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Coastal Slope Instability in Auckland and Northland

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Abstract: This paper considers some of the slope stability problems in coastal regions of Auckland and Northland due to continued residential development and provides a few case histories of instabilities and lessons to be learnt. The geotechnical principles to be considered in the construction of the dwellings in coastal situations have been discussed.

INTRODUCTION

Auckland and Northland region of New Zealand extends from the Bombay Hills to the north encompassing developed areas, coastal cliffs, beaches, extinct volcanic centres, hilly areas and alluvial plains. From east to west the region extends from the coastline of the Pacific Ocean to that of the Tasman Sea (Figure 1).

Most popular construction sites are overlooking the harbours or the sea offering spectacular water views. Continued development in the coastal region and encroachment toward the edges of the coastal cliffs for the sake of a good view has resulted in slope stability problems.

This paper outlines the geological and geo-morphological factors responsible for instability in the coastal regions of Auckland and Northland and gives examples of a few claims that have been lodged with the Earthquake Commission in recent years.

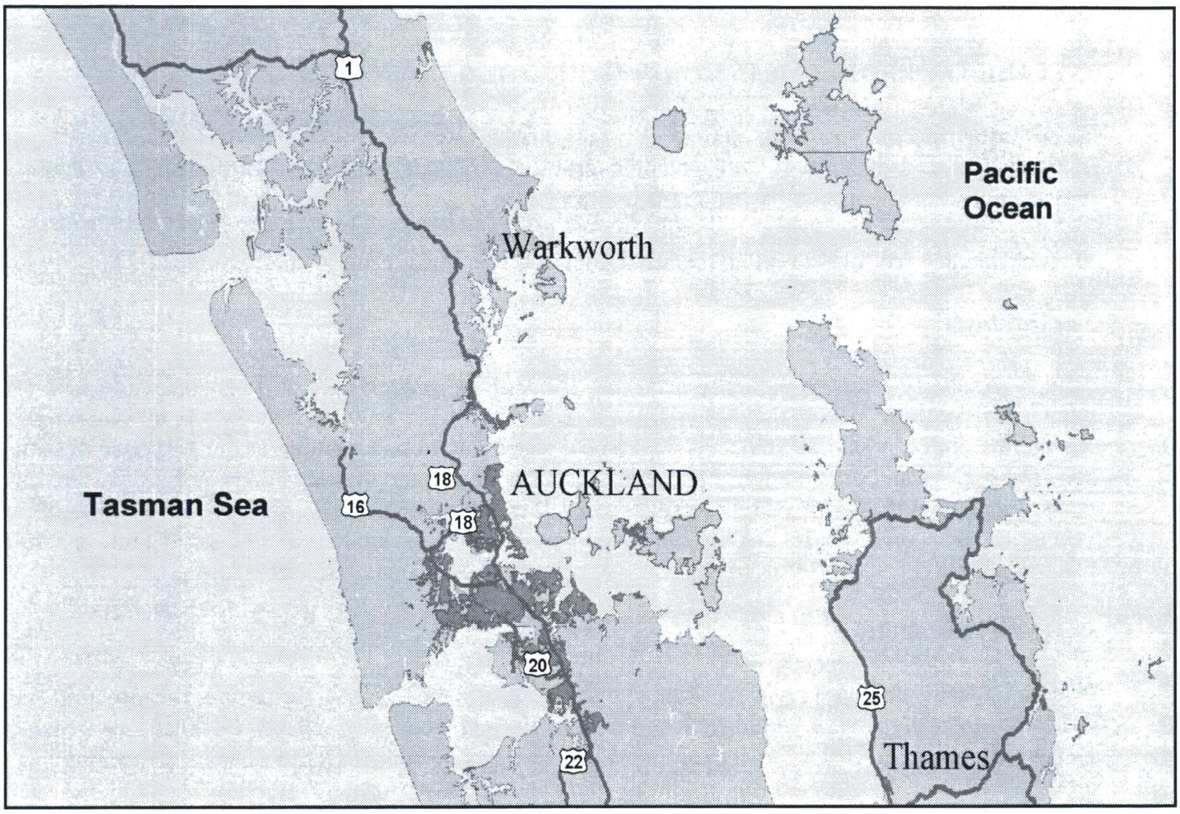

Figure 1. Greater Auckland Area and Southern Part of Northland

LANDSLIP DEFINITION

Earthquake Commission Act came into force on the 1st day of January 1994 replacing the Earthquake and War Damage Regulations 1970. According to the Act: *Natural landslip means the movement (whether by way of falling, sliding, or flowing, or by a combination thereof) of ground forming materials composed of natural rock, soil, artificial fill, or a combination of ground forming materials, which before, movement formed an integral part of the ground.*

