2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.11

2050 and 2100 Immediate Geotechnical Hazards, Crackneck

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.12

2050 and 2100 Immediate Geotechnical Hazards, Bateau Bay

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.13

2050 and 2100 Immediate Geotechnical Hazards, Toowoon Bay

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.14

2050 and 2100 Immediate Geotechnical Hazards, Blue Bay

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.15

2050 and 2100 Immediate Geotechnical Hazards, Karagi Point

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

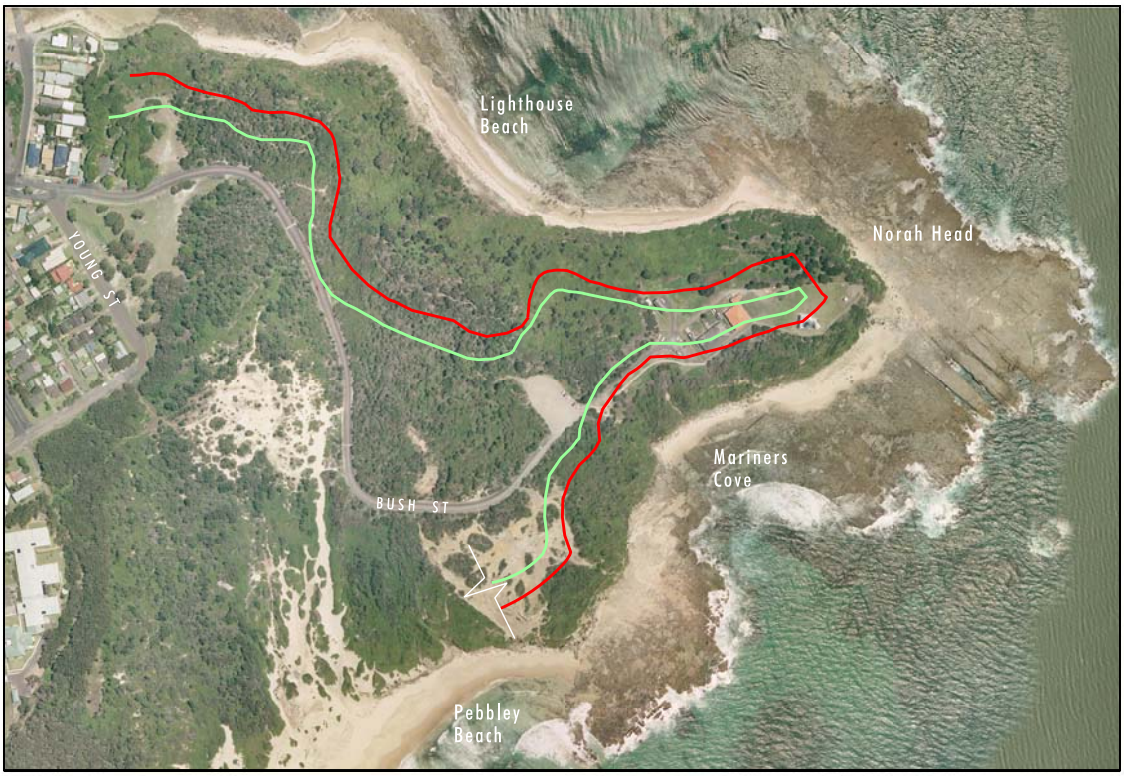
0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.16

2050 and 2100 Immediate Geotechnical Hazards, Soldiers Point

2050



2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.17

2050 and 2100 Immediate Geotechnical Hazards, Norah Head

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.18

2050 and 2100 Immediate Geotechnical Hazards, Cabbage Tree Harbour

2050

2100

Source: Shirley Consulting Engineers Pty Ltd (see Appendix 4)

0 100 200 300m
1:7000

Legend
- Low Hazard Line
- Immediate High Hazard Line

FIGURE 11.19

2050 and 2100 Immediate Geotechnical Hazards, Noraville

File Name (A4): R03_V1/1869_109.dgn

11.1.2 How is this Action Plan different to what happens now?

Council currently applies the clauses of its LEP and DCP 2005 Chapter 77 to its decision making in relation to development on coastal cliffs and bluffs. Both of these planning instruments are based on earlier assessments of geotechnical processes and hazards. They contain a number of ambiguities and are inconsistent with current geotechnical assessment and landslide risk management.

