time so they will be able to compare the results. Moreover, the operators will not need to carry the device with them for inspections.

This device is expensive, complicated to use and would need operator training. This device is mounted permanently in the SW device and could be an eyesore and may be subject to vandalism. This device needs regular maintenance. Sediment depth readings can only be taken at a fixed location in the SW device.

This device and technique uses water surface level to calculate the sediment depth. Errors could be introduced if the water level is different to the design water level due to evaporation or leakages. If the water level in stormwater treatment device is lower than the design level, the reading on the staff will be higher suggesting higher than actual sediment build-up. This might trigger an un-necessary clean up of the sediments leading to increase in the maintenance costs.

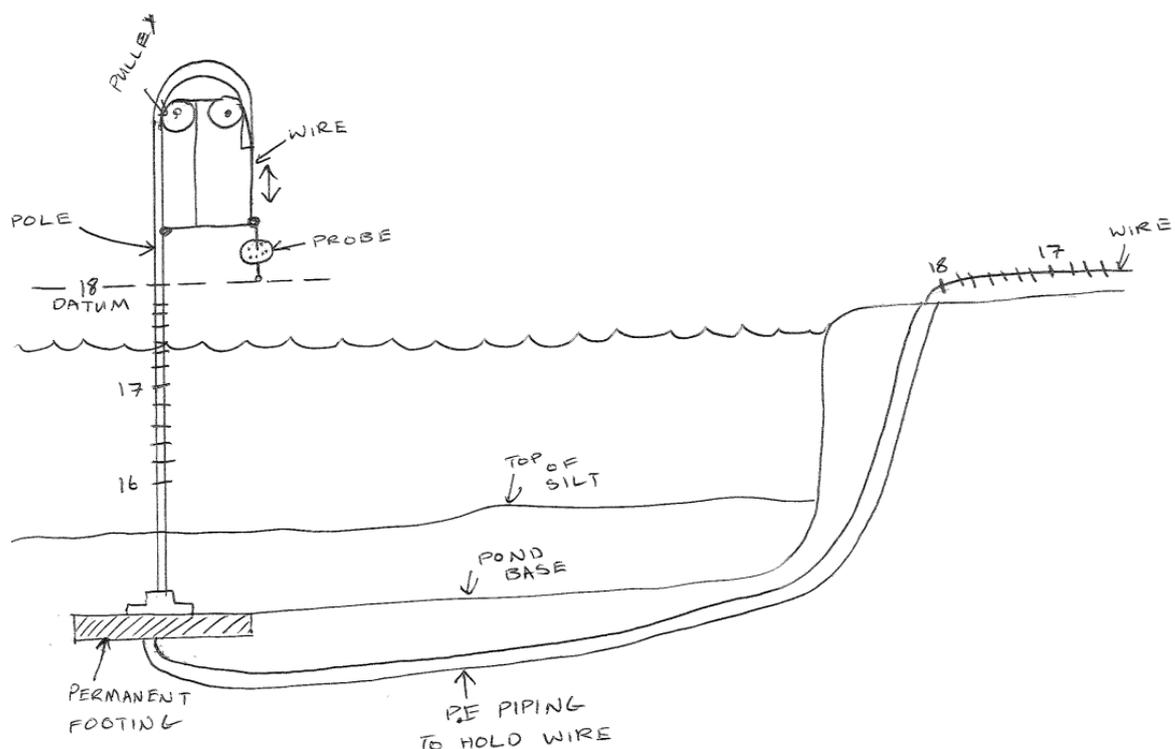


Figure 11: Permanent Cable and Pulley

Tower Crane System

This design consists of a pulley system similar to a Tower Crane that gets attached to a base at the side of the SW device. This system can swivel 180° and reach out a substantial radius enabling sediment measurement anywhere in that half circle. A probe gets lowered into the water until it rests on the top of sediment. The depth of sediment is then read off the graduations on the cable/tape taking readings once when the probe touches the water surface and once when it rests on the sediment. This measurement is then subtracted from the known permanent depth of the SW device (water level to base).

