26 Ground settlement

Overview

Potential ground settlement associated with the construction and operation of the proposed Expressway has been estimated. Potential sources of settlement considered include:

- direct loading within the construction footprint from the road embankments,
- groundwater drawdown associated with the modification of the foundation materials below the road embankments,
- groundwater drawdown associated with new stormwater features,
- retaining walls, and
- vibration.

Key geotechnical considerations for settlement potential are the presence of peat deposits, and the thickness and nature of them. The potential effects of the estimated settlement on existing buildings, services and transport infrastructure have also been assessed and are set out in Technical Report 35, Volume 3, Assessment of Ground Settlement Effects, and associated Plan Sets in Volume 5. Key conclusions are:

- The predicted risk settlement effects on residential buildings are assessed to be low.
- The predicted risk of settlement effects on commercial and industrial buildings are also identified as negligible. It is proposed that for buildings in close proximity to the proposed Expressway, individual assessments of potential settlement effects will occur during detailed design.
- The predicted risk of settlement effects on services beyond the Project footprint is assessed as being low. The services located outside the proposed earthworks extents are likely to be subject to relatively small changes in grade and horizontal strain. Discussions are on-going with all of the service providers to seek to ensure that appropriate circumstance specific solutions are used. Services located below the footprint and founded above the base of the peat deposits will require relocation or active protection due to either the predicted settlement effects or physical construction works.
- The predicted risk of settlement effects on local roads has been assessed as low.

A settlement monitoring regime is proposed which will utilise a method for measuring the actual occurrences of settlement and resulting effects. The monitoring will include building condition assessments for structures within a conservatively assessed corridor, together with measurement and reporting of ground settlement and groundwater levels and the results against trigger levels. Further mitigation measures can be implemented should the measured settlement or its effects require it.

26.1 Introduction

Potential ground settlement associated with the construction and operation of the proposed Expressway has been calculated, and an assessment of the expected effects of this settlement on existing buildings, services and transport infrastructure was undertaken.

The Project incorporates design elements to address the potential for ground settlement effects. A monitoring regime is proposed and there are mitigation measures available that can be implemented should the measured settlement or its effects require it.

Technical Report 35 Assessment of Ground Settlement Effects (Volume 3) and the Ground Settlement Effects Management Plan in Appendix J of the CEMP (Volume 4) inform this Chapter. This assessment relies in part upon modelling of groundwater effects and so should be read in conjunction with Technical Report 21 (Volume 3).

26.2 Existing environment

The consideration of the existing environment in this Chapter focuses on ground conditions that may result in ground settlement, and the structures that may be impacted by such settlement.

The proposed Expressway route traverses the sand dune and swamp deposits of the Kāpiti coastal lowlands. The sand dunes form areas of higher relief, rising to around 20m in elevation, between the intervening low lying areas. These low lying areas and depressions are located a few metres above sea level and typically contain peat deposits. The dune sands are often inter-laced with peat deposits, where the dune sands have in places advanced over the swampy ground.

Low lying terraces of recent river and fan alluvium are located adjacent to the Waikanae River.

The predominant characteristics of the existing environment by Project sector are:

Sector 1 – Raumati South

From south of Poplar Avenue to just north of Raumati Road, the topography is fairly low lying, comprising peat and/ or organic silts overlying Holocene alluvium and sand, and Pleistocene gravel at depths of 5 to 10m below ground level until chainage 4000 of the proposed Expressway, where dunes of around 15m height overly the Pleistocene sand and gravel. The peat deposits in Sector 1 are typically described as silty peat, with some organic silt, and vary in thickness from 1.0 to 3.5m.

Sector 2 - Raumati/Paraparaumu

From north of Raumati Road to north of Mazengarb Road, the topography is undulating. The route crosses dunes which reach up to 15m in height, with lesser amounts of lower lying inter-dunal areas in between. It appears that much of this sector of the road corridor preserves a remnant of what was a larger dune field which has undergone extensive earthworks for residential development in Paraparaumu.

The geology generally comprises Holocene sand (dune), overlying Pleistocene sand, with peat and organic silt in low lying areas. The peat deposits in Sector 2 are typically described as silty peat, with some organic silt and vary in thickness from 1.0 to 3.5m. It is understood the peat deposits have been excavated from below the newer subdivisions and replaced with sand. Anecdotal evidence suggests that this is the case west of the proposed Expressway between Milne Drive and Mazengarb Road.

