Watercare Services Limited

Motions Catchment Improvement

Groundwater and Settlement Assessment of Effects

August 2025

Tonkin+Taylor

Watercare

Ki te ora te wai, Ka ora te whenua, Ka ora te tangata

Document Control

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Executive Summary

Watercare Services Limited (Watercare) is a lifeline utility providing water and wastewater services to 1.7 million Aucklanders every day and the future growth of 2.3 million people. Its services are vital for life, keeping people safe and helping communities to flourish. Watercare is responsible for municipal wastewater within Auckland, and the provider of bulk services to Pōkeno and Tuakau in the Waikato District.

Watercare's activities and programmes are funded through user charges and borrowings. They are required by the Local Government (Auckland Council) Act 2010 to be a minimum-cost, cost-efficient service provider.

This Groundwater and Settlement Assessment of Effects (GSEA) has been prepared to assess Watercare's resource consent application for the Motions Catchment Improvement Project, part of the broader Western Isthmus Water Quality Improvement Programme (WIWQIP). The Project proposes a new 3.2 km-long wastewater collector sewer from Canada Street in Auckland CBD to Western Springs Park, including 17 shafts, 3 branch lines, and 16 Engineered Overflow Points (EOPs).

The assessment considers two construction methodologies; pipe jacking and tunnel boring, and defines a moderately conservative "critical case" to represent the upper bounds of potential geotechnical and groundwater effects, forming the basis of a single consent application.

This report specifically assesses the potential effects on groundwater and ground settlement associated with deep excavations and tunnelling. Key findings include:

- Groundwater Drawdown: Temporary localised drawdown is expected at shaft locations. Permanent groundwater diversion is minimal and is not expected to materially alter the wider groundwater regime. Effects on neighbouring bores and surface water bodies are assessed as negligible.
- Basque Park Branch Tunnel: Tunnelling beneath two multi-storey piled buildings (15 Fleet Street and 6 Piwakawaka Street) is expected to result in ≤2 mm of settlement at pile toe level. This magnitude of settlement at pile toe would typically result in negligible effects; however a structural review of the existing condition of affected buildings should also be considered. Pre-construction condition surveys and construction-phase monitoring should also be carried out.
- Utilities: A conservative screening assessment against predicted surface settlement contours has been undertaken (see Appendix F). While most utilities are expected to tolerate differential settlement gradients up to 1V:750H (the steepest resulting gradient from our assessment), localised effects may occur, particularly for gravity-based services with strict grade requirements. Asset specific impacts cannot be fully confirmed at this stage due to limited information on depth and construction. Further consultation with asset owners may be required.
- Private and Commercial Properties: Most properties along the alignment are predicted to experience <10 mm of settlement, corresponding to Burland Class 1 (Very Slight) damage risk. In isolated locations near deeper shafts in soft ground, settlement may reach

approximately 23 mm, consistent with the lower end of Burland Class 2 (Slight), typically associated with minor cosmetic effects (e.g., internal plaster cracking, exterior repainting, or minor door/window misalignments).

- Monitoring and Mitigation: A monitoring framework is proposed, including groundwater and settlement instrumentation with alert and alarm thresholds. A Ground Settlement and Monitoring Contingency Plan (GSMCP) will guide response actions if movement exceeds thresholds.

This report provides a technical basis to inform the Assessment of Environmental Effects (AEE). The predicted effects, where quantified, are generally low. Mitigation and monitoring measures have been recommended to manage residual risk.

Table of Contents

1 Introduction

1.1 Watercare

Watercare Services Limited (Watercare) is a lifeline utility responsible for the planning, maintenance, and operation of wastewater services to communities in Auckland. Its activities and programmes are funded through user charges and borrowings. Watercare is required by the local authority by the Local Government (Auckland Council) Act 2009 to be a minimum-cost, cost-efficient service provider.

Watercare collects wastewater from 1.7 million people's homes including trade waste from industry, through approximately 8,700 Km of pipelines. It pumps through 534 pump stations, treats approximately 410 million litres of wastewater daily through 18 treatment plants and disposes in environmentally responsible ways to protect the public health, the local environment and coasts and harbours.

