NZ TRANSPORT AGENCY
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Roads of national significance

16 20

Western Ring Route – Waterview Connection

Stormwater and Streamworks Design Philosophy Statement

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1. Project Description

The Project Description provides a summary of the form and function of the Western Ring Route – Waterview Connection Project. This includes the resilience and capacity improvements on State Highway 16 (SH16), between St Lukes Interchange and Te Atatu and the Combined Surface Tunnel option for Waterview, between Great North Road and Maioro Street Interchanges, as well as other key transport components of the project (e.g. the cycleway and integrated road/rail corridor).

In summary, the project works includes the following:

- Improving the resilience of the Western Ring Route (by raising the causeway on SH16 between Waterview and Rosebank Interchanges to correct historic subsidence and "future proof" it against sea level rise)
- Providing increased capacity on the SH16 corridor (between St Lukes and Te Atatu Interchanges)
- Providing a new section of SH20 (the Combined Surface and Tunnel option) between the Great North Road and Maioro Interchanges.

The Project sector diagram provides an overview of the extent and works for the Waterview Connection project, refer Figure 1 at the end of Section 1.

In summary, the project generally includes the following (these relate to 'sectors' of work identified in the Project sector diagram):

- Between Te Atatu and St Lukes Interchanges the following key elements of work will be undertaken on SH16:
    - Significant improvements and reconfiguration of Te Atatu Interchange to accommodate additional lanes and to provide for bus shoulder and priority for buses and other High Occupancy Vehicles (HOVs) (Sector 1)
    - A shared use cycle and pedestrian way running parallel to the motorway from Te Atatu to Great North Road interchange (Sectors 1 through to 6)
    - Enlargement of the existing Whau River Bridge to accommodate additional lanes and a separate dedicated cycle/pedestrian bridge (Sector 2)
    - Reconfiguration of the existing Rosebank on and off ramps to improve traffic merging on and off these ramps (Sectors 3 and 4)

- Additional lanes between the Te Atatu and Rosebank Interchanges to provide four lanes east and westbound and a bus shoulder in each direction (Sectors 3 and 4)

- Additional westbound lanes from Rosebank Road interchange and Great North Road Interchange, to create a total of four eastbound lanes, five westbound lanes plus a dedicated bus shoulder (Sectors 3 and 4)

- Enlargement of the existing Patiki Bridge to accommodate additional lanes and a separate dedicated cycle/pedestrian bridge to be constructed alongside the enlarged Patiki Bridge (Sectors 3 and 4)

- The footprint of the existing causeway between Rosebank Peninsula and the Great North Road interchange will be enlarged by additional reclamation (Sector 4)

- In conjunction with the reclamation works, the Causeway height will be increased to protect it against inundation and to "future proof" it against predicted sea level rise in the future. Stormwater treatment devices will be provided within the reclamation (Sector 4)

- Additional lanes will be provided between the Great North Road Interchange and St Lukes Interchange (in the east) This will also include providing a stormwater pond, cycleway and bus priority lane (sector 6)

- For SH20, between Great North Road Interchange (with SH16) and Maioro Interchange, a new state highway alignment will be provided over a length of approximately 5km and a capacity (ultimately) for three traffic lanes in each direction. The following key elements of work will be undertaken:

  - A new interchange will be built at the 'Great North Road Interchange' to provide motorway-to-motorway connections SH16 and SH20, while maintaining the existing connections between Great North Road and SH16 at this interchange. The existing cycleway will be retained and the existing interchange will be reconfigured to maximise land to the north of the interchange (Sector 5)

  - The project provides future capacity for three traffic lanes in each direction, separated by either central median barrier or separate tunnel construction. However, at opening the project will be constructed with two lanes in each direction, with bus shoulders where appropriate (Sectors 5 through to 9)

  - A cycleway connection between the existing Northwestern Cycleway along SH16 and the SH20 cycleway (that terminates at Maioro Street) will also be provided (Sectors 5 through to 9)

  - From the Great North Road Interchange, the alignment will be two cut-cover tunnels (some 2.5m apart) beneath Great North Road to connect to the deep tunnel (Sector 7)

- The alignment is in two 'deep tunnels' (one in each direction) from the cut-cover tunnel beneath Great North Road through to the Alan Wood Reserve, passing beneath Avondale Heights/ Springleigh, the North Auckland Rail Line and New North Road (Sector 8)

