WAIKATO EXPRESSWAY-CAMBRIDGE SECTION

Assessment of Effects on Water

Waikato Expressway
Cambridge Section
Assessment of Effects on Water
December 2010

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Executive summary

The NZ Transport Authority (NZTA) intends to construct the Cambridge Section of the Waikato Expressway (the Project) between the northwest side of Cambridge to Tirau Road in the southeast. The Project will improve the capacity of SH1, and will help reduce congestion during holiday periods.

This report details the stormwater/water-related works for the 11.6km four lane Expressway that has a 220m long bridge across the Karapiro Stream. Without mitigation, the proposed Expressway has the potential to cause both short-term and long-term adverse environmental effects related to stormwater.

Short-term effects related to stormwater occur during construction, as a result of earth working activities. Stormwater flowing over the Project site could mobilise sediment and carry it off-site into neighbouring drains and into the Karapiro Stream. Sediment-laden runoff would reduce stream water quality, and when it settles out, could smother the base of downstream waterways, which can suffocate aquatic life. To mitigate the damage that this sediment could cause, erosion and sediment control measures, as outlined in Environment Waikato Technical Publication, *Erosion and Sediment Control Guidelines for Soil Disturbing Activities* will be used on the Project.

Long-term effects related to stormwater could occur after construction has been completed, during the life of the Expressway. To mitigate these long-term effects, the NZTA has adopted the Auckland Regional Council's (ARC) Technical Publication No. 10 *Stormwater management devices: design guidelines manua*l (TP10).

Mitigation of the Project's long-term stormwater effects can be classified as:

- Flood mitigation;
- Stream erosion protection; and
- Treatment.

Infiltration swales and wetlands will be used throughout the Project to mitigate environmental effects using a combination of underground and surface storage, in conjunction with bio-filtration and microbiological action.

The Project will create a large area of new impermeable pavement, which will cause stormwater to runoff the site at a higher rate and in larger volumes than currently occurs. This could result in erosion of streambanks, and flooding of properties located near the Mangaone Stream. Stream erosion and flood control will be mitigated throughout the Project by applying the guidance provided in TP10.

To mitigate stream erosion, TP10 requires stormwater runoff from the extended detention design storm be stored and slowly released over a 24 hour period. The infiltration swales proposed as part of the Project will mitigate stream erosion by storing and discharging excess runoff to ground. The wetlands will mitigate stream erosion by storing road runoff. This runoff will be slowly released to achieve TP10's criteria for preventing stream erosion and to mitigate flooding.

Stormwater runoff from the Project will be discharged to ground over the northern half of the Expressway between the intersection with Hautapu Road and Swayne Road. An infiltration-based stormwater management strategy is required as there are no major watercourses in this section of the route that are able to accept large volumes of stormwater runoff. Geotechnical investigations indicate that infiltration rates are relatively high, but the engineering properties of the soil in this area are variable. Perched water tables and lenses of impervious soils are present, and will need consideration during future stages of design. Continuous infiltration swales will be constructed on each side of the Expressway and interconnected by culverts constructed under the Expressway at low points to accommodate overland flows. This stormwater system will help spread the risk of encountering low permeability soils or high perched water tables. This section of Expressway, between the intersection with Hautapu Road and Swayne Road, needs to be built on low height embankments to prevent it from becoming inundated during extreme storms. Culverts will be installed at waterway crossings, and at locations where overland flow would otherwise pond.

Wetlands will be used to treat and attenuate stormwater runoff between Watkins Road, and the Southern Interchange Overbridge. Wetlands are proposed on either side of the Karapiro Bridge at approximately Stations 9100m and 10200m and will need to be set back from the abutments of the Karapiro Stream Bridge to prevent piping failures. Two additional wetlands will be constructed to treat and attenuate stormwater collected from the Southern Interchange on and off-ramps and from Stations 10900 to 11600m of the Expressway.

The Expressway will mainly be constructed in cut between Watkins Road and the Southern Interchange Overbridge (Station 8200m to 10600m). As a consequence the Expressway's drainage system will need to cater for overland flows and the waterways intercepted. This is considered to be acceptable as this section of the Expressway (Station 8200m to 10600m) can drain to the Karapiro River, and there is little risk of the Expressway becoming inundated.

Vehicle use releases pollutants such as heavy metals, and hydrocarbons. Most of these pollutants collect on the pavement and the grass verges beside roads. These pollutants are invariably washed into the road stormwater collection network, which, in the vicinity of the Project will discharge into the Karapiro Stream and Waikato River. The proposed infiltration swale and wetlands will treat this runoff to remove pollutants, through bio-filtration and microbiological action. Biofiltration will occur as the runoff passes through the vegetation on the surface of the swale. Micro-biological treatment will occur as the stormwater percolates through the bioretention media below the surface of the swale.

The stormwater/water-related environmental effects created by construction and operation of the Cambridge Section of the Waikato Expressway can be successfully mitigated. The infiltration swales plus the wetlands represent best practices and will treat the stormwater runoff to remove pollutants. Erosion will be mitigated by storing and slowly releasing the runoff from new road.

1 Introduction

The Cambridge Section of the Waikato Expressway (the Project) will connect State Highway 1 (SH1) from the intersection with Hautapu Road on the northwest side of Cambridge to Tirau Road in the southeast. (See Figure 1) The predominantly greenfields Expressway will improve the capacity of SH1, and will help reduce congestion during holiday periods. Once construction has been completed, the Expressway will be an 11.6km long, four lane road with a 220m long bridge across the Karapiro Stream.

The stormwater design will:

- Limit the release of sediment during construction;
- Limit the discharge of road-derived pollutants to the Karapiro Stream, and to groundwater;
- Avoid or mitigate flooding, stream erosion, and the Expressway's effect on overland flow paths;
- Prevent the Expressway from becoming inundated during intense storms; and
- Minimise ongoing maintenance.

