Collaroy Beach 2016 – D Day Storm - Lessons learnt

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Introduction

The May/June period has historically been the time for the occurrence of events that have the potential for significant beach erosion in the Collaroy/Narrabeen embayment. Such events have resulted from intense storm activity associated with the development of East Coast Lows (ECLs) (PWD, 1986). Events have been particularly prevalent in years when: the Eastern Australian Current (EAC) is still actively delivering warm water south along the NSW coast well into autumn/winter; there is a tendency for trough development along the coast; and at the same time cold upper air masses drift easterly over the coast. This combination tends to produce upward collapsing columns of air which produce the intense ECLs.

The late May and early June period is also a time of "King Tides" which, in combination with the ECL-generated storm surge and the wave set-up, enhance the potential for erosion by delivering storm waves directly onto the beach berm and to the base of the dunes, thereby allowing direct attack of the dunes.

The Storm

On Thursday 2nd June 2016 the synoptic situation was beginning to look ominous. The sea temperature off Sydney was still 22 degrees, a trough was predicted to develop off the coast in the next couple of days and there was a reported pool of cold air in the upper atmosphere. By Friday 3rd it was clear that an erosion event was a likely outcome and authorities were warned. On the 4th June the east moving frontal trough crossed the coast and an associated upper cold pool of air combined with the still relatively warm water to generate an ECL north of the NSW Queensland border. At the same time there was also a second low, on the same frontal line but well south and inland near the NSW Victorian border.

The ECL continued to develop and intensify during the day off the southeast Queensland coast and began travelling south along the trough line between the two low pressure areas. While there were varying degrees of erosion of the beaches in the north of NSW, as the system moved south, it also moved further offshore, allowing the wave fetch, and the intensity of the system, to develop. This resulted in a NE wave approach direction at Collaroy on the 5th. The initial storm centre passed Sydney late on the 5th with a maximum wind speed of 52 kts and a central barometric pressure of 990mb. However the complex nature of the trough meant there was more than one centre so again, late on the 6th, a second centre passed by with a similar central pressure but further offshore, progressively swinging the waves to the east. As both centres moved south the wave direction moved SE by the 7th.

Erosion and inundation

Coastal erosion is related to: wave height, direction, period, duration and set-up; and tidal range and the tidal anomaly generated by storm surge (wind and pressure set-up). Serious erosion, such as occurred at Collaroy during the D-Day storm, was caused by a combination of locally generated storm waves and elevated water levels due to wave set-up, "King Tides" and storm surge. Experience dictates that it is possible to have minimal erosion when large waves, from a distant storm, combine with low tidal conditions. However significant erosion can result from even moderate wave attack from a local storm that induces storm surge that also coincides with times of high tidal ranges, particularly if the duration of the storm is more than 2 days and hence encompasses two of the peak high tides. Because there are so many independent or partially dependent factors involved, it is difficult to meaningfully assign return periods to erosion events. It is argued that it is more reasonable to adopt the simpler approach of ranking the outcomes rather than the components that made up the event. It is known that in the last 100 years there have been at least 5 events that have produced similar or worse erosion than the D-Day storm (PWD, 1986) and hence it is not unreasonable to assign it a ranking of 1 in 20 years, that is an ARI of 5%.

By nightfall on Sunday 5th significant erosion began to develop at Collaroy, particularly in front of 10 properties between Stuart and Ramsay Street. They had no seawall and had been identified as being within the "Immediate Impact Zone". Initially the waves were coming from NE, and although refracting, were still at an angle to the beach, giving rise to a strong southerly sweep in the surfzone. The longshore current was estimated to be up to 2 metres/sec. Over the period centered on 2 to 3 hours either side of the predicted high tide of 2.05m (+0.16 storm surge) at 2030hrs on Sunday 5th 2016, major beach erosion occurred along the 100m fronting the Stuart/Ramsay Street sector. Based on aerial photography before and immediately after the event it is estimated that between 12,000 and 14,000 m^3 was lost from this region at this time. Erosion continued, albeit at an abated rate, during the 6th as the morning high tide was only 1.54m. However the next high tide of 2.04m (+ 0.15 storm surge) at 2120hrs also corresponded with some local intensification of the storm (the second centre). Again the erosion tended to be maximum around 2 to 3 hours either side of high tide but this time, with the more shore-normal wave direction, and the slumped seawall crests, the overtopping was noticeably greater. Over the next two days, as the ECL tracked south, the focal area of erosion shifted north. Progressively many of the existing rock revetments, along a 1km front, slumped and were overtopped resulting in a back-of-wall erosion escarpment developing which threatened residences that were thought to be protected by revetments.

