STORMWATER MAINTENANCE AND OPERATIONS AT NEW ZEALAND'S MOST CRITICAL ROAD NETWORK – AUCKLAND MOTORWAYS

Presenter Profile: Peter Mitchell is an environmental engineer and associate with Opus International Consultants and is also the stormwater asset manager in the Auckland Motorway Alliance. Peter has 24 years of experience in Stormwater Management and Environmental Engineering. Peter provides practical, safe, and innovative solutions for challenging projects, and delivers whole of life and value for money outcomes to meet and exceed customer and stakeholder expectations.

ABSTRACT

The Auckland motorway network supports much of the social and economic activity of the greater Auckland region, with nearly 1,000,000 vehicle trips per day, and carrying over 10% of the nation's traffic the motorway network has the highest criticality rating of any road network in New Zealand – For a liveable city and communities, good stormwater management, maintenance and operation is essential at Auckland motorways.

The Auckland Motorway Alliance (AMA) maintains and operates the New Zealand Transport Agency (NZTA) Auckland network and is dedicated to improving the motorway experience for all stakeholders. Our focus is delivering safe, efficient, and reliable travel.

In addition to all elements of a traditional stormwater network the motorway has New Zealand's highest concentration of stormwater treatment devices. Significant focus is being placed on the stormwater assets to deliver safe and whole of life value for money maintenance and operational activities and outcomes. Maintenance and operations includes keeping the motorway free of stormwater safety risks like vehicle aquaplaning, to ensure that the motorway is not made impassable by flooding, and to effectively manage network vulnerability risks such as aged and collapsing culverts, and to manage environmental risks such as pollution and legal compliance with resource consents.

The Auckland motorway network is the current focal point of many of the Transport Agency's nationally significant capital projects and roads of national significance, which further contributes to the scale, importance, and complexity for good stormwater maintenance and operational outcome needs.

Industry has not always been well informed of the outcome and operational needs of the Auckland motorway stormwater network. This presentation will cover some key maintenance and operational lessons and innovations by the AMA that help contribute towards making Auckland City the most liveable city in the world – some of the AMA learnings will be of relevance and 'transportable' to other stormwater networks throughout the Asia-Pacific Region.

KEYWORDS

Maintenance and Operation, Stormwater Management, Auckland Motorways

STORMWATER MAINTENANCE AND OPERATIONS AT NEW ZEALAND'S MOST CRITICAL ROAD NETWORK – AUCKLAND MOTORWAYS

1.0 INTRODUCTION

The Auckland motorway network is unique, complex, and of national significance, and while not big on an international scale, it is very busy and critical to New Zealand's economy. The 240km network connects the 1.5 million people of the country's largest region, and is trafficked by nearly 1 million vehicle movements per day, which amounts to about 20% of state highway traffic and 10% of New Zealand's daily traffic.

The Auckland Motorway Alliance (AMA) must ensure that the stormwater management assets deliver the right level of network service, and that safe and healthy outcomes are achieved for people, plant and the environment.

The AMA brings together its partners in a single organisation with common aligned objectives, and core values that have been set out in a charter. The key alliance partners are the New Zealand Transport Agency (NZTA), Fulton Hogan, Opus, Beca, Resolve Group, and Armitage. The AMA purpose is to 'operate and maintain a connected network for all stakeholders where customers feel informed and are confident that they will get to their destinations comfortably, safely and reliably at all times'. Our mission is zero harm to our people, environment and business.

This paper provides a brief insight of the AMA way, important stormwater operational considerations, and Capital Project maintenance and operations guidance that helps to positively influence operational legacy outcomes.

2.0 THE AMA WAY

Due to asset criticality and network vulnerability and resilience risks the AMA places high emphasis on delivering operational management of the stormwater management assets as well as influencing the operational legacy outcomes of Capital Projects.

Being such a heavily trafficked road network it is essential the motorway pavement is free of surface water that can induce safety risks like aquaplaning, that the motorway is not impassable because of flooding, and that assets are in a safe condition to manage vulnerability, resilience and network availability risks.

Water quality, pollution, erosion, and protection of the receiving environment are also important factors to manage for legal compliance needs and positive environmental outcomes. Stormwater runoff from the Motorway network includes pollutants like sediments, litter, and debris, oils, and heavy metals. The NZTA has many Resource Consents and associated operational conditions for stormwater discharge at Auckland Motorways that must be well managed to ensure legal responsibilities are delivered.

By traditional delivery procurement approaches the unique operational delivery needs for the motorway network level of service and compliance needs were not always achieved. Prior to the AMA stormwater operational maintenance activity at Auckland Motorways was all delivered reactively. By delivering proactive work (cyclic and periodic maintenance) and through the alignment and streamlining of activity (e.g. multiple work stream activities delivered under single traffic closures), and delivering most maintenance activity at night (to minimise network efficiency issues and risks), etc., we are now spending less than before. We now spend less than 10% of the stormwater asset budget on reactive work.

The AMA model empowers and enables opportunities for safe delivery of the stormwater assets, and better whole of life and value for money outcomes. The challenge for the AMA is to continue to maintain and deliver the assets while reducing overall costs.

Stormwater surface flooding presents safety risks to motorists

2.1 Stormwater Vision, Strategic Goals, and Actions

Vision

To provide customers and stakeholders with the positive legacy of a world class, safe, efficient, and optimal stormwater management asset which delivers an appropriate level of service, and best practicable option to avoid, remedy or mitigate adverse environmental effects

The AMA stormwater strategy and activity plan currently includes a number of goals and activities that have all been outcome focus risk profiled such as:

- Improved asset knowledge and data to enable improved asset management practice and outcomes.
- Delivery of the stormwater management assets to reduce the incidence of unsafe flooding and to deliver environmental compliance.
- Deliver agreed levels of service and seek to change levels of service where there are opportunities to improve value for money outcomes.
- Measure asset performance and condition with respect to the level of service and asset renewal needs.
- Manage risk registers and prioritise activity needs for all maintenance delivery.
- Optimise expenditure and balance programmes of works to reduce the life costs, and develop models so that funding scenarios can be linked to levels of service.
- Reduce cost of maintenance by innovation.
- Develop robust and continuously improving forward works program.
- Stakeholder and customer requirements and perceptions are included in asset management decisions by good understanding of needs.
- Have the 'right' people - qualified, trained, experienced, skilled and knowledgeable.
- Manage a register of ideas and innovations, and pursue 'additional' strategic improvement opportunities when timing, resource, and funding become available.

2.2 Auckland Motorway Stormwater Management Assets

The Auckland Motorway stormwater management asset includes all elements of a traditional stormwater 'drainage' collection and conveyance network such as slot drains, catch-pits, manholes and pipes; waterway and network crossing culverts; pump stations and soakage disposal systems, etc. The AMA also delivers the highest concentration of stormwater treatment devices (and rapidly growing) of any network in New Zealand.

There are three primary types of stormwater management asset that provide different service and outcome needs. These assets are of different material types, all with different deterioration rates and performance capabilities. These assets all have unique operational delivery needs (i.e. monitoring and maintenance activity needs vary).

For improved linkage to outcome needs and important network values AMA has defined the three primary types of Auckland Motorways Stormwater Management Assets as:

Type 1 - Surface water collection, conveyance, and disposal: This is the means of collecting stormwater off the motorway surface (e.g. median drains, slot drains, catchpits), conveyance (e.g. pipes, manholes, open channels, pump stations, entryway crossing, secondary flows), and discharge disposal (e.g. streams, soakage to ground, pipe outfall networks). These assets essentially help to deliver the right level of service against unsafe surface flooding.

Type 2 - Waterway and Network Crossings: Where the motorway crosses a major waterway or regional reticulation network (e.g. major culverts at streams, local council pipe, or coastal waterway). These assets typically include elements such as the barrel, headwall/wingwall, erosion and scour protection, energy dissipation, and ecological provisions such as fish passage, and landscape planting. These assets are essential to manage local and regional flooding and risks to network availability (e.g. network unpassable due to unsafe flooding).

Type 3 - Stormwater Management Devices: Water quality treatment, and quantity attenuation devices such as swales, ponds, basins, sediment tanks, proprietary treatment devices. These assets are required to manage environmental risks by treating contaminated runoff prior to discharge at the receiving environment. These assets have operational conditions of resource consents that must be managed and delivered to ensure that legal compliance needs are delivered.