Sector 3 - Otaihanga/Waikanae

From north of Mazengarb Road to north of Te Moana Road, the topography is undulating, with the route passing over dunes (which reach up to 20m height) and lower-lying inter-dunal areas.

The geology generally comprises Holocene sand (dune) overlying Pleistocene sand, with peat and organic silt in low lying areas. Toward the centre of this sector, the Waikanae River cuts through the route east-west with associated low-lying alluvial terraces on either side. Geology at depth beneath the Waikanae River area comprises very dense Pleistocene gravel, and some Pleistocene silt. The peat deposits in Sector 3 are typically described as organic silts and sands, and vary in thickness from 1.0 to 2.5m.

Sector 4 - Waikanae North

From north of Te Moana Road to Peka Peka, the topography is undulating, dominated by dunes until Smithfield Road, east of which the route flattens out.

The geology comprises Holocene (dune) sand overlying Pleistocene sand and at depth, Pleistocene gravel. Beyond Smithfield Road there are areas of peat and organic silt in low lying areas, particularly north of chainage 15600 of the proposed Expressway. From chainage 16200 to 16700 the alignment crosses the Hadfield Fault. The peat deposits in Sector 3 are typically described as silty peat, with some organic silt and vary in thickness from 0.5 to 4.5m.

Built Environment Features

The main features of the existing built environment that are relevant to ground settlement effects are buildings, services and transport infrastructure.

In general, the land use adjacent to the proposed Expressway is a mix of urban residential and rural in nature. As part of the general development of the Kāpiti Coast, the ground conditions have been modified in some areas. Rural farming and lifestyle properties are located between Otaihanga Road and the Waikanae River, and north of Te Moana Road. Elsewhere the land use is primarily urban residential with some commercial development on Kāpiti Road.

Commonly adopted urban development techniques have included excavation of the peat and replacement with dune sand to provide adequate foundations and excavation of the sand dunes to provide a fill resource. The construction of surface drainage networks in the past has increased the productivity of the land. The techniques proposed to construct the proposed Expressway are consistent with these activities, and the resulting ground settlement effects are known and widespread in the Project area.

The majority of residential buildings have been built over the last 50 years with a number of newer subdivisions. There are commercial and light industrial buildings in the Paraparaumu town centre near the proposed Expressway alignment. These are typically two storey portal frame structures.

The Kāpiti Coast District Council (KCDC) Wastewater Treatment Plant and the Waikanae Christian Holiday Park (El Rancho) are adjacent to the proposed Expressway and have been specifically considered in this assessment.

There are multiple services crossing or in close proximity to the proposed Expressway alignment. These services are typical of residential areas, and include water, wastewater and stormwater networks, electricity and gas distribution and telecommunications.

The Vector Gas Transmission Pipeline Corridor crosses the proposed Expressway alignment at several locations within a 1.6 km stretch north of the Waikanae River.

The proposed Expressway passes under the Transpower Bunnythorpe to Haywards A and B 220kV Transmission Lines north of Smithfield Road.

The proposed Expressway crosses the existing local road network at nine locations, including secondary arterial roads. There are also local roads that are in close proximity to the proposed Expressway. The existing local roads are generally two lanes (one lane in each direction) and are finished with a chipsealed surfacing.

The North Island Main Trunk (NIMT) Railway line runs roughly parallel with the existing SH1. At the southern and northern extents of the proposed Expressway, the NIMT is located on an embankment to the east of the existing SH1. There are no proposed crossings of the NIMT.

26.3 Methodology

The methodology used to assess potential settlement effects incorporated an assessment of the four potential sources of settlement associated with the construction and operation of the proposed Expressway.

The settlement associated with the proposed Expressway will predominantly result from consolidation of the peat deposits, which will occur due to direct loading from the new road embankment, as well as by the lowering of the groundwater as a result of altering the embankment foundation materials, new stormwater features and construction activities.