The Geotechnical Hazards Action Plan will facilitate updates of Council's planning instruments and deliver both clarity and certainty for Council and land holders.

Council's intention is that the LEP and DCP will discourage land use intensification and reduce risk in areas with a high probability of geotechnical hazards.

In addition, the geotechnical assessment undertaken as part of the preparation of the WSCZMP establishes a transparent and repeatable process for predicting geotechnical hazards, based on geological stratigraphy and structure, field observations, historical records, high resolution terrain modelling (using the LiDAR data and site specific surveys) and slope stability equations. This means that as new information becomes available, hazard calculations for geotechnical processes can be reviewed and updated.

Regular updates of LiDAR data for the coastal cliffs and bluffs will allow high resolution comparison of micro scale changes to terrain, which may help refine the prediction (probability) of geotechnical process events, and highlight localities which require more detailed investigation of geotechnical processes and events.

Council proposes specific actions to address ongoing geotechnical risks at Cabbage Tree Harbour. The results and recommendations of recent studies of the situation at Cabbage Tree Harbour are summarised in **Section 11.2**.

11.1.3 Who will be responsible for making a difference?

Implementation of the Geotechnical Hazards Action Plan will be the responsibility of Council's Environment and Natural Resources Unit, strategic planning team and development assessment team, reporting through the Environment and Planning Directorate. However, other sections of Council, particularly Shire Services, will also be involved, where actions such as modification of stormwater drainage are required.

In addition, some geotechnical hazards affect safe public access along pathways and lookouts on coastal cliffs and bluffs which are on Crown land. Council's social and recreation planners will work with DPI (relevant sections of former L&PMA) and OEH to minimise risks to public safety.

Council will work with affected private landholders to ensure they are aware of the hazards, and that Council and landholders are working together on shared issues such as drainage, to minimise unnecessary hardship. In addition, through the LEP and DCP, Council will require that proponents of development in coastal geotechnical recession areas conduct detailed investigations which will add to Council's geotechnical knowledge data base. Figure D3 in **Appendix 4** shows a potential method for these investigations and ongoing data management at Council.

11.2 Managing Cabbage Tree Harbour

Council has been taking advice from geotechnical specialists about the drivers of landslip hazards at Cabbage Tree Harbour for several years. Council has also sought specialist advice on effective risk minimisation measures for Cabbage Tree Harbour. Details of these studies are in **Section 16.8** of **PART C** and in **Appendix 4**.

Council's current management approach at Cabbage Tree Harbour involves two main strategies:

- Implement new planning controls for affected properties, based on the most up to date geotechnical information
- Construct a new toe protection and drainage structure at the base of the slope

In addition, Council has consulted closely with affected landholders about new requirements and provided information to the wider community.

Cabbage Tree Harbour is a popular and well used beach area, with the only ocean boat ramp in Wyong Shire located at the south eastern end of the beach. A rock pool that is popular with young families is also located at the eastern end of the beach. Temporary access restrictions to parts of the beach at Cabbage Tree Harbour were in place for part of 2010.

To reduce safety risks to beach goers and people using the reserve above the bluff, Council:

- Has conducted monitoring of the landslip
- Placed signs advising beach users about potential landslip risks on the beach and in the reserve
- Provides information about issues at Cabbage Tree Harbour through local media
- Has requested residents to remove external structures from high risk areas on the cliff top

11.2.1 Install effective toe protection and drainage

Council has commissioned detailed geotechnical advice and has also obtained detailed engineering designs and costing for a proposed structure at Cabbage Tree Harbour. Council has applied to the NSW government for funding assistance. The NSW government has agreed to a 50/50 funding arrangement for the toe drainage and protection structure. The total cost is more than $1.9 million.

The concept of the toe drainage structure is different to a standard sea wall. It is intended to:

- Provide for good groundwater drainage from the indurated sand slope above.
- Protect the toe of the slope from wave erosion. The structure will use large rocks to protect the base of the slope and is designed to withstand a 1 in 20 year coastal storm without severe damage. This reflects a balance between up front construction costs for a very robust structure and the high maintenance costs associated with a design for a lower return period. It is anticipated that the design that Council proposes to construct will provide protection for 15 to 20 years.
- Reduce sand loss from the beach, by having a sloping face, rock and gravel construction. The area behind the structure will be backfilled with sand.

