WATERVIEW CONNECTION STORMWATER, STREAMWORKS AND FLOOD PROTECTION

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ABSTRACT

The Waterview Connection project for the NZ Transport Agency involves construction of 5 km of new motorway – half of it underground in tunnels – to connect the Southwestern and Northwestern motorways in Auckland.

Stormwater design for the motorway includes several kilometres of new pipe network, stormwater treatment devices, and connections to existing infrastructure. The more complex and challenging stormwater aspects included the integration with and utilisation of the existing SH16 drainage network, the innovative design and construction of tunnel drainage to capture and convey tunnel deluge flows, and a length of box culvert in a section of road with minimal cover to tie-in to the Oakley Creek motorway bridge aqueduct.

Large areas of Hendon Park and Alan Wood Reserve at the southern end of the project were subject to flooding from Oakley Creek before the project. The project required realignment of the creek away from the motorway route. This presented opportunities to increase conveyance for better management of flood flows, to improve in-stream habitat values and to naturalise the creek. Completion of the streamworks was critical to the timely commencement of tunnelling and to ensure adequate flood protection at the start of the tunnel enabling works.

KEYWORDS

Waterview, SH16, Oakley Creek, tunnel, box culvert, wetlands, flood protection

PRESENTER PROFILE

Stefan Whiting is a Senior Drainage Engineer with 15 years' experience in the design of a large range of drainage and civil projects. Stefan has extensive experience within a number of large scale road, rail and civil projects within New Zealand and Ireland.

Tom Basset is a Senior Engineer and Manager of the Water Resources Group in Tonkin & Taylor. He has over 30 years' experience in catchment management and modelling, flood control works and river engineering. Tom has project design experience on various land transport infrastructure projects in New Zealand, Malaysia, Ghana and UK.

1 INTRODUCTION

The Transport Agency Waterview Connection project involves construction of 5 km of new three lane motorway – half of it underground in tunnels – to connect the Southwestern and Northwestern motorways in Auckland.

The motorway alignment is located within the Oakley Creek catchment, which is a suburban stream with an urbanised catchment. It flows through Mt Roskill (the south), Wesley and Owairaka (above the tunnels) to its mouth at Waterview (the north), where it discharges into the Whau estuary of the upper Waitemata Harbour.

In the south the motorway alignment passes mainly through areas of reserve land in Mt Roskill. The motorway land use will change to impervious motorway surface, having an effect on both water quality and quantity of stormwater runoff generated from this area.

The purpose of this paper is to provide an overview of:

- The project
- Some of the project's more interesting drainage features, including the specific design of the tunnel drainage
- The stormwater quality and quantity requirements and management outcomes
- The flood protection works to protect the tunnel and minimise any potential flood risks of the motorway on the existing catchment
- The Oakley Creek realignment and improvement works to increase conveyance and naturalise the creek.

2 THE PROJECT

2.1 PROJECT OVERVIEW

The Waterview Connection project will complete Auckland's Western Ring Route, a 48 km north-south motorway alternative to State Highway 1 (SH1) that bypasses the central city (refer Figure 1).

Figure 1: Waterview Connection location plan

The project involves construction of a new 5 km long three lane motorway – half of it underground tunnels – to connect the Southwestern (SH20) and Northwestern (SH16) motorways. It is being undertaken by the Well-Connected Alliance (WCA) and is due to be completed in early 2017.

The project involves construction of twin 2.4 km tunnels with an outside diameter of 14.41 m beneath residential suburbs. The project's tunnel boring machine (TBM) – Alice – is the 10th largest in the world. In addition to the tunnels, the project also includes the construction of a large interchange at the northern end including four bridges (ramps) to connect the SH16 and SH20 motorways. A future rail corridor alongside the new motorway has been provided in the south.

The project benefits Auckland by:

- Providing a second motorway route through the city
- Taking traffic off local roads
- Giving people more travel choices by providing walking and cycling paths
- Providing community benefits including skateboard parks and sports facilities
- Providing better transport links for Auckland's regional neighbours in Northland and in Waikato/Bay of Plenty.

The project is includes three distinct areas, as shown in Figure 2:

1. The north – the SH16 interchange (or Great North Road Interchange) at Waterview
2. The tunnels – underground section between Mt Roskill in the south to Waterview in the north
3. The south – the extension of the existing SH20 at Maioro Street, Mt Roskill to the tunnel southern portals.

Figure 2: Waterview Connection layout

2.2 DESIGN PROCESS

A feature of the Waterview Connection project is the comprehensive and inclusive design process integrating the inputs of all design disciplines, construction and operation and maintenance (O&M) staff, peer reviewers and the owner verifiers. This approach was essential on a project of this scale. It was also made possible, or at least easier, by having designers, constructors and O&M personnel working together from the same office location.