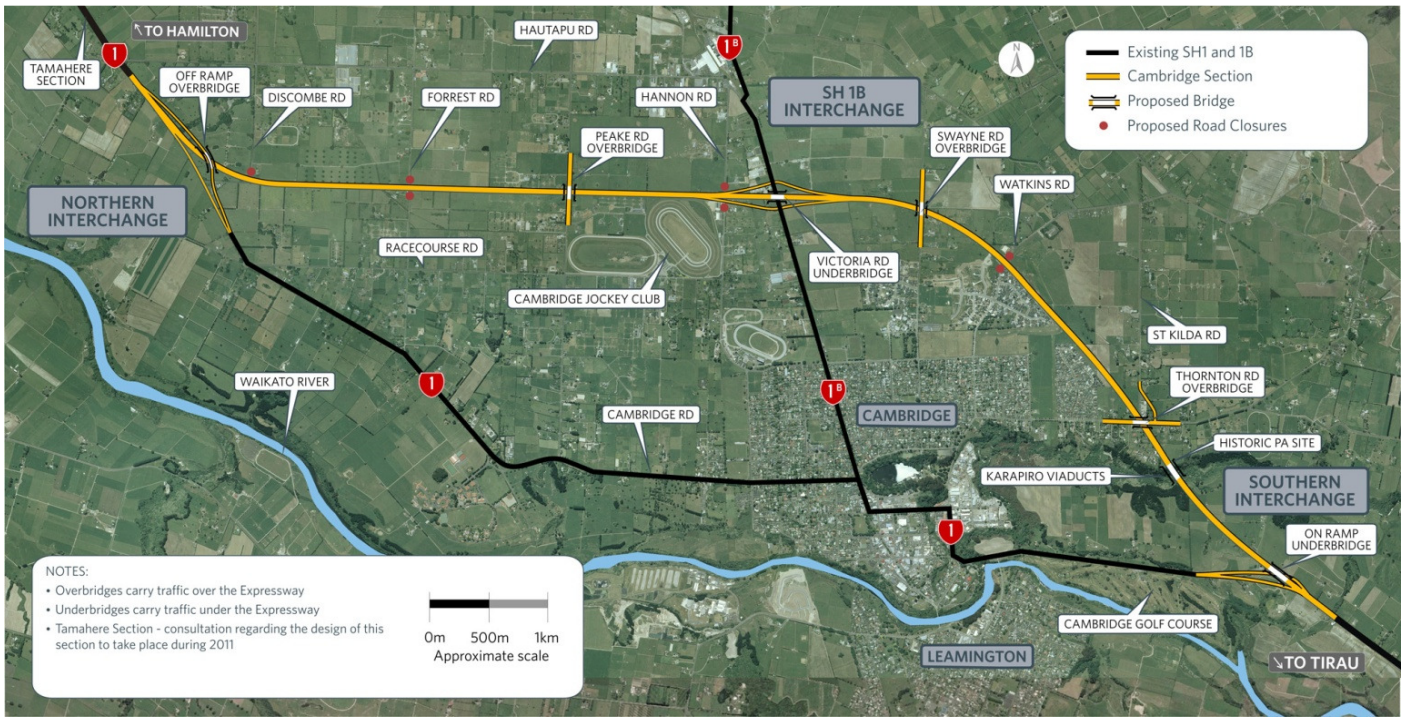

Figure 1: Locality Plan

Between the northern end of the Expressway and south of Swayne Road (Station 7200m), the topography is relatively flat, and there are very few waterways available for receiving runoff. Soakage in the area is relatively good, and has been selected for disposal of stormwater runoff.

South of Swayne Road (Station 7200m) the road runoff can be discharged to the Karapiro Stream. This section of the Expressway will be constructed in cut and geotechnical investigations indicate that portions of the route will be below the groundwater table. It is anticipated that the post construction groundwater table will find a new equilibrium. Road drainage will be designed and constructed to control any potential groundwater problems.

The Expressway crosses the Karapiro Stream Gully between Station 9800m and 10000m. The gully is approximately 200m wide and 40m deep.

Appendix 11 contains the Stormwater Management Overview Drawings for this Project.

1.1 Abbreviations Used in this Report

- *AEP* *Annual Exceedance Probability Storm*
- *ANZECC* *Australia and New Zealand Environment Conservation Council*
- *ARC* *Auckland Regional Council*
- *ARI* *Average Return Interval Storm*
- *EW* *Environment Waikato*
- *NZTA* *The New Zealand Transport Agency*
- *TP10* *Auckland Regional Council: Stormwater Management Devices Design Guidelines Manual*
- *TP108* *Guidelines for Stormwater Runoff Modelling in the Auckland Region*

2 Climate Change and Rainfall Intensity

Over the next 100 years global warming could increase the average temperature in New Zealand by 0.6°C – 5.6°C.This will change the country's weather patterns, and cause the east coast to become more arid, and the west coast more wet.

Increased temperatures will allow the atmosphere to hold more water. This will cause storms to become more intense, and will exacerbate flooding around the country.

2.1 Impact of Climate Change in the Waikato Region

In 2008 the Ministry for the Environment (MfE) released a publication called "*Climate Change Effects and Impact Assessment – A Guidance Manual for Local Government in New Zealand*" (2nd Edition, May 2008). This document was produced to provide guidance to regulatory bodies on how they should prepare for global warming. Environment Waikato requires new stormwater devices to take into consideration the predicted effects of global warming as outlined in the MfE 2008 report.

Table 1 below outlines the projected changes in mean temperature between 1990 and 2090 as outlined in the MfE guidance document.

Table 1: Projected climate changes in degree Celsius

	Lower limit	Average change	Upper limit
1990 – 2040	0.2°C	0.9°C	2.4°C
1990 - 2090	0.6°C	2.1°C	5.6°C

Table 2 outlines the adjustments to rainfall intensities recommended by the MfE for each 1˚C rise in temperature.

Table 2: Factors for use in deriving extreme rainfall information for screening assessments

Duration	2-year ARI	10-year ARI	100-year ARI
10 minutes	8.0%	8.0%	8.0%
30 minutes	7.2%	7.6%	8.0%
1 hour	6.7%	7.4%	8.0%
2 hours	6.2%	7.2%	8.0%
6 hours	5.3%	6.8%	8.0%
12 hours	4.8%	6.5%	8.0%
24 hours	4.3%	6.3%	8.0%
48 hours	3.8%	6.1%	8.0%

2.2 Existing Rainfall Intensity in Cambridge

Table 3 below outlines the current design rainfall intensities for Cambridge. These values have been taken from High Intensity Rain Design System (HIRDS Version 2), and do not take into consideration the effect of global warming.

Table 3: Current Cambridge rainfall intensities without global warming

Duration	2-year ARI	10-year ARI	100-year ARI
10 minutes	10 mm	14.4 mm	24.5 mm
30 minutes	16.6 mm	23.7 mm	40.2 mm
1 hour	22.8 mm	32.5 mm	54.9 mm
2 hours	28.8 mm	40.8 mm	68.3 mm
6 hours	41.6 mm	58.4 mm	96.6 mm
12 hours	52.5 mm	73.3 mm	120.2 mm
24 hours	66.2 mm	92 mm	149.6 mm
48 hours	77.7 mm	107.4 mm	173.2 mm

2.3 Impact of Climate Change on the Rainfall Intensity in Cambridge

New stormwater devices will be designed for the Project to accommodate the impacts of climate change. Environment Waikato has advised that the mid-point prediction of the worst case scenario in terms of global response to emissions be used for the design of stormwater devices for the Project. This equates to a predicted increase in temperature of 3°C by 2090.

The modified rainfall intensities for Cambridge are outlined in table 4 below.

Table 4: Cambridge Rainfall Intensities (2090) with global warming

Duration	2-year ARI	10-year ARI	100-year ARI
10 minutes	12.4 mm	17.9 mm	30.4 mm
30 minutes	20.2 mm	29.1 mm	49.8 mm
1 hour	27.4 mm	39.7 mm	68.1 mm
2 hours	34.2 mm	49.6 mm	84.7 mm
6 hours	50.1 mm	70.3 mm	119.8 mm
12 hours	62.7 mm	87.6 mm	149.0 mm
24 hours	78.7 mm	109.4 mm	185.5 mm
48 hours	91.9 mm	127.1 mm	214.8 mm

Note that the above rainfall intensities due to a predicted temperature rise of 3°C are approximately 24% higher than the current 2010 rainfall intensities for Cambridge.

3 Ground Conditions

3.1 Geology

The geology in Cambridge is predominantly Hinuera Formation. This is a volcanic soil that has been re-deposited by stream flows. It exhibits similar engineering properties to alluvium.

Geotechnical investigations indicate that the soils along the Project route are predominantly sands and silts. These soils have been re-deposited in thin layers that exhibit a variety of engineering properties. Typically the soils are highly permeable, but there are impervious lenses present that have formed perched water tables in some locations. The fact there are few waterways, normally dry, along the first 7km of road embankment indicates good soakage characteristics.

The regional groundwater level is controlled by the Karapiro Stream which is about 45m below existing ground along the Project alignment. At the northern end of the alignment, the groundwater level is about 5m below ground level and generally gets deeper toward the gully. At the southern end, the groundwater table is at least 25m deep.

There are numerous lenses of perched water along the alignment, some within a few meters of the surface. From the investigations carried out to date these lenses appear to be perched on layers of silt within the upper several meters of the soil profile. There also appears to be a downward seepage gradient in some areas.