- The alignment between the deep tunnel and the Maioro Street Interchange is 'at-surface', alongside the existing land set aside for rail (the Avondale Southdown Line Designation), for a length of around 900m. New north-facing ramps will be built at the Maioro Street Interchange to provide local traffic access to SH20 northbound (Sector 9)

- An integrated road / rail corridor is proposed to retain opportunity for the existing rail designation from the Maioro Street Interchange to the southern tunnel portal in Alan Wood Reserve (Sector 9)

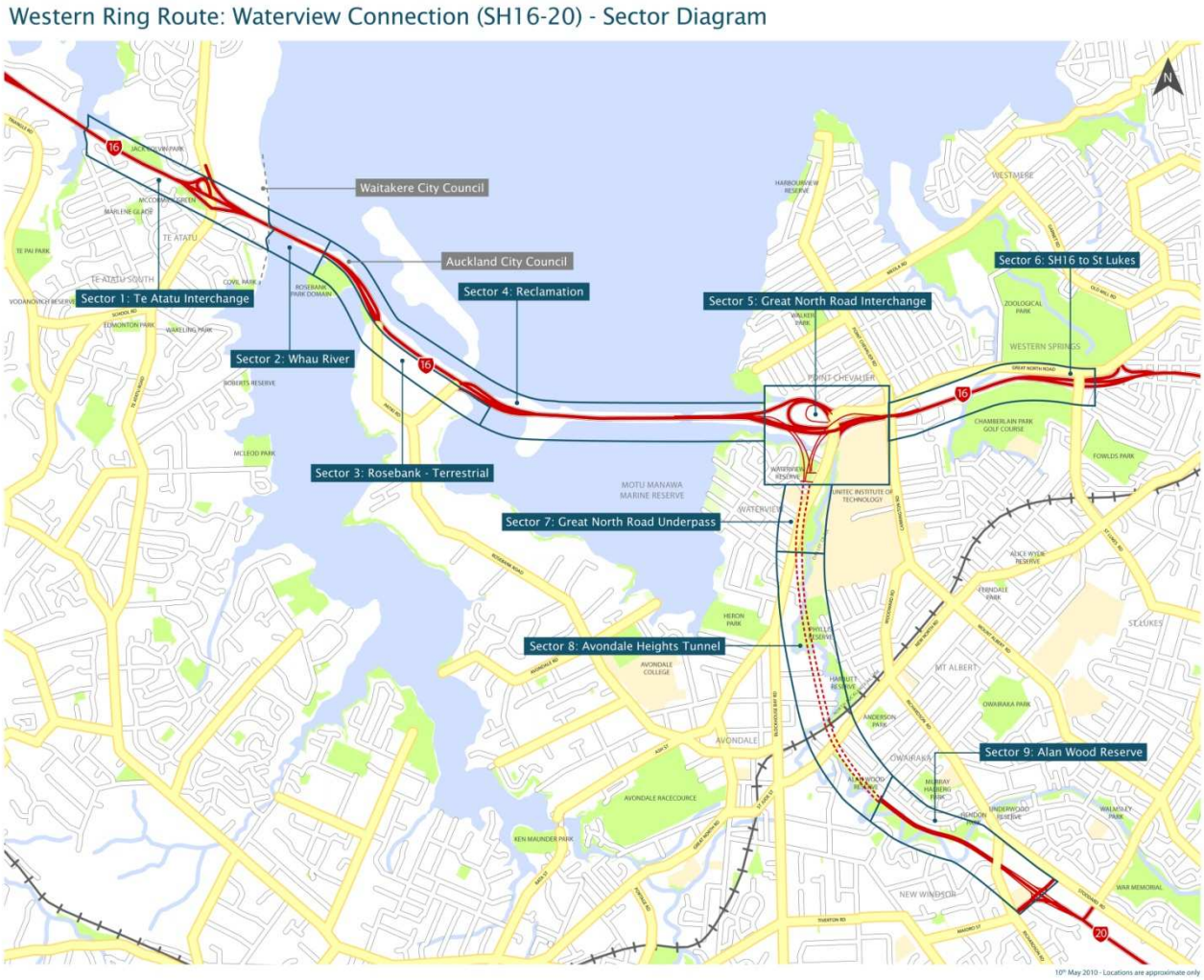

Figure 1 – Project Sector Diagram

2. Introduction

This report has been produced to outline the philosophy that will be used for design of stormwater systems and streamworks for the SH16 St Lukes to Te Atatu Interchange upgrade and SH20 Waterview Combined Surface and Tunnel (CST) project. The project includes key works proposed by the NZ Transport Agency (NZTA) to progress completion of the Western Ring Route and will be known as the Waterview Connection project.