The likely extent of ground settlement resulting from the Project is determined by superimposing, as applicable, settlement caused by the various sources. These are as follows:

Consolidation of the ground due to the construction of the embankments

This potential source of settlement is time dependent and represents by far the largest component of predicted ground settlement. Such settlement will occur beneath and for a small distance beyond the earthworks embankments where they are constructed on peat. As a result, they primarily affect the completed highway pavement and any services buried within the underlying peat.

Consolidation settlement is directly related to the embankment height and to the nature, thickness and permeability of the peat. Most of this movement will occur during construction, with on-going secondary compression (creep) settlement continuing at a reducing rate through the operation (i.e. after the proposed Expressway is in use). Up to 1300mm settlement is calculated to occur beneath the higher embankments where they are underlain by several metres of peat.

Calculated settlement beyond the earthworks footprint range from 0mm to 20mm, and extend up to approximately 10m from the embankment toe.

Consolidation of the ground due to lowering of the groundwater

The lowering of the groundwater level will result in consolidation of the peat deposits over time. This will occur due to the change in material permeability below the proposed Expressway and at some of the unlined stormwater features. Lowering of the groundwater level will occur as a result of excavation, which may be either temporary (for example, short-term undercutting to remove peat from beneath the embankment footprint) or long term around excavated stormwater ponds.

This form of settlement is also time dependent and extends beyond the earthworks footprint. It is predicted to be much smaller in magnitude than the movement resulting from embankment loading, typically reducing to 12.5mm within 70m of the embankment toe.

Mechanical settlement

Mechanical settlement will occur as a result of the new retaining walls and construction vibration. Mechanical settlement will occur in the dune sands and in close proximity to the source of vibration, and due to this mechanical settlement due to retaining walls and due to vibration have been considered independently. Consolidation settlement is predicted to be significantly larger, in both magnitude and extent, compared to mechanical settlement.

Mechanical settlement of the ground due to the movement of retaining walls

Lateral movement of embedded retaining walls (as the ground is excavated in front of them) results in localised settlement of the ground above.

This form of settlement occurs relatively quickly, during and immediately following wall construction.

Mechanical settlement of the ground due to vibrations

Vibration is used in construction to densify sandy or gravelly soils. This densification results in immediate settlement of the ground surface extremely close to the vibration source.

Vibration resulting from general construction activities, and from traffic on the completed Expressway, is not expected to generate sufficiently high shear stresses to cause ground settlement. Consequently, vibration induced settlement is predicted to be confined to the construction footprint and is essentially “built out” by the construction operation.

26.3.1 Elements of ground settlement analysis

Compression Parameters

The geotechnical compression parameters used to predict consolidation settlement in the peat deposits have been derived from available laboratory data, in situ testing and a number of field trials, as well as from historic data. These information sources are detailed in Technical Report 36, Volume 3.

Soil Profiles & Cross Sections

The soil profile was analysed based on an assessed peat thickness for each specific reference cross-section location. The groundwater level was modelled at 0.5m below the existing ground surface at all locations to represent reasonable long-term average conditions.

The reference cross-sections were selected to be representative of the varying peat thicknesses and peat treatment methodologies for the new road embankment. In addition, the cross-sections cover the new stormwater treatment ponds and flood storage areas that may result in lowering of the groundwater level, as identified in Technical Report 21, Volume 3.

Embankment Settlement Methodology

Consolidation settlement resulting from direct embankment loading has been analysed.

Groundwater drawdown settlement methodology

The predicted groundwater drawdowns are based on 2 dimensional groundwater modelling, with the extent of drawdown predicted from the regional 3 dimensional groundwater model.

There are a number of proposed stormwater features along the proposed Expressway alignment, including treatment ponds and offset flood storage areas. Detailed 3-dimensional models have been used to predict the groundwater lowering at the key stormwater features.

The sensitivity of the settlement predictions to a number of variables has been considered, including the unit weight of the peat deposits, existing groundwater levels and initial building surcharge.

Retaining Wall Settlement Methodology

Vertical settlement will occur behind the retaining walls as a result of lateral movements. These lateral movements will arise as the retaining wall is loaded, including during construction, and by excavation in front of the wall and backfilling behind the wall. These settlements have been assessed.