Management of the emergency

On the Sunday evening, as the erosion escarpment approached the houses between Stuart and Ramsay Streets, a rapid assessment of coastal engineering, geotechnical and structural factors indicated that the residents had to be evacuated and the Emergency Sub Plan (WorleyParsons, 2012) put into effect. There was little opportunity for residents to take much with them. Police went house to house asking people to leave while at the same time the SES and Council were making arrangements to cordon off the area. One owner refused to leave, so the Police "arrested" him. Once clear of the danger he was

cooperative and the Police, recognizing that it was an emotional situation, “un-arrested” him; a very pragmatic action that built credibility.

For the next several days there was good cooperation between the residents and the authorities. On the Monday morning of the 6th, with some easing of conditions, the residents were keen to re-enter their homes and recover precious items and changes of clothing. The Police requested the coastal engineers advice and as a result there was a need to consider the condition of each of the houses. An assessment of likely escarpment slumping and the setback required to account for the “Zone of Reduced Foundation Capacity” was compared with the pre-prepared dossier (Patterson Britton, 2007) of the foundations of all beachfront buildings. This assessment was the basis for decision-making regarding re-entry. The lesson being that, if there is an absence of access to specialist coastal engineers, a conservative setback table that can be applied to a specific beach situation and a readily available dossier on the foundations of all beach front properties should form part of any emergency action plan.

It soon became apparent that there was potentially a new danger. The smell of gas could be detected in some of the houses. Many lights and electrical appliances were still active as a result of the emergency nighttime evacuations. Inspections were therefore temporarily suspended while all services to the 10 houses were disconnected. Water supply to each house was included in the disconnections as it was felt that if settlement/slumping broke a main it could add to the potential for collapse of the erosion escarpment. In the course of the inspections it was also found that on the seaward side of one of the apartment buildings, a fire hydrant was only half a metre away from the escarpment, so arrangements were made for NSW Fire and Rescue to isolate that particular outlet, which they were able to do while still retaining a viable fire fighting capability. The sewer was another challenge. The main sewer line servicing the houses had been laid in the dunes that once fronted the houses. The erosion had destroyed the sewer lines; they were strewn across the beach, spilling raw sewage into the surf zone. The solution was to locate the remaining serviceable manholes at the upstream and downstream ends and drop sandbags down to temporarily block the pipes. With all services secured it was possible to allow the residents to enter their houses to the limit of what had been assessed to be “safe”, albeit for just enough time to recover whatever precious and basic items they could. Entry to each house was generally restricted to 15 minutes and the residents were accompanied by an engineer and a Police officer. Again there was good cooperation and understanding of the seriousness of the situation and the residents patiently waited their turn. Detailed briefings and a forthright exchange of information were key to this cooperation.

An interesting problem arose because, in a couple of cases, the owners of the residences were overseas and had asked friends to recover whatever they could. The Police had the challenge of checking their credentials. This was just as well as one person attempted to enter an apartment block, however the information he provided to the police proved false. Threatened with arrest, he quickly left the scene.