This report provides an overview of the design parameters and standards to be adopted. It also documents the constraints upon design and details assumptions in the design.

This Stormwater Design Philosophy Report is considered to be the definitive document that outlines the parameters of design. The Design Philosophy Report provides the standards and guidelines for appropriate design, yet it is intended that it shall not be a constraint to innovative design.

The Stormwater Design Philosophy Report will be updated as required. It may need to be updated once designations and consents are in place to incorporate the conditions of those designations and consents.

3. Design Philosophy / Principles Statement

The following Design Principles will be adopted for the design:

- The design will incorporate the total stormwater management system (collection and conveyance network; treatment devices; stormwater cross drainage; Oakley Creek culverts and diversions).

- The objective of the stormwater management system is to provide a best practicable option (BPO) to avoid, remedy or mitigate adverse environmental effects, determined through a robust evaluation of options.

- The design should include full consideration of stormwater operational implications throughout the design life.

- The design should best practicably mimic the existing hydrologic regime and setting, to deliver outcome objectives that remedy or mitigate adverse environmental effects. The design should also consider any measures to improve current flood issues in the catchment.

4. Design Standards & References

The following Design Standards will be referenced for this design:

- Stormwater Management Devices: Design Guidelines Manual, ARC Technical Publication No. 10 (ARC TP10), Second Edition, 2003.
- Development and Connection Standards, Auckland City and Metrowater, 2009.
- Guidelines for Stormwater Runoff Modelling in the Auckland Region, ARC Technical Publication No. 108 (ARC TP108), 1999.
- NZTA & AMA Draft Stormwater Design and Asset Management Document, 2009.
- NZS3725: Loads on Buried Concrete Pipes, 1989.
- Bridge Manual (SP/M/022) Second Edition, Transit New Zealand, June 2003.
- Highway Surface Drainage – Design Guide for Highways with a Positive Collection System, NRB, November 1977.
- Waterway Design – A Guide to the Hydraulic Design of Bridges, Culverts and Floodways, AUSTROADS, 1994.
- Watercourse Guidelines – How to Care for Streams in Auckland City, Auckland City Council and Metrowater, October 2003.
- Fish Passage Guidelines for the Auckland Region, ARC Technical Publication No. 131, 2000.
- Riparian Zone Management, ARC Technical Publication 148, 2001.
- Fish passage in the Auckland Region – A Synthesis of Current Research, ARC Technical Report 2009/084, 2009.
- Climate Change Effects and Impacts Assessment - A Guidance Manual for Local Government in New Zealand, Ministry for the Environment, Second edition, 2008.
- Specification for Pipe Subsoil Drain Construction, Transit New Zealand, F/2: 2000.
- Specification for Pipe Culvert Construction, Transit New Zealand, F/3 2000

- Specification for Drainage Systems, Transit New Zealand, HM21
- 'LINZ Tidal Level Information for Surveyors' Land Information New Zealand, 2007
- Hydrological and Hydraulic Guidelines, Environment Bay of Plenty (EBoP), 2001

Documents referenced in the design will also include:

- Oakley Stormwater Management Study Report No 4, Volumes 1-3, prepared for Auckland City Council by Beca Carter Hollings and Ferner Limited in August 1995, together with Report No 5, the Comprehensive Management Plan dated June 1998.
- Resource Consent No 9610752 granted by the Auckland Regional Council for diversion and discharge of stormwater from the Oakley Creek catchment into the Waitemata Harbour, with an expiry date of 31 December 2032, together with its recent variation.
- The implications for stormwater runoff of the Southwestern Strategic Growth Management Area, identified by Auckland City Council in its Growing our City through Liveable Communities 2050 Strategy adopted June 2000.
- The Stormwater Management Peer Review Report prepared for Transit by Beca Carter Hollings and Ferner Limited in September 2000.
- Hydrodynamic Design Conditions for the North Western Motorway (SH16) Upgrade: Waterview to Royal Road prepared by the National Institute of Water & Atmospheric Research Ltd (NIWA) for Connell Wagner Ltd. NIWA Client Report: HAM2007-075 June 2007 (Final version: October 2009). NIWA Project: CWL07201.
- Western Ring Route – Oakley Creek Re-alignment and Rehabilitation Guidelines, Boffa Miskell for NZTA 2010
- Waterview Connection Project SH16/SH20 - Coastal Processes Assessment, Tonkin & Taylor for NZTA 2010

The design must also comply with all statutory requirements, designation conditions and resource consent requirements.