3.2 Percolation Tests

Eight percolation tests were completed along the Project route. See **Appendix 1**. The following table presents the percolation rates that were recorded during these tests:

Table 5: Percolation Tests Results

Station (m)	Bore Number	Percolation Rate ($L/m^2/min$)	Percolation Rate (mm/hr)
900	N29	0.39	23.4
3150	P2	3.19	191.4
3150	P2a	0.96	57.6
7050	S7	3.49	209.4
8950	T21	1.04	62.4
10200	M26	3.61	216.6
10500	M27a	16.63	991.8
10550	M27b	2.36	141.6

The infiltration rates nominally range from 23mm/hr to 216.6mm/hr. The rates are within the values recommended in TP10 (3mm/hr-210mm/hr). The average rate of the road section

where infiltration swales are to be used is 120mm/hr or 2 litres/m^2/min. An infiltration rate of 0.5 litres/m^2/min has been used to design the Project infiltration swales. This infiltration rate has been reduced from the average rate to allow the system to cater for areas that are less permeable, potential clogging of the surface of the swales, and to account for anisotropic soil conditions.

3.3 Groundwater levels

Investigational boreholes have been drilled along the alignment and groundwater levels were recorded over the course of 2008. Two major storms occurred in July and August 2008. The groundwater levels recorded during these storms is a good indicator of the highest seasonal groundwater level. These values are outlined in the table below:

Table 6: Groundwater Level

Station (m)	Existing Ground Level (RL m)	Road Height Above Ground Level (m)	Groundwater Level (RL m)	Groundwater Depth Below Ground Level (m)	Groundwater Depth Below Road Height (m)
Discharge to Project infiltration swales					
950	57.8	2.2	49.3	8.5	10.7
2650	59.6	2.9	57.8	1.8	4.7
3920	62.1	1.7	54.9	7.2	8.9
4860	63.9	2.6	57.7	6.2	8.8
4980	64.2	2.8	57.7	6.5	9.3
5340	63.9	7.7	57.9	6.0	13.7
5400	64.3	7.8	57.9	6.4	14.2
5500	64.4	8.6	58.6	5.8	14.4
5620	65.3	8.2	57.9	7.3	15.5
6400	66.4	2.6	64.1	2.3	4.9
6620	67.9	0.3	63.6	4.3	4.6
6780	67.9	0.9	65.0	2.9	3.8
6800	67.9	1.1	62.7	5.2	6.3
Discharge to the Karapiro Stream					
7820	67.9	0.4	64.6	3.3	3.7
8160	68.4	-1.3 (in cut)	65.8	2.6	1.3
8340	70.8	-4.4 (in cut)	56.5	14.3	9.9
8560	70.2	-4.2 (in cut)	66.5	3.8	-0.5*
8820	69.7	-5.0 (in cut)	67.6	2.1	-2.9*
9040	70.2	-6.0 (in cut)	68.8	1.4	-4.6*
9060	70.2	-6.1 (in cut)	68.5	1.7	-4.4*
9720	70.9	-5.0 (in cut)	68.7	2.3	-2.8*
10200	70.7	-2.6 (in cut)	66.7	4.0	1.4
10240	70.6	-2.2 (in cut)	65.8	4.9	2.6
10320	70.8	-1.5 (in cut)	67.3	3.5	2.0
10440	70.7	-0.5 (in cut)	66.8	3.9	3.4
10760	72.0	0.5	67.0	5.0	5.5
10980	73.3	0.3	70.3	3.0	3.3

NOTE: *Groundwater levels above road level.

See **Appendix 2** for a graph showing measured groundwater levels in relation to the existing ground level and Expressway design level. Also shown is a plot of the infiltration

swale invert levels that will be constructed along the section of road (i.e. Station 0m to 7200m) for stormwater mitigation.

To help prevent the pollutants from being discharged to groundwater, the base of the infiltration swales will be above the groundwater table. TP10 guidelines suggest that there is at least 1m separating the base of the infiltration system and the groundwater level as illustrated on the plot. Infiltration swales assist in removing pollutants from the runoff. However, a majority of pollutants are removed in the unsaturated zone above the groundwater table. Except for a short section of swale near Station 2650m the TP10 guideline is met. This is not viewed as a significant variance of the guidelines. If runoff is discharged below the groundwater table, less pollutants will be removed, and it could exacerbate groundwater contamination.

If the road runoff is pre-treated by, for example, grass swales prior to being discharged to ground, (which it will be) it is possible to use infiltration in areas where there is less than 1m separating the water table from the base of the infiltration system.

Groundwater conditions are also highly variable through the cut section of the road. Regional groundwater levels in the areas of the major cuts are controlled by the depth of the Karapiro Stream, about 40m below ground level. However, there are perched water tables at various levels as well. It is anticipated that groundwater from perched water tables will be encountered while constructing the cut section of the road between Stations 8500 and 9800m and at the on-ramp underpass near Station 10,850m. Groundwater may also be encountered at the wetland ponds. Pre-draining of road cut slopes using horizontal drains and ditches prior to final finishing of the cut surface is recommended to address this issue.

4 Resource Consents and Engineering Approvals

4.1 Environment Waikato Resource Consents

The following resource consents are required from Environment Waikato for the construction and operation of the Expressway:

- ***Stormwater Discharges***

    1. To discharge stormwater to ground using infiltration swales located on each side of the Expressway between Stations 0m to 7200m.

    2. To discharge to the Karapiro Stream, in the vicinity of the new bridge, stormwater collected between Stations 7200m to 10200m. Stormwater will be treated by passing through the northern wetland.

    3. To discharge to the Karapiro Stream, in the vicinity of the new bridge, stormwater collected between Stations 10200m and 10900m. Stormwater will be treated by passing through the southern wetland.

    4. To discharge stormwater to an unnamed gully of the Waikato River collected from the on-ramp and off-ramp of the southern interchange, and from between Stations 10900m and 11600m of the Expressway. Stormwater will be treated by passing through the two wetlands located at the bottom of the ramps.

- ***Bridges***

    1. To construct a permanent bridge approximately 220m long and 40m high spanning the Karapiro Stream.

    2. To construct a temporary crossing over the Karapiro Stream in order to construct the permanent bridge.

- ***Culverts***

    1. To construct three culverts on ephemeral waterways through the Expressway embankment at approximate Stations 2400m, 7510m and 7640m.

    2. To construct up to 60 culverts at low points within swales to pass overland flows through the Expressway embankment between Stations 0m to 7200m.

- ***Earthworks***

    1. To construct the Cambridge Section of the Waikato Expressway approximately 11600m long and 60m wide as on the preliminary design drawings.

- ***Water Takes***

    1. To take up to 500m^3 per day from the Waikato River, at the Cambridge jetty, for dust suppression and fill compaction during the construction of the Expressway.

    2. To take groundwater from perched water tables during road construction in cut sections where the finished road levels are below observed groundwater levels between Stations 8500m to 9800m, the on-ramp underpass near Station 10900m and at wetland ponds.

Specific details for each consent are in the Opus document *Waikato-Expressway-Cambridge Section, Resource Consent Applications.*

4.2 Waipa District Council Engineering Approvals

Drainage systems west of Victoria Rd are generally administered by Waipa District Council, while southeast of Thornton Road, stormwater management is dominated by the large, deep gully of the Karapiro Stream. Engineering approval from the Waipa District Council will be required for alterations to the Council's drainage assets.

4.3 Waikato District Council Engineering Approvals

The Pukeroro Drainage District east of Forrest Road is administered by Waipa District Council. A major culvert will need to be constructed beneath the road embankment to pass stormwater flows. Engineering approval from the Waikato District Council will be required for alterations to the Council's drainage assets.

4.4 Environment Waikato Engineering Approvals

The Project passes through the Mangaone Stream Drainage District, set up and formerly controlled by the Hautapu Drainage Board, but now administered by Environment Waikato. Alterations to drains in this area will require the approval of Environment Waikato.

5 Design Criteria

The design of the stormwater devices and conveyance network will need to meet the New Zealand Transport Agency, Waipa District Council, Standards New Zealand, and Environment Waikato criteria. Relevant documents are listed below.