The Tower Crane style system can be folded up and transported from one SW device to the other. The base of this device is secured permanently close to the SW device. This device can be used in all of NZTA's SW devices including ponds, wetlands, sediment chambers. It is good for health and safety as the operator will not need to get into the device.

This device is expensive, complicated to use and would need operator training. The base permanently secured permanently close to the SW device could be an eyesore and may be subject to vandalism. This device needs regular maintenance and the portable part could be clumsy to carry in a car or a pick-up truck by the operators.

This device and technique uses water surface level to calculate the sediment depth. Errors could be introduced if the water level is different to the design water level due to evaporation or leakages. If the water level in stormwater treatment device is lower than the design level, the reading on the staff will be higher suggesting higher than actual sediment build-up. This might trigger an un-necessary clean up of the sediments leading to increase in the maintenance costs.

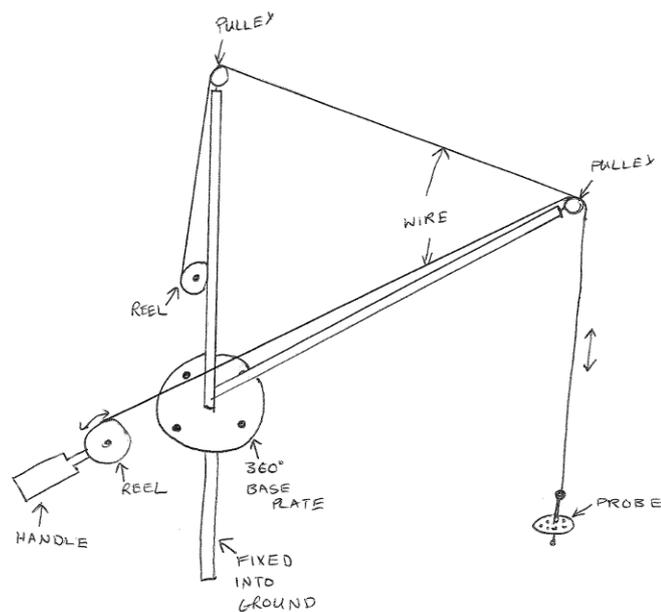


Figure 12: Tower Crane System

Gantry Pulley System

This design consists of a pulley system that extends from one side of the SW device to the other. It gets attached to a base at each side of the device. The operator then stands at one end of the device and can move the probe from one end to the other and up or down.

The depth of sediment is then read off the graduations on the cable/tape taking readings once when the probe touches the water surface and once when it rests on the sediment. This measurement is then subtracted from the known permanent depth of SW device (water level to base). This will allow the operator to get a cross-section of sediment depth. It does not however collect core samples; this is not an important factor for this scope of works.

The Gantry Pulley system can be folded up and transported from one SW device to the other. The base of this device is secured permanently close to the SW device. This device can be used in all of NZTA's SW devices including ponds, wetlands, sediment chambers. It is good for health and safety as the operator will not need to get into the device.

This device is expensive, complicated to use and would need operator training. The base permanently secured permanently close to the SW device could be an eyesore and may be subject to vandalism. This device needs regular maintenance and the portable part could be clumsy to carry in a car or a pick-up truck by the operators.

This device and technique uses water surface level to calculate the sediment depth. Errors could be introduced if the water level is different to the design water level due to evaporation or leakages. If the water level in stormwater treatment device is lower than the design level, the reading on the staff will be higher suggesting higher than actual sediment build-up. This might trigger an un-necessary clean up of the sediments leading to increase in the maintenance costs.