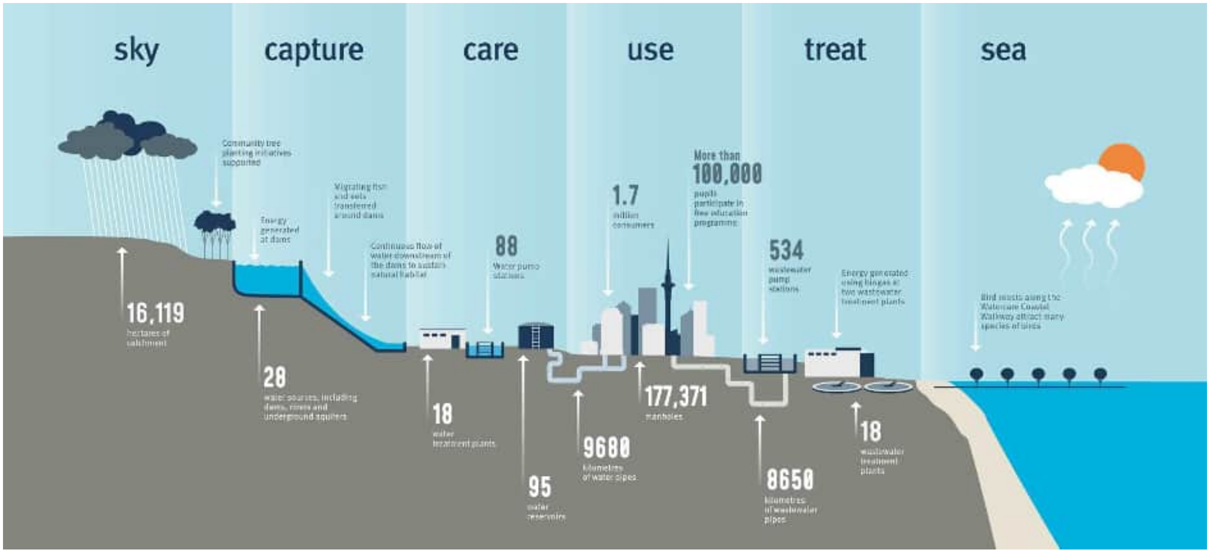

Figure 1: Overview of our assets and operations.

Watercare's activities are intrinsically linked to the health of people and the natural environment. Auckland's wastewater sources must be of sufficient volume and reliability to improve the quality of beaches and waterways.

Watercare carries out significant work to upgrade and build infrastructure, to maintain levels of service and provide capacity for a fast-growing population. Watercare ensures Auckland and its people continue to enjoy dependable services by upgrading its assets, planning, building, and delivering new infrastructure in cost-efficient ways.

1.2 Project background and description

The Western Isthmus Water Quality Improvement Programme (WIWQIP) Motions Catchment Improvements Project (the Project) involves the construction of a new collector sewer approximately 3.2 kilometres in length from Canada Street in Auckland's Central Business District (CBD) to Western Springs Park in Western Springs. The collector sewer is proposed to be a diameter ranging from 2.4 m up to 4.5 m and will have three branch connections. Two branch connections will go under State Highway 16 connecting the Newton Catchment to Suffolk

Reserve and connecting Arch Hill Scenic Reserve and southern parts of Grey Lynn to Nixon Park. The third branch connection will connect Suffolk Reserve to Basque Park. There will also be 16 Engineered Overflow Points (EOPs) and 16 local network connections. The Project will tie into the Central Interceptor at Western Springs Park.

The Project is part of the WIWQIP which aims to significantly reduce wastewater overflows into the Waitematā Harbour in order to improve stream and beach water quality across the City's Central Western Isthmus. The aim of the Project is to build a new pipeline to collect combined wastewater and stormwater flows from the Motions Catchment and convey these to the Central Interceptor at Point Erin Park, where they can then be safely conveyed to the Māngere Wastewater Treatment Plant. The WIWQIP is a joint initiative between Watercare and Auckland Council's Healthy Waters that was established in 2017 and has been identified in Watercare's Asset Management Plan 2021 – 2041 as a key programme to further protect the environment and provide clean harbours and waterways. At a high level, the three main goals of the WIWQIP are:

- To reduce risks to public health by alleviating uncontrolled discharges into local catchments;
- To remove the permanent health warning status of both Meola Reef and Cox's Bay; and
- To reduce intermittent beach closures in the area over the next 10 years.

The Project is a critical component of the wider WIWQIP which will enable Watercare to bring about considerable environmental benefits, reduce risks to public health and improve the amenity of the Motions catchment. For further detail regarding the proposed works and the Project's objectives, please refer to Section 4 of the Assessment of Effects on the Environment.

1.3 Purpose of this report

Watercare have engaged Tonkin & Taylor Limited (T+T) to undertake a Groundwater and Settlement Assessment of Effects (GSEA) for the proposed wastewater alignment Motions Catchment Improvement Project located in Central Auckland.