It is also important to note that whilst not measured as a stormwater treatment device that of the more than 4.7M m^2 of motorway pavement about 85% is paved with open graded porous asphalt (OGPA). Although not a traditional stormwater treatment asset, OGPA has a high inherent treatment capability by acting like a permeable pavement. Runoff from OGPA surfaces receives good pre-treatment that helps to improve the quality of runoff as a valuable component of the stormwater treatment train.

The spray suppression benefit of fresh open graded porous asphalt (OGPA)

3.0 STORMWATER OPERATIONS

It rains a lot in Auckland and it is critical the motorway network remains safe during wet weather. To improve motorway reliability and safety it is important that the stormwater assets are well maintained and that appropriate operational activities are delivered.

'Risk based - outcome focussed' - To enable the smart delivery of operational activity needs individual risk locations at Auckland Motorways have been profiled (prioritised) based on likelihood (of blockage and flooding) and consequence (including safety and network traffic efficiency). Benefits of improved network efficiency (inefficiency is generally a social-economic cost of travel time and vehicle operating cost), includes a reduction in pollutant generating potential. Despite the good operational activities to improve surface flooding and pollution, future incidents will occur (e.g. storms and unexpected blockages). Being prepared with the right resources to deliver activity needs is very important.

The AMA deliver a wide range of operational monitoring and maintenance activities that contribute towards the right level of service and environmental outcome needs. Some important factors include:

- Team and Resource
- Knowledge and Data
- Monitoring and Inspection
- Pollution and Contaminant Removal
- Incident Response
- Training and Education
- Innovations and Promulgation
- Capital Project Engagement

A brief insight to these important operational factors is outlined in the following:

3.1 Team and Resource

Having the right team helps to ensure that the right stormwater outcome needs are achieved. Timely and informed intervention with skilled and properly equipped staff to do the right activity at the right time, safely and effectively, helps to achieve good value for money. This includes:

- Suitably trained, experienced, and qualified staff with specialist skills - good asset and activity knowledge.
- Availability of specialist tools and resources (e.g. tools for automated data capture, and plant such as combo trucks that flush, vacuum and recycle).
- Great customer and stakeholder relationships, partnerships, and proactive collaborative engagement across industry (e.g. Specialist contractors, Auckland Council, Auckland Transport, special interest groups).
- Empowered and specialist teams take good 'ownership' of assets – this helps to deliver better stormwater outcomes (cost, performance and timeliness of needs).

3.2 Knowledge and Data

Good available, accurate, and accessible data and data management systems is the foundation of good asset management – this is essential for good operational activity delivery and outcomes.

In addition to the criticality of having good core stormwater asset data such as accurate as built data and comprehensive RAMM data, good monitoring and maintenance data is essential. Data that is important to the AMA includes:

- Measured asset performance and condition data helps to ensure that the right level of service and environmental outcome needs are delivered at the right time.
- Data that clearly links assets to level of service risks and compliance is important e.g. mapped surface flooding risk sites, and data that provides a clear linkage of resource consent numbers to individual treatment devices.
- Based on measured asset data the asset activity needs are risk profiled then programmed and logged to the AMA activity Level of Service reporting system to ensure timely delivery of the required maintenance activity.
- Monitoring data of selected treatment devices includes sediment and water quality sample collection, lab testing, and data analysis for the purpose of performance capability evaluation as well as determining optimal contaminant disposal options.
- Good monitoring data and analysis enables good decision making and improved value for money outcomes.

3.3 Monitoring and Inspection

To determine the right maintenance activity, the right intervention frequency, and any asset renewal needs there are three key principles for good operational monitoring:

- To detect defects in a timely manner that may cause unacceptable safety, serviceability, environmental compliance risks, or a serious maintenance requirement to safeguard the public, the asset, and the environment.
- To get data to enable management and maintenance to be planned and implemented on a rational basis.
- Inspections to be undertaken by suitably experienced and competent staff.

It is important to distinguish asset performance from condition. Performance failure generally determines any maintenance needs (e.g. blocked catchpits or pipes) while asset condition failure (and deterioration data) generally determines the renewal needs (e.g. cracked and structurally failing culverts, aged and unsafe assets, pond landscape failure).

Standard monitoring and exception-based reporting ensures that the right operational activities (cyclic, periodic, reactive, renewal, improvement, new asset) are proactively and safely undertaken at the right time ('just in time' intervention) using the right resources ('fit for purpose'). The AMA way includes:

- Standardised and simple procedures enable familiarity, efficiency, and consistency of delivery, and empowerment to deliver better quality outcomes.
- The AMA has developed innovative asset specific schedules for the delivery of consistent monitoring and condition measurement of the treatment devices that enables automated condition rating and data of the critical elements of the devices.
- "Boots to suits" field guides facilitate operator activities, helping the AMA to secure increased confidence in the delivery of activity needs and give confidence that the stormwater management asset is being responsibly delivered.
- Compliance monitoring by use of CS-VUE online environmental management and compliance system, with linkage to activity needs (delivery and reporting) as well as proactive regulatory compliance reporting.

3.4 Pollution and Contaminant Removal

Each year the AMA collects about 3,000 tonnes of contaminants that could otherwise end up in the receiving environment via the stormwater system. It is also important that contaminants collected are responsibly managed and safely disposed e.g. contaminated waste, managed fill, recycling, and re-use. Important AMA pollution and contaminant management activity includes:

- Litter runs and sweeping at debris hotspots.
- Routine maintenance of stormwater treatment devices.
- Cyclic catchpit cleaning.
- Maintenance of soakage disposal assets.
- Litter and pollution warning letters (to recidivist prone areas).
- Identification of fly tipping offenders.
- Enforcement by securing prosecutions.

Treatment assets help capture contaminants and manage receiving environment pollution risks

3.5 Incident Response

Incidents such as unsafe surface flooding and spills at Auckland Motorways network present a significant risk to the safety of people and the environment. AMA has a trained team that is always available for highly responsive attention to incidents.

Unsafe surface flooding can cause immediate safety and network availability risks, while contamination incidents can present a serious threat to the receiving environment. Recent spills have included potentially harmful oils, sewerage, fertiliser, and milk powder. Despite much of the stormwater treatment system having inherent containment capability, the AMA way includes:

- Being highly responsive to containing spill incidents and making good in a timely manner - rather than costly and time consuming pollution clean ups.
- Specially trained operators in the procedures and requirements for incident management, who are equipped with a range of tools and resource e.g. spill kits, safety equipment and plant that enables captive water cleaning techniques.
- Good collaborative relationships are important for responsive and trained attention during incidents e.g. specialist contractors (e.g. HydroTech and HydroVac), the Auckland Council pollution response team, Watercare Services Limited (e.g. burst sewer), and Fire Service (e.g. tunnel foaming), etc.

SH16 Causeway 23rd January 2011 – 6 tonnes of coastal debris cleared following morning tide

3.6 Training and Education

It is important that all staff are culturally aligned with organisational objectives. This requires suitably knowledgeable, experienced, qualified and trained personnel for the diversity of activities. It is also important that any specialist service suppliers are suitably trained and educated of the safety and outcome needs to ensure that effective and efficient 'fit-for-purpose' activity can be delivered in a timely manner. Useful training and education activity that AMA pursues includes:

- The safety of road users and operators at all levels is of utmost importance and a critical component of success. This requires activity specific safety training and education (e.g. gas detection and confined spaces training).
- SafeStart training empowers staff and changes behaviour towards looking for risk patterns and application of critical error reduction techniques. This technique enables continuous improvement to the way all activity is delivered. SafeStart takes account of the safety of people, plant, and environment.
- Training and education on asset function and operational procedures help to ensure clarity and consistency of activities.
- Presentations, conferences, and publications to share knowledge and ideas with industry about our way of delivering the stormwater management assets.
- "Boots to Suits" - All activity must be commonly understood for optimal empowerment (e.g. language and medium of instructions should be clearly understood). Using specialised engineering terminologies is often meaningless to 'boots' operators, and 'suits' awareness of what 'actually' happens often needs translation to successfully close the asset lifecycle gap for stormwater asset operational needs.