Vibration Settlement Methodology

Construction stage vibrations will be generated by earthworks, the installation of ground improvement (stone columns) and piling. The assessment of vibration effects is detailed in Technical Report 18, Volume 3.

Mechanical settlement of loose sand deposits may occur due to construction stage vibration. The potential settlement is expected to be of relatively small magnitude and is anticipated to occur in extremely close proximity to the vibration source. It is therefore not expected to occur outside the proposed Expressway footprint. This settlement does not occur concurrently with the settlement from other sources. As such, the vibration settlement is expected to have a negligible effect and has not been considered further. The vibration settlement and subsequent effects on the built environment are expected to be significantly less than the direct vibration effects. The management of the vibration effects are detailed in CEMP Appendix F, Volume 4.

Combination of Settlement Predictions

Predicted total consolidation settlement has been calculated based on a combination of both embankment and groundwater drawdown settlement. The settlement from each source has been superimposed by adding individual values at the same points across each cross-section. The extent of vibration and retaining wall settlement is considerably more localised in extent than for the embankment and groundwater drawdown consolidation settlement.

26.3.2 Methodology for assessment of effects

Buildings

The method described by Burland (Burland, 1997) is used to assess the effects of settlement on buildings. The concept of Limiting Tensile Strain enables a classification of the expected severity of damage of an “idealised” building at each location where vertical and horizontal ground movement data is available.

All buildings will exhibit a degree of restraint against a bending action imposed by the ground and this restraint will be a function of the building stiffness and continuity. For this reason, the effects of an assessment using the method described by Burland can generally be taken as conservative.

No buildings have been identified that lie within an area where the settlement modelling estimates greater than “negligible” effects (i.e. damage category 0).

The building damage category has been specifically assessed, based on the predicted settlement contours, for the following buildings and structures:

- Commercial and industrial buildings,
- KCDC Wastewater Treatment Plant buildings and structures,
- Waikanae Christian Holiday Camp (El Rancho),
- All buildings within 10m of the proposed Expressway.

The buildings within the expected area of effects have been visually assessed to determine the structural form and susceptibility to settlement.

Services

Existing Service Plans have been prepared from as-built records provided by the service providers (refer Drawings M2PP-AEE-DWG-GT-SE-200 to 232 in Appendix I). Collection of further information on the construction of the services and existing condition investigations are on-going.

Services directly impacted by the proposed Expressway will need to be protected or relocated, either temporarily or permanently. NZTA is working with the service providers and their representatives to seek to ensure appropriate solutions are used.

In addition, the Vector Gas Transmission Pipeline Corridor and the Transpower Bunnythorpe to Haywards A and B Transmission Lines have been considered specifically.

Modelling Uncertainties

There are a number of inherent uncertainties within the settlement predictions. While a conservative approach has been adopted there remains a risk that actual settlement will exceed the predicted values. If the predicted values are exceeded, the dwellings with the greatest potential to be affected by settlement are:

- Dwellings within 20m of the proposed peat treatment extents,
- Dwellings adjacent to new stormwater features with predicted groundwater drawdown of greater than 0.2m, and
- Dwellings in areas where the predicted settlement is greater than 12.5mm, including (as a precautionary measure) 10m beyond the predicted 12.5mm settlement contour.

These dwellings are proposed to be inspected prior to construction commencing to identify any pre-existing defects or sensitive features. For the more vulnerable building construction types, individually assessed during detailed design, considering the specific structural foundations and soil conditions.

26.4 Assessment of construction effects on ground settlement

This section presents the assessment of effects beyond the earthworks footprint based on the estimated settlement occurring from the construction phase onwards. The impacts on the main features of the existing built environment have been assessed, including buildings, services and transport infrastructure.

Plans showing the area of expected effects are provided in Technical Report 35 Assessment of Ground Settlement Effects in Volume 4. The predicted settlements are generally less than 25mm beyond the edge of the earthworks. In areas of deeper peat deposits (3.5 m thick and above), the predicted settlements are in the order of 25 to 50mm up to 20m from the earthworks footprint, reducing to less than 25mm beyond this.

Based on these relatively small estimated levels of settlement, the assessed effects on the existing buildings, services and transport infrastructure adjacent to the proposed Expressway are expected to be low.