The purpose of this report is to assess the resource consent application for the construction of a new collector sewer approximately 3.2 kilometres in length from Canada Street in Auckland's Central Business District (CBD) to Western Springs Park in Western Springs where the Project ties into the Central Interceptor. The Project also involves the construction of three branch connections and 16 Engineered Overflow Points (EOPs). The following reasons for consent pertaining to groundwater have been identified:

- Rule E7.4.1 (A20): Groundwater is expected to be encountered, and dewatering is likely needed for greater than 30 days at certain locations, therefore cannot comply with Standard E7.6.1.6. This requires a restricted discretionary activity resource consent.
- Rule E7.4.1 (A28): The wastewater pipeline diameter is 1.8m and groundwater diversion will be needed for more than 10 days at specific locations. Standards E7.6.1.10(2) – (6) therefore apply to the groundwater diversion activity. The activity cannot comply with Standards E7.6.1.10(2)(b), 4(b) and 5(b) and therefore requires a restricted discretionary activity resource consent.

For all resource consent triggers, please refer to the Assessment of Environmental Effects (AEE) for further details. Watercare is seeking to obtain consent for two different tunnelling methodologies: pipe jacking and tunnel boring machine (TBM). For the purposes of this assessment, we have assessed both options with, results of the technical assessments undertaken summarised in the following sections of this report, and the full technical memoranda presented in the Appendices. However, our effects summary assesses which option is critical, and presents a summary of effects based on only the critical case, to inform the consenting of an effects envelope which represents the greater effects of either methodology.

1.4 Project alignment

The proposed alignment and shaft locations are shown in Figure 2.

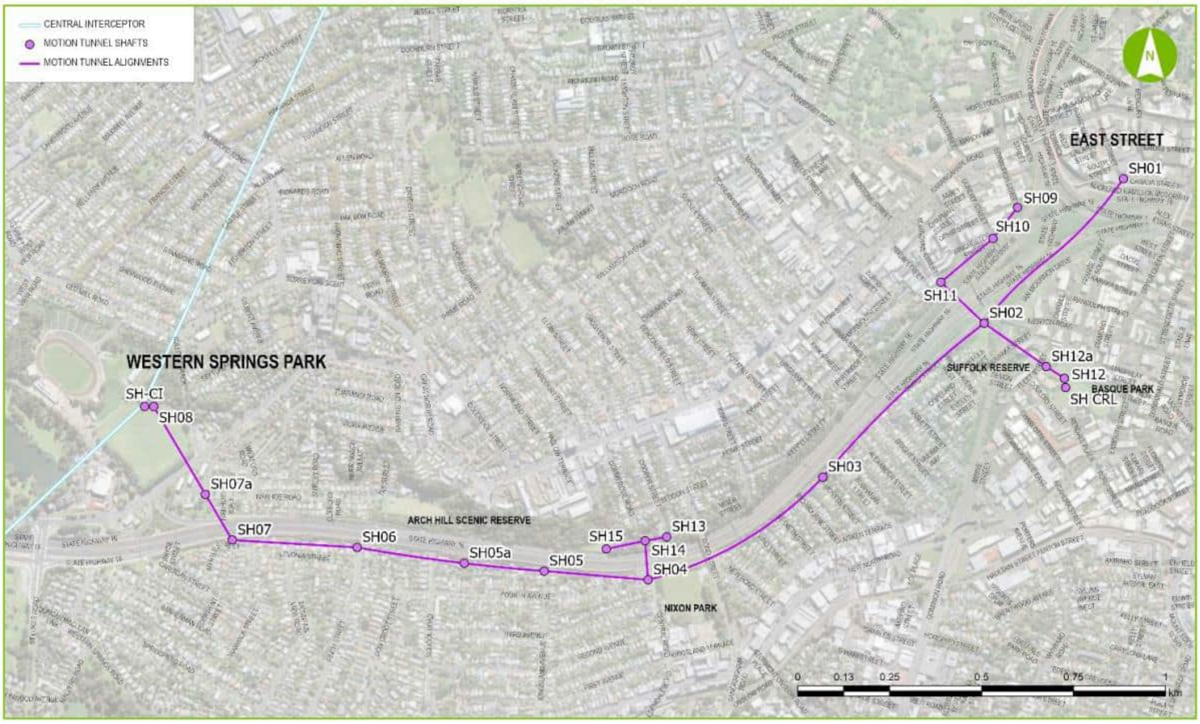

Figure 2: Project location and connections.

1.5 Scope of work

The following summarises the scope and objectives of this assessment and report:

- Review of the proposed construction methodology provided in Watercare's construction statement.
- Assess groundwater drawdown and associated induced settlement, associated with shaft construction. The proposed tunnelling methodologies actively control groundwater drawdown as such groundwater drawdown for tunnelling has not been assessed.
- Assess mechanical excavation-induced settlement associated with shaft construction and tunnelling.
- Assess the combined resultant effects on neighbouring building, utilities, and structures.
- Assess groundwater depletion on neighbouring water bodies.
- Recommendation of mitigation measures and construction monitoring.