The design process included three stages:

1. Stage 1 – Concept design
2. Stage 2 – Detailed design
3. Stage 3 – Pre-construction approval.

At each design stage the following aspects were considered:

- Project-specific Transport Agency requirements and minimum standards (MRs)
- Other relevant local and national (or international) standards
- Safety in Design and risk management. All potential safety issues and risks were assessed through workshops and where possible the issues designed out, and/or risk mitigation measures passed on to the ultimate asset owner (e.g. O&M)
- Whole of Life and Design Life. The design life for drainage is 100 years for inaccessible drainage assets, and 40 years for drainage assets accessible for refurbishment and maintenance
- Fire safety, specifically within the tunnel. The tunnel drainage has been designed to prevent fire from burning liquids entering the conveyance system and spreading to other parts of the tunnel
- Other design disciplines. All design elements were coordinated with other design disciplines to provided and integrated design (e.g. drainage elements coordination with barriers and pavement design)
- Constructability. Constructor input was invaluable to understand the construction process, which could then feed into the design of that asset
- O&M requirements. As per the constructability, understanding how an asset would be maintained contributed to the design arrangement developed
- Peer review. All design packages went through an independent (to the project) peer review prior to being issued to Transport Agency
- Owner Verifier review. All design packages were reviewed separately by Transport Agency owner verifiers. Any comments or recommendations resulting from the owner verifier review were incorporated (where required or appropriate) into the next stage of the design.

3 STORMWATER PAVEMENT DRAINAGE

The project includes approximately 220 new manholes or catchpit manholes, 310 new catchpits or double catchpits, over 12 km of new pipe and about 300 m of box culvert.

The majority of the motorway drainage features in the north and south outside the tunnels comprises conventional catchpit, manhole and pipe arrangements. In a number of locations, particularly in cut areas where there is limited space beyond the road shoulders (such as the northern and southern approach trenches to the tunnel), catchpit manhole arrangements with no sumps have been adopted in the design. These reduce the complexity of drainage infrastructure and reduce maintenance requirements.

The majority of the motorway is either in cut or bounded by solid concrete barriers, and therefore is designed to collect and convey the 100 year ARI storm event.

A specific drainage design was developed for the tunnel to allow for the specific tunnel flows and physical constraints within the tunnel, which is discussed in more detail in Section 3.2.

Some of the more interesting drainage aspects on the project include:

- The utilisation and integration with existing drainage infrastructure along SH16 in the north
- The specific tunnel drainage design
- The use of box culvert upstream of Oakley Creek Bridge in the south.

3.1 SH16 DRAINAGE IN THE NORTH

A section of SH16, from just east of Carrington Road Bridge to the Great North Road (GNR) over-bridge is being widened as part of the Waterview Connection project (refer to Figure 5. Separate projects for the SH16 widening and upgrade works are underway either side of the Waterview project – St Luke's project to the east of Carrington Road, and the Causeway Alliance to the west of GNR over-bridge.

The SH16 drainage connections were difficult to design as these included integration with the existing SH16 drainage infrastructure that was installed some 30 years ago, or designing around it where required. The existing SH16 drainage network comprises of a primary carrier pipeline down the median, with lateral connections from catchpits and other small stormwater networks. The depth of the existing primary pipeline approaches 4 m towards the downstream end near the Whau estuary.

The tender design was based on utilising the SH16 existing network to take as much of the 100 year ARI storm flow as possible. The tender design did not include for significant new drainage, mainly catchpit lead extensions beyond the new traffic lanes. It was expected that any surcharging resulting from the design would be managed within the road shoulders and elsewhere within the drainage network.

This approach was considered appropriate at the time of tender. However, during detailed design it became apparent that the existing SH16 drainage network did not have the capacity to convey the flows for a motorway catchment area that has essentially doubled in size and included for climate change effects on runoff generation. Managing surcharged flow in the motorway drainage network would be difficult due to:

- The motorway along this section of SH16 is in cut and bounded by retaining walls, so there are limited locations for secondary flow paths

- There is a low point on the carriageway where the new two-lane eastbound ramp from the tunnel merges with SH16 eastbound. There is limited space and length for ramp traffic from the tunnel to change lanes to avoid ponding, particularly those in the outside lane. Appropriate drainage management of the low point was critical.

Numerous design options were developed, with close coordination and collaboration with the construction team and other design disciplines.

The condition of the existing SH16 drainage motorway network was also assessed during the optioneering stage. An initial CCTV survey of the existing network was undertaken between March and April 2013. In June 2013, the existing drainage pipes were flushed clean and re-surveyed using CCTV.

The overall CCTV condition rating of the existing median network, based on the NZ Pipe Inspection Manual (3rd Edition), ranged from excellent to moderate, with two of the pipelines in possible poor condition. This condition rating was considered to be consistent with a concrete pipe network that has been in service for over 30 years.

The adopted drainage design following the optioneering was to install two separate stormwater networks:

1. To utilise the existing median drainage to convey the eastbound stormwater, including some remedial works to fix defects in the existing pipelines that were to be retained

2. A new network down the GNR westbound off-ramp from SH16 to convey the westbound stormwater.

The adopted design is very different to tender design and required additional drainage infrastructure, as well as an additional StormFilter unit for treatment (refer to Section 4.1).

3.2 TUNNEL DRAINAGE

The design of the tunnel drainage was one of the most technically challenging and complex aspects of the drainage design, especially given the design requirements and space constraints of the tunnel.