The actual settlement and associated effects will be monitored to confirm this assessment, as detailed in the CEMP Appendix J, Volume 4.

26.4.1 Effects on buildings

The predicted groundwater lowering, from both the embankment construction and localised stormwater features, and the resulting consolidation settlement extend a distance from the proposed Expressway. Potential settlement effects on dwellings and other buildings in the Project area have been assessed. This assessment ignores the (commonly beneficial) interaction between building foundations and the ground, and is consequently considered to be conservative. The actual risk of damage is therefore likely to be less than the assessed damage category. All buildings assessed fell in Damage Category 'negligible' described as hairline cracks at worst. As a result, the potential ground settlement effects on buildings are assessed as being low.

At the KCDC Wastewater Treatment Plant, the settlement is estimated to be less than 12.5mm, based on limited geotechnical investigation data at this site. Accordingly, there is the potential that the actual settlement is greater than the predicted. There are a number of sensitive buildings and structures, including concrete tanks and pipe network that have the potential to be affected by settlement. Therefore, a detailed assessment of these structures is proposed, including confirmation of the structural forms and soil conditions across the site.

The Waikanae Christian Holiday Camp is not within the area of predicted settlement. Assessment has been undertaken however for buildings on this site identified as sensitive to differential movements. It is proposed that these be inspected prior to construction commencing to identify any pre-existing defects or sensitive features and again following completion of construction.

For the commercial and industrial buildings that have been identified based on the proximity to the alignment and the potential sensitivity of these structures to settlement effects, individual assessments will be undertaken during detailed design to confirm the assessed 'negligible' Building Damage Category.

26.4.2 Effects on services

Services may be impacted by settlement due to potential changes in grade and horizontal strain (i.e. elongation). The sensitivity of a service to these changes is dependent on the type of service, construction material, joint type and the age and condition of the service. The predicted total settlement contours have been combined with the as-built service drawings where available to show the potential settlement effects on the services (refer Drawings M2PPAEE- DWG-GT-SE-200 to 232 in Appendix I of the CEMP).

The services that are located below the footprint and founded above the base of the peat deposits will require relocation or active protection due to either the predicted effects of settlement or physical construction works. The services located below the peat deposits or in areas where peat deposits are not present will not be affected by settlement resulting from the Project.

The services located outside the proposed earthworks extents are likely to be subject to relatively small changes in grade and horizontal strain, as indicated on the settlement effects plans provided with Technical Report 35. Discussions are on-going with all of the service providers regarding the existing condition of their assets, their ability to tolerate the predicted settlement values and monitoring and mitigation options. Many of the services require relocation and or active protection measures regardless of the estimated settlement effects.

Vector Gas transmission pipeline corridor and delivery point station

The Vector Gas pipes are to be relocated as part of the Project. The Project team and Vector Gas are currently assessing the relocation options and likely timing of these works. Any potential settlement effects will be addressed as part of the relocation design.

Transpower Bunnythorpe to Haywards A and B Transmission Lines

Transpower transmission towers are located in close proximity to the edge of the proposed Expressway. The tower foundations are expected to be founded on sand deposits based on historical construction methods. Therefore, settlement effects are expected be negligible.

The Project team is in on-going discussions with Transpower, as some of the towers may require either foundation strengthening or relocation as a result of the proposed physical works.

26.4.3 Effects on transport infrastructure

Local road network

The effects of the predicted settlement and subsequent changes in road gradients have been assessed for the road network. The effects on the local roads outside the proposed construction designation are assessed as negligible, with all changes in grade less than 1 in 2000.

Appropriate monitoring and mitigation measures will be undertaken as part of the proposed Expressway detailed design.

North Island Main Trunk (NIMT) railway

The NIMT Railway is not within the area of predicted settlement. Therefore, the potential for a settlement effect on the railway line is considered to be negligible. The proposed settlement monitoring will be used to confirm that no detectable settlement extends to the railway.

Preconstruction and Construction Reporting and Actions Arising

Ground settlement monitoring and resulting effects will be reported to GWRC and KCDC. Preconstruction monitoring will be carried out and reported prior to the start of construction. This monitoring data will be factual in nature, with assessment only required for anomalous results. The report will form part of the input for the construction phase assessments.

