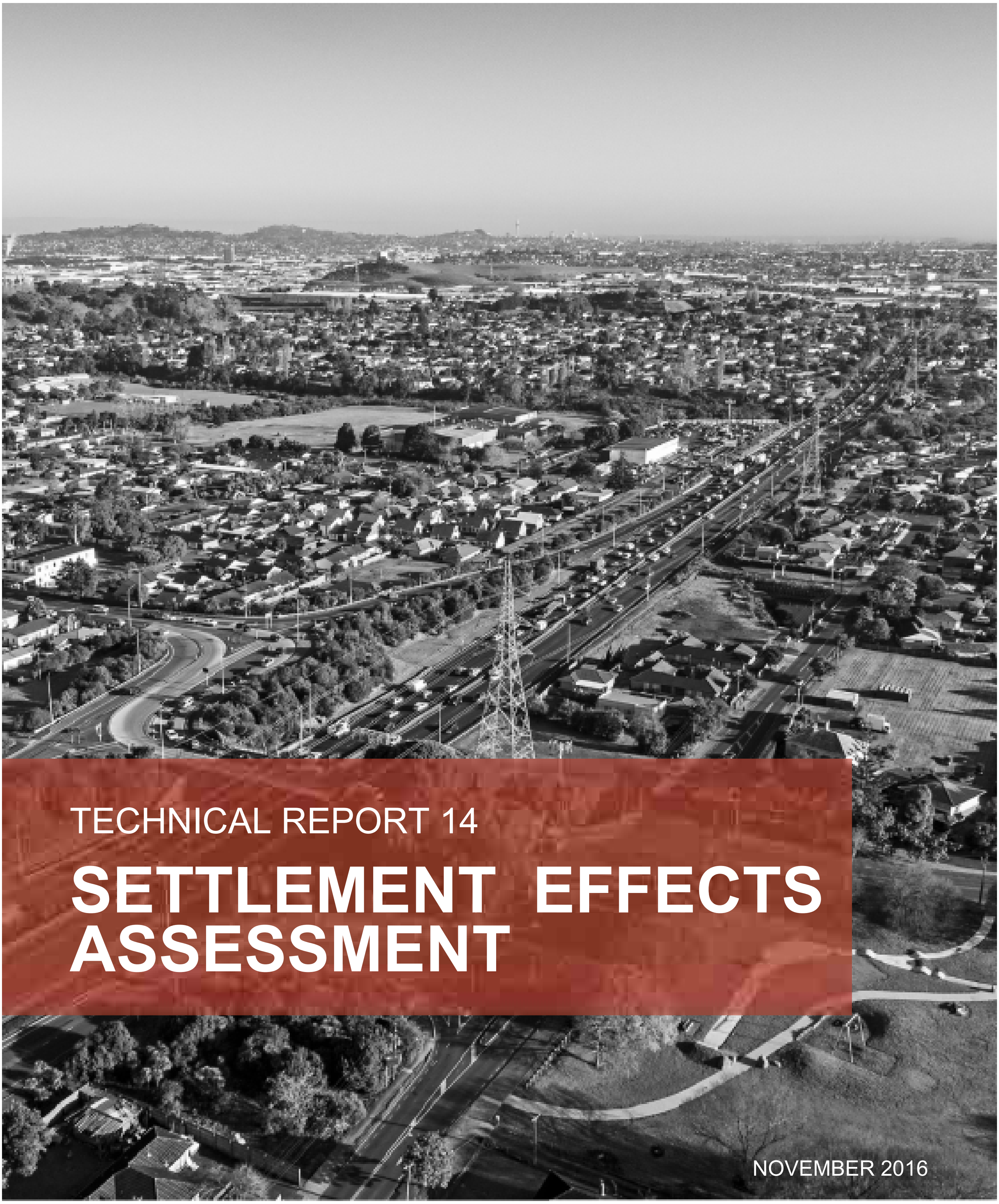

TECHNICAL REPORT 14

# SETTLEMENT EFFECTS ASSESSMENT

NOVEMBER 2016

NZ TRANSPORT AGENCY
WAKA KOTAHI

East West Link

| Quality Assurance Statement | |
|---|---|
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| Approved for release | Patrick Kelly (EWL Alliance Manager) |

| Revision schedule | | | | | |
|---|---|---|---|---|---|
| Rev. N° | Date | Description | Prepared by | Reviewed by | Approved by |
| 0 | November 2016 | Final for Lodgement | Dora Avanidou | Gavin Alexander | Patrick Kelly |

***Disclaimer***

# EXECUTIVE SUMMARY

1. This report presents the results of the assessment of the potential magnitude and effects of ground settlement (settlement) due to the construction of the East West Link.

## Existing environment

2. A series of site investigations and laboratory testing were undertaken to define the underlying geology in the Project area.
3. A 3-D subsurface ground model has been developed from existing and current field investigations to provide an understanding of the ground conditions in the Project area.
4. The majority of buildings in the Project area can be characterised as low-rise residential, commercial and industrial buildings.
5. Typical services networks, associated with residential and industrial areas of Auckland were identified in the Project area.
6. The area around the proposed alignment has a mix of typical local and trunk transportation infrastructure comprising roads and rail.
7. High voltage transmission lines pass along over the proposed alignment.

## Methodology

8. Ground settlement can be generated by three separate sources, consolidation or compression of the ground due to the construction of fills; mechanical settlement of the ground due to the movement of retaining walls; and consolidation of the ground due to lowering of the groundwater.
9. The compression, consolidation and mechanical settlements have been calculated using proprietary software at representative cross sections along the alignment, chosen at locations with possible settlement effects.
10. The area in which compression settlement will occur is mainly below the embankment/fill areas and extending a few meters beyond the footprint. Mechanical and consolidation settlement is expected to occur as a result of the East West Link Trench adjacent to Onehunga Wharf construction.
11. An initial screening has been used to eliminate buildings and utilities having negligible risk of settlement damage.

## Settlement effects

12. The calculated settlement resulting from the Project is very small when compared to deep excavation projects. As a result settlement effects beyond the Project footprint are expected to be negligible. More significant settlement leading to weathertightness or more serious effects is not expected.
13. None of the buildings considered required further study.
14. There are some locations where the Project works cross existing buried utilities where larger settlement is calculated. These utilities will either be protected from settlement or relocated so the residual effects will be negligible.

## Conclusions

15. The ground settlement beyond the immediate project footprint is calculated to be very small, typically in the range of 0-10mm. Adverse effects of such small settlements are expected to be nil to negligible.

16. Monitoring requirements for particularly sensitive infrastructure, expected to be railway lines and transmission towers on shallow spread foundations, will be developed in consultation with the utilities operators.

17. Monitoring during construction of the EWL Trench will be implemented to confirm calculated settlement in this location.

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## Glossary of Technical Terms/Abbreviations

| Abbreviation | Term |
|---|---|
| AEE | Assessment of Effects on the Environment |
| BoI | Board of Inquiry |
| EPA | Environmental Protection Authority |
| EWL | East West Link |
| EWLA | East West Link Alliance |
| GIR | Geotechnical Interpretive Report |
| The NZ Transport Agency | New Zealand Transport Agency |
| SH(x) | State Highway (number) |

## Glossary of Defined Terms used in this report

| Abbreviation | Term |
|---|---|
| Auckland Council | Means the unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010. |
| Earthworks | Means the disturbance of land surfaces by blading, contouring, ripping, moving, removing, placing or replacing soil, earth, or by excavation, or by cutting or filling operations. |
| Alignment | Means the route and designation footprint selected. This development involved specialist work assessing environmental, social and engineering inputs. |
| 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 the Project). Its purpose is to inform the Assessment of Effects on the Environment Report (AEE) and to support the resource consent applications, new Notices of Requirement and an alteration to existing designations required for the EWL.

This report assesses the settlement effects of the proposed alignment of the Project as shown on the Drawings in *Volume 2: Drawing Set*.

The purpose of this report is to:

1. Identify and describe the existing ground conditions;
2. Describe the potential ground settlement, and potential adverse ground settlement effects, of the Project;
3. Recommend measures as appropriate to avoid, remedy or mitigate potential adverse settlement effects (including any conditions/management plan required); and
4. Present an overall conclusion of the level of potential adverse settlement effects of the Project after recommended measures are implemented.

Ground settlement beyond the Project footprint is the focus of this assessment. Large settlement may occur within the footprint in some locations (where the alignment crosses refuse and no ground improvement is undertaken, for example) but that is a design issue. It is quantified for use in the overall design development and construction methodology (where it may impact material quantities, truck movements and construction form and duration), but is not included in this assessment except where it directly affects underlying utilities.

Similarly, ongoing decomposition related landfill settlement in areas where the Project does not apply significant new loading is not considered to be an effect of the Project. This is because that settlement will occur whether or not the Project is built.

## 1.2 Project description

The 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 port 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 and across 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 Plans in *Volume 2: Drawing Set*.

# 2 Experience

## 2.1 Expertise

Gavin Alexander is a Technical Fellow in Beca Limited's (Beca) Geotechnical Group based in Auckland. He holds a Bachelor of Civil Engineering from the University of Auckland (1986) and a Masters Degree in Soil Mechanics and Engineering Seismology from Imperial College, University of London (1991). Gavin is a New Zealand Chartered Professional Engineer, a Fellow of the Institution of Professional Engineers of New Zealand, and a Member of the New Zealand Geotechnical, Earthquake Engineering and Large Dam Societies. He is currently an ex officio member of the Management Committee of the New Zealand Geotechnical Society, and holds the role of Immediate Past Chair. Gavin has 34 years' experience in geotechnical and civil engineering, and over the past 30 years has provided geotechnical advice on a wide variety of civil, commercial, industrial, and land development projects in many parts of New Zealand, and in Australia and further afield. Of particular relevance, Gavin has provided advice on the Tauranga Eastern Link highway (TEL), and the Board of Inquiry hearings on the Waterview Connection Project (Waterview) and the MacKays to Peka Peka Expressway (M2PP).

The TEL project comprises a new four lane highway some 21km in length that cross very soft ground. Gavin was the lead geotechnical engineer for the early stages of the project, and reviewed the geotechnical work of his colleagues as it developed and was consented. Gavin's role on Waterview was focussed on the ground settlement effects from tunnel and retaining wall construction. It involved the estimation of the quantum of ground settlement resulting from the project and assessment of the effects of that settlement on houses, other structures and buried and surface infrastructure. His role on M2PP encompassed geotechnical team leadership and review through design development, consenting, and then through detailed design. He prepared the assessment of settlement effects for that project, with those effects dominated by consolidation and creep settlement of extensive areas of peat. The settlement at M2PP is largely caused by direct loading of peat (by new embankments) and to a lesser degree by construction and long term groundwater changes and the resulting consolidation.

Dora Avanidou is a Senior Hydrogeologist at Beca Ltd. She is a graduate of the Aristotle University of Thessaloniki, Greece with the degrees of Bachelor of Science and Master of Science in Civil and Environmental Engineering (1997). She completed the degrees of Master of Science and Doctor of Philosophy in Hydrogeology (2003). Dora has over 15 years of experience in infrastructure projects and environmental assessments in both urban and rural areas. In her role at Beca Dora has been leading the M2PP settlement monitoring programme, management and reporting, she has prepared the assessment of effects on AUT confidential development in Auckland and the monitoring and contingency plan to meet the resource consent conditions and she is assisting Auckland Council to peer review of AEEs and supporting technical documents in order to understand effects (drawdown, mechanical and consolidation settlement) on third parties.

# 3 Existing Environment

## 3.1 Ground conditions

A Desktop Gap Analysis was undertaken to identify and evaluate the spatial extent and the usefulness of existing geological data in order to develop a digital three dimensional subsurface ground model and refine the scope of the field investigations. Over 500 investigation records dating back over 30 years were identified and have been categorised on the basis of data quality to identify dependable data to be used in addition to the data gathered from current field investigations in the development of the ground model which is presented in the Geotechnical Interpretive Report (GIR).

A series of site investigations (Appendix A) and laboratory testing were undertaken to define the underlying geology in the Project area. Specifically 65 overland machine drilled boreholes, 12 overwater machine drilled boreholes, seven Geonor boreholes, 15 CPTs and 20 test pits were initially undertaken to provide soil and rock profile information, in situ strength data and samples for geotechnical and environmental testing. All but one of the overland boreholes were fitted with piezometers to monitor groundwater levels. Data and testing results are detailed in the East West Link Geotechnical Factual Report.

A 3-D subsurface ground model from existing and current field investigations was developed using the software Leapfrog® Geo 3.1. The ground surface used in that model was obtained from the project's GIS team (Auckland Council LIDAR 2014/2015) and is consistent with the surface used for civil and structural design of the project. Published geological maps (Kermode, 1966; Kemode and Searle, 1966; Kermode, 1992 and Edbrooke et al, 2001) were also used to assess the geology underlying the Project area. Details of the development of the subsurface ground model are provided in the Geotechnical Interpretive Report (GIR).

The Project area is located within the Waitematā basin, a sedimentary basin which formed as a result of tectonic subsidence some 20 million years ago. Sediments that accumulated in the basin came from erosion of the surrounding land mass and andesitic volcanism that was occurring to the west.

Continued subsidence of the basin and thickening of the basin-filling sediments resulted in consolidation, forming the weak sandstone and siltstone rocks of the Waitematā Group. A period of uplift caused deformation of the Waitematā Group rocks which resulted in variable topography across the basin.

From about six million years ago, deposition has occurred in the Auckland area, with sediments originating from predominantly terrestrial sources. The sediments are known as the Tauranga Group, and overlie the Waitematā Group across most of the Project area. The Tauranga Group comprises mainly pumiceous, terrestrial and minor estuarine deposits (silts, sands, gravels, clays, and peat).

The Project area is underlain by the Manukau Lava Field built largely of lava flows from One Tree Hill and Mt Smart volcanoes, but also from Mt Wellington volcano in the east. One Tree Hill is the oldest of these volcanoes and is understood to have erupted on a pre-existing land surface that is now well below sea-level in the mouth of a valley system. The Hōpua explosion crater (Gloucester Park) comprises an elevated tuff ring that was breached when sea-level rose; marine and organic muds were deposited within it. The breach was closed some 70 years ago and the tuff ring reclaimed with both urban refuse and fill. Details of volcanic features are provided in *Volume 3: Technical Report 4–Geological Heritage Assessment*.

Basalt lava and tuff overlie and are locally interbedded with a variable thickness of Tauranga Group alluvium, which comprises pumiceous silt, sand and gravel with muddy peat and non-welded and alluvially reworked ignimbrite and tephra.

The basalt flows are bound to the east by an uplifted block of Waitematā Group sandstone and siltstone, although some lava and tuff from Mt Wellington volcano have flowed around the block from the north-east in the area of Anns Creek.

Uncemented dense to vesicular sand to gravel sized basalt fragments are mapped as underlying the area between Alfred Street and Captain Springs Road and north to Patrick Street. The ash/tuff also forms a lobe between Angle and Edinburgh Streets extending into the foreshore.

Recent marine sediments (part of the latest Tauranga Group) overlie the Manukau Lava Field and older Tauranga Group soils at the coastal margin and offshore, and partially infill Hōpua crater (Gloucester Park).

The Onehunga Bay and Māngere Inlet foreshore have been progressively reclaimed with landfill and engineered fill extending some 500m inland from the present foreshore.

Waitematā Group rock underlies the north-eastern end of Anns Creek, the southern part of Great South Road and Sylvia Park Road. Lithic tuff, comprising broken up pre-volcanic materials, basalt fragments and unconsolidated ash and lapilli, is mapped as underlying the area between Abattoir Lane and Portage Road to SH1, north towards Sylvia Park Road and south to Ōtāhuhu Creek. The tuff is thought to be sourced from the Mt Richmond and McLennan Hills craters which last erupted some 30,000 years ago. Pumiceous mud, sand and gravel with muddy peat and lignite beds, non-welded ignimbrite, tephra and alluvially reworked tephra of the Puketoka Formation (also Part of the Tauranga Group) occur locally beneath part of SH1 adjacent to Sylvia Park and adjacent to Ōtāhuhu Creek.