1.6 Associated reports and drawing sets

Our assessment is based on information provided in the Geotechnical Factual Report (GFR)[1] and Geotechnical Interpretive Report (GIR)[2] that have been issued separately and should be reviewed in conjunction with this report. Concept level scheme plans presented as long sections[3,4] for the project are provided in **Appendix A**. As described in **Section 2**, the drawing sets comprise two tunnelling options, referred to as TBM and pipe jacking methods.

2 Construction methodology

2.1 General

A construction statement[5] prepared by Aurecon and provided by Watercare has been used as a basis for the assessment undertaken.

The Motions Collector Sewer will be constructed using a combination of pipe jacking (up to DN[6] 2400) and Tunnel Boring Machine (TBM) methods (DN 3000 to DN 4500), depending on the section of the alignment and option chosen. Shafts will be constructed along the alignment to serve as launch and/or receiving points for tunnelling equipment, as well as for hydraulic connections.

The assumed sequence includes:

- Site mobilisation and establishment
- Enabling works and service diversions
- Shaft construction
- Tunnelling operations
- Manhole installation and shaft decommissioning
- Final reinstatement.

2.2 Shaft excavation

Shaft depths vary from approximately 6 m to 45 m, depending on the proposed alignment and tunnelling method. Excavation support systems may comprise multiple construction methods, such as secant piles, caissons, and temporary steel casing. The choice of method will depend on site-specific geological, hydrogeological, and logistical factors. However, for this assessment and to establish a consenting envelope, we have narrowed the excavation support system to secant piles on the basis that these can be optimised to constrain effects. Other methods may be used in construction, provided that the resulting effects do not exceed the consented limits.

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[1] Aurecon (21 February 2025). WIWQIP Motions Catchment Improvement. Ground Investigation Factual Report: Stage 1-3. Ref: 521290-064

[2] Aurecon (24 April 2025). WIWQIP Motions Catchment Improvements. Geotechnical Interpretative Report. Ref: 521290-W00064-REP-GG-0003.

[3] Watercare (16 May 2025). Motions Collector Sewer – Additional Drawings for Resource Consent: DN2400 Pipe Jacking Option. Drawing Set No. 2014581.100-144.

[4] Watercare (16 May 2025). Motions Collector Sewer – Additional Drawings for Resource Consent: DN4500 TBM Option. Drawing Set No. 2014581.200-230.

[5] Aurecon (14 May 2025). Construction Statement Memorandum. Ref: 521290-064.

[6] "DN" = nominal diameter

Dewatering is identified as a necessary activity during shaft construction. The construction statement refers to the use of dewatering pumps but does not specify the method (e.g. sump or wellpoint systems). For our assessment, we have assumed that dewatering will occur via a sump within the excavations due to the limited site work areas.

Upon completion of tunnelling, a watertight manhole will be installed within the shafts, and the void between the shaft and manhole structure will be backfilled. Therefore, no long term effects are anticipated from the shafts.

2.3 Tunnelling

It is proposed that tunnelling will be carried out using:

- Pipe Jacking Machines or Tunnel Boring Machines (TBMs) for the main collector sewer.
- Pipe Jacking Machines or directional drilling for the branch lines.

Due to the topography of the alignment, two options exist for the pipe jacking methodology if it is adopted for the main collector. This is as follows:

- Option B1: The main sewer cascades at the shaft locations. This approach minimises the depth of the pipe jacking operation and some of the shaft depths.
- Option B2: The main collector is constructed at a relatively consistent gradient along its length, similarly to that of a TBM methodology.

3 Existing environment

3.1 Site location

Figure 3: Site location (copied from drawing set[3]).

The site is located within the central-western suburbs of Auckland, New Zealand, extending from East Street in the east to Western Springs Park in the west. The project alignment traverses a mix of residential, commercial, and transport corridor land uses, including areas beneath State Highway 16, the Central Motorway Junction (CMJ), and the Northwestern Cycleway.

The legal descriptions of land parcels intersected by the project include a combination of public road reserves, parklands (e.g. Basque Park, Nixon Park, Western Springs Park), and utility corridors. We understand specific legal parcel details are referenced in the associated planning and property documentation.

The project area spans approximately 3.2 km in length. The site is topographically variable, sloping generally from east to west, with elevations ranging from approximately 55 m RL at East Street to 15 m RL at Western Springs Park. Notable topographical features include elevated ridgelines and low-lying incised catchments.

Refer site location Figure Appendix B.1.

3.2 Built environment

Our review of the built environment surrounding the proposed shaft and tunnel alignment is based on public data sources, including LINZ building outlines, Auckland Council underground services data, aerial imagery, Google Street View, and site walkovers. Infrastructure such as roads, footpaths, cycleways, and bridge footings were identified and assessed for proximity and potential impact. As well as a mix of vegetated parkland, asphalted road corridors, and concrete-paved urban infrastructure.

