RAPID ASSESSMENT OF PERCEIVED SILTATION IN PLACES WITHIN THE THESEN ISLANDS CANALS, KNYSNA

Prepared for

Thesen Islands Home Owners' Association

by

Laurie Barwell

May 2017

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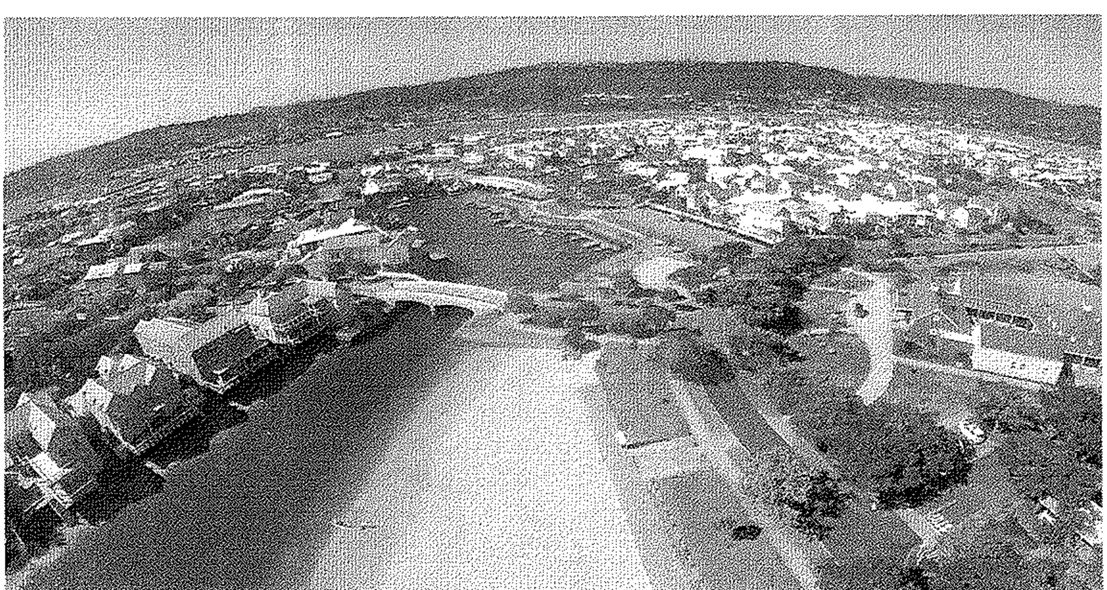

Northward view across the main beach and adjacent canal (KiteKam: 21-01-2017 at 17:00)

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Limitations of the study and the meaning of 'rapid assessment'

The survey methodologies used in this study are a combination of in-situ observations and measurements of the physical characteristics of the canals (e.g. the canal profile levels, bottom sediments and beach sand). The horizontal reference baseline for the profile levels is deduced from the measured tide level recorded at a specific time by the KEMP water level recorders that form part of the Knysna Basin Project. This is an alternative to the conventional, more expensive and more accurate method of DGPS-based bathymetric and ground penetrating sonar surveys. The accumulative error bar of this method is in the order of 10% to 15%, which is more than adequate to address the key questions.

The aerial image and photographic analysis that forms the basis of the beach-canal interface stability assessment, conclusions and recommendations are based on the availability of historical and recent data and information. The resolution of the satellite-based imagery (Google Earth™) remains a challenge for accurate feature analysis. Much use is made of the interpretation of landscapes and features as well as the technical skill of undertaking comparative image analysis, which is shaped via experiential learning. As such, only a broad idea of the relevant dynamics can be reached. However, this approach has proven to be useful in identifying long-term trends that are important when attempting to understand natural processes and their potential impact on, and potential response to, developmental and/or management actions.

The choice of the specific points where the siltation assessment studies were done were determined by the TIHOA based on requests and feedback from home owners and boat users.

Author

The author (Mr Laurie Barwell) has a B.Eng. Civil and an MSc.Eng degree in Coastal Engineering, specialising in coastal environmental assessment and engineering with specific reference to climate change risk and vulnerability assessment and response strategies. Having retired from the CSIR in 2014, the author has 35 years of experience related to water and coastal environmental engineering and environmental management practices. Mr. Barwell coordinated the CSIR specialist team that carried out the baseline studies and canal design as part of the EIA of the Thesen Islands development study in the period 1994 to 2004 and thus has first-hand experience of the physical parameters in play.

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EXECUTIVE SUMMARY

The Thesen Islands Home Owners' Association (TIHOA) is responsible for the maintenance and management of the various aspects of the Thesen Islands canal estate in Knysna. The construction of the development was completed in 2004. While much information was gathered as part of the baseline studies for the environmental impact assessment, design and the Environmental Management Plan during construction, little in-depth monitoring of the changes, including sediment movement, within the canals has taken place. Canal users have expressed some concern about areas perceived to be silting up (becoming shallower) over time. There has also been concern expressed about beach sand being moved by wind, tides, and storm water from the beach into adjacent canal areas. An opinion was ventured that the beach-user experience could be improved by adding additional sand to the beach.

To obtain specialist input, the TIHOA commissioned Coastal Environmental Engineer, Laurie Barwell, to carry out a rapid assessment as a first phase to establish whether there is reason to be concerned about sedimentation in the identified areas. The study included an assessment of the beach sand movement from the beach into the canal system.

The results of the first phase, as described in this report, addresses the following objectives: (1) to establish whether sand is migrating off the beach into the canal system; (2) to get a first-order idea of the extent of the sand movement (if any); and (3) to assess the extent of siltation (if any) in identified places within the canals.