5. Stormwater System Design Criteria

5.1 General

Stormwater systems will be designed to meet the performance criteria described in the following sections. Note that the return period in years is equivalent to average recurrence interval (ARI) in years, and equivalent to the annual exceedance probability (or AEP), i.e:

100 year return period = 100 year ARI = 1% AEP

20 year return period = 20 year ARI = 5% AEP

10 year return period = 10 year ARI = 10% AEP

5 year return period = 5 year ARI = 20% AEP

The design life for all new civil stormwater and streamworks infrastructure will be 100 years.

Climate Change adjustments will be applied to rainfall estimates based on the Ministry for the Environment (MfE) (2008) guidelines. The mid range climate change scenario will be applied for the year 2090 as climate change predictions do not extend to the end of the design life ~2110.

The maximum probable development (MPD) of catchments, especially those outside the designation containing urban development, shall be used for the purpose of assessing the hydrology for the design of cross-drainage.

The following rainfall depths have been adopted to be used by the project:

Table 4.1.1: ARC TP108 24 hour rainfall depths

Location	Rainfall Depth (mm)		
	2 year ARI	10 year ARI	100 year ARI
Sectors 1 - 7	80	130	200
Sectors 9 - 10	75	123	181

The TP108 rainfall data for the project have been factored by the recommended increment identified in Climate Change Effects and Impacts Assessment (MfE 2008). These have been determined assuming a mean predicted temperature increase for the Auckland region of up to 2.1°C to 2090. This results in an increase in rainfall depths of approximately 9% for the 2 year ARI event, 13% for the 10 year ARI event and 17% for the 100 year ARI event.

The adjusted ARC TP108 values that will be used for design are shown in Table 4.1.2.

Table 4.1.2: Design 24 hour rainfall depths based on ARC TP108 adjusted for climate change to 2090

Location	Rainfall Depth (mm)		
	2 year ARI	10 year ARI	100 year ARI
Sectors 1 - 7	87	147	234
Sectors 9 - 10	82	139	212

Note that climate change adjustment for sea level are to 2100.

5.2 Pavement Drainage

The design of pavement drainage shall be to Transit F/2 and to ensure that the pavement materials remain dry. A pavement drain shall refer to a drain provided to drain the pavement materials, while a subsoil drain shall refer to a separate drain provided where it is required to control ground water levels.

5.3 Motorway Surface

The design of drainage for the motorway surface shall provide for:

- Runoff volumes and peak flows will be determined using Rational Method (small catchments only) and ARC Design Guideline TP108 as appropriate.

- 100 year ARI flows (Q100yr) shall be contained within drainage gutters and shoulder (i.e. no encroachment onto traffic lanes). Also refer to Section 7 for protection of the tunnel from Oakley catchment flood waters.

- The runoff across the road surface shall meet NZTA standards for aquaplaning to ensure vehicle safety. Surface water should not exceed 4 mm in a 5 year ARI rainfall event with 5 minute time of concentration (refer to NRB (1977) Highway Surface Drainage, Clause 1.3.1).

- The motorway level at the outer edge of lane line shall have 500mm freeboard to the 100 year flood level. The 100 year flood level shall include for maximum probable development and climate change for 2090.

- The SH20 Bridge across the Oakley Creek shall have 600mm freeboard to bridge soffit in accordance with NZTA Bridge Manual.

- For the Oakley Inlet (tidal section of Oakley Creek with downstream extent defined by the opening into the Waterview estuary inlet at the Motu Manawa reserve boundary) the combined effect of floods in combination with extreme sea levels should be considered.

- 100-year ARI rainfall event including climate change to 2090, with 20-year ARI sea level including climate change to 2100 (EBoP, 2001).

