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Beach nourishments at Coolangatta Bay over the period 1987-2005: impacts and lessons

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Abstract

Erosion of the southern Gold Coast beaches (SE Queensland, Australia) was exacerbated after the extension of the Tweed River training walls in the early 1960s. To achieve the objective of restoring and maintaining beach amenity, significant nourishment works have been undertaken in Coolangatta Bay over the past 30 years. Particularly, under the Tweed River Entrance Sand Bypassing Project (TRESBP) since 1995, a number of nourishment campaigns and the implementation of a permanent sand bypass system in 2001 have resulted in significant changes of Coolangatta Bay morphology. The present case study investigates the influence of both wave climate and nourishment works on the area extending from the updrift Snapper Rocks area to downdrift Kirra Beach. SWAN spectral wave model is implemented at Coolangatta Bay area and forced by the global wave model WW3 to estimate wave forcing and the potential natural longshore drift entering in Coolangatta. Specific transects extracted from accurate bathymetric surveys are used to investigate and quantify Coolangatta Bay sedimentation for the period 1987-2005. A network of Argus video stations provides high sample rate information on the shoreline evolution. Results show that, over the past 10 years, Coolangatta Bay has infilled rapidly. Sedimentation reached up to 6 m in some areas between 1995 and 2005, with beach width increasing by 200 m at Kirra Beach. Rapid seaward shoreline migration is consistent with the intense over-pumping of sand relative to the natural potential to move sand alongshore. The nourishment strategy used during this project has successfully delivered large amounts of sand to the southern Gold Coast embayment, although it has been up to now controversial from many community perspectives. The artificial sand bypassing process proved to be much more efficient than depositing the dredged sand in the nearshore area which requires a significant period of low energy condition in order for the deposited sediment to migrate shoreward and

weld to the shore. This case study confirms that, when carefully undertaken, sand bypassing is a sustainable and flexible soft engineering approach which can work in concert with natural processes.

Key words: Artificial sand bypassing, beach nourishment, dredging, sand supply, embayment

1 Introduction

Coastal erosion is a worldwide occurrence along sea shores, and has been reported in the literature for several decades. Traditionally, eroding coastlines have been protected by civil engineering structures involving groynes, seawalls, breakwaters and the like (Charlier et al., 2005). This approach, while providing local relief, can also result in the transfer of the problem from one geographical site to another. Major advances in the technology of beach nourishment have been made over the past 3 decades (Dean, 1996; Houston, 1991, 1996; Elko et al., 2005). Generally speaking, beach nourishment involves the placement of sediment on an eroding beach to migrate the shoreline seaward in order to promote storm protection, natural habitat and beach amenity. Due to the widespread use of beach nourishment worldwide (Hamm et al., 2002; Hanson et al., 2002), it is now important that not only coastal engineers but also geoscientists investigating coastal processes understand the performance of beach nourishments. Various numerical models, both simple (Dean and Yoo, 1992; Elko et al., 2005) and more complex (Van Duin et al., 2004; Li et al., 2006), have been developed to predict the impact of nourishment projects. However, the impact of beach nourishments on both short-term and long-term evolution of complex coastlines warrants continued investigation.

20 Coolangatta Bay (Fig. 1), located on the east coast of Australia just north
21 of the state border between Queensland and New South Wales, is a major
22 international and national tourism destination. In the early 60s, the Tweed
23 River entrance training walls, located immediately to the south of Coolan-
24 gatta Bay (Fig. 2), were extended seaward approximately 380 m to improve
25 navigation conditions at the entrance. These walls also created a trap for
26 the natural northward longshore drift, resulting in loss of sand supply to the
27 southern Gold Coast beaches (DHL, 1970), particularly in Coolangatta Bay.
28 Coolangatta Bay beaches eroded to an extent that sea walls were constructed
29 to protect property and infrastructure. Coolangatta Bay beaches had not re-
30 covered by the early 1990s, despite various groyne constructions and beach
31 nourishment campaigns. These works, culminating in the implementation of
32 a permanent sand bypassing system in 2001, have resulted in significant and
33 complex changes of Coolangatta Bay morphology.