Shaft sites are primarily located within parks and reserves or at the ends of streets adjacent to buildings. The tunnel alignment predominantly passes beneath residential dwellings, with branch networks also extending under the northwestern motorway.

Refer built environment Figure Appendix B.2.

3.3 Natural environment

The natural environment within and surrounding the site consists of a varied topography, with elevated ridgelines underlain by East Coast Bays Formation (ECBF) and low-lying incised catchments filled with alluvium and basaltic lava flows from the Auckland Volcanic Field (AVF).

Refer natural environment Figure Appendix B.3.

4 Ground settlement assessment

4.1 Sources of settlement

Ground movements due to the project can result from excavation of the proposed shafts and tunnels. We do not expect the ongoing operation of the shafts and tunnels to result in significant ground movement, once construction is complete.

The potential for construction related settlement associated with the proposed excavations (shafts and tunnelling) and dewatering is caused by the following mechanisms:

- Consolidation settlement – Consolidation of the ground due to groundwater drawdown. This settlement is due to extraction of groundwater and is related to the volume of groundwater removed and corresponding increase in effective stress in the soil.
- Mechanical settlement – Relaxation of the ground adjacent to the excavation, whether retained or not. These deflections will translate into settlement of the ground adjacent to the excavation.

The total ground surface settlements result from a combination of the consolidation and mechanical settlement effects. The maximum total settlement has been estimated by summing the contributions from each settlement source.

4.2 Assessment approach

The following assessment approach was adopted:

1 Groundwater drawdown and associated consolidation settlement:
   a Developed conceptual models at each of the proposed 17 temporary shaft locations and used these to inform the selection of 26 modelling “cases”, as summarised in Table 4.1. These cases differentiate between shaft locations and/or different proposed design options.
   b Selected moderately conservative groundwater and geotechnical parameters based on a combination of project-specific investigation data and engineering judgement for this settlement effects assessment, outlined in **Appendix C.**
   c Undertook numerical modelling to assess groundwater drawdown and associated consolidation settlement for each defined shaft case. Results are presented in **Appendix E**.
2 Mechanical settlement arising from shaft excavations
   a We have developed representative models for similar shafts to determine mechanical settlement effects at each location. This is based on the ground model, proposed shaft locations, and shaft dimensions; resulting in three “base” cases and “two sensitivity” cases, as summarised in Table Appendix F.1 and Appendix Table F.2. The adoption of representative models at the other shaft locations is considered to be conservative and results in slight over-prediction of mechanical settlements.
   b We have selected moderately conservative geotechnical parameters based on a combination of project-specific investigation data and engineering judgement for this settlement effects assessment. The adopted parameters used in our modelling are outlined in **Appendix F.**
   c Conducted mechanical settlement analysis for the selected shaft cases. Results are presented in **Appendix F**.
3 Mechanical settlement arising from tunnelling
   a Undertook an assessment of potential settlement effects due to tunnelling. Mechanical settlement is caused by the slight over extraction of material by the tunnel boring machine (TBM) in excess of the constructed tunnel volume. Modern TBM techniques have significantly reduced this effect. The small over-excavation results in relaxaion/strain in the surrounding ground which manifests as vertical and horizontal ground displacement ahead of and around the tunnel. The method of New and O’ Reilly (1982) has been used to assess the maximum magnitude and lateral extent of mechanically induced ground settlement due to the construction of the proposed tunnels. Results are presented in **Appendix H**.

4 Combine consolidation and mechanical settlement together and evaluate the potential for damage due to settlement at buildings, utilities, and structures along the project alignment against published literature and commonly adopted damage thresholds by Auckland Council. Results are presented in **Appendix G.**

