Beach scraping as a coastal management option

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Abstract

This paper examines the feasibility of beach scraping as a coastal management option. Beach scraping has been and continues to be widely undertaken, but there is little published literature on it. Conversely, it has been discontinued in some locations due to environmental concerns.

Beach scraping is defined as the movement of sand from the intertidal zone to the dune or upper beach by mechanical means. It has also been called beach skimming, beach panning, nature assisted beach enhancement and assisted beach recovery. Beach scraping mimics natural beach recovery processes, but increases the recovery rate compared with natural processes. In combination with revegetation schemes, beach scraping has commonly been used for dune building.

The paper details case studies from two locations and addresses the following aspects of beach scraping:

- Literature review;
- International best practice;
- Design methodology;
- Target dune profile;
- Impacts of climate change;
- Seasonal factors;
- Approximate costs;
- Preliminary environmental effects;
- Precautions.

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Beach scraping differs from beach nourishment in that nourishment involves sand being imported from outside the active littoral compartment, whereas with beach scraping, sand is redistributed within the littoral system. This redistribution used in scraping means that natural forces may do some of the work, potentially resulting in lower costs than nourishment.

Clearly, beach scraping is not a universal panacea for coastal management. This paper identifies the most suitable locations, criteria for suitability and the limitations of beach scraping.

Introduction

Beach scraping refers to the anthropogenic movement of small to medium quantities of sand from the lower part of the littoral beach system to the upper beach/dune system, thus mimicking the natural beach recovery processes (Figure 1), but at a greatly increased recovery rate. Beach scraping has been widely practised (Figure 2) but there is relatively little published literature on its application. Most work has been done without detailed environmental approvals or studies.

Other definitions include:

- "the removal of material from the lower part of the beach for deposition on the higher part of the beach or at the dune toe" (Bruun, 1983).
- "the transfer of sand from the lower beach to the upper beach (within the beach system), usually by mechanical equipment, to re-distribute the sand to parts of the beach above tide level" (BSC, undated).
- "the process of mechanically removing a layer of sand from the foreshore and transferring it to the backshore" (Clark, 2005).

Beach scaping has also been called:

- Beach skimming;
- Beach panning;
- Nature assisted beach enhancement (NABE);
- Assisted beach recovery;
- Beach recycling and re-profiling.