3.7 Innovation and Promulgation

Innovations and initiative projects delivered by AMA help to improve operational delivery and network outcome needs. Innovations can help to reduce risks, reduce operational expenditure, reduce congestion, improve safety, reduce complaints, and positively influence industry. Some AMA stormwater innovations include:

- Rationalisation of resource consents and agreed activity and frequency needs.
- Safe access grates for underground vaults.
- Grated trench drain development with global suppliers.
- Efficient catchpit grate systems developed in collaboration with suppliers.
- Standardised Operational Monitoring and Maintenance schedules.
- Data verification tools – measuring stick and camera systems.
- Landscape planted swales.
- Algae management trials.
- Stormwater treatment asset conversion for safer and more effective outcomes.
- New Zealand's first bifurcated wet pond and study of Floating Vegetated Island.
- Automation of critical treatment and spill containment assets.
- Improved forecasting of tide and weather events, as well as 'events' that result in increased risk of contamination e.g. rock concerts when litter spikes occur.
- Safe access initiatives that enable timely delivery of routine and reactive needs.

The sharing and promulgation of ideas, innovations, and lessons of 'fit-for-purpose' activities importantly contributes towards improved outcomes for our stormwater management industry.

3.8 Capital Project Engagement

Auckland Motorways are a current focal point of many of NZTA's nationally significant projects which further contributes to the scale, importance, and complexity of good management and responsible delivery of the stormwater assets. Active engagement with Capital Projects helps to positively influence the operational legacy outcomes. This activity includes:

- Comments on planning, proposed designs and construction based on our knowledge of maintenance issues and opportunities. Engagement with Capital Project consortiums (NZTA, consultants and contractors) throughout the delivery phase helps to ensure that whole of life value and safe positive legacy stormwater outcomes best achieved.
- Handover inspections to help operational familiarity.
- Inspection of stormwater management assets for acceptance. SNAG identification e.g. defects, condition, safety at handover (practical completion and at end of defects liability period).
- Review of special needs for stormwater assets at handover such as specific tools and parts needs at project handover.
- Stormwater asset product and material review/acceptance for handover.
- Review of the stormwater component of all asset owner manuals and the specific stormwater MO documents for handover acceptance.
- Review of asset handover data for acceptance (e.g. as built drawings, cctv data review, special agreements, permits, and risk/opportunity registers).
- Review handover material for adequacy to deliver level of service and regulatory compliance needs.
- Interface with delivery consortiums and the regulatory body for confirmation and clarifications of asset ownership and maintenance ownership responsibility.
- Production of an Operation and Maintenance Guideline for the planning, design and construction of Capital Projects. This document outlines the issues, values, opportunities, and handover needs that influence improved operations and water quality outcomes.

4.0 CAPITAL PROJECT OPERATION AND MAINTENANCE GUIDELINES

"Customers First" - Customer engagement for the NZTA Highway Asset Management Plan identifies a number of values and bottom line expectations of the state highway network. These values are grouped into three categories:

- safer journeys.
- efficient and reliable journeys.
- social and environmental responsibility.

Good stormwater management assets should deliver on these values in all areas of need, particularly with respect to risks such as unsafe surface flooding, asset durability and resilience, network vulnerability, the ability to deliver timely operational monitoring and maintenance by good safe off road access to stormwater assets, and the need for delivery of environmental compliance (legal requirement), etc. The delivery of holistically good stormwater management assets and outcomes also requires good consideration of other risks and opportunities throughout the delivery lifecycle such as water quality, biodiversity, ecology, cultural, social, and amenity values.

Throughout the stormwater asset lifecycle, many factors can significantly influence Capital Project outcomes. Often overlooked is that the operational life delivery of stormwater asset dwarfs the planning, design, construction, and handover phases of these Capital Project assets in terms of the associated life timeframe and delivery costs.

In context it is important to consider that Auckland Motorways are nationally significant and critical (National Significance Criticality Rating 1). Auckland motorways are also unique for the sheer volume of traffic, and some principles that may be considered 'fit-for-purpose' for stormwater assets at say local roads or highways in a rural context are different to some of the principles that most importantly apply for the Auckland Motorway network. For example there is no such thing as simply pulling over to the side of the road to deliver operational management. For strict safety reasons, often timely and costly temporary traffic management (TTM) is essential for what may seem on the surface to be the simplest of operational needs.

The purpose of the AMA Maintenance and Operations Guideline is to assist capital projects to achieve positive outcomes and deliver values that are important for good operational management of stormwater assets such as available and reliable function, whole of life value for money, and safety (people, plant, and the environment).

Fundamentally, good Stormwater Management outcomes that need to be safely delivered at the Auckland Motorway network broadly fall into two primary categories:

- **Level of Service** e.g. to ensure there are no unsafe assets or unsafe motorway surface flooding, and that the network remains available and resilient during flood flows;
- **Environmental Compliance** i.e. delivery of legal compliance against conditions of Resource Consents including physical issues such as erosion, sediments, contaminants & ecological health.

The target audience of the guideline is all personnel involved in delivery of Capital Projects throughout the asset management lifecycle for the NZTA stormwater management asset including; planners, designers, contractors, MSQA staff, and importantly the end asset owners. All personnel involved in project development and delivery are encouraged to be inherently outcome focused and develop a strong sense of 'ownership'. Throughout the project life:

- Think about the **legacy** of the asset (positive, safe, sustainable and resilient).
- Think about the stormwater implications on network **efficiency** and **reliability**.
- Think how **customers** and **stakeholders** will value/perceive the assets.
- Robust evaluation of **whole of life** outcome implications, and **value for money**.
- Think about **holistic health** of stormwater management assets - environmental, social, cultural, and financial.

4.1 WHOLE OF LIFE VALUE CONSIDERATIONS

Robust whole of life value in decision making is critical for good stormwater management outcome requirements such as:

- Full consideration of stormwater operational implications throughout the asset life (Preliminary Feasibility, Planning, Design, Construction, MSQA, Operations, Renewal and/or Disposal).
- Consider the implications of Resource Consent conditions on maintenance and operation costs that occur during the planning, design, and construction delivery stages. Look for solutions and agree consent conditions (with the AMA stormwater asset manager) that have low operational monitoring and maintenance time and cost implications.
- Ensure that a robust evaluation of options is undertaken including a rigorous assessment of whole of life operation and maintenance costs, including temporary traffic management, safety permitting and associated costs (e.g. confined spaces

entry), activity delivery (people and plant), and costs associated with delivery of compliance with consent conditions). Whole of life value assessment should demonstrate holistic value for money. As part of this process the **50** year operational monitoring and maintenance costs should be included.

- Never underestimate the whole of life costs associated with Temporary Traffic Management (TTM) for the purpose of delivering operational activity needs at stormwater assets that do not have good safe off road, all weather access. For example the TTM for a motorway closure typically costs about $4,000 per night, and a motorway ramp closure typically costs about $2,500 per night.

4.2 PLANNING, DESIGN, CONSTRUCTION, AND HANDOVER

To ensure that optimal operational outcomes are achieved for the stormwater management assets there are a number of considerations that should be addressed during development and delivery. A number of considerations are general and relate to all phases of the asset lifecycle, whilst some points are more specifically pertinent and influenced at the planning, design, construction, or handover phases of project delivery.

Fundamentally, it is important to always be mindful that the two primary drivers for the stormwater management asset are to deliver the right level of service such as structural integrity, safe condition of assets, available performance (e.g. pavement surface drainage, flood protection), and to effectively and efficiently deliver legislative compliance (e.g. comply with conditions of resource consent) throughout the asset lifecycle.

4.2.1 GENERAL

Some common and useful considerations for good operational outcomes for the stormwater asset development and delivery lifecycle include:

a. **Collaborative engagement** to ensure that good capture of the asset intent is recorded and to ensure that operational risks and opportunities are included in the decision making process. This include having copies of the project life reporting documents (preliminary feasibility reporting; scheme assessment reporting, assessment of environmental effects, preliminary and detailed design reporting, peer review reporting, & construction reporting). Good consultation with the Operators will help to ensure the effective transfer of knowledge (especially the delivered 'intent') and to capture of appropriate information in the stormwater asset owners' manual (including operational review as part of Consent sign off process).

b. To help ensure that good and **safe positive legacy outcomes** are achieved for the stormwater management asset, it is important to carefully consider every element of the total stormwater management system being developed and delivered (collection & conveyance network; major waterway & network crossings; treatment devices). AMA offer guidance and advice for all elements of the Stormwater management asset throughout Capital Project lifecycle.

c. **Compliance** - Ensure that all general conditions, specific conditions and advice notes of the Resource Consents are adhered to throughout the capital project delivery, and ensure that linkage of relevance to the future operational requirements is captured for the stormwater asset owners' manual. Ideally the statutory 'requirements' (consent conditions) will facilitate the delivery of a consistent and pragmatic regime for intelligently aligned cyclic monitoring and maintenance.