5.1 Environment Waikato

To help guide the design of long-term mitigation measures for the Project the following documents were used:

- Auckland Regional Council's TP10: Stormwater Management Devices; Design Guidelines Manual
- Auckland Regional Council's TP108: Guidelines for Stormwater Runoff Modelling in the Auckland Region
- EW: Erosion and Sediment Control Guidelines for Soil Disturbing Activities

These documents are typically used as the basis of design of stormwater mitigation measures.

5.2 The New Zealand Transport Agency

- Transit New Zealand Bridge Manual for the design of culverts
- Transit New Zealand F/3:2000 "Specification for Pipe Culvert Construction"
- NZTA Stormwater Treatment Standard for State Highway Infrastructure

5.3 Waipa District Council

- Hamilton City Council Development Manual

5.4 Standards New Zealand

The collection and conveyance system will be designed in accordance with:

AS/NZS 3725:2007; Design for installation of buried concrete pipes.

6 Mitigation of Environmental Effects

Environmental effects associated with road construction can generally be divided into short-term effects that occur during construction of the road and long-term effects that occur during the operation and maintenance of the road.

6.1 Short-Term Stormwater Effects

Short-term adverse effects that may be related to construction of the Project are:

- Erosion and sedimentation;
- Dust; and
- Dewatering of perched water tables during construction of the road section in cut.

Erosion and sedimentation

Short-term effects relating to stormwater are likely to arise during construction of the Project as a result of earth-works activities. Stormwater flowing over the Project site could mobilise sediment, and carry it off-site into neighbouring streams. This sediment-laden runoff would reduce stream water quality, and, as it settles out, could smother the base of the stream and adversely affect aquatic life.

For the Project, such effects will be avoided or mitigated by implementing erosion and sediment control practices that are consistent with the *Erosion and Sediment Control Guidelines for Soil Disturbing Activities* (Environment Waikato 2009). Opus has prepared an Erosion and Sediment Control Plan (See **Appendix 12**).

Dust

Various measures will be implemented to minimise the generation of dust from the Project. These measures are discussed within the Erosion and Sediment Control Plan and will be updated by the construction contractor and approved by the relevant authorities as part of the overall Construction Environmental Management Plan.

Dewatering of perched water tables

As shown in **Appendix 2** the measured groundwater level between Stations 8500 to 9800m are above the finished road level. It is anticipated that during the construction of this cut section the perched water tables will be dewatered. Pre-draining of road cut slopes using horizontal drains is a construction option. The on-ramp underpass near Station 10900m and the wetland ponds may also dewater perched water tables.

An information search for existing bores in the vicinity of the cut sections was provided by EW (See **Appendix 3** for bore detail). Existing bores near the ramp underpass (72-484 and 72-1661) are all deeper then 60m and are taking water from the regional groundwater system and not from the top perched water tables. Thus, the bores should not be affected by the road cuttings.

The bore closest to the deepest cut section (#70-1090) is approximately 600m away and is deeper than 70m. It will be taking water from the regional groundwater system and not from the top perched water tables. Thus the bore should not be affected by the road cuttings.

Most of the other bores shown are deep bores and should not be affected by the Project. There are some shallow bores (#70-467, #70-31 and #72-1053) 6 to 8m deep, with the closest approximately 600m away. However, the cut section of finished road level is above the observed groundwater and should not affect these shallow wells.

At one point, the upper end of the Mangaone Stream runs within 100m of a section in cut. However the cut section of finished road level is above the observed groundwater. Flows in this section of the stream are normally minimal, and it is understood that, when the approved St Kilda subdivision is constructed, the Mangaone Stream will be diverted further away for the road. The Project's effects on the stream are considered minor, if not negligible.

6.2 Long-Term Stormwater Effects

Operation of the completed Expressway could have long-term adverse environmental effects. These effects will be mitigated by implementing practices that are consistent with those outlined in the Auckland Regional Council's Technical Publication TP10 *Stormwater Management Devices Design Guidelines Manual.*

Potential long-term adverse effects related to the operation of the Expressway and measures to mitigate them are as follows:

- **Pollution**
  Runoff from pavement will be treated by infiltration swales and wetlands to remove pollutants.

- **Stream erosion**
  Extended detention will be provided for stormwater runoff from road pavement in order to minimise the discharge from the site and the potential for scouring material from stream beds.

- **Flooding**
  In situations where a downstream flood problem may exist, the additional stormwater runoff created by the road will be detained and slowly released for up to the 100 year ARI storm.

TP10 proposes three stormwater management objectives (with the applicable Waikato-based interpretation in brackets):

- Water quality (first flush volume based on 25mm depth of rain detained and treated),
- Extended detention (34.5mm depth of rain detained and released over 24 hours); and
- Flood control by matching the pre- and post-development peak flow rates (for the 10 year/24 hour event including climate change i.e. 109.4 mm).

Through consultation with EW staff it was agreed that the TP10 flood control objective was not required for the Project, as discharge from the Expressway will be to the Waikato River via a short section of the Karapiro Stream, and any increase in the post development peak flow rate from the site represents no risk to downstream assets. The remaining two stormwater management objectives were the design criteria for the four wetlands.

As stated in section 7.1, based on the post-development minus pre-development conditions of the Expressway corridor, between Stations 0m to 7200m, stormwater runoff will be discharged into continuous grassed swales constructed on each side of the Expressway. The swales will mitigate flooding by infiltrating extra runoff caused by building the Expressway. Depending on elevations, check dams will be constructed within the swales to trap water for infiltration. The check dams will be designed to allow water to flow to the adjacent swale cell. Also, the swales on each side of the Expressway will be interconnected by culverts at low points to accommodate potential overland flows. This system will help spread the risk of encountering low permeability soils or high perched water tables.

Wetlands are proposed on either side of the Karapiro Stream Bridge at approximately Stations 9100m and 10200m and two at the Tirau Road connection on-ramps and off-ramps. (See sections 7.2, 7.4 and 7.5 of this report.) These devices will treat and attenuate stormwater runoff in accordance with Environment Waikato guidelines. Overflow pipelines from each wetland will be designed for the 100 year event. Each outfall will be designed for erosion protection including energy dissipation to prevent localised scour in the gully.

6.3 Pollution

Contaminants in road stormwater runoff include sediment, heavy metals, hydrocarbons, and gross pollutants. Heavy metals present in road stormwater runoff include lead, copper and zinc.

Sedimentation is the most common pollutant removal mechanism because many pollutants tend to be associated with fine particulate material and/or organic matter (Pitt et al., 1995).

Treatment by infiltration through the soil to groundwater will occur between Stations 0m to 7200m of the Project. Biofiltration will also occur as the runoff passes through the vegetation on the surface of the swale. The bottom of the swales will be at least 1m above the groundwater table.

Runoff from Stations 7200m to 10900m will eventually discharge to the Karapiro Stream which has a “fishery class” management classification defined in the Waikato Regional Plan. Constructed wetlands will help remove suspended solids, heavy metals and hydrocarbons from road runoff and are designed to treat the Water Quality Storm defined in TP10. The water quality component of the runoff from the 200m section of the road between Stations 10000m and 10200m will be conveyed to the northern wetland for treatment, with the balance discharged to the Karapiro Stream through the southern wetland outfall. The southern wetland has been sized to compensate for this runoff balance.

6.4 Flood Attenuation and Stream Erosion Mitigation

The creation of road pavement can cause stormwater to be concentrated and discharged at a faster rate, and in greater volumes than from greenfield conditions. This can result in flooding and increased erosion rates within streams.

Stream erosion is mitigated by retaining and slowly-releasing flow from extended detention/infiltration design storm, which is a storm that is representative of more frequent storms.