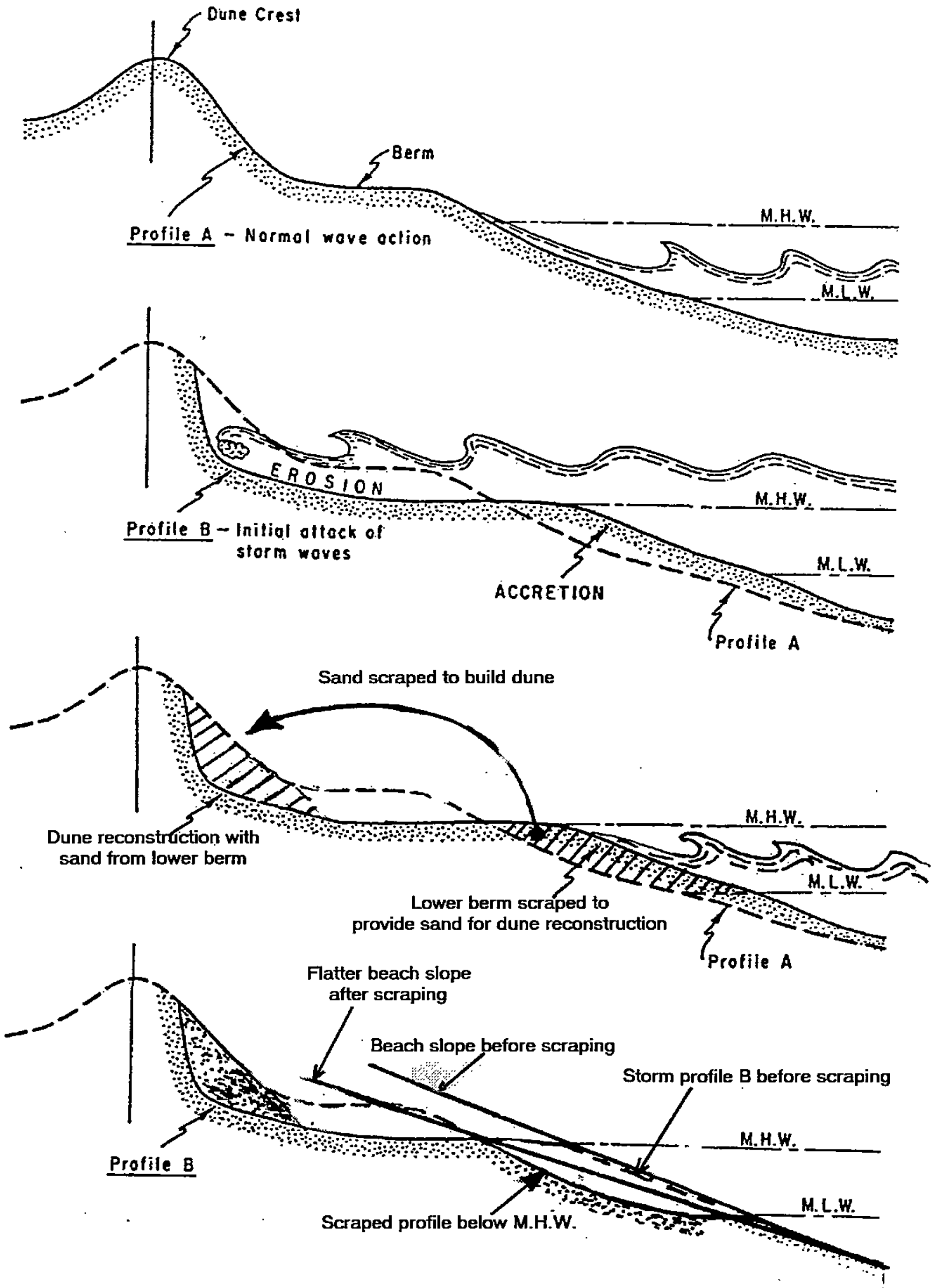

Figure 1: Beach scraping concept (Source: Lex Nielsen)

Gold Coast 1967

Sydney 2008

Figure 2: Photos of beach scraping

Literature Review

Physical Factors and Effects

Smutz, Griffith and Wang (1980)

Smutz et al. (1980) reasoned that by removing a small amount of sand from the lower beach and placing it above the wave run-up limit, accretion of the lower beach is accelerated because a flatter nearshore profile prevails. Flatter profiles promote accretion, whereas steeper profiles are more prone to erosion. Smutz et al. reported on physical model studies of this and also presented theoretical wave steepness calculations.

They acknowledged that their work was not based on field studies, but argued that beach scraping was more efficient than conventional nourishment because nature provides most of the energy (in accreting the lower beachface).

Bruun (1983)

Bruun (1983) commented on scraping practice in Denmark and the USA. He recommended "responsible scraping", with scraping depths of 0.2 to 0.5 m and that placing material into the dune provided the best coastal protection. "Responsible scraping" did not have adverse effects on neighbouring beaches. He argued from his extensive observations that if material is removed from a seaward berm during accretionary conditions, another berm will form. Bruun concluded:

1. "Beach scraping .... is not harmful, but rather is beneficial as coastal protection of eroding dunes...

2. Undertaken in a technically responsible way, it also has beneficial rather than adverse effects on adjacent beaches.

3. Beach scraping is a way of organizing available beach material in a more sensible way – on a short term basis. But it is a temporary measure only. It does not replace artificial nourishment,..."

Tye (1983)

Tye (1983) examined the seasonal effects, post storm recovery and the response of an eroded beach to scraping and artificial dune construction at Folly Beach, South Carolina, USA following a major hurricane. The analysis involved six beach profile transects at 1.6 km intervals along the beach. The scraping volumes averaged 28 m^3/m (cubic metres of sand per metre of beach/coast). Tye found that this scraping rate was excessive on profiles which did not recover naturally, and resulted in additional erosion in subsequent storms .

Tye stated that a "well organized and prudently monitored beach scraping program can prove beneficial to dune and beach restoration." He concluded that "By working in conjunction with the natural beach recovery cycle, beach recovery can be accelerated with minimal environmental damage." This was predicated on scraping rates not exceeding natural recovery rates.