On Monday Council acted expeditiously to arrange for the entire site to be secured. This involved the erection of temporary construction fencing from Ramsay to Stuart Street and beyond, to the north, where some properties with were starting to experience collapse of their revetments. The fencing not only made it far easier to control the large crowds but also helped manage media access. With many television, radio and newspaper journalists and cameramen gathered, and the potential dangers of providing access, the Police commander arranged for a briefing of the media and then asked them to nominate one journalist and one cameraman who they all trusted to bring back and share the footage

and story. Once elected the Police and the engineers provided controlled access to some key viewing areas. Again there was excellent cooperation by all parties.

Access for emergency works

With real estate being at a premium for prime beachfront properties there is an understandable tendency to maximize site coverage. This includes minimizing side and beach side setbacks. Further, there is a tendency to develop the seaside area with entertainment areas such as pools, outdoor kitchens, cabanas and privacy fences. Therefore often access from the road through to the beach is restricted to foot traffic. During a storm access to and along the beach is usually unsafe, if at all possible. This was the case at Collaroy from the 5th to the 7th, particularly along the region between Ramsay and Stuart Streets where not only were the waves washing up to the erosion escarpment, but also debris such as timber, steel and glass were both in the swash zone and precariously overhanging from the fronts of the damaged residences. With no practical safe access to ocean side of these properties, it was not possible to undertake inspections of the undermining, let alone any protective measures until the seas had subsided sufficiently to allow access from one of the road-heads.

Given that a recently certified and gazetted Coastal Zone Management Plan (CZMP), (Haskoning, 2014), included a seawall/revetment along the 1.1km, including the region between Ramsay and Stuart Street, temporary works were commenced to shore-up the threatened houses between these two streets as soon as the sea had subsided sufficiently to allow safe access. On the 7th work commenced on the road-head access at Ramsay Street. Geotextile sheets were placed down the slope and rock placed by an excavator so as to construct a ramp down to the “beach” level.

Two excavators were then employed constructing a sand bund wall approximately 10m seaward of the escarpment. The same technique as described by Gordon (2015) was used to “mine” the swash zone for sand; interestingly the swash zone recovered almost as rapidly as the sand was excavated. The excavators constantly replenished and maintained the bund wall, which, on average, comprised approximately 700 cubic metres of sand. At the same time the excavators were able to fill and place multiple rows of 2.5 cu m geobags, placed as a retaining structure to prevent the houses slipping down the escarpment. Because some beach recovery (approximately 1m recovery in berm level by late on the 7th) had occurred before the first row of geobags could be placed, and there was the potential for a following storm by the next weekend, the first row was above the desirable toe level. This necessitated a follow-up action during the week, after the “new storm” threat had subsided, of excavating between the sand bund and the geobags and the placement of 2 new rows (founded on a relatively inerodible cemented sand layer in front of, and below, the existing 2 rows). At the same time the retaining structure was extended up to the level of the building foundations. This unusual procedure was necessitated by timing and availability of material including the supply of geobags and the potential threat of a second storm on the 11th June.

On the night of Tuesday 7th, sandbags were placed on properties to the north of Stuart Street where the walls had collapsed backwards due to the loss of sand through the walls. However access was limited to the narrow footpaths between buildings so the State Emergency Services, NSW Fire and Rescue, and the Rural Fire Service put out calls for assistance. In addition, members of the Surf Clubs in the area rallied “troops” via the social media. In response, several hundred people arrived which allowed “conga lines” to be

formed from bag filling stations, up the street and through the pathways to the areas under threat. An estimated 12,000 sand bags were placed from late afternoon till midnight when the seas started to abate.

How the existing protection faired

Conventional sandbagging was employed in an attempt to save houses along the beachfront, between Arlington Hall (now the Beach Club) and Jenkins Street during, and after, the 1925 storm. However the attempts were unsuccessful and five houses were lost with several others severely damaged and removed (PWD, 1987). Further, Arlington Hall suffered some damage on its ocean side, and as a result the existing seawall was constructed in front of the building during the later 1920s (PWD, 1987). The seawall and the Beach Club again suffered damage during the 2016 storm.