GEOLOGICAL SETTING

The strongly stratified Miocene age Waitemata Group sandstones and mudstones form cliff exposures in the Waitemata and Manukau Harbours and southern parts of Auckland and Northland regions. They contain a few beds of resistant rock and give rise to a homogenous well-dissected landscape of moderate slopes. The residual soils and completely weathered rocks can extend down to 10m or more below the ground surface.

The Mesozoic age greywackes consisting of deformed sandstones and mudstones have been exposed in the eastern part of the Auckland region including Waiheke and Motutapu Islands. The weathered zones extend more than 10m below the ground surface with clay rich soils at the surface. On the coast, the greywackes occur as hard, closely jointed, steeply dipping beds with zones of crushed and sheared rocks. The latter gives rise to sea caves with hard resistant rocks between them.

The Upper Pleistocene volcanic eruption produced circular explosion craters (Panmure and Orakei Basins) surrounded by very steep tuff rings offering spectacular views to the basins.

A considerable part of the coast of Auckland and Northland consists of sand deposits, which were accumulated during the last 1.5 to 2 million years.

INSTABILITY PROBLEMS IN COASTAL REGIONS

Slope instability is occurring sporadically in coastal areas affecting the residential properties. Most homeowners are not aware of the potential problems in their properties. The awareness of the instability prevails only when a problem arises in the property or in the neighbourhood.

In Auckland and Northland region, the instabilities are two folds: Natural and Developed.

Natural Instability

Natural instability refers to naturally occurring instabilities through natural processes without or with limited human intervention. Along the beach front, the rocks are softened and weakened by natural processes of weathering, and can also be subject to high shear stress due to undercutting at the cliff base. Existing alluvial soils (silts, clays and organic clays) overlying the older rocks, and the clays derived from weathering are often in marginal stability and give rise to rotational slides during extreme rainfall events. Moderately to slightly weathered rocks on the cliffs can be subjected to wedge failures due to the presence of joint sets unfavourable to slope stability.

Developed Instability

Human impact is undoubtedly a major input in destabilising the coasts in the region. Construction activities can radically affect the slope hydrology, load the cliff top and frequently reduces the cliff face vegetation cover. Developed instability refers to inappropriate construction techniques used causing natural slopes to fail or move downhill. Concentrated run-offs from roofs and paths, stormwater overflowing and septic tank effluent added to run-off output can result in increased cliff instability due to elevated water tables that lead to reduced shear strength and overloading.

Where man made factors are added to natural conditions favouring low shear strength, seaward dipping beds and/or intersections of joints and high shear stress due to undercutting at the cliff base, then disastrous cliff failures do occur, frequently resulting in serious damage to property (Taylor et al, 1977).

CASE HISTORIES

In the Auckland region, the cliff landforms are the product of the resistance of Waitemata Sandstone and/or the Parnell Grit Member of the Miocene Waitemata Group. Differential weathering of the surface layers of the interbedded Waitemata sandstones and mudstones degrades the rocks into residual soil comprising silty clay and clayey silt. Continued erosion and retreat of the coastal cliff results in the marginal stability of the residual soil and the overlying Pleistocene alluvial sediments. There are instances in Northland, where sandy cliffs are subject to slope failures when some destabilising force acts upon them.

Case History No 1.

Location: Stanmore bay, Whangaparaoa
Geology: Waitemata cliff with shallow residual soil on top
Development: *Deck/viewing platform on shallow pile footings*
Problem: Coastal slide affecting the footings of the viewing deck. Advise on the remedial options.