The results of the so-called rapid assessment will enable the definition and costing of further steps (if any) to enable the management of the situation. This phased approach allows for stop/go/redirect decisions at appropriate times within the project time frame. Management actions should be included in the Maintenance Management Plan for Thesen Islands, Knysna, which should be drawn up at a later stage.

The rapid assessment was undertaken in four steps, namely:

(1) An analysis of available aerial imagery to establish any observable beach system changes and/or trends;
(2) In-field observations of the bottom conditions within the canal and the spread of sediment within the identified points within the study areas;
(3) Analysis of the data to obtain an overview of 'what-is-where?' in terms of siltation at the study points. If siltation is found to be an issue, a first-order attempt at quantifying the volume of sediment found beyond the logical boundaries of the beach and canal system; and
(4) Presentation to and discussion of the results within a team of local knowledgeable people to workshop the 'so-what?' and the 'what-now?' questions. The conclusions will guide any future phases (and/or specialist studies) and provide input to a future Maintenance Management Plan for the canal estate.

The following conclusions were drawn:

1. The analysis of aerial images for the period of 2003 to 2016 shows that the beach is functioning as a typical 'pocket beach' with no net loss or gain of sediment due to the prevailing hydrodynamic processes. It is important to understand that the system is still dynamic and that seasonal changes do occur locally.

2. Storm-water runoff draining onto the beach increases the saturated beach area and may result in a more rapid wash-away of the thin layer of beach sand above the compacted foundation profile. This

washed away beach sand is deposited into the adjacent deeper canal. This sediment is redistributed within the pocket-beach system and does not migrate into adjacent canals.

3. The wind surge, wind-wave energy and incoming tidal currents entering the beach canal area from the canal at P117 can churn up and redistribute the beach sediment eastwards along the beach-canal interface in the form of alongshore sediment movement. This action effectively keeps the beach sand within the beach area. The opposing easterly wind-wave energy and outgoing tidal current is significantly less and thus a net eastwards movement of sediment is expected.

4. The energy associated with the strong northerly and north-northwesterly wind-waves superimposed onto outgoing tidal flow currents in the canal between Quill and Plantation Islands can result in sediment being transported southwards and alongshore at the beach-canal interface. This also effectively counters the leaking of beach sand northeastwards along the canal beneath the bridge at Erf Q1.

5. The beach is well protected from the dominant winds and wind-blown sand related movement is easily manageable as part of a Maintenance Management Plan.

6. The compacted surface beneath the imported beach sand prevents outgoing tidal water from draining sufficiently. This leaves a saturated area on the beach in the form of a layer of beach sand between 20 mm thick at the average low-tide mark and 50 to 100 mm at the average high-tide mark that feels soft and 'mushy' underfoot. This phenomenon is not uncomfortable or dangerous and beach users easily get used to it. Some consultation with residents is recommended to determine the need for an intervention. More beach sand can be added to the middle and upper beach without impacting on the functioning of the 'pocket beach'.

7. As the sea level rises in time (in response to climate change) the saturation area will extend across the whole beach, with little if any dry upper beach left by 2030 (even at low tide). A practical response will be to construct a pole retaining structure at a point parallel to the high-water mark to form a 'perched' dry beach with a greater volume of beach sand brought in.

8. The well-compacted foundation profile beneath the shallow beach sand in the upper beach area forms a physical barrier when beach users dig into the sand (for example to build sand-castles or put up beach umbrellas). The sand depth is up to 260 mm deep in this area. A practical intervention is to place more sand in identified areas, thereby creating specific 'sand-box' type play areas that will enhance the beach-use experience in the upper beach area. More beach sand can be added to the middle and upper beach to enhance the user experience without impacting on the functioning of the 'pocket beach'. In time, the construction of the 'perched' dry beach as discussed above will be necessary in any case.

9. No significant sedimentation of adjacent canals has taken place along the beach canal, or in the canals to the west or northeast of the beach. The beach dynamics stabilised after 2010 and it is functioning as a typical 'pocket beach', secure between the hard Gabion™ structures on the western and northeastern edges of the beach.

10. The rapid assessment concluded that no abnormal sediment movement or siltation has occurred at the surveyed points within the study area. The bottom levels of the canal at the surveyed canal profiles are all still at (or below) the design level of -1,5 m MSL even though an accumulation of organic rich sediment of up to 200 mm has occurred in places.

11. Observations from available aerial images taken at low tide indicate some specific areas (not surveyed during this study) that may require further investigation and monitoring. A high-definition, drone-based aerial survey of the whole Thesen Islands canal network will greatly assist in establishing a baseline for prioritising possible sediment removal as part of the Maintenance Management Plan.

The beach canal at the main beach

Acknowledgements

- The assistance of Mr Kobus Venter during the field survey.
- The use of a boat and canoe supplied by TIHOA.
- Tidal records and boat support supplied by the Knysna Basin Project.
- Critical review by Prof. Brian Allanson and Ms Louw Claassen from the Knysna Basin Project.