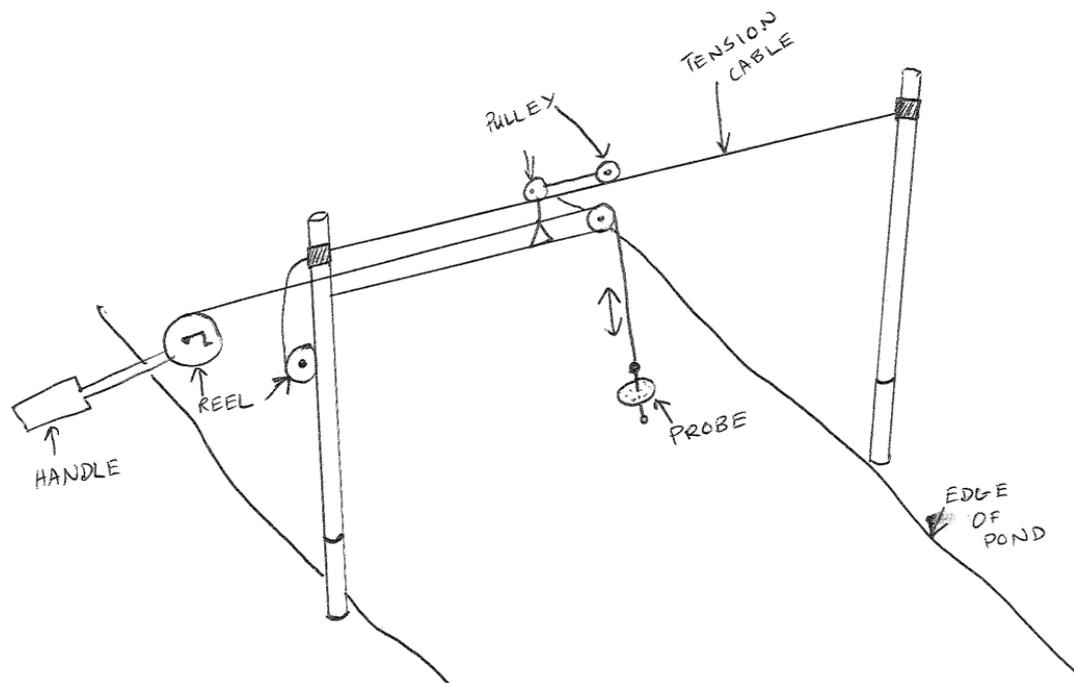


Figure 13: Gantry Pulley System

Manual Blanket Level Detector

This concept has taken the sludge level detector gun from Markland Speciality Engineering LTD or trials to measure sediment levels in SW devices. This product consists of a gun like shape with a probe on the end of a cable. The probe gets lowered down and beeps as soon as it hits the sediment surface. The operator can measure the depth to the sediment layer by reading the graduation on the cable. The sediment depth is then determined by subtracting this depth off the depth of SW device (water level to base)

A Manual Blanket Level Detector can be used in any SW device without getting into the SW device if it is small and by getting into the SW device if it is big viz., a large pond. This device is small, portable and very easy to use as it beeps exactly when it hits the top of sediment.

This product expensive and needs regular maintenance. It also cannot collect sediment samples.

This device and technique uses water surface level to calculate the sediment depth. Errors could be introduced if the water level is different to the design water level due to evaporation or leakages. If the water level in stormwater treatment device is lower than the design level, the reading on the staff will be higher suggesting higher than actual sediment build-up. This might trigger an un-necessary clean up of the sediments leading to increase in the maintenance costs.