The landslip site is located on the edge of a 30m high rock coastal cliff overlooking Stanmore bay in Whangaparaoa. The cliff is generally very steep (60 degrees), but sub-vertical at the upper part. Most of the ground above the cliff with residential properties is inclined away from the cliff in the opposite direction towards Vipond Road. However, there is a small strip of land that falls towards the cliff at an angle of about 15 to 20 degrees. A viewing platform exists at the backyard of the property at the edge of the cliff. The footings of the platform were founded in residual soils on pile footings (Figure 2). The platform was constructed several years ago by the previous owner without any building permit.

After a heavy rainfall, a landslip has occurred at the edge of the cliff involving the upper residual soils without affecting the underlying rock mass. The slide debris swept away the thin colluvial cover and the vegetation down the slope to the bay. The slip represents a combination of rotational and translational failures. The slip occurred as a result of high porewater pressure in the residual soil subjected to long soaking rainfalls.

The remedial options included dismantling the deck, removing the unstable material, boring into the rock and in-situ casting of timber piles into concrete sockets and re-instating the deck. Significant problems in regards to obtaining consents for the deck are obvious.

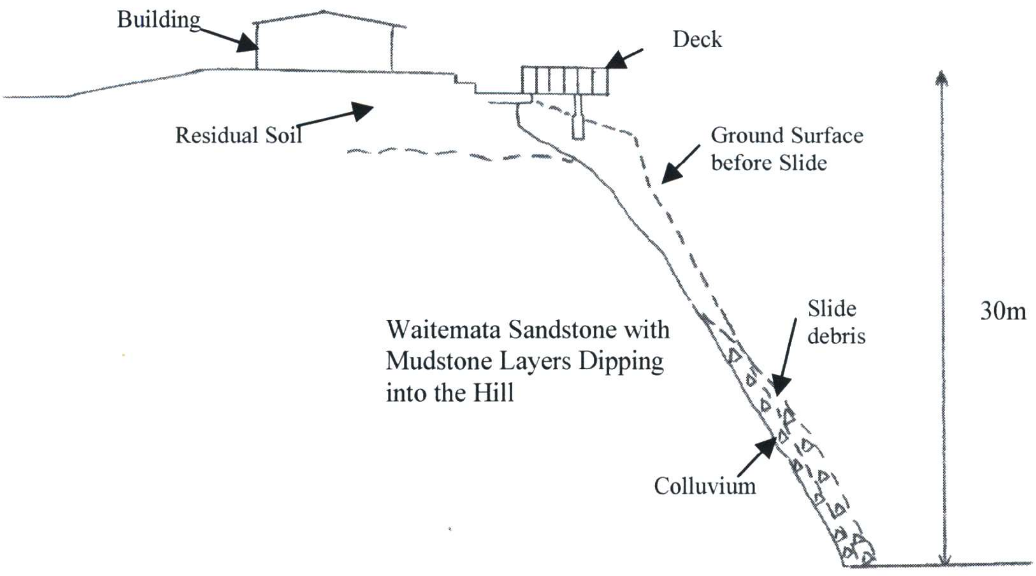

Figure 2. Schematic Cross Section: Case History 1.

Case History No 2

Location: Mangawhai Heads overlooking the sea
Geology: Dune Sand cliff
Development: *Timber houses and retaining wall*
Problem: Coastal slide affecting the two properties. Advise on the remedial options.

Ground movements affected two properties located above a coastal cliff in Mangawhai Heads overlooking the Mangawhai Harbour. The distress features observed were ground cracks on relatively level ground above a steep cliff approximately 35m above the Harbour. There had been a vertical drop of the ground surface and horizontal separation of several centimetres on the properties. The exposed soils on the level ground and on the steep cliff were well-drained dune sands.

The developments on site included landscaping, construction of a timber pole retaining wall and the two houses. Figure 3 shows the cross section through the northern house. The retaining wall supported the sand fill platform for the southern house. There were three downpipes on the northern property, which discharged stormwater to the failure surface.

This event caused structural damage to the first house, tilted the concrete water tank and damaged the front decking of the second house. The concrete water tank, the front decking of the second house and the retaining wall are not shown in the figure.