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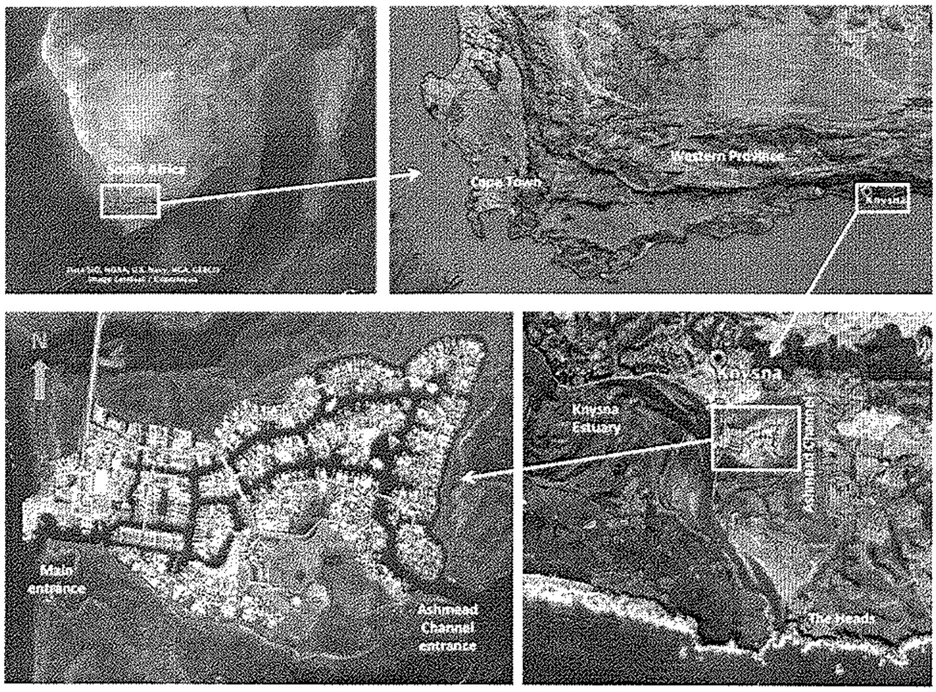


Figure 1: Thesen Islands, Knysna, is a tidal canal estate located within the Knysna Local Municipality about 1 km south of the CBD and 3 km NNW of the Heads in the Western Cape province in South Africa.

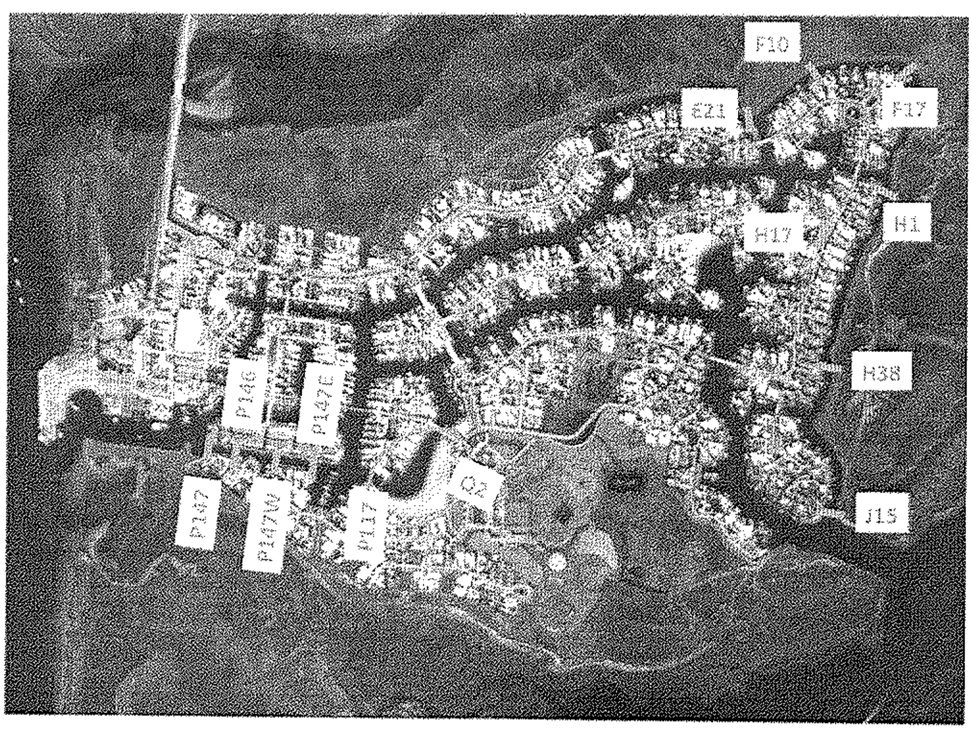


Figure 2: Thesen Islands marina showing the study site positions that correspond to the nearest Erf number.

1. INTRODUCTION

The construction of the Thesen Islands Canal Estate development in Knysna was completed in 2004. On completion, the Thesen Islands Home Owners' Association (TIHOA) took over the responsibility for the maintenance and management of the various aspects of the Thesen Islands, Knysna.

While much information was gathered as part of the baseline studies for the environmental impact assessment, design and the Environmental Management Plan during construction, little in-depth monitoring of the sediment movement within the canals has taken place since construction.

Canal users have expressed some concern about areas perceived to be silting up (becoming shallower) over time. There has also been concern expressed about beach sand being moved from the beach into adjacent canal areas. An opinion was ventured that the user experience of the main beach could be improved by adding additional sand to the upper beach area.

To obtain specialist input, the TIHOA commissioned Coastal Environmental Engineer, Laurie Barwell, to carry out a rapid assessment as a first phase to establish whether there is reason to be concerned about sedimentation in the areas pointed out by the TIHOA. The study included an assessment of the beach sand movement from the beach into the adjacent canal system.

1.1 Study area

Thesen Islands, Knysna, is located within the Knysna estuary and coastal embayment system in the Eden District Municipality. The site lies within the Knysna Municipal area in the Western Cape province in South Africa (Figure 1). Measured along the main channel within the estuary, the study site, indicated on Figure 1, is approximately 2 km from the Heads. This deep and wide connection to the Indian Ocean effectively makes the Knysna system a coastal embayment or 'arm-of-the-sea', ensuring a continuous exchange of 'new' seawater into the estuarine system under tidal forces[1].