McNinch and Wells (1992)

McNinch and Wells (1992) reported on a scraping project at Topsail Beach, North Carolina, USA. The scraping rates in their project were small, averaging 0.21 m^3/m per day over 3.5 weeks, scraping to a depth of 0.15 to 0.2 m, and using only a single piece of machinery. Their borrow area was below the high water mark. They cautioned that unsuccessful scraping projects involved scaping more sand than natural recovery rates, and that such excessive scraping may involve oversteepening of beaches and additional erosion. They quoted a project at Folly Beach, South Carolina, USA which used scraping rates of 5.2 m^3/m/day which was considered unsuccessful, in that the lower beach borrow area had not recovered 5 weeks after scraping.

McNinch and Wells (1992) concluded that "under certain conditions, beach scraping can be beneficial in preventing overwash and preventing damage to backshore features..... we recommend limited scraping, only on that part of the beach inundated daily by tides...."

NSW Department of Land and Water Conservation (2001)

The NSW Coastal Dune Management Manual provides management and rehabilitation techniques for coastal dunes in NSW. The manual provides some guidance on dune reforming including suggested dune profiles, materials and position geometries. The manual states that "reconstructed dunes should vary in slope, size and shape just as natural dunes do. However unnatural protruding hummocks or steep-sided undulations that may interrupt or concentrate wind flow should be avoided." The manual further states that "the height and width of a reconstructed dune depends on a number of factors including:

- the height and width of existing dune remnants
- the availability of sand
- available space
- the degree of landward protection required.

It may be desirable to reconstruct the dune to a height that will prevent wave overtopping during storms."

Queensland BPA (2003)

The Queensland BPA (2003) suggested that dune heights on open coasts should be 5 to 7 m AHD. Dunes will ultimately develop their own profile, but they suggested a seaward design slope of 1V:5H for sand dune design.

Dare (2003)

Dare (2003) stated that a lack of research on beach scraping has led to differing opinions on its impact to the beach and its success in erosion control and prevention. A listing of the benefits and problems of beach scraping as a form of coastal erosion protection was compiled by Dare and is presented below with additional comments.

Positives:

- Widening of the beachfront enhances recreational use and tourism.
- Temporary coastal protection of infrastructure and housing is provided by increased beach (and dune) width.
- Scraping is aesthetically unobtrusive following the initial works period.
- An emergency response option which can be implemented rapidly without permanence.
- It utilises a natural and compatible sediment supply which is beneficial to beach flora and fauna rehabilitation and natural dune formation.

- There is minimal impact to the natural cycles of the coast.
- Temporarily increased defence without the need to expensively import volumes of sand.

Negatives:

- The temporary nature of beach scraping works for protection from coastal erosion may need to be repeated frequently in the future.
- Sediment supply is temporarily interrupted and has the potential to result in down-drift erosion.
- Modification and destruction of habitat and flora and fauna is inevitable.
- Disturbance of flora and fauna has a follow on effect to foraging patterns on species who feed on those organisms.
- Alteration to foraging, nesting and breeding patterns of avifauna and turtles.
- Erosion rates may initially be increased in the 'borrow' area.
- Beach profile has the potential to become adversely steepened depending on the size of the borrow area.

Conaway and Wells (2005)

Conaway and Wells (2005) reported on aeolian dynamics on scraped shorelines in North Carolina. Their study noted that as beach scraping increases the dry sediment volume above the high tide and increases the foredune surface area with loose, unconsolidated material, sand movement due to aeolian (wind-induced) processes is increased. This increased aeolian transport may result in in-situ dune growth but may also be lost from the active beach system completely if blown onshore. Mitigation of wind erosion was therefore suggested desirable, with wind fencing recommended as the most effective means.

Govarets (2009)

The work of Govarets was primarily focussed on ecological impacts, but also provided comments on physical impacts. Govarets (2009) stated that "soft" coastal erosion responses (such as beach nourishment and scraping) have less impact on the natural environment as they allow for the processes of sediment erosion, deposition and transportation to continue. As with any form of beach nourishment, beach scraping derives various environmental (physical) and ecological effects. However, if undertaken in accordance with appropriate site specific management techniques (e.g. scrape depth and sand placement technique) the severity of any detrimental impacts may be reduced. Reducing the severity of impacts may allow for more rapid recolonisation of beach macrofauna and provide for improved fauna and flora habitat.

Ecological Factors and Effects

Numerous studies have been undertaken on the ecological effects of beach nourishment (defined as importing sand into the littoral system), but few specifically address beach scraping.

Committee on Beach Nourishment and Protection (1995)

An improvement to the subaerial beach following scraping works can supply indigenous biota and other biota with appropriate foraging and nesting sites. In the longer term beach scraping can modify, enhance and provide new habitats in the form of enhanced dunes for beach flora and fauna.

