

## **Tools and methods to manage groundwater and settlement effects from the construction of an expressway on peat deposits**

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### **ABSTRACT**

The Mackays to Peka Peka Expressway is part of the Wellington Northern Corridor, identified as a Road of National Significance for New Zealand. The Expressway runs in close proximity to several wetlands of significant ecological and cultural value with unique fauna and flora, and to transport infrastructure and residential buildings built over peat deposits. Approximately 50% of the Expressway earthwork footprint is underlain by peat deposits that are typically 0.5m to 8.0m thick and are characterised as very soft, highly organic and compressible. Groundwater in the peat deposits is shallow and is directly connected to nearby wetlands. Expressway construction required either removal of the peat beneath its footprint or preloading and surcharging of it, to manage long term settlement. Both approaches involve significant potential alteration to the near surface groundwater system.

A comprehensive groundwater monitoring and settlement monitoring programme was established prior to construction commencing, with some 110 piezometers to record natural variations in groundwater levels and 100 settlement monitoring points. In order to differentiate construction effects from normal seasonal variations, a statistical approach was developed for setting both high and low trigger levels for the 22 telemetered piezometers located in and around five sensitive wetlands. Recorded groundwater levels and settlement have generally remained within the consented levels. Some exceedances were recorded however a pragmatic approach to monitoring and management of these exceedances allowed works to continue with minimal disruption and no adverse environmental effects.

### **1 INTRODUCTION**

The MacKays to Peka Peka (M2PP) Expressway Project is one of eight sections that make up the Wellington Northern Corridor, identified as one of the 'Roads of National Significance' (RoNS). The Expressway consists of approximately 18km of four lane median-divided Expressway from the Raumati Straights in the south through to Peka Peka in the north (Figure 1). The Expressway runs in close proximity to several wetlands of significant ecological and cultural value, transport infrastructure and residential buildings built over peat deposits. Groundwater in the peat deposits is shallow and is directly connected to nearby wetlands. The Expressway is predominately on embankments, rising up to 10m high at crossing points. Expressway construction activities required embankment construction with localised preload and surcharge or excavation and replacement of peat below the groundwater table to manage long term settlement (Figure 2).

Additionally construction of stormwater devices for treatment, conveyance and attenuation of run-off, and short-term groundwater take for construction water supply, have the potential to

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change groundwater level and might result in ground settlement, or changes to water levels in existing wetlands, ecological systems or water supplies.



Figure 1: Project Location and Extents

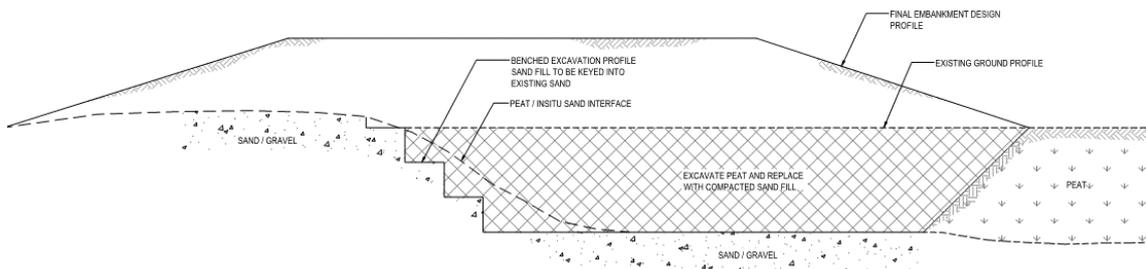


Figure 2: Typical cross section: Peat undercut for embankment on peat and sand

During the project consenting process an assessment of groundwater effects (France and Anderson, 2012) was undertaken, in order to assess potential changes to the existing groundwater regime as a result of the Expressway construction and operation. The effects on groundwater were assessed by the development of regional and area-specific 2- and 3-dimensional computer groundwater models, calibrated to water level monitoring data, and taking into consideration the modelling work carried out in the past. The associated Groundwater Management Plan (GMP)

(Williams, 2013) defined the best practicable options for groundwater monitoring and management practices and procedures to minimize impact on the environment. Furthermore an assessment of ground settlement effects (Coe, 2012) was also undertaken associated with the construction and operation of the Expressway and the expected effects of the settlements on existing buildings, services and transport infrastructure. The Settlements Effects Monitoring Plan (SEMP) (Ainsworth, 2013) defined the settlement monitoring procedure and measures to manage ground settlements associated with the Expressway.