The specific study points are located within the Thesen Islands canal estate as indicated in Figure 2.

1.2 Approach and process

In January 2017 a meeting was held with representatives of the TIHOA, where it was agreed that the available budget only allowed for a limited assessment within a phased approach. It was agreed that the first phase would consist of a rapid assessment where limited field measurements and data analysis would serve to get a first-order understanding of the situation at the specific points of concern identified by the TIHOA.

This report therefore addresses the following objectives: (1) to establish whether sand is migrating off the beach into the canal system; (2) to get a first-order idea of the extent of the sand movement (if any); and (3) to assess the points of siltation in identified places within the canals.

The results of the so-called rapid assessment will enable the definition and costing of further steps (if any) to enable the management of the situation. This phased approach allows for stop/go/redirect decisions at appropriate times within the project time frame.

[1] CSIR, 1985. Estuaries of the Cape: Part II. Report no 30 – Knysna (CMS13). CSIR Research Report 429, Stellenbosch

The rapid assessment was undertaken in four steps, namely:

(1) An analysis of available aerial imagery to establish any observable beach system changes and/or trends;
(2) In-field observations and measurements of the bottom conditions and siltation depth within the canal and the spread of sediment within the study areas;
(3) Analysis of the data to obtain a first-order overview of 'what-is-where?' in terms of sediment distribution within the study area. A first-order attempt at quantifying the volume of sediment found beyond the logical boundaries of the beach and canal system was made; and
(4) Presentation to and discussion of the results within a team of local knowledgeable people to workshop the 'so-what?' and the 'what-now?' questions. The conclusions guide any future phases (and/or specialist studies) of the assessment.

In order to understand the local abiotic processes and in particular the historic stability of the beach-canal interface at the study site, the available information, including available ground-level photographs and historical aerial images[2] were used to determine if there was a measurable trend in the position of the beach-canal interface over the period since the completion of construction.

Historical information is available in research studies undertaken as part of the EIA, the design reports and plans and the data report compiled as part of the construction Environmental Management Plan. These were incorporated into the analysis where appropriate.

2. PHYSICAL ENVIRONMENT

2.1 Introduction

In order to ensure that the correct developmental and management decisions are taken and implemented, it is important to have a basic understanding of the physical environment at the study site. In particular, this involves having knowledge of the construction methods, the established physical processes, and being able to predict the likely environmental consequences of management or developmental actions with a reasonable degree of certainty.

2.2 Site description

The study site is situated within the greater Knysna estuarine and coastal embayment system. A comprehensive description of the Knysna System is provided in CSIR (1985)[3].

The canal estate consists of a network of constructed canals. The network is tidal and connects to the Knysna coastal embayment through two constructed entrances.

The main entrance is located on the western side of the development and is deep enough to allow deep-draft ocean-going yachts to enter, moor and exit safely under all tidal conditions. The design bottom level of the entrance canal and mooring area is -3,0 m MSL.

Two canals, located to the north and south of the Drymill Island, form the small-boat entrance and exit fairways into the Canal Estate. The design bottom level of these canals is -1,5 m MSL. The

[2] Thesen Islands Development: Data Report. Pieter Badenhorst Professional Services cc, October 2006.
[3] CSIR, 1985. Estuaries of the Cape: Part II. Report no 30 – Knysna (CMS13). CSIR Research Report 429, Stellenbosch

transition from -3,0 m MSL to -1,5 m MSL of the canals takes place over a short distance at the western end of the Drymill Island.

The eastern entrance to the canal system links to the Ashmead Channel, a relatively shallow natural tidal arm of the Knysna estuary that forms the northern and eastern physical borders of the original Thesen Island.

The Thesen Islands network consists of canals of various widths but with most having a design depth down to -1,5 m MSL. In a few places, however, the sill level under shorter span bridges and culverts are at a higher elevation. No 'as-built' plans or drawings are available and the actual sill level will have to be determined at a later stage.

The design dimensions (width and depth) and parameters (maximum and minimum current flow rates and water exchange rates) were determined by the CSIR using a state-of-the-art hydrodynamic computer model[4]. The design objectives were, inter alia, to (1) ensure that adequate water exchange due to tidal action takes place so as to avoid pockets of stagnant water within the network; and (2) that the tidal current velocity was within predetermined limits so as to avoid scouring, due to too high velocities, or siltation and stagnation, due to too low velocities. A further engineering consideration was to allow the 'cut-to-fill' volumes to balance. This was due to the fact that a condition of environmental authorisation was that no excess material was to be removed from the island or no additional fill material could be brought onto the island. The implication was that the required canal dimensions needed to be ensured and that the required island ground level was high enough to allow for storm surges as well as the projected sea-level rise.