Ground conditions specific to each sector are summarised in the GIR.

## 3.2 Buildings

The majority of the building stock within the Project area can be characterised as low-rise industrial, commercial and residential buildings. The stock of buildings comprises a number of construction types. For the purposes of assessing susceptibility to the effects of settlement buildings have been grouped into two types (Type A and Type B), which are defined below.

The buildings within the expected area of effects have been visually assessed to determine the structural form and susceptibility to settlement. The commercial and industrial buildings in the Onehunga area are low-rise and typically long span structures. Buildings in close proximity to the proposed work that may be affected have been assessed specifically. Ground movements associated with proposed retaining walls close to residential buildings have also being considered. The structural form of these buildings and assessed sensitivity to settlement effects are detailed in Appendix C, and summarised in Table 3-1 and Table 3-2.

The calculated settlement resulting from the Project is very small when compared to deep excavation projects. As a result settlement effects beyond the Project footprint are expected to be negligible to very slight (hairline to fine cracks at worst). More significant settlement leading to weathertightness or more significant effects is not expected.

In the summary Table 3-1, the sensitivity to movement is based on the following two categories:

Type A-May be susceptible to visual (hairline) cracking in the event of slight differential ground movement due to cladding type (i.e. unreinforced concrete block walls, brick and mortar, glass panels, plaster or stucco.

Type B–Not expected to be susceptible to visual cracking in the event of slight differential ground movement (i.e. timber, steel cladding and precast reinforced concrete walls/panels).

A similar approach has been adopted for residential dwellings (Table 3-2).

**Table 3-1: Existing commercial and industrial buildings summary**

| Building ID | Location | Description of Structural Form | Sensitivity to movement |
|---|---|---|---|
| B-ID1 | 2–2a Hill Street | Concrete blockwork and steel cladding | Type A |
| B-ID2 | 3–5 Gloucester Park Road | Reinforced concrete and steel cladding | Type B |
| B-ID3 | 2–6 Onehunga Harbour Road | Concrete walls (The Landing Restaurant and Bar), timber frame with plasterboard cladding (Airport Harbour View Motel and Apartments) | Type B/A |
| B-ID4 | 40 Victoria Street | Reinforced concrete panel structure | Type B |
| B-ID5 | 69 Captain Springs Road | Reinforced concrete with steel cladding | Type B |
| B-ID6 | 59 Miami Parade | Steel portal frame “car port” | Type B |
| B-ID7 | 138 Hugo Johnston Drive | Reinforced concrete with localised glass panel facade | Type B |
| B-ID8 | 5 Monahan Road | Reinforced block with steel clad. Steel shed structure | Type A |
| B-ID9 | 7 Carmont Place | Reinforced concrete panel and steel cladding | Type B |
| B-ID10 | 11 George Bourke Drive | Reinforced concrete panels and steel cladding | Type B |
| B-ID11 | 63 Angle Street | Concrete block (unreinforced) with steel cladding and roof | Type B |

**Table 3-2: Existing residential buildings summary**

| Building ID | Location | Description of Structural Form | Sensitivity to movement |
|---|---|---|---|
| B-ID12 | 112 Hillside Road | Two storey building with plasterboard finish | Type A |
| B-ID13 | 110 Hillside Road | Single storey weatherboard dwelling | Type B |
| B-ID14 | 16 Coppins Road | Single storey weatherboard dwelling | Type B |
| B-ID15 | 14 Coppins Road | Single storey weatherboard dwelling | Type B |
| B-ID16 | 14a Coppins Road | Single storey weatherboard dwelling | Type B |
| B-ID17 | 31/31a Frank Grey Place | Single storey weatherboard dwelling | Type B |
| B-ID18 | 95 Princes Street | Single storey weatherboard dwelling | Type B |

Similar to other major infrastructure projects in the Auckland region (i.e. Waterview, CRL) the analyses have assumed that there will be no settlement of rock (Basalt or Waitematā Group) therefore buildings that are founded in basalt have not been assessed.

## 3.3 Services

The Project runs along residential and industrial areas of Auckland which has typical services networks associated with it. Services located within the Project and their typical construction comprise:

- Sanitary and combined sewers–brick, concrete, asbestos concrete, vitrified clay;
- Stormwater–Concrete, asbestos concrete;
- Watermains–Cement-lined steel, steel, polyethylene (PE);
- Gas–PE, steel;
- Communications–Bundled copper networks, cable in PVC/PE duct, fibre optic in PVC/PE duct; and

- Power–High voltage transmission towers, direct buried cable, cable in PVC/PE duct.

The age and condition of these services vary greatly. Meetings have been held with representatives from all utility owners and investigations are ongoing into the condition of the services. Preliminary service plans have been prepared based on as-built information received. Discussions are ongoing with each of the service providers.

## 3.4 Transportation infrastructure

The area around the proposed alignment has a mix of typical local and trunk transportation infrastructure comprising roads and rail. The South Auckland rail line runs approximately parallel to the proposed alignment along Sylvia Park Road and also crosses the alignment or area of proposed works at CH4320-4450 Anns Creek Bridge, close to the Great South Road/Sylvia Park Road Intersections and at the SH1 ramps.

# 4 Methodology for Assessing Effects

Initial assessments were based on familiarity with the general area, together with the findings from published literature and earlier subsurface investigations. In early June 2016 and following completion of the first phase of detailed geotechnical investigations undertaken specifically for this Project, all parts of the site were inspected visually to assess buildings/ structures within the expected area of effects, to determine the structural form and likely susceptibility to settlement.

This assessment is based on an initial subsurface ground model supplemented where necessary with the results from specific geotechnical investigations.

Furthermore this assessment relies on data and investigations as follows:

- Technical Report 4–Geological Heritage Assessment;
- Technical Report 13–Assessment of Groundwater Effects;
- East West Link geotechnical design;
- Section 8 of the AEE: Construction of the Project;
- Section 12.4 of the AEE: Network Utilities;
- Geotechnical and Geoenvironmental Factual Report; and
- Geotechnical Interpretive Report (GIR).

There are three potential sources of settlement associated with the construction and operation of the Project.

**1. Consolidation or compression of the ground due to the construction of fills**

This is of significance when fill is placed on the weak underlying non engineered fill and, urban refuse (landfills), soft recent marine sediments and, possibly, undifferentiated Tauranga Group deposits. The consolidation settlements are time-dependant, and are directly related to the nature, thickness and permeability of the underlying materials. The majority of the settlement will occur during the construction period, with ongoing secondary consolidation and creep settlements continuing at a reducing rate through operation. This is the primary source of settlement effects resulting from the Project.

**2. Mechanical settlement of the ground due to the movement of retaining walls**

This settlement results from movement of the wall as it is loaded. The load is applied as material is either excavated in front of the wall or is backfilled behind it. The lateral displacement most commonly translates to a vertical settlement above the wall, and will occur in close proximity to the rear of the wall. These settlements will occur relatively quickly, during or immediately following wall construction. This mechanism of settlement is most significant in Sector 1, Neilson Street Interchange, where a trench is proposed to be constructed. Where retaining walls are used to support fill in areas of relatively weak ground there is also the potential for ground settlement to occur below and beyond the toe of the wall. This case is covered under item (1) above.

**3. Consolidation of the ground due to lowering of the groundwater**

Temporary lowering of the existing groundwater level may occur during construction due to the excavation of foundation materials. These changes in groundwater regime are detailed in the *Technical Report 13-Assessment of Groundwater Effects*. Lowering of the groundwater level can cause a reduction in pore water pressure and therefore an increase in effective overburden pressure. This can result in compression of the fill, marine sediments or Tauranga Group deposits over time. Consolidation settlement is time-dependant, and depends upon the amount of groundwater drawdown, and the nature, thickness and permeability of the underlying material and the existing seasonal variation in groundwater levels. The Project extends below groundwater level in Sector 1, Neilson Street Interchange, where construction of a trench is required, using secant pile walls.

The groundwater model indicates a small mounding (~10cm) north of the trench (Gloucester Reserve area) and a smaller drawdown (5cm) south of the trench. These effects are within the likely seasonal range, so are not expected to lead to ground settlement. The other area where the Project extends below groundwater level is where landfill leachate collected and associated cut off measures are proposed. This work will be undertaken in short lengths, limiting groundwater and resulting settlement effects. As a result of the above this source of settlement is not expected to be significant.

The analyses have assumed that there will be no settlement of rock (Waitematā Group siltstone/sandstone, basalt) as the particle matrix will substantially carry the change in load. Conversely the refuse material which underlies part of the Project is subject to ongoing settlement irrespective of loading or groundwater changes. This mechanism has been considered in the Project design but is not an effect of the Project. That settlement will occur whether or not the Project is built.

Unlike tunnelling and deep excavation projects where groundwater changes during construction can lead to large and laterally extensive ground settlement, this largely surface based project is expected to result in settlement predominantly caused by the direct effect of new fills and the EWL Trench, source (1 and 2) above.

Mechanical and consolidation settlement has been analysed as separate components at selected cross sections along the length of the proposed alignment, where possible effects have been identified (e.g. buildings in close proximity to retaining walls, fill over landfills close to railway lines etc). The calculated settlements have been used to develop settlement contours beyond the Project footprint shown on the plans in Appendix B.

The magnitude of settlement from the three potential sources has been assessed using the following techniques, similar to other major infrastructure projects (e.g. Waterview, M2PP):

- Mechanical settlement resulting from wall movement–embedded pile walls using proprietary software (WALLAP), then published relationships between ground settlement and wall height/movement (CIRIA Report No. C580 “Embedded retaining walls–guidance for economic design”);
- Consolidation or compression due to fill loading–settlement calculated using proprietary software (SETTLE 3D). Settlement on landfills was also calculated with the method described by Wong et al (2013). The paper presents a method to estimate long term settlement on landfills and the effect of additional surcharge due to afteruse development;
- Consolidation settlement due to groundwater lowering–groundwater changes assessed by the groundwater team have been used to calculate resulting consolidation settlement using proprietary software (SETTLE 3D) adopting a coefficient of volume compressibility “mv” approach. Such settlement is possible at the Sector 1 trench, though groundwater effects are sufficiently small that measurable settlement from this mechanism is not expected;
- The geotechnical parameters used to predict settlements have been derived from laboratory data, in situ testing as well as historic data and are summarised in the Table 4-1. These information sources are detailed in the GIR.

**Table 4-1: Geotechnical parameters**

| Description | Unit Weight, γ' | Undrained shear strength, Su | Cohesion c' | Friction angle, φ' | Stiffness, E | Compression Index Parameter Cc/(1+e0) | Mv | Cv |
|---|---|---|---|---|---|---|---|---|
| | (kN/m$^3$) | (kPa) | (kPa) | (◦) | (MN/m$^2$) | (%) | m$^2$/MN | m$^2$/yr |
| Existing Fill | 18 | - | 0 | 30 | 20 | - | - | - |
| Recent Marine Sediments | 16 | 12 | - | - | 2 | 20 | 0.3-0.6 | 3.0 |
| Tauranga Group, SILTS | 18 | 50-70 | 2 | 28 | 10-15 | 5-10 | 0.05-0.1 | 5.0 |
| Tauranga Group, SANDS | 18 | - | 0 | 30 | 20 | - | - | - |
| Tauranga Group, Peat/ Organics | 14 | 25 | 2 | 25 | 10 | 20 | 0.3-0.6 | 0.5 |
| Imported Fill/Hardfill | 20 | - | 5 | 35 | - | - | - | - |

To assess the effects of the settlement on buildings, services and other features, ground movement has been calculated at individual locations. To produce results that are directly comparable to one another, the settlement from each source has been calculated at points located on a consistent set of cross sections along the Alignment. These cross sections were chosen to provide representative examples of the relevant geology, hydrogeology and construction types proposed, at locations with possible settlement effects, while retaining a good coverage of the entire alignment.

The cross-section locations that have been analysed are detailed in Table 4-2 and also shown on in Appendix B. A summary table and the calculated settlement versus distance are plotted for each cross section and are presented in Appendix C. Settlement contours have been developed from the results at representative locations and are shown on settlement plans attached in Appendix B.

**Table 4-2 Settlement analyses cross section locations**

| Sector Number | Sector Name | Location | Cross Section | Settlement Source |
|---|---|---|---|---|
| 1 | Neilson Street IC | CH 00 | 1–1' | Undercut then construction of fill and Retaining Wall S1/RW1 |
| 1 | Neilson Street IC | CH 80 | 2–2' | Open Cut, S1B stormwater wetland |
| 1 | Neilson Street IC | CH 475 | 3–3' | Undercut then construction of fill and Retaining Wall S1/RW4 |
| 1 | Neilson Street IC | CH 725 | 4–4' | Undercut then construction of trench walls (secant piles walls) |
| 6 | Local Works | Captain Springs Rd | 5–5' | Cut in landfill |
| 3 | Anns Creek | CH 4420 | 6–6' | Undercut then construction of fill and Retaining Wall S3/RW3 and S3/RW4 |
| 3 | Anns Creek | Hugo Johnston Drive | 7–7' | Construction of fill and S3A wetland |
| 3 | Anns Creek | CH 5050 | 8–8' | Undercut then construction of fill and Retaining Wall S3/RW9 – extension of rail overbridge |

| Sector Number | Sector Name | Location | Cross Section | Settlement Source |
|---|---|---|---|---|
| 3 | Anns Creek | Great South Road | 9–9’ | Undercut then construction of fill and Retaining Wall S3/RW7 and S3/RW7 |
| 5 | State highway | Hillside Road<br>CH 7150 | 10-10’ | Construction of fill |
| 5 | State highway | Frank Grey Place | 12–12’ | Undercut then construction of fill and Retaining Wall S5/RW23 |
| 5 | State highway | SH1 Princes Street Southbound ramp | 13–13’ | Undercut then construction of fill and Retaining Wall S5/RW28 |
| 5 | State highway | Princes Street | 14–14’ | Construction of abutment of Panama bridge |

### 4.1.1 Buildings

The total settlement profile has been calculated at the selected sections. The method of Burland (2012) has been used to assess the severity of effects on nearby buildings. The approach upon which this paper is based is most commonly used in international references.

An initial screening has been used to eliminate buildings having negligible risk. The cut off used for this screening is a maximum slope of 1/500 and a building settlement of 10mm. These limits are considered by Burland to provide a conservative basis for identifying buildings requiring further study. None of the buildings considered required further study.

Had greater settlement been predicted for each of the settlement profiles, an arbitrary building is assumed to “bend” to follow the predicted ground shape. The maximum tensile strain arising in the building as a result of this profile is calculated and combined with the predicted horizontal strain at the same location, using the method described by Burland 2012. The resulting maximum tensile strain is then compared to the limiting strains that correspond to thresholds or categories of damage. In Appendix E, Table 11.1 shows the limiting strains that are typically adopted and overviews an objective system for the classification of damage providing the link between estimated building deformations and the possible severity of damage. Table 11.2 (Appendix E) assigns a description of typical damage, severity and ease of repair to each of the categories described.

These categories, and the associated descriptions, have been used as the basis of settlement effects assessments for many recent major projects in Auckland (e.g. Waterview, CRL). There is some difference of opinion regarding the building damage category that corresponds to “less than minor” effects. For Waterview, Category 0 (negligible) was adopted. For CRL, Category 2 (slight) was used. For this project, where settlement beyond the Project footprint is not expected to be extensive, we have adopted the conservative (Category 0, Negligible) approach.

### 4.1.2 Services

Settlement can affect services due to change in grade and horizontal strain (i.e. elongation). The ability of a service to withstand this change in grade and strain is depending on the construction material, the type of joints used for the components, the age, and the condition of the service. There are a number of existing services crossing or in close proximity to the proposed works with the potential to be impacted by settlement. These services include water, wastewater and stormwater networks, electricity and gas distribution, and telecommunications. Refer to section 12.4 of the AEE: Network utilities for details. Total settlement contours (including those beneath the Project footprint) have been overlain on the services plans (Appendix B).