34 This case study investigates the influence of wave climate, nourishment works
35 and permanent sand bypassing on Coolangatta Bay coastline morphology. The
36 study focuses on the period 1987-2005 which coincides with the implementa-
37 tion of a number of coastal protection measures, and more particularly the
38 period 1995-2005, when the most important changes to the embayment were
39 observed. This work combines accurate bathymetric surveys, video imagery,
40 quantification of beach nourishment and artificial sand bypassing and wave
41 and longshore drift modeling.

43 *2.1 Location and settings*

44 The 70 km long Gold Coast has been the state of Queensland's premier coastal
45 holiday resort destination for more than 40 years. Coolangatta Bay is located
46 at the southern end of the Gold Coast (Fig. 1). The area is characterized
47 by the presence of the Tweed River entrance and a major headland called
48 Point Danger immediately to the south. Figure 2 shows the configuration
49 of Coolangatta Bay including the different coastal structures that have been
50 built over the past few decades: the training walls on both sides of the Tweed
51 River entrance and two groynes (Kirra Point groyne and Miles Street groyne).
52 The area of investigation covers approximately 6 km of coastline, comprising
53 3 distinct embayments within Coolangatta Bay: Rainbow Bay, Coolangatta
54 Beach and Kirra Beach. Tides are semi-diurnal, with a tidal range varying from
55 0.2 to 2 m, with a mean of 1 m. The area is exposed to high energy waves.
56 South to SE waves are generated by intense low pressure systems off the New
57 South Wales coast in winter and spring, and contribute to the main component
58 of the northerly longshore drift. From December to April, tropical cyclones
59 can generate NE to E waves, sometimes with a destructive power (Hobbs and
60 Lawson, 1982), with significant wave height up to 8 m. The sediment consists of
61 fine sand, with $d_{50} = 200 \mu\text{m}$. The estimated net rate of littoral sand transport
62 within the general Gold Coast region is of the order of $500\,000 \text{ m}^3/\text{y}$ toward
63 the north (Turner et al., 2006). The Tweed River itself is considered to be a
64 net sink for sediment, as the river discharges minor quantities only of fluvial
65 sand to the littoral system.

66 In the early 1960s, the Tweed River entrance training walls were extended
67 seaward approximately 380 m to improve navigation. The wall extensions im-
68 proved navigation conditions for almost 20 years before a sand bar moved past
69 the end of the southern training wall to infill the channel once more. The loss
70 of longshore sand supply from the south resulted in the progressive recession of
71 the Coolangatta Bay beaches. The Gold Coast also experienced severe storms
72 in 1967 (McGrath, 1967), 1972 and 1974, resulting in major erosion along the
73 entire SE Australian coastline. As outlined in further details below, a number
74 of measures have been undertaken in an attempt to restore and maintain the
75 southern Gold Coast beaches.

76 2.2 *Nourishment works*

77 To achieve the objectives of restoring and maintaining beach amenity, two ma-
78 jor nourishment projects were completed to combat beach erosion in Coolan-
79 gatta Bay over the study period 1987-2005 . The first major nourishment
80 project, called the Southern Gold Coast Beach Nourishment Project, took
81 place between November 1989 and May 1990. This project involved nourish-
82 ment of the nearshore and upper beach extending from Kirra East to several
83 kilometers north using sand sourced from inactive offshore deposits in water
84 depths of 20 to 28 m. 400,000 m³ of sand was bottom dumped in nearshore ar-
85 eas in water depths of 6 to 9 m, and an upper beach nourishment of 3,200,200
86 m³ from January to May 1990.