The final design, as shown in Figure 3 and described in the following section, includes:

- A slot drain with 300 mm diameter channel to capture the tunnel flows

- A access grate located below a removable steel barrier plate

- A catchpit including inlet chute and flame trap (a hydraulic seal in the catchpit formed by a baffle)

- A catchpit outlet pipe with 60 ° saddle connection into a main carrier pipeline.

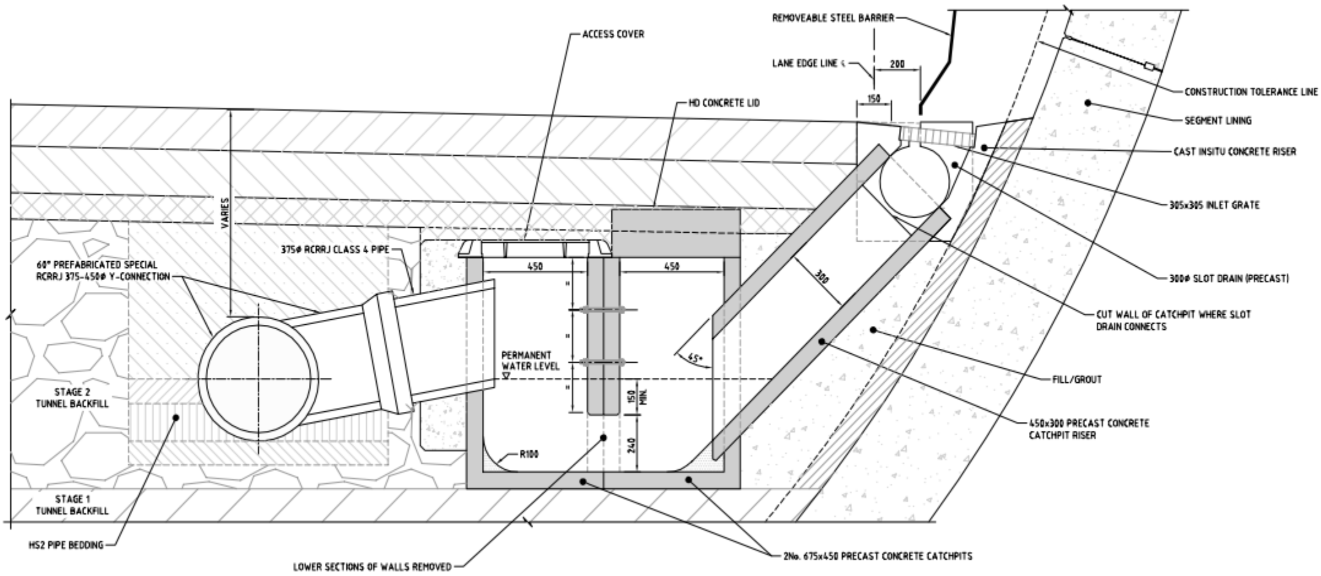

Figure 3: Tunnel catchpit and main carrier pipe cross-section (final design)

3.2.1 DESIGN REQUIREMENTS AND CONSTRAINTS

Although it doesn’t rain in the tunnel, the extensive tunnel drainage system serves an important function to safely collect and convey flows from:

- Accidental spillage of liquids
- Deluge flows from fire-fighting systems in the tunnel
- Fire hydrant and testing
- Fire main rupture
- Tunnel wash-down and maintenance
- Surface water up to the 2,500 year ARI event from the carriageway approaches that is not captured in the drainage system outside the tunnel and flows through the tunnel portals
- Groundwater and tunnel seepage flows

The largest flow scenario catered for is deluge system flows, fire hydrant flows and groundwater flows concurrently. The design flow for this scenario is estimated to be 210 L/s. A total design flow of 240 L/s was adopted for the drainage design to allow for redundancy in both the deluge and drainage systems.

For design the tunnels were split into deluge zones, each 30 m long. A maximum of three adjoining deluge zones will be active at any one time; i.e. 90 m of active deluge. All flow is to be caught within three catchpits of the active deluge zone to ensure that only one cross passage connection is affected by an event. The cross passage connections are links between the two tunnels and are used as emergency escape routes during tunnel events. The catchpits are spaced at approximately 50 m centres, spaced evenly between cross passage connections.

The catchpits have been designed with a flame trap to prevent fire from for instance burning liquids entering the primary carrier pipe and spreading to other parts of the tunnel.

As well as the design flow and the flame trap requirements, other constraints included:

- MRs required no drainage feature on the surface within traffic lanes, i.e. all drainage surface features must be within the road shoulder or buried if in traffic lanes. This was a difficult constraint given that the shoulder width in the three lane tunnels is only 200 mm (refer to Figure 3)
- Given the curvature of the tunnel below road level there was limited space to locate drainage within the shoulder below ground, pushing the main drainage features into the road (refer to Figure 3).

3.2.2 INLET DESIGN

Depending on the location of the active deluge zones in relation to the catchpits a minimum of four (one within and three beyond the deluge zones) and maximum of five (two within and three beyond the deluge zones) catchpits will be active during an event. Based on a flow of 240 L/s this equates to a design flow of 60 L/catchpit for four catchpits.

The challenge in the inlet design was trying to capture 60 L/s/catchpit in an inlet that had to fit within a 200 mm shoulder. A flow of up to 70 L/s/catchpit was modelled to provide additional redundancy to the inlet design and assess the sensitivity of the inlet design to increased flows.