d. **Less is more**. Consider opportunities to minimise the extent of asset whilst delivering the required outcomes (e.g. if space is available, rather than say a traditional catchpit/manhole/piping stormwater system, that swales can provide the collection, conveyance, and treatment objectives as a single and simple asset which is easy to monitor and maintain).

e. **Consistency** (and compatibility) of asset elements, standards, and specifications. Consistency reduces the need for specialised tools, resources, and personnel for effective operational monitoring and maintenance activity to be delivered. Avoid 'special' or 'bespoke' assets that require unique operational needs or knowledge - Keep it simple and intuitive. Assets with monitoring and maintenance activity needs that are familiar to maintenance operators stand a much greater chance of being delivered well.

f. Consider all aspects of **safety** by Safety in Design (e.g. clear zone requirements, road users, operational staff during monitoring and maintenance activities, neighbours, emergency services). Safe off road access is important due to the time required to maintain some assets such as periodic pond cleaning, or the time taken to replace sand media in a sandfilter. It is however important to carefully weigh-up consumption of land for treatment (often limited by designation footprint, or available hydraulic head limitations) versus the provision of the off-road access.

g. Stormwater management solutions should adhere to good principles of crime prevention through environmental design (**CPTED**). In context this includes minimising the risk of vandalism, judicious landscape planting at ponds, thoroughfare control at major culverts and waterway crossings (e.g. consider risks associated with culverts adjacent to private properties, parks and reserves).

h. **Access** for ease of monitoring and maintenance. Delivery of operational monitoring and maintenance of the Auckland motorway network is normally undertaken at night (when visibility is poor) to best manage the motorway network efficiency (i.e. customers/drivers do not want to be stuck in traffic while maintenance is delivered). Sometimes maintenance is also delivered in wet conditions. Hence good safe all-weather access (24/7) is required. Avoid assets where operational monitoring and maintenance needs to be undertaken within the carriageway area and requires temporary traffic management. Avoid locating stormwater assets at median or gore areas due to the operational challenges of safety exposure and safe access (e.g. swales, sediment vaults, soakage disposal, and filtration treatment devices, etc. at medians cannot be accessed for maintenance activity without costly TTM). Assets are best located outside of the carriageway area. Also, best practicably avoid solutions that require specific permitting or operational activities (e.g. working at heights or confined spaces activity).

i. Consider **emergency incidents** such as the capacity of the stormwater assets/system to contain, intercept, or isolate environmental incidents like unsafe spills, or flooding). Ideally the stormwater management system should include mechanisms to inherently contain oil, grease and other floating contaminants, as well as to provide an isolation capacity of $20m^3$ (e.g. consider the event of a petrol tanker spill, or say a truck load of milk powder, fertiliser, or cement entering the stormwater network and receiving environment).

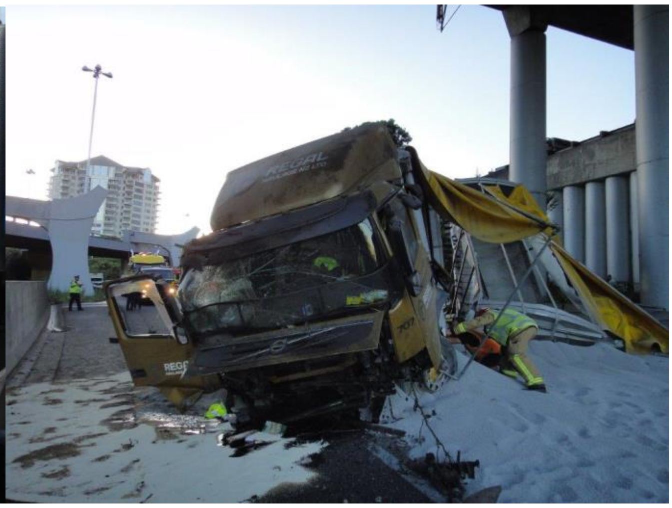
j. **Secondary flow paths** (SFPs) are critical. Ensure that SFPs are robust (i.e. durable and safe for peak design discharges). SFPs should be secure in perpetuity (e.g. easements), and reflected on as-built information (i.e. mapped). Take good account of the potential implications of other assets on intended secondary flow paths (e.g. fences, noisewalls, and bridge piers, etc. can interfere with intended SFPs.

k. **Debris** blockage will impair performance of the network. All elements of the delivered stormwater management asset need to be given essential assessment for the reliability and functionality of performance. Assets that minimise the risk of blockage occurring through accumulation need consideration (i.e. appropriate catchpit grate types, protection grilles at pond outlets, and waterway culverts).

l. **Aesthetics**. It is important that Auckland Motorways always look great. A good stormwater management asset should ideally blend with nature (e.g. swales, waterways, and ponds to be of 'naturalised' appearance) or be hidden (e.g. below ground pipe networks, or treatment vaults). Avoid solutions attractive to graffiti artists, or assets that can create unsafe distractions to drivers.

m. **Mental time** at the asset. Imagine the completed asset and the full range of conditions encountered during a lifetime of operational monitoring and maintenance. Think about factors such as daily conditions, night maintenance activities, wet weather, drought, the asset after a month of operation, after a year, ten years, fifty years, safety of users and operators, aesthetics, health of vegetation, ecological health, risks of failure such as pollution, erosion or flooding.

n. **Risk management** - Through the planning, design, and construction phases, all operational risks, liabilities, and opportunities must be effectively managed (hazard/risk register). From day one, develop and manage an outcome focused risk and opportunity strategy for level of service and compliance outcome requirements and needs. All elements of the stormwater risk register should include the likelihood, consequence, and operational monitoring and management strategy.



4.2.2 PLANNING

It is important to recognise that stormwater concept solutions are often simply developed to sufficiently demonstrate that a technically and physically viable solution can be achieved (for the purpose of supporting resource consent processing – at which time the conditions for design, construction and future operation are often set).

The planning phase of Capital Projects is critically important to ensure that good legacy outcomes can actually be delivered by the latter 'lifecycle' phases of the project (i.e. design, construct and operate). For example if land requirements have not been adequately identified and secured at the project planning stage (so that the stormwater assets can be pragmatically delivered within designation) there will be subsequent challenges and issues like high costs for ancillary works such as significant earthworks, retaining walls, or 'structural' solutions (e.g. large concrete vaults). Inadequate 'space' also means that some fundamental outcome values such as good safe all weather off road access cannot be effectively achieved (resulting in high future costs for temporary traffic management, etc.). Good planning sets the foundation to delivering and achieving good stormwater management operational outcomes and values.

It is also important to recognise that often the 'foundation' set at the planning phase of capital projects carries through the latter delivery phases (e.g. a conceptualised pond at planning more often than not results in a conceptually similar pond being built). Good robust stormwater planning cannot be understated nor underestimated. Some important principles include:

a. The high level philosophy and objectives for the stormwater management system needs to provide a best practicable option (BPO) to avoid, remedy or mitigate adverse environmental effects. The Resource Management Act states: *"Every person has a duty to* ***avoid, remedy or mitigate*** *any adverse effect on the environment arising from an activity. . ." S*ection 77 (2) of the Land Transport Management Act 2003 (LTMA), also includes that adverse environmental effects be avoided or managed with the (BPO). This includes important consideration of whole of life operational monitoring and maintenance.
b. Consider opportunities for an integrated and centralised approach to manage stormwater quality and quantity issues. Maximise the value of water management systems through partnerships with others, and avoid piecemeal systems which require multiple operational establishments).
c. Ensure that works will not induce or result in an increase to pollution, erosion or flood risks on the upstream and downstream properties. OM intervention for renewals or improvements (resulting from sub-standard capital project delivery) is not cost effective. Robust and resilient stormwater solutions need to be delivered during the project design and construction lifecycle. Best practicably mimic the predevelopment hydrologic regime and setting, to deliver outcome objectives which are aligned with the issues, values, and opportunities of the receiving environment (e.g. post development discharges to mimic predevelopment flow rates and volumes to manage erosion and/or flood risks).
d. Future-proofing: Ensure that designs are future-proofed for the maximum probable development (MPD) for the catchment. In some cases council plans do not accurately reflect the 'likely' or 'potential' MPD (e.g. for sites adjacent to the urban limit). Also consider positioning of all stormwater assets with respect to future road widening or development projects.
e. Challenge operational conditions of consent to ensure that all conditions enable effective and efficient delivery of operational needs to satisfy legal responsibilities. Aim for consistent, simple, and meaningfully measureable conditions.
f. Signoff on conditions as they are satisfied (don't wait until project completion), and all compliance 'updates' should be recorded at CSVue.

