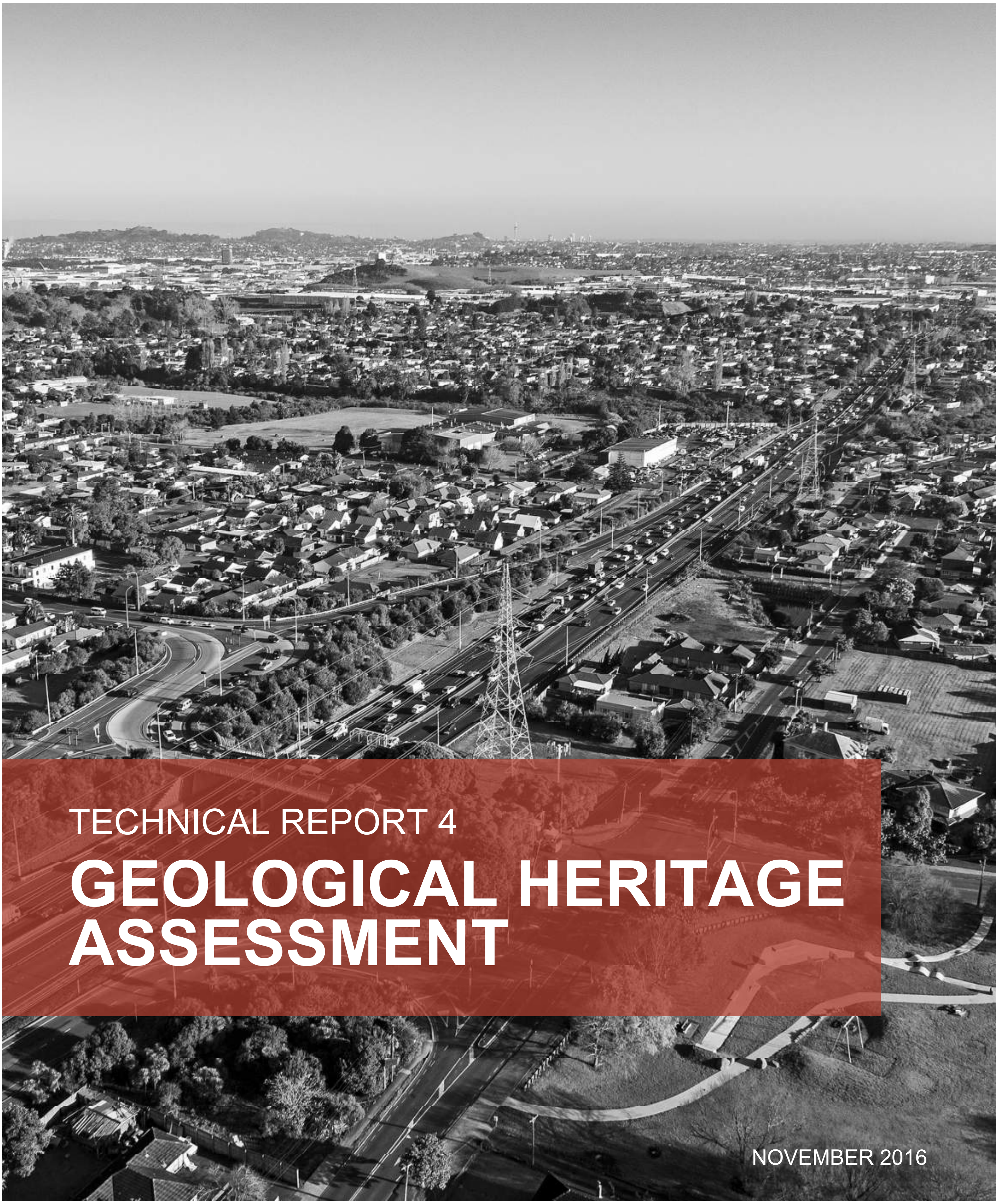

TECHNICAL REPORT 4

GEOLOGICAL HERITAGE ASSESSMENT

NOVEMBER 2016

NZ TRANSPORT AGENCY
WAKA KOTAHI

East West Link

Quality Assurance Statement	
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Reviewed by	Mike Trebitsch
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Revision schedule					
Rev. N^o	Date	Description	Prepared by	Reviewed by	Approved by
0	November 2016	Final for Lodgement	Ian Smith	Mike Trebitsch	Patrick Kelly

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EXECUTIVE SUMMARY

Volcanic features within the Project area

1. There are a number of known / visible volcanic features in the vicinity of the East West Link Project. These include:

   - Te Hōpua tuff ring

     The tuff ring is a small volcanic feature of the Auckland Volcanic Field. Previous human development in the area has extensively modified the tuff ring. Parts of Te Hōpua have been identified as an ONF in the PAUP; however, these areas are essentially the area of the crater floor which was infilled during the 1940s and are therefore not primary volcanic features.

   - Remnant basalt outcrops along the Onehunga foreshore

     Much of the foreshore along the northern margin of the Māngere Inlet consists of outcrops of the distal ends of lava flows which originated from One Tree Hill, Mt Smart and Mt Wellington volcanoes. The original form of the coastline has been profoundly modified by infilling of the embayments between the lava flow terminations.

   - Lava flows within and around the Anns Creek area

     In the northeastern corner of Māngere Inlet lava flows from Mt Smart and Mt Wellington volcanoes are juxtaposed and there are some significant outcrops which have not been affected by subsequent development. Several of these outcrops have been identified as ONFs.

Results of assessment

2. This report concludes that while some Project works will occur within the mapped extent of the Te Hōpua ONF, they follow the alignment of the current northbound off ramp from SH20 and will therefore will not impact on the geological characteristics and qualities that contribute to its values. On the southern side of Te Hōpua, the Project works do not impact on the form of the tuff ring because here the original structure lies below current sea level. In summary the Project works:

   a) Avoid the unmodified areas of the tuff ring and will mainly occur on fill within the crater floor;

   b) Will not impact on the remaining overall circular form of Te Hōpua;

   c) Will not affect its potential value as a component of the larger Auckland Volcanic Field.

3. This report also concludes that the impact of the proposed works on volcanic features along the northern foreshore of Māngere Inlet will be minimal and that development of recreational walk ways and the like will increase access and appreciation of the volcanic nature of the Māngere Inlet foreshore.

4. The Anns Creek area includes exposures of the distal lava flow lobes from Mt Smart and Mt Wellington volcanoes. Here there are numerous outcrops of lava flows including surface textures. Examples of pahoehoe (ropey) textures which are generally rare in the Auckland Field are seen in the western part of the Anns Creek area. Although the designated route of the East-West Link is elevated in this section and largely avoids these outcrops, some care is needed in planning for the siting of piers.

Summary of recommendations

5. It is recommended that efforts are made in project planning to improve access to and connectivity between the crater floor of Te Hōpua tuff ring, the lava flows along the northern side of Māngere Inlet and particularly in the Anns Creek area. The Anns Creek area offers an opportunity for an integrated geological and ecological environment which would be an addition to the scientific themed walks that already exist in the Auckland area (e.g. Otuataua Stonefields). In addition, I recommend that interpretive signs be provided in and around Anns Creek and Te Hōpua for educational purposes.

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Glossary of Abbreviations and Defined Terms

Table 1-1 sets out the technical terms/abbreviations used in this report.

Table 1-1: Glossary of technical terms/abbreviations

Abbreviation (if applicable)	Term
AEE	Assessment of Effects on the Environment
EWL	East West Link
ONFs	Outstanding Natural Features
ONLs	Outstanding Natural Landscapes
PAUP	Proposed Auckland Unitary Plan
SH(x)	State highway (number)

Table 1-2 sets out the defined terms used in this report.