- Blend with the local landscape, by using 'natural earth colour' rocks, covering the structure with sand and establishing native vegetation where possible.

11.3 How geotechnical management actions contribute to objectives and targets

Table 11.1 sets out objectives and targets that are relevant to effective management of risks associated with geotechnical processes along the coast, together with a summary of proposed actions.

Table 11.1 – How geotechnical actions contribute to Council's Objectives and Targets

Objectives and management targets	Action summary
O1 To provide for efficient and effective coastline management based on access to best available science and information about community values and attitudes **Target** By 2012, WSC has in place an adaptive management framework for the coastline, incorporating structured actions, performance monitoring and review processes.	A73: Repeat LiDAR surveys of the coast at approximately 5 year intervals. Analyse high resolution digital terrain data at 5 yearly intervals to identify any changes in the terrain of areas affected by geotechnical hazards. A87: Confirm the boundaries of areas where this is interaction of coastal erosion and geotechnical processes and refine hazard assessments A88: Council will include information about geotechnical hazards affecting infrastructure in the coastal zone, such as stormwater drains, sewer reticulation and pumping systems, in its asset data base and will take geotechnical hazards into account when planning upgrades, relocation or other major system maintenance activities. Council will set out appropriate design requirements in the LEP, which will apply to Council activities, projects by other government agencies and private development. A89: Develop and continue to refine a 3D geotechnical model for predicting geotechnical hazards A90: Further investigate the interaction of coastal erosion and geotechnical hazards in areas where both types of hazard (coastal erosion and geotechnical recession) may apply now or within the 2100 planning period.

Objectives and management targets	Action summary
O7 To enhance the awareness of residents, landholders and land users of coastal processes, climate change, impacts and adaptation measures **Target** By 2012, there is a measurable increase in the awareness of coastal residents and landholders of the variability of coastal processes, the impacts of predicted climate change and how they can adapt to the predicted changes.	A33: Council will place notation on the s149 certificate for all properties within immediate, 2050 and 2100 coastal risk areas (coastal erosion) and also on properties seaward of the 2100 low hazard line for geotechnical hazards. Council will also inform affected ratepayers via information supplied with rate notices. A71: Review Plans of Management for coastal reserves in coastal hazard areas (geotechnical), both for Crown Reserves and for Council community land. Ensure that each Plan of Management takes geotechnical hazards and risks into account. A74: Make Australian GeoGuides, published by the Australian Geomechanics Society, available on Council's web site, as reference material on good practice for landowners and Council.
O8 To develop efficient and effective strategies for minimising Council's and the community's exposure to risk in the coastal context **Targets** • By 2012, Council business planning, land use planning and reporting includes consideration of coastal process and climate change risks, integrated with other aspects of climate change risk management across the Shire. • By 2012, development applications from coastal landholders demonstrate risk reduction strategies appropriate for coastal processes and predicted climate change.	A72: Council will construct a toe drainage structure at Cabbage Tree Harbour that both improves groundwater drainage and protects the toe of the slope against erosion. This structure will be partly funded by OEH. A69: Council will introduce planning clauses in the LEP and DCP with consistent requirements for appropriate geotechnical assessments of proposed development within the zone bounded by the immediate hazard line and 2100 low geotechnical hazard line (assessments prepared by a properly qualified geotechnical practitioner). No new development will be approved within immediate geotechnical hazard areas. A82: LEP zoning and DCP clauses will discourage land use intensification and reduce risk in areas with a high probability of geotechnical hazards A70: Review stormwater drainage systems in the vicinity of geotechnical hazard areas to ensure that they do not discharge runoff into areas where it could trigger a landslide. This applies to both council stormwater systems and stormwater systems on private property.
O9 To support WSC planning for sustainable coastal development **Target** By 2012, the Wyong LEP includes planning measures to reduce risks and to improve the net social, cultural, economic and environmental benefits of coastal development	A69: Council will introduce planning clauses in the LEP and DCP with consistent requirements for appropriate geotechnical assessments of proposed development within the zone bounded by the immediate hazard line and 2100 low geotechnical hazard line (assessments prepared by a properly qualified geotechnical practitioner). No new development will be approved within immediate geotechnical hazard areas.