The tension cracks represent an outline of a rotational slide, which was probably caused by internal changes in the stability condition of the loose, cohesionless slightly silty fine sand due to intense rainfall, the steep slope gradient and high intensity rainfall. The stability conditions were exacerbated by poor drainage management on site.

Due to site constraints, the only practical means of reducing further ground movements would be to undertake measures for improvement of drainage conditions and to construct a buttress at the toe of the slope.

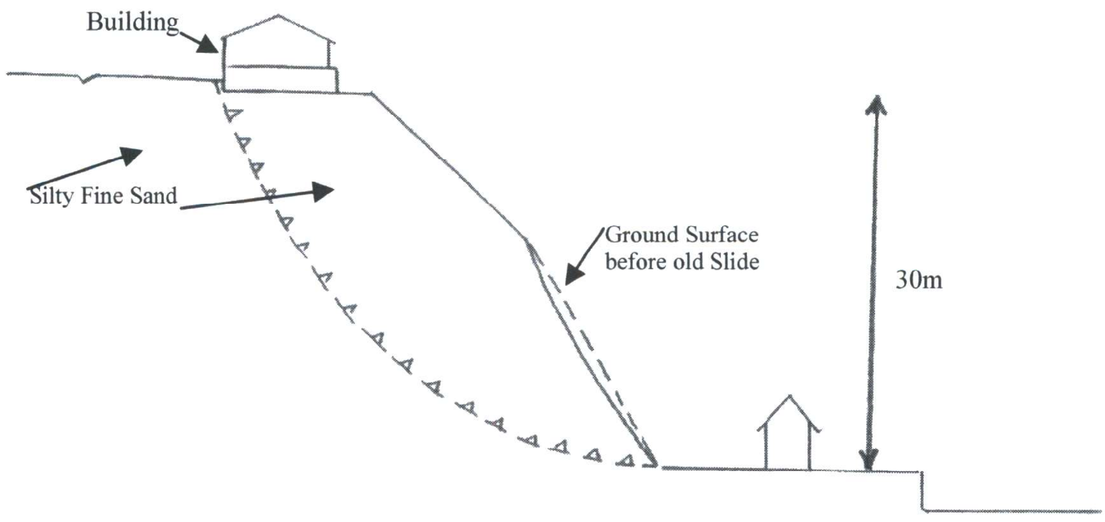

Figure 3. Schematic Cross Section: Case History No 2.

Case History No 3

Location: Eastern beach, Auckland
Geology: Waitemata cliff with thick residual soil on the upper part
Development: *Lawn and the house*
Problem: Coastal slide affecting the lawn and council land. Landslip appraisal.

In 2000, a rotational landslip occurred on the coastal cliff comprising residual soil (10m thick) and weathered Miocene Waitemata sandstones and siltstones (Figure 4). The slip affected the public reserve and the garden of a private property. Most of the property was on the coastal platform 16-17m above the sub-horizontal wave cut intertidal shore platform. The cliff face had undergone a couple of slope failures in the past as evidenced by a series of scarps. The slope movements regressed further up the cliff to the coastal platform level. The most recent scarp (0.1 to 0.4m high) ran roughly parallel to the cliff line on the front lawn. There were several other open cracks on the lawn in the vicinity of the scarp and the distress features included the rotated timber pole retaining wall. Initial movements on the slope seem to have occurred only about 10m above the shore platform.

Remedial works following previous failures included the installation of fan drains. However, the water discharged from the drains to the failed slide mass and exacerbated the potential for additional slope instability.

The loss of the support to the cliff coupled with poor drainage management as well as heavy and prolonged rainfall led to further slumping within the lawn and caused the timber pole retaining wall to lean down hill. If no remedial action taken then , additional slope movements would occur in the future.

One essential measure to remedy the situation was to divert the surface run-off and discharge from the fan drains away from the unstable ground. Most of the unstable landmass was confined to the reserve and preferred remedial measures incorporating slope retention systems such as anchored retaining walls in combination with improved drainage measures have not been erected.