Table 1-2: Glossary of defined terms

Term	Meaning
Alignment	Means the selected route and designation footprint. This development involved specialist work assessing environmental, social and engineering inputs.
Motorway	Means a motorway declared as such by the Governor-General under Section 138 of the PWA or under Section 71 of the Government Roading Powers Act 1989.
Project	Means the East West Link Project as described in *Part C: Description of the Project* in the *Assessment of Effects on the Environment Report* contained in *Volume 1: AEE* and shown on the Drawings in *Volume 2: Drawing Set.*
State highway	Means a road, whether or not constructed or vested in the Crown, that is declared to be a State highway under section 11 of the National Roads Act 1953, Section 60 of the Government Roading Powers Act 1989 (formerly known as the Transit New Zealand Act 1989), or under section 103 of the LTMA.

1 Introduction

1.1 Purpose and scope of this report

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's East West Link Project (the EWL or Project). Its purpose is to inform the Assessment of Effects on the Environment Report (AEE) and to support the resource consent applications, new Notice of Requirement and an alteration to existing designation required for the EWL.

This report assesses the effects on volcanic heritage features of the proposed Alignment of the Project as shown on the Project Drawings in *Volume 2: Drawing Set*.

The purpose of this report is to:

- Identify and describe the existing volcanic features in the Project area;
- Describe the potential effects of the Project on those features;
- Recommend measures as appropriate to avoid, remedy or mitigate potential adverse effects on the features; and
- Present an overall conclusion of the level of potential effects of the Project after recommended measures are implemented.

1.2 Project description

The EWL Project involves the construction, operation and maintenance of a new four lane arterial road from State highway 20 (SH20) at the Neilson Street Interchange in Onehunga, connecting to State highway 1 (SH1) at Mt Wellington as well as an upgrade to SH1 between the Mt Wellington Interchange and the Princes Street Interchange at Ōtāhuhu. New local road connections are provided at Galway Street, Captain Springs Road, the ports link road and Hugo Johnston Drive. Cycle and pedestrian facilities are provided along the Alignment.

The primary objective of the Project is to address the current traffic congestion problems in the Onehunga, Penrose and Mt Wellington commercial areas which will improve freight efficiency and travel reliability for all road users. Improvements to public transport, cycling and walking facilities are also proposed.

For description purposes in this report, the Project has been divided into six sectors. These are:

Sector 1. Neilson Street Interchange and Galway Street connections

Sector 2. Foreshore works along the Māngere Inlet foreshore including dredging

Sector 3. Anns Creek from the end of the reclamation to Great South Road

Sector 4. Great South Road to SH1 at Mt Wellington

Sector 5. SH1 at Mt Wellington to the Princes Street Interchange

Sector 6. Onehunga local road works

A full description of the Project including its design, construction and operation is provided in Part C: Description of the Project in the Assessment of Effects on the Environment Report contained in *Volume 1: AEE* and shown on the Drawings in *Volume 2: Drawing Set.*

2 Experience

2.1 Expertise

This report has been prepared by Associate Professor Ian Smith, BSc (VUW), BSc (Hons) (VUW), PhD (ANU) of the University of Auckland, Faculty of Science. Assoc. Prof. Smith is a fellow of the Geological Society of Australia.

Assoc. Prof. Smith's research uses the petrology and geochemistry of volcanic materials to understand the way that magmatic systems work on a variety of time scales. The basis of this research is detailed sampling of sequences of deposits in individual volcanoes coupled with study of their mineralogy and chemical compositions. The results lead to a better understanding of the way volcanoes work and of the hazards presented by their eruptive activity. As the basis for these studies Dr Smith has been involved in mapping out the distribution of the volcanic deposits in the Auckland Volcanic Field and interpreting their characteristics in terms of known types of eruptive behaviour.

Dr Smith's expertise gained during 35 years of research into the nature and origin of Auckland's volcanoes has been recorded in numerous published scientific publications and technical reports on the impact of infrastructure projects on the volcanic structures of the Auckland Volcanic Field.

2.2 Preparation of this report

In preparing this report the author has drawn on available published information on the Auckland Volcanic Field as well as extensive research notes collected during 35 years of research in the area. Key recent sources of volcanological information are Hayward, B.W., Murdoch, G., Maitland, G. Volcanoes of Auckland, *Auckland University Press 2011* and the Auckland Urban Area 1:50,000 geological map of the Auckland area. Additional materials are the author's unpublished research notes on the volcanoes of the Auckland Volcanic Field. Site visits were undertaken at Te Hōpua during 2013 and 2014 and on 9 August 2016 to examine the features in the Anns Creek area, including features within TR Group's property.

Material provided to inform this report included a set of annotated aerial photographs illustrating the proposed East West Link Project with accompanying drawings together with the record of a drill core situated on the southern side of Te Hōpua tuff ring.

3 Assessment Methodology

In relation to each volcanic feature this report:

- Describes the formation of the feature, and its nature and origin;
- Explains how the feature has been modified;
- Identifies the values of the feature, taking into account the relevant factors for which it has been identified as an ONF in the PAUP and the author's assessment of the remaining geological features that contribute to those values; and
- Assesses the effects of the Project on those identified values.

In addition the report also provides:

- A summary of the Auckland Volcanic Field to provide context for the features within the vicinity of the Project and
- Definitions of volcanic cone, tuff ring and volcanic field and which of these definitions best categorise Te Hōpua.

4 Background to Assessment

The following sets out a background description of volcanic features to provide context for the assessment of effects on volcanic features within the vicinity of the East West Link Project.

4.1 The volcanological context

Much of Auckland is built on and around the volcanoes of the Auckland Volcanic Field. The volcanic field is a feature of the Auckland area, has international scientific significance as an excellent example of a young volcanic system and has considerable cultural importance to Māori. The issues that need to be taken into account with regard to construction projects in the Auckland area are:

- Any modification of the geomorphic form of a volcanic cone. This is a particularly sensitive issue because many of the original ~50 cones have been modified by quarrying or road construction and some have been completely removed;
- Any modification of the surface features of lava flows associated with the volcanic cones. This is a less significant aspect because many of the flows have soils developed on them and original volcanic features have been removed or covered by natural features. However, there could be an issue with modification of the original surface shape of lava flows;
- Excavation or destruction of lava caves within lava flow sequences. There are many mainly small examples of lava caves within lava flow sequences particularly in the central isthmus area and these attract much public interest; and
- Sight lines have been defined to allow Auckland's volcanic cones to be viewed across the city and any potential restriction of these can be an issue. This aspect is addressed in *Volume 3: Technical Report 6 - Landscape and Visual Impact Assessment.*

4.2 Definitions of volcanic features

4.2.1 Volcanic field

The general concept of a volcano is that of a single volcanic cone built up by a succession of eruptions during a time period that may extend to several thousand years. Named volcanoes of the world are typically the product of eruptions from a focused plumbing system feeding a single centralised vent at the surface; they are commonly referred to as central volcanoes or cone volcanoes.

In contrast to central volcanoes, volcanic fields occur where the rate of production of magma is very small so that a focused plumbing system does not develop. Volcanic fields consist of clusters of small volcanoes which are built during a single sequence of eruptions. Individual volcanoes in a field are usually tuff rings or scoria (cinder) cones commonly associated with lava flows. A typical volcano field may contain 10 to 100 or more volcanoes. Examples of volcano fields in northern New Zealand are the Kaikohe Field, the Whangarei Field, the Auckland Field and the South Auckland Field. Examples of volcanoes within the Auckland Field are Mt Eden, Lake Pupuke and Rangitoto.

Volcanic fields vary in size, total volume, longevity and rates of eruptive activity. Characteristic features of volcanic fields are:

- Many small volcanic vents occur within the confines of the field;
- Renewed activity in a field results in a new volcano (vent);
- Individual volcanoes represent only a single eruptive episode;
- Eruptive episodes are typically short;
- Volcano fields most commonly erupt basalt magma;
- Low rates of magma production;
- Clustered vent distributions;
- Magma processes dominated by sub crustal mantle environment; and

- Dramatic changes in rates of vent formation and vent distribution over periods of 100,000 years or less.