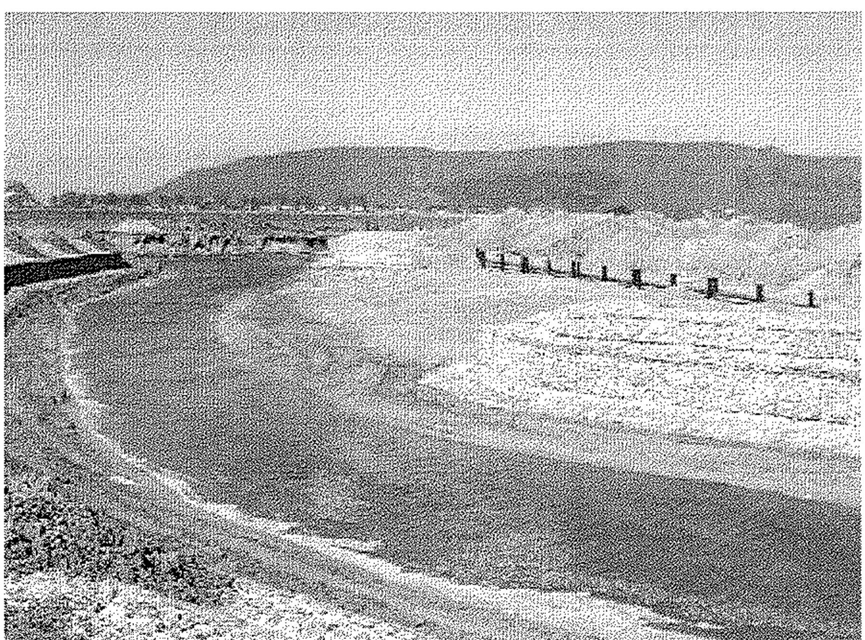
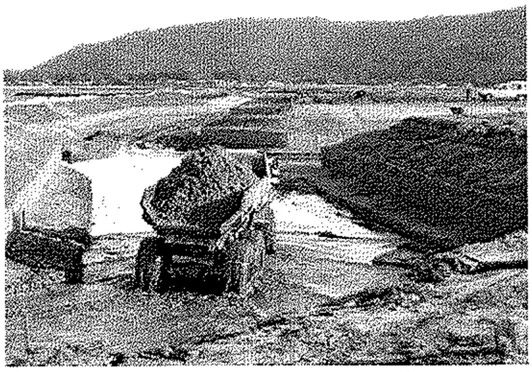


Figure 3: The canals were constructed 'in-the-dry'. (Photo Ashmead perimeter canal 13/10/2000)[5]

[4] CSIR EMS-C-2002-006. Circulation in Thesen Islands final layout including industrial area. January 2002. Stellenbosch.
[5] Thesen Islands Development: Data Report. Pieter Badenhorst Professional Services cc, (PBPS) October 2006.



Ashmead perimeter canal (19/04/2001).

Finishing off canal (29/09/2000).

Figure 4: Heavy construction vehicles were used which resulted in a highly compacted foundation profile within the canal system and beaches. (Photos: PBPS)[6]

Figure 5: The main beach and canals prior to the opening of the main entrance. (Photo: 18/08/2003)[7]

Figure 3 shows the typical construction method employed for the canals at Thesen Island, Knysna. The area where the canal was excavated was dewatered by lowering the ground water table by installing a series of dewatering pumps along the peripheral of the excavation area. The excess material was then excavated and the revetment and Reno mattress structures installed 'in-the-dry'. As can be seen in Figure 4, use was made of heavy construction vehicles that resulted in the design profile foundation becoming well compacted.

Once the profile and retaining structures were completed to design specifications, the dewatering pump system was removed and the water level stabilised within the completed canals (Figure 5). The eastern (Ashmead) entrance was first opened and a section of the canal estate became tidal. The completion of the Drymill Island, mooring area and western entrance were the last areas of the marina to be completed and the final connection to the sea was established in 2004.

[6] Thesen Islands Development: Data Report. Pieter Badenhorst Professional Services cc, (PBPS) October 2006.
[7] Thesen Islands Development: Data Report. Pieter Badenhorst Professional Services cc, (PBPS) October 2006.

2.3 Wind climate

The annual wind rose for the Knysna area is shown in Figure 6 and indicates a predominance of wind from the southern and southeastern sectors with apposing winds from the northern sector significant.

The study site is essentially sheltered from all the significant winds. Given the orientation of the Drymill and Ashmead perimeter canals and the main beach and adjacent canals, the winds from the north-northwest to north as well as those from the western sectors are of importance.

Local wind-waves (generated by west-southwesterly and westerly winds) can propagate eastwards along the Drymill canals and can cause a small surge and increased alongshore currents that can extend through the canal at bridge P117 and enter the main beach canal.

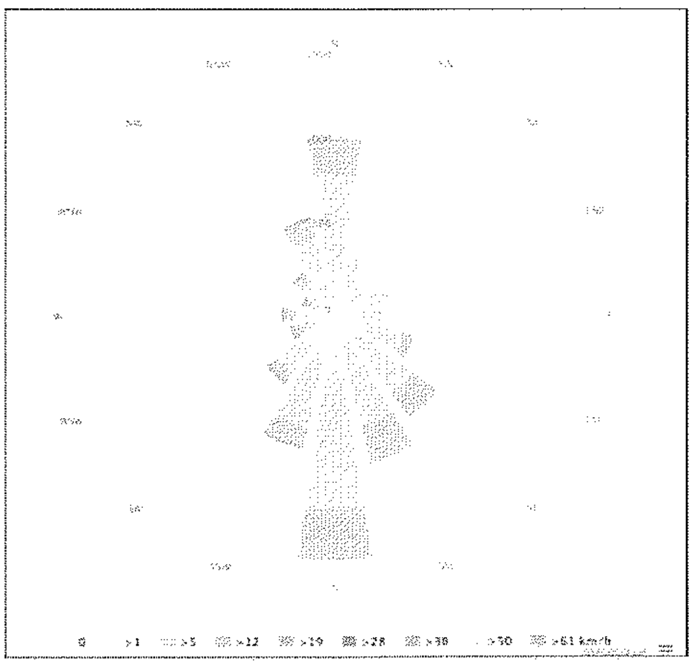


Figure 6: Seasonal wind roses for Knysna (https://www.meteoblue.com).