The monitoring data will be processed and compared to the design analyses. Once construction starts, the data will be used to reassess the building damage categories and these categories will then be compared to the results in the settlement assessment report. The effects on services will also be assessed from the settlement gradients. If the reassessment indicates that the damage category has increased by a significant amount, then additional analyses or more frequent monitoring may be required and the affected buildings identified for potential mitigation work. Similarly, an increase in estimated effects on the services will require additional review and potentially amended monitoring and mitigation.

Consideration may also need to be given to modifying the construction approach to reduce ground settlement, if groundwater drawdown is greater than expected due to ground excavation.

Reporting will be determined by the stage of construction and actual results. During the active construction stage it is anticipated that initial internal review of monitoring results will take place shortly after receipt of the processed data. As long as the results show no significant anomalies or assessed significant increased risk to buildings, these monitoring results would be presented on a quarterly basis.

If there are any significant anomalies or significantly increased risk to buildings, then, following a more detailed review of the data, the owners and occupiers of those buildings would be notified and mitigation measures determined. The results of this more detailed work and the outcomes, along with the proposed way forward would then be reported.

26.5 Assessment of operational effects on ground settlement

Monitoring of the actual ground settlement and the resulting effects will be undertaken to confirm the estimated settlement and the predicted effects of the settlement. The majority of settlement beyond the footprint is expected to occur during the construction phase, with little additional settlement occurring during the operational phase.

Groundwater monitoring will be carried out for a defined period to confirm the predicted groundwater drawdown, which has been used to estimate the settlement.

Post- construction Reporting and Actions Arising

Ground settlement monitoring and resulting effects assessment will be reported to GWRC. The post active construction stage results (quarterly and six monthly) will be reviewed and reported shortly after receipt of the processed data.

Where any significant anomalies or after assessment significantly increased risk to buildings occurs, then the reporting will follow the process as described for the active construction phase.

26.6 Monitoring

Monitoring is required prior to construction, during construction and immediately following construction to provide a comprehensive assessment of effects. The measured settlement and resulting effects will be compared with the predicted values. The settlement predictions will be calibrated as the monitoring results become available and the assessment of potential effects updated.

The settlement monitoring set out in Technical Report 35, Volume 3, extends beyond the earthworks extent and the expected area of resulting effects.

Groundwater monitoring will also be carried out to confirm the predicted groundwater drawdown, which has been used to estimate the settlement.

The monitoring will be used to refine the settlement predictions. The results will serve as a trigger to require more comprehensive monitoring and/ or implementation of mitigation measures if required.

Table 26.1 sets out the proposed survey monitoring regime.

Table 26.1: Survey Monitoring Regime

Project Phase	Survey Monitoring Frequency of Framework Marks Vertical Survey Monitoring
Preconstruction	Monthly for 12 months
During Construction	Quarterly
During Active Construction	Monthly
Post Active Construction (1)	Quarterly for 6 months, reducing to half yearly for 3 years post-construction.
'active construction' can be defined as: ■ Starting when earthworks commence within 500m of a particular location and ending when pavement construction is complete at that location, and ■ Starting when excavation in front of a retaining wall comes within 50m of a section and ending when the permanent wall supports are in place beyond a distance of 50m.	

If the monitoring results indicate the movements are outside the expected range, or if there are other reasons for concern, then the monitoring frequency and / or extent can be increased to cover those areas of concern.

Services monitoring

In addition to the survey marks monitoring, CCTV inspections of some stormwater and wastewater services will be carried out to assess the effects of the settlement. As the construction progresses, additional CCTV inspections may be carried out depending on the results of the survey monitoring and feedback from service providers.

For other services identified as being susceptible to damage or particularly critical, visual inspections may be undertaken by excavating to expose the service if required.

26.7 Managing unanticipated ground settlement effects

The Project is predicted to give rise to negligible actual or potential adverse settlement effects beyond the construction footprint. In the unlikely event that unanticipated adverse effects arise beyond the construction footprint then measures outlined in Table 26.2 can be put in place.