87 The second phase of nourishment was initiated as a component of the Tweed
88 River Entrance Sand Bypassing Project (TRESBP) commencing in 1995. This
89 project was formulated to overcome the significant erosion of the southern

90 Gold Coast beaches as well as to address the navigation issues due to the
 91 Tweed River entrance infilling. Stage 1 involved removing the sand bar from
 92 the Tweed River entrance to provide material for the initial restoration of the
 93 southern Gold Coast beaches. As part of this campaign, 600,000 m³ of sand
 94 was placed on the upper beaches from Rainbow Bay in the east to North Kirra
 95 in the west. Additional sand quantities were placed in the nearshore (Dyson
 96 et al., 2001). Stage 2 resulted from refinements to the Stage 1 placement areas
 97 (Boswood et al., 2001; Colleter et al., 2001). An exclusion deposition zone also
 98 provided a 100 m buffer around Kirra natural reef. Most of the sand was placed
 99 in an area to the east of Snapper Rock (see deposition areas on Fig. 3). Sand
 100 placed in this area was transported by the longshore drift and naturally fed the
 101 sandbanks and beaches of the southern Gold Coast. The innovative aspect of
 102 the TRESBP (Stage 2) was the implementation in 2001 of a permanent sand
 103 bypassing system (see Fig. 2) to collect sand from the southern side of the
 104 Tweed River entrance and transport it to the southern Gold Coast beaches in
 105 perpetuity (Dyson et al., 2001). The sand was pumped to 5 different locations
 106 within Coolangatta Bay (see outlet locations on Fig. 2). The majority of the
 107 sand during the period 2001 - 2005 was pumped to the Snapper Rock outlet,
 108 at the eastern (updrift) extremity of Coolangatta Bay.

109 The nourishments during the period 1987 to 2005 are summarized below, with
 110 specific location and placement quantities indicated in Tables 1 and 2:

- 111 • 1989-1990: Southern Gold Coast Nourishment Project (3,600,000 m³).
- 112 • 1995-1996: TRESBP Stage 1A, dredging of Tweed River Entrance and as-
 113 sociated nourishment of the southern Gold Coast beaches (2,300,000 m³).
- 114 • 1997-1998: TRESBP Stage 1B, dredging of Tweed River Entrance and as-
 115 sociated nourishment of the southern Gold Coast beaches (800,000 m³).

- 116 • 2000-2002: TRESBP Stage 2A, dredging of Tweed River Entrance and as-
117 sociated nourishment of the southern Gold Coast beaches (1,100,000 m³).
- 118 • 2001: Start of the permanent sand bypassing system
- 119 • 2003-2006: TRESBP Stage 2B, dredging of Tweed River Entrance and as-
120 sociated nourishment of the southern Gold Coast beaches (500,700 m³).

121 3 Methods and materials

122 3.1 *Quantities of delivered sand, potential natural longshore drift and over-* 123 *pumping estimation*

124 The spectral wave model SWAN (Booij et al., 1999) is used in stationary
125 mode. The wave forcing provided by the global wave model WW3 (Tolman,
126 1991) nearest output point (see Fig .1) is applied to the offshore and lateral
127 boundaries of the model. The ability of this modeling strategy to estimate
128 nearshore waves within the Gold Coast region has been successfully demon-
129 strated (Browne et al., 2006, 2007). Accurate bathymetric surveys were used
130 to build a numerical bathymetry with a curvilinear grid at a cell size of $O(100$
131 $m)$. A more refined rectangular grid (mesh size of 5 m) was nested within
132 the coarser curvilinear grid updrift of the Tweed walls on the Leatitia Spit
133 area (Figure 4). Three hour time-series of wave parameters were generated
134 along two representative cross-shore profiles $T1$ and $T2$ (Figure 4) where the
135 breaking point was defined as the point for which $H_s/depth = 0.6$. The em-
136 pirical formula developed by Kaczmarek et al. (2005), using time-series of H_s
137 and wave angle to the shore at the breaking point, was used to estimate the
138 corresponding time-series of potential (without training walls) longshore drift

139 entering in to the Coolangatta Bay region. Although these sand transport
140 predictions were not directly calibrated with field data, their integration over
141 the study period resulted in values of the order of 500,000 m³, which matches
142 the generally accepted alongshore transport rate for this area (Turner et al.,
143 2006). The same methodology has been successfully applied at a dissipative
144 beach (Bertin et al., 2008) and at a sandspit (Allard et al., 2008) located on
145 the western coast of France. In the following, only the longshore drift com-
146 puted in $T1$ is used, as the cross-shore wave parameter profiles at $T2$ were
147 substantially perturbed by the presence of a shallow shoal (immediately to
148 the Est of $T2$, see Fig. 4) during SE wave events.