Table 4.1: Shaft modelling cases

Shaft ID	Design option(s)	Groundwater settlement analysis Case ID (numeric)	Mechanical settlement analysis Case ID (alphabetic)	Excavation depth adopted for analysis, including assumed 0.5 m over dig (m)
SH01	Pipe Jacking – Option B2	Case1	A	45.5
	TBM	Case2	A	45.5
	Pipe Jacking – Option B1	Case3	A	24.0
SH02	Pipe Jacking – Option B2	Case4	B	40.4
	TBM	Case5	B	40.4
	Pipe Jacking – Option B1	Case6	B	32.1
SH03	Pipe Jacking – Option B2	Case7	B (Sensitivity)	25.8
	TBM			
	Pipe Jacking – Option B1	Case8	B (Sensitivity)	17.6
SH04	Pipe Jacking – Option B1	Case9	A (Sensitivity)	24.8
	Pipe Jacking – Option B2			
	TBM	Case10	A (Sensitivity)	24.8
SH05	Pipe Jacking & TBM	Case11	B	23.1
SH06	Pipe Jacking & TBM	Case13	B (Sensitivity)	22.8
SH07	Pipe Jacking & TBM	Case14	A (Sensitivity)	21.0
SH07a	TBM	Case15	B	21.3
	Pipe Jacking	Case16	B	21.3
SH08	Pipe Jacking	Case17	A (Sensitivity)	25.3
	TBM	Case18	A (Sensitivity)	25.3
SH09	Pipe Jacking & TBM	Case19	C	9.7
SH10	Pipe Jacking & TBM	Case20	C	6.4
SH11	Pipe Jacking & TBM	Case21	B (Sensitivity)	25.0
SH12	Pipe Jacking & TBM	Case22	C	8.2
SH12a	Pipe Jacking & TBM	Case23	B (Sensitivity)	17.6
SH13	Pipe Jacking & TBM	Case24	C	8.6
SH14	Pipe Jacking & TBM	Case25	B (Sensitivity)	15.4
SH15	Pipe Jacking & TBM	Case26	C	6.5

4.3 Assessment summary

The results of the settlement analyses are presented in Appendix G. A summary of the settlement assessment is presented below. The results presented in Figure 4 are referenced at a 3-metre distance from the edge of each shaft excavation, which can be considered to represent the maximum estimated settlement magnitude for each shaft location. The 3-metre reference distance provides a basis for comparison and risk assessment across the various shaft locations.

Detailed results included in the Appendix G demonstrate a general trend of reducing settlement magnitude with increasing distance from the excavation perimeter

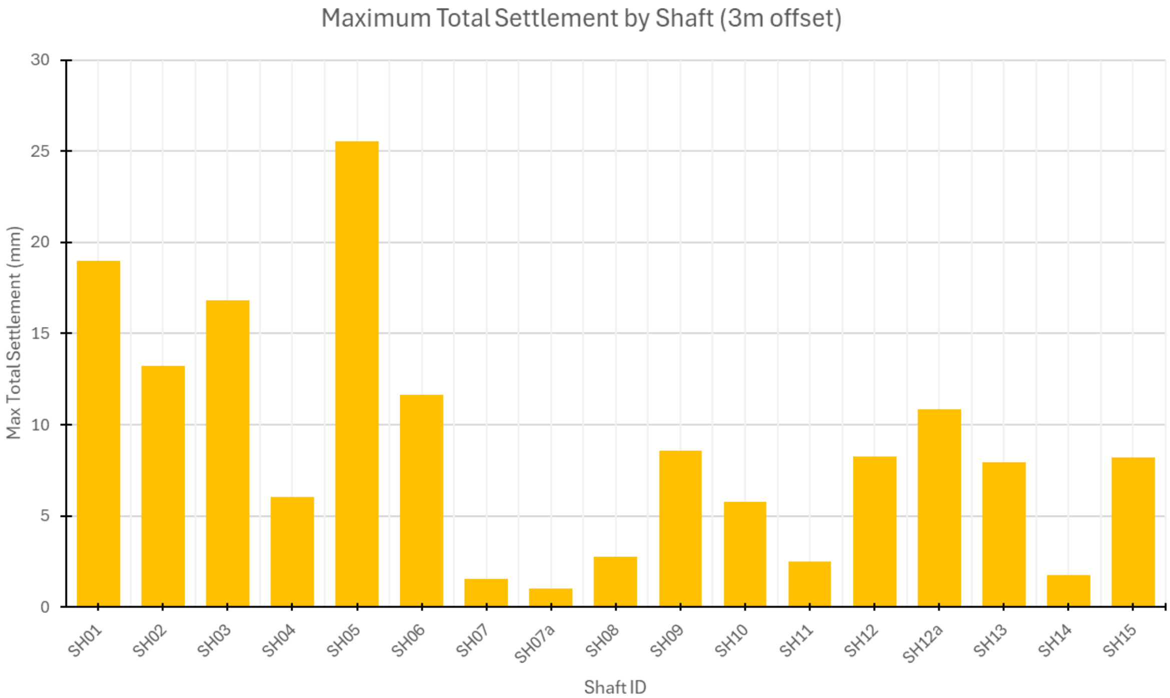

Figure 4: Project location and connections

5 Effects assessment

The sections below provide a summary of potential effects based on a moderately conservative assessment.

5.1 Groundwater effects

5.1.1 Potential effects on groundwater levels

Based on our assessment, some localised temporary groundwater drawdown is expected around the proposed shaft locations, with groundwater levels expected to return to pre-construction levels after sealing and backfilling of the excavations. The drawdown in groundwater will result in some ground settlement which is further discussion in Section 5.2.