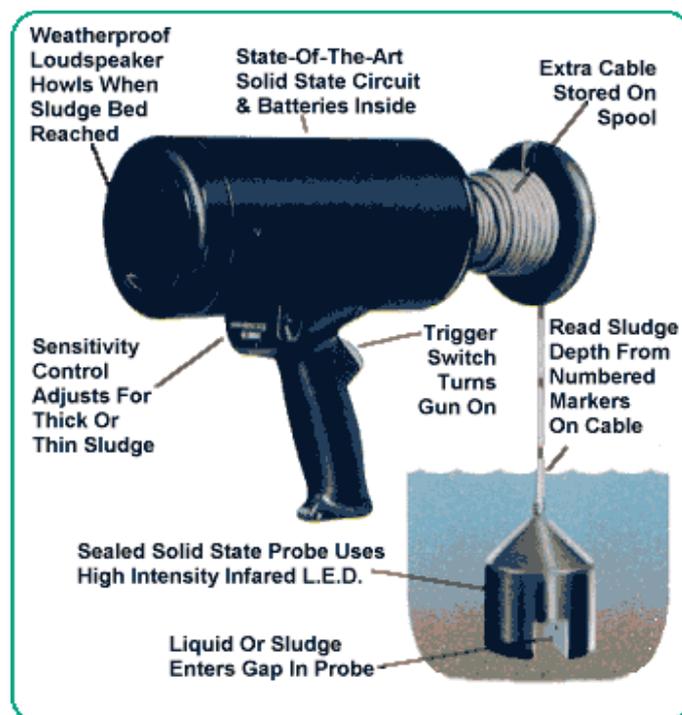


Figure 14: Manual Blanket Level Detector

Stick/Gum Spear

This is the simplest idea and is currently used around Auckland as a technique to measure sediment depth. It involves the operator using a stick (e.g. cutting off a long flax stick from the site) or bringing a Gum Spear and poking around the SW device measuring sediment build up. This is done by poking stick into the base of the device and when the stick is brought out the sediment it leaves a mark on the stick which is measured by the operator. This way is very fast and convenient.

A Stick or a Gum Spear can be used in any SW device without getting into the SW device if it is small and by getting into the SW device if it is big viz., a large pond. This is convenient to carry and very easy to use. There are no or very little manufacturing and maintenance costs and the stick can be disposed of after one or a few uses.

The accuracy of this device and technique is subject to the skills of the operation. The sediment dept readings are not very accurate and retrieving sediment samples is not possible. The operator will not be able to test the same spot each time to be able to compare the results from previous inspections.

In case of a metal Gum Spear or a smooth stick, there is a high risk of the silt getting washed out when it is pulled out of the water. The adherence of silt can be improved by using a stick/spear with a rough surface (square timber section or similar) so as the silt will get stuck to the tool. This will also improve the accuracy of the measurements as the sediment stains on the stick can be accurately measured. Field trials of this modification are necessary to ensure the stick will last a long time without becoming too stained from previous tests that make it difficult for the operator to read the new test result.