149 Monthly quantities of delivered sand since the beginning of the permanent
150 sand bypassing system, with associated deposition and pumping locations,
151 were collated from the TRESBP website (www.tweedriverbypass.nsw.gov.au).
152 These monthly sand quantities were used in the present study to assess the im-
153 pact of dredging and pumping on both the short-term (weekly - monthly) and
154 longer-term (seasonal - multi-year) evolution of Coolangatta Bay morphology.
155 Using computed monthly potential natural sand supply from the downdrift
156 coast and real delivered sand quantities, monthly over-pumping quantities
157 from the TRESBP were estimated.

158 3.2 Surveys

159 Figure 3 shows the area of interest for the present study, and the period of
160 survey data availability is from 17/9/1987 to 15/7/2005. Survey data were col-
161 lected in this area by a number of organizations for a variety of investigations
162 and projects. Not all the surveys have been taken on the same survey lines

163 and not all the survey data collected are available for the present study. In the
164 1970's and 1980's, in response to the severe erosion of Coolangatta Bay, the
165 Gold Coast City Council established survey lines at Coolangatta Beach (CG
166 lines), Kirra Beach (K lines) and Rainbow Bay (RB line). Specific survey lines
167 were chosen to compute the shoreline position. There is an extensive range of
168 shoreline indicators reported in the literature (Boak and Turner, 2005). In the
169 present study, the shoreline position is defined as the intersection of the beach
170 profile with the Mean Sea Level (MSL), which corresponds approximately to
171 0 m Australian Height Datum (AHD) at the Gold Coast beaches.

172 The location of the 8 specific survey lines used for this study are shown on
173 Figure 3. The survey lines cover the bay from North Kirra in the west (tran-
174 sect K28) to Rainbow Bay in the east (RB5). These survey lines were chosen
175 because they are representative of the Coolangatta Bay alongshore variations,
176 and importantly, because a large number of surveys were undertaken on these
177 specific transects. At all 8 transect locations, shoreline position has been nor-
178 malised so that a shoreline position of 0 m equates to erosion of the beach
179 back to the boulder wall.

180 3.3 *Video imagery*

181 Commencing in mid 2002 a network of Argus coastal imaging stations (Hol-
182 man and Stanley, 2007) has been operating on a continuous basis, providing
183 full coverage of Coolangatta Bay and vicinity. A total of 16 cameras are used,
184 located atop three beach front buildings and a lighthouse, encompassing the
185 southern region of Kirra Beach, Coolangatta Beach, Rainbow Bay/Snapper
186 Rocks, as well as the up-drift Duranbah Beach located on the southern side of

187 Point Danger (refer Fig 2). Two additional and landward-looking cameras are
188 located on the sand bypassing pier, to monitor the localised beach changes in
189 the immediate vicinity of this structure. The cameras were installed for the
190 primary purpose of providing continuous and real-time monitoring capabil-
191 ities to the TRESBP management team (Turner et al., 2004, 2006). Image
192 analysis is undertaken and updated on a regular (weekly) basis, to document
193 and quantify the longer-term impacts of the bypassing and nourishment op-
194 erations, and to assess the current beach conditions against a range of target
195 indicators, for the purpose of determining the location and quantity of regular
196 sand delivery (Turner and Anderson, 2007).