Numerous catchpit inlet design options were developed, and assessed in terms of hydraulic performance, the interface between barrier and pavement, constructability and O&M requirements. Collaboration between a number of project disciplines was required to agree on the suitable design solution.

The options (or variations to the options) that were considered included:

1. Double inlet grate behind a removable steel barrier with no lead-in channel drain
2. Single inlet grate behind a removable steel barrier with a lead-in channel drain within the road shoulder
3. Single inlet grate with a lead-in drainage channel that is recessed below and under a cast in-situ barrier
4. Single inlet grate behind a removable steel barrier and lead-in drainage channel behind the barriers, which contains regular slotted gaps (500 mm long by 50 mm high at 3 m centres)
5. Single inlet grate behind a removable steel barrier with a lead-in slot drain within the road shoulder.

Each option included advantages and disadvantages. Ultimately Option 5 (refer to Figure 4), with some further optimization, was adopted as the preferred design solution.

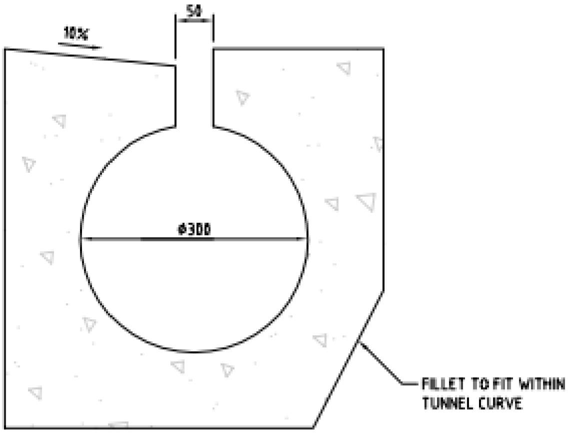

Figure 4: Tunnel catchpit slot drain

The open width of the slot drain was set at 50 mm to provide a balance between inlet capacity (and length of slot drain required) and the likely size of debris/sediment that can enter the tunnel drainage network. Increasing the cross-fall (shoulder/gutter cross-fall) of the slot drain also improved hydraulic inlet efficiency and reduced slot drain lengths. A grade of 10 % was confirmed as optimal. The length of slot drain varies from 5 m to 6 m depending on the longitudinal grade of the tunnel. The slot lengths were determined based on the method outlined in FHWA, Hydraulic Engineering Circular No. 22 (HEC-22), Third Edition, Urban Drainage Design Manual and checked using FlowMaster.

The minimum diameter to the pipe channel below the slot was determined to be 300 mm to convey the design flows at a minimum grade of 0.5% (approaching the low point of the tunnel).

The inlet grate behind the barrier does not provide much inlet capacity and for the purposes of design was assumed not to capture any flow. The grate however does provide an access point to the catchpit for maintenance purposes, as well as some nominal secondary inlet capacity.

3.2.3 CATCHPIT DESIGN

The initial catchpit design carried through from the tender was a large bespoke catchpit chamber. The chamber was shaped to follow the curve of the tunnel and included a built in baffle to form the flame trap.

However, during the design process it was considered that the cost and time frame required to construct the bespoke catchpit was not feasible. Thus, the catchpit design was updated (refer to Figure 3) with an emphasis on utilising standard precast drainage products where possible, which was a key learning of the project. Various arrangements were considered, including:

- Flume shape (pipe or square) and angle. A square flume (utilising standard precast concrete catchpit risers) 90 ° to the slot drain was considered the most suitable option in terms of constructability and butting the slot drain against the slot drain
- Flume size. A 300 mm x 300 mm square flume was initially selected, but was increased to a 450 mm x 300 mm flume for improved hydraulic performance
- A double catchpit arrangement or manhole with built-in baffle to create a flame trap. This double catchpit arrangement, whereby two catchpits are joined back to

back, was considered the simpler solution than trying to construct a baffle within a manhole. 675 mm x 450 mm concrete catchpits were selected as these are the most common and readily available precast catchpit product. The flame trap was created by removing the lower sections of the adjoining catchpit walls. The baffles were initially trialed by cutting out the walls of the catchpits on site. However, the manufacturer, Humes, is now producing the catchpits with the box-outs in the factory.

- The angle of the 375 mm diameter outlet pipe into the primary carrier pipeline. Once the double catchpit arrangement was selected, the cut face of a 375 mm diameter pipe cut at 45 ° was found to be too acute to fit within the 675 mm wide catchpit wall (allowing for construction tolerances). Therefore, the pipe angle was adjusted to 60 ° to provide a squarer connection to the catchpit wall.

The catchpits are located in a traffic lane so will be buried below the road pavement. The inside catchpit (closest to the tunnel wall) is fitted with a permanent concrete lid. The outside catchpit is fitted with an access cover. In the unlikely event that there is significant blockage that cannot be cleaned from the regular access grate, the cover provides access to the catchpit outlet chamber without the need to remove the entire catchpit. The road pavement, however, will need to be dug up to access the cover.

3.2.4 PRIMARY CARRIER PIPE

The tunnel drainage tender design provided for a longitudinal primary carrier pipe within the pavement backfill with in-line catchpit inlet connections at regular intervals. The primary drainage pipe entered and exited catchpits through syphon bends, which provided flame traps.