- 20-year ARI rainfall event including climate change to 2090, with 100-year ARI sea level including climate change to 2100 (EBoP, 2001).

- The motorway level at the outer edge of lane line shall have freeboard that tapers from 500mm at New North Road to zero at the Motu Manawa reserve boundary, where the effects of Oakley Creek flooding are considered to be minor. Seaward of this location the motorway level is based on studies by NIWA (refer next bullet).

- A minimum crest elevation of 3m RL be adopted for rock protection along the causeway based on upper maximum of sea level rise of 0.8m increase at 2100 (refer to Hydrodynamic Design Conditions report prepared by NIWA)

- The MHWS level of 1.63m RL be adopted based on the LINZ publication 'LINZ Tidal Level Information for Surveyors' (LINZ,2007) with allowances for tidal amplification, refer to Coastal Processes Assessment report for details.

5.4 Motorway Collection and Conveyance Systems

The design of collection and conveyance systems shall provide for:

- The systems to be designed to the following standards:

  - For areas where flood attenuation of the 100 year ARI runoff is required (refer Section 6.3):

    - 100 year ARI event to flow full but not surcharged

    - Backwater effects from 100 year ARI flood event in Oakley Creek and/or stormwater wetland should be considered and a freeboard of 0.5m within the stormwater system should be maintained (e.g. hydraulic grade line 0.5m below road surface). The effect of the difference in timing between the motorway catchments and the catchment flood peak may be considered.

  - For areas discharging to the lower Oakley Creek, lower Meola Creek and other freshwater receiving environment where flood attenuation is not proposed:

    - 10 year ARI event to flow full but not surcharged provided that the 100 year ARI overland flow is managed in overland flows path without damage or hindrance to other property or risk to person.

- Backwater effects from 10 year ARI flood event in freshwater receiving environment and or stormwater wetland should be considered and a freeboard of 0.5m within the stormwater system should be maintained. The effect of the difference in timing between the motorway catchments and the catchment flood peak may be considered.

- For areas discharging to the Coastal Marine Area:

  - 10 year ARI event to flow full but not surcharged provided that the 100 year ARI overland flow is managed in overland flows path without damage or hindrance to other property or risk to person.

  - 10 year ARI rainfall event including climate change to 2090, with 2-year ARI sea level including climate change to 2100 should be considered and a freeboard of 0.5m within the stormwater system should be maintained.

  - 2 year ARI rainfall event including climate change to 2090, with 10-year ARI sea level including climate change to 2100 should be considered and a freeboard of 0.5m within the stormwater system should be maintained.

- Stormwater flow into the tunnels to be minimised.

- Secondary / overland flow paths to be designed for the 100 year ARI rainfall event.

- Pipes to be Reinforced Concrete Rubber Ring Jointed ('RCRRJ'), with the pipe classes selected based on the Concrete Pipe Association of Australasia design guidelines.

- Where practicable the minimum pipe cover under the carriageway to be 900mm. Specific design measures to be incorporated where this cannot be achieved.

- Pipe capacity to be calculated using the Colebrook White method, with roughness factors based on the manufacturer's specifications.

- The minimum catchpit lead diameter to be 300mm.

- Piped stormwater reticulation to generally run parallel with the motorway alignment and be located in the berm or central median, dependant on the motorway super elevation. There should not be manhole lids in the carriageway including road shoulders. Safe access for maintenance to be considered when locating manholes.

- Concrete to be used in saltwater environments should have sufficient durability to meet the design life.

5.5 Other Roads/Cross Drainage

The design of secondary roads and cross drainage shall provide for:

- The primary system shall be designed for the requirements of the Auckland City Council (ACC)/ Metrowater.
- Secondary/overland flow paths shall be designed for the 100 year ARI rainfall event.

5.6 Culverts

The design of culverts shall provide for:

- Culverts shall pass the 10 year ARI rainfall event flow without heading up above the culvert soffit.
- Culverts shall pass the 100 year ARI rainfall event flow with headwater generally limited to 2m above the culvert soffit, but not within 0.5m vertical of the road edge of shoulder.
- Consideration shall be given to the likelihood and consequence of culvert blockage.
- The need for energy dissipation and erosion protection shall be considered as part of the design.