Flood attenuation controls the peak discharge rates from the less frequent, extremely intense storms. It ensures that the peak discharge rates following construction of the Expressway do not exceed the predevelopment rates. Flood attenuation is only appropriate when there is a real or potential downstream flood risk which is not the case for this Project.

The infiltration swales between Stations 0m to 7200m have been sized to infiltrate pavement runoff for up to the 100 year ARI event. The swales will be connected both longitudinally and across the alignment. The swales will be partitioned approximately every 100m, depending on swale grades, with low earth bunds (check dams) to allow water to pond until it soaks away into the ground. The bunds will be constructed so that flow may occur between adjacent swale cells.

Runoff from Stations 7200m to 10900m will eventually be discharged to the Karapiro Stream, after first being routed through constructed wetlands for extended detention. The overflow pipelines, one from each wetland, have been designed for the 100 year ARI event. Discharge outfalls constructed in the Karapiro Stream gully will be designed to dissipate energy to avoid or minimise erosion. (See **Appendix 13** for typical stormwater outlet drawings).

Runoff from the southern interchange area (i.e. Stations 10900m to 11600m including the on- and off-ramps) will eventually be discharged to an unnamed gully of the Waikato River after first being routed through two constructed wetlands for extended detention. The overflow pipelines have been design for the 100 year ARI event. Discharges to the unnamed gully will be conveyed by the drainage systems that currently service this section of existing SH1.

7 Stormwater Management Philosophy

There are limited opportunities to dispose of runoff at the northern end of the Expressway. There are no major watercourses in this section (Station 0m to 7200m), and the watercourses that cross the route are predominantly shallow artificial drains that are dry most of the year. Geotechnical testing indicates that runoff from the more frequent storms can be discharged to ground using an infiltration swale. These devices will mitigate flooding, stream erosion and will treat the stormwater runoff. In this section of the route, the Expressway will be constructed on a low-height fill embankment to allow overland flows to discharge to culverts constructed beneath the Expressway. A typical crossing section showing this arrangement is in **Appendix 4**.

The Expressway will mainly be constructed in cut between Watkins Road, and the Tirau Road interchange (Station 8000m to 10500m). This will allow stormwater runoff to be discharged to the Karapiro Stream, after it has been detained and treated by the wetlands. Infiltration will not be feasible in this section as the road will be constructed in cuts up to 8m deep. The geotechnical investigation indicates the existing groundwater table will be above the road level for large portions of this section of the Expressway.

Wetlands will be used to treat and attenuate stormwater runoff between Watkins Road and Tirau Road. Wetlands are proposed on either side of the Karapiro Stream Bridge at approximately Stations 9100m and 10200m. These devices will treat and attenuate stormwater runoff. EW has confirmed that flood attenuation will not be required for discharge to the Karapiro Stream. (See **Appendix 8**) The Karapiro Stream discharges to the Waikato River approximately 2.5 km downstream from the discharge points near the proposed Karapiro Bridge site.

The Waikato River is controlled by the flood control gates at the outlet from Lake Taupo and the hydro dams along its length. Consequently, flood mitigation is not required for discharges to the Waikato River. Flood attenuation is not required for the stream reach between the discharge points from the Expressway and the Waikato River as the stream runs through a deep gully area that does not contain any buildings or other structures that could be affected.

Figure 2 shows the proposed stormwater management strategy.

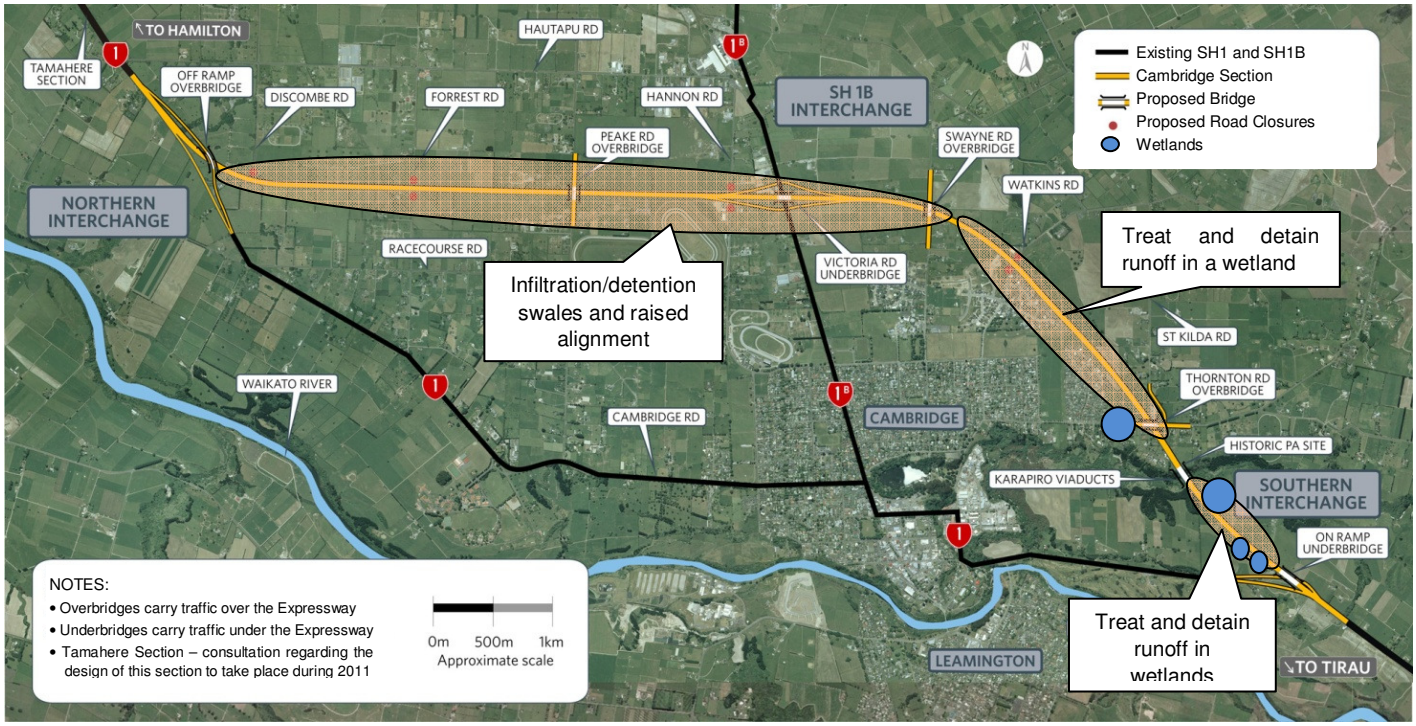

Figure 2: Stormwater Management Strategy

7.1 Station 0m to 7200m

Northwest of Watkins Road the Expressway crosses flat agricultural land, and there are few waterways in the area that are capable of receiving stormwater runoff from the Expressway. The geotechnical investigations indicate that the groundwater depth ranges between 1m at Station 2660m to 9.2m at Station 940m. (See Table 6). The fact there are few waterways, normally dry, in this area indicates good soakage characteristics along this section of proposed road.

There are large areas of land that currently drain across the proposed Expressway route. The NZTA does not typically allow runoff to flow across State Highways as this would be a safety hazard, and it can cause the road pavement to fail. Also, at dip points in the road, ponding could occur during intense storms in areas where there are no natural outfalls. Culverts will be installed at low points within the swales to accommodate overland flows and thereby avoid these potential adverse effects. A typical crossing section showing this arrangement is in **Appendix 4**.

Infiltration Swales and Raised Alignment

Along this section of the Expressway, the road level will be raised above the surrounding countryside so it is above the flood ponding level and to allow culverts to be installed beneath the Expressway to connect swales that will be constructed on each side of the road. Culverts will be provided at existing watercourses and will be located to connect swales in low areas where overland flow would otherwise occur during extreme rainfall events.