## **2 GEOLOGICAL AND HYDROGEOLOGICAL SETTING**

The Expressway route is bounded, in the east, by the Tararua Ranges. These are steep greywacke hills which have formed by tectonic activity along NESW oriented faults such as the Ohariu fault (which runs along the base of the hills). The Expressway crosses the coastal plain west of the Ranges, an area which has been further shaped by repeated cycles of glaciation that have occurred in the past two million years. During the glacial cycles, sea levels were approximately 120m lower than present, as water was locked in ice-sheets and glaciers. The Tararua Ranges held valley glaciers during these times and physical weathering of rock, combined with sea level fall, contributed to severe erosion in the Ranges generating alluvial fans. These processes, in combination with longshore drift, formed large coastal plains. With each large scale tectonic movement, the rivers altered course and slowly migrated north and south across the alluvial fans depositing gravels, sands and silts. Episodic flood events resulted in finer materials (silts and clays) being deposited further away from the river channels, and in between such events, areas of peat developed in low lying areas between dunes. Sand dunes inter-finger with the peat deposits and rise up to 20 m in elevation along the coast.

The groundwater regime consists of unconfined aquifers in the Holocene sand and peat deposits above a series of unconfined aquifers in the Pleistocene sand and alluvium layers. The alignment passes through the Waikanae Groundwater Zone (WGZ), one of six broad groundwater management zones on the Kāpiti Coast. The key aquifer horizons within the WGZ are the deep Waimea Aquifer and Parata Aquifers, from which the Kapiti Coast District Council (KCDC) production wells abstract water for public water supply. Domestic wells in the area generally abstract water from the shallow Pleistocene and Holocene Sands.

A large number of wetlands occur within the WGZ. Wetlands and lagoons have typically formed in the low lying areas between dunes where peat has been deposited and where the groundwater level is very close to the surface. Wetlands are generally thought to be points of groundwater “discharge” with flows largely sustained by shallow groundwater (Gyopari, 2002). However there is also evidence that some wetlands within the Kapiti Coast are “recharge” wetlands fed by rainfall and run-off perching on the low permeability peat (Allen, 2010). Data collected and modelling carried out as part of this project confirms that both types of wetland occur, depending on the particular conditions at each site.

## **3 MONITORING**

### **3.1 Groundwater Monitoring**

A comprehensive groundwater monitoring programme was established prior to construction commencing, with some 110 piezometers (Figure 3) monitored monthly for at least one year to record natural variations in groundwater levels.

This baseline data has been used to identify natural seasonal groundwater level variations and to set alert and action levels (Figure 4). The groundwater alert level was set at the lowest recorded level (preconstruction) minus the predicted drawdown reduced by 25% or 200mm. A further

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100mm was allowed for the action trigger level. Similarly high trigger levels have been set to check against surface ponding. All piezometers were measured monthly, with monitoring frequency increased to twice weekly in active construction areas.