5.7 Swales

The design of swales shall provide for:

- The 100 year ARI rainfall event flow shall be contained below the edge of the carriageway with 300mm of freeboard.
- The 10 year ARI rainfall event velocity should be less than 1.5 m/s.
- The velocity in the swales during the Water Quality Storm (ARC TP10, 2003) should be less than 0.8 m/s.
- The base width in any swales used as part of stormwater treatment system shall not exceed 2 m.

5.8 Filter Strips

The design of filter strips shall provide for:

- The 100 year ARI rainfall event flow shall be contained below the edge of the carriageway with 100mm of freeboard.

- The 10 year ARI rainfall event velocity should be less than 1.5 m/s.

- The velocity for the Water Quality Storm should be less than 0.4 m/s.

- The maximum water depth above vegetation for the Water Quality Storm shall not exceed 25mm.

5.9 Drainage in Tunnel

The design of drainage for the tunnels should provide for the following processes:

- Normal operation of the tunnels providing for stormwater brought in by vehicles and groundwater seepage into the tunnels.

- Washing down the tunnels as part of their cleaning.

- Fire fighting flows in the tunnels including flows from the deluge system.

The design of drainage to capture fire fighting flows is likely to dictate the general arrangement and features of the tunnel drainage. Special features of the tunnel drainage to manage fire flows include the following requirements:

- Capture of all deluge flow within deluge zones as specified in the Design Philosophy Statement for the tunnel.

- Fire traps to extinguish fire in any burning liquids (e.g. petroleum products).

- Fire/heat resistance of drainage products.

- Storage and pumping from the low point in the tunnel.

- Above ground storage of all fire fighting flows after the fire event for disposal to approved contaminated liquids facility or to stormwater systems if proven to have similar water quality to treated stormwater.

Combinations of operational scenarios will be used to determine the design flows and volumes for the surface water collection systems, the primary drainage systems, and attenuation and pumping requirements for the tunnel drainage system. Design scenarios will be developed based on the worst case combination of fire flows (peak flow rate and volumes) and normal flows.

6. Stormwater Treatment

6.1 Introduction

The design philosophy for this project is to select the best practicable options (BPO) for stormwater treatment to address the direct effects of the motorway extension. The areas from which runoff shall be treated have been identified as:

- All motorway pavement surfaces that to be constructed, including both surface and tunnel motorway sections.
- Additional pavement surfaces that are planned for future motorway widening.
- Existing pavement surfaces where it is practicable to do so.
- All ancillary pavement areas on local roads affected by the works to the extent that these are additional to existing pavement areas.
- All cut batter slopes from which runoff will be managed in conjunction with pavement runoff.
- Stormwater collected from the Maioro Interchange as part of the Mt Roskill SH20 extension project that cannot be directed to the Roma Road pond.
- Stormwater from the Christ the King site as per the agreement between NZTA and the owner of the property.

It may not be practical to direct runoff to the proposed ponds from some of the areas listed above. In these cases it may be acceptable (subject to approval from the ARC) to provide treatment for equivalent areas of existing similar type road/motorway (with similar containment loading) that can be more readily drained to the stormwater treatment device.

The minimum target adopted for treatment has been set out in ARC TP10, i.e. to remove at least 75% of the total suspended solids on a long-term average basis. Stormwater treatment devices that discharge directly to the CMA (Sectors 1 – 5) shall remove 80% or more TSS on a long term average basis.

Treatment devices shall be designed in accordance with ARC TP10 and/or ARC approved proprietary devices shall be used.

When designing permanent stormwater treatment devices, consideration shall be given to the possibility of the temporary application of these devices (with modifications), to meet the sediment control requirements of ARC TP90.

Backflow into stormwater treatment devices be avoided by hydraulic design and/or backflow prevention.

Stormwater treatment devices shall include isolating valves/devices where practicable to enable containment of spills into the motorway stormwater system.

6.2 Stormwater Wet Ponds/Wetlands, Geometry and Treatment

Stormwater treatment and attenuation may be provided by stormwater wet ponds/wetlands if this is the BPO. ARC TP10 will be used as the design guideline for design treatment ponds, as either Wet Pond or Wetland Pond. The design of stormwater ponds and wetlands shall provide for:

- Ponds may be classified as a dual-purpose pond in terms of ARC TP10. A dual-purpose pond requires sufficient volume for both stormwater treatment and attenuation.

- Treatment of the Water Quality rainfall event (one third of the 2 year ARI) should be provided for stormwater systems for the purpose of water quality.