4.2.2 Volcanic cones

Volcanic cones are the accumulation of erupted material around the vent of a volcano.

There are considerable variations in the size, shape and deposits of volcanic cones. On the smallest scale, cones develop from single eruptions on timescales as short as a few days. On the largest scale, volcanic mountains are the product of several hundred thousand years. Some cones reflect a single eruption style, others cones grow by the accumulation of many different types of deposits produced by a variety of eruption styles.

There are several terms used to classify cones that have developed from specific eruption styles or which have particular shape. These are:

Scoria cone

Scoria cones are also referred to as cinder or tephra cones. They are relatively small but common volcanoes that form by the eruption of low viscosity, commonly basaltic magma, in Strombolian and Hawaiian type eruptions. Typical Auckland examples are Mt Eden and Mt Wellington.

Tuff ring

Tuff rings are volcanoes for which the crater rim is less than 50m high which enclose a crater. The craters formed have a small depth to width ratio at or above mean ground level and the outer flanks consist of low aprons of ejected pyroclastic debris (tuff) made up of beds dipping at $<25^{o}$. The debris consists of a mixture of juvenile and accidental fragments. Auckland examples are Ōrākei Basin and Te Hōpua.

Tuff rings are the product of explosive phreatomagmatic eruption styles, although they can include deposits from Hawaiian/Strombolian eruptions. The term “tuff” is used for the heterogeneous mixture of fine to coarse material produced in explosive eruptions.

Maar

Maars are also a type of tuff ring. They are defined as bowl shaped craters lying about 10m to more than 500m below the pre-eruption land surface. Maars are surrounded by low ramparts of well bedded ejecta that decrease rapidly in thickness away from the rim.

Tuff cone

Tuff cones are a variant of tuff rings characterized by higher profiles than tuff rings and steeper external slopes with beds dipping $> 25^{o}$. Their crater floors are generally above the general land surface.

4.2.3 The Auckland Volcanic Field

Volcanoes are a conspicuous feature in the Auckland city landscape. In some cases their form is emphasised by their preservation as reserves and parks, while in other cases they have been quarried to meet the City’s demand for building materials. Within a 20km radius of Auckland city there are ~50 named volcanic vents; this is the area referred to as the Auckland Volcanic Field.

Of the 50 volcanic vents in the Auckland Volcanic Field, 19 are known to have formed within the last 20,000 years. Of these 19, about 18 erupted between 20,000 and 10,000 years ago. By comparison, there were only 21 eruptions between 20,000 and 100,000 years ago, and about nine eruptions earlier than 100,000 years ago. The oldest date for an Auckland volcano is 250,000 years.

Auckland’s volcanoes erupt basalt magma, which is the dense rather than the fluid type, well known from active volcanoes in Hawaii. Basalt magmas originate from a mantle source 50-100km below the surface. The shape of an Auckland volcano depends on the style of eruption that formed it; its size depends on the duration of the eruption and the volume of magma available. The two examples of cone building eruptions in the Auckland field are phreatomagmatic and Hawaiian/Strombolian. In many of Auckland’s volcanoes, phreatomagmatic activity has been the initial style of eruption followed by Hawaiian/Strombolian eruptions and in some cases by the effusion of lava flow.

Phreatomagmatic eruptions

When magma reaches the surface and it comes into contact with water, either with the sea or with groundwater or with a river, then an explosive eruption occurs. This type of eruption is known as phreatomagmatic (phreato = steam).

When magma at high temperatures (about 1,000 degrees Celsius) mixes with water it is instantly chilled and the pressure of its contained gas breaks it up into fragments. The water, when it comes into contact with the hot magma, flashes to superheated steam. The result is a violent explosion of steam, magmatic gas, fragmented lava and rocks from around the vent which forms a rapidly expanding cloud. The solid material in this cloud is pyroclastic (fragmented and explosively ejected) and is referred to by the general term tephra or tuff. Tephra is divided on the basis of size into ash (diameter less than 2mm), lapilli (2-64mm) and blocks and bombs (greater than 64mm) components.

In phreatomagmatic explosions, columns of tephra containing ash to gravel-sized (lapilli) fragments are ejected together with steam and magmatic gas to form an eruption column which may rise to heights of 500m or more. Larger fragments (bombs and blocks) are thrown out from the vent on ballistic trajectories. At the base of the eruption column explosive surges expand as a collar-like blast of tephra, gas and steam moving at speeds of hundreds of kilometres per hour, whereas at the top of the eruption column, wind disperses the tephra downwind to fall as a layer of air fall tephra.

Phreatomagmatic eruptions in the Auckland Volcano Field have typically produced a wide roughly circular crater half to one kilometre in diameter surrounded by a low pyroclastic ring. In Auckland, Lake Pupuke, Ōrākei Basin and Crater Hill are larger examples. There is evidence of phreatomagmatic activity in 73% of the volcanoes in the Auckland field but in many cases this has been followed by other types of eruption. Most of the explosion craters have been infilled by mud or have been breached by the sea.

Hawaiian/Strombolian eruptions

Without the interaction of magma with surface water, eruptive activity is driven by magmatic gas. Gas-charged magma erupts at the surface in a fire-fountain which may play continuously (Hawaiian style) or pulsate discontinuously (Strombolian style) to build a cone of coarse tephra, commonly referred to as a scoria cone. An examination of the deposits making up a scoria cone reveals layers consisting of lumps of rock of various sizes. Most of these are rounded and honeycombed with small holes known as vesicles. These were lumps of hot magma thrown out of the volcano in a molten state. The vesicles represent bubbles of the magmatic gases which powered the eruption (the gas has long since escaped).

Many of Auckland's volcanoes are excellent examples of scoria cones. To name a few there are Mt Victoria, One Tree Hill, Mt Albert and Mt Māngere. When fire fountaining becomes particularly intense lava flows can form when hot fragments of magma fuse together as they land. Toward the end of fire fountaining episodes magma which has lost most of its gas content may form a flow which runs relatively quietly out of the vent. In some cases (e.g. Mt Māngere) the eruption of lava flows has accompanied collapse of a part of the crater rim to form a breached crater.

5 Description of the Environment

5.1 Volcanic features along the proposed EWL route.

At the western most extent of the Project area is Te Hōpua. Te Hōpua is a small explosion crater with a low tuff ring about 500m in diameter. Heading east the EWL route encounters lobes of lava from One Tree Hill (Maungakiekie) as far as Alfred Street, Onehunga apart from a short section in the vicinity of Pikes Point then successively lava flows from Mt Smart cone (Rarotonga) and a flow from Mt Wellington cone along Great South Road.

Along the stretch of Māngere Inlet foreshore, are outcrops of lava flows. These exposures are of the rubbly tops of distal lava flows and there do not appear to be any surface texture or flow morphology issues. In its original form the foreshore had a deeply scalloped form made up of lava flow lobes and interspersed indentations. However, subsequent development has infilled the embayments between lava flow lobes to create a straight coastline.

At its eastern end the proposed EWL route comes off SH1 and skirts the southern margin of Mutukāroa-Hamlins Hill along the alignment of Sylvia Park Road. Mutukāroa-Hamlins Hill is made up of sandstone/mudstone of the Waitematā sedimentary group and is not itself volcanic. However, on top of the hill is an exposure of rhyolitic tuff, approximately 10m wide and up to 2m high. The PAUP states that its position on top of the hill suggests the rhyolitic ash is from airfall or a pyroclastic flow and not reworked by water as is more common (PAUP, Schedule 6, ONF 38). The EWL Project will not impact on this tuff exposure. In addition, lava flows from McLennan Hills cone flowed northward and ponded against Mutukāroa-Hamlins Hill beneath Sylvia Park Road. These underlie the existing Sylvia Park roadway and are not further affected by the proposed EWL Project. There does not appear to be any adverse effects on volcanic features in this area because the proposed route avoids the Mutukāroa-Hamlins Hill mapped ONF area.