The sensitivity to movement depends on the construction type, age and condition of service. The main services of concern are expected to be older piped services constructed of brick, glazed earthenware and asbestos cement which are likely to have the least ability to absorb movement. Discussions are ongoing with the utility owners regarding the existing condition of their assets, their ability to tolerate the estimated settlement values and monitoring and mitigation options.

Much of the Auckland isthmus is subjected to seasonal ground movement (settlement in summer, heave in winter) of up to 25mm with little apparent effect on shallow buried services. This is assumed to indicate an upper bound to an assessment of nil to negligible settlement effect on services.

#### 4.1.3 Transport infrastructure

The assessment of effects on the existing road network and railway track comprises overlaying the estimated settlement contours over the roads and rail, and determining changes to the gradients of those assets. The effect of those changes in gradient on each road and the railway was then assessed, and monitoring and potential mitigation options proposed, if required.

# 5 Estimated Project Ground Settlement Effects

## 5.1 Settlement effects overview

Overviews of the design and proposed construction methodology for the embankment and retaining walls for each sector are provided in Sections 9 (Description of the Project) and 10 (Construction of the Project) of the AEE. Settlement will occur over the construction period and in some areas will continue on into the operational phase of the Project at reducing rates. Mechanical settlement from the construction of retaining walls will occur during the construction phase. This assessment considers the potential effects based on the estimated settlements that give the highest risk of damage. For example, relatively small short term settlement that varies over a short length is often more damaging than larger area wide settlement.

In areas of particular sensitivity the monitoring regime described in Appendix F will provide on-site confirmation of the rate and magnitude of settlement.

### 5.1.1 Buildings

For the commercial/industrial and residential buildings identified in section 4.2 (Table 4-1 and Table 4-2) visual assessment of structural elements and construction type has been undertaken to assess potential building damage (as defined in Appendix B, Table 2 and based on Burland, 2012). The effects on those buildings are discussed in each sector below. In all cases the calculated settlement is less than 10mm, so the assessed building damage category is “Negligible” and no further assessment or monitoring conditions are warranted.

### 5.1.2 Services

The predicted total settlement contours have been combined with the as-built service drawings to show the potential settlement effects on services that will not be relocated as part of the Project. The services that need protection as they are located below or at the footprint of works and that are not intended to be relocated are identified in the plans on Appendix B (details are provided in section 12.4 of the AEE).

Baseline monitoring in other large infrastructure projects in Auckland has measured seasonal ground movement (settlement in summer, heave in winter) of up to 25mm with little apparent effect on shallow buried services. This is assumed to indicate an upper bound to an assessment of nil to negligible settlement effect on services, unless the utility owner has alternative requirements.

The services located outside the proposed earthworks extents are likely not to be affected due to relatively small changes in grade and horizontal strain, as indicated on the settlement contours plans (Appendix B).

### 5.1.3 Transport infrastructure

**Roads**

The assessment of effects indicates that the changes in road gradients as a result of the estimated settlement will typically be negligible with calculated level changes to roads which are not being reconstructed as part of the Project being less than 10mm.

**Rail**

The rail runs parallel to and crosses the Project works at part of Anns Creek Bridge and south of Great South Road/Sylvia Park Road Intersection. The railway is not within the area of predicted settlements, therefore the settlement effect on the railway line is considered to be negligible. Settlement monitoring will be used to confirm that detectable settlements do not extend to the railway.

## 5.2 Sector 1–Neilson Street Interchange

### 5.2.1 Buildings

The buildings outlined in Table 5-1 are assessed to have a “negligible” building damage category, as the calculated settlement arising from the Project is less than 10mm. The effects on building B-ID4 have been assessed as negligible as the cut is above the existing groundwater table and no drawdown and hence consolidation settlement is expected.

**Table 5-1: Building settlement summary**

| Building ID | Location | Calculated Settlement at closest point (mm) | Building Damage Category |
|---|---|---|---|
| B-ID 1 | 2–2a Hill St | <<10 | Negligible |
| B-ID 2 | 3–5 Gloucester Park Rd | <<10 | Negligible |
| B-ID 3 | 2–6 Onehunga Harbour Road | <<10 | Negligible |
| B-ID 4 | 40 Victoria St | Nil | Negligible |

The buildings at 2-6 Onehunga Harbour Road (B-ID 3) will be monitored for settlement as a precautionary measure.

### 5.2.2 Services

Baseline monitoring in other large infrastructure projects in Auckland has measured seasonal ground movement (settlement in summer, heave in winter) of up to 25mm with little apparent effect on shallow buried services. This is assumed to indicate an upper bound to an assessment of nil to negligible settlement effect on services, unless the utility owner has alternative requirements. Where greater values of settlement are estimated, services will be relocated or protected as agreed with the utility owner as identified in Table 5-2.

**Table 5-2: Services summary**

| Service ID | Service Type | Material | Calculated Settlement | | Calculated Gradient Range |
|---|---|---|---|---|---|
| | | | Total (mm) | Differential (mm) | |
| S-ID 1 | Transpower ROS-PEN-A (110kV)–TWR 21 | Steel tower. Foundations unconfirmed | <<10 | <<10 | <1/5,000 |
| S-ID 2 | Watercare 900mm | Reinforced concrete | <10 | <10 | <1/2,000 |
| S-ID 3 | Transpower ROS-PEN-A (110kV)–T5WR 20 | Steel tower. Foundations unconfirmed | <10 | <10 | <1/2,000 |
| S-ID 4 | Vector fibre | Assumed ducted | <10 | <10 | <1/2,000 |
| S-ID 5 | Vector MV | Assumed ducted | <10 | <10 | <1/2,000 |
| S-ID 6 | Watercare 150mm wastewater | Asbestos concrete | <10 | <10 | <1/2,000 |
| S-ID 7 | Watercare 100mm watermain | Cement lined cast iron | <10 | <10 | <1/2,000 |

| Service ID | Service Type | Material | Calculated Settlement | | Calculated Gradient Range |
|---|---|---|---|---|---|
| | | | Total (mm) | Differential (mm) | |
| S-ID 8 | 1350mm and 900mm stormwater | Assumed concrete | <10 | <10 | 1/500 to 1/1,000 |
| S-ID 9* | Vector MV and LV to be undergrounded | Unconfirmed | 70 | 60 | 1/500 to 1/1,000 |
| S-ID 10* | 450mm stormwater | Concrete | 70 | 60 | >1/250 |
| S-ID 11 | Vector gas 3" main | Unconfirmed | 25 | 15 | 1/500 to 1/1,000 |
| S-ID 12 | Vodafone fibre optic | Assumed ducted | 25 | 15 | 1/250 to 1/500 |
| S-ID 13 | 1800mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| * Services to be protected or relocated | | | | | |

### 5.2.3 Transport infrastructure

**Roads**

The assessment of effects indicates that the changes in the gradients of roads which will not be rebuilt as part of the Project be less than minor with calculated level changes less than 10mm.

**Table 5-3: Existing roads**

| Road Section ID | Location | Calculated settlement Total (mm) | Significance of effect |
|---|---|---|---|
| 1 | SH20 at Gloucester Park | <10 | Negligible |
| 2 | Neilson Street/Gloucester Park Road intersection | <10 | Negligible |

## 5.3 Sector 2–Foreshore works

### 5.3.1 Buildings

The building outlined in Table 5-4 is assessed to have a "negligible" building damage category, as the calculated settlement arising from the Project is less than 10mm.

**Table 5-4: Building settlement summary**

| Building ID | Location | Calculated Settlement at closest point (mm) | Building Damage Category |
|---|---|---|---|
| B-ID 6 | 59 Miami Parade | <10 | Negligible |

### 5.3.2 Services

Baseline monitoring in other large infrastructure projects in Auckland has measured seasonal ground movement (settlement in summer, heave in winter) of up to 25mm with little apparent effect on shallow buried services. This is assumed to indicate an upper bound to an assessment of nil to negligible settlement effect on services, unless the utility owner has alternative requirements. Where greater values of settlement are estimated, services will be relocated or protected as agreed with the utility owner as identified in Table 5-5.

**Table 5-5: Services summary**

| Service ID | Service Type | Material | Calculated Settlement | | Calculated Gradient Range |
|---|---|---|---|---|---|
| | | | Total (mm) | Differential (mm) | |
| S-ID 14* | 1500mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 15* | 1650mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 16* | 1800mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 17** | 900mm stormwater | Concrete | 100 | 90 | >1,250 |
| S-ID 18* | Twin 1050mm and 1650mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 19* | 900mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 20* | 1800mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 21* | 1800mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| S-ID 22* | 1200mm stormwater | Concrete | <<10 | <<10 | <1/5,000 |
| * Embankment over ground improvement is not expected to have settlement with underlying basalt | | | | | |
| ** Services to be protected/relocated | | | | | |

### 5.3.3 Transport infrastructure

**Roads**

Local roads in Sector 2 are not expected to be affected by ground settlement owing to their distance from the construction and / or the nature of works proposed.

### 5.3.4 Effects on landfill surface

The landfill sites along the alignment have been filled in a relatively uncontrolled manner. They are considered to be aged landfills, nearing the final stages of decomposition. Ongoing decomposition and residual /creep settlement in the range of 100 – 200mm over 100 years has been estimated for 3m landfill thickness. The relatively uncontrolled placement means the refuse is likely to be inherently inconsistent. As a result, ongoing settlement may vary markedly, in some cases over a very short distance.

Ongoing decomposition related landfill settlement will occur beyond and beneath the Project footprint. That settlement will occur whether or not the Project is built, so is not considered to be an effect of the Project. No additional effect is expected to occur as a result of the project. If groundwater (leachate) levels were to be markedly and permanently lowered as a result of the Project, decomposition of refuse may accelerate, and additional primary settlement may occur. Significant lowering of leachate levels is not anticipated, so this effect is not expected to develop.

The effect of ongoing decomposition related settlement of refuse below the piled roadway is expected to be reduced to some degree by pile skin friction, supporting adjacent material. The piled hardfill raft is designed to protect the refuse from new loading and to isolate the road surface from residual settlement within the refuse.

## 5.4 Sector 3-Anns Creek

### 5.4.1 Buildings

The building outlined in Table 5-6 is assessed to have a "negligible" building damage category, as the calculated settlement arising from the Project is less than 10mm.

**Table 5-6: Building settlement summary**

| Building ID | Location | Calculated Settlement at closest point (mm) | Building Damage Category |
|---|---|---|---|
| B-ID 7 | 138 Hugo Johnston Drive | <<10 | Negligible |

### 5.4.2 Services

Baseline monitoring in other large infrastructure projects in Auckland has measured seasonal ground movement (settlement in summer, heave in winter) of up to 25mm with little apparent effect on shallow buried services. This is assumed to indicate an upper bound to an assessment of nil to negligible settlement effect on services, unless the utility owner has alternative requirements. Where greater values of settlement are estimated, services will be relocated or protected as agreed with the utility owner, as identified in Table 5-7.

**Table 5-7: Services summary**

| Service ID | Service Type | Material | Calculated Settlement | | Calculated Gradient Range |
|---|---|---|---|---|---|
| | | | Total (mm) | Differential (mm) | |
| S-ID 23 | Vector comms fibre optic | Ducted | <<10 | <<10 | <1/5,000 |
| S-ID 24 | Chorus 2*cables | PVC ducted | <10 | <10 | <1/2,000 |
| S-ID 25 | Chorus 2*cables | PVC ducted | <10 | <10 | <1/2,000 |
| S-ID 26 | Vector gas fibre optic | Assumed ducted | <10 | <10 | <1/2,000 |
| S-ID 27 | Watercare wastewater pipe weir | Assumed concrete | <10 | <10 | 1/500 to 1/1,000 |
| S-ID 28* | Chorus 8 fibre cables | 24 ducts, 8 occupied, 16 spare | 100 | 90 | >1/250 |
| S-ID 29 | Chorus 4*100mm copper and fibre | PVC ducted | 25 | 15 | <1/2,000 |
| S-ID 30 | Watercare eastern interceptor siphon dual 1700mm pipes | Assumed concrete | <<10 | <<10 | <1/5,000 |
| S-ID 31 | Watercare wastewater scour valve | Assumed concrete | <<10 | <<10 | <1/5,000 |
| * Services to be protected/relocated | | | | | |

### 5.4.3 Transport infrastructure

**Roads**

Local roads in Sector 3 are not expected to be affected by ground settlement owing to their distance from the construction and/or the nature of works proposed.

**Rail**

The rail runs parallel to and crosses the Project works at part of Anns Creek Viaduct and at Great South Road on this sector. The railway lies beyond the area of predicted settlements, therefore the settlement effect on the railway line is considered to be negligible. Settlement monitoring will be used to confirm no detectable settlements extend to the railway.

## 5.5 Sector 4–Great South Road to State Highway 1

### 5.5.1 Buildings

There are no buildings in close proximity to project works that have the potential to be affected by settlement from the Project.

### 5.5.2 Services

Services in Sector 4 are not expected to be affected by ground settlement owing to the widespread presence of basalt or Waitematā Group rock close to or at the ground surface and the nature of the proposed construction work.

### 5.5.3 Transport infrastructure

**Roads**

Local roads in Sector 4 are not considered to be affected by ground settlement owing to their distance from the construction and/or the nature of works proposed.

**Rail**

The rail runs parallel to Sylvia Park Road on this sector. The railway is not within the area of predicted settlements, therefore the potential settlement effect on the railway line is considered to be negligible.

## 5.6 Sector 5–State Highway 1

### 5.6.1 Buildings

The buildings outlined in Table 5-8 are assessed to have a “negligible” building damage -category, as the calculated settlement arising from the Project is less than 10mm.

**Table 5-8: Building settlement summary**

| Building ID | Location | Calculated Settlement at closest point (mm) | Building Damage Category |
|---|---|---|---|
| B-ID 8 | 5 Monahan Road | Nil | Negligible |
| B-ID 9 | 7 Carmont Place | Nil | Negligible |
| B-ID 10 | 11 George Bourke Drive | Nil | Negligible |
| B-ID 12 | 112 Hillside Road | <<10 | Negligible |

| Building ID | Location | Calculated Settlement at closest point (mm) | Building Damage Category |
|---|---|---|---|
| B-ID 13 | 110 Hillside Road | <<10 | Negligible |
| B-ID 14 | 16 Coppins Road | Nil | Negligible |
| B-ID 15 | 14 Coppins Road | Nil | Negligible |
| B-ID 16 | 14a Coppins Road | Nil | Negligible |
| B-ID 17 | 31/31a Frank Grey Place | <10 | Negligible |
| B-ID 18 | 95 Princes Street | <10 | Negligible |

### 5.6.2 Services

Baseline monitoring in other large infrastructure projects in Auckland has measured seasonal ground movement (settlement in summer, heave in winter) of up to 25mm with little apparent effect on shallow buried services. This is assumed to indicate an upper bound to an assessment of nil to negligible settlement effect on services, unless the utility owner has alternative requirements.

**Table 5-9: Services summary**

| Service ID | Service Type | Material | Calculated Settlement | | Calculated Gradient Range |
|---|---|---|---|---|---|
| | | | Total (mm) | Differential (mm) | |
| S-ID 32 | Vodafone Fibre | Ducted | <<10 | <<10 | <1/5,000 |
| S-ID 33 | Chorus 2*50mm | Ducted | 20 | 10 | <1/2,000 |
| S-ID 34 | Vector MV and LV | Assumed ducted | 20 | 10 | <1/2,000 |

### 5.6.3 Transport infrastructure

**Roads**

The assessment of effects indicates that the changes in the gradients of roads which will not be rebuilt as part of the Project will be less than minor with calculated level changes less than 10mm.