5.1.2 Potential groundwater diversion effects

The effect of diversion refers to the alteration of the natural groundwater flow paths due to the presence of installed subsurface structures. This assessment has considered whether such diversion results in permanent changes to groundwater flow patterns caused by structures (e.g. shafts), and whether these changes lead to increases or decreases in groundwater levels that may impact lawful groundwater users.

Some groundwater diversion is expected to occur as groundwater flows are redirected around the installed structures (i.e. the wastewater pipeline and shafts). However, the extent of this diversion is anticipated to be localised to immediately around these structures, ie. within a few metres of the shafts. Consequently, any associated changes to groundwater levels are assessed as negligible.

5.1.3 Potential effects on neighbouring bores

Neighbouring bores have the potential to be affected by groundwater level changes associated with construction dewatering activities, which may become significant if the ability to obtain an adequate groundwater supply from these bores is compromised.

Groundwater drawdown is assessed to be small, occurring predominantly within the overlying soils, and reduces with distance from the shaft excavations, therefore any related effects on neighbouring bores are assessed as negligible.

5.1.4 Potential saline intrusion effects

Saline intrusion occurs when groundwater in an aquifer near the coast is replaced by seawater from the ocean. The Project is located over 1 km from the coastline, and our review of groundwater monitoring data indicates that the groundwater at the site is not influenced by tidal effects. Therefore, we consider that there is negligible risk of saline intrusion.

5.1.5 Potential effects on nearby waterbodies

Due to the proposed construction methodology and offset distance of the proposed excavations to existing water bodies, effects on nearby waterbodies is assessed to be negligible.

5.2 Settlement effects

The construction of shafts and tunnels has the potential to induce both vertical and lateral ground movement. For this assessment, the "zone of influence" is defined as the area where total ground settlement may exceed 10 mm. This threshold is consistent with published guidance, including the Burland (1995) classification of building damage risk, where settlements below 10 mm generally correspond to negligible or very slight risk of cosmetic damage. The assessment of combined drawdown-induced consolidation and mechanically induced settlement has been used to estimate ground movements and estimate potential effects on surrounding structures at shaft locations. Estimated total settlements shaft excavations are presented in Appendix G.

Tunnel boring may induce up to an additional 3 mm of settlement within 6 m of the tunnel centreline. This settlement associated with tunnelling is comparatively small in comparison to the settlements associated with the shafts, and (perhaps even more importantly) differential settlement due to tunnel boring will be very slight, due to the depth of the tunnels. For these reasons, tunnel boring settlement has not been added to shaft settlement as the assessed classification of building damage risk is not considered to materially change.

Where total or differential settlement thresholds have been defined for buildings and utilities, a comparison between the assessed settlement values and published thresholds has been undertaken and presented in Appendix G. Results of this assessment indicate that the risk of damage of existing structures is less than minor.

5.2.1 Summary of predicted settlements

Ground settlement has been assessed across all shaft and tunnel locations using combined groundwater and mechanical settlement modelling. Our assessment indicates that settlements may range from less than 5 mm in areas of minimal impact to up to approximately 28 mm in locations with deeper excavation or softer ground conditions. The largest settlements are generally anticipated to occur within the construction work area and reduce with distance from each excavation.

5.2.2 NZTA and Transport Infrastructure

The proposed tunnel alignment intersects or passes in close proximity to NZTA managed assets including State Highway 16, the Newton Road and Bond Street overbridges. Vertical settlement is calculated to be generally less than 15 mm with dididifferntial settlement less than 1V:3500H, with potential for localised settlement up to approximately 18 mm in softer ground areas (e.g. Shaft 05). Further consultation is underway with NZTA to determine asset specific effects and suitable management measures.

NZTA has reviewed the proposed works and issued written approval under section 95E of the Resource Management Act 1991, confirming support in principle. This is subject to detailed design confirmation, ongoing consultation with NZTA on effects, and provision of supplementary geotechnical and groundwater data to ensure their assets are protected.

5.2.3 Basque Park tunnelling under existing building

The Basque Park branch traverses fill materials associated with a closed landfill and is, underlain by soft alluvium. Our assessment estimates settlements of up to 11 mm at the ground surface in this area, reducing to 10 mm or less at surrounding structures due to the proposed shaft excavation. The level of predicted settlement at buildings equates to a Burland Risk Classification of 1 – Very Slight.

The branch connection that traverses from the main alignment to the shaft in Basque Park is proposed to be tunnelled under two multi-storey buildings (15 Fleet Street and 6 Piwakawaka Street). Both of these buildings have basements and are supported on pile foundations. Estimated settlement at pile toe level is small (≤2 mm); however, a structural review of the existing condition of affected buildings should also be considered during the detailed design phase. Construction monitoring and pre-condition surveys are also recommended.