4.2.3 DESIGN

For all elements of the design of stormwater management assets associated with capital projects, the practicality of all future operational monitoring and maintenance requirements should be carefully considered in the context of Auckland Motorways. Reliable functionality and a capability to pragmatically deliver and achieve compliance is the essence of good stormwater management operational outcomes. As simple as it may seem, it is important to ensure that the asset can actually be safely accessed to enable physically monitoring and maintenance.

Standards and Level of Service

i. Ensure that appropriate engineering standards are applied. Aside from NZTA Minimum Standards (Z series), few NZTA Stormwater Instruction Standards, Policy, Interim Standards (or standard drawings) are documented or available (aside from 1977 NRB Highway Surface Drainage), and the design expectations or 'requirements' are often not clearly defined. NZTA need a stormwater engineering standards document (current default is Austroads).

ii. Being a nationally significant and strategic network the Auckland Motorways need to be safe and trafficable during extreme storm events (up to the 1% AEP critical storm event). This includes the need for design tide levels and rainfalls to include appropriate allowances for factors such as storm surge and climate change.

iii. The maximum surface water depth at any point on any running lane, including merge, diverge and gore areas, during a 50% Annual Exceedance Probability (AEP) 5 minute duration rainfall event should not be greater than 4mm above the top of the surface texturing. As per NZTA TM-2502 - 'Preferred method of calculating surface water runoff in NZ' - Surface Drainage should be evaluated in accordance with the RRL method documented in the 1977 MOW document - Highway Surface Drainage Design Guide for Highways with a Positive Collection System. This document is based on the formula developed by the Road Research Laboratory (RRL) in 1968 for the UK Ministry of Transport. The Galloway or any other method should not be used. In situations where this standard cannot be achieved, such as super-elevation development, specific departure is required. Normal crossfall on all pavements of 3% should be maintained wherever practical. Where it is impractical to maintain a 3% crossfall then specific design should be undertaken to ensure that the pavement remains free from surface water.

iv. When reviewing departure requests to the surface drainage standard, some additional considerations that need to be demonstrated before acceptance of the departure include:

- Good practical diligence and consideration of the surface drainage system where the potential consequences of aquaplaning failure present elevated risk profile (e.g. elevated safety risk of aquaplaning at zones of acceleration/braking and bends).
- Scope to modify the pavement crossfall or superelevation to encourage more efficient and effective surface drainage.
- Pragmatic consideration of the travel direction and the significant impact that wheel drag has on where unsafe surface water results. Ensure that catchpit systems immediately 'downstream' (travel direction) of the risk sites also have good reliable inlet efficiency (e.g. enlarged catchpits or slot/grated trench drains).
- Redundancy needs be adequately considered (for blockage). Note - a catchpit with 50% blockage does not necessarily mean that the remaining 50% inlet 'efficiency' is available. At grade often even lesser blockages (as low as 10-20%) can mean that <u>all</u> water 'skips' past the intended collection catchpit. Carefully consider the risks associated with the nature of landuse and landscape at the contributing catchment in context of catchpit blockage and reliability of inlet efficiency.
- Merge and diverge gore areas tend to accumulate pollutants - more so than standard running shoulders. The reliability of inlet efficiency at these zones needs good consideration because they are often difficult to safely access for routine maintenance. Enlarged inlets provide a good longer term and reliable level of service against unsafe surface flooding.
- Consider if additional slot/trench drainage and/or say double, back-entry, or super catchpits rather than standard single catchpits improve the situation. Note - there

is very little difference in capital project turn out cost, yet significant performance increase in the reliability of asset function.

Stormwater – Grated Trench Drains – Global Brand Improvement

Opportunity:

Grated trench drains help to manage **surface flooding**. Nationally and internationally a range of grated trench drainage systems are available. A range of 'varieties' exist at the AMA Motorway Network. Traditional grated trench drainage systems present a range of **risks** including:

- Safety risk of flying objects if grate becomes dislodged.
- Small grate apertures are susceptible to blockage causing flooding.
- Pavement overlays that can damage slot drains.
- Poor robustness against pavement milling operations.
- Fine tolerance fastenings mean additional parts and special tools required for operation. Small/fiddly bits are not desirable during night works under traffic control in dirty conditions.

Solution:

Positive engagement and collaboration between the AMA and globally reputable brand ACO has resulted in the development of a new grated trench drain product that is suitable for motorways and heavily trafficked and constrained environments, the **ACO TraffikDrain™ System with HiFlo PowerLok grates**.

Estimated Results:

- **Improved reliability and function** of hydraulic performance with much larger aperture slots being less susceptible to blockage and flooding .
- **Improved safety** for motorists and operators having a robust, reliable and simple boltless fastening mechanism for the grate.
- **No special tools** or special parts are required for operations
- **Quick and easy** to install and to operate

KRA	Increase
Maximise Efficiency	Yes
Customer focus	Yes
Positive Legacy	Yes
Value for Money	Yes
Healthy Organisation	Yes

v. Sufficient collection and conveyance capacity should be provided so that the shoulder flows do not encroach onto trafficable lanes during a 5% AEP 10 minute duration rainfall event. The depth of shoulder flow should not exceed 100mm depth and its velocity should not exceed 2m/s.

vi. In a 1% AEP 10 minute duration rainfall event one lane of a multi-lane section of carriageway may be covered with water that is no more than 100mm deep and its velocity should not exceed 2m/s. On a single lane link road in the same event, at least 2m of carriageway should be kept free of stormwater greater than 4mm depth.

vii. At super elevated areas the design should include for the collection of stormwater adjacent to the normal centreline. No stormwater from the uphill side of the carriageway on multi-lane roads should be allowed to flow across the pavement of opposing lanes of traffic or, in the case of multiple on/off ramps, across the pavement of traffic on adjacent carriageways.

Durability

i. All elements of the Stormwater Management asset should be designed to provide adequate durability. Culverts >3.4m^2 should be in accordance with requirements in the TNZ Bridge Manual and relevant material design codes. All mainline crossing culverts should be designed with a minimum design life expectancy of 100 years. The surface collection and conveyance network, and management devices should be designed with a minimum life expectancy of 50 years.

ii. Where culverts or piping material, other than concrete, is proposed (e.g. multi plate or metal pipes) demonstrate the adherence to the longevity criteria by assessing whole of life value in design, including the costs for providing and maintaining adequate protection against corrosion and/or abrasion throughout the life of the structure.

iii. Also consider the resilience of materials e.g. StormBoss Pipe - Although product literature refers to material as 'plastic' it is made from Polypropylene. Polypropylene is not self-extinguishing in the event of fire.

iv. Structures should be sufficiently durable to ensure that without reconstruction or major renovations, they continue to fulfil their intended function throughout the design life.

v. All Streetware (e.g. lids, trench gratings, catchpits grates) must be NZTA approved and rated for D Class (140kN) loadings.

vi. All exposed steel (e.g. scruffy domes, grates) must be either stainless steel or HD galvanised (to AS/NZS 4680).

Network Design

i. The stormwater management system should be via gravity systems (except tunnels).

ii. All pipes within the local road network should have a minimum diameter of 225mm. For all other pipes (on the state highway) the minimum diameter is 300mm except lines crossing the carriageway, in which case a minimum diameter is 375mm dia.

iii. Reticulated networks should be self-cleansing (consider pipe grade, flow rates and network tractive forces). The minimum water velocity in the stormwater conveyance network (e.g. channels and pipelines) should be 0.6m/s at a flow arising from half the 50% AEP critical storm.

iv. All new pipelines crossing the road should cross as directly as is practicable, and in no case, should the angle between the longitudinal direction of pipeline and the centreline of the road be less than 40^o (degrees).

v. A maximum pipe run should be 90m, or as required to suit change in pipe direction, or grade and to suit inspection structures such as manholes and catchpit locations (or rodding/flushing points for subsoil drainage).

vi. No access covers (e.g. catchpits and manholes) should be situated within the trafficable flexible pavement lanes.

vii. Slot or catchpit grating covers should be attached by a removable hinged system, or fastening systems that do not require specialised tools to open. For example do not use fastenings such as small fine threaded bolts (these may work on a brand new clean asset system, but during night works on a dirty system it is very difficult to re-attach such gratings). Consider the direction of traffic flow for hinge orientation.

viii. Additional catchpits, slot/trench drain, or other suitable inlet collection systems should be placed at gore areas or low points to best manage the risk of unsafe surface flooding.

ix. All catchpits should have sumps at least 400mm deep (below the invert of the outlet pipe level). These provide good pre-treatment benefit reducing the frequency of maintenance at treatment devices. Sumps also help to minimise the migration of sediments into often flat pipe networks where gradual sediment accumulation can become bedded and cement-like.

x. Any catchpit siphons should be removable to facilitate flushing, rodding, and CCTV inspections.

xi. Swales should provide a discrete trafficable section (e.g. a 3m wide strip of gobi-block or rip-rap lining) to enable maintenance vehicles to safely traverse across the swale without causing damage to the profile or invert (e.g. to avoid wheel rutting).