**Table 5-10: Existing roads summary**

| Road Section ID | Location | Calculated settlement Total (mm) | Significance of effect |
|---|---|---|---|
| 3 | Junction of Panama Road and McLennan Road | <10 | Less than minor |
| 4 | Junction of Panama Road and Hillside Road | <10 | Less than minor |
| 5 | Limit of works–west end of Panama Road | <<10 | Less than minor |
| 6 | Panama Road Cul-de-sac adjacent SH1 southbound | Nil | Less than minor |
| 7 | Mataroa Road–parallel to southbound SH1 | Nil | Less than minor |
| 8 | Deas Place and Luke Street East – parallel to southbound SH1 | Nil | Less than minor |

| Road Section ID | Location | Calculated settlement Total (mm) | Significance of effect |
|---|---|---|---|
| 9 | Limit of works–east end of Princes Street East | <10 | Less than minor |
| 10 | SH20 | <10 | Less than minor |

## 5.7 Sector 6–Local Works

The buildings outlined in Table 5-11 are assessed to have a “negligible” building damage category, as the calculated settlement arising from the Project is less than 10mm.

**Table 5-11: Building Settlement Summary**

| Building ID | Location | Calculated Settlement at closest point (mm) | Building Damage Category |
|---|---|---|---|
| B-ID 5 | 69 Captain Springs Road | <10 | Negligible |
| B-ID 11 | 63 Angle Street | <10 | Negligible |

### 5.7.1 Services

Services in Sector 6 are not expected to be affected by ground settlement owing to their distance from the construction and / or the nature of works proposed.

### 5.7.2 Transport Infrastructure

**Roads**

Local roads in Sector 6 are not expected to be affected by ground settlement owing to their distance from the construction and / or the nature of works proposed. Existing local roads that cross landfills will experience ongoing decomposition related settlement as described in section 5.3.4. The new port link road will be built on a reinforced hardfill raft at similar levels to existing. As a result, it will experience settlement that would occur without the project but will not cause significant additional settlement.

# 6 Assessment of Potential Adverse Settlement Effects

Overall, only negligible settlement effects have been identified from the analysis of the Project. This results from the Project largely comprising above or on ground works, with little construction work extending below groundwater level. As a result, settlement primarily arises from the direct response of foundation soils to loading from new fills or structures. The effects of such loading are largely experienced beneath the loaded area, and do not extend far beyond it.

The EWL Trench does extend below groundwater level (leading to possible consolidation settlement), and excavation of it will lead to retaining wall deflection and mechanical settlement. The magnitude of settlement effects on nearby building and infrastructure has been assessed and it is concluded that the effects will be negligible.

On-going decomposition related landfill settlement will occur beyond and beneath the Project footprint. That settlement will occur whether or not the Project is built, so is not considered to be an effect of the Project. Long term groundwater (leachate) lowering in the landfills is not expected to be significant so accelerated decomposition or additional primary settlement is not anticipated.

# 7 Recommendations

Ground settlement beyond the Project footprint is calculated to be minimal, and as a result the effects are assessed to be negligible. No settlement mitigation is therefore required. There are however some areas where even very small settlement can be critical, and close liaison with the relevant utilities owners will be required through design and construction.

Rail lines and shallow founded transmission towers will need to be monitored, utilities operators consulted, and some additional utilities may need to be relocated or protected.

The EWL Trench adjacent to Onehunga Wharf excavation has the potential to cause both mechanical and consolidation settlement extending a modest distance from the structure. While the effects on nearby buildings and infrastructure have been assessed as negligible, monitoring of reference sections and buildings is proposed to confirm that is the case.

# 8 Conclusion

The ground settlement beyond the immediate Project footprint is calculated to be very small, typically in the range of 0-10mm. Adverse effects of such small settlements are expected to be nil to negligible, i.e. less than minor.

There are some locations where the Project works cross existing buried utilities where larger settlement is calculated. These utilities will either be protected from settlement or relocated, so the residual effects will be negligible.

Monitoring requirements for particularly sensitive infrastructure, expected to be railway lines and transmission towers on shallow spread foundations, will be developed in consultation with the utilities operators. Monitoring during construction of the EWL Trench adjacent to Onehunga Wharf will be implemented to confirm the conclusions of this assessment, that the effects in nearby buildings and infrastructure will be negligible.

# 9 References

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## Appendix A

# Site Investigations Location Plans

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| No | Issued Status | Drawn | Check'd | App'd | Date |
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East West Link

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| Scale: 1:5,000 | Original Size: A3 | Contract No PA4041 | |

Drawing Title: GEOTECHNICAL
2016 Ground Investigations

Drawing Number: GIS-Q-AEE-001

Rev No. A

Plot Date: 25/10/2016 Plotted by: Ben Peyton File: W:\CAD\ArcGIS\TGI\55_Workspaces\01_mxd\Geotech (Q)\DRAFTS\GIS-Q-AEE-001_006_GeoTech_EWC_GroundInvestigations.mxd

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## Legend

- Geotechnical Boreholes over water (BH) and In-situ Geonor Vane Test (GN)
- Geotechnical Boreholes (BH)
- Environmental Boreholes (BH)
- Groundwater Boreholes (BH)
- Test Pits (TP)
- Cone Penetration Test (CPT)
- EWL Alignment

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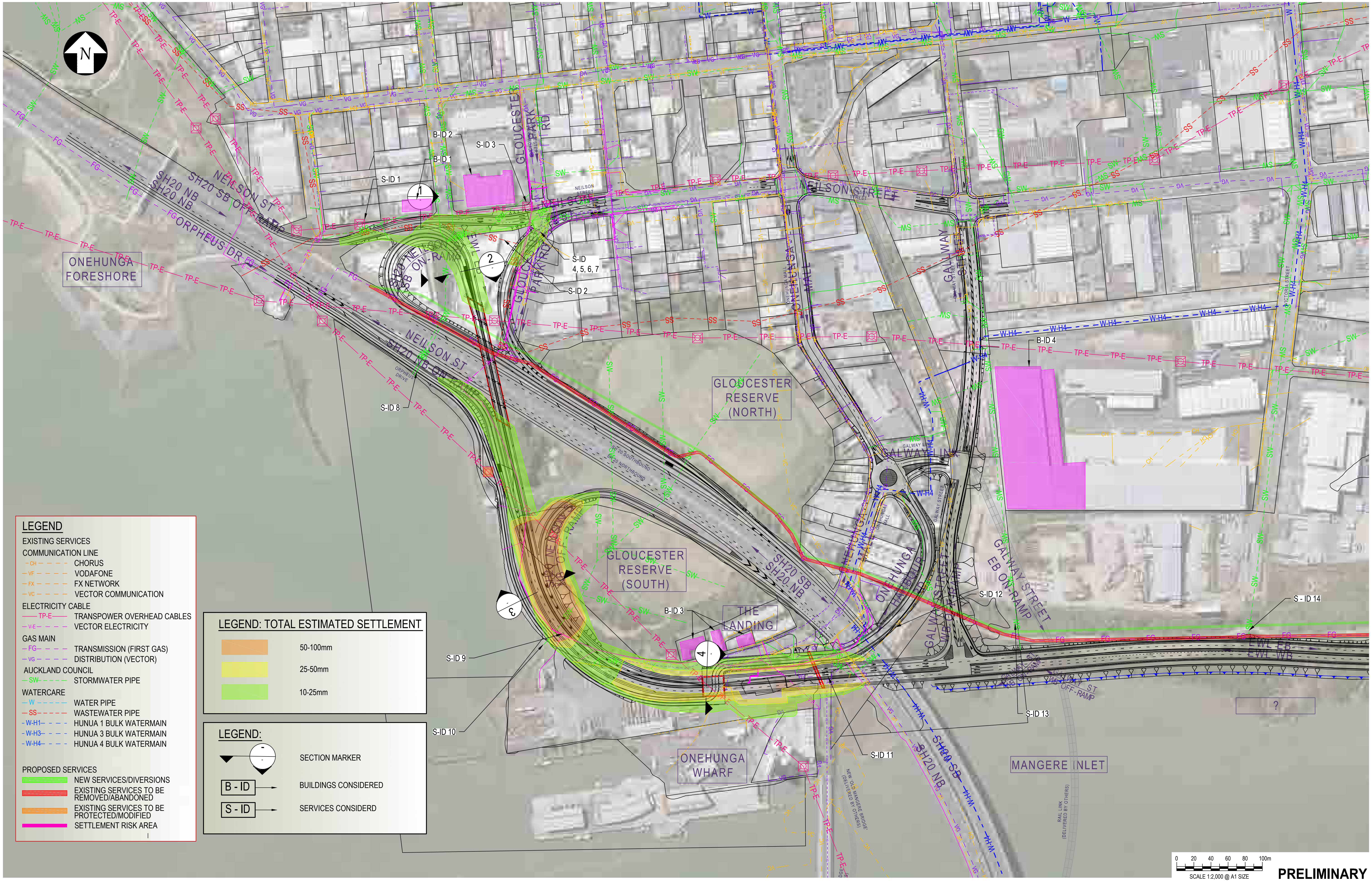
Appendix B

# Calculated Settlement Contours




**PRELIMINARY**

| No. | Issued Status | Drawn | Check'd | App'd | Date |
|---|---|---|---|---|---|
| B | ISSUED FOR INFORMATION ONLY | AR | | | 15/11/2016 |
| A | ISSUED FOR INFORMATION ONLY | AR | | | 12/08/2016 |

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NZ TRANSPORT AGENCY WAKA KOTAHI

East West Link

Drawn: A RAM
Drafting Check
Reviewed Design Manager
Approved Alliance Manager
Designed
Design Check
Scale: Original Scale (A1) Reduced Scale (A3) AS SHOWN
Contract No PA4014

Drawing Title: GEOTECHNICAL
TOTAL SETTLEMENT CONTOURS
NELSON ST INTERCHANGE - SHEET 1

Drawing Number: Z-EF-021
Rev No. B


**PRELIMINARY**

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East West Link

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Contract No PA4014

Drawing Title: GEOTECHNICAL
TOTAL SETTLEMENT CONTOURS
EMBANKMENT - SHEET 2

Drawing Number: Z-EF-022
Rev No. B

Plot Date: 16 November 2016 - 3:07 PM Plotted by: Julian Murahidy Cad File No: W:\CAD\AutoCAD\DWGs\Z-EF-021-026.DWG


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Design Check
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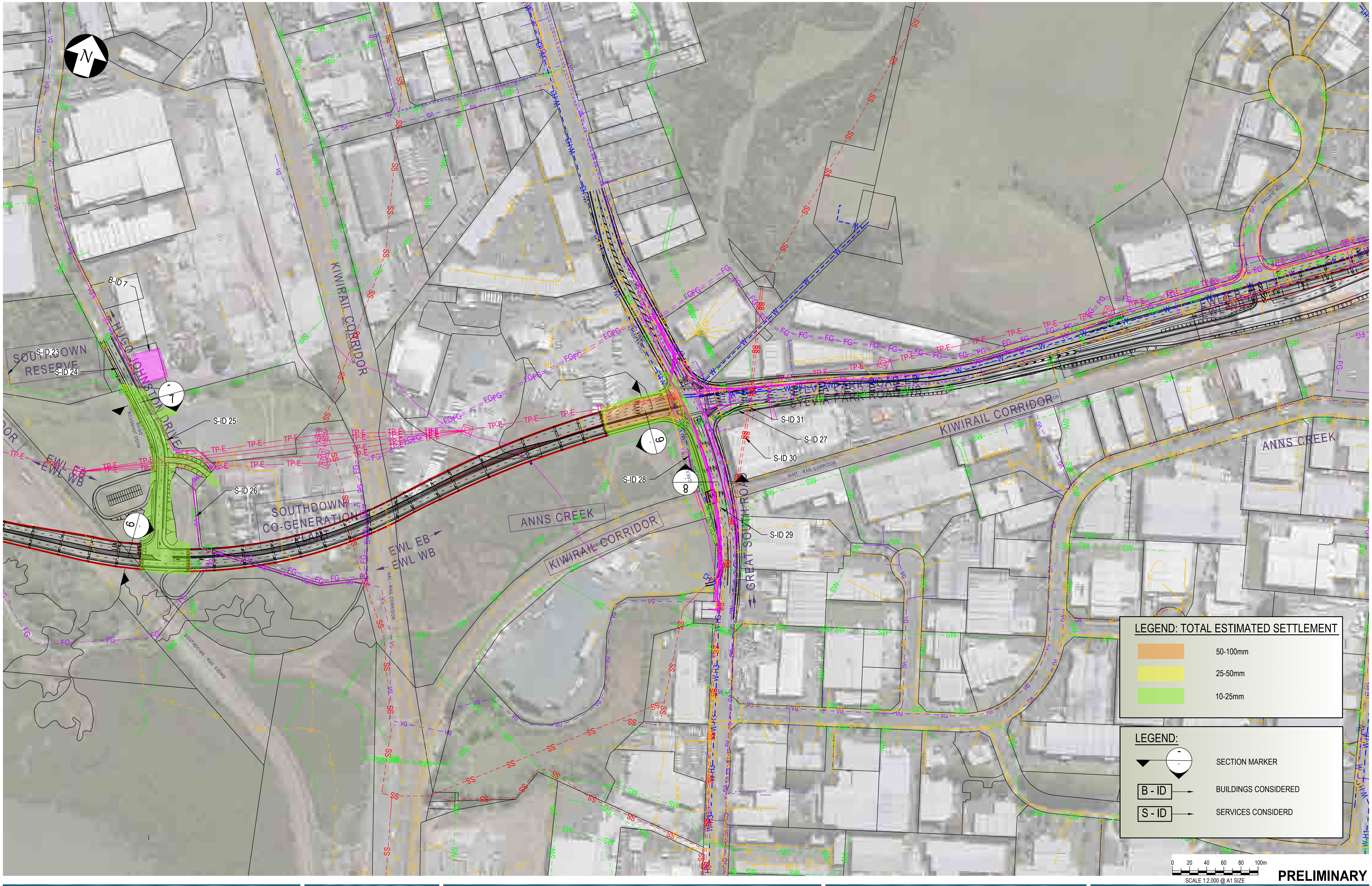
Contract No PA4014

Drawing Title
GEOTECHNICAL
TOTAL SETTLEMENT CONTOURS
EMBANKMENT/ ANNS CREEK - SHEET 3

Drawing Number Z-EF-023
Rev No. B

Plot Date: 16 November 2016 - 3:07 PM Plotted by: Julian Murahidy Cad File No: W:\CAD\AutoCAD\DWGs\Z-EF-021-026.DWG