11.4 Implementation

Table 11.2 summarises the most important actions for managing geotechnical risks. The table indicates the rationale for the proposed action, which organisations/positions would be responsible for the action and specific locations for attention. In general, the actions relate to planning controls which are within Council's existing responsibility and routine budget allocations.

At Cabbage Tree Harbour, Council has sought funds to allow the construction of toe protection for the steep, unstable slope. The toe protection will stop wave trimming of soil and rock debris that has accumulated at the base of the slope, reducing the incidence of undercutting and oversteepening of the lower slope.

Table 11.2 - Strategies for managing geotechnical hazards

Step 2: Take action to reduce risk **A69**: Council will introduce planning clauses in the LEP and DCP with consistent requirements for appropriate geotechnical assessments of proposed development within the zone bounded by the immediate hazard line and 2100 low geotechnical hazard line (assessments prepared by a properly qualified geotechnical practitioner). No new development will be approved within immediate geotechnical hazard areas. The LEP/DCP will specify required qualifications based on advice from Australian Geomechanics Society. **A82**: LEP zoning and DCP clauses will discourage land use intensification and reduce risk in areas with a high probability of geotechnical hazards			
Intent and logic Council's current planning instruments are out of date in relation to geotechnical hazards. The amended clauses of the LEP will provide clear guidance for landholders in affected locations about the nature of immediate and longer term geotechnical hazards and how they affect the development and use of their property. Notation on s149 certificates will help to raise awareness of geotechnical hazards and their implications for land use planning and development assessment. Proponents of development in areas where coastline recession due to geotechnical hazards is predicted in the 2050 and 2100 planning periods may be required to conduct further detailed studies, including site specific topography and geology and three dimensional studies of geotechnical hazards. Figure D3 and Section 8.3 of **Appendix 4** provide an example of how this could be done. This information will contribute to Council's 3D model of geotechnical hazards (see Action 89).			
Responsibility and key partners	**When - Priority**	**Where – locations for investment**	**Indicative cost and source of funding**
WSC strategic and development planners, in consultation with DP&I and DPI (relevant sections of the former L&PMA)	The new geotechnical hazard information should be included in the current revision of the LEP, as soon as possible.	This action applies urgently to cliffs and bluffs at Cabbage Tree Harbour and Noraville, but is also relevant to all cliffs and bluffs	The amendments of the LEP and DCP are within the responsibilities of Council officers, but additional training may

	Review: it is likely that understanding of geotechnical hazards for the longer planning periods will be enhanced as further climate change impact studies are completed and new reports are released by IPCC. The spatial application of planning controls should be reviewed every 5 years.	along the coast. In the longer term, further assessment of indurated sand stability at Toowoon Bay is necessary.	be required on hazard management.

Step 2: Take action to reduce risk

A70: Review stormwater drainage systems in the vicinity of geotechnical hazard areas to ensure that they do not discharge runoff into areas where it could trigger a landslide. This applies to both council stormwater systems and stormwater systems on private property.

Intent and logic

Some geotechnical processes are exacerbated by inappropriate management of surface and groundwater flows.

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC and landholders. Link to Water Sensitive Urban Design projects within Council	Within 5 years Review after approximately 5 years to accommodate any additional information on changes to rainfall and runoff associated with climate change.	This action is relevant to all cliffs and bluffs where there is urban development.	Allow approximately $100,000 per year for adjustments to stormwater drainage

Step 2: Take action to reduce risk

A71: Review Plans of Management for coastal reserves in coastal hazard areas (geotechnical), both for Crown Reserves and for Council community land. Ensure that each Plan of Management takes geotechnical hazards and risks into account.

For instance, Plans of Management should address surface and subsurface drainage in geotechnical hazard areas; they should address landslip and rockfall risks affecting lookouts and walking tracks. All structures (including access or other facilities) within geotechnical hazard areas should be designed by a properly qualified engineer. Examples of relevant requirements are in Gosford Council's DCP 163 and Pittwater Council's geotechnical risk management policy.

Intent and logic

Currently very few Plans of Management for coastal reserves on Crown land or on Council managed community land specifically deal with geotechnical hazards. Geotechnical hazard assessment at Norah Head/Mariners Memorial area in 2007 indicated risks associated with community infrastructure.