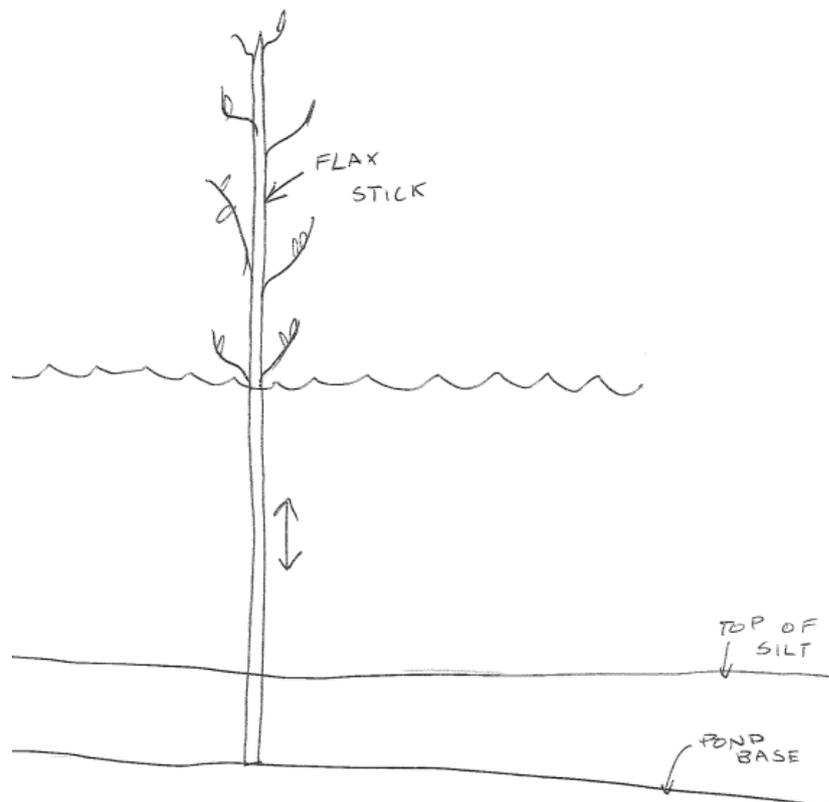


Figure 15: Flax Stick

Desktop Evaluation

This section sets out the desktop evaluation of the 10 designs to determine the three solutions that are the most suitable for use by the NZTA operators. The short-listing of the solutions is based on a robust multi-criteria analysis (refer to Table 1). The aspects considered in the multi-criteria analysis are as below:

Assessment Criteria

Usage – the solution was assessed for its suitability to use in a variety of Stormwater Treatment Devices and other aspects viz., portability, convenience to use, level of skill required. NZTA's emphasis was more on the solution being portable, convenient and simple to use without a high level of training. Hence extra weightage of 20% was assigned to this aspect in our multi-criteria analysis. The option of being able to use the identified solution both in a variety of Stormwater Treatment Devices was more a preference for NZTA than being a mandatory requirement. Hence a lower weightage of 5% was assigned to this aspect. This shows the Usage to be worth 25% of the weightage which is fairly substantial.

Economic – the solution was assessed for the cost of manufacture and maintenance. The cost of maintaining a device to monitor sediment build-up is only a fraction of the cost of manufacturing it, this is due to NZTA wanting an easy to maintain device. This is important as many of the operators do not have time to look after high maintenance tools. A higher weightage was assigned to the cost of manufacture (15%) than the cost of maintenance (5%) in our assessment. This assigned the economic section a total of 20%.

Flexibility – the ability of the device to measure at different depths and sediments of different particle sizes and stormwater treatment devices of different sizes was assessed. The stormwater treatment devices in the NZTA network are not very large and the particle sizes are unlikely to vary significantly from one treatment device to the other due to the catchment being of similar characteristics. Hence a relatively lower weightage was assigned (total of 10%) compared to the aspects like Usage and Economic.

Social – the solution was assessed based on whether it is a permanent fixture (5%), acceptability due to its visual impact (5%) and acceptability by the Operators. If the structure is permanent it has a higher risk of being opposed by the community or vandalised. We also included the level of service under this aspect. As the accuracy of the readings achievable is a primary requirement, a high weightage (20%) was assigned to the Level of Service a solution can provide. This provides a total of 30% which is the highest portion of weightage for the whole desktop evaluation.

Risks – The risks of Operators not accepting the solution and a solution not been seen as practicable by the NZTA was assessed in our analysis and given a 2% weighting. The risk of fabrication/construction being complicated was also assessed and given a weightage of 8%. The risk of cost escalation from the market was given a 5% weighting. A moderate weightage (15%) was assigned in our assessment for this aspect of the solution.

Method of Evaluation

The multi-criteria analysis of the identified options/solutions was independently completed by people with varying engineering knowledge and experience. The results of the assessments were collated and tabulated in the table below. No field trial was included at this stage of assessment.

Results

In our desktop evaluation, simple devices and techniques performed better than more complex designs. Designs that use water surface level to calculate the sediment depth did not perform well in our multi-criteria analysis due to their complexity and errors introduced by the varying water level. The results of our desktop evaluation indicate that **Stick/Gum Spear**, **the Dipstick with disk** and **Jagged Tooth Scoop** are the three most suited (in the same order) for use on the NZTA network by AMA operators.