**PRELIMINARY**

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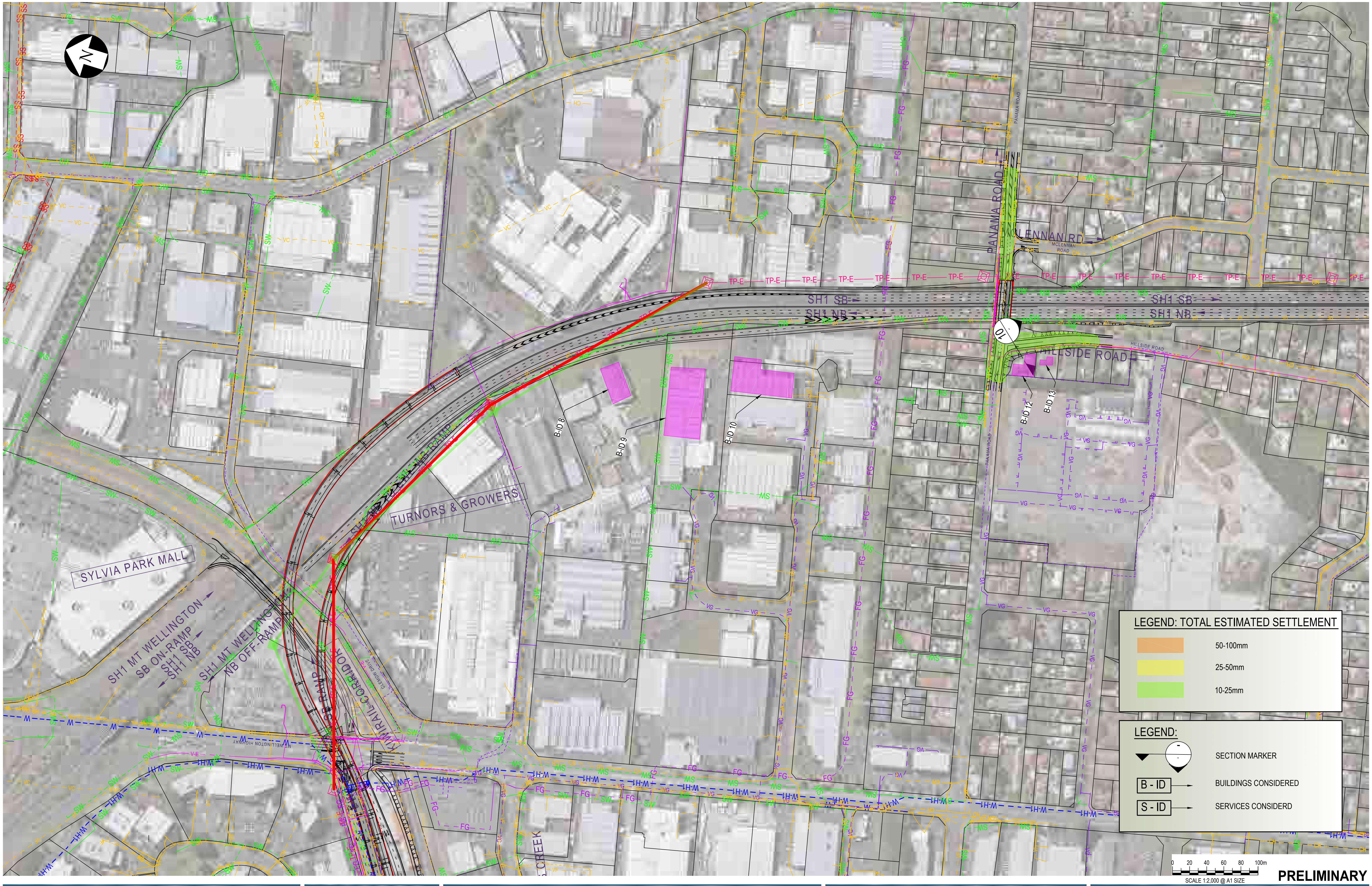
| Designed | Design Check | | |
| Scale: Original Scale (A1) | Reduced Scale (A3) | AS SHOWN | Contract No PA4014 |

Drawing Title: GEOTECHNICAL
TOTAL SETTLEMENT CONTOURS
ANNS CREEK/SYLVIA PARK ROAD

Drawing Number: Z-EF-024 | Rev No. B

Plot Date: 16 November 2016 - 3:08 PM Plotted by: Julian Murahidy Cad File No: W:\CAD\AutoCAD\DWGs\Z-EF-021-026.DWG




**PRELIMINARY**

| No. | Issued Status | Drawn | Check'd | App'd | Date |
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| | | | | | |
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East West Link

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|---|---|---|---|
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| Designed | Design Check | | |
| Scale: Original Scale (A1) | Reduced Scale (A3) AS SHOWN | Contract No PA4014 | |

Drawing Title: GEOTECHNICAL
TOTAL SETTLEMENT CONTOURS
SH1/SYLVIA PARK RAMPS - SHEET 5

Drawing Number: Z-EF-025 | Rev No. B

Plot Date: 16 November 2016 - 3:08 PM  Plotted by: Julian Murahidy  Cad File No: W:\CAD\AutoCAD\DWGs\Z-EF-021-026.DWG


PRELIMINARY

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East West Link

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|---|---|---|---|
| A RAM | | | |
| Designed | Design Check | | |

Scale: Original Scale (A1) Reduced Scale (A3) AS SHOWN

Contract No PA4014

Drawing Title: GEOTECHNICAL
TOTAL SETTLEMENT CONTOURS
SH1/ PRINCES ST INTERCHANGE - SHEET 6

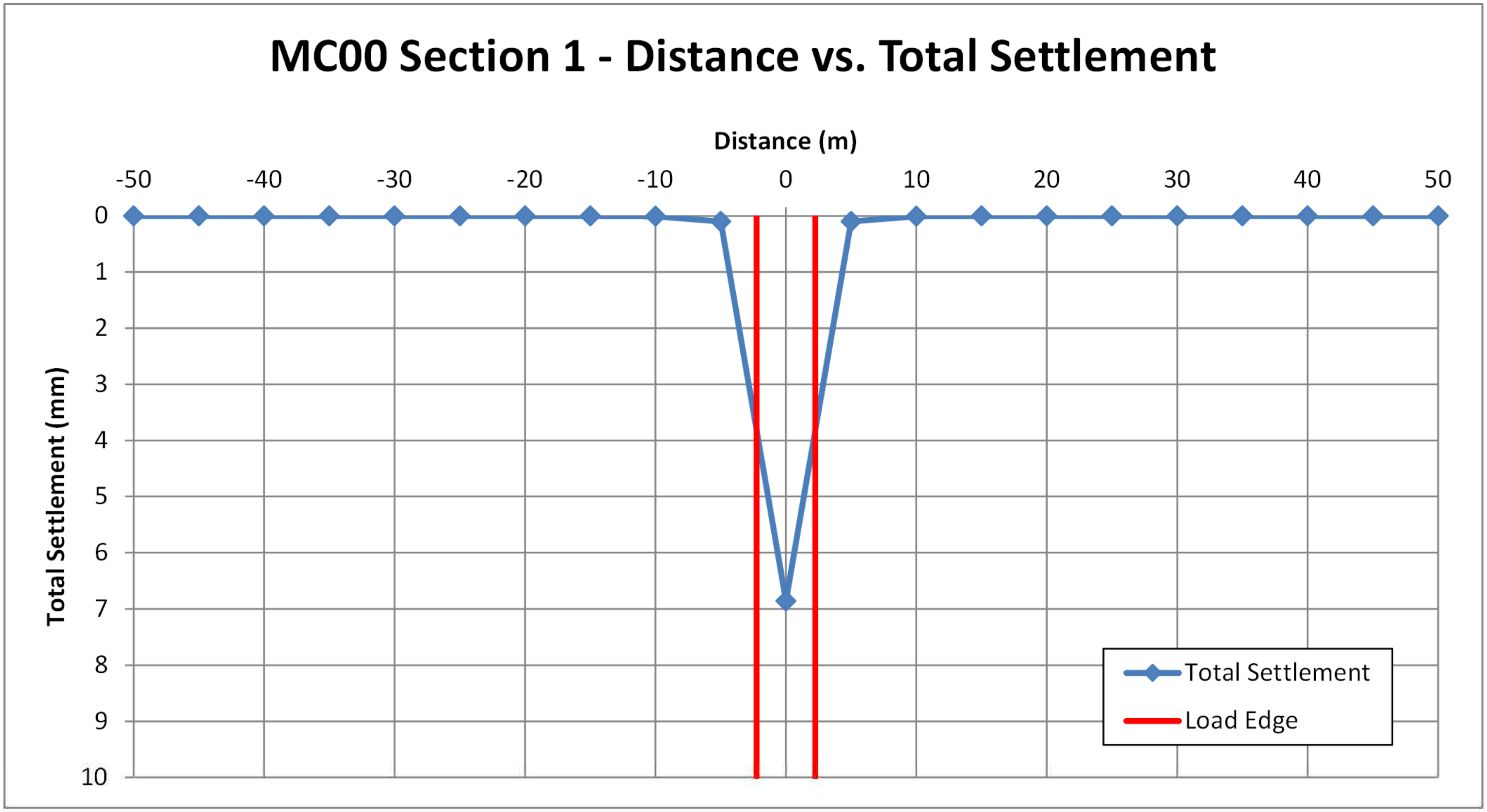
Drawing Number: Z-EF-026

Rev No. B

Plot Date: 16 November 2016 - 3:09 PM Plotted by: Julian Murahidy Cad File No: W:\CAD\AutoCAD\DWGs\Z-EF-021-026.DWG

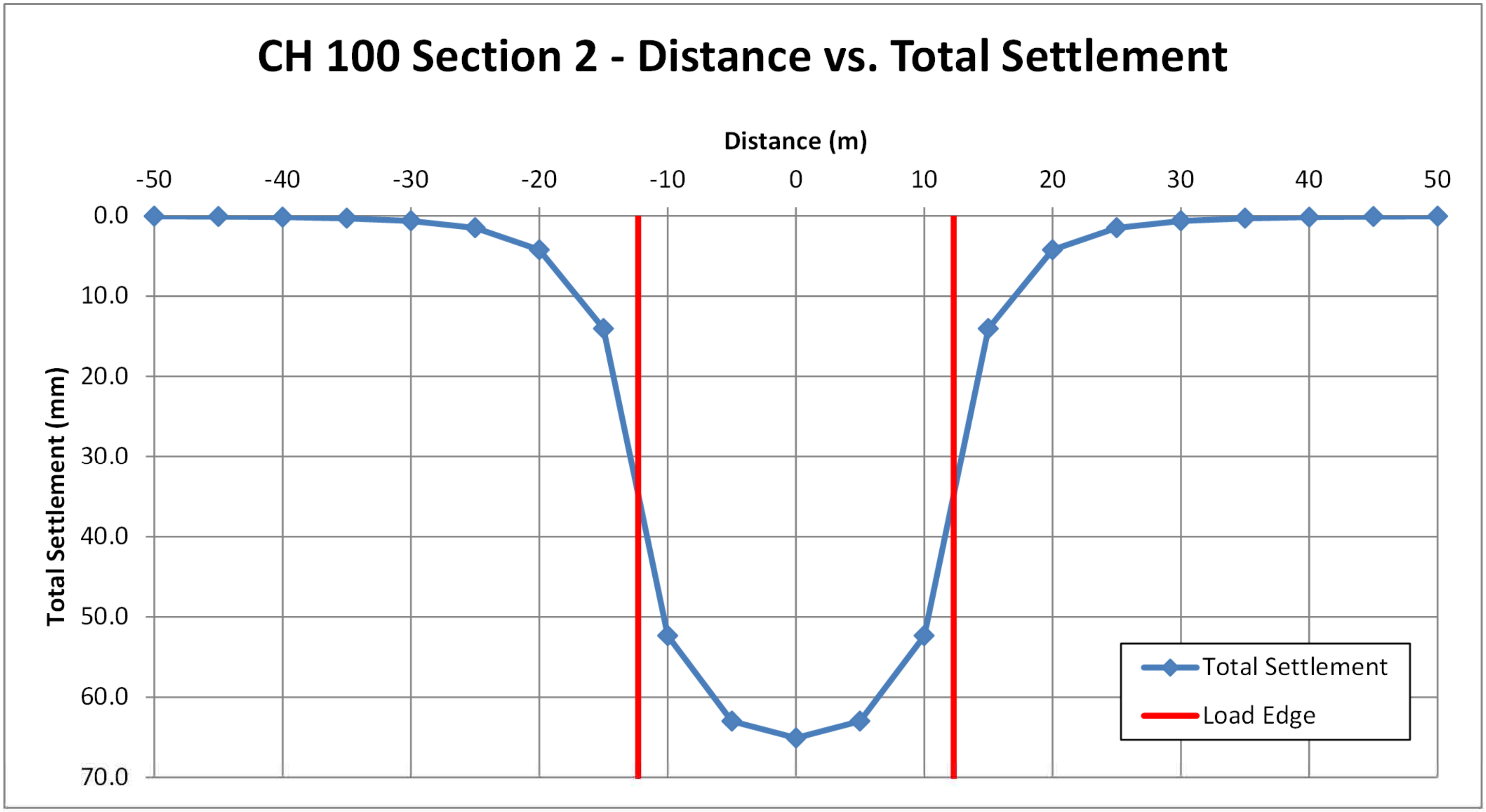
Appendix C

# Cross Sections Calculated Settlement




NZ TRANSPORT AGENCY WAKA KOTAHI

East West Link

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WAKA KOTAHI

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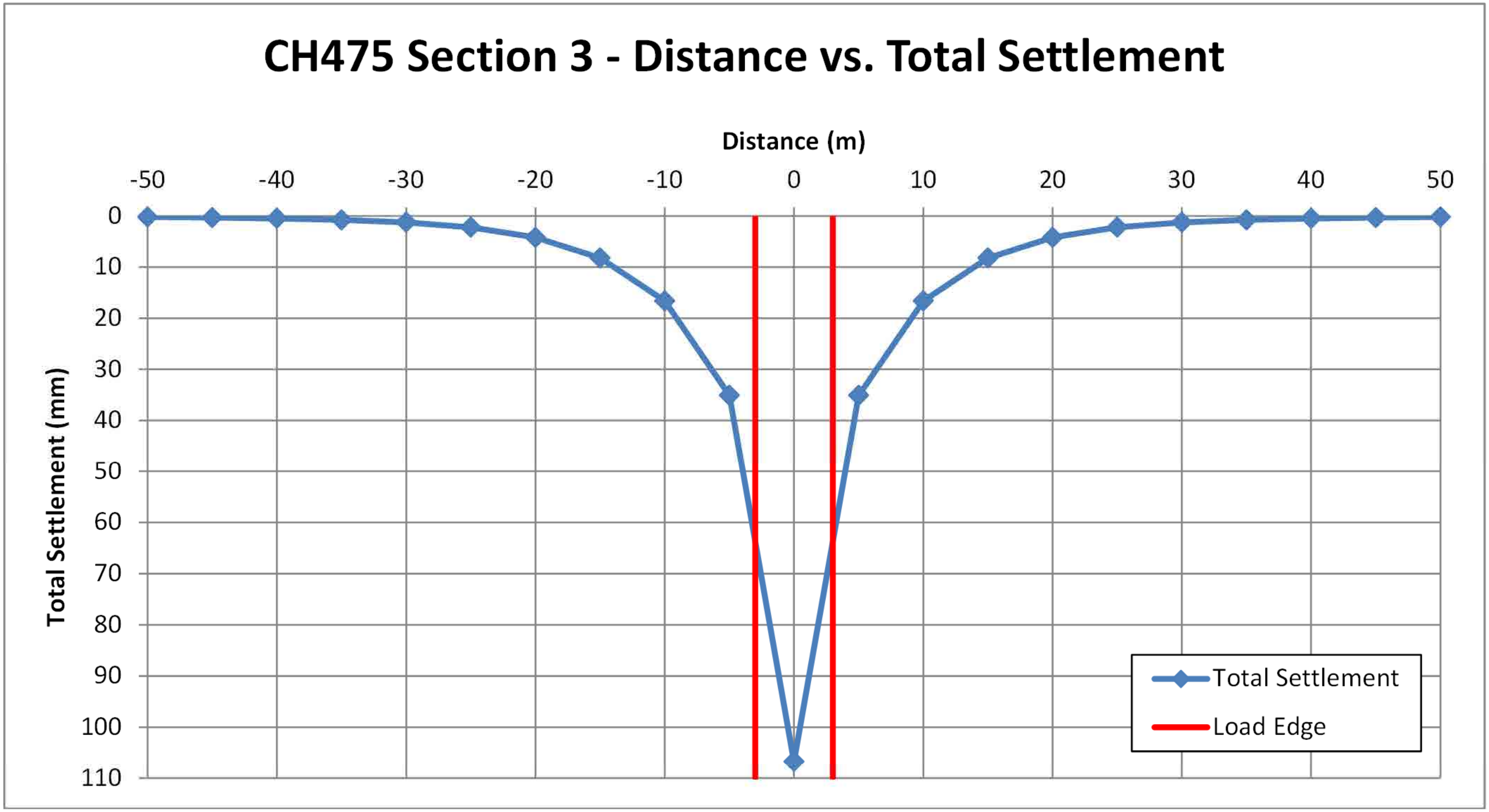