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC, with DPI (relevant sections of the former L&PMA) and OEH (for National Parks)	At approximately 5 years	Key Plans of Management are for Norah Head and southern sections of Wyrrabalong National Park.	DPI (relevant sections of former L&PMA) and OEH

Step 2: Take action to reduce risks

A88: Council will include information about geotechnical hazards affecting infrastructure in the coastal zone, such as stormwater drains, sewer reticulation and pumping systems, in its asset data base and will take geotechnical hazards into account when planning upgrades, relocation or other major system maintenance activities. Council will set out appropriate design requirements in the LEP, which will apply to Council activities, projects by other government agencies and private development.

Intent and logic

This action reflects the ways in which slope instability hazards in the coastal zone affect the asset life and maintenance costs of Council infrastructure. Proper planning of new or upgraded infrastructure to minimise the impacts of hazards will reduce costs and maintenance effort required to maintain effective functioning infrastructure. This action presents good value for money, as early investment in good planning and design will save significant maintenance expenditure.

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC engineering services and asset managers, in consultation with Central Coast water and sewer provider.	Planning and design that take geotechnical hazards into account should be part of all infrastructure projects, now and ongoing.	All infrastructure projects on rock based terrain in the coastal zone should consider geotechnical issues.	Planning and design costs will be incorporated in the investigations for each infrastructure project.

Step 2: Take action to reduce risks

A72: Council will construct a toe drainage structure at Cabbage Tree Harbour that both improves groundwater drainage and protects the toe of the slope against erosion. This structure will be partly funded by OEH.

Council and OEH will share the $1.9 million cost of this structure.

Intent and logic

Council has received geotechnical advice about how best to reduce geotechnical hazard risks at Cabbage Tree Harbour. Previously installed 'horizontal drainage' controls have failed. The toe of the landslip area at Cabbage Tree Harbour is undercut by storm waves, destabilising shallow landslip upslope.

As a pocket beach with limited sand buffer, Cabbage Tree Harbour is likely to be affected (removed by) by beach recession due to sea level rise. The toe protection structure will help to decouple the geotechnical hazards from these beach recession hazards.

Ongoing regular monitoring of slope condition and geomorphic character will alert Council and residents early to changes in the slope that may signal further geotechnical activity. See also A73 in relation to long term monitoring and scenario testing using high resolution LiDAR data.

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC with OEH and DPI (relevant sections of former L&PMA), and affected landholders upslope.	Immediately Initially, the condition and effectiveness of the structure should be monitored and reviewed frequently, to ensure it is performing as intended. It should be monitored after storm events, and in the longer term, at intervals of not more than 5 years, in conjunction with reviews of the condition of the beach.	This action applies only to Cabbage Tree Harbour	Council has sought funding from the NSW Government. Council and NSW Government will share the $1.9 million cost of the structure.

Step 3: Enhance knowledge and monitor achievements

A73: Repeat LiDAR surveys of the coast at approximately 5 year intervals. Analyse high resolution digital terrain data at 5 yearly intervals to identify any changes in the terrain of areas affected by geotechnical hazards.

Intent and logic

LiDAR provides high resolution remote sensed data about the ground surface. Analysis of digital terrain models prepared from sequences of LiDAR survey can provide accurate information about changes in the morphology of slopes, which will be important for assessing the success of management structures and also for observing when a slope is becoming oversteep.

Note that some ground truthing of LiDAR analysis may be necessary in specific areas of steep slopes, to clarify vegetation and overhangs effects.

See also **Action 89** which refers to development of a data base and 3D model, as per Figure D3 of **Appendix 4.**

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
NSW Government	The Central Coast LiDAR was collected in 2007. New LiDAR data should be collected after approximately 5 years. However, much of the NSW coast has not been mapped using LiDAR at all yet.	LiDAR data is relevant to tracking landform change along the entire Wyong coastline – both cliffs and bluffs and sandy shorelines.	NSW Government. Council may choose to invest in LiDAR data itself, to accelerate the process. Allow $60,000 per run for the local area.

Step 3: Enhance knowledge and monitor achievements

A74: Make Australian GeoGuides, published by the Australian Geomechanics Society, available on Council's web site, as reference material on good practice for landowners and Council.