During the development of the design following tender award an invert service culvert was introduced into the tunnel. As a result the primary carrier pipe was moved from the backfill into the service culvert, with catchpit inlet connections at regular intervals.

Optioneering and feasibility were investigated during the concept design stage. The preferred drainage option from that exercise was a primary carrier pipe within the tunnel backfill, with off-line catchpit inlet connections at regular intervals. This design was determined to be about $2 million cheaper than the option of having a pipe (including structural fittings) within the service culvert. It also had the added advantage of reducing the low point sump size, providing additional cost savings.

The primary carrier pipe is a 450 mm diameter pipe within the tunnel backfill. As the main carrier pipe is located within the road departure was sought and approved to provide saddle 375 mm catchpit connections directly to the carrier pipe instead of manhole connections. If required the pipeline can be accessed from the buried catchpit access lid described in Section 3.2.3.

The primary carrier pipes (two from each tunnel) discharge into the tunnel low point sump. Water from the tunnel low point sump is pumped to the northern portal sump (NPS), then onto the Waterview Reserve wetland.

3.3 BOX CULVERT

The southern drainage works comprise mainly catchpit manholes and catchpit to manhole and pipe arrangements. However, there is a 300 m section of box culvert.

The motorway bridge crossing of Oakley Creek (refer to Section 5.3) includes a pipe bridge (aqueduct) to convey stormwater flows over Oakley Creek to the Valonia wetland.

The invert level of the aqueduct is set 600 mm above the 100 year ARI storm event flood level in Oakley Creek. The invert level of the pipe bridge dictates the levels of the drainage system upstream. There is also a low point approximately 180 m upstream of the bridge. The constraints of the bridge level and low point resulted in minimal available cover or possibly daylighting of the pipe network within the road shoulder leading up to the bridge.

A number of options were assessed to increase cover while providing a drainage solution that works hydraulically. The options assessed were:

- Smaller multiple (double) pipes
- Directing flows through multiple networks running parallel to the main pavement network and reconnecting into the pipe bridge
- Restricting flows from a network outside the motorway into the pavement drainage network to the 10 year ARI storm event, with excess runoff from less frequent events conveyed as overland flow down a new cycleway to Valonia sports field reserve
- Lower the pipes leading to the bridge and construct a large syphon under Oakley Creek
- A 1 m high by 2 m wide box culvert.

From hydraulic analysis of the options, and consultation with the construction team and other design disciplines, the box culvert was identified as the preferred solution as it can convey the entire design flow and can specifically be designed for HN-HO-72 loading with no cover. The entire box culvert length has a cover less than the project MR of 1.2 m, with a minimum cover of about 0.2 to 0.3 m at the road low point. Therefore, departure was sought and approved for reduced pipe cover.

4 STORMWATER TREATMENT AND ATTENUATION

The motorway alignment is located within the Oakley Creek catchment. Oakley Creek is a suburban stream with an urbanised catchment. From analysis of stream water samples, the level of metals such as zinc copper and lead are high as is typical for highly urbanised catchments. Additionally, much of the existing SH16 drainage network within the Waterview site discharges untreated flows into an Auckland Council stormwater network and into Oakley Creek.

The consent conditions for the project set specific quality and quantity requirements for the project, which vary slightly between each work area.

The required stormwater treatment and peak flow attenuation devices were designed in accordance with Stormwater Management Devices: Design Guideline Manual: ARC Technical Publication No 10, 2nd Edition (TP10).

4.1 NORTH TREATMENT

As the northern area is located at the mouth of Oakley Creek no water quantity or extended detention was required.

However, the water quality treatment MR for the project required 80 % total suspended solids (TSS) removal. This requirement exceeds the standard best practice of 75% TSS removal, as set out in TP10.

The type of treatment device used in the north varies according to the contributing catchments, which are shown in Figure 5.

Figure 5: North treatment catchment areas

Runoff from catchments 1(a) and 1(b) are treated in the Waterview Reserve Wetland. Catchment 1(a) discharges into the wetland via gravity. This catchment includes the interchange ramps from the highpoint falling toward the tunnels and the ramp embankment. Catchment 1(b) is pumped to the wetland. Catchment 1(b) includes the Northern Approach Trench (NAT), which is a retained cut that grades down to the tunnel portals) and the flows pumped to the NPS from the tunnels.

Pump rates from the NPS have been limited to 25 L/s, except for events greater than the water quality event for which the pump rate increases to 50 L/s. The volume of runoff that will accumulate in the sump before pumping is triggered has been limited to a maximum of 6 hours of pumping, so that the operation and treatment efficiency of the wetland is not compromised.

During tunnel walls wash-down or deluge testing, runoff from the tunnel is expected to be highly contaminated. Pumped flow from the tunnel in these scenarios can be directed to the trade waste sewer so as not to damage the wetland plants.

All the wetlands on the project are designed to be not just functional but also to incorporate significant features of the area. This design process included close collaboration the project Urban Design team. Features of the Waterview Reserve wetland represent a historic mill ponds and mill race. The forebay forms one of two rectangular deeper pools separated by a rock and mortar/weir wall that follows an alignment between the historic mill and the Oakley Creek. This wall will form a visual sightline with a one metre high drop between water levels. The Waterview Reserve wetland discharges into Oakley Creek.