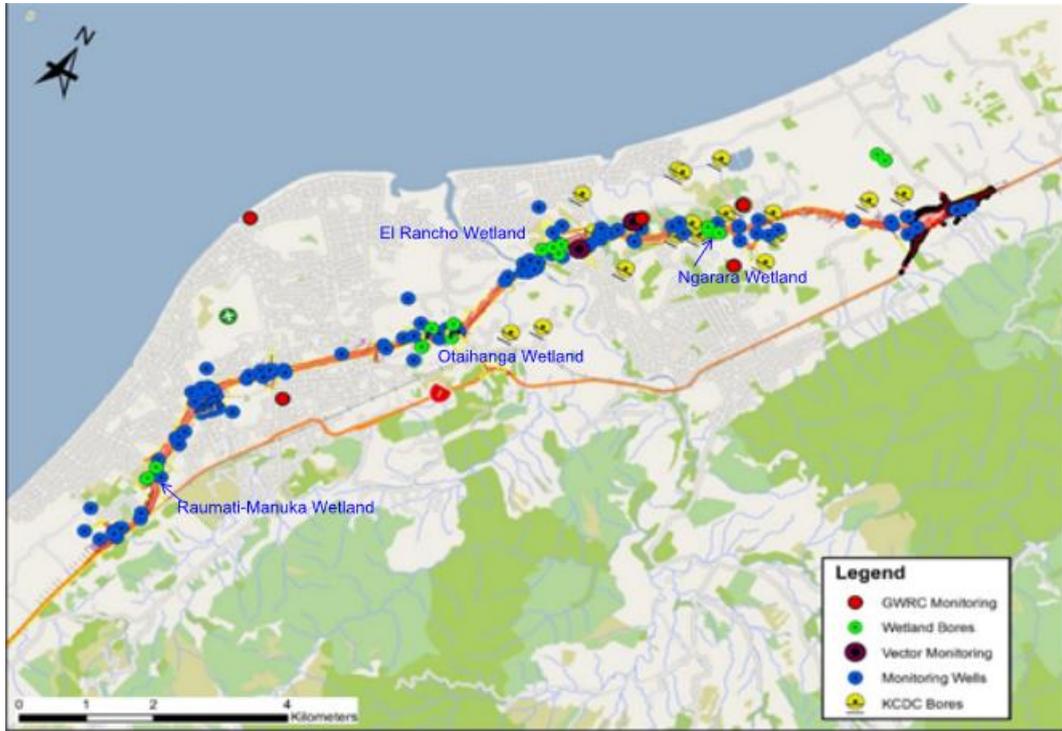


Figure 3: Overview map of groundwater level monitoring

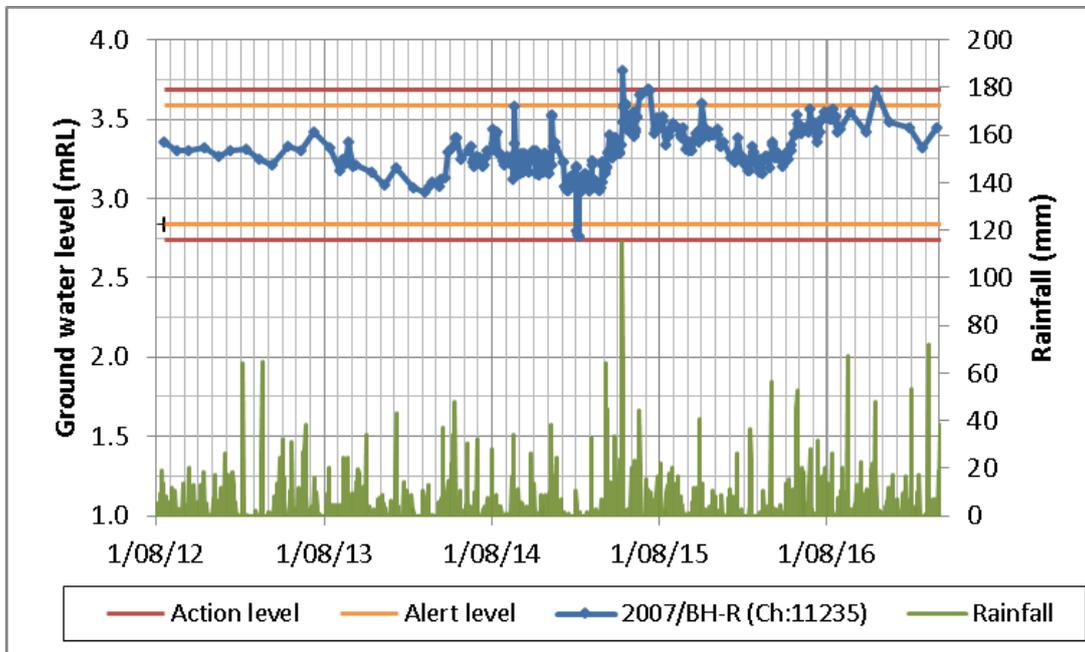


Figure 4: Groundwater levels measured in piezometer 2007/BH-R plotted against trigger levels and rainfall data

Five wetlands: Raumat Manuka, Otaihanga Northern & Southern, El Rancho and Ngarara were identified as “sensitive” for this project and 22 telemetered piezometers were installed to monitor the groundwater levels in these areas (Figure 3). As mentioned above the Kāpiti Coast wetlands

were formed in different ways according to the local ground and groundwater conditions and the water level in some will naturally vary more than in others. The baseline monitoring data was reviewed to identify likely hydrogeological behaviour of each wetland.