Infiltration swales will help reduce the volume of runoff flowing off the Expressway site and will mitigate downstream flooding and streambed erosion (i.e. maintain hydraulic neutrality). The swales have been designed to infiltrate and mitigate the post-development minus pre-development road runoff for up to the 100 year ARI event. **Appendix 4** contains the infiltration swale calculations.

Infiltration will also remove pollutants suspended in road runoff. The infiltration swales will pre-treat road runoff prior to it being discharged to ground through bio-filtration. This will occur as the runoff flows through grass growing at the base of the swale.

To prevent groundwater contamination, EW requires at least 1m separation between the base of the infiltration swales and the ground water table. A majority of the physical and biological processes that remove pollutants occur in the unsaturated (aerobic) zone above the watertable. In areas where there is less than 1m of unsaturated soils beneath the swale, the runoff will be pre-treated prior to discharge.

The reduced levels diagram in **Appendix 2** shows the existing groundwater levels in relation to the existing ground levels, the design road elevations and the bottom of the infiltration swales along the Expressway route. The 1m clearance between the bottom of the swale and the groundwater level is generally achieved, except near Station 2660m near Forrest Road where elevated ground water tables were encountered. A drainage channel exists near this area which may explain the high water table. Further investigation will be carried out during detailed design to identify whether this evaluation was due to the presence of a perched groundwater table, or was generally indicative of the area's groundwater level. If further testing indicates that the area-wide groundwater table is elevated, the stormwater from this section will be conveyed to the existing drainage channel or to other sections of the swale with better infiltration properties, or alternatively will be mitigated by detention swales or another approved mitigation strategy.

The infiltration swale will be constructed at the toe of the road embankment to maximise infiltration rates. During the more frequent water quality storms, limited volumes of runoff will drain into the swales, but they will probably be inundated during the more intense events. During these storms, runoff will continue to be discharged to ground, and consequently will continue to mitigate flooding. Swales have been designed to infiltrate and detain up to the 100 year post-less-pre development runoff from the carriageway (i.e. hydraulic neutrality for up to the 100 year ARI event). A typical cross section is shown in Figure 3 below.

The swale type solution helps limit the risk of the stormwater management strategy being compromised if an area of less-pervious soils, or perched water tables is encountered. If these areas are encountered, the runoff will overflow into the next section of the infiltration swale downstream. If larger areas of impervious soils are encountered, alternative mitigation mechanisms such as detention swales could be adopted. During intense storms, the excess flow that cannot be discharged to ground will be retained within the swale or conveyed to the appropriate culvert outlet or overland flow path adjacent to the designation.

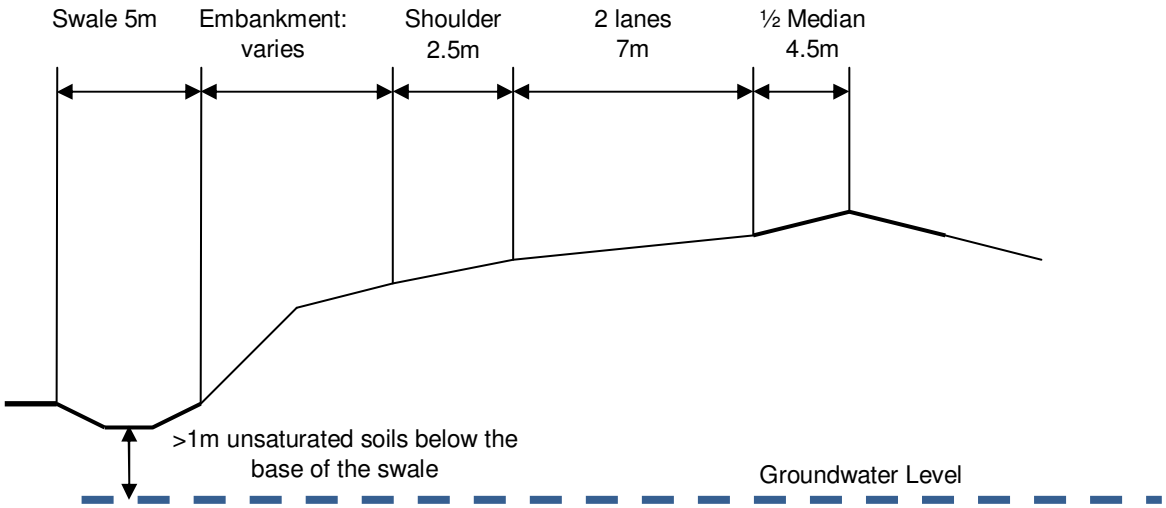

Figure 3: Typical Infiltration Swale Section: Station 0m to 7200m

7.2 Station 7200m to 9100m

From Station 7200m, between Swayne and Watkins Roads, the Expressway will be graded towards the Karapiro Stream to a low point near Station 9100m, which is the entrance to the northern wetland. This grading will allow stormwater runoff to be discharged to the stream, after it has been detained and treated by the wetland located near Station 9100m.

The topography is relatively flat in this area and the land beneath the footprint of the road is mainly pasture. Residential subdivisions have been developed on the south-western side of the alignment. Two major culverts will be installed under the road embankment near Watkins Road where the road is in fill to allow drainage from the residential developments. Opus has been consulting with Waipa District Council staff and Tonkin &Taylor regarding these culverts and Council will confirm the final size that is required for the culverts.

Between Station 7900m to 9800m the Expressway will be constructed below existing ground level in a cut up to 8m deep. A typical cross section is shown in Figure 4 below. Geotechnical testing indicates that the groundwater level fluctuates, but large proportions of the route will be below the groundwater table. This will prevent the use of infiltration in this section. However, road inundation is a lesser concern in this section of the Expressway as stormwater runoff from intense storms can be discharged to the Karapiro Stream.

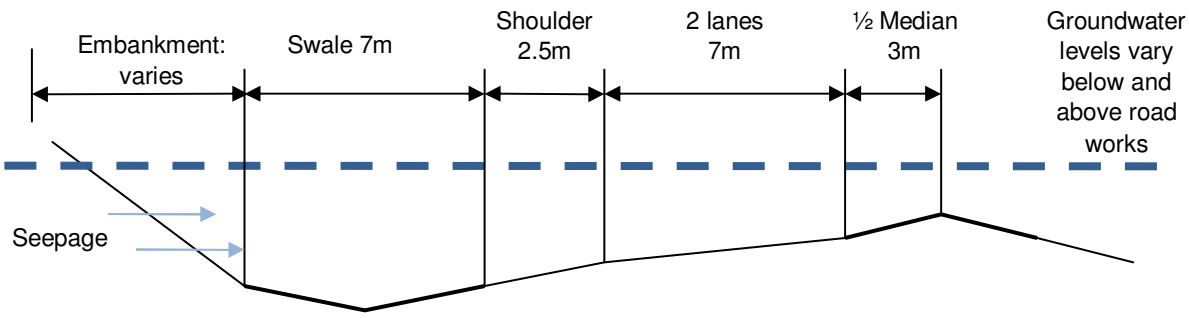

Figure 4: Typical Cut Section: Station 7900m to 10600m

Conveyance swale and wetland

For this section of the Expressway conveyance swales will be formed on either side of the road. These swales will convey the runoff that collects in the cutting to a constructed wetland near Thornton Road at Station 9100m. The conveyance swales have been designed for the 100 year event. The volume of the wetland, considering water quality and extended detention, has been sized at approximately 3030m^3. (See **Appendix 5** for conveyance and wetland calculations).

The final shape and planting of the wetland will be determined by its safe operation and maintenance, landscaping requirements and in consultation with the local community.

Overflow and bypass from the wetland will be piped to the floor of the Karapiro Stream gully to safely discharge runoff from the Expressway for up to the 100 year ARI event. To prevent erosion at the outlet of this discharge point, appropriate energy dissipation will be provided. (See **Appendix 13** for typical stormwater outlet drawings.) Trenchless methods to install the overflow pipeline will probably be the most practical in this situation. Erosion protection will be installed downstream from this outlet to prevent localised scour (See **Appendix 6** for diagram of stormwater system).