The currents associated with these wind-waves superimposed onto the incoming tidal current can result in sediment transport alongshore the beach towards the east and northeastern side of the beach area.

Similarly, northerly and north-northwesterly winds blowing across the canal between Quill and Plantation Islands can create small wind-waves, and a surface current superimposed onto the outgoing tidal current can result in sediment transport alongshore the beach towards the southwestern and western side of the main beach embayment.

The combination of these wind and tidal-driven processes along with the crescent (or half-heart) design shape of the beach embayment, results in a fairly stable beach-canal interface with only a redistribution of the finer sediment within the beach system taking place in time. No loss of sediment from the beach embayment is thus anticipated. This will be explored in later sections.

The northerly and north-northwesterly winds blowing across the dry (unsaturated) area of the beach can result in wind-blown sand moving downwind. Although relatively little (and manageable) this volume can cause a net movement of valuable beach sand off the beach and onto adjacent areas. Practical and effective wind-blown sand management techniques exist and should form part of a Maintenance Management Plan.

2.4 Tides

As part of the Knysna Basin Project[8], two automatic continuous tide recorders have been installed to complement the SA Navy Tide Recorder and a water-level gauge. The SAN recorder, the Knysna Basin Project recorder (ST3) and the water-level gauge are located together at the southern tip of the Thesen Jetty at the SANParks offices in Knysna. These all measure the water level at a point adjacent to deep water within the main channel of the Knysna coastal embayment.

A tide recorder (ST1) has also been installed at Mooring 14 (near P147E) on Plantation Island, located at the eastern end of the southern Drymill canal, approximately 200 m from ST3 at the main entrance. Due to the relatively shallow Drymill canals it is expected that there will be a slight time delay in the incoming tidal water between ST3 and ST1. Likewise the outgoing tidal level will drop a little faster at ST3 when compared to that at ST1. However this difference is expected to be negligible for the purpose of this rapid assessment exercise. There is no tide recorder monitoring the eastern canals within the network but it is expected that the comparative tidal variation will also be relatively little due to the effective Ashmead channel entrance to the canal network.

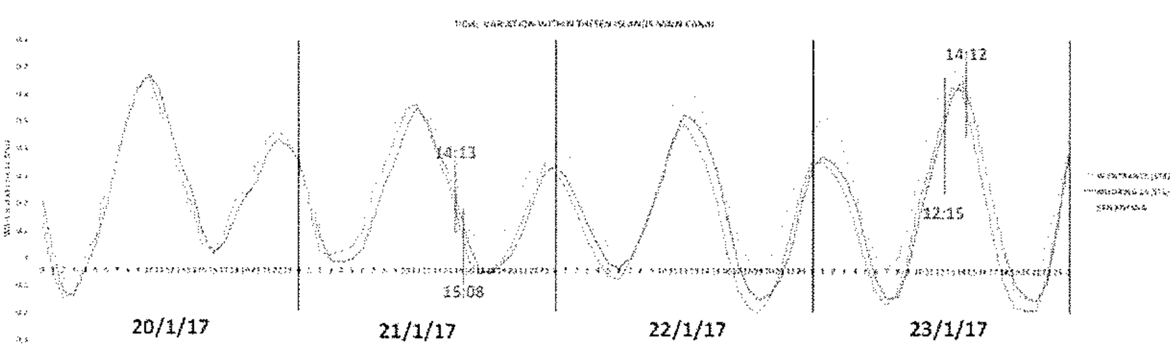
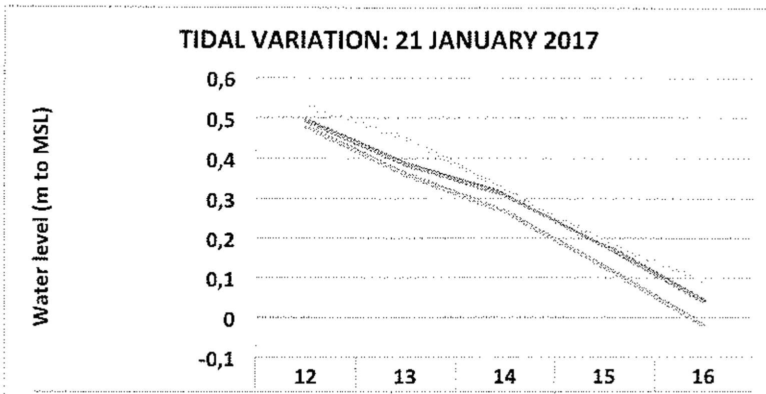


Figure 7: Tide-level recordings (ST1, ST3 and predicted tide from SA Navy [SAN]).

The tidal level (to MSL) as recorded at ST3 was therefore used as the baseline reference for the canal profile surveys carried out on 21 and 23 January 2017 as described later. A copy of the tide record for the period of 20 to 23 January 2017 is shown in Figure 7. The water-level state for the actual day and time period during which the field surveys were done is indicated. More detailed data are shown in Figures 8 and 9, where the slight time differences (for the same level) are seen.