- Ponds situated in or close to the CMA shall have a minimum crest elevation of 3.25m RL to provide a reasonable level of security against wave overtopping to 2100 during the 100 year ARI event.

- Stormwater devices should have facility for outlets to be manually shut to enable capture of spilt fluids from the motorway.

- Underground services will be identified to determine any constraints that they might impose on pond development.

- Maintenance access to each pond will be provided via the existing road network or proposed access tracks. Access into the pond proper will be via a 3 m wide metalled strip suitable for track access.

6.3 Stormwater Wet Ponds/Wetlands, Attenuation

The design of stormwater wet ponds/wetlands will need to consider attenuation requirements:

- The peak runoff from the ponds in the 2, 10 and 100 year ARI storms shall be limited to the corresponding pre-development catchment peak runoff, for the catchments draining to Oakley Creek.

- Extended detention of the 34.5 mm rainfall event should be provided for stormwater systems discharging to creeks for the purpose of erosion protection.

- Peak flow attenuation and extended detention will not be required for catchments discharging to the Oakley Inlet and coastal management areas where flooding and erosion are not issues.

- Discharges from the ponds shall be safely conveyed in such a way that there is no significant erosion of natural streams. Preferably a length of channel should be provided between the discharge outfall and the natural stream or CMA.

6.4 Tunnel drainage treatment

Due to the potential hazardous nature (e.g. petrol combustion by-products) of an accident or fire in the tunnels, it is considered that the spillage and all subsequent deluges, hydrant and other flows during the incident must be collected and stored prior to disposal. Appropriate treatment must be included in the disposal method. Refer to Technical report no. G15 Assessment of Stormwater and Streamworks Effects (T&T/Aurecon, 2010) for treatment and disposal methods.

The storage volume requirements will be based on the flow combination scenarios outlined in Section 5.9 above and will be calculated for flows over a one hour period, which is the deluge flow operational period.

6.5 Bio-Filter Strips & Swales, Geometry and Treatment

Stormwater treatment may be provided by stormwater bio-filter strips and swales if this is the BPO. ARC TP10 will be used as the design guideline for the design of the bio-filter strips and swales. The design of stormwater bio-filter strips and swales shall provide for:

- The minimum target adopted for treatment has been set out in ARC TP10, i.e. to remove at least 75% of the total suspended solids on a long-term average basis.

6.6 Proprietary Stormwater Treatment Devices

Stormwater treatment may be provided by proprietary stormwater devices if this is the BPO. ARC TP10 will be used as the design guideline. The design of proprietary stormwater device shall provide for:

- The minimum target adopted for treatment has been set out in ARC TP10, i.e. to remove at least 75% of the total suspended solids on a long-term average basis.

- The proprietary treatment device and filter media should be approved by the ARC.

- Proprietary treatment devices should be suitable and approved from a network operations and maintenance perspective by the NZTA and Auckland Motorway Alliance (AMA).

7. Catchment flooding

The design philosophy to manage the effects of catchment flooding and hydrological change is as follows:

- The project will be developed to have a negligible effect on the 100 year ARI flood flows and levels in the Oakley catchment under the ACC maximum probable catchment development scenario.

- Opportunities to reduce flood levels shall be considered in conjunction with Metrowater for mutual benefit of lower motorway alignment and reduction in habitable floor flooding.

- The vertical alignment of the motorway should be set to preserve a minimum of 500mm freeboard above the 100 year ARI flood level in Oakley Creek to the edge of the lowest lane.

- The tunnels shall be protected from flooding from Oakley Creek or overland flow, during the 100 year ARI rainfall event. Measures to protect the tunnel from flooding, and manage the consequences should flooding occur during more extreme rainfall events shall be implemented with the 2500 year ARI rainfall event being considered as the design storm. The minimum level for flood defences shall be based on the backwater from the overland flow path that overtops the western line railway, caused by extreme events or blockage of the Bollard Avenue culverts.

8. Stream Works

The stream works shall be developed to provide the level of flood production and freeboard detailed in previous sections of this Design Philosophy statement.

The stream works should also consider the principles detailed in the Oakley Creek Re-alignment and Rehabilitation Guidelines. These guidelines provide a detailed design philosophy for the stream works that integrate hydraulic, ecological and landscape requirements.