197 The key feature of coastal imaging systems that distinguish them from con-
198 ventional 'surfcams' is the ability to extract quantitative information from
199 a time-series of digital images. This core capability is achieved through the
200 solution of a set of camera model parameters (Holland et al., 1997), that en-
201 able the determination of three-dimensional real-world $[x,y,z]$ position from
202 two-dimensional $[U,V]$ image coordinates. These geo-referenced images are
203 then subjected to a range of digital image analysis techniques, to identify, en-
204 hance and quantify the particular coastal processes or features of interest. For
205 the present study, the key analysis is determination of the weekly alignment
206 of the shoreline corresponding to mean sea-level. The 'PIC' (Pixel Intensity
207 Clustering) shoreline detection and modeling method is used for this purpose
208 across all Coolangatta Bay sites (Aarninkhof et al., 2003; Plant et al., 2007).
209 Weekly beach widths are then extracted from the time-series of shorelines,
210 corresponding to the same 8 locations for each of the longer-term (pre 2002)
211 but less frequent survey transects, identified in the previous section.

213 *4.1 Pre-TRESBP Coolangatta Bay evolution*

214 Figure 5 shows the temporal morphological variability of the 8 specific crossshore
215 transects gathered from the bathymetric surveys throughout the study period.
216 In particular, it shows that there is no significant bathymetric change deeper
217 than 15 m depth. Difference in beach profile sometimes reached 8 m showing
218 the strong variabilities of both the bay morphology and shoreline positions over
219 the study period. Figure 6 shows the time-series of the shoreline evolution be-
220 tween 1987 and 2005 for these 8 crossshore transects. This figure shows that,
221 prior to the Southern Gold Coast Nourishment Project in 1989, the shoreline
222 positions were experiencing a generally slow decreasing trend. This progres-
223 sive erosion was resulting from the re-establishing of sand transport pathways
224 at the Tweed Entrance. In the late 80s, both the spit southward (updrift) of
225 the Tweed River training walls and the Tweed bar were approaching a new
226 equilibrium, and the Tweed River was also approaching the pre-1962 situa-
227 tion. Thus, natural sand bypassing had greatly increased resulting in a weaker
228 rate of shoreline retreat that was experienced in the 1960's and 1970's (DHL,
229 1992). However, Coolangatta Bay and particularly Kirra, was still at this time
230 the top Gold Coast nourishment priority and the beach zone identified as in
231 most need of storm protection (Smith and Jackson, 1993).

232 The 1989 beach nourishment was quite unique as compared with previous
233 Gold Coast nourishment works. To satisfy community demand, it was chosen
234 to place only 11% of the total amount of sand in the nearshore area, with the
235 bulk of the sand placed at the beachface in order to create an 'instant' and

visibly wider beach. The onshore nourishment (89%) substantially offset the erosion of the beaches from Kirra to a few kilometers to the North, though the nourishment volume had not fully offset the severe erosion at Kirra and the eastern beaches of Coolangatta Bay (DHL, 1992). This beach response is obvious on Fig. 6: the western part of Coolangatta Bay (transects K1, K9, K17 and K28) experienced a seaward shoreline migration of 120 m on average, while the eastern part (PSM18, CG9, CG6 and RB5) experienced a very weak accretive event. During the period 1990-1995, the beach width remained relatively stable, with a 50 m shoreline retreat on average westward to Kirra groyne.

In 1995, Stage 1A of the TRESBP resulted in a marked beach width increase in the whole bay. This was particularly evident for Coolangatta Beach and the eastern part of Kirra Beach. A 40 m reduction in the length of the Kirra Point groyne was also implemented at this same time. The most significant evolution of Coolangatta Bay is observed from 2001, which coincided with the start of the permanent sand bypassing. This period 1995-2005 is described in more details below.

4.2 *Annual morphological evolution of Coolangatta Bay 1995-2005 (TRESBP)*

Figure 7 shows the evolution of the computed Coolangatta Bay morphology during the TRESBP, and reveals significant changes of the sub-aerial beach. Rainbow Bay beach experienced the least significant changes over the study period, while Coolangatta beach and particularly Kirra beach intensively evolved. Vertical accretion reached 6 m over the period in some areas of Kirra beach and Miles Street groyne was mostly buried by sand in 2005.