Runoff from catchments 2(a) and 2(b), including a previously untreated section of SH16, will be treated through Stormwater 360 StormFilter units. As the motorway designation in this section of SH16 is essentially all road carriageway there is limited space to locate other treatment devices such as ponds, wetlands or swales. Therefore, below ground proprietary treatment devices were the best practicable option (BPO). As outlined in Section 3.1, two treatment units are required – one to treat the eastbound catchment 2(a), the other the westbound catchment 2(b). Both units discharge into an existing Auckland Council stormwater network, at different locations, and into Oakley Creek via a single existing outfall.

Runoff from catchments 3 and 4 discharge into the St Luke's and Causeway Alliance project drainage networks respectively for stormwater management. The design at the project interfaces was coordinated with the respective project design teams.

Road runoff from catchment 5 is treated through vegetated swales.

4.2 SOUTHERN TREATMENT

The motorway alignment in the south passes mainly through areas of reserve land in Hendon Park and Alan Wood Reserve, Mt Roskill, which are flood prone (refer to Section 5). Therefore, water quality treatment – to 75% TSS removal – and attenuation are required.

Stormwater runoff from the motorway in the south is managed by two wetlands:

1. Valonia wetland, which receives stormwater from the motorway between Maioro Street and Oakley Creek Bridge (refer to catchment 1, Figure 6) and the Christ the King school (developed prior to the Waterview Connection with the agreement the stormwater would managed in the new motorway stormwater network).

2. Alan Wood wetland, which receives runoff from the motorway between Oakley Creek Bridge and the southern tunnel portals, and groundwater from the Southern Approach Trench (SAT). Catchment 2(a) (Figure 6) discharges via gravity into the wetland. Flows from the SAT catchment 2(b) (Figure 6) are pumped to the wetland.

Both wetlands discharge into realigned sections of Oakley Creek (refer to Figure 6 and Section 5.3) through new outfalls with erosion protection measures that tie into the new creek realignment.

As with the Waterview Reserve wetland, both of the southern wetlands were designed with significant Urban Design input to maximise the amenity value and passive open space adjacent to the wetland and Oakley Creek. Features of the southern wetlands include exposed basalt outcrops, which are also prominent in the adjacent stream.

Figure 6: South treatment catchment areas

5 FLOOD PROTECTION AND STREAMWORKS

5.1 EXISTING CATCHMENT

As outlined in Section 4, the motorway alignment is located in the Oakley catchment. Oakley Creek is a suburban stream with its headwaters in Hillsborough, south of the project site. It flows through Mt Roskill, Wesley and Owairaka to its mouth in the Whau estuary at Waterview. The total catchment area is 12.9 km^2 with an urbanised catchment.

The lower reaches of the creek, near Waitemata Harbour, is a mostly natural channel, including a natural waterfall, with extensive riparian vegetation. A walkway runs along most of this section of Creek. No flood protection measures or streamworks were required in this area.

The upper catchment is predominantly residential land-use with a small area of industrial and commercial land-use within Mt Roskill. Many of the stream tributaries have been piped and much of the stream waterway itself is highly modified with culverts and historical channel diversions (refer to Figure 7).

Although the upper catchment is highly urbanised, the motorway alignment in the south passes mainly through areas of reserve land in Hendon Park and Alan Wood Reserve. This section of Oakley Creek is prone to flooding, with a number of adjacent properties flooded in the past (refer to Figure 7).

In some areas the motorway alignment intersects with Oakley Creek and occupies part of the floodplain. A bridge was required over Oakley Creek at within Hendon Park reserve.

The motorway land use will change to impervious motorway surface, having an effect on both quality and quantity of runoff flowing to Oakley Creek.

Figure 7: Oakley Creek in Alan Wood Reserve showing basalt rock wall channel sections, Flooding downstream of Richardson Road culvert on 1 June 2010 after rainfall equivalent to 1 to 2 year ARI rainfall intensity

5.2 FLOOD PROTECTION

As the motorway in the south passes through the Oakley Creek flood plain, flood protection of the motorway is required. The project MRs specified that the flood protection of the tunnels at the southern portal is to meet the following standard:

1. 2,500 year ARI storm; or
2. The flood level established by overland flow paths across the Western Rail Line for flow scenarios involving partial blockage of the Bollard Avenue culvert; and
3. Overflow past the southern portal in the 2500 year ARI storm event is to be less than the capacity of the tunnel drainage and pumping systems
4. Flood protection for the motorway outside the southern portal area for the 100 year ARI storm event with minimum 500 mm freeboard
5. 1200 mm freeboard to the Oakley Creek motorway bridge soffit for the 100 year ARI. Approval was sought and approved to reduce the freeboard to the aqueduct to 600 mm.

Additionally, the flood protection was designed in accordance with the catchment management option preferred by Auckland Council with allowances for climate change, sea-level rise and Maximum Probable Development (MPD) in the catchment and the effects of anticipated Council streamworks upstream which would increase peak flows.