7.3 Station 9100m to 10000m

This section of the Expressway will be built near Thornton Road at Station 9100m to the southern abutment of the Karapiro Stream Bridge at Station 10000. The Karapiro Stream gully dominates the topography of this section. This gully is in the order of 40m deep, and some 220m wide. The topography north of the Karapiro Stream gully is relatively flat, and the land use is a combination of residential and pastural land.

The road will be constructed below ground level in a cut up to 8m deep. A bridge will be built to cross the Karapiro Stream gully. This bridge will be approximately 220m long and up to 40m high. The road will be graded towards the northern wetland inlet at Station 9100m. Runoff from the bridge and this section of road (Station 9100m to 10000m) will be collected by kerb and channel and piped to the wetland at Station 9100m. Swales are not appropriate for this section due to the proximity to the Karapiro gully plus potential piping and limited road designation width. Stormwater runoff will be discharged to the Karapiro Stream once it has been detained and treated in the wetland (See **Appendix 6** for diagram of stormwater system).

Infiltration in this section is not practical as a large proportion of the alignment is below the groundwater table and there is a risk of piping failure close to the Karapiro Stream gully. The geology in the area is predominately alluvial, and contains a lot of sandy soils. Steep hydraulic grades could form near the Karapiro Stream, and this may cause piping in the sandy soils.

A Pa site and burial ground has been identified on the northeast side of the Expressway near the Karapiro Stream. The NZTA is therefore keen to avoid this site. A wide swale is not desirable in this location because it would mean that a very high retaining wall would be needed to support the archaeological sites. To overcome this pinch-point, a kerb and channel system will be used from Station 9100 (the wetland) to the south abutment of the proposed Karapiro Stream Bridge.

7.4 Station 10000m to 11600m

This section of the Expressway will be built between the southern abutment of the Karapiro Stream Bridge (Station 10000m) and Tirau Road (Station 11600m).

The topography in this section of the Expressway slopes gently north towards the Karapiro Stream, but is interrupted by a 5m deep gully at Station 10500m, and the Karapiro Stream Gully at Station 10000m. The land use in this area is predominantly pastural.

Between Station 10000m and 10600m the Expressway will be constructed in a cut up to 3m deep. A fill embankment will be built to support the road at Station 10500m. Between Station 10600m and 11600m the road will be built at grade, but an underpass will be required near Station 10900m.

For this section of the Expressway conveyance swales will be formed on either side of the road. The conveyance swales have been designed for the 100 year ARI event. These swales will convey the runoff to three constructed wetlands. (See **Appendix 5** for conveyance and wetland calculations). One located at Station 10200m will treat and attenuate runoff between Stations 10200m to 10900m. The other two are located where the on-ramp and off-ramp connect to the existing SH1, will treat and attenuate runoff between Station 10900m to 11600m. (See Sheet 67 from the document Waikato Expressway-Cambridge Section: Drawings)

The wetland located at Station 10200m will be over-sized to provide compensatory detention for the Expressway between the southern abutment of the Karapiro Bridge (Station 10000m) and Station 10200m. The volume of the wetland, considering water quality and extended detention, has been sized at approximately 910m^3. The final shape and planting of the wetland will be determined by its safe operation and maintenance and landscaping requirements.

The water quality runoff component from the road between the southern bridge abutment (Station 10000m) and southern wetland (Station 10200m) will be conveyed over the bridge for treatment in the northern wetland. Kerb, channel and piping will be used to collect and convey this runoff over the bridge. The balance of the stormwater will be discharged to the Karapiro Stream through suitable outfall structure incorporating erosion protection. To compensate for this, the southern wetland will be designed to hold extra volume equal to the extended detention component. (See **Appendix 6** for diagram of stormwater system)

The wetlands treating and attenuating runoff between Stations 10900m to 11600m are described in Section 7.5 below.

Similar to the previous section, bypass and overflow from the wetland will be piped to the floor of the Karapiro Stream gully to safely discharge runoff from the Expressway for up to the 100 year ARI event. To prevent erosion at the outlet of this discharge point, appropriate energy dissipation will be provided. (See **Appendix 13** for typical stormwater outlet drawings.) Trenchless methods to install the overflow pipeline will probably be the most practical in this situation. Erosion protection will be installed downstream from this outlet to prevent localised scour.

7.5 The Southern Interchange

The southbound on-ramp and a local access road underpass will cross beneath the Expressway at Station 10900m. Also, a northbound ramp exiting SH1 to Cambridge is to be constructed. Adjacent to each ramp will be an access road to neighbouring properties.

The underpass on-ramp and local access road will need to be at least 5m below the level of the Expressway to allow traffic to pass beneath the Expressway. Due to this level difference it will be difficult to convey the stormwater runoff that collects on the ramps adjoining the underpass to the swales leading to the southern wetland at Station 10200m. Two wetlands are to be constructed between Tirau Road and the ramp intersections. Runoff from the ramps will be collected and conveyed by swales to the wetlands. These wetlands will also treat and attenuate runoff generated between Stations 10900m to 11600m of the Expressway. The wetland servicing the southbound on-ramp is sized at 1100m^3 and the northbound off-ramp wetland is sized at 1000m^3 (See **Appendix 7** for diagram of stormwater system at the Southern Interchange). The final shape and planting of the wetlands will be determined by safe operation, maintenance and landscaping requirements.

Stormwater overflow and bypass from the two wetlands will be conveyed to the floor of an unnamed gully stream of the Waikato River (Karapiro dam tailrace) by the drainage systems that currently service this section of existing SH1. Erosion protection will be installed downstream from this outlet to prevent localised scour.

8 Road Culverts and Overland Flows

8.1 Road Culverts

Road culverts will be needed at three locations where existing farm drains (one) and residential development runoff channels (two) cross the Expressway alignment. Table 7 below shows culverts required for existing watercourses that will cross the Expressway between the northern end of the route and Station 7700m:

Table 7: Culverts (See **Appendix 10** for design details)

Approximate Station	Description	Approximate Culvert Size
2400m	Existing farm drain (normally dry), servicing very flat agricultural land Approximate catchment of 1.8km^2; Q_{100}= 1.8m^3/s:	1.8m diameter 45m in length
7525m	Existing swale servicing residential development at Watkins Rd. (normally dry) Design criteria used: Q_{100}=4.56m^3/sec with a peak water level at 66.88mRL (Note that Q_{100} has been adjusted to account for climate change)	Twin box culvert 2.5m wide X 1m high 45m in length
7650m	Existing farm drain servicing residential development near Watkins Rd. (normally dry) Design criteria used: Q_{100}=1.12m^3/sec with a peak water level at 65.78mRL (Note that Q_{100} has been adjusted to account for climate change)	1.5m diameter 45m in length

It is anticipated that the above culverts will be constructed in their existing channels, which are normally dry. Diversion channels will be installed so if there is a rainfall event, any stormwater flow will safely bypass each culvert. Standard erosion and sedimentation controls will be implemented during culvert construction as outlined in the Erosion and Sedimentation Control Plan.

8.2 Overland Flows

To accommodate overland flows, it is proposed to install culverts generally at low points along the Expressway connecting swales on each side of the road between Stations 0m to 7200m. A typical crossing section showing this arrangement is in **Appendix 4**.

As shown in the Stormwater Management Plans (sheets 1 to 6 in **Appendix 11**), up to 60 culverts (450mm to 600mm in diameter) may be required. Due to the very flat nature of the ground, it was impractical to determine individual culvert catchments using LIDAR contour plans. However, Racecourse Road generally acts as the back boundary for most culverts. With the average spacing of the culverts at approximately 120m and the Racecourse Road boundary approximately 650m away, the average culvert catchment is 7.8ha. Overland flows for Q_{50} events have been calculated for 5ha, 7.8ha and 10ha catchments along with designs for 450 and 600mm diameter culverts. (See **Appendix 10** for design details). At the design stage of the Project, the successful contractor will determine the number, location and size of the culverts.