Discussion

From our desktop assessment of various options, it is apparent that simple tools viz., Gum Spear or a Stick being used by some AMA operators could provide reliable results with some modifications and further training. With standardising the method of measurement and the device to be used, measurements of sediment build-up can be taken at the same locations in the stormwater devices every time the measurements are taken. This will assist in NZTA being able to monitor trend in sediment built up at different locations in the stormwater devices. The modifications and further training required to achieve this are simple and economical.

As finer adjustments will be required to many of the identified solutions to ensure they are effective and convenient to use. Hence it is apparent that field trials of shortlisted solutions will be required before standardising tools and techniques for sediment monitoring by NZTA. At this stage it will be appropriate for NZTA to incorporate these standardised methods in the Operation and Maintenance Manuals of stormwater devices as User Instructions. Alternatively, an Operator Instruction Manual can be prepared to induct the new Operators into using standard methods.

It has become apparent through this study that there is limited review or field trial of various solutions for monitoring sediment build up in stormwater devices. There is no published literature in the industry that provides a comparative evaluation or review of sediment monitoring techniques and their effectiveness. This is surprising given that a reliable solution could optimise the operation of stormwater devices and save hundreds of thousands of dollars in maintenance costs for the asset owners viz., TLAs and network operators. One of the key result areas for AMA is to leave a Positive Legacy for the industry. NZTA may wish to publish the outcomes of this investigation for the wider benefit of the industry.

Multi-Criteria Analysis

Table 1: Desktop Multi-Criteria Analysis of solutions

Wellbeing	General Category	Scoring	Assessment Method	Indicator	Weighting		Option 1: Half Tube with Disc		Option 2: Piston Suction Pump		Option 3: Flax Stick/Gum Spear		Option 4: Jagged tooth scoop		Option 5: Dip Stick with Disk		Option 6: Fishing Rod Style		Option 7: Permanent Cable Pulley System		Option 8: Tower Crane System		Option 9: Gantry Pulley System		Option 10: Sludge Level Detector	
					%	Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Usage	Different uses	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Can be used in sediment chambers as well as ponds	5%	1	4	4	3.8	3.8	4.3	4.3	4.6	4.6	5	5	3.2	3.2	1	1	1	1	1	1	4.6	4.6
	Easy to Use	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Portable, easy to use, can be used by skilled/unskilled staff	20%	4	3.5	14	2.1	8.4	4.8	19.2	3.8	15.2	4.5	18	1	4	1	4	1	4	0	0	2.4	9.6
Economic	Cost of Manufacture	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Estimated cost of manufacture	15%	3	4.5	13.5	4.3	12.9	5	15	3.2	9.6	4.6	13.8	2.2	6.6	2.1	6.3	2.2	6.6	1.5	4.5	3.2	9.6
	Maintenance costs	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Estimated cost of maintaining assets	5%	1	3	3	3.6	3.6	5	5	4.2	4.2	4.2	4.2	2.1	2.1	1	1	1.8	1.8	2	2	2.8	2.8
Flexibility	Flexibility for uses	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Can be used on many pond sizes/shapes, different site conditions	5%	1	3.6	3.6	3.7	3.7	4.2	4.2	4.5	4.5	3.6	3.6	3.8	3.8	3.2	3.2	2.8	2.8	4.2	4.2	4.6	4.6
	Measurement flexibility	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Can measure different depths of sediment of varying size particles, also allowing for collection of samples	5%	1	2.1	2.1	1.8	1.8	2	2	2.2	2.2	2.6	2.6	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	4.2	4.2
Social	Permanent	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Will it be a permanent structure or can it be transported	5%	1	3.9	3.9	4	4	5	5	5	5	5	5	5	5	0	0	3.8	3.8	3.2	3.2	5	5
	Amenity Value	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Physical nuisance, effect on amenity values, susceptibility to vandalism etc	5%	1	3.2	3.2	4.6	4.6	5	5	4.8	4.8	5	5	4.4	4.4	1	1	4.2	4.2	3.9	3.9	5	5
	Level of Service	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Accuracy of measurement to allow for accurate readings	20%	4	3.2	12.8	2.2	8.8	2.2	8.8	3.2	12.8	2.8	11.2	2.1	8.4	2.1	8.4	2.1	8.4	2.1	8.4	2.1	8.4
Risk	Financial	1=(High Risk) 3=(Mod Risk) 5=(Low Risk)	Qualitative	Risk of cost escalation	5%	1	4.1	4.1	4.1	4.1	5	5	3.6	3.6	4.2	4.2	2.8	2.8	3.2	3.2	2.4	2.4	2.4	2.4	3.2	3.2
	Failure to achieve desired outcomes	1=(High Risk) 3=(Mod Risk) 5=(Low Risk)	Qualitative	Risk of operator opposition, solution not being practical, etc	2%	0.4	2.8	1.12	2.8	1.12	3.5	1.4	3.8	1.52	5	2	4.4	1.76	1	0.4	3.1	1.24	1.24	0.496	4.2	1.68
	Construction	1=(High Risk) 3=(Mod Risk) 5=(Low Risk)	Qualitative	Feasibility/achievability of construction	8%	1.6	3.2	5.12	3	4.8	5	8	4.6	7.36	4.6	7.36	2.8	4.48	2.1	3.36	2.6	4.16	2.6	4.16	4.6	7.36
				Totals	100%	20	41.1	70.44	40	61.62	51	82.9	47.5	75.38	51.1	81.96	35.6	48.34	19.5	33.66	28.8	42.2	25.94	36.056	45.9	66.04
				Ranking			4		6		1		3		2		7		10		8		9		5	