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WAKA KOTAHI

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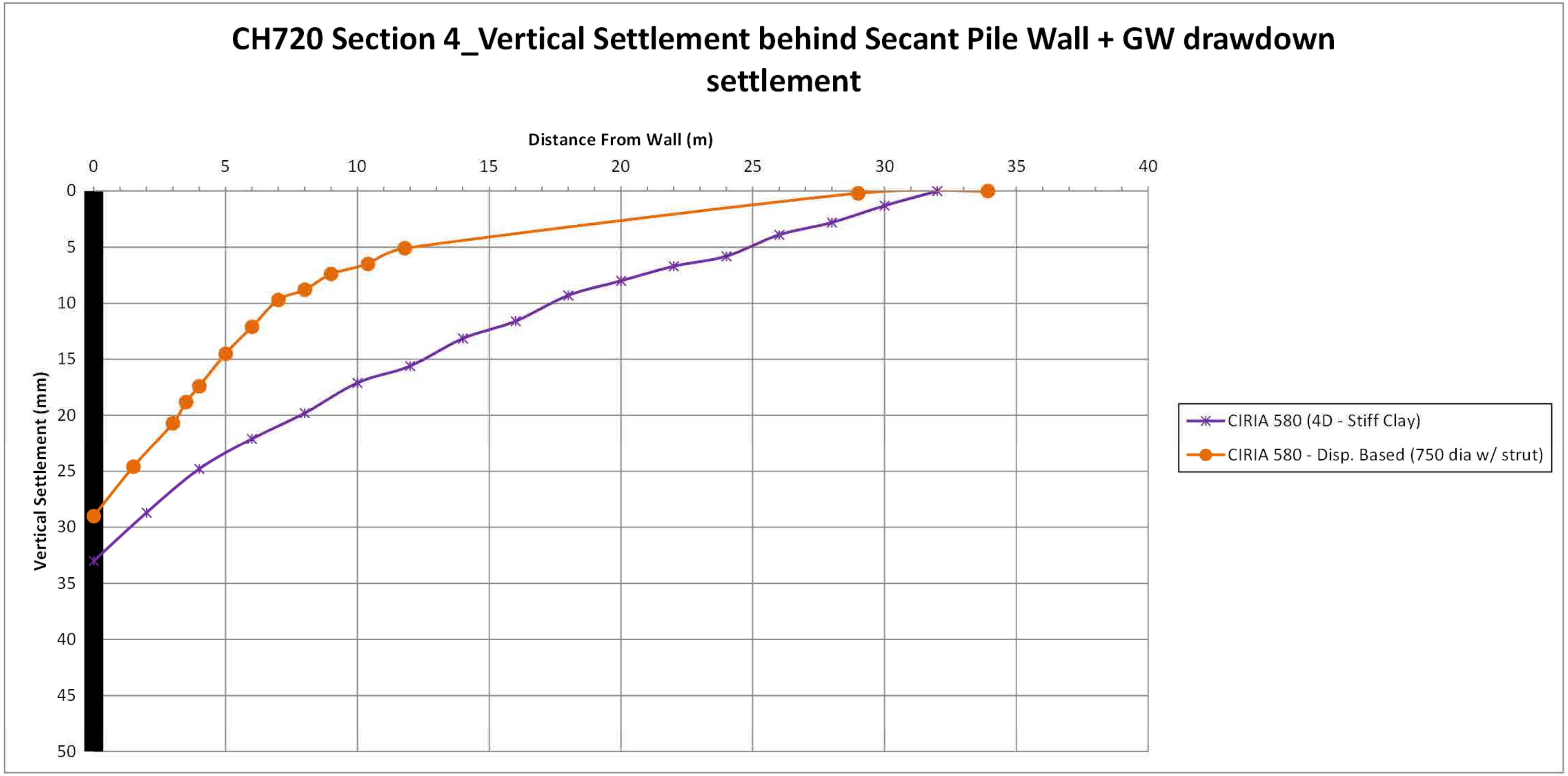
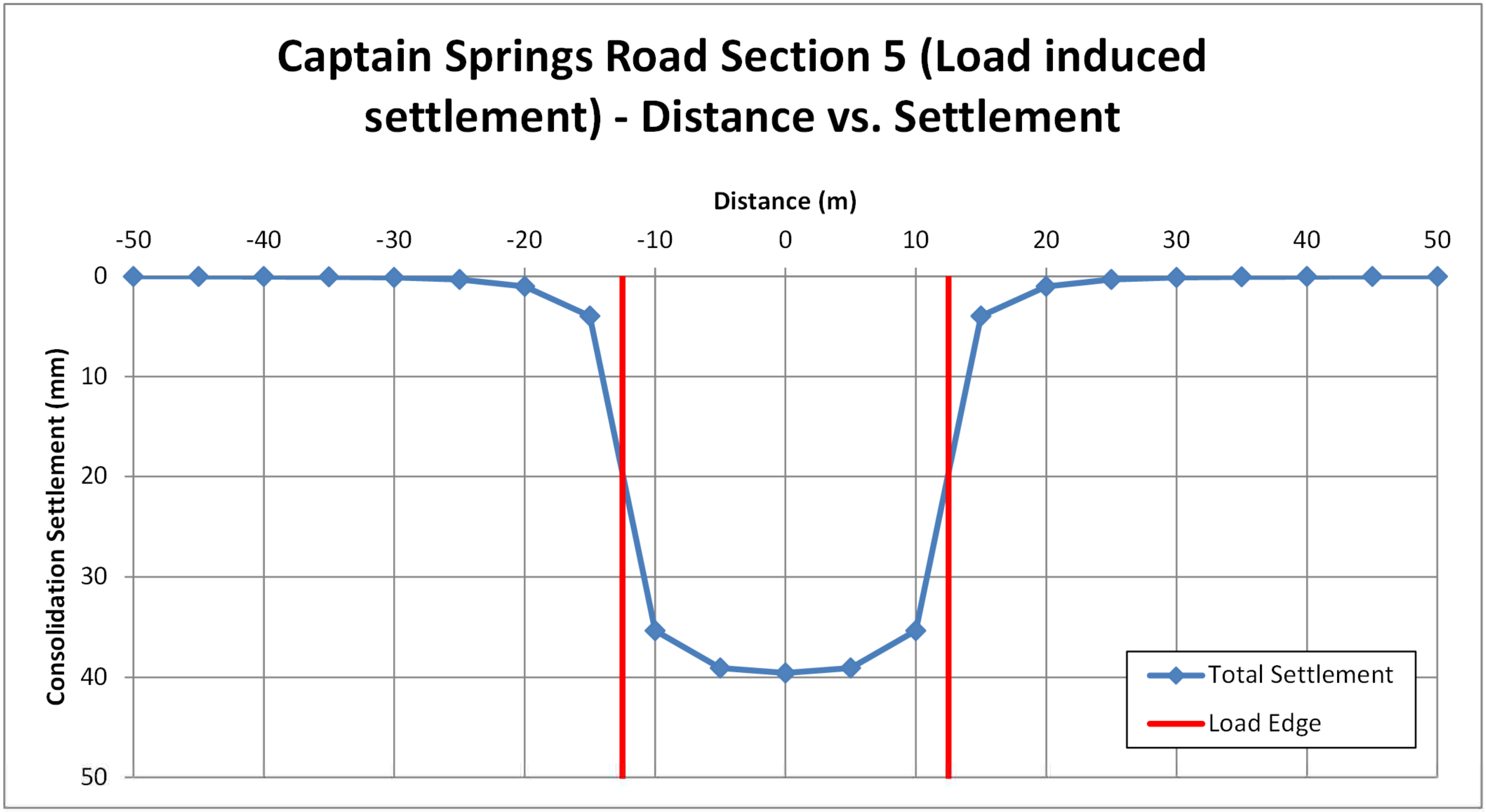


CH720 Section 4_Vertical Settlement behind Secant Pile Wall + GW drawdown settlement
Distance From Wall (m)
0
5
10
15
20
25
30
35
40
Vertical Settlement (mm)
0
5
10
15
20
25
30
35
40
45
50
CIRIA 580 (4D - Stiff Clay)
CIRIA 580 - Disp. Based (750 dia w/ strut)

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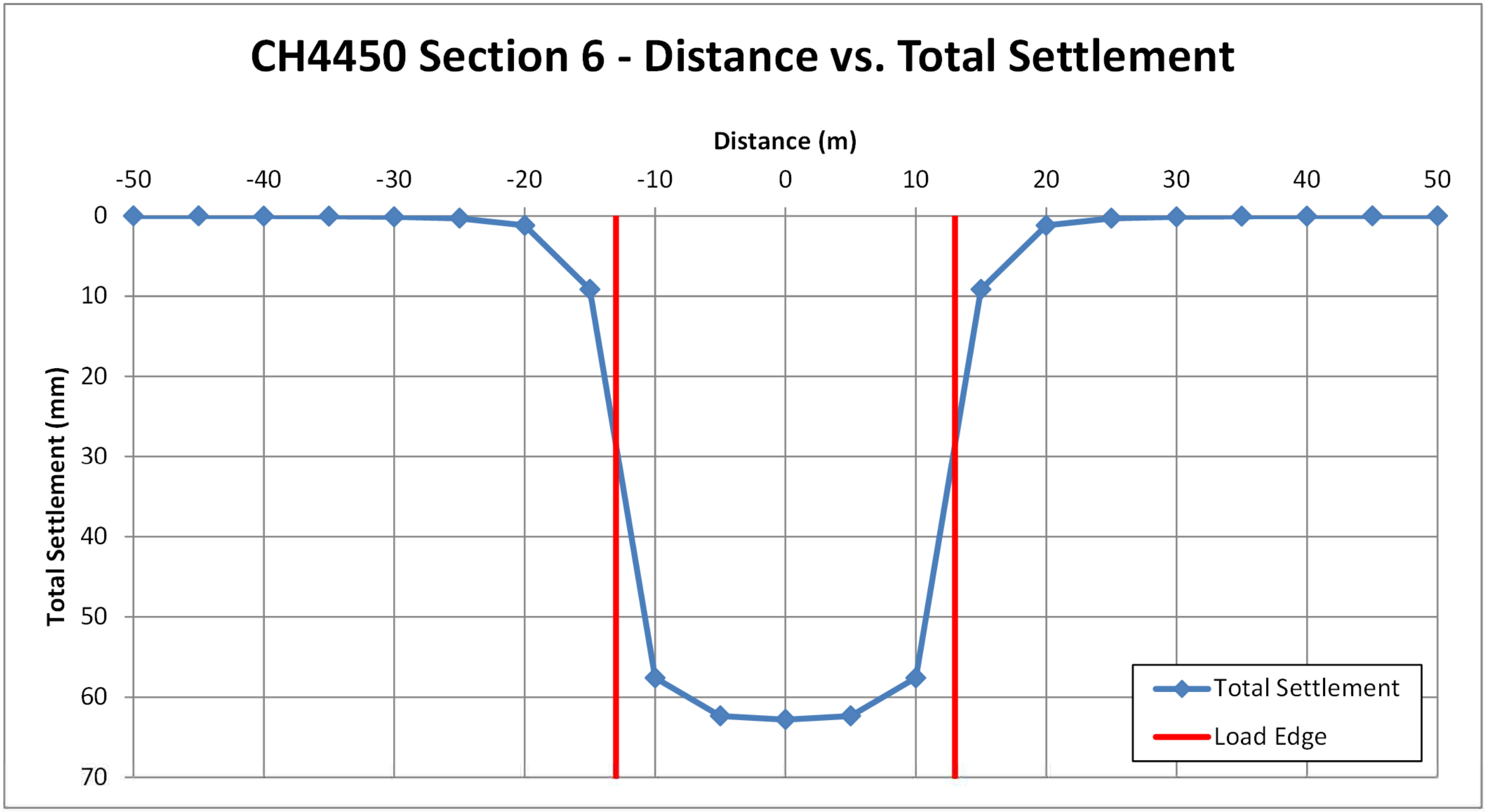


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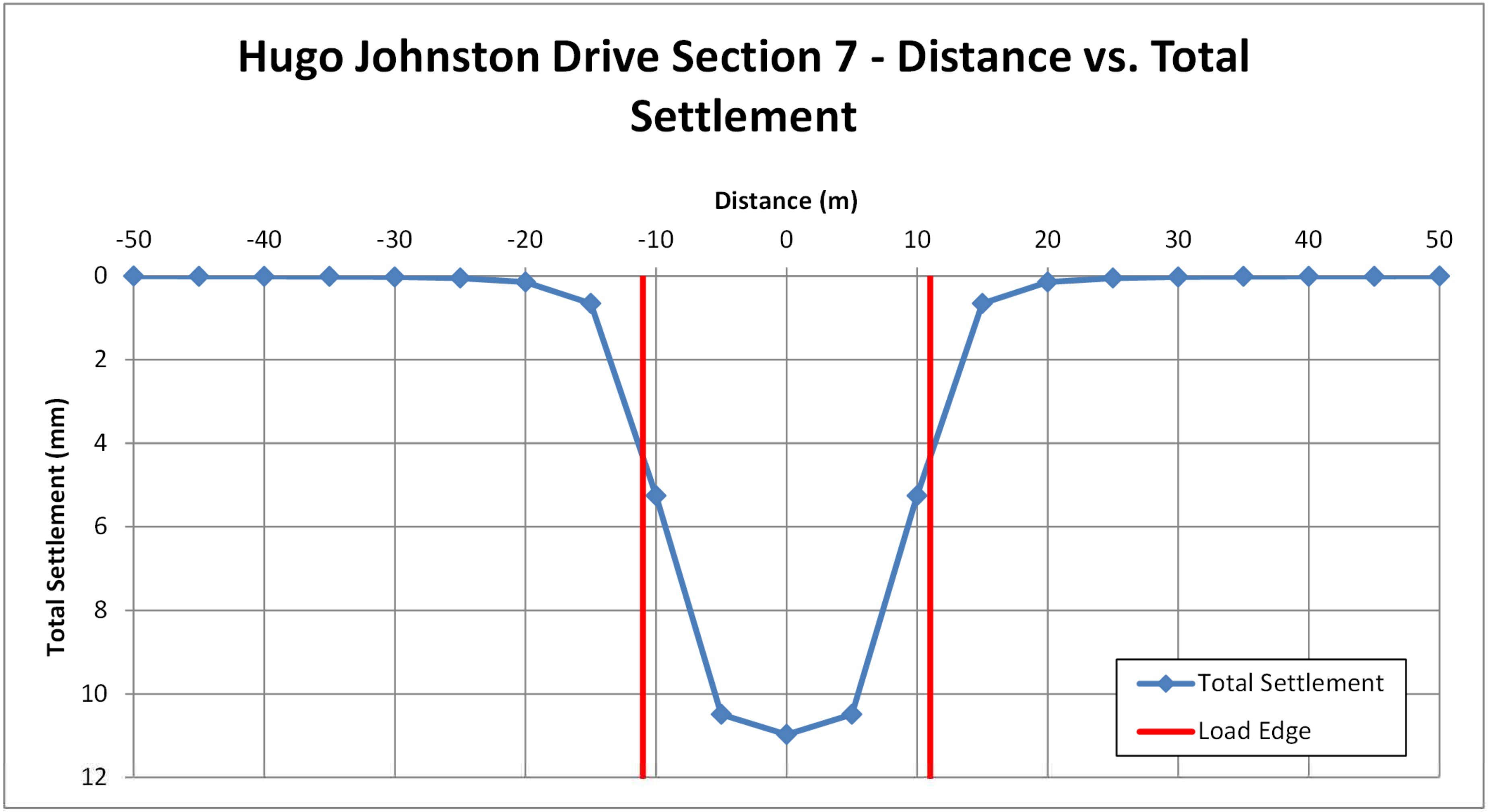