Grain (1995)

Alterations to the natural beach system as resulting from beach nourishment, which can negatively affect sea turtles, include compaction, density, shear resistance, colour and gas exchange (Grain, 1995). Compaction and changes in density is thought to decrease nesting success, alter nest changing geometry and alter nest concealment (Grain, 1995). Gas exchange of the beach sands can influence the incubating environment of a nest which could in turn affect hatchling success and sex ratios (Nelson and Dickerson, 1988 in Speybroek et al. 2006).

Various other studies deduced no significant difference in hatching and emergence success of turtles on nourished as opposed to non-nourished beaches occurred (Raymond 1984, Nelson et al. 1987, Ryder 1992 in Committee on Beach Nourishment and Protection, National Research Council, 1995). The studies discussed above focused on the immediate impacts of beach nourishment practices during turtle nesting periods.

Henry (1999)

Henry (1999) undertook a B.Sc. thesis on the biological effects of beach scraping at Wooli, northern NSW, where beach scraping has been used primarily to improve pedestrian beach access. The following species of macrofauna were identified:

- *Crustacea* (crustaceans);
- *Ocypode cordimana* (ghost crab);
- *Gastrosaccus sp*.
- *Excirolana sp*.
- *Polychaeta* (beach worms)
- *Polychaeta sp*. A (cf. Lumbrinereis sp.)
- *Polychaeta sp*. B (cf. Glycera sp.)
- *Nephtys* sp.
- *Mollusca* (molluscs)
- *Donax deltoids* (pipi)
- *Insecta* (insects)
- *Bledius sp.*(shore beetle)
- *Coelopidae sp*. (kelp fly).

From a limited sampling scope and duration, Henry found that species abundance was less for the scraped sites than the unscraped, but there was no significant difference in species diversity between sites. Henry found highly significant differences in populations of *Donax deltoids* (pipi) and significant differences in populations of *Ocypode cordimana* (ghost crab).

Though not mentioned by Henry, it may be that the scraped sites were subject to increased pedestrian traffic (since the scraping was undertaken to improve pedestrian access). This may be an alternative explanation for the observed differences between scraped and unscraped sites.

Erskine and Thompson (2003)

Erskine and Thompson (2003) suggested that pipis are migratory species; therefore timing beach scraping works to occur when pipis are absent will reduce the negative impacts to pipi populations.

Speybroek et al. (2006)

Speybroek et al. (2006) determined that re-colonisation processes and rates of recovery are species specific and can be determined by the duration and intensity of works. Research on sand nourished beaches (different to beach scraping) suggests that nourishment is a 'short-term pulse' disturbance and hence provokes a 'short-term pulse' response.

Batton (2007)

Benthic invertebrate community recovery is dependent on the size and arrangement of the disturbed zone (Batton, 2007). Invertebrate abundance is greatest in the top 30cm of sediment, therefore deeper areas of impact with a smaller surface area are preferred.

While it is generally considered that that the impacts are greatest where material is sourced (Batton, 2007), the impact to benthic invertebrate communities adjacent to the extraction site and at the replenishment site are generally perceived as short term (Van Dolah, 1996 in Batton, 2007).

The intertidal zone is an area of high wave and tidal action. This high energy environment is less likely to be in a stable equilibrium assemblage structure under natural conditions and it is believed species habituating this area recover from disturbance swiftly (Bolam and Rees, 2003 in Batton, 2007). Fast recovery is associated with sandy beach species as these species have adapted to a highly variable and dynamic environment which is often subject to large physical disturbances such as storms, wave action, tides, sediment transport and turbidity (Batton, 2007).

Defeo et al (2009)

Defeo et al stated that recovery of ecosystems is assumed to occur in matter of months as opposed to years. It is recognised that direct crushing of intertidal invertebrates occurs as a result of human trampling (Defeo et al. 2009, Moffett et al., 1998 in Defeo et al. 2009) and the presence of humans has a negative effect on macrobenthic populations and communities (Veloso et al., 2006 in Defeo et al. 2009).

Defeo et al listed potential impacts on birds which include;

- Changes to foraging behaviour resulting in less feeding time, shifts in feeding times and decreased food intake;
- Decreased parental care when disturbed birds spend less time attending the nest, thus increasing exposure and vulnerability of eggs and chicks to predators;
- Decreased nesting densities in disturbed areas and population shifts to less impacted sites.