[8] www.knysnabasinproject.co.za

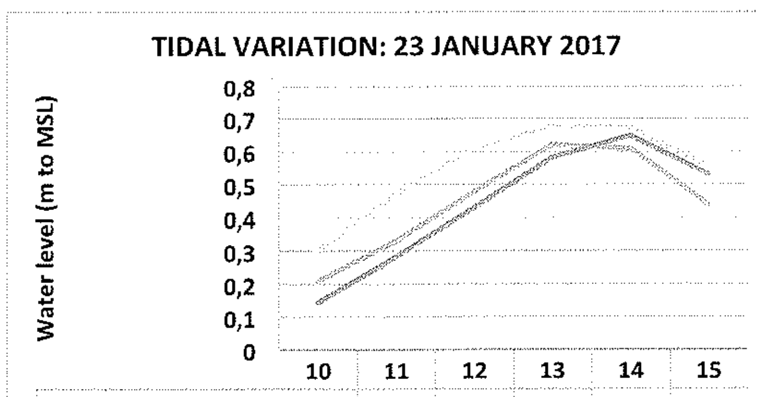


	12	13	14	15	16
W ENTRANCE (ST3)	0,48	0,36	0,27	0,13	-0,02
MOORING 14 (ST1)	0,50	0,39	0,31	0,18	0,04
SAN KNYSNA	0,53	0,45	0,32	0,19	0,09

Figure 8: Tide-level recordings for 21/01/2017 (ST1, ST3 and predicted tide from SA Navy [SAN]).

The field surveys were undertaken between 14:13 and 15:08 on 21 January 2017. Figure 8 shows the recorded water levels at ST3 for this period as used as the horizontal reference level to determine the canal profile as discussed below.

Likewise the field surveys were undertaken between 12:15 and 14:12 on 23 January 2017. Figure 9 shows the recorded water levels at ST3 for this period as used as the horizontal reference level to determine the canal profile as discussed below.



	10	11	12	13	14	15
W ENTRANCE (ST3)	0,21	0,33	0,48	0,62	0,61	0,44
MOORING 14 (ST1)	0,14	0,29	0,43	0,58	0,65	0,53
SAN KNYSNA	0,30	0,47	0,61	0,68	0,67	0,55

Figure 9: Tide-level recordings for 23/01/2017 (ST1, ST3 and predicted tide from SA Navy [SAN]).

3. BEACH STABILITY

The beaches within the Thesen Islands canal estate were constructed using beach sand imported from the Touw Estuary mouth area[9]. Formal permission was obtained from the relevant authorities at the time (2003).

Concern was expressed about the possibility of the imported beach sand at the main beach washing off the beach and 'leaking' into the adjacent canals and thereby possibly impacting negatively on the in-situ sediment characteristics and thus the local environment.

Unfortunately no 'as-built' information exists for the beach area and adjacent canals. If this information had been available it would have been simple to do a follow-up survey and compare the current shape and profile to the 'as-built' profile to thereby determine the degree of change.

The design parameters as shown in Figure 17 give an indication of the probable dimensions and the key dimensions were therefore used as the baseline for this assessment. It is recommended that a comprehensive bathymetric and topographical survey be done of the beaches and key areas within the canal network to form the baseline for future change monitoring as part of a Maintenance Management Plan.

The situation was evaluated in the following way:

(a) The variation in the physical shape of the beach and the horizontal position of the beach-canal interface was determined over 13 years (2003 to 2016);
(b) The beach sand characteristics were analysed and compared to those of the in-situ sediment;
(c) The physical depth of the sand in the canals on either side of the beach was measured;
(d) Photographs of the bottom of the canal at different points were taken.

The results are discussed below.

3.1 Beach-canal interface

The aerial image and photographic analysis that forms the basis of the beach-canal interface stability assessment is based on the availability of historical and recent data and information. Infrastructure (such as bridges, footpaths and buildings) was used to overlay the images at a common scale, which enabled the comparative image analysis to be undertaken.

The resolution of the satellite-based imagery (Google Earth^{TM}) remains a challenge for accurate feature analysis. Furthermore the actual time on the specific date that the image was taken is not readily available so the tide level at that time and date could unfortunately not be used. As such, only a broad idea of the relevant dynamics can be reached. However this approach has proved to be useful in identifying long-term trends, which are important when attempting to understand the local processes and their potential impact on and response to developmental and/or management actions. Once available, the high-definition, drone-based image of the study area, along with a comprehensive bathymetric and topographical survey, will form an accurate baseline for monitoring future changes.

[9] Thesen Islands Development: Data Report. Pieter Badenhorst Professional Services cc, (PBPS) October 2006.

Figures 10 and 11 show the 'beach-canal interface', which is relatively easy to observe on aerial images as the boundary between the dark areas (canal and deeper water) and the light areas (beach sand and shallower water). Tracking these lines over time provides a useful indicator of positional trend/stability as discussed below. Adjacent infrastructure such as the Gabion™ canal edge and bridge structure provides reference points.

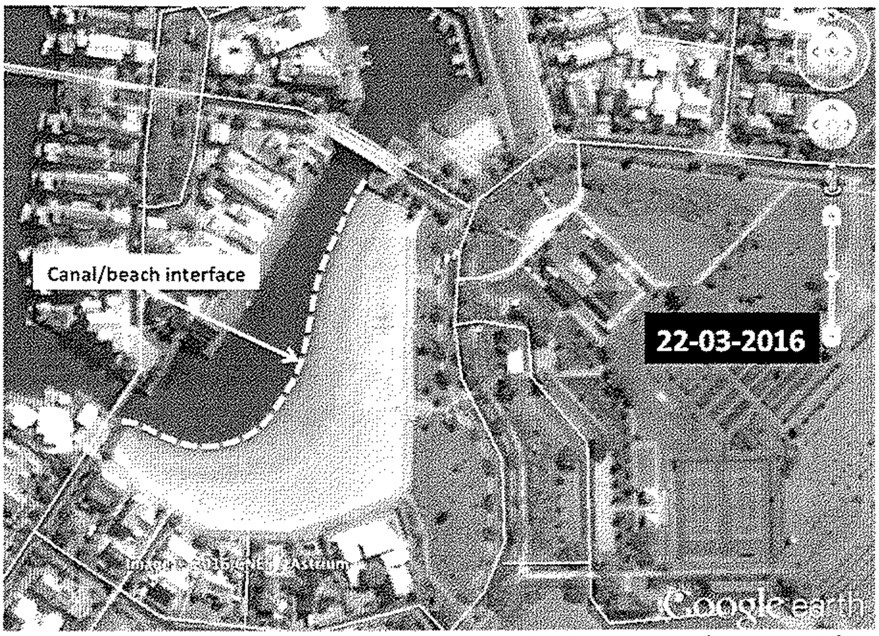


Figure 10: Example of tracing the 'beach-canal interface' on the March 2016 aerial image.