260 The water line reached Kirra Point groyne only at high tide. In 2005, both
261 Coolangatta and Kirra beach were about 200 m wide with non-vegetated dunes
262 reaching 6 m above AHD. In contrast, since 2002, Rainbow beach has expe-
263 rienced a weak erosive state, Coolangatta Beach appears to have reached a
264 quasi-equilibrium state and Kirra beach continued to infill rapidly.

265 The nearshore area also experienced intense changes. Referring to Figure 7,
266 before 2001, the nearshore bar was mirroring the shape of the crenulated
267 embayments, but this feature has now both widened and straightened. This
268 straight nearshore bar development started in 2001 and coincided with the
269 start of the permanent sand bypassing. The nearshore bar changed its ori-
270 entation westward to Kirra groyne between 2002 and 2005. This change in
271 the nearshore bar configuration was associated with an intense beach width
272 growth of Kirra Beach.

273 Figure 8 shows the time-series of the shoreline position for each of the 8 beach
274 profiles, together with offshore wave conditions and the monthly volume (in-
275 cluding placement areas) of both pumped and deposited sand in the bay. This
276 figure clearly shows the coincidnence of significant evolution of Coolangatta
277 Bay and the implementation of the TRESBP, as expected, given that there
278 has been significant over-pumping of sand relative to the natural potential
279 to move sand alongshore (Tables 1 and 2). Indeed, offshore wave conditions
280 during this five year monitoring period do not appear to have had a signifi-
281 cant impact on the global evolution of the bay, as this interval coincided with
282 a relatively calm period for the Gold Coast beaches, with no severe erosive
283 event(s) observed.

284 Both Stage 1A and Stage 1B dredging had a significant impact on the shore-

line position of the eastern part of Coolangatta Bay. The western part of Coolangatta Bay did not experience significant change of the shoreline position over the period prior to the artificial sand bypassing plant implementation (Fig. 7 and 8). The start of the artificial sand bypassing resulted in an almost immediate seaward migration of the shoreline in the whole bay (except the eastern extremity: K17 and K28). At the beginning (early 2001), increasing beach width was observed at the eastern extremity of Coolangatta Bay i.e. Rainbow Bay (RB5 on Fig. 4). In late 2001, beach width increased at Coolangatta Beach (CG6 and CG9), then at Kirra in 2002. Since 2002, the shoreline position in the eastern part of Coolangatta Bay (RB5, CG9, CG6) was almost stable, with a slight downward trend, while Kirra continues to infill from the east to the west.

4.3 Short-term (weekly) shoreline evolution in response to over-pumping

Figure 9 shows time-series of both monthly over-pumped quantities of sand relative to the natural potential to move sand alongshore and weekly shoreline position computed from the video imagery. This figure reveals the impact of over-pumping on the shoreline position within the bay on the time scale of days to months which was impossible to grasp from the previous (annual) beach survey analysis.

These monitoring data show that over- or under-pumping has an almost immediate impact in Rainbow Bay (transect RB5). For instance, it only takes a few days for the RB5 shoreline position to migrate seaward when substantial over-pumping occurred. As soon as under-pumping or weak over-pumping occurs, the RB5 shoreline position migrated shoreward. When the delivered

sand quantities remain close to the potential natural longshore drift for a few months, for instance early 2005 (Fig. 9), the RB5 shoreline position seems to oscillate around and equilibrium position at about 50 m. The impact of over-pumping on Coolangatta Beach can also be noticed for the transect CG6. A substantial lag exists between the over-pumping peaks and the CG6 shoreline evolution (Fig. 8). Most of the peaks can be identified on Fig. 8, with a lag estimated to be of about 5 to 6 month. Given the CG6 and RB5 transects are about 500 m spaced, the bulk of sand migration rate can be estimated to be on the order of 100 m/month between Rainbow Bay and Coolangatta Beach. The impact on the CG9 shoreline position is barely shown on Fig. 8 as the Kirra Point groyne (Fig. 2) acts as a sand trap and tends to filter the sand bulk migration. This sand bulk migration is much more difficult to identify within the Kirra Beach embayment. The overall observed trend is characterized by a quasi-steady seaward migration of the shoreline from Kirra Point groyne to the K17 transect, as observed from the beach survey analysis (Fig. 7). This behaviour shows once again that Kirra Beach seems to act as a sediment sink and keeps infilling to a significant degree.