Parsons Brinckerhoff (PB, 2009)

PB undertook an extensive *Review of Environmental Factors* for proposed beach scraping at New Brighton in Byron Shire. Both Green and Loggerhead turtles have been recorded at New Brighton Beach (NPWS Wildlife Atlas) and generally nest between November and January (PB, 2009 in Carley et al. 2009). Limiting a trial scraping episode to extend no later than 30 September ensures that potential impact to nesting turtles is limited. Allowing time for natural beach profile accretion (approximately 4 weeks before the start of turtle nesting season) will further enhance the natural state of the beach allowing turtles to nest in relatively natural conditions.

Fitzgerald (2010)

Removal of sand by mechanical means is likely to cause direct mortality of benthic macrofauna, and deposits of sand on the foredune may smother fauna within this zone. Beach fauna such as ghost crabs, invertebrates, pipis, polychaete worms, crustaceans and molluscs are expected to be affected by beach scraping works.

Threatened species having the potential to be effected by a trial beach scraping episode at New Brighton Beach were identified in Fitzgerald (2010). "They include two littoral zone plant species: Sand Spurge (*Chamaesyce psammogeton*) and Dwarf Heath Casuarina (*Allocasuarina defungens*); Green Turtle (*Chelonia mydas*) and Loggerhead Turtle (*Caretta Caretta*). The latter species is known to nest at New Brighton Beach. Eight shorebirds are the remaining threatened species of concern. These are Beach Stone-curlew (*Esacus magnirostris*), Sooty and Pied Oystercatchers (*Haematopus fuliginosus* and *Haematopus longirostris*), Lesser Sand Plover (*Charadrius mongolus*), Terek Sandpiper (*Xenus cinereus*), Sanderling (*Calidris alba*), Great Knot (*Calidris tenuirostris*) and Little Tern (*Sternula albifrons*).

As with the sites identified in the Henry (1999) study, heavy pedestrian traffic and domesticated dog walking currently occurs throughout the proposed New Brighton Beach scraping site. For New Brighton, high levels of disturbance (by people and dogs), during both day night were identified by Fitzgerald, which could reduce the number of flora and fauna species present in the proposed works area. Undertaking a beach scraping episode within a high human use area has the potential for a relatively lower environmental impact than what may be observed in an undisturbed system.

Fitzgerald (2010) identified that food resource for littoral (seashore) birds may be temporarily diminished via temporary loss of intertidal benthic macrofauna. Disturbance to foraging, nesting and breeding shorebirds may occur during beach scraping works, however the construction phase can also attract species such as gulls through the supply of sediment, should it contain food (Govarets, 2009). Fitzgerald (2010) suggested that given the high use of New Brighton Beach, impacts to threatened avifauna as resulting from any beach scraping works (if undertaken before October) are not expected to be significant.

Aim and Scope of Beach Scraping

There are several possible aims and scopes of beach scraping, which could be attained either singly or as a combination. These are:

1. Restore and maintain pedestrian beach access following storm erosion.
2. Build a dune to a design profile by:
    a. Raising low points of the dune to a design level.
    b. Increasing the dune volume over the long term to meet storm demand.
3. Accelerating beach recovery following storm erosion.
4. Increase the dune volume to offset recession due to sea level rise (as a medium term measure).

Designing a beach scraping project

Coastal processes

Coastal processes which need to be considered in the design of a beach scraping project include:

- Water levels;
- Sea level rise;
- Wave climate;
- Wave setup;
- Wave runup;
- Littoral drift (net and gross);
- Beach erosion ;
- Beach recovery;
- Beach recession;
- Wind blown sand;
- Beach rotation;
- Seasonality.

Project design

Factors which need to be considered include:

- Aim and scope of beach scraping;
- Sand borrow area;
- Design sand dune profiles;
- Existing representative profiles;
- Preferred profiles of deposited sand;
- Required sand volume;
- Quantity of sand gained per episode;
- Machinery to be used to scrape and transport sand;
- Estimates of machinery hours/days per scraping episode;
- Number of scraping episodes for present day hazards;
- Economics.

Some examples of coastal processes and project design are provided below, however, the scope exceeds the limitations of this paper. More detail is provided in Carley et al (2009).

An example of typical water levels for the NSW coast is shown in Table 1. These indicate a typical borrow area should extend between about -0.4 m AHD and 1 m AHD.