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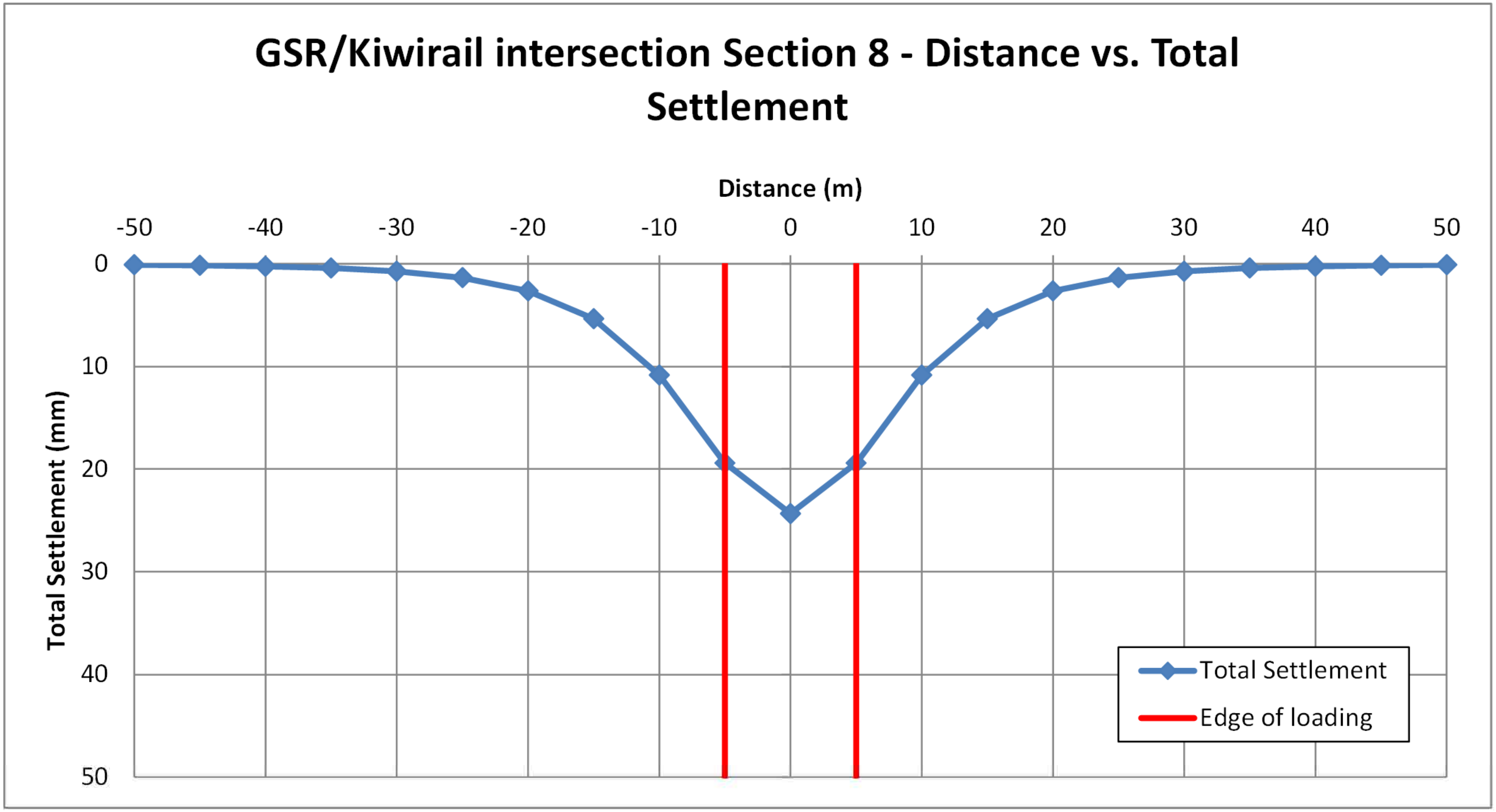
East West Link

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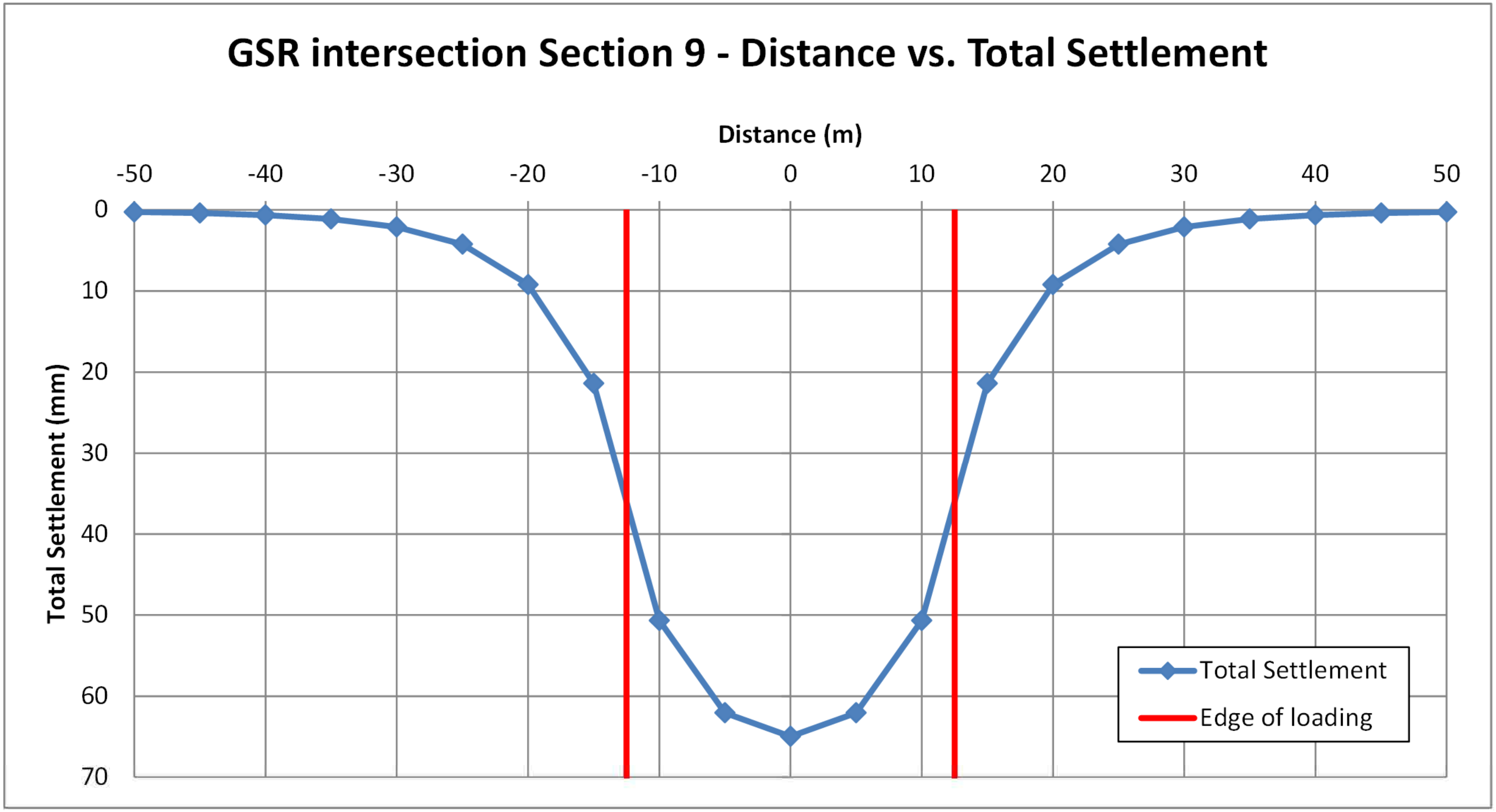
East West Link

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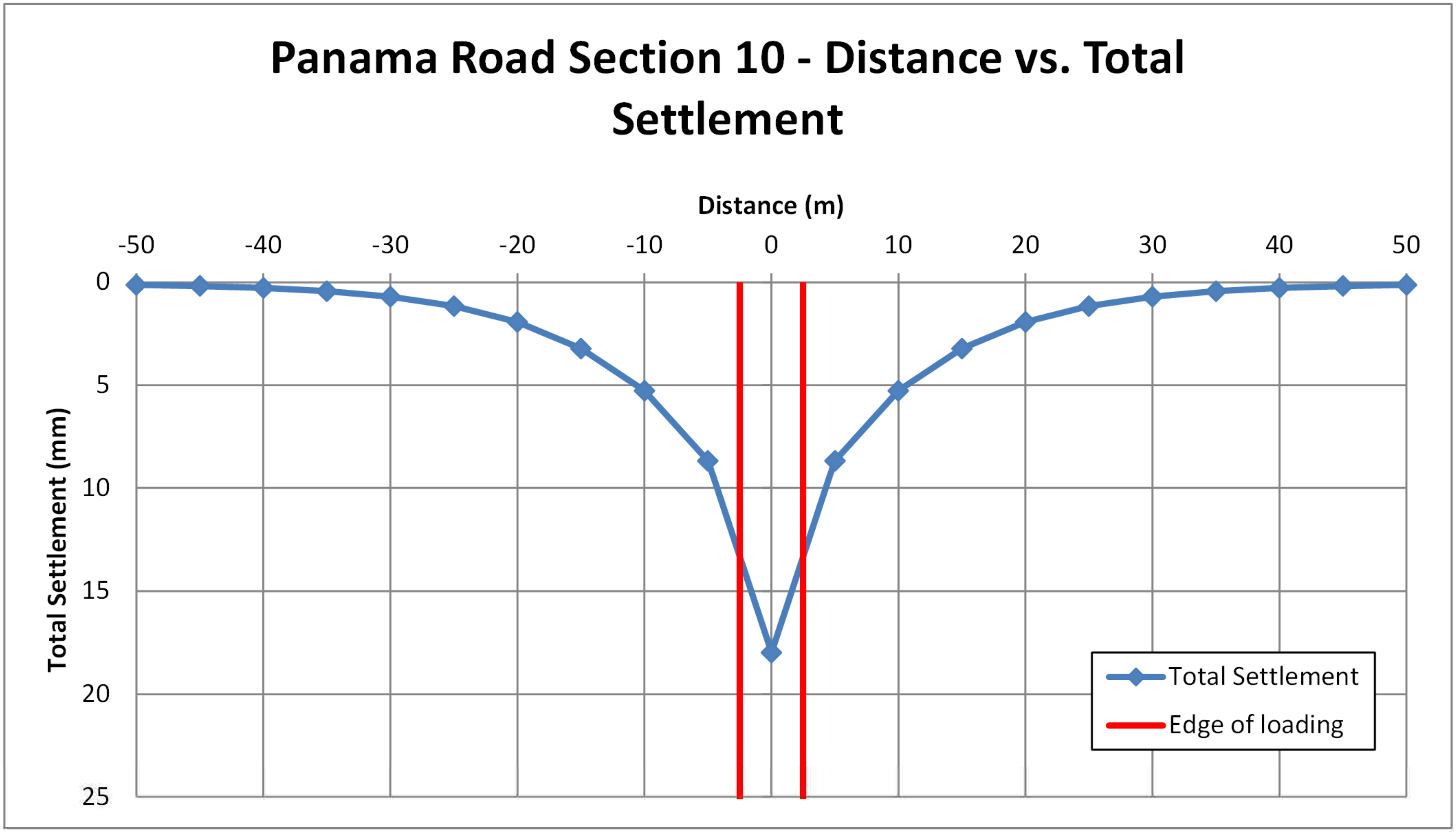
WAKA KOTAHI
East West Link

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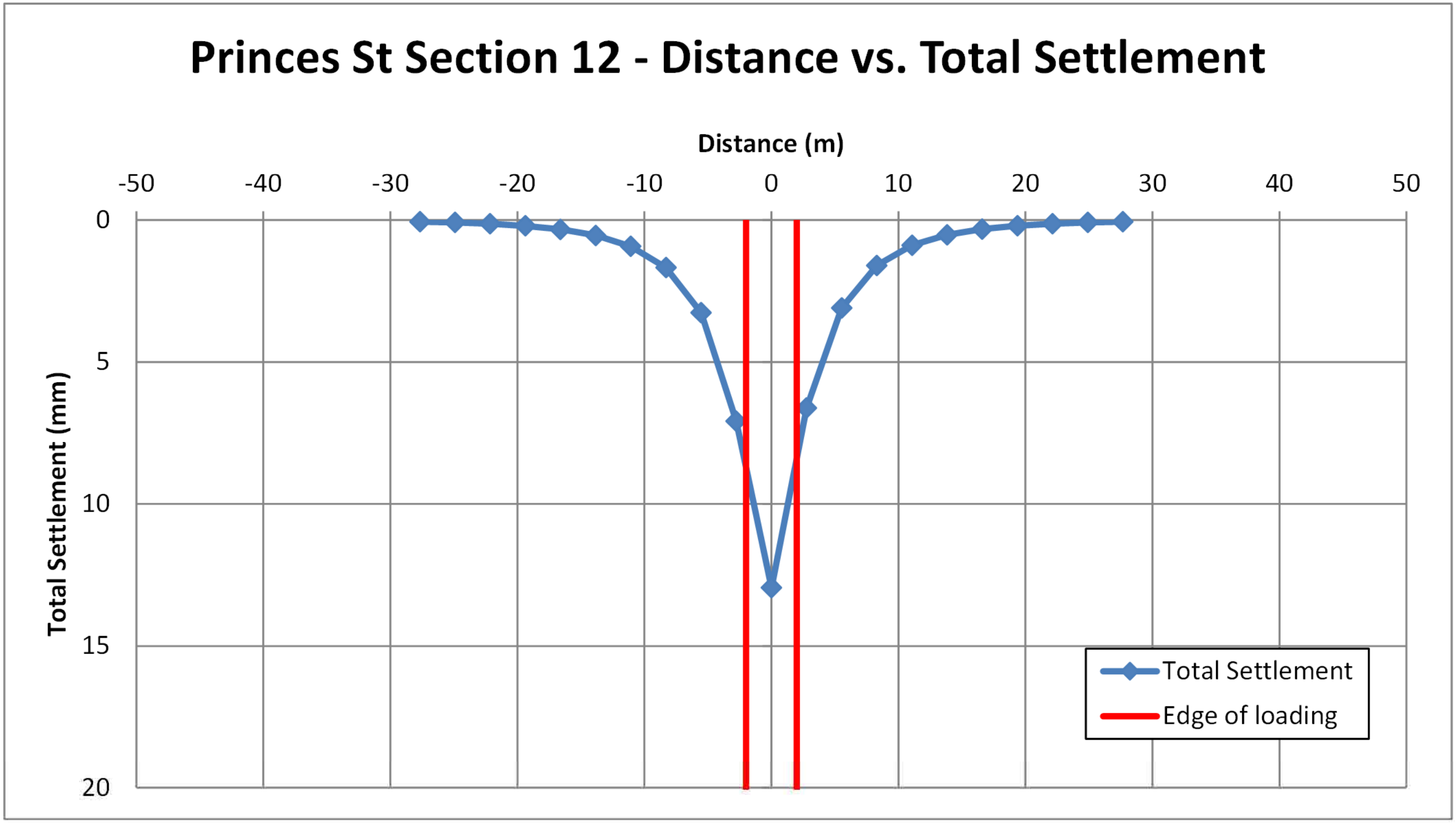