Table 26.2: Methods to Manage Ground Settlement Effects

Actual or Potential effect	Possible method to avoid, remedy or mitigate potential effect
Road embankment settlement contingency measures If the actual settlement beyond the earthworks footprint are of greater magnitude than predicted and/ or extend further beyond the footprint affecting local roads	▪ Change the ground improvement approach where the proposed Expressway is constructed over peat deposits by interchanging treatment methods of: – Excavate and Replace or – Preload and Surcharge. ▪ Locally modify the ground improvement approaches such as a load transfer platform combined with foundations, to avoid excavating or loading the underlying peat. ▪ Reduce the embankment footprint over localised areas. This may be achieved by using geogrid reinforcement to allow steepening of embankment slopes, to increase the distance between the construction activity and the sensitive items.
Groundwater drawdown settlement contingency measures Lowering of the groundwater level will occur due to construction of the road embankment and at unlined stormwater features. In addition, short term ground water lowering will occur due to temporary excavations. If the actual settlement are beyond modelled levels, the groundwater drawdown contingency measures are detailed in Section 4.1 of the GWMP (Appendix I of the CEMP) and summarised in the next column.	▪ Change the construction methodology, including: – Alternative peat treatment – Lining (temporary and/ or permanent) of cuts below the groundwater level – Limit the length and drained duration of temporary excavations – Local cut off (clay bund or slurry wall) – Recharge trenches/ walls.
Retaining wall settlement contingency measures Lateral movement of embedded retaining walls (as the ground is excavated in front of them) will result in localised settlement of the ground above. These settlements occur relatively quickly, during and immediately following wall construction. Potentially the retaining wall deflections could exceed the anticipated limits.	▪ Review of the design undertaken to assess the increased load in the piles. If required, the following actions may be taken: – Remove surcharge close to the wall – Place a berm in front of the wall – Reduce the extent of temporary over excavation in front of the wall – Install additional or stiffer piles – Install props or ground anchors
Building damage repair measures *Non-structural effects* If the proposed Expressway works result in building damage	▪ General repairs required. These repairs may include repointing of brickwork, repainting and redecorating. ▪ If cases are more severe, repairs may require some partial re-building work. This is considered highly unlikely. The timing of such repairs would depend on the stage of construction, the building owner's preference and the degree of damage.

Actual or Potential effect	Possible method to avoid, remedy or mitigate potential effect
Building damage repair measures *Structural effects* The settlement effects assessment has not identified any buildings with a Building Damage Criteria of greater than 'negligible'. As such, structural building damage is highly unlikely and not envisaged on this Project. However, it is theoretically possible that effects of a structural nature could be identified during the course of the monitoring programme	■ A detailed evaluation undertaken by a Structural Engineer and recommendations for repair and an increased level of monitoring arising from this evaluation will then be implemented. ■ If an extreme case arose where local repair or re-construction was not sufficient, then additional measures such as underpinning or strengthening might be required.
Services repair measures Services located below the footprint and founded above the base of the peat deposits	■ Relocation or active protection due to either the predicted settlement effect or physical construction works. ■ These works determined with the service providers prior to Project works commencing.
Services repair measures The services outside the earthworks extents will be monitored. If this monitoring indicates damage may have occurred measures available to mitigate damage to services would depend on the type of service, location and severity of the damage and discussions with the service provider.	■ Undertake detailed investigation of the area and affected services. Include detailed examination of the site, and coordination with the relevant service providers to ascertain what effects their network is experiencing, and assess what remedial action is required. Any remedial works will be carried out as soon as practicable. If the investigation revealed no immediate damage, the services would continue to be monitored closely until all parties were satisfied no damage had occurred. ■ Permanently divert the service through another nearby service and abandon the original service line (the capacity of the nearby service would need to be checked). ■ Temporarily divert the service and repair the original service. ■ Expose the service and undertake a repair. ■ Replace the service. In cases of severe damage, a length of the service might be replaced.
Transport infrastructure repair measures The potential for settlement effects on the local roads outside the proposed construction designation is assessed as negligible, with the predicted changes in grade being relatively small. However, settlement might result in grade changes and differential movements and the measured effects might be greater than anticipated.	■ Overlay the road surface to raise to the previous level and re-shape any differential movements. ■ Reconstruct the kerb channels and footpaths to mitigate changes in grade and/ or differential settlement. ■ Install additional drainage if new areas of ponding are identified.