For a typical NSW site and a range of scraping depths between 0.1 and 0.5 m, the volume of material obtained per scraping episode is shown in Table 2. Indicative costs for beach scraping range from $\$2/m^3$ to $\$10/m^3$ (ex GST), with a value of $\$7/m^3$ ex GST adopted. Costs are shown in Table 2. This compares with typical costs for beach nourishment of $\$5/m^3$ to $\$50/m^3$ (ex GST).

Design erosion volumes for the open NSW coast from Gordon (1987) are shown in Table 3. When erosion volumes from a major storm are compared with the volumes obtainable from a single scraping episode, it can be seen that the scraping volumes are small.

Table 1: Design water levels for operational scraping conditions

Parameter	Low Tide	High Tide
Spring Tide (MLWS & MHWS)	-0.6 m AHD	+0.7 m AHD
Wave Setup for Hs = 1.6 m	0.2 m	0.2 m
2 % Wave Run-up for Hs = 1.6 m, Tp = 10 s	0.7 m	0.7 m
Typical Nearshore Water Level	- 0.4 m AHD	+ 0.9 m AHD
Typical Nearshore Runup Level	+0.1 m AHD	+1.4 m AHD

Table 2: Typical scraping volumes per episode and costs

Scrape depth (m)	m^3/m	$/m @ $7/m³
0.1	4	28
0.2	8	56
0.3	12	84
0.4	16	112
0.5	20	140

Table 3: Design erosion volumes for NSW coast (Gordon, 1987)

ARI (years)	Erosion volume (m_3/m above AHD)	
	Low demand open coast	High demand rip heads
1	5	40
2	26	68
5	53	104
10	74	132
20	95	160
50	122	197
100	143	224

An example of dune crest levels relative to design wave runup (indicated as "target dune crest level") is shown in Figure 3. Beach scraping may be feasible for raising the crest of dune areas with a crest below the runup level, to prevent dune overwash.

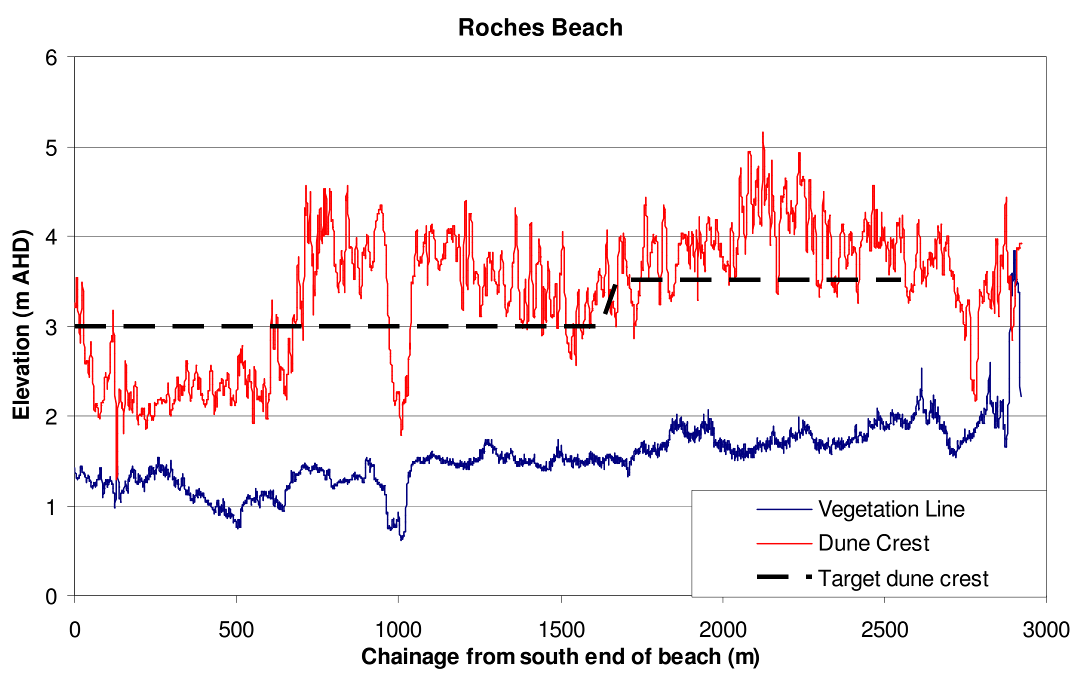

Figure 3: Dune crest level versus design wave runup level

An example of quasi-seasonal changes in beach width is shown in Figure 4. This figure (from Blacka et al, 2007) shows beach width on the northern Gold Coast. The beach width generally increased in spring and decreased during the first half of the year. Similar patterns are likely to occur in northern NSW.