Stream and Waterway Crossing Design

i. Where any proposed culvert serves a permanent watercourse that contains existing or potential future ecological values (e.g. upon restoration) in addition to meeting the hydraulic requirements for passing design flows, culverts should be designed to include features for the provision of ecological connectivity for the passage of aquatic and terrestrial fauna.
ii. To mitigate erosion at the interface between natural streams and culvert headwalls, wing-walls and structures, appropriate debris control, erosion control and energy dissipation measures must be incorporated. Also consider contractions and expansions of the streams at the proposed culverts in order to manage local scours, erosion and increases of flood levels.
iii. Consider the safety risks associated with culverts adjacent to private properties, parks and reserves where grills are required.

Stormwater Devices

i. Ensure that any below ground structures have safe access and best optimise the ability to safely perform operational monitoring and maintenance activities without the need to enter the system (e.g. grated tops over sediment chambers, and suitable size manhole access over the forebay zone as well as the filter bed for filter system (e.g. sandfilters or StormFilters), observation access platforms at pond outfalls).
ii. Ponds should have dewatering facilities to incrementally draw down the water levels to pond forebay and base level for the purpose of delivering maintenance operations. Carefully consider dewatering orifice sizes relative to practical draw down time.
iii. All stormwater management devices (i.e. ponds, filters) should have a flow bypass facility to facilitate the timely delivery of routine operational activities (e.g. desludging) as well as emergency procedures (e.g. spill containment/isolation).


Stormwater Landscaping

Good landscaping associated with 'green' stormwater management assets such as swales and ponds can make a big difference to the delivery of good and safe whole of life outcomes and values.

Consider the types of landscape species best suited to the delivery of operational function of the stormwater management asset such as:

i. Safety is a significant issue. Good consideration must be given to what delivering safe landscape means for stormwater assets at busy motorways (e.g. consider proximity to traffic lanes before specific temporary traffic management is required for maintenance (which comes at a financial and network efficiency cost).
ii. Maintenance costs associated with landscape maintenance of stormwater assets are high. Good consideration of whole of life value for money is critical when selecting and specifying suitable plants (e.g. maintaining grass costs about 6-9 times more than maintaining established landscape.
iii. Consider the life of landscaping in its intended form before rehabilitative maintenance is required (e.g. how long before landscaping passes it's use-by date and removal/replacement is required). Good plant selection for stormwater management assets is critical.
iv. Drought and inundation tolerant species are often important at 'green' stormwater assets. Motorway landscaping is manually watered (due to safety and cost considerations). When plant species associated with stormwater assets become inundated, mortality must not result. Saline tolerant landscape plant species are important at coastal locations (consider coastal inundation and wind spray resilience). Consider the mortality of certain species. It is not desirable when whole stands of vegetation die-off in quick succession i.e. avoid overly sensitive species that can suddenly die-off and cause blockages at stormwater assets. *Apodasmia similis* (Oioi) is an example of a good resilient plant for stormwater management asset outcomes.
v. Simplicity of planting is important e.g. 'fancy' landscape quickly becomes operationally 'lost' hence do not specify a multitude of plants when a couple of key species will reliably deliver the outcomes needed. Low growth and hardy landscape plant species are preferred. For motorways the simplicity and commonality of planting is important to reliably achieve a good sustainable landscape outcome. Fewer and greater consistency of plant species also enables increased operator awareness and capability of delivering the right landscape maintenance activity at the right time. Landscape planting that is familiar and intuitive to maintenance operators also stands a much greater chance of being well maintained.
vi. NO stormwater landscape planting should be delivered at confined or isolated areas that can only be safely accessed with TTM and closures (COPTTM standard). Planted medians are very costly and unsafe to maintain to the right level of service. For example stormwater treatment swales must not be positioned at medians or locations where safe off road access cannot be achieved.
vii. Infiltration type stormwater devices are not desirable for Auckland Motorways due to the rate of clogging that is caused by the sheer amount of CRAP (Crude road

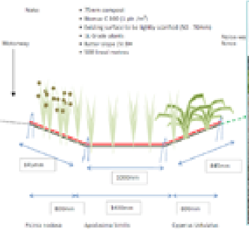
accumulated pollutants). Raingardens, and biofiltration assets clog very quickly which can increase the risk of surface flooding and compromise fundamental level of service needs (i.e. no unsafe surface flooding). Infiltration assets are not a good whole of life solution and should not be used for stormwater management at Auckland motorways.

viii. Swales are a great stormwater management asset. Landscaped stormwater swales deliver better outcomes than grassed swales. See below case:

Landscaped Stormwater Swales

Opportunity: Swales are an excellent stormwater management asset for the multiple benefits of good runoff collection, flow conveyance, improved flood storage, and stormwater treatment by filtration. Traditional stormwater treatment swales are grassed. AMA trials and research (published 2011) identified a significant opportunity is to **improve outcome values** by the using **Landscaped Stormwater Swales**.

Solution: Compared with traditional grass swales, **Landscaped Swales** use native plant species that provide good filtration characteristics and environmental outcomes, as well as other the positive attributes such as low growth (less maintenance), and resilience to spray, drought, flooding, and capability to 'spring' back up if flattened (by foot or flood).



Results: Landscaped stormwater swales deliver better outcomes by:

- Landscaping **deters unwanted traffic** that results in damaged swale profile e.g. motorists drive onto grass swales to use phones
- **Less Pollution**: Better litter capture by taller plants that is easier to clean up = less rubbish at the receiving environment
- **Reduced damage** to the swale profile that can be caused by routine operations (e.g. mowing is not required at landscape planted swales)
- **Looks great**: Improved visual/aesthetic outcome – people like plants
- **Delineation**: Defined edges improve roadway and swale demarcation
- **Reduced spraying** needs – healthier for people and the environment
- **Cheaper** to maintain – Grass maintenance typically costs about 6 to 9 times more than landscape planting (great whole of life value)
- **Network Efficiency**: Less disruption from reduced maintenance needs
- **Safety**: less maintenance = less exposure of operators to traffic risk, and improved reliability of filtration function = safer for environment
- Improved **habitat**, **biodiversity**, and **ecological connectivity**

Promulgation: This innovation that was developed and delivered to industry by the AMA (2011), has now been promulgated and applied at several significant capital projects nationwide (including RONs)

KRA	Increase
Maximise Efficiency	Yes
Service Excellence	Yes
Positive Legacy	Yes
Value for Money	Yes
Healthy Organisation	Yes

ix. Avoid the use of deciduous trees at locations where catchpit or system blockage can result in level of service issues such as flooding, Deciduous trees are a major problem with respect to the sheer volume of organic mass that can very quickly accumulate causing major problems at stormwater assets (e.g. catchpits matting and blocking very quickly requiring high seasonal maintenance cost/frequency to manage unsafe surface flooding risks). Provide good buffer planting for safety (barrier) at pond perimeters.