In Raumati-Manuka and Otaihanga wetlands groundwater level data indicates a downwards gradient, suggesting that rainfall is held up on the near-surface peaty soils, but slowly infiltrates through them to recharge the underlying sands and gravels. The El Rancho wetland is complex and the northern part of the wetland exhibits a downward gradient and the southern part exhibits a downward gradient with recharge to the underlying soils during the winter months, but is fed by the underlying aquifer during the summer months. In the Ngarara wetland groundwater both recharges and drains the aquifer beneath it. Because even small changes in groundwater level outside the normal seasonal variation may have a deleterious effect on a wetland and the limited number of measurements that were available for the establishment and understanding of the normal wetland water levels, a statistical approach was developed for calculating both high and low trigger levels.

Using data from telemetered piezometers screened in the same shallow aquifers outside the project area and monitored by the Regional Council for many years, the “expected” water level was calculated for each project piezometer based on a multiple linear regression analysis for each reading. A variation of the expected value increased by the margin of error of the 80% confidence prediction interval outside the expected water level triggers an alert for the monitoring bore (Figure 5).

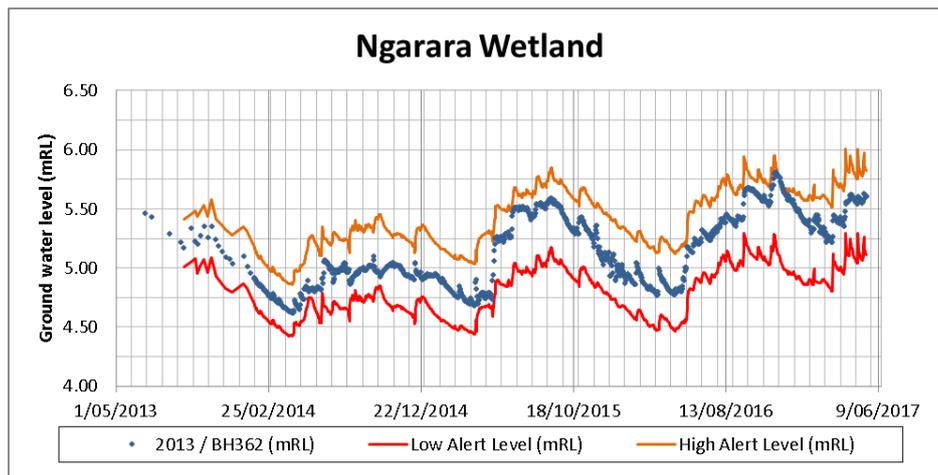


Figure 5: Groundwater levels plotted against statistically calculated trigger levels

This statistical approach was also employed to check exceedances in piezometers that were in active construction zones (earthworks within 200m) but where the works were not anticipated to influence the groundwater levels. The monitoring data demonstrated that the statistically calculated triggers take into consideration district-wide changes in groundwater levels and more clearly distinguish natural effects such as weather patterns (a low trigger level alert during dry summer months) from those resulting from construction activities (pumping during excavation) than triggers set as a standard difference as illustrated in Figures 6a and 6b. This approach allowed for minimum disruption to the construction works from unwarranted alert or alarm readings, and no adverse environmental effects.