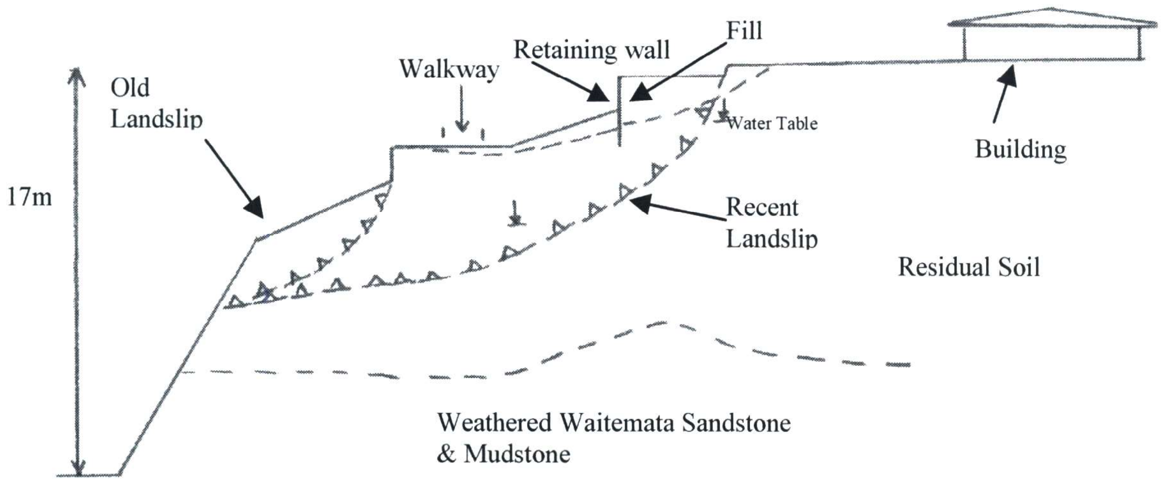

Figure 4. Schematic Cross Section: Case History No 3

LESSONS LEARNT

The case histories described above represent some of the problems on the coastal cliffs of Auckland and Northland. Similar problems may have occurred in other parts of the country.

The instabilities were observed on the edges and faces of the cliffs, in drainage depressions as well as in areas with a previous history of instability. Most of the instabilities occurred as a result of ignoring the common drainage management principles on sloping sites and the installation of incomplete remedial actions.

The problems relate to

- Interference of man on a cliff, which is in marginal stability due to natural processes such as tidal action and weathering.
- Consequences of construction and remedial action, which are not compatible with sound geotechnical principles.
- Risk taken by the property owners without understanding the natural processes acting on the cliff.

- Lack of interaction with local authorities.

CONCLUSIONS

The edges of the coastal platforms and the cliff slopes below are the main areas of potential instability. These are the areas where stability is always a matter of concern. There is a requirement for three parties to play roles in ensuring and maintaining the coastal slope stabilities. The three parties are a) developer and/or property owner b) local authorities and c) geotechnical consultants.

The principles to be adhered by the developer or property owners during and after the construction of the dwellings on coastal platforms are:

- Obtain advice from a qualified geotechnical consultant experienced in slope stability assessment and mitigation prior to any new or additional development.
- Know your site and be aware of the implications of owning a property in a coastal area and of further development, and be prepared to accept the risk of instability.
- Improve construction practices, such as minimise height and depth of excavation, create appropriate slope batter with engineered retaining wall, construct a wall as soon as possible after excavation, retain natural vegetation.
- Ensure proper surface and sub-surface drainage management.

The local authorities must adhere to the above principles as any hazard on the public reserve along the coasts impact private properties located up hill. Their responsibilities are two fold. First is to follow the sound principles described above while installing public drainage system and associated structures along the coastal cliffs and second to ensure that the property owners follow these principles. The local authority should:

- Complete a geotechnical assessment including site-specific slope stability assessments to minimise the potential problems in coastal areas where such assessments have not been undertaken.
- Develop a land stability map along coastlines to advise property owners for potential problems.
- The role of geotechnical consultants is to raise awareness among the community and provide education on construction practices to developer and property owners through seminars, conferences and private meetings.

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