See **Section 10.4.1** for current titles. See also TAB D in **Appendix 4**.

Engineers Australia also prepares technical guidelines for coastal engineering issues and is currently updating their documents. Council should also provide/encourage access to these documents when updated versions are released

Intent and logic

These guides provide information about managing development on land affected by geotechnical hazards

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC – in conjunction with Australian Geomechanics Society and Engineers Australia	As soon as possible Information should be updated as new guides or revised guides are released.	The guidelines are relevant to all landowners, architects and developers operating in the coastal zone.	No additional cost is involved.

Step 3: Enhance knowledge and monitor achievements

A89: Develop and continue to refine a 3D geotechnical model for predicting geotechnical hazards (See Figure D3 in **Appendix 4**) and Section 8.1 in **Appendix 4**.

Intent and logic

The general geology of the Wyong coastline is well known but the details of stratigraphic and structural interactions and presence of dykes at an individual property scale are less well defined. Council proposes to progressively develop a three dimensional model of geotechnical processes and hazards along the coast. The model could incorporate a range of information such as high resolution terrain models (LiDAR), known geology, known geotechnical processes and engineering equations for stable slopes in various materials. Council will collect more information about these factors from development applications for properties within specified geotechnical hazard zones. By collating this information within a data base linked to the coastal recession model, Council will continuously improve its knowledge and capacity to predict slope instability hazards along the coast.

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC, (Planning, natural resources and asset management sections) with information supplied from detailed studies submitted with development applications.	An indicative model is provided in **Appendix 4**. Council could establish the model and data management process within the first two years of implementing the Plan. The model and hazard lines should be reviewed at regular intervals, likely to be 3 to 5 years.	This action applies to all rock and indurated sand based sections of the coast. Cliffs and bluffs which have residential development within existing and predicted geotechnical recession areas are a priority.	Data base establishment would be a task for existing WSC staff. Council may seek further geotechnical advice and further expertise in the management of very large spatial data sets. This additional advice is likely to involve consultants. Allow up to $50,000 over the first five years of the Plan.

Step 3: Enhance knowledge and monitor achievements

A90: Further investigate the interaction of coastal erosion and geotechnical hazards in areas where both types of hazard (coastal erosion and geotechnical recession) may apply now or within the 2100 planning period.

Intent and logic

At several locations, rock based terrain is overlain by a shallow sand deposit, or is landward of sand based landforms which are expected to be eroded within the 2050 or 2100 planning horizons. The details and hazard implications of these stratigraphic relationships at these locations are not currently clear. Further investigation, either by Council or as part of studies required for new development proposals in these areas will clarify the hazard relationships and provide more certainty about how they should best be managed.

New information would be entered in Council's coastal process data base.

Responsibility and key partners	When - Priority	Where – locations for investment	Indicative cost and source of funding
WSC, with input from information provided by proponents.	This work is expected to commence within the first two years of the Plan and will be ongoing.	Examples of locations where sandy coast and rock coast processes interact are at Cabbage Tree Harbour, The Entrance, Blue Bay and Toowoon Bay.	Allow $10,000 for clarification at priority sites, but other information will come from private land developers.

11.4.1 Information to assist land owners

The Australian Geomechanics Society is a specialist technical society within Engineers Australia, established in 1970. Its members are fully qualified engineers or engineering geologists (members of IEAust and AustIMM) with particular experience and expertise in engineering geology, geomechanics and geotechnics. The Society has prepared a series of technical guides on geotechnical processes which are intended to assist stakeholders to understand hazards and risks associated with geotechnical processes and the principles of sound management of areas affected by geotechnical processes (Australian Geomechanics Society 2007). Current titles include the following (see TAB D of **Appendix 4**):

- Geoguide LR2 – Landslides
- Guideline LR3 – Landslides in Soil
- Geoguide LR4 – Landslides in Rock
- Geoguide LR7 – Landslide risk
- Geoguide LR10 Coastal landslides

Other guidelines on water management, hillside construction and effluent management are also available and may be relevant to some properties.

Council will provide links to these documents from its website and will reference the advice in the Geoguides in its own work.

Easy access to this best available technical information will assist landholders and the broader community to understand the ways in which geotechnical processes affect sustainable coastal development and how geotechnical process risks can be reduced.