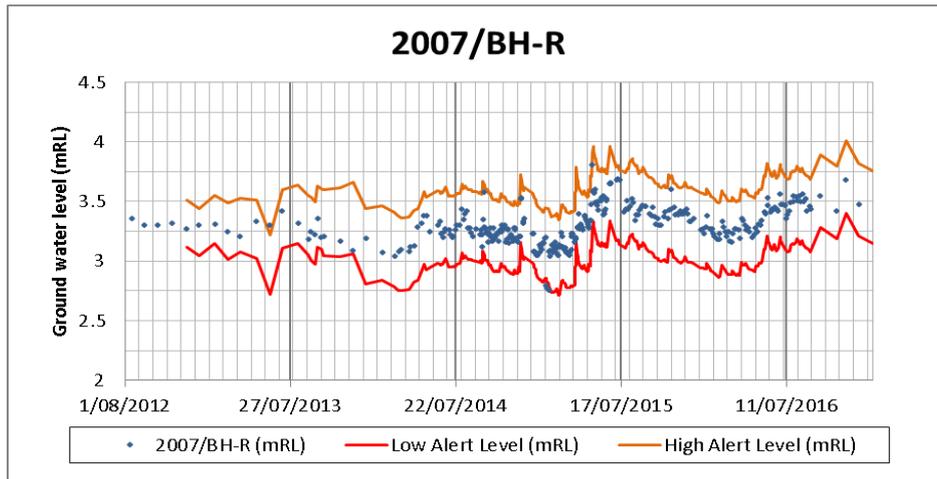


Figure 6a: Observed Water Levels in piezometer 2007/BH-R plotted against statistical trigger levels calculated based on regional data

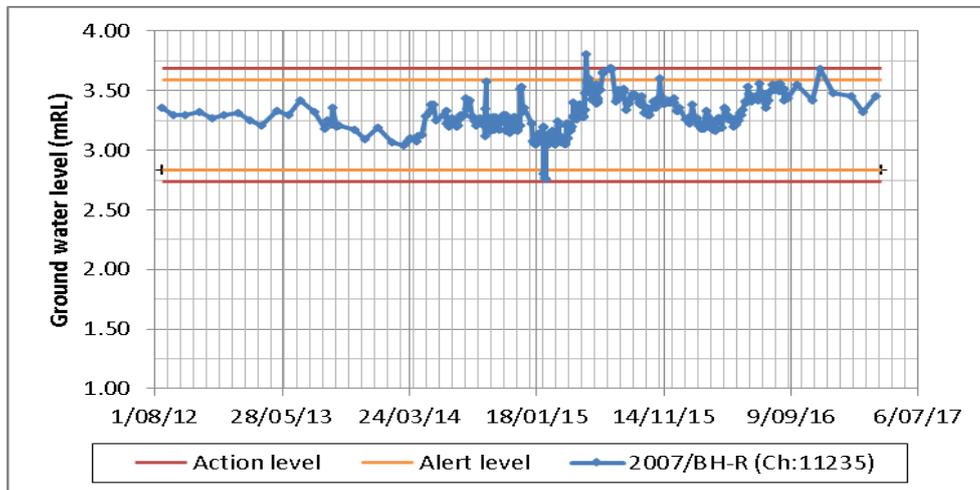


Figure 6b: Observed Water Levels in piezometer 2007/BH-R plotted against constant trigger levels

### 3.2 Settlement Monitoring

Consolidation settlements from embankment construction (preload and surcharge and groundwater lowering from excavation and replacement of peat) have been analysed in 13 cross sections along the length of the expressway. The location of one of the cross sections analysed is shown in Figure 7. Figure 8 presents the predicted combined settlement for that location and Figure 9 the monitoring results from one of the marks in that section.

Approximately 100 survey marks along the length of the expressway were installed and regularly monitored to provide information to compare to the settlement estimates. Monitoring marks were placed as far as practical to match with cross sections that have been used for the settlement estimates and extended out from the Expressway where settlements were expected to be greater than 12.5mm. Marks were also placed at specific stormwater features where groundwater drawdown of more than 0.1m was predicted and they coincided with groundwater level monitoring piezometers in selected locations. The marks were installed and monitored for vertical movement with 13 sets of baseline values taken during the year prior to the Expressway construction commencing. The lowest preconstruction value was used as the base value to calculate differences in vertical movement (where positive movement indicates settlement). The trigger level for each mark was set equal or lower than the expected/ estimated settlement at that location (Figure 9).