5.2.4 Utilised and services connections

A range of utilities are located within the Project corridor, including water, wastewater, stormwater, gas, power and telecommunications services. These are typically situated within road reserves and, in general, are expected to tolerate minor ground movement. However, in areas where assets have shallow cover, are constructed from brittle materials, or are in an unknown condition, settlement of 15 mm or greater may pose an elevated risk.

Due to limited available information on asset depths and construction details, it is not currently possible to confirm the specific effects of settlement on individual utilities. To address this, a conservative screening assessment has been undertaken against predicted surface settlement contours. The methodology and results of this exercise are presented in Appendix F.

Our assessment indicates that construction of the proposed shafts and tunnels may cause differential settlements of up to 1V:750H. Most utilities are likely to be able to accommodate these differential settlements without damage. Localised effects may still occur (e.g. for a pipe with an already very flat grade. Further consultation with utility asset owners will be required to confirm asset condition and establish appropriate mitigation and monitoring measures.

Pre-construction condition assessments and the development of contingency plans are recommended for higher-risk services to ensure continuity of service and effective response if unexpected movement occurs during construction.

5.2.5 Private and commercial properties

Most residential and commercial properties along the alignment are predicted to experience less than 10 mm of settlement, equating to Burland Risk Classification of 1 – Very Slight. In limited locations, particularly where shafts are located in softer ground, surface ground settlement at buildings may approach approximately 23 mm and differential settlements of up to 1V:850H. The predicted settlements correspond to a Burland Risk Classification of 2 – Slight when assessed against total settlement and a Burland Risk Classification of 1 – Very Slight when assessed against differential settlement.

These levels correspond to mostly cosmetic damage such as:

- Cracking of internal brittle finishes such as plaster. Cracks are expected to be easily filled and repaired.
- Exterior cracking may be visible, some repainting may be required for weather tightness.
- Doors and windows may stick slightly requiring adjustment.

Based on the nature of the settlement (differential settlement equating to Burland Risk Classification of 1 – Very Slight) the extent of these effects is expected to be limited.

Condition surveys are recommended for structures located within areas predicted to experience 10 mm of settlement or greater.

6 Proposed monitoring

Ground settlement and groundwater drawdown monitoring during the construction works will be undertaken to assess if the response of the surrounding buildings and structures is within expected tolerances. This process allows for the geotechnical effects to be monitored and can act as a trigger for mitigation measures to be implemented if required.

The purpose of the monitoring programme is to monitor actual settlements and establish alert and alarm triggers below levels that can be expected to result in the onset of minor damage to structures under worst-case assumptions. Predicted settlements at monitored structures in many instances are too small to accurately measure and below the threshold of damage. As such, we recommend that the potential for the onset of minor damage (Burland Risk Classification of 1 – Very Slight) under worst-case assumptions equates to the Alarm Trigger Level, and the Alert Trigger Level is set at 80% of the Alarm for ground deformations. These recommended trigger levels can then be reviewed and confirmed through preparation of a Ground and Settlement Monitoring and Contingency Plan (GSMCP).

The following monitoring techniques will be incorporated where appropriate:

- Building and Ground Settlement Monitoring Points via survey markers. These should be placed around the proposed excavation sites to monitor sensitive structures, outside areas where they may be damaged by construction equipment. A minimum of 3 survey markers per building is required. However, buildings with complex structural forms, or that show particular susceptibility to ground movement, may warrant additional markers.
- Groundwater level monitoring via standpipe piezometers. These should be installed and monitored prior to construction to establish baseline levels. Their locations should be near proposed excavation sites, but outside the actual proposed excavation.
- Tunnel settlement survey arrays spaced every 600 m from the launch shaft along the length of the tunnel, as well as near critical structures such as where the tunnel traverses under SH1, Bond Street overbridge, Newton Road overbridge, and the approach towards Canada Street, particularly in the vicinity of the SH1 overbridges.
- Routine visual building and pavement observations, where estimated settlement are predicted to be 10 mm of greater.
- Pre and post condition surveys of buildings, services, and structures where settlements are estimated to be 10 mm or greater.

Alert and alarm levels will be established using a staged trigger-response framework, typically including:

- Alert level: 80% of the predicted movement threshold for very slight damage.
- Alarm level: Onset of movement that could indicate a risk of slight damage.

The specific location of monitoring and buildings to be monitored shall be confirmed in the GSMCP. However, preliminary recommendations for monitoring identifying monitoring type and locations are presented in a draft GSMCP.

7 Applicability

This report has been prepared for the exclusive use of our client Watercare Services Limited, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for resource consent and that Auckland Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

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