In 1944 storms caused erosion that resulted in the loss of outbuildings and the undermining of some houses. As a result sand bag walls were erected. However it was the severe erosion during the storm in June 1945 that resulted in the loss of 2 houses with a further 6 or 7 reported to be seriously damaged, and Arlington Hall was again damaged (PWD, 1987). One of the houses washed into the sea was reported as having its “electric lights still burning” (PWD, 1987). Following the storm some works including the dumping of “huge concrete tank traps” were undertaken in an attempt to retain some of the remaining houses in the vicinity of Frazer Street. However it was the main 1967 event that resulted in the dumping of rock and earth fill, placement of concrete cubes and the use of timber poles to stem the erosion threat to the remaining houses between Fielding and Wetherill Streets. Following the storm the reinforced concrete wall near Jenkins Street was constructed (PWD, 1987). The storm had also exposed the pile foundations supporting the two high-rise unit blocks, “Flight Deck” and “Shipmates”, between Frazer and Ramsay Street. Sand was pushed back under these buildings and a rock wall constructed.

Over time rock walls have progressively become a feature, albeit sometimes controversially, of the southern third of the Collaroy/Narrabeen embayment (PWD, 1987). At the time rock revetment design was not as well understood as it is today. Although seawalls and revetments first made their appearance in NSW in the early 1800s, the first major revetment to feature modern design methods was the Second Runway into Botany Bay, built during the late 1960s. The Banksmeadow revetment protecting Port Botany followed this shortly after. The design of both of these structures relied on multiple layers of, progressively fining, underlying filter rock protected by an outer layer of interlocking concrete units; geotextile underlays had not yet become a readily available product.

Given the need for rapid response, the post 1967 storm revetments tended to be either constructed using a range of rock sizes with the heaviest on the outer face or, more commonly, simply tipped rock from whatever source was readily available. The walls generally comprised sandstone boulders with sizes ranging from “quarry run” up to 2 to 3 tons. Little thought was given to the provision of underlay or the need for interlocking rock shape and hence many rocks were of a shape that promoted slippage. In addition some of the sandstone was of a poor quality and so progressively broke apart over the years. For the revetments that had some design component, the slope tended to be 1 in 1.5 to 1 in 2 and, because their crest was at the adjacent surface level of approximately +6 to +7m AHD, were of sufficient height to deal with most wave runup. Inevitably construction commenced some time after the storm abated and beach recovery had already commenced so, not only was there no design toe structure, but the actual toe of the

armour was perched above future likely scour depths. For those revetments that were simply tipped rock, the slopes were often an unstable 1 in 1.25 or steeper and so shed rock onto the beach, thereby weakening the revetment itself albeit fortuitously creating a partial scour blanket toe.

The 1974 “storm” was actually two separate events a couple of weeks apart (Foster et al, 1975). The very intense May storm focused erosion in the area between Goodwin and Devitt Streets but also caused significant erosion to the dunes to the north. Those properties not yet “protected’ as a result of the 1967 threat, including the new high rise apartment block, “Marquesas”, near Devitt Street, rushed to tip rock in late May/early June so as to “save” the buildings, and continued tipping right through the second storm in June. There was neither the time nor the inclination to design and construct the revetments to a competent engineering standard, nor were there the controls to require this to happen. Over the years since 1974 there has been a tendency for homeowners to continue to construct/repair/upgrade rock walls, in some cases supplemented by concrete blocks, generally without design or approval. The net result is that the 1 km of rock revetments in the southern third of the embayment have historically not been capable of receiving engineering certification as to their competency (DPWS, 1999, Patterson and Britton, 1999). Because of the potential danger of rocks being dislocated from the walls, Council has erected warning signage in several locations. In recent times, with redevelopment taking place, the newer buildings have been required to be on piles and there have been efforts to repair and/or upgrade some of the revetments to a better standard (Patterson Britton, 2001). Because the three-story unit block near Jenkins Street that has the reinforced concrete wall is now surrounded by public parkland, it remains vulnerable to outflanking.