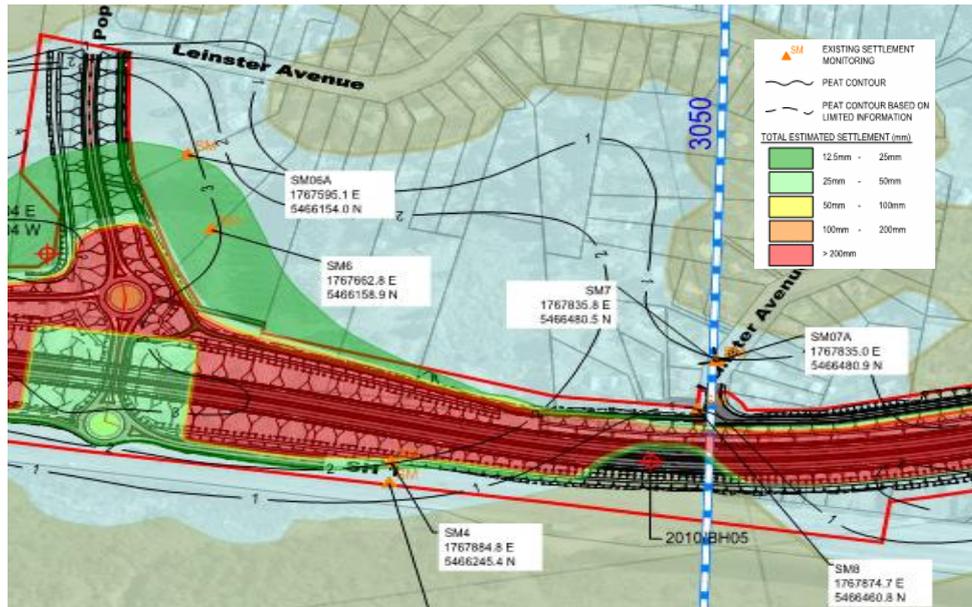


Figure 7: Settlement Markers in Cross Section 3050

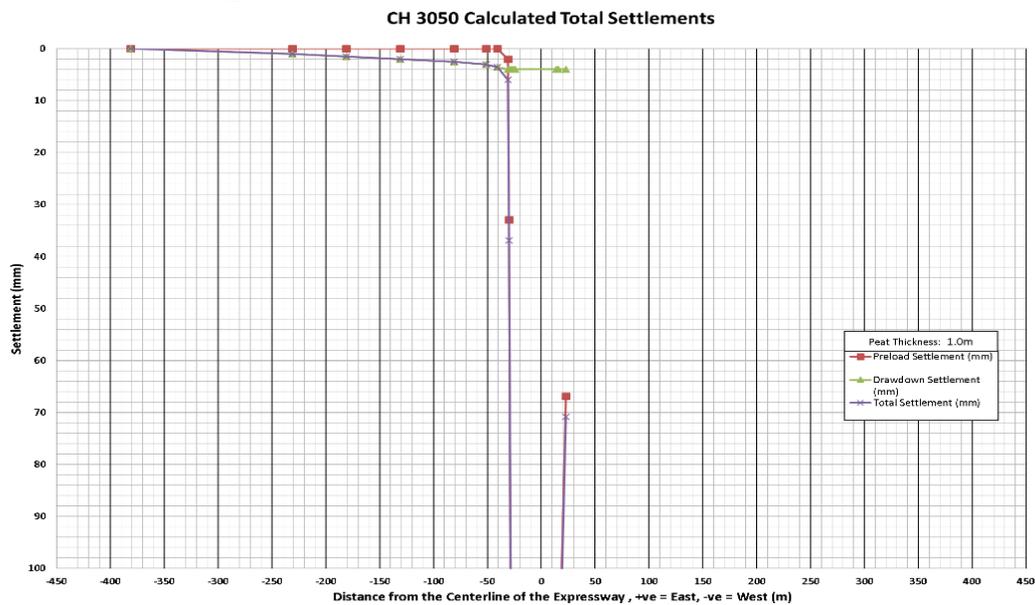


Figure 8: Predicted settlement at Cross section 3050

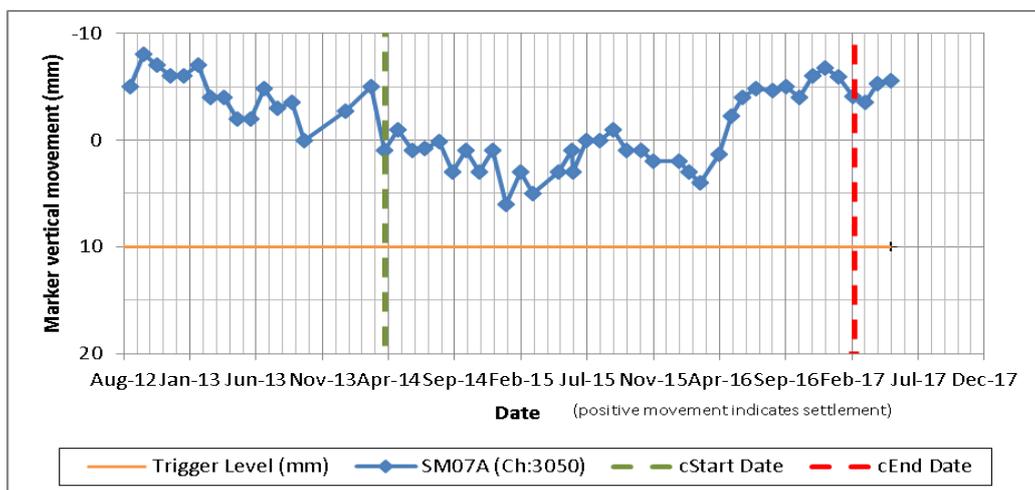


Figure 9: SM07A mark vertical movement (cross section 3050)

Monitoring frequency following the establishment of the baseline was reduced to quarterly and increased to monthly when active construction started (earthworks commenced within 200m of a particular location). When pavement construction was completed the monitoring is reduced to quarterly for 6 months and to half yearly for two years following that. The predicted settlements were generally less than 25mm beyond the edge of the earthworks. In areas of thicker peat deposits, the predicted settlement was in the order of 25 to 50mm up to 20m from the earthworks footprint, reducing to less than 25mm beyond this. Monitoring data generally were within the magnitude and range of predicted settlements (Figures 8 and 9). Two exceedances were recorded (i.e. monitoring results indicated movement outside the expected range) and additional monitoring was undertaken and an assessment of effect of this movement was undertaken.

#### **4 CONCLUSIONS**

A comprehensive groundwater monitoring and settlement monitoring programme was established prior to construction commencing. In order to differentiate construction effects from normal seasonal variations, a statistical approach was developed. Recorded groundwater levels and settlement have generally remained within the consented levels. Some exceedances were recorded however a pragmatic approach to monitoring and management of these exceedances allowed works to continue with minimal disruption and no adverse environmental effects.

The monitoring data demonstrate that the statistically calculated triggers take into consideration district-wide changes in groundwater levels and more clearly distinguish natural effects such as weather patterns from those resulting from construction activities than triggers set as a standard difference.

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#### **REFERENCES**

- Ainsworth, P. (2013) Settlements Effects Management Plan (SEMP), *MacKays to PekaPeka Expressway Project Construction Environmental Management Plan (CEMP)*.
- Allen, C. (2010) *Hydrological characteristics of the Te Hapua wetland complex: The potential influence of groundwater level, bore abstraction and climate change on wetland surface water levels*. Unpublished MSc thesis
- Coe, L. (2012) Assessment of Ground Settlement Effects: Technical Report 35, Volume 3, *MacKays to PekaPeka Expressway Project AEE*.
- France, S. & Anderson, M (2012) Assessment of Groundwater Effects: Technical Report 21, Volume 3, *MacKays to PekaPeka Expressway Project AEE*.
- Gyopari M. (2002) *Te Harakeke Wetland, Kapiti Coast, Hydrological Study Final Report*, Report prepared for the Wellington Regional Council.
- Williams, A. (2013) Groundwater Management Plan (GMP), *MacKays to PekaPeka Expressway Project Construction Environmental Management Plan (CEMP)*.