5 Discussion and conclusions

5.1 Site specific outcomes

Coolangatta Bay experienced significant morphological changes over the past decade, extending from 15 m water depth landward to the subaerial beach. Vertical accretion has reached 6 m in some areas such as Kirra Beach, where the seaward shoreline migration attained 200 m. In comparison to the de-

332 pleated beach conditions in the 1980s, it is evident that the TRESPB has
333 been successful in both increasing the beach width and enhancing the abil-
334 ity of the southern Gold Coast beaches to accomadate future extreme events.
335 From a local perspective, the principal outcomes of the present study are:

336 (1) The Coolangatta Bay beaches are very wide. The shoreline seaward migra-
337 tion ranged from 50 m in Rainbow Bay to more than 200 m at Kirra Beach in
338 comparison to the shoreline prior to the TRESPB. The subaerial beach is cur-
339 rently a significant buffer against a severe storm event. The beaches of Kirra
340 and Coolangatta seem to be currently the most able to withstand extreme
341 event of all the Gold Coast beaches (Castelle et al., 2008).

342 (2) Kirra Beach appears to act as a downdrift sink. This is not surprising given
343 that this section of coastline experienced the greatest negative impact of the
344 erosion wave that followed the construction of the Tweed walls.

345 (3) Rapid evolution (weekly to monthly) seems to be strongly correlated to
346 the over-pumping of sand relative to the natural potential to move sand along-
347 shore. The resulting bulk of sand observed from Snapper Rocks to Kirra
348 Point groyne migrates toward the Kirra section at a rate of the order of 100
349 m/month. The bulk of sand is then trapped in the Kirra Beach embayment.

350 In 2005, the TRESPB had been successful in providing wide and healthy
351 beaches within Coolangatta Bay. However, worldwide no beach nourishment
352 or coastal engineering works program will ever meet everybody's expectations.
353 The TRESPB is another example, as several issues have been raised recently
354 by the community, despite the overall success of the engineering components of
355 the project. Some locals and tourists opinions are that beaches are currently
356 too wide (especially at Kirra), and that surfing, swimming, fishing, diving

357 and beach use amenity has been compromised as a result of over-pumping.
358 The width of the nearshore bar has increased such that the natural rock reef
359 seaward of Kirra Beach (Fig. 1) is threatened to be fully covered by sand,
360 which raises both fishing and ecological integrity issues. The formation of the
361 straight and wide nearshore bar along the whole bay, known by the surfers
362 as "Superbank", is regarded by some to have resulted in the disappearance of
363 Kirra Point's world-class surf break.

364 5.2 *Generic lessons learnt*

365 This case study at Coolangatta Bay demonstrates that artificial sand bypass-
366 ing can have a significant and rapid impact on beach and nearshore mor-
367 phology. Sand that is pumped to shallow water is readily transported by the
368 longshore current and can naturally feeds the sandbanks and beaches. This
369 process has proven to be much more efficient than depositing the dredged
370 sand in the nearshore area, which requires a significant period of low energy
371 conditions in order for the deposited sediment to migrate shoreward and weld
372 to the shore.

373 Several arguments support the use of sand bypassing system in coastal areas
374 where significant net longshore drift is observed, and where this sand supply
375 has been interrupted. Indeed, nourishment works often result from the desire
376 to both dispose of available sand dredged to maintain navigable depths in
377 a nearby harbor or inlet, and widen the beach (for storm damage-reduction
378 purposes and/or recreational space). Permanent sand bypassing systems can
379 potentially offer the possibility to both remediate these issues and later prevent
380 them in a sustainable way. If properly formulated and managed, this strategy

381 can remove the requirement for regular refills, dredging and additional hard
382 structures. Collecting sand at the updrift coast also means that the same
383 grain size as the native one is deposited, which is a generally favoured. As
384 illustrated in this case study, behavior oriented numerical models can be used
385 to estimate potential natural longshore drift along sandy coastlines. Therefore,
386 it is possible to pump sand quantities comparable to the natural longshore
387 drift. This can allow permanent sand bypassing systems to work in concert
388 with natural processes. These possible dynamic and flexible characteristics of
389 the implementation of permanent sand bypassing system may have to be taken
390 into greater account in future practices.