By first light on Monday the 6th June 2016, following the intense wave attack of the previous night, it was not obvious that there was much damage to the walls protecting many of the properties. It was however noted that the properties to the immediate north of Stuart Street had started to suffer some subsidence in their yards, and some of these walls were showing signs of collapsing backwards. Other than that, most walls seemed relatively intact. However, during the night the obliquity of the storm waves produced a very strong longshore current to the south progressively undermining the toes of the walls.

On Monday night the high tide combined with the storm surge produced water levels of 1.25m AHD; near their Sunday night high of 1.29m. With the waves now shore normal and no strong longshore current, the wave set-up effect was greater and the runup was noticeably higher with some “sets” resulting in “green water” overtopping in places where the crest levels were +6m to +7m AHD. This water again saturated the yards and lawns resulting in a further surcharge of the groundwater levels behind the walls. By the morning of Tuesday 7th the damage to the walls became apparent. Along most of the 1 km stretch it was obvious that there had been extensive toe failure and hence slope slippage and/or collapse. In retrospect it was considered that this was most likely initiated on the night of the 5th through the scour caused by the longshore current, and was exacerbated by the shore-normal plunging breakers on the revetments on the night of the 6th. However, on the morning of the 6th the toe scour could not be detected because of the continued wave action and elevated water levels.

By the morning of the 7th most walls had slumped, rocks had been dislodged and crests had been overtopped resulting in either, or both, direct erosion of the land behind the wall or sand being washed through the walls, thereby removing their support. So, during the period 5th to 7th June all of the over 1 km of seawalls in the southern third of the Collaroy/Narrabeen embayment suffered at least one form, if not more, of the five modes

of damage; toe failure, slope failure, overtopping, filtration failure and, where the adjacent properties didn't have walls, or the walls had collapsed, outflanking. Some walls sustained relatively minor damage, generally due to toe settlement or overtopping, while at the other extreme some experienced complete collapse, most suffered damage somewhere in between these extremes.

An unexpected lesson

In keeping with the modern principles of water sensitive urban design Council had, for a number of years, sought to achieve as much residential on-site disposal of stormwater as possible. The use of on-site disposal assists in maintaining the water table and hence improves the opportunity for robust vegetative cover. It also reduces the need for visually unappealing, and sometimes unsafe, stormwater outfalls onto beaches that, during periods of runoff, create erosion channels through the beach berm allowing waves to penetrate to the back of the beach, and therefore promoting erosion in the vicinity of the outfall (Gordon, 2011). As a result of the on-site disposal policy, many of the houses at Collaroy had disposal systems that featured detention tanks and infiltration trenches.

Once daylight broke on Monday morning the extent of the damage could be observed and included the identification of debris from stormwater detention and disposal systems scattered in the swash region in front of the escarpment. To the north of Stuart Street some rock walls had partially collapsed backwards into the yards of the houses indicating that supporting sand had been washed out through the walls. Again, the broken–up remains of on-site stormwater disposal systems were obvious amongst the debris of the collapsed walls.

Prior to the development of the East Coast Low, the preceding trough system had produced several days of heavy rain so on-site stormwater disposal systems were fully charged, saturating the sandy soil and super elevating the water table. The situation was exacerbated by the addition of overtopping water from wave run-up, some of which flowed directly back into the ocean, however a considerable quantity simply percolated into the exposed soft surfaces. With no specific drainage systems to relieve the super elevated water tables, pore water pressures created flows that exacerbated the erosion potential of the "unprotected" dune areas and resulted in sand flowing through the rock walls.

Reflecting on the experience at Collaroy, on-site disposal remains the most appropriate form of stormwater disposal, both from the maintenance of water table recharge for most of the time and from reducing, as much as possible, the need for stormwater outfalls across beaches. However attention is needed to the guidelines for on-site disposal so as to reduce the potential for exacerbation of erosion.