Fabrication and Testing

It is considered important that the solutions identified by the desktop review are in fact practicable and reliable. To ensure this, our recommendation is to fabricate the three shortlisted solutions and carry out field evaluations with the assistance from the NZTA operators. This will also ensure the acceptability by the people who will be using it before the new solutions are standardised and implemented.



Photo 8: Pond where the forebay looks as if it needs sediment cleaning

Field Evaluation

Field Evaluation

During the stage of field trials it is essential to seek, collate and evaluate feedbacks from the operators using the same multi-criteria analysis used for the desktop assessment.

A comprehensive field trial would increase the robustness and reliability of this investigation.

Our recommendation is that the field trials are carried out over a period of one year including all NZTA operators in the study. To provide adequate feedback for a comparative assessment of the solutions, it is prudent for all operators to trial all three solutions during the field trials.

Depending on the performance of some of the solutions, further amendments could be made to improve their reliability or discarded if deemed completely unsuitable. The outcome of the first years field trials will determine if further investigation of the same solutions or further solutions in the list of ten overall solutions identified will be required.

Summary of Findings

The evaluation of the proposed options revealed the following:

- Devices and techniques that used water surface level to measure the sediment depth are less accurate
- Complex devices need more training and skilled labour to use
- Portable devices are cheaper, easy to use and need very low maintenance
- Permanently fixed devices are more expensive, require regular maintenance and are susceptible to vandalism
- Simple devices can produce accurate and reliable results. They are also more likely to be attractive to the operators

This evaluation indicated that the **Stick/Gum Spear**, the **Dipstick with disk** and **Jagged Tooth Scoop** are the three most suited (in the same order) for use on the NZTA network by AMA operators.

Recommendations

Following the desktop review, we have prepared a brief list of parameters to be used to compare the three tools/techniques to measure consistency and ease of measurements during field trials.

- Field testing will need to be completed in the next financial year (2010/2011).
- Prior to the field trials, a log book/sheet will also be prepared for use and to review the accuracy of the readings recorded.
- While the new tools and techniques are being tested, all measurements recorded will be verified by using the current techniques NZTA/AMA maintenance staffs are using.
- The manuals and log sheets developed at this stage will be passed on to the NZTA.

Our recommendation is to use the same multi-criteria analysis with the same aspects of the solutions for reviewing the performance during field trials. Also when testing the devices on site the designs can be modified to suit problems/preferences that occur on site. Each operator should comment on how they think the design could be improved to suit them.