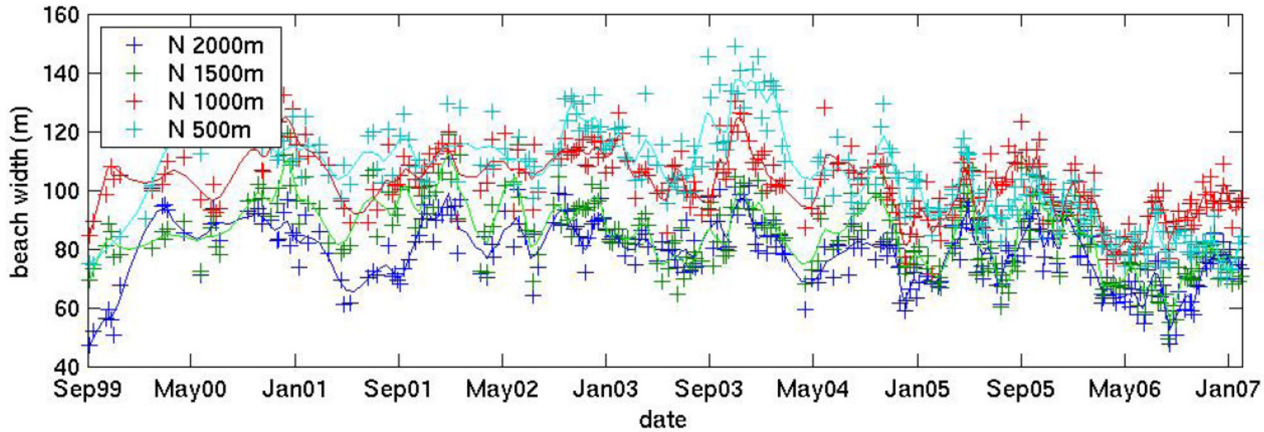

Figure 4: Seasonal change in beach width on northern Gold Coast (Blacka et al 2007)

Natural dune building occurs when the wind is onshore and exceeds a critical threshold to mobilise a given sand grain size. The threshold of motion for 0.22 mm beach sand due to wind has been calculated from the methods of CEM (2002), which yield:

- Dry sand: 6.8 m/s (13 knots, 25 km/hour);
- Wet sand: 11.9 m/s (23 knots, 43 km/hour).

The large difference in motion threshold between wet and dry sand shows the sensitivity to location on the beach face and tidal water level, as well as changes in rainfall, which may be due to natural variability, seasonality, cyclic patterns (el niño-southern oscillation and inter-decadal Pacific oscillation) and climate change. A plot (from Cape Byron) of the seasonal occurrence of winds at 3 PM which are favourable for dune building is shown in Figure 5. This plot shows that dune building through wind is least prevalent from May to August.