To summarise, the volcanic features in the direct vicinity of the East West Link Project that could potentially be affected by the Project are:

- Te Hōpua ā Rangi tuff crater

  The tuff ring is a small, volcanic feature of the Auckland Volcanic Field. Previous human development in the area has extensively modified the tuff ring.

- Remnant basalt outcrops along the Onehunga foreshore at Pikes Point and Victoria Street

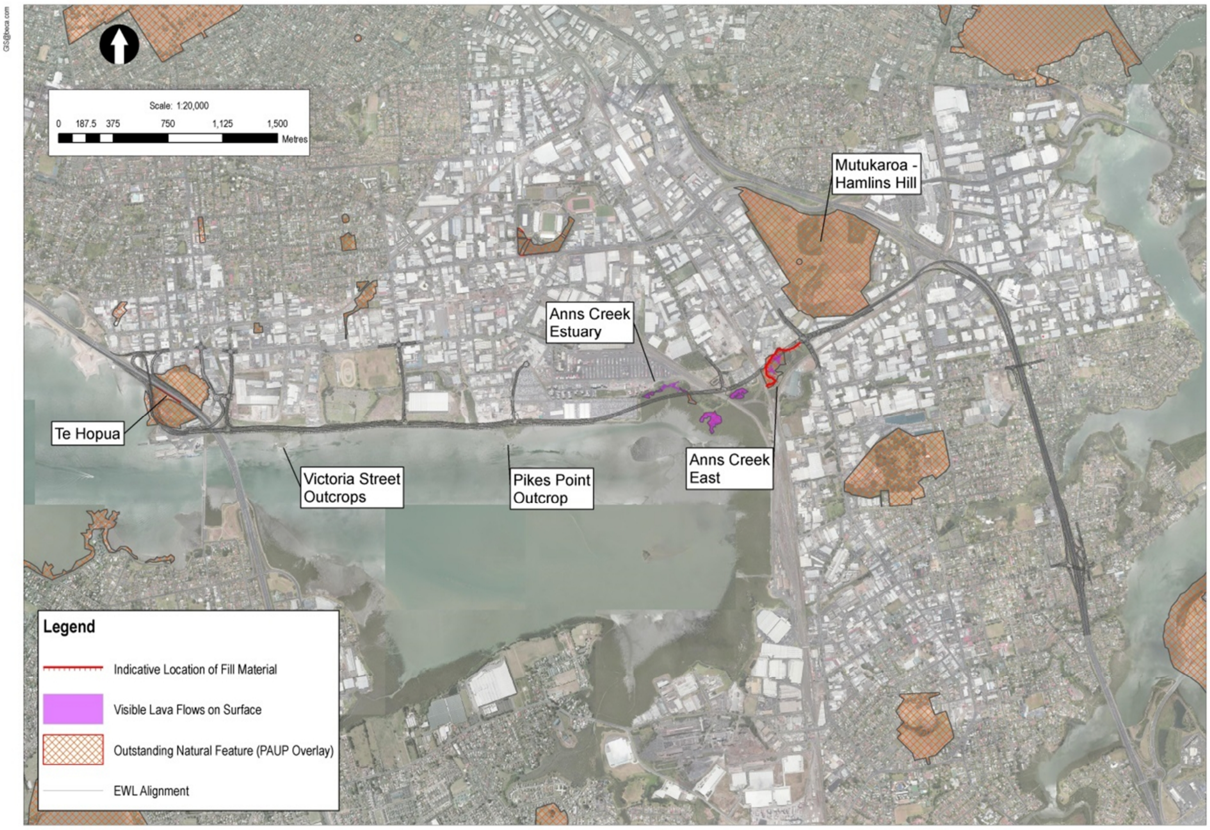
  Much of the foreshore along the northern margin of the Māngere Inlet consists of outcrops of the distal ends of lava flows which originated from One Tree Hill, Mt Smart and Mt Wellington volcanoes.

- Lava flows within and around the Anns Creek area

  In the north-eastern corner of Māngere Inlet lava flows from Mt Smart and Mt Wellington volcanoes are juxtaposed and there are some significant outcrops.

Figure 5-1 shows the locations of the ONF areas at Te Hōpua and within the Anns Creek areas and the remnant basalt outcrops along the Onehunga foreshore (a larger copy is included in **Appendix A**).

Figure 5-1: Locations of Te Hōpua, remnant basalt outcrops along the Onehunga foreshore and lava flows in the Anns Creek area



The specific aspects of the EWL Project that have a potential impact on these volcanic features are:

Sector 1. The Interchange from SH20 to Onehunga Harbour Road;

Sector 2. Foreshore works along the Māngere Inlet foreshore; and

Sector 3. Anns Creek from the end of the reclamation to Great South Road.

The features are described in more detail below.

5.2 Te Hōpua ā Rangi tuff crater

Te Hōpua is a small volcano in the southern part of the Auckland Volcanic Field. With an estimated erupted volume of 855,664 cubic metres (the total volume for the Auckland field is 1,704,603,213 cubic metres) it is one of the smaller centres in the field. The age of the eruption is not known at this stage but is assumed to be one of the younger centres (i.e. less than 30,000 years before present) and is possibly related to a group of explosion craters between One Tree Hill and Three Kings.

Te Hōpua is an example of a tuff ring produced by explosive phreatomagmatic eruptions. It appears to be a simple structure consisting only of tuff and is comparatively small. Other examples of tuff rings in the Auckland field are Ōrākei Basin, Panmure Basin, Māngere Lagoon and Pukaki which are all larger than Te Hōpua. Lake Pupuke and Crater Hill are much larger and show more complex structure as well as a greater variety of deposits.

There are only very limited outcrops of the tuff forming the ring remaining on the northern side of the ring. These have not been studied in any detail. Most of what is known about the volcano is inferred from the shape of the ring. The tuff ring has a low profile and is breached on the southern side. Because of the buildings located along much of the crater and the presence of SH20 which bisects the crater it is not easily identified as a volcanic structure.

Te Hōpua ā Rangi tuff crater is variously known as Te Hōpua, Te Hōpua Tuff Ring, Gloucester Park, Geddes Basin and Onehunga Basin.

5.2.1 History

Te Hōpua was originally formed on the Manukau lowlands by the eruption of basalt magma. The eruptions that formed the tuff ring were phreatomagmatic. In other words, the eruptions involved the interaction of water with magma to produce ash surges and ash falls. The constituent materials of the resultant tuff cone were a poorly sorted mixture of fine ash grading to blocks and bombs. After formation the crater was a low lying swamp or shallow lake in which organic sediments would have accumulated.

It is not known whether, at the time of the eruptions, sea level was sufficiently high to fill the Manukau Harbour as at present. The magma that formed Te Hōpua encountered water, probably near surface ground water, and as mentioned phreatomagmatic eruptions ensued. These eruptions built a tuff ring with the high side to the north-northeast and the low side to the south-southwest. As happened at a number of other Auckland tuff rings when sea level rose after the last ice age (i.e. since 10,000 years ago) the crater rim was breached and it was a shallow tidal lagoon up until about 60 years ago. In this state it became the Onehunga boat harbour.

The lagoon was subsequently reclaimed with fill in the 1940s. During the 1970s the motorway was constructed through the middle of the crater.

Currently the crater floor exists as a playing field and an underdeveloped park bisected by SH20. The form of the rim of the crater can be identified although it has been modified by development and construction (especially on the southern, eastern and northern sides). The location of the crater floor enclosed by the raised tuff ring is also identifiable as areas of flat land. With knowledge and a wider perspective, Te Hōpua can be recognised as a volcanic centre. However, it is probably one of the least obvious volcanoes in the Auckland field.