391 It must also be recognised that sand bypassing may be ineffective or inap-
392 propriate, dependant upon site specific considerations. For example, over-
393 pumping can have negative consequences on natural habitats. In the case
394 of Coolangatta Bay, a large amount of natural reefs were buried under tons of
395 sand, which raised both fishing and ecological integrity issues. Coarser sand
396 than the native beach material is sometimes preferably used in beach fill prac-
397 tices, particularly when there is requirement for offsetting serious erosion and
398 stabilizing the upper part of the beach. This cannot be achieved with sand
399 bypassing alone.

400 Hamm et al. (2002) strongly recommended the development of monitoring
401 strategy and techniques together with sustainable soft engineering approach.
402 Use of innovative techniques such as video-imaging, accurate bathymetric sur-
403 veys, and the properly documented quantities of delivered sand quantities,
404 offer a great potential for obtaining very valuable operational and long-term
405 monitoring data at Coolangatta Bay and other coastal management sites
406 world-wide.

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Table captions

Table 1. Dredging quantities (m^3) and placement area over the period 1995-2005

Table 2. Pumping quantities (m^3) and outlet locations over the period 2001-2005

Year	D1	D2	D3	Total
1995	?	?	?	1731949
1996	?	?	?	572403
1997/1998	?	?	?	800407
2000	237266	73010	96007	405853
2001	9721	257996	148490	416207
2002	190285	9014	40831	240130
2003	146628	57425	26839	230892
2004	123771	11200	34955	169926
2005	111483	38573	26133	176189

Table 1

Year	OSRE	OSRW	OK	OD	OG	Total
2001	409746	1586	97279	67258	0	575869
2002	564577	0	84915	71872	0	721364
2003	602953	0	81918	70224	31931	787026
2004	459554	0	0	36813	0	496367
2005	683244	0	0	41687	0	724931

Table 2

Figure captions

Figure 1. Location of Coolangatta Bay (Queensland, Australia) with indication of the WW3 grid point and the SWAN grid boundary used for wave modeling

Figure 2. Aerial photograph of Coolangatta Bay (July 1998) with general settings and superimposed permanent sand bypassing system layout

Figure 3. Coolangatta Bay morphology (October 2004) with locations of the specific survey transect lines, video imagery transect lines, the SWAN wave output point and the 3 main deposition areas D1, D2 and D3 (KB=Kirra Beach, CGB=Coolangatta Beach, RBB=Rainbow Bay Beach)

Figure 4. Evolution of Coolangatta Bay from 1997 to 2005: beach widening and formation of a straight and wide nearshore bar. The thick dot line is the shoreline location (0 AHD) and the thick line is the spring high tide sea level

Figure 5. Superimposed beach profiles over the period 1987-2005 for the specific survey lines, with indication of the Lowest Astronomical Tide (LAT) level, Mean Sea Level (MSL) and Highest Astronomical Tide (HAT) level

Figure 6. Shoreline evolution at the specific survey lines over the period 1987-2005

Figure 7. Evolution of Coolangatta Bay from 1997 to 2005: beach widening and formation of a straight and wide nearshore bar. The thick dot line is the shoreline location (0 AHD) and the thick line is the spring high tide sea level

Figure 8. Time-series of significant wave height H_s in the Bay with superim-

posed 15 days low-pass-filtered H_s (thick line), pumping and dredging quantities, and shoreline position at the specific transects over the period 1995-2005. OSRE: Snapper Rock East Outlet; OSRW: Snapper Rock East Outlet; OK: Kirra Outlet; OD: Duranbah Outlet; OG: Greenmount Outlet

Figure 9. Time-series of over-pumping quantities and shoreline positions using video imagery during the TRESBP

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.