Design flood levels were determined with computational hydraulic modelling as part of detailed design. The computational model was originally developed by AECOM for Auckland Council, and provided a tool for Council's own catchment and stormwater management planning. The model was used for the Specimen Design investigations and assessment of environmental effects for the resource consent application.

The flood protection measures designed for the project included:

- Mitigation of project structures within the 100 year ARI flood plain by hydraulic design to ensure that adverse effects on flooding are at least minimised, or reduced
- Protection levels to ensure no flooding of the motorway in the 2,500 year ARI event
- A bund along the northern side of the motorway in Hendon Park to ensure no overflow out of the creek system corridor
- A new Council stormwater pipe under the motorway to convey runoff from the Hendon Avenue catchment north of the motorway to minimise the flood risk
- Improved creek conveyance through the creek realignment works (refer to Section 5.3).

5.3 STREAMWORKS – REALIGNMENT AND RESTORATION

Stream works for the project were required in the south, where the proposed motorway alignment crossed Oakley Creek and occupied the flood plain in Hendon Park and Alan Wood Reserves. Downstream of the new motorway bridge three sections of stream realignment, and four sections of stream rehabilitation were proposed (refer to Figure 6). The realignments were necessary where the existing stream course clashed with the proposed motorway alignment, and to make space available for proposed new sports grounds at Valonia, which are part of the offset mitigation to improve community amenities.

As described in Section 5.1, within the reserve the existing stream flowed in a historically diverted channel, in many reaches including basalt rock walls. The new creek realignment and rehabilitation as part of the Waterview Connection project were based on a naturalised channel form. This was developed to increase and enhance the aquatic and terrestrial habitats, and create a stream form more amenable and accessible to the public. A typical realigned creek cross section profile is shown in Figure 8.

Completion of the streamworks was critical to the timely commencement of tunnelling and to ensure adequate flood protection at the start of the tunnel enabling works.

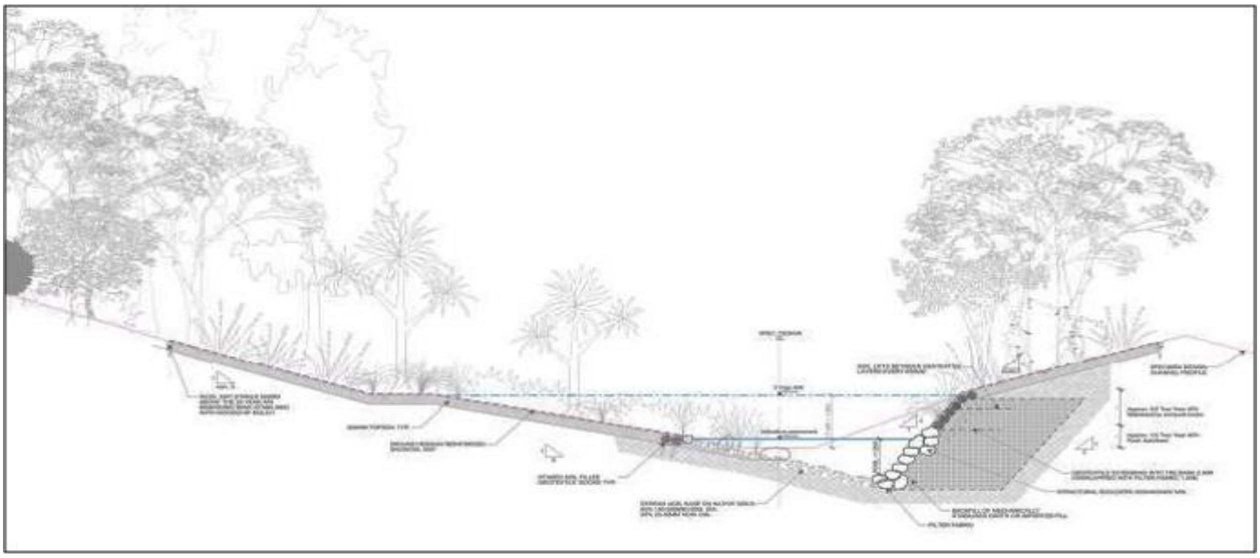

Figure 8: Realigned creek profile

The streamworks design applied a bioengineering approach in accordance with the approach set out in the Oakley Creek Re-alignment and Rehabilitation Guidelines developed during the Specimen Design phase of the Project. This involved a combination of:

- Persistent materials and structures such as rock and mass block retaining walls
- Temporary materials such as biodegradable mats to stabilise surfaces until riparian planting become established
- Plants themselves with associated root systems that provide for long-term stabilisation of surfaces and banks.

The rehabilitated stream design was based on repeating Pool-Riffle-Run sequences in accordance with the local geology and the wavelength of the designed channel meander. Pools are located at the outside of bends where erosion of the stream bed would naturally occur. Riffles retain these pools, and change the longitudinal gradient and direction of the stream flow. Runs connect riffles to the next downstream pool.

The design included for localised steepening at outside bends and shallow inside point bars to account for helical flows from the outside to the inside of bends along the base of the channel. The bank stabilisation measures at these locations were designed to provide adequate factor of safety on bank stability.