Figure 5-2: Aerial image of Te Hōpua looking south

5.2.2 Shape of Tuff Ring

In its original form Te Hōpua is a roughly circular volcanic crater defined by a low profile tuff ring about 500m in diameter. The rim enclosing the crater was highest on the northern and north eastern side (about 20m above the crater floor) and lowest to the west southwest where it was open to the Manukau Harbour. The inner slopes of the tuff ring when formed would have been relatively steep ~ 25-30^o and the outer slopes relatively gentle <20^o. The approximate location of the rim of the crater is shown in Figure 5-3 below.

5.2.3 History of modifications

As sea level rose at the end of the last glacial period, the Manukau lowlands became inundated. Te Hōpua, on the resulting shore line of the Manukau Harbour became part of the estuarine environment as a shallow embayment and the crater was filled with water. With time, marine muds were deposited within the former crater.

During the 1930s Te Hōpua was used by Europeans as a centre for marine activity as it had an opening to the Manukau Harbour at the low point of the original crater rim to the south-southwest.

Subsequent modifications to the original form of Te Hōpua volcano are:

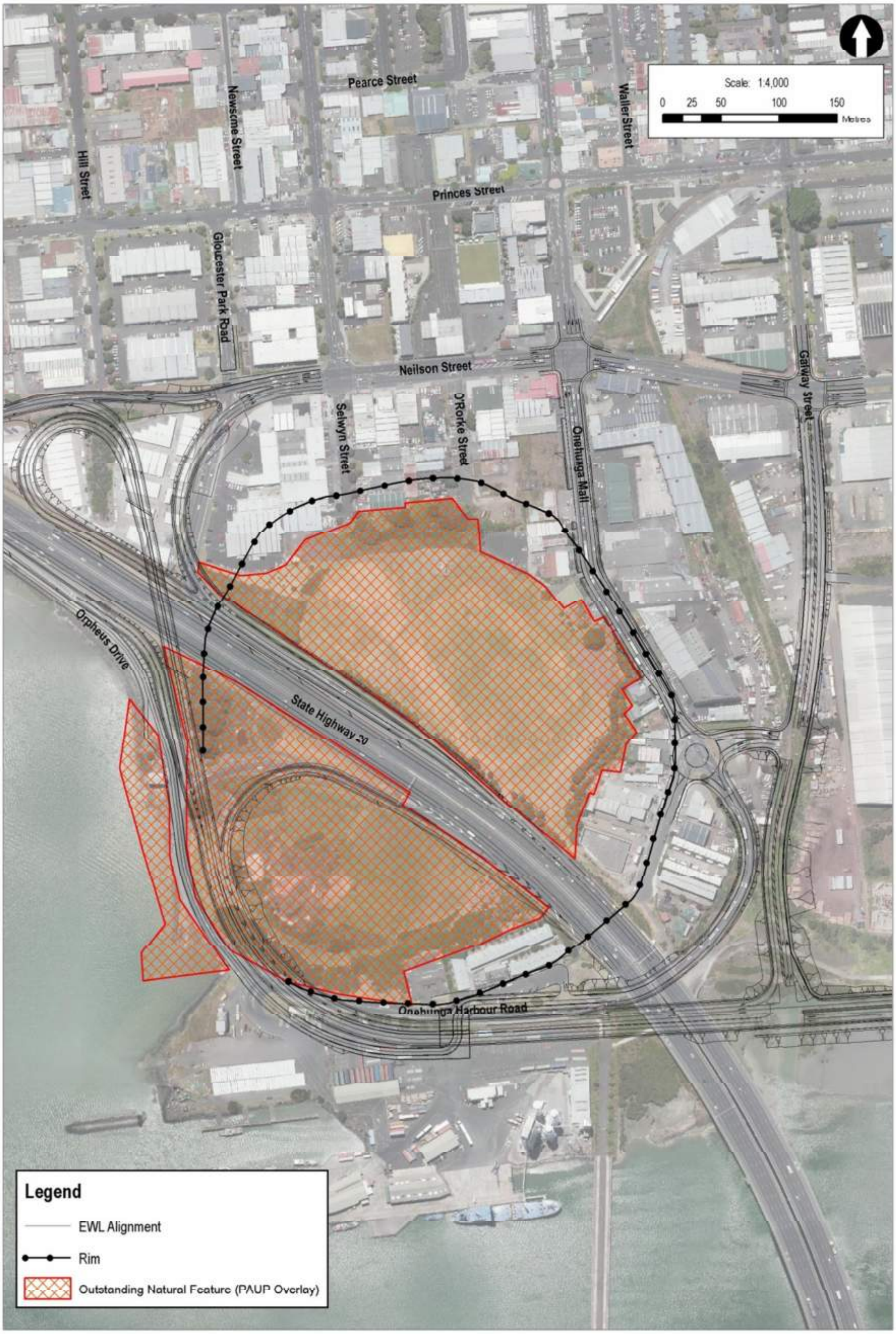
- Closure of the opening of the Te Hōpua lagoon to the Manukau Harbour;
- Filling of the crater for a range of uses. The area is now used as playing fields in the northeastern part of the crater and an open park on the south western side. The low point in the crater on the southern side is currently a saline wetland;
- Building of a hotel and more recently a motel on the southern part of the crater rim adjacent to Onehunga Wharf. The Onehunga Wharf facilities are built on reclaimed land on the southern outer slopes of the Te Hōpua tuff ring;
- Urban development of the eastern and northeastern crater rim and adjacent outer slopes. This development is mostly light industrial; and
- Development of SH20 which bisects the crater and cuts into rim deposits on the northern side. This exposure was <2m high and is now grassed over. At the southern end the road rises above the crater rim.

5.2.4 Assessment of the current state of Te Hōpua Tuff Ring

Te Hōpua is one of the smallest of the ~50 eruptive centres that constitute the Auckland Volcanic Field. The primary volcanic features of the cone are its circular form visible in aerial photographs, the low crater wall on the northern and northeastern side of the crater, a low tree covered mound on the eastern side of the crater north of the northbound Neilson Street off ramp and the southern crater rim along the northern side of Onehunga Harbour Road. There are no significant outcrops of the tuff deposits that form the cone.

Parts of Te Hōpua have been identified as an ONF (outstanding natural feature) in the PAUP (Schedule 6, ONF 46). The flat area occupying the former crater is infill material. Figure 5-3 shows the approximate location of the crater rim and the area that has been mapped as an ONF (a larger copy is included in **Appendix B**).

Figure 5-3: Extent of mapped ONF at Te Hōpua and approximate crater rim location



The areas mapped as an ONF largely encompass the flat area of the crater floor on either side of SH20 and a small coastal strip on the seaward side of Orpheus Drive. In its natural form the crater floor was below sea level and the current surface is underlain by landfill deposited in the 1940s.

The PAUP describes the Hōpua explosion crater and tuff exposure as follows (Schedule 6, ONF 46):

> *Hōpua volcano is a small explosion crater with a low tuff ring about 500m in diameter. The original crater was breached by the sea and filled with marine sediments. Although damaged by reclamation and motorway construction, the tuff ring is still discernable as a volcanic feature. An intertidal exposure of Hōpua tuff in the Manukau Harbour foreshore contains large blocks of basalt.*

The ONF is categorised as site type B (Schedule 6), which is explained generally as applying to features that are smaller more fragile landforms or other features that could be damaged or destroyed by relatively small-scale land disturbance or constructions (see Table D10.4.1).