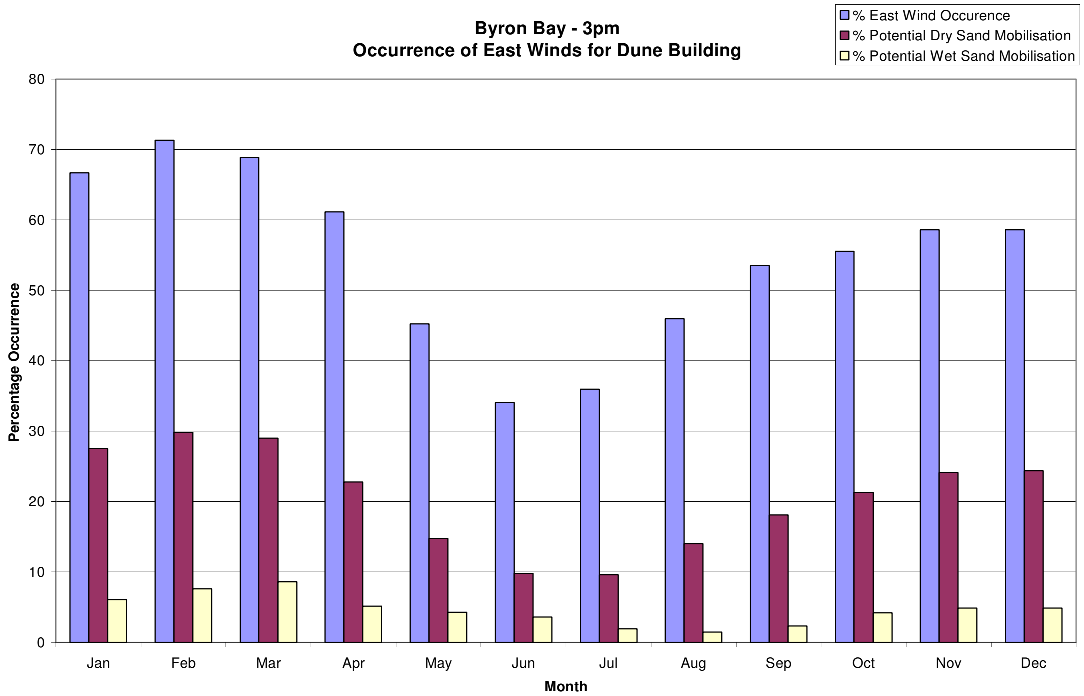

Figure 5: Seasonal winds (3 PM) favourable to dune building (Cape Byron data)

Economics

WBM (2003) estimated the cost of beach erosion on gross tourism receipts using limited data for Byron Shire. This was predominantly based on work undertaken by Raybould and Mules (1998) for the Gold Coast. It should be noted that the assumed revenue losses due to beach erosion are a small proportion of total tourism revenue. WBM (2003) presented four scenarios for tourism effects:

Scenario 1: revenue grows at 2% per annum, revenue losses with major erosion are 2%.

Scenario 2: revenue grows at 2% per annum, revenue losses with major erosion are 10%.

Scenario 3: revenue grows at 4% per annum, revenue losses with major erosion are 2%.

Scenario 4: revenue grows at 4% per annum, revenue losses with major erosion are 10%.

Rawlinsons (2007) provided the following quotation on Life Cycle Costing or Net Present Value Analysis: “Life Cycle Costing is best used in a comparative situation to provide an approximate answer to a precise question rather than a precise answer to an approximate question.”

For Scenario 1 above, a discount rate of 7%, and combining the work of WBM (2003) and numerous assumptions presented in Carley et al (2009), the following benefit to cost ratios were estimated for beach scraping:

- Preserve/restore beach access following storm erosion (tourism only): 444
- Build a dune to a design profile to reduce erosion hazard (property benefits): 1.0

Site and project specific costing is needed. Furthermore, the economics is affected by the storm events and long term beach change. For the example cited, the benefit to cost ratio for restoring beach access is high, and justify beach scraping on economic grounds. This is predominantly because beach scraping is a potentially cheaper form of beach nourishment, whereby much of the work is performed by nature.

As discussed previously, beach scraping has higher uncertainty as a protection measure than other coastal management options, so should only be undertaken in conjunction with a comprehensive monitoring program. The monitoring program should encompass both physical and ecological surveys.

Summary

This paper examines the feasibility of beach scraping as a coastal management option. Beach scraping has been widely undertaken, but there is little practical guidance and published literature on its physical and ecological effects. Conversely, it has been discontinued in some locations due to environmental concerns.

Beach scraping is defined as the movement of sand from the intertidal zone to the dune or upper beach by mechanical means. Beach scraping mimics natural beach recovery processes, but increases the recovery rate compared with natural processes. In combination with revegetation schemes, beach scraping has commonly been used for dune building.

Beach scraping differs from beach nourishment in that nourishment involves sand being imported from outside the active littoral compartment, whereas with beach scraping, sand is redistributed within the littoral system. This redistribution used in scraping means that natural forces may do some of the work, potentially resulting in lower costs than nourishment.

Clearly, beach scraping is not a universal panacea for coastal management. Beach scraping is most feasible for improving or restoring beach access, and for raising low points in dunes. It is unlikely to be feasible as a primary coastal management option to offset sea level rise of 0.9 m.

The ecological impacts of minor scraping on beaches subject to high pedestrian and/or dog traffic are low. Ecological studies are needed before undertaking major scraping works. Appropriate timing of scraping can avoid or reduce impacts on seasonal nesting species. If scraping is undertaken, a comprehensive monitoring program encompassing both physical and ecological surveys is needed.

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