It is likely that the overland flow culverts will be installed by excavating once the base of the embankment has been established. No diversion will be required and the work will lie within the embankment boundaries set out in the Erosion and Sedimentation Control Plan. (See **Appendix 12**)

Between Stations 7900m and 10600m the Expressway will be constructed in cut. It is not practical to convey overland flows and existing watercourses across the Expressway cut and, consequently, any intercepted runoff from outside the designation will need to be discharged to the Expressway drainage network.

Between Station 10600m and the Project's southern end the Expressway, the road is in fill. The alignment is more or less on a ridge and overland flows will not be a problem.

Additional culverts may be required to convey small drains or overland flow paths that are not apparent on the contour plans.

9 Karapiro Stream Crossings

9.1 Hydrology

The Karapiro Stream catchment area extends approximately 80km^2 above the proposed Expressway crossing. The stream discharges into the Waikato River approximately 2.5km downstream of the crossing. Land use within the catchment is mainly pastoral farming with pockets of native forest, pine plantings and scrub in the gullies.

There is no gauging station on the Karapiro Stream. EW has provided all of the flow gaugings it has on record and these may be found in **Appendix 8**. Fourteen flow gaugings were made at Hickey Road Bridge during the summer months. The average flow was 0.35m^3/sec with a high flow of 0.75m^3/sec. By proportioning gauged flows by catchment areas (80km^2 at crossing to 64km^2 at Hickey Rd Bridge) and based on the data available, likely summer flows at the Expressway crossing are an average of 0.44m^3/sec and a high of 0.94m^3/sec.

Using the TP108 worksheet (that was used to calculate wetland sizes) the following estimated stream discharges at different periods were calculated, based on the rainfall figures from Section 2 of this report:

Return Period ARI (yrs)	Discharge (m^3/sec)
2	21.2
10	44.2
100	95.4

By plotting the above figures on semi-log paper, an annual discharge of 5m^3/sec was determined.

9.2 Expressway Bridge

The proposed Expressway bridge crossing the Karapiro Stream gully is at least 220m long and 38m above stream bed level. Four sets of bridge piers will be located in the gully but not within the normal stream channel. A plan and elevation of the proposed bridge is attached in **Appendix 9**. The final bridge design will be completed by the successful design-build contractor awarded the contract of this section of the Waikato Expressway.

Normal flows of the Karapiro Stream will not be affected by the bridge piers. Due to the height of the bridge, flood flows will not be affected either. Some flood flows will surround the two middle sets of bridge piers but this would not be a detriment to flood flows as there are no major assets immediately upstream of the bridge. Appropriate erosion and sedimentation controls will be implemented as outlined in the Erosion and Sedimentation Control Plan (See **Appendix 12**).

Runoff from the bridge surface will be conveyed, treated and detained for extended detention in the northern wetland.

9.3 Temporary Stream Crossing

To construct the Expressway bridge, access to the base of the gully will be provided by a purpose built track located on the south side of the gully. The specific location of the access track is detailed in the Stormwater Management Overview Drawings (See **Appendix 11**). This track will provide access to the south side of the Karapiro Stream.

Once access to the base of the gully is provided, appropriate erosion and sediment control will be established to protect the Karapiro Stream during the construction of the bridge. These erosion and sediment controls are stated in the Erosion and Sediment Control Plan (See **Appendix 12**).

Access from the northern side of the gully cannot be provided because of the potential effects on the adjacent pa site and potential urupa. Thus, access to the northern side of Karapiro Stream will need to be established by a temporary stream crossing.

A temporary ford constructed using reno rock mattress to line the stream channel and bank accesses is the preferred method of stream access, because:

- It does not prevent stream flow during operation or cause backing-up during flood events
- It does not inhibit fish passage during operation or post construction
- It is more compatible with a temporary installation and consistent with the existing stream bed.

However, if a ford structure is not permitted by EW, then a temporary bridge or culvert crossing is proposed. The main stream channel is near the northern bank as shown on the bridge drawing (See **Appendix 9**). It is proposed to construct the stream crossing at this location providing enough waterway area to pass the annual flood flow estimated at $5m^3$/sec. Discharges greater than $5m^3$/sec would flow around the temporary crossing. During times of flood flows the temporary crossing would not be used. Erosion and sedimentation measures will be implemented as set out in the Erosion and Sedimentation Control Plan (See **Appendix 12**). The final design of the temporary crossing will be completed by the successful contractor subject to EW approval and conditions.

10 Conclusions

The potential effects of the Project on stormwater quality and quantity entering the receiving environment are assessed as being no more than minor provided the mitigation measures noted below are implemented.

Key Issue	Significance of Effects	Mitigation	Significance of Effects with Mitigation
Pollution	Moderate	Treat the stormwater runoff using infiltration swales and wetlands.	Minor
Stream bed and bank erosion	Moderate	Detain and slowly release stormwater runoff collected within the wetlands. Maintaining hydraulic neutrality for northern end of the Expressway by providing infiltration swales. Energy dissipation and scour protection at outlets.	Minor
Flooding	Moderate	Maintaining hydraulic neutrality for northern end of Expressway by discharging road runoff to ground (100 year ARI mitigation). Flood control is not required for discharges to the Karapiro Stream and Waikato River for the Project.	Minor
Mitigation of construction effects	Moderate	Use of accepted erosion and sediment control methods such as those outlined in EW's Erosion & Sediment Control Guidelines for Soil Disturbing Activities.	Minor

10.1 References

- *Sustainable Subdivision Development – An Environment Waikato Perspective*, Environment Waikato, 2006.

- *Stormwater Management Devices: Design Guidelines Manual*, Auckland Regional Council, Technical Publication No 10 (TP10), Second edition, May 2003.

- TP108 Guidelines for Stormwater Runoff Modelling in the Auckland Region

- *Erosion and Sediment Control: Guidelines for Soil Disturbing Activities,* Environment Waikato Technical Report TR2009/02, 2009.

- NIWA, 2002: HIRDS V2.0 – High Intensity Rainfall Design System.

- Transit New Zealand Bridge Manual for the design of culverts.

- Transit New Zealand F/3:2000 "Specification for Pipe Culvert Construction".

- NZTA Stormwater Treatment Standard for State highway Infrastructure.

- *Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in NZ* (2nd Edition, May 2008) Ministry for the Environment.

- Pitt, R., R. Field, M. Lalor, and M. Brown. 1995. Urban stormwater toxic pollutants: assessment, sources, and treatability. Water Environment Research 67(3):260-275.

Appendix 1:

Percolation Testing Results

Appendix 2:

Groundwater Level

Appendix 3

Existing Bore Information

Appendix 4

Infiltration Swale Calculations

Appendix 5

Wetland and Conveyances Calculations

Appendix 6

Diagram of Stormwater System Stations 7200m to 10900m

Appendix 7

Diagram of Stormwater System at the Southern Interchange

Appendix 8

Karapiro Stream Flow Information

Appendix 9

Karapiro Stream Bridge Drawings

Note that the Karapiro Bridge Drawings will be included in the *Waikato Expressway-Cambridge Section: Drawings* document

Appendix 10

Culvert Calculations

Appendix 11

Stormwater Management Overview Drawings

Note that the Stormwater management Overview Drawings will be included in the *Waikato Expressway-Cambridge Section: Drawings* document

Appendix 12

Erosion and Sedimentation Control Plan

Note that the ESCP Drawings will be included in the *Waikato Expressway-Cambridge Section: Drawings* document

Appendix 13

Typical Stormwater Outlet and Inlet Drawings