The PAUP identifies the following factors as being relevant to the identification of Te Hōpua as an ONF (Schedule 6 and Policy B4.2.2(4)):

> *(a) The extent to which the landform, feature or geological site contributes to the understanding of the geology or evolution of the biota in the region, New Zealand or the earth, including type localities of rock formations, minerals and fossils;*
>
> *(d) The extent to which the landform, geological feature or site is part of a recognisable group of features;*
>
> *(e) The extent to which the landform, geological feature or site contributes to the value of the wider landscape;*
>
> *(g) The potential value of the feature or site for public education;*
>
> *(h) The potential value of the feature or site to provide additional understanding of the geological or biotic history.*

The Landscape Assessment by Mr Lister (*Technical Report 6: Landscape and Visual Impact Assessment*) considers the potential impacts on aesthetic and landscape values (i.e. factor (e)).

In my view, remaining geological characteristics and qualities are:

- The overall circular form of Te Hōpua, visible in aerial photographs. Its circular form is emphasised by the southern part of Onehunga Mall and its continuation as Onehunga Harbour Road, which follows the line of the former crater rim;
- The steep crater wall on the northern and north-eastern side of the crater. The rim is built upon but a small outcrop of tuff is exposed below buildings adjacent to the entrance to Gloucester Park off Onehunga Mall;
- Part of the crater rim remains as a low tree covered mound on the eastern side of the crater north of the intersection of the northbound Neilson Street exit and Onehunga Harbour Road. This is planted with pōhutukawa and macrocarpa trees; and
- The outer slopes of the tuff ring are built upon to the north but the slopes of Selwyn and O'Rorke Streets reflects the original form of the volcano.

It is these characteristics and qualities that contribute to the factors (or values) for which it has been identified as an ONF (factors (a), (d), (g), and (h)).

The crater floor area, which is mapped as an ONF, has no direct value as a primary volcanic feature since it is made up of fill material. In summary I consider that the geological values of Te Hōpua are the areas of Tuff Ring that remain unmodified, its overall circular form when viewed from aerial photos and its contribution as a component of the Auckland Volcanic Field. Accordingly, although it has been identified as an ONF for the purposes of the PAUP, its relative value compared for example to Lake Pupuke, is more limited.

Overall, in its current state Te Hōpua represents little value as a volcanic feature characteristic of the Auckland Volcanic Field. In part this is because in its original form it had a topographically low profile, the product of one of Auckland's smaller volcanic eruptions. The development of Onehunga obscures the northern crater rim and outer slopes of the cone. The crater wall in this sector is mainly covered by low scrub with a few larger trees. Motel and hotel buildings lie on the south eastern and southern sector of the rim and there is planting of low trees (Ngaio). The former breach is now built up road. Part of the crater rim north of the former breach remains as a low tree covered mound on the western side of the crater north of the intersection of the northbound Neilson Street exit and Onehunga Harbour Road. This is planted with pōhutukawa and macrocarpa trees.

The former crater floor has been reclaimed and is mainly grass developed as playing fields in the northern half. The southern half is mown grass with a small area of swampy vegetation in its centre. SH20 bisects the crater and dominates the area. However, aside from where it bisects the crater rim, it does not directly impinge on the volcanic features of the tuff ring.

In summary the original low profile of Te Hōpua tuff cone together with subsequent development leaves little that is significant as a volcanic feature. Te Hōpua can be recognised as a tuff cone but is probably one of the least obvious of the volcanic centres of the Auckland Volcanic Field.

5.3 Foreshore outcrops and Pikes Point

The Māngere Inlet foreshore is defined by outcrops of lava flows except for a length immediately east of Te Hōpua as far as Alfred Street and, further east a section immediately west of Pikes Point. In its original form the foreshore had a deeply scalloped form made up of lava flow lobes and interspersed indentations. The lava flows originated from One Tree Hill volcano and Mt Smart volcano. Those from One Tree Hill flowed southward from multiple vents to the present day Onehunga Bay Reserve and eastward to the vicinity of Pikes Point. Eastward, lava flows from Mt Smart volcano are juxtaposed against those from One Tree Hill. The boundary between these two flow packages is poorly defined.

5.3.1 History

One Tree Hill volcano is one of the largest of Auckland's volcanoes and one of the older cones in the area. Te Hōpua was erupted through the distal parts of One Tree volcano lava flows and lava flows from Mt Smart overlie the eastern end of the One Tree flows where they form the northern Māngere Inlet foreshore adjacent to Anns Creek. A lava flow from Mt Wellington overlies the Mt Smart lava flows in the Anns Creek area.

5.3.2 History of modifications

The original coast line on the northern side of Māngere Inlet would have been defined by a number of lava flow lobes emanating from One Tree Hill and Mt Smart volcanoes. The flow lobes would have been of varying thickness and would have had blocky or rubbly tops. Although the ages of the flows are not well known, it is likely that sea level at the time of the eruptions was lower than at present and so there was no lava/water interaction. The very straight coastline of the northern side of the Māngere Inlet has been created by a combination of infill and probably some dredging. Much of the foreshore is relatively undeveloped.

5.3.3 Assessment of the current state of the foreshore outcrops and Pikes Point

The original foreshore along the northern side of Māngere Inlet was made up of the distal ends of lava flows from One Tree Hill and Mt Smart volcanoes; these lobes of lava flow were interspersed by deep embayments. Development of the foreshore has seen infilling of these embayments to produce todays straight northern margin of the northern side of Māngere Inlet. The remaining small lava outcrops along this coastline cannot be considered to have any significant volcanic heritage value.

Figure 5-4: View towards Māngere Mountain showing lava flows within Māngere Inlet

Figure 5-5: View of lava flows within Māngere Inlet

5.4 Anns Creek lava flows

The northeastern corner of Māngere Inlet contains lava flows from Mt Smart volcano and a lobe from Mt Wellington which flowed around the sedimentary rock of Mutukāroa-Hamlins Hill. For the purposes of this assessment this area has been subdivided into three discrete zones. From west to east these are Anns Creek Estuary, Anns Creek West and Anns Creek East (Figure 5-8). In the Anns Creek area the outcrops of lava flows are thicker and more visible than those to the west and there are areas of unmodified flow top which have significance as volcanological features. The potential impacts of the East West Link Project are most significant in this area because these unmodified lava flows are relatively rare and provide a unique environment for indigenous flora. The Ecological Assessment (Technical Report 16) states that Anns Creek is the only area remaining in the Auckland region where native herb species, including threatened species, grow together on lava.

Figure 5-6: Lava flow within Anns Creek East

5.4.1 History

Mt Smart volcano erupted through the south-eastern edge of the One Tree Hill volcano. Lava flowed out from the base of the volcanic cone and spread east and south to form a small lava field. The distal toes of these lava flows forms part of the foreshore of Māngere Inlet. About 10,000 years ago a small lava lobe originating from Mt Wellington volcano flowed around the eastern side of the Mt Smart lava flows along the route of present day Great South Road and came to a stop in the vicinity of Southdown at present day Māngere Inlet.