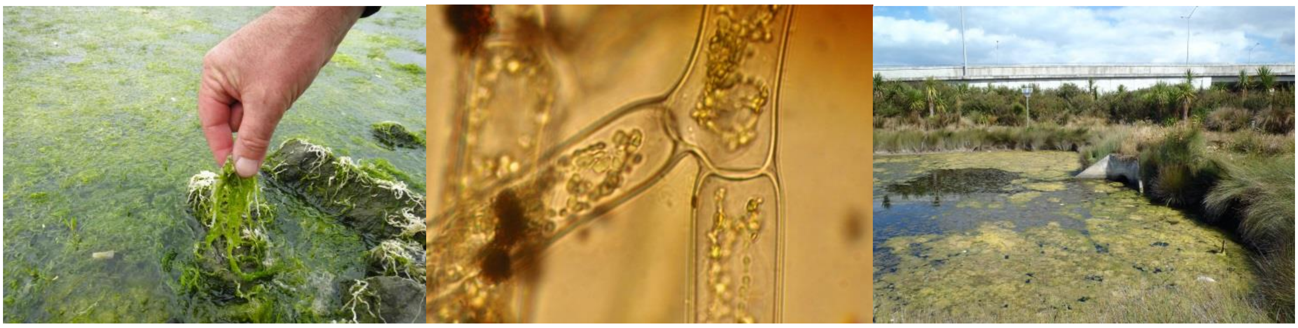
x. Good clearance of landscape planting to stormwater structures is desirable. Some plants too close to manholes and catchpits can result in structural damage (root growth), and landscape planting can quickly hide the assets (e.g. a manhole in the motorway corridor can be 'lost' in overgrown plants within a matter of months/years presenting operational time and cost implications – whole of life).

xi. Pine needles are very problematic at stormwater inlets. Pine needles create dense and fine mesh matting that can quickly render a standard catchpit 'blocked'. Consider stormwater inlet specifications where pine trees are in proximity.

xii. No large trees should be planted at ponds that are sited on embankments, or perched ponds where dying roots can generate 'piping' failure issues through the dead root zones. Piping can compromise the structural/geotechnical integrity of the dam/embankment creating a safety risk (of bund failure).

xiii. Mature specimen trees should be planted at the northern aspect of streams, ponds and wetlands to provide shading that will manage thermal impacts (i.e. of 'heated' motorway runoff) and ecological habitat (e.g. flora/fauna/fish passage). Where waterbody shading is needed to ensure the delivery of consent compliance requirements (i.e. discharge temperatures less than 20.3 degrees), then trees should be established from the time of handover (i.e. a seedling planted today may not provide the necessary shading and stormwater temperature management needs for 20 years when grown).

xiv. At shallow ponds ensure that planting is selected to best minimise the risk of weed and algae blooms that are often induced by thermal and contaminant loading effects.



xv. Ensure appropriate wetland plant species are incorporated into a pond of good bathymetric design, to ensure that environmental compliance requirements can be achieved. Wetland plants that generate excessive biomass are not considered particularly good for stormwater management assets as the biomass will consume the stormwater quantity management capacity (e.g. reduced channel cross sections and capacity), or stormwater quality improvement performance (e.g. ponds may require increased frequency of maintenance in order to retain sufficient water quality volume for the treatment performance needs).

xvi. Carefully consider the use of bark mulch for landscaping at areas contributing runoff to the stormwater management network. The stormwater assets are regularly adversely affected by bark blocking channels and catchpit inlets. Excessive bark mulch washed off the landscape areas often appears in ponds consuming the water quality and quantity management capacity of the asset (increased frequency and nature of maintenance needed). Use good stabilising agents if bark mulching.

xvii. New Zealand Flax or *Phormium tenax* and *Phormium cookianum* (maori name *harakeke* and *wharariki* respectively) are a very hardy and perennial plant that can look great. Caution must however be applied in selection of the right location the species in proximity to stormwater assets. Flax is very hardy (and even harder to remove when it becomes overgrown at pipe inlets and outlets) and the root mass can damage traditional stormwater infrastructure such as culvert headwalls and wingwalls).

xviii. Loose placed round river run rocks should be avoided in stormwater landscape features. These rocks can be a safety risk (when run over by tyres they become missiles).

xix. Good established vegetation is very important during an 'earthworks' establishment phase e.g. landscape planted swales and permanent ponds can be subject to excessive sediment loading during a landscape establishment phase, resulting in smothering of the target planting and premature consumption.

xx. Compliance with conditions of resource consents is a legal responsibility. Any landscape planting that is linked to conditions of consent (e.g. a consented swale with an 'approved' OM document referring to specific plants) must be effectively conveyed to the Auckland Motorway Alliance to ensure operational delivery.

Safety in Design (SiD)

Safety = Zero Harm to People, Plant, and the Environment. Stormwater Management Assets present a range of potential hazards. Good SiD can help to minimise risk. Hazards include: Drowning; Collisions; Confined Spaces; Congestion; Falls; Contamination; Loss of Control. Importantly a robust risk assessment of proposed assets should be undertaken in accordance with AS/NZS 4360:2004; AS/NZS ISO 31000; NZTA Z/44.

Stormwater asset reliability, availability, and functionality helps to achieve reduced operational exposure to safety risks. Consider system functionality to deliver the fundamental Level of Service (e.g. surface flooding, local flooding, and regional flooding). Also ensure that critical asset evaluation is undertaken with consideration of robust and resilient lifeline needs (consider network vulnerability).

The following points can be considered a useful checklist for a safety in design assessment of proposed stormwater management solutions and important operational outcome values.

i. Access: Safe, All Weather, Off-Road Access (24/7).
ii. Access: Timing for activity delivery e.g. consider that some activity delivered at night to manage network congestion under reduced visibility.
iii. Access: Confined Spaces access for operational activity e.g. clearance and facilitation of access set-up like tripod.
iv. Access: into Assets e.g. larger lids for sedimentation, spill containment, treatment vault access, etc.
v. Access: Inlets and Outlets (e.g. main culverts) - Asset type and location with access to enable operational delivery.
vi. Access: Ladder Rungs in Structures - Consider positioning for confined spaces entry.
vii. Access: Enable visual monitoring e.g. vault treatment systems that can be monitored and inspected safely from ground; safe access to pond viewing position. Safe access to Pond outlet structures is important for monitoring purposes.
viii. Access: Consider Asset ownership versus maintenance boundary versus legal responsibility (e.g. conditions of consent).
ix. Condition: Integrity - Premature failure of assets (e.g. collapsed culvert).
x. Condition: Durability - Different assets and elements of assets have different failure rates (deterioration and consumption).
xi. Condition: Material Selection e.g. marine environments, or corrosive environments.
xii. Condition: Robust lid fittings i.e. often manhole lids not well specified for frame fastening.
xiii. Condition - Some assets may be in a poorer condition than was verified by preliminary investigation or data records.
xiv. Condition: Loose rocks e.g. consider grouting to secure.
xv. Distractions - Some assets can look 'wrong' and be distracting.
xvi. Drowning: Water levels and proximity to deep water influences safety risk profile (e.g. in adjacent ponds, waterways, harbour, etc. - risk of drowning and falls).
xvii. Environment: Compliance - Planning and Design interface to ensure that construction and operational conditions will not result in exposure to safety risks.
xviii. Environment: Spill and Pollution - Incorporate contaminant management into design (e.g. half siphon at catchpits, containment vaults, treatment devices).



xix. Falls: Heights - Some assets can present fall risk e.g. headwalls, wingwalls, retaining walls, etc, may need safety rails and or ladders to facilitate operational access.
xx. Falls: No Landings in Deep Manholes owing to impediment to confined spaces entry.
xxi. Flooding: Surface Flooding - aquaplaning/loss of control.
xxii. Flooding: Secondary Flow Paths - Reliable and available secondary flow paths.
xxiii. Flooding: Consider implications of limit state events (e.g. what if 0.2% AEP storm).

xxiv. Flooding: Bridge Deck Drainage e.g. unsafe surface flooding; waterfalls created by passing vehicles.
xxv. Flooding: Severe Storms during construction and operation - environmental risk and human safety risk (operators and motorists).
xxvi. Security: e.g. loose of flying bits such as slot drain covers; fencing if drowning hazard; grating covers and debris/safety grill if public access.
xxvii. Security: Failures from outside corridor/designation (e.g. ponds uphill, flood debris causing blockage at culverts).
xxviii. Security: Surcharging at pressure lines - e.g. manholes popping and flipping.
xxix. Security: Fastenings - e.g. risk of assets failing e.g. small screws to fasten assets are not wanted.
xxx. Security: Utilities - appropriate clearances e.g. proximity to power assets.
xxxi. Security: Unidentified Assets - encounter assets not identified by investigation and exploratory works (e.g. power assets; culverts).
xxxii. Security: Vandalism: Apply CPTED principals - consider security of manhole and catchpit grates at say cycleways.
xxxiii. Trafficability: Location of Assets e.g. No structure within trafficable lanes.
xxxiv. Trafficability: Frangibility - consider proximity to shoulder and position within corridor designation.
xxxv. Trafficability: Traversable assets (e.g. catchpits and roadside channels/access). Consider approach Safety e.g. direction of hinged grates, kerbs form.
xxxvi. Trafficability: Safe Slopes - Consider trafficability and slip potential e.g. pond slopes.