The design stream profile provides for a slightly entrenched main channel to convey the normal water flow and more frequently occurring storm events. Above 'bank-full' level is a second defined flood channel comprising a flood bench and higher flow waterway. The higher flow waterway is defined by flood benches, reduced bank slopes to provide for widening and slowing of stream flow that exceeds the capacity of the main channel, and denser, larger vegetation.

In addition the streamworks were designed to:

- Maintain the passage of fish (specifically the short and longfin eel species recorded in Oakley Creek)and other aquatic organisms both up and down stream, by preventing impediments due to any in-stream structure, and creating refugia for fish moving within the catchment through the provision of dedicated pools throughout the proposed design

- Restore and enhance the habitats of indigenous fauna, by creating a plant-soil-water interface to replace existing stone walls and through incorporation of natural material of basalt rock
- Include for capturing and germinating rare plant species currently found within the project area to ensure no permanent loss of these species.
- Include planting of stream banks and floodplain to provide stream shading to reduce in-stream macrophytes, enhance aquatic habitat, and contribute to slope stabilisation
- Provide Visual and physical public access to the stream

The rehabilitation of Oakley Creek includes weed control and restoration planting of 15 m to 20 m buffers on each bank to provide self-sustaining indigenous vegetation. This is provided to suppress ongoing weed incursions and provide a micro-climate for the stream corridor.

The channel profile for Oakley Creek rehabilitation incorporates a stream channel terrace to accommodate margin planting. Sedge and rush species will overhang the stream channel contributing to aquatic habitat in the form of leafy material and insects. In addition the stream terraces in combination with sedges, grasses and rushes will cast shade over the stream for much of the day and provide direct overhead shade over at least one third of the stream channel runs at mature growth.

In addition to stream margin planting, lower bank planting proposes shrub species common to Auckland stream banks, such as mahoe, karamu, cabbage trees and kanuka, which will establish a broader and taller habitat that will both shade the stream and provide for cooler ambient temperatures.

Single bowled tree species will also be included on lower banks, which will only have partial impact on stream flows and roughness, but will contribute considerable shade. This includes species such as putaputaweta, kowhai, and kahikatea. There are also species in basalt areas that provide a very heavy shade, made possible by a basalt invert and therefore a reduced need for margin planting normally excluded under dense shade. These species include taraire, puriri, and karaka, which at maturity will have considerable canopy to span the full stream width.

Photographs of the realigned creek under construction are shown in Figure 9.

Figure 9: Photographs of the realigned section of Oakley Creek under Construction

The new creek alignment also provides improved management of flood flows, with a lower 100 year ARI flood level in the stream through the reserve areas downstream of the motorway and reduced flood footprint, and protection of the motorway alignment from the 2,500 year ARI event in the catchment.

6 CONCLUSIONS

The Transport Agency Waterview Connection project involves construction of 5 km of new three lane motorway – half of it underground in tunnels – to connect the Southwestern and Northwestern motorways in Auckland. The project will complete Auckland's Western Ring Route, a 48 km north-south motorway alternative to State Highway 1 (SH1) that bypasses the central city.

A feature of the Waterview Connection project is the comprehensive and inclusive design process integrating the inputs of all design disciplines, construction and operation and maintenance (O&M) staff, peer reviewers and the owner verifiers.

The project includes approximately 220 new manholes or catchpit manholes, 310 new catchpits or double catchpits, over 12 km of new pipe and about 300 m of box culvert. The more complex and challenging stormwater aspects on the project included:

- The utilisation and integration with existing drainage infrastructure along SH16 in the north

- The specific tunnel drainage design that captures and conveys large deluge flows within a narrow shoulder and includes flames traps to prevent fire from entering the primary carrier pipe and spreading to other parts of the tunnel

- The use of box culvert upstream of Oakley Creek Bridge in the south to convey flows to the Oakley Creek aqueduct through an area of minimal motorway cover.

A key learning from the design process was that where possible utilising standard precast drainage products is preferable, as the cost and time frames involved to produce bespoke designs can be high.

The MRs for the project set specific quality and quantity requirements for the project. In the north no attenuation was required as this area discharges into the mouth of Oakley Creek. However, increased treatment of 80% TSS removal was required, above best practice guidelines. The north was treated via a combination of a wetland, swales and Stormwater 360 StormFilter Units. Both stormwater quality and quantity management was required in the south which is achieved through two new wetlands.

Large areas of Hendon Park and Alan Wood Reserve at the southern end of the project were subject to flooding from Oakley Creek before the project. The project required realignment of the creek away from the motorway route. This presented opportunities to increase conveyance for better management of flood flows, to improve in-stream habitat values and to naturalise the creek. Completion of the streamworks was critical to the timely commencement of tunnelling and to ensure adequate flood protection at the start of the tunnel enabling works.

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REFERENCES

Auckland Regional Council (2003), Stormwater Management Devices: Design Guideline Manual, Technical Publication No 10 (TP10), 2nd Edition

Boffa Miskell (2010) 'Western Ring Route – Maioro Street Interchange and Waterview Connection - Oakley Creek Re-alignment and Rehabilitation Guidelines', prepared for the NZ Transport Agency

US Department of Transportation Federal Highway Administration (2009), Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22 (HEC-22), Third Edition, FHWA-NHI-10-009