5.4.2 History of modifications

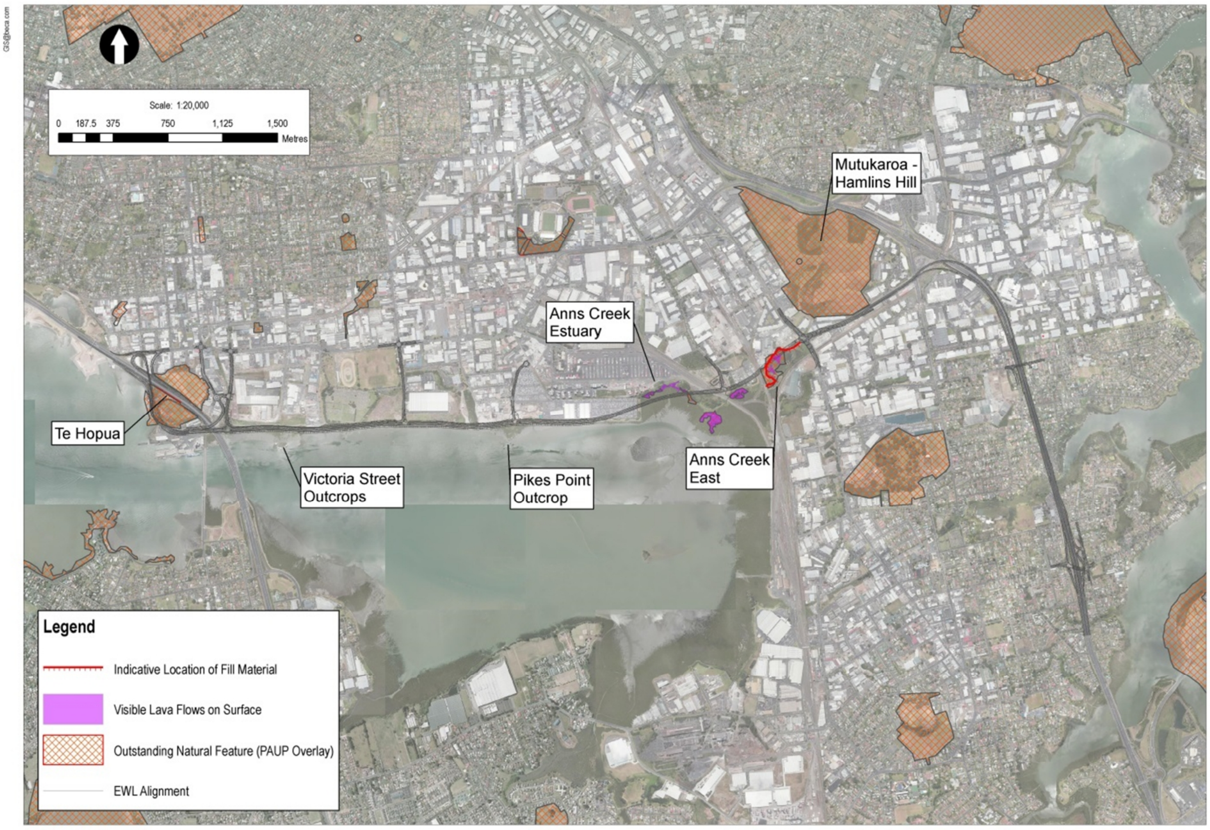
The Anns Creek area is mainly an industrial complex with roads, railway lines and warehouses. Lava flow surfaces have been extensively built over. However closer to Māngere Inlet there are areas of mangrove and in these areas there are outcrops of lava flows which show examples of cooling textures (or pahoehoe).

Figure 5-7: Pahoehoe lava flows within the Anns Creek estuary area

5.4.3 Assessment of the current state of the Anns Creek lava flows

In the Anns Creek area several areas have been mapped as ONFs (PAUP, Schedule 6, ONF 192). Volcanic features that are worthy of preservation largely coincide with these, except in the Anns Creek East area. In Anns Creek East the lava flow surfaces tend to be highly weathered and some areas mapped as ONF have been buried under fill and reclamation. In two discrete locations, intact surface features were observed. Figure 5-8 below shows the location of the mapped ONFs and the location of visible surface lava flows that I observed on a field trip undertaken in August 2016, as well as fill material that was observable (a larger copy of Figure 5-8 is included in **Appendix C**):

Figure 5-8: Extent of mapped ONF for Southdown Pahoehoe lava flows including Anns Creek



The East West Link Project is planned to be elevated along this section, and the only section which will actually overlie an ONF is in Anns Creek East where the proposed route runs along the northern margin of an ONF.

The PAUP describes the Southdown pahoehoe lava flows, including Anns Creek as follows (Schedule 6, ONF 192):

> *One of few examples of pahoehoe surfaces on basalt lava flows in the Auckland volcanic field. Several small flow lobes (probably from Mt Wellington volcano) are visible from the coastal walkway on Māngere Inlet and at Ann's Creek between Great South Rd and the railway line.*

The ONF is categorised as site type B (Schedule 6), which is explained generally as applying to features that are smaller more fragile landforms or other features that could be damaged or destroyed by relatively small-scale land disturbance or constructions (see Table D10.4.1).

The PAUP identifies the following factors as being relevant to the identification of the Anns Creek lava flows ONFs (Schedule 6 and Policy B4.2.2(4)):

- *(a) The extent to which the landform, feature or geological site contributes to the understanding of the geology or evolution of the biota in the region, New Zealand or the earth, including type localities of rock formations, minerals and fossils;*
- *(c) The extent to which the feature is an outstanding representative example of the diversity of Auckland's natural landforms and geological features;*
- *(d) The extent to which the landform, geological feature or site is part of a recognisable group of features;*
- *(g) The potential value of the feature or site for public education;*
- *(i) The state of preservation of the feature or site;*

Lava flow surfaces in the Anns Creek area have been extensively modified by industrial development. However, there are areas of mangrove scrub that include unmodified lava flow surfaces and outcrops. In this area visible features of volcanological significance are the undulating upper surfaces of a number of lava flows and a number of exposures of lava flow margins together with some preservation of cooling textures on the lava flows. The lava flows are up to 3-4m in thickness. Adjacent to industrial complexes they have been covered by fill material but away from this, distal lobes of several lava flows can be seen. The surfaces are uneven and cooling textures are mainly obliterated by weathering except for an area of pahoehoe (ropey) texture on the foreshore about 400m west of Hugo Johnston Drive in the area described as Anns Creek Estuary.

In summary, in my view the geological characteristics and qualities that contribute to the factors (or values (a), (c), (d), (g), and (i)) of the Anns Creek ONFs are:

- The Anns Creek Estuary area contains one of a few examples of pahoehoe surfaces on basalt lava flows in the Auckland Volcanic Field (the unmodified areas which have retained their surface textures showing the ropey cooling surface textures);
- In the Anns Creek East and West areas there are outcrops of basalt lava flows up to 3-4m in height. Although surface textures have been modified by soil development they remain as good examples of young Auckland Volcanic Field features; and
- The Ecological Assessment notes that the substrate of lava flows results in a unique and unusual assemblage of native plants in this area (*Technical Report 16 - Ecological Impact Assessment*).

6 Assessment of Effects on Volcanic Features

This section considers the actual and potential effects of the Project on volcanic features.

6.1 Potential impact of the proposed Neilson Street Interchange

It is understood that the Neilson Street Interchange has been specifically designed to minimise impacts on the tuff ring. Specific feedback from engagement with some parties (including Mana Whenua) indicated a strong preference for avoiding options that would require cutting into the tuff ring.

Three aspects of the proposal have the potential to impact on the Te Hōpua tuff ring:

1. Development of the northbound off-ramp of SH20 will involve minor earthworks along the existing alignment of the Neilson Street off-ramp sited on landfill of the Te Hōpua crater floor. The Alignment avoids the remnant of crater rim on its northern side. Here the tuff ring is a subdued topographic feature and the planned extent of the work follows the line of the existing off-ramp and so will have no impact on the form of the tuff ring.
2. Construction of the connections between SH20 and the EWL will potentially require a small encroachment into the side of a remnant section of the tuff ring. This is in the north-western corner of the tuff ring, adjacent to the location of the historic breach.
3. Along the southern margin of Te Hōpua tuff ring a cut trench will excavate landfill material, minor tuff deposits from Te Hōpua and underlying sediments. This is an area already extensively modified by earlier development of motels, hotels and Onehunga Wharf. The upper part of the cut trench will encounter landfill material and the lower part is likely to encounter deposits of volcanic material. The tuff deposits that will be intersected in this trench lie below current sea level and are beyond the mapped extent of the ONF. Although the excavation will be partly within the deposits of Te Hōpua a Rangi, it will not affect the existing form of the tuff cone. Although there will be an effect below sea level, there will be no impact on the values that I have described above.