Other matters for consideration

All of the houses between Stuart and Ramsay Street, and the Beach Club further south, had patios or decks at ground level and most had first floor balconies. These structures typically featured conventional foundations and building attachments in keeping with an "add on" approach to construction. Even some of the buildings on piles had balconies on conventional, small footings that were rapidly undermined and failed during the storm. As the foundations failed, the balconies/patios collapsed seaward and "tore-off" parts of the

main building and/or hung precariously above the area that was later needed for access to construct the temporary retaining wall. In the worst cases the entire front walls of the houses were torn apart and the internal rooms exposed to spray and runup. Clearly balconies, and the like, need the same rigor applied to the provision of their foundations as is applied to the main building, and are integrated into the structure of the building so that they do not break free from the building and cause collateral damage and an unnecessary debris issue.

An often-used photo of the storm damage was that of a concrete pool which had been undermined and had collapsed into the swash zone. A similar fate for a pool was experienced at Bilgola in 1974. At Collaroy, the concrete structure of the pool survived the collapse surprisingly well, but the pool is now dysfunctional and presents a challenge as to how to handle its future. Again this was a substantial, and expensive, structure in front of the main building that did not have the foundations necessary to manage its exposure to the erosion hazard; albeit that it could be argued it ended up providing some protection to its house, and was an anchoring feature of the temporary wall.

Many of the houses along the 1.1km strip had extensively landscaped yards fronting the beach. The landscaping took various forms including minor structures such as tool sheds, barbeques, cabanas and observation decks. Even in the areas where the revetment damage was modest, much of the landscaping ended up as debris in the swash zone of the embayment; creating problems and dangers to surfing for more than a week. In one case a large feature palm tree had to be cut down because erosion of its root ball had made it unstable.

Conclusions

When a major event such as the June 2016 storm occurs it is important to de-brief after the event and identify the lessons learnt from the event. For Collaroy, the lessons learnt included:

The 2016 storm tracked south along a trough line, which was a similar behaviour to the main erosion-causing historic storms of 1967 and 1945, but different from the south to north track of the 1974 event which was more intense but of shorter duration (PWD, 1987). Little is known of the track of 1925 storm that damaged Arlington Hall. From the evidence it would seem that the south tracking storms tend to focus erosion in the southern area of the embayment, whereas the north tracking storms tend to focus erosion more in the central to northern area of the embayment. Further, the south tracking storms produce a longer duration of wave attack. This might be as expected when considering the embayment alignment, the outstand of Long Reef Head as compared to Turimetta Head (the embayment ends), and both the moving fetch and the clockwise rotation of the storms which generate the most severe conditions on their right hand leading edge.

Another lesson is that where developed areas have beachfront properties with little separation, it is particularly difficult to undertake emergency works, let alone competent revetment construction. The construction of adequate protective structures requires good, safe site access, and their ongoing maintenance and upgrade requires sufficient setback between the revetment and any structures, to allow vehicular access along behind the wall; that is a building set-back behind the landward side of the crest of a minimum of at least 6m and any structures within this setback, including fences, need to be readily removable.

An important, but unexpected lesson was that water sensitive urban design principles and guidelines need expansion to include the design of infiltration systems in situations such as those existing at Collaroy. There is clearly a need to prevent "filtration losses" of sand, so any revetment protection structures must include robust filter layers. Further, both protected and unprotected regions need suitable drainage systems to manage overtopping runup and spray. But most importantly, Private Certifiers must ensure that on-site disposal systems do not promote failure of sea defence protective works.

In regard to seawalls and revetments the key lesson, which was a reinforcement of other past experiences, was the need for properly designed and constructed protection measures that adequately address all five of the potential failure modes. These include: an adequate toe design to cope with potential scour, a well-designed slope with appropriately sized armour, for the selected slope angle, rock and underlays and robust geotextiles to prevent filtration losses of material through the slope. The crest needs to be of sufficient height and width to cope with wave runup, and if overtopping can occur, then adequate drainage must be provided. The design, approvals and construction of structures require considerable time that clearly is not available during a storm event.

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