4.2.4 CONSTRUCTION

Several factors through the construction phase of a capital project delivery can influence legacy outcomes and values achieved for the stormwater management assets, including:

Erosion and Sediment Control (E&SC)

The earthwork and construction stage of capital projects, present significant risk to the safe, reliable, and compliant operational delivery of motorway stormwater management asset.

Good E&SC is fundamental and can have a significant and positive implication on the safety (people/plant/environment) outcomes associated with delivery of the motorway stormwater management assets.

i. During construction and earthworks, ensure that industry best practice is applied for the management of E&SC measures (e.g. Auckland Council TP90). Good adherence to this guideline helps to ensure the longevity of the stormwater asset performance (e.g. filtration and infiltration characteristics of treatment systems will be best preserved by minimising the scope for premature clogging and consumption).
ii. Consider the implications of transitioning between an earthworks site (TP90) versus a permanently stabilised site with permanent stormwater level of service and compliance is important. Without good stabilisation (e.g. established vegetation) of the earthworks, premature consumption of the permanent stormwater assets occurs.
iii. Good E&SC helps to manage risks such as blockage to motorway stormwater inlets (e.g. sediment laden catchpits causing unsafe surface flooding), and the premature consumption of critical stormwater assets (e.g. consumption of roadside channels by sediments can cause surface water to enter traffic lanes presenting an unacceptable safety risk, and ponds can become prematurely consumed by sediments requiring ‘out of cycle’ and often costly operational activities.
iv. Good established vegetation is very important during an ‘earthworks’ establishment phase. E.g. Vegetated swales and permanent ponds can be subject to excessive sediment loading during a landscape establishment phase, resulting in smothering of the target planting.

Temporary Traffic Management (TTM)

Good TTM = Reduced Incidents = Safer Outcomes - During the construction and delivery of capital projects, good TTM can have a significant and positive implication on the safety (people/plant/environment) outcomes associated with stormwater management.

It is also very important to recognise that because most motorway maintenance and operational activity is delivered at night (when visibility is poor) and risks to operators are high, during wet weather visibility gets worse and safety risks increase.

Good consideration of stormwater management for TTM activity can help to reduce the likelihood of unsafe incidents. Factors to consider include:

i. Consider the positioning of TTM relative to stormwater inlets and outlets. For example sign stand footings (and sandbags) often collect debris and CRAP (Crude

Road Accumulated Pollutants) that can cause runoff to spill onto trafficable lanes, and barriers can block or reduce runoff and flows from reaching the intended inlet, outlet or to follow intended secondary flow paths). Positioning of signs downstream of catchpit inlets and concrete barriers with underdrainage are good TTM measures.

ii. Rain and stormwater runoff can obscure signs and road markings (and 'temporary' road markings) leading to driver confusion. This issue is compounded at Capital Project sites where risks are highest and 'normal' operating conditions are altered.

iii. Stormwater runoff and flows can be concentrated by temporary barriers (meaning regular primary and secondary flow paths are not viable). This can result in unsafe depths of surface water at trafficable lanes. Consider barrier positioning and drainage needs. Maintain good Primary and Secondary Flow Paths (consider regular and high flow routes).

iv. Concentrated runoff and flows from constructions sites can wash gravel onto the road causing safety risks to drivers, vehicles, and the environment.

v. 'Temporary' pavements during construction can cause unsafe surface flooding e.g. without the 'final' pavement layer catchpit frames may be 'perched' resulting in water ponding on the temporary road surface which can cause aquaplaning and 'splashing' that obscures drivers vision.

vi. Consider the durability and resilience of all TTM measures to withstand high flows (e.g. to avoid washouts).

vii. Good TTM includes maintaining the TTM assets for stormwater risks such as blockages and being prepared for reactive/unscheduled activity (if things go wrong during extreme rainfall storms this will help to ensure timely action). Further, because every project is different and continuously evolving it is important monitor the conditions (i.e. monitor and observe if stormwater runoff during storms is causing problems due to TTM activity). If unsure, engage with the site environmental manager, stormwater engineer, and/or the AMA stormwater asset manager.

Construction Delivery

"Build it once – build it right" - Whilst generally delivering and constructing stormwater assets is in accordance with designers plans and specifications, during the construction and delivery of capital projects, good consideration of certain construction 'factors' can make a significant and positive implication on the safety, reliability, and resilience of the stormwater management assets. Some useful factors to consider include:

i. Decommissioning of existing stormwater management infrastructure made redundant by new works should be appropriately treated in a manner that will prevent any future deformation or loss of support to the pavement or any other structure (e.g. remove redundant or fill with 5MPa flowable fill backfill).

ii. Epoxy cement grout (or similar) at cut RC surfaces to ensure that spalling and premature aging does not occur (e.g. too often pipe joints at manholes and catchpits have not been 'end' treated which results in reinforcing rust and concrete spalling that results in joint failure).

iii. During construction secondary flow paths should be well maintained. Any secondary flow paths interrupted by the temporary works should accommodate the effects caused by the works (e.g. safe and efficient management of disposal to the receiving environment).

iv. During project construction delivery, proactive monitoring and maintenance are considered to be in the best interest of NZTA and the Contractor. The quality of the stormwater management assets should not be compromised by the activity or inactivity of others (e.g. sub-contractors).

v. The stormwater management asset should always look great including during the defect liability period (e.g. consider the separable portion of landscaping associated with ponds or grass swales).

4.2.5 HANDOVER

Some important considerations and needs for the successful handover of stormwater management assets from Capital Project planning/design/construction status to operational delivery of the assets include:

a. Asset Owners Information: The draft stormwater AOM (including asset information data) and a familiarisation briefing should occur at least one month prior to Practical Completion. This will enable adequate time for handover meeting, project snag and document review, for the final AOM to be supplied before Practical Completion, and for Auckland Council sign off as approved. The AMA require hard and electronic copies of the AOM Document (MS Word format) and Drawings (CAD and PDF).
b. Asset Information Data: NZTA format RAMM and spatially compatible digital format data to include fundamental asset management data including what, where, condition, design performance for quality and quantity.
c. Handover Condition: Verification of the condition including CCTV records and inventory record/reporting sheets. This includes that appropriate maintenance is undertaken prior to the handover (i.e. flush, clean and CCTV network that is utilised by the finished solution). Handover to include operational monitoring inspection, and maintenance activity closure forms at the time of handover. It is important to note that a 'new' asset should be just that – a NEW asset. Too often the assets received (historically) have been very poorly maintained or consumed, and are not to an adequate commissioning standard for handover to operations.
d. Special Tools and Parts: Any special tools or parts (e.g. manhole or penstock keys, fish passage moulds) to be supplied prior to opening.
e. Handover Meeting(s): A joint inspection and meeting to debrief on the specific operational monitoring and maintenance, as well as any defect liabilities for the stormwater management asset should be held at least six (6) weeks prior to opening. Depending on findings there may be important need for a second meeting for issue closure. This should occur at least two (2) weeks before opening.
f. It is critical that any planning, design, and construction conditions are satisfied and closed off by capital projects prior to handover for operational activity. With the current compliance chronology, the legal ownership cannot be fully owned by operations until the preceding delivery consent conditions have been signed-off.

5.0 SUMMARY

The Auckland motorway network supports much of the social and economic activity of the greater Auckland region, with nearly 1,000,000 vehicle trips per day, and carrying over 10% of the nation's traffic the motorway network has the highest criticality rating of any road network in New Zealand – For a livable city and communities, good stormwater management, maintenance and operation is essential at Auckland motorways.

The Auckland Motorway Alliance has defined objectives for the stormwater management assets, and delivers a diverse range of activities that contribute towards operational outcome needs. Activities that help towards stormwater management asset needs include: having an empowered team; good asset knowledge and data; standardised activity; proactive pollution and contaminant management; responsiveness to incidents; training and education; innovations and promulgation; and inputs to capital projects.

To help ensure that optimal operational outcomes are achieved for stormwater management assets there are a number of considerations that should be addressed during project development and delivery. A number of considerations are general and relate to all phases of the asset lifecycle, whilst some points are more specifically pertinent and influenced at the planning, design, construction, or handover phases of project delivery. For this purpose the AMA has prepared a Maintenance and Operations Guideline to assist capital projects to achieve positive outcomes and deliver values that are important for good operational management such as available and reliable function, whole of life value for money, and safety (people, plant, and the environment).

AMA stormwater maintenance and operational activities, learnings, and project guidelines help contribute towards making Auckland City the most livable city in the world – some of these lessons will be of relevance and 'transportable' to other stormwater networks throughout the Asia-Pacific Region.