It is concluded that the proposed East West Link Project will have negligible impact on the existing volcanological characteristics and qualities that contribute to the values of the Te Hōpua Tuff Ring (as identified in the PAUP and assessed in section 5.2.4) because:

- Construction works will largely avoid the unmodified parts of the crater rim;
- Te Hōpua's overall circular form when viewed from aerial photos will not be affected; and
- It's contribution as a component of the Auckland Volcanic Field will not change.
- It's potential public educational value and its potential to provide an understanding of geological history will not be affected.

As mentioned, the *Technical Report 6: Landscape and Visual Impact Assessment* considers the potential impacts on aesthetic and landscape values.

6.2 Potential impact of the foreshore Alignment

The proposed EWL route follows the Alignment of the Māngere Inlet foreshore. On the plans, to the seaward side of the proposed road there are a series of small lagoons and pathways which more or less follow the undulating shape of the lava flow lobes and form a buffer between the roadway and the sea. The proposed EWL route lies to the north of the current coastline and does not impact on any of the surviving volcanological features. The proposed boardwalk in the Inlet will cross the remnant flows at Pikes Point and opposite the end of Victoria Street. However as mentioned these outcrops have little volcanic heritage value. Currently volcanological features along the foreshore are not well displayed however planned mitigation along the Māngere Inlet coastline provides an opportunity to highlight its formerly volcanic nature by improving public access and providing interpretive and informative material, such as signs containing scientific information about the composition and origins of the lobes. A link between the tuff cone of Te Hōpua and the lava flow features on the Anns Creek area provides the opportunity for a volcanically-themed foreshore walk. The proposed landscaping associated with the EWL Project, together with signs containing information about the lava lobes will achieve this aim. If these works are undertaken then in this area the Project will have a positive impact.

6.3 Potential impact of the Anns Creek Alignment

Lava flows from Mt Smart and Mt Wellington volcanoes occur in the Anns Creek area. For the most part, original volcanic features have been obliterated by the development of roads, rail lines and industrial buildings. Relatively small areas of mangrove scrub include patches of lava outcrop illustrating surface lava features. The proposed Alignment avoids many of the mapped ONF areas. In addition, in this area the proposed road is elevated and so the impact will be negligible if supporting piers are carefully positioned. The siting of piers supporting the elevated road in the west and east Anns Creek areas will need to consider the existence of lava flow features.

In the Anns Creek East area, a proposed exclusion area has been developed within which no works will be undertaken, including construction activities. The exclusion area will ensure that adverse effects are avoided on the most sensitive parts of the ONF. In addition, the temporary staging required for construction will be placed on the northern side of the bridge structure. This will minimise adverse effects on the ONF

Where the Alignment lies adjacent to the Anns Creek Estuary area, there is potential for construction activities to damage the significant lava features in this area.

This has been taken into account in the design of the Alignment, which has been carefully located to avoid most of the ONF areas within Anns Creek Estuary. It has also been taken into account in planning future construction activities. The proposed construction methodology includes placing any temporary staging on the southern side of the bridge structure. This will avoid the most sensitive parts of the ONF within Anns Creek Estuary and will minimise effects on the small areas that the bridge structure will overlap.

In summary, potential adverse effects on the lava flows of the Anns Creek area can largely be avoided by careful siting of piers and appropriate planning of the construction phases of the Project. As mentioned, the *Technical Report 16: Ecological Impact Assessment* considers the potential impacts on ecology in this area.

Mitigation of any remaining impacts could take the form of increasing public access and providing interpretative displays to increase public education about these features.

7 Recommendations

Volcanic features along the proposed route of the East West Link Project are relatively subdued and are not particularly significant features of the Auckland Volcanic Field. An opportunity exists because of the Project to improve access to such volcanic features and create an environmentally and volcanologically themed connection between Te Hōpua tuff ring and the lava flows of the Anns Creek area.

7.1 Te Hōpua a Rangi tuff crater

The volcanic nature of the Te Hōpua a Rangi tuff crater can be emphasised by appropriate development and linking of the existing parks, including interpretive material. Recommended mitigation measures include:

- Providing educational opportunities including installing interpretative educational material and improving public access; and
- Enhancing a link between Gloucester Park and the pathway that runs along the Māngere Inlet to the east. The current path is largely on lava flows from One Tree Hill and Mt Wellington so the opportunity exists to develop a volcanic heritage walk.

Although Te Hōpua Tuff ring as a whole does not represent a significant volcanic feature, the Project offers the opportunity to emphasise some aspects of Te Hōpua and enhance the area as a public amenity. This will enhance two of the factors for which it was identified as an ONF ((factors (g) and (h)).

7.2 Foreshore remnants and Pikes Point

Development of a walking/cycle path along the foreshore together with planned landscaping on the seaward side of the proposed highway will serve to enhance the appreciation of the volcanic nature of the northern foreshore of Māngere Inlet.

7.3 Anns Creek lava flows

Many volcanological features in this area have largely been modified by development; those that remain have been mapped as ONFs. The EWL Project largely avoids these features by appropriate siting of piers and careful planning of the construction phase.

Subject to access arrangements, an opportunity exists to create an accessible environmental/geological park in the Anns Creek Estuary area, linked by pathways toward the west, in which volcanological and other environmental features can be seen and interpreted.

If public access is possible for the Anns Creek West and east areas pathways and interpretative signs could emphasise their volcanic nature. Alternatively a pathway associated with the elevated roadway could allow viewpoints to achieve the same objective.

8 Conclusions

The Project will build an arterial road on and around volcanic features of the Auckland Volcanic Field. These features are Te Hōpua ā Rangi tuff crater and distal lava flows from One Tree Hill, Mt Smart and Mt Wellington volcanoes. Currently these features have been extensively modified by various forms of development and their value as examples of volcanic features has been much reduced as a consequence. Overall, the further impact of the proposed Project will be minor. An opportunity exists as a result of the Project to create positive outcomes. Recreational parks and connections could be improved with appropriate interpretive signage that will emphasise the volcanic nature of the northern Māngere Inlet and will increase public awareness about the existing volcanic features.

Appendix A

Figure 5-1

Overview figure showing locations of ONFs and lava outcrops along the Onehunga foreshore

GIS@beca.com
Scale: 1:20,000
0 125 250 500 750 1,000
Metres
Mutukaroa - Hamlins Hill
Anns Creek Estuary
Te Hopua
Anns Creek East
Pikes Point Outcrop
Victoria Street Outcrops
Legend
Indicative Location of Fill Material
Visible Lava Flows on Surface
Outstanding Natural Feature (PAUP Overlay)
EWL Alignment

Appendix B

Figure 5-3

Extent of mapped ONF at Te Hōpua and approximate crater rim location

GIS@beca.com
Scale: 1:4,000
0 25 50 100 150
Metres
Pearce Street
Newsome Street
Waller Street
Hill Street
Princes Street
Gloucester Park Road
Neilson Street
Galway Street
Selwyn Street
O'Rorke Street
Onehunga Mall
Orpheus Drive
State Highway 20
Onehunga Harbour Road
Legend
EWL Alignment
Rim
Outstanding Natural Feature (PAUP Overlay)

Appendix C

Figure 5-8

Extent of mapped ONF for Anns Creek lava flows

GIS@beca.com


Scale: 1:3,000
0 12.5 25 50 75 100
Metres
Southpark Place
Hugo Johnston Drive
Great South Road
Bell Avenue
Anns Creek East
Anns Creek West
Anns Creek Estuary
Lava flows feature 3-4mm thickness visible
Actual extent in this location unknown due to fill material on top of flow
Relatively unweathered lava flows
Pahoehoe feature
ONF Layer consistent with visible surface features
ONF Layer consistent with visible surface features
Legend
Indicative Location of Fill Material
Visible Lava Flows on Surface
Outstanding Natural Feature (PAUP Overlay)
EWL Alignment