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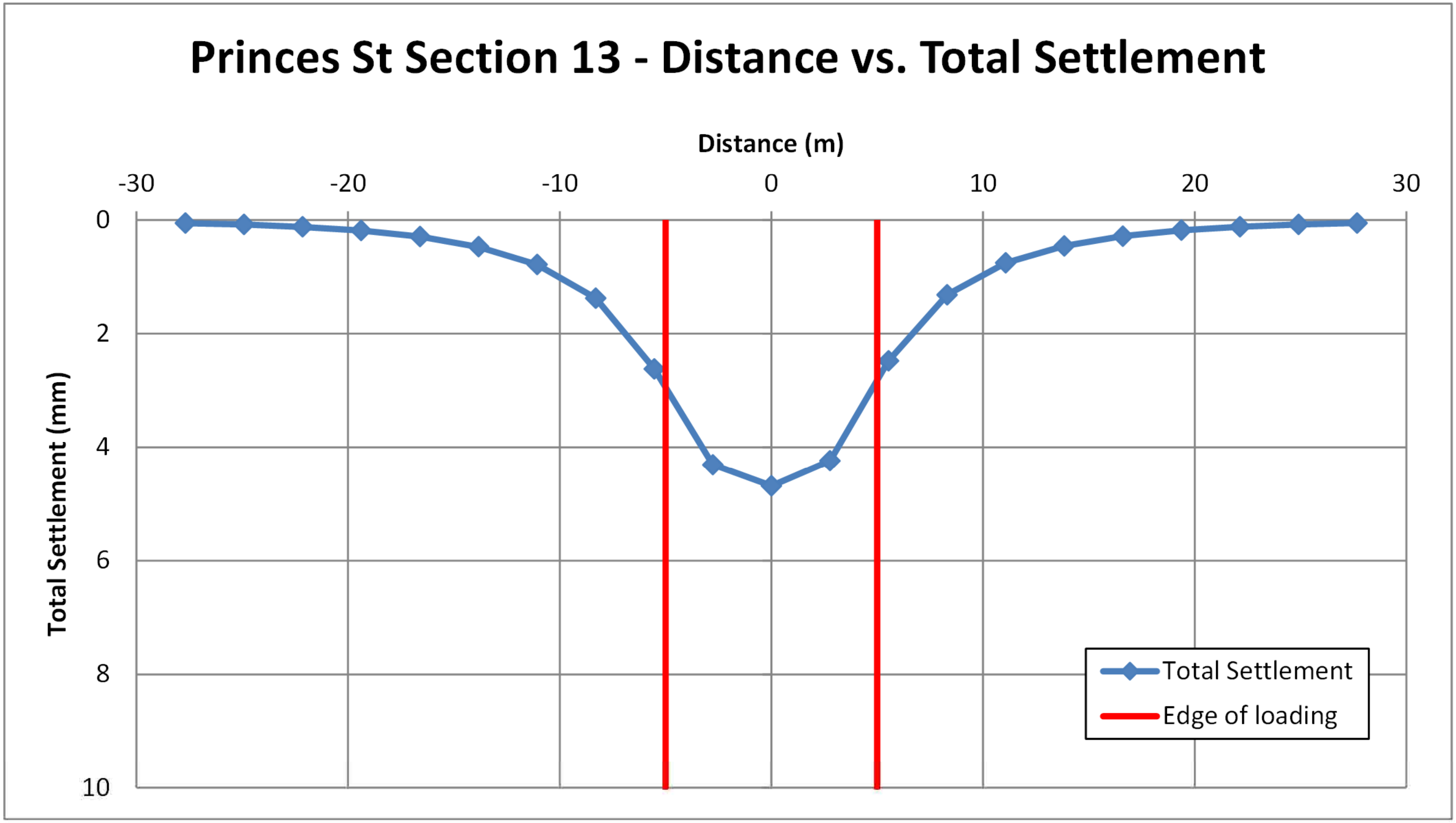


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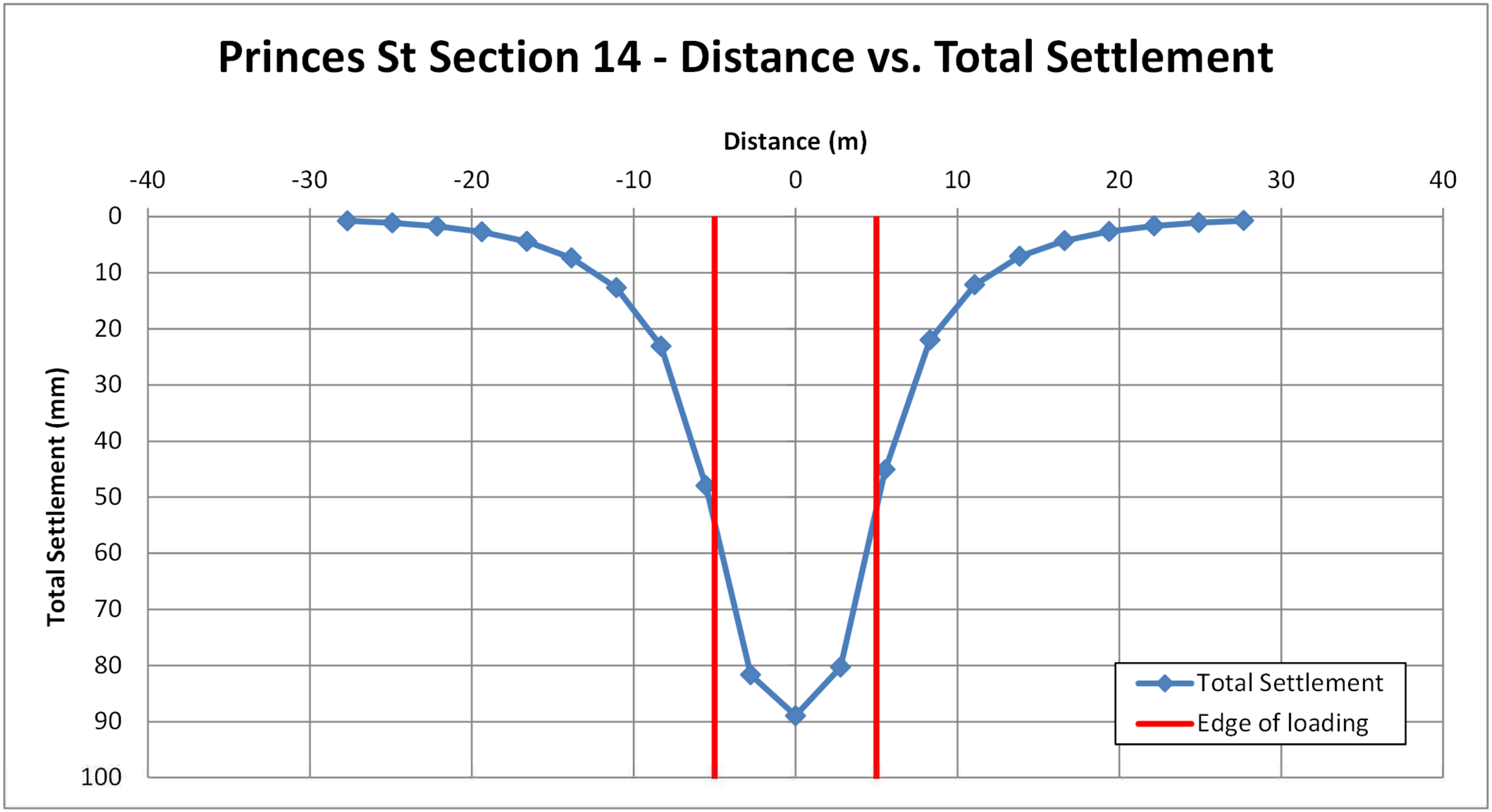
WAKA KOTAHI

East West Link




NZ TRANSPORT AGENCY
WAKA KOTAHI

East West Link

Appendix D

# Existing Building Preliminary Assessment

## Commercial and Industrial Buildings

### Specific Building B-ID 1: 2/2a Hill Street, Onehunga

**Figure 1: 2 to 2a Hill Street. Satellite view.**

This is a portal frame building with concrete blockwork walls situated on the boundary of the construction designation and shown in Figures 1, 2 and 3. The walls are unlikely to be reinforced and are locally clad with steel. Due to the construction type this building is expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 2: 2 to 2a Hill Street. Neilson Street frontage.**

**Figure 3: 2 to 2a Hill Street. Hill Street frontage.**

## Specific Building B-ID 2: 3-5 Gloucester Park Road, Onehunga

**Figure 4: 3-5 Gloucester Park Road. Satellite view.**

This is a reinforced concrete building with steel cladding situated on the boundary of the construction designation and shown in Figure 4 and Figure 5. The concrete walls are likely to be reinforced and are locally clad with corrugated steel. Due to the construction type this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 5: 3-5 Gloucester Park Road. . Neilson Street frontage.**

## Specific Building B-ID 3: 2-6 Onehunga Harbour Road, Onehunga

**Figure 6: 2-6 Onehunga Harbour Road. Satellite view.**


The three potentially affected buildings on this site comprise: a timber and plasterboard building (western most); plasterboard clad building (central building); and a concrete building (eastern most), which are all situated on the boundary of the construction designation and shown in Figures 6, 7 and 8. The western and central buildings (the motel and apartments) are likely timber frame with mainly plasterboard cladding. The eastern building (The Landing Restaurant and Bar) is a historic concrete building, surrounded by a basalt block wall, and is unlikely to be reinforced. Due to the construction type of these buildings, they are expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 7: 2-6 Airport Harbour View Motel.**

**Figure 8: 2-6 The Landing Restaurant and Bar (right), and adjacent apartments (left)**

## Specific Building B-ID 4: 40 Victoria Street, Onehunga

**Figure 9: 40 Victoria Street. Satellite view.**

This is a reinforced concrete panel building on the boundary of the construction designation and shown in Figures 9 and 10. This large scale distribution warehouse has a 10m high stud. The concrete walls are likely to be reinforced and there are steel clad portal frames on the northern side of the building footprint. Due to the construction type this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement

**Figure 10: 40 Victoria Street. View of northern side.**

## Specific Building B-ID 5: 69 Captain Springs Road, Onehunga

**Figure 11: 69 Captain Springs Road (Seamount Building). Satellite view.**

The Seamount building has a reinforced concrete base supporting steel cladding and roof, and is on the boundary of the construction designation. The building is shown in Figures 11 and 12. The concrete walls are likely to be reinforced and the building contains significant storage of, amongst other things, glass items. Due to the construction type this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 12: 69 Captain Springs Road. Street view.**

### Specific Building B-ID 6: 59 Miami Parade, Onehunga

**Figure 13: 59 Miami Parade (Car Distribution Group). Satellite view.**

These are portal frame buildings with steel cladding on the boundary of the construction designation and shown in Figures 13 and 14. The walls are unlikely to be reinforced and are clad with steel. Due to the construction type this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 14: 59 Miami Parade. View from Māngere Inlet footpath.**

## Specific Building B-ID 7: 138 Hugo Johnston Drive, Southdown

**Figure 15: 140 Hugo Johnston Drive (Anton's Seafoods). Satellite view.**

This is a reinforced concrete building on the boundary of the construction designation and shown in Figures 15 and 16. The concrete walls are likely to be reinforced and the building has a localised glass panel façade at its north-western end. Due to the construction type this building is expected to be susceptible to visual cracking in the event of slight differential ground movement

**Figure 16: 140 Hugo Johnston Drive. View from local road.**

## Specific Building B-ID 8: 5 Monahan Road, Mt Wellington

**Figure 17: 5 Monahan Road (PPG Industries). Satellite view.**

This is a concrete block building with steel cladding on the boundary of the construction designation and shown in Figures 17 and 18. The concrete blocks are likely to be reinforced. There is a small shed, assumed to be of steel construction, adjacent to the main building. Due to the construction type the buildings are not expected to be susceptible to visual cracking but the small block building is expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 18: 5 Monahan Road. View from nearby property.**

## Specific Building B-ID 9: 7 Carmont Place, Mt Wellington

**Figure 19: 7 Carmont Place. Satellite view.**

This is a concrete panel building with steel cladding on the boundary of the construction designation and shown in Figures 19 and 20. The concrete panels are likely to be reinforced. Due to the construction type the main building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 20: 7 Carmont Place. Street view.**

## Specific Building B-ID 10: 11 George Bourke Drive, Mt Wellington

**Figure 21: 11 George Bourke Drive. Satellite view**

This is a reinforced concrete panel building on the boundary of the construction designation and shown in Figures 21 and 22. Due to the construction type the main building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 22: 11 George Bourke Drive. View from car park.**

### Specific Building B-ID 11: 63 Angle Street, Onehunga

**Figure 23: 63 Angle Street (Zebra Broken Car Collection Company). Satellite view**

This is likely a concrete block building with steel cladding on the boundary of the construction designation and shown in Figures 23 and 24. The concrete panels are unlikely to be reinforced. Due to the construction type the main building is expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 24: 63 Angle Street. View from local road.**


## Residential Buildings

### Specific Building B-ID 12–112 Hillside Road, Ōtāhuhu

**Figure 25: 112 Hillside Road. Satellite view.**

This is a two storey plasterboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figures 25 and 26. Due to the construction type, this building is expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 26: 112 Hillside Road. Street view.**

## Specific Building B-ID 13–110 Hillside Road, Ōtāhuhu

**Figure 27: 110 Hillside Road. Satellite view**

This is a single storey weatherboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figures 27 and Figure 28. Due to the construction type, this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 28: 110 Hillside Road. Street view.**

### Specific Building B-ID 14–16 Coppins Road, Ōtāhuhu

**Figure 29: 16 Coppins Road. Satellite view**


This is a single storey weatherboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figure 26 and Figure 27. Due to the construction type, this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 30: 16 Coppins Road. Street view.**

## Specific Building B-ID 15–14 Coppins Road, Ōtāhuhu

**Figure 31: 14 Coppins Road. Satellite view.**

This is a single storey weatherboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figures 31 and 32. Due to the construction type, this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 32: 14 Coppins Road. Street view.**

## Specific Building B-ID 16–14a Coppins Road, Ōtāhuhu

**Figure 33: 14a Coppins Road. Satellite view.**

This is a single storey weatherboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figure 33 and Figure 34. Due to the construction type, this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 34: 14a Coppins Road. Street view.**

## Specific Building B-ID 17–31-31a Frank Grey Place, Ōtāhuhu

**Figure 35: 31-31a Frank Grey Place. Satellite view.**

This is a single storey weatherboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figures 35 and 36. Due to the construction type, this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

**Figure 36: 31-31a Frank Grey Place. Street view.**


## Specific Building B-ID 18–95 Princes Street, Ōtāhuhu

**Figure 37: 95 Princes Street. Satellite view.**

This is a single storey weatherboard building constructed on shallow foundations situated on the boundary of the construction designation and shown in Figures 37 and 38. Due to the construction type, this building is not expected to be susceptible to visual cracking in the event of slight differential ground movement.

Figure 38: 95 Princes Street. Street view.

Appendix E

# Building Damage Categories, Burland (2012)

**Table 1: Relationship between category of damage and limiting tensile strains (εlim), Burland (2012)**

| Category of damage | Normal degree of severity | Limiting tensile strain (εlim) (%) |
|---|---|---|
| 0 | Negligible | 0–0.05 |
| 1 | Very slight | 0.05–0.075 |
| 2 | Slight | 0.075–0.15 |
| 3 | Moderate | 0.15–0.3 |
| 4-5 | Severe to very severe | >0.3 |

**Table 2: Classification of visible damage to walls with reference to ease of repair of plaster and brickwork or masonry (after Burland 2012)**

| Category of Damage | Normal degree of severity | Description of typical damage<br>Ease of repair is underlined |
|---|---|---|
| 0 | Negligible | Hairline cracks less than about 0.1mm |
| 1 | Very slight | Fine cracks which are easily treated during normal decoration. Damage generally restricted to internal wall finishes. Close inspection may reveal some cracks in external brickwork or masonry. Typical crack widths up to approximately 1mm. |
| 2 | Slight | Cracks easily filled. Re-decoration probably required. Recurrent cracks can be masked by suitable linings. Cracks may be visible externally and some repointing may be required to ensure weather tightness. Doors and windows may stick slightly. Typical crack widths 2-3mm but may be up to approximately 5mm locally. |
| 3 | Moderate | The cracks require some opening up and can be patched by a mason. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired. Typical crack widths are approximately 5-15mm or several closely spaced cracks >3mm. |
| 4 | Severe | Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted. Typical crack widths are 15-25mm, depending on the number of cracks |
| 5 | Very severe | This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and require shoring. Windows broken with distortion. Danger of instability. Typical crack widths are >25mm, depending on the number of cracks. |

Table Notes:
- Crack width is only one aspect of damage and should not be used on its own as a direct measure.
-The table is based on buildings of brick/blockwork masonry construction (i.e. standard domestic and office buildings)

Appendix F

# Monitoring

Monitoring requirements for particularly sensitive infrastructure, expected to be railway lines and transmission towers on shallow spread foundations, will be developed in consultation with the utilities operators.

Monitoring of the EWL Trench construction will comprise reference sections where wall deflections, groundwater changes and surface settlement will be regularly measured. Building markers will be installed on the three nearby buildings on Onehunga Harbour Road as a precautionary measure. Baseline monitoring of ground and groundwater levels will be undertaken for a minimum period of 12 months before active construction commences in this area.