It is fortunate that the imported beach sand has a distinctly different colour to that of the in-situ sand. The shape of the beach-canal interface is therefore clearly seen on aerial photographs even when the tide level is unknown.

A further feature of the main beach is that it is formed between two hard points (the Gabion™ structures) at the bridges on the western and northeastern edges of the beach. This gives it the characteristics of a typical 'pocket beach'. A pocket beach by nature has a finite volume of sand within its system and the prevailing natural processes (waves, currents, winds and storm water) will shape it until it finds a dynamic stability. Unless replenished by human intervention, no sand leaves or enters the beach system due to natural processes. This can be seen to be true for the beaches at Thesen Islands although a small volume can be moved off the upper beach as wind-blown sand and if left unchecked will be lost from the system.

Figure 11: Example of tracing the 'beach-canal interface' on the January 2017 KiteKam aerial image.

The deeper water of the canal and the grey colour of the slope shaped in the in-situ sediment on the Quill Island (northern) side can clearly be seen in Figure 11.

3.2 Aerial image analysis

Aerial images from Google Earth™ are available from 2003 to 2016 and were used in the analysis.

The images were used to determine and assess the variation in the beach-canal interface over the 13-year period. A comparative analysis of the lines on the available images for the selected years is shown in Figure 12.

It is important to note that the error band of this type of analysis is in the order of 2 m. Present day low-level (drone-based), high-definition imagery reduces the error to a few cm, which will make future aerial-image based monitoring more effective. Having said this, the technique has a high confidence level for reaching conclusions on the overall trend in the stability of the shoreline, especially over longer periods.

It is concluded that the pocket beach system underwent post-construction settling over the period of 2003 to 2010, where variations of between 3 and 6 m occurred. Variations of between 2 and 3 m have occurred since 2010. Given the possible error band of up to 2 m for this type of analysis it can be concluded with a high degree of confidence that the beach shape has reached a point of dynamic stability. This means that the beach is functioning as a typical 'pocket beach' with no net loss or gain of sediment due to the prevailing hydrodynamic processes.

However, it is important to understand that the system is dynamic by nature and that seasonal changes do occur locally as discussed below.

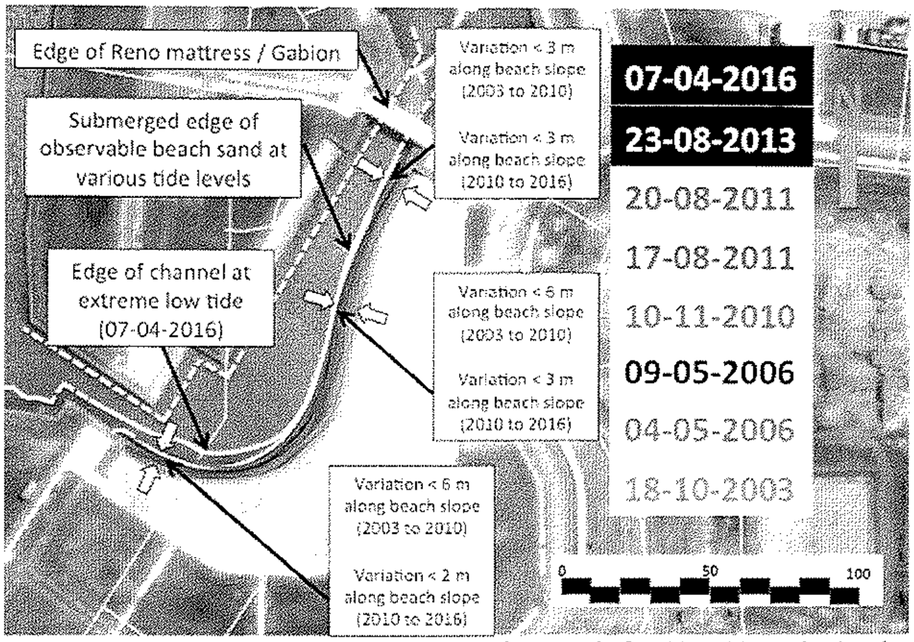


Figure 12: Positional change in the 'beach-canal interface' over the period of 2003 to 2016. The October 2003 aerial image is used as the analysis base.

3.3 Beach dynamics

Unfortunately no 'as-built' profile data are available for the beach profile. Use is therefore made of the design profile of the canal system and through interpretations of in-situ observations and local measurements.

By digging into the relatively thin layer of imported (white) beach sand, the underlying constructed profile of the in-situ sand (grey) is reached (Figure 13). As can be seen in Figure 14, the thickness of the layer varies from between 260 mm at the upper edge of the dry beach (Point EB4) next to the boardwalk, 50 mm (Point EB1 in Figure 12) to only 20 mm at the water's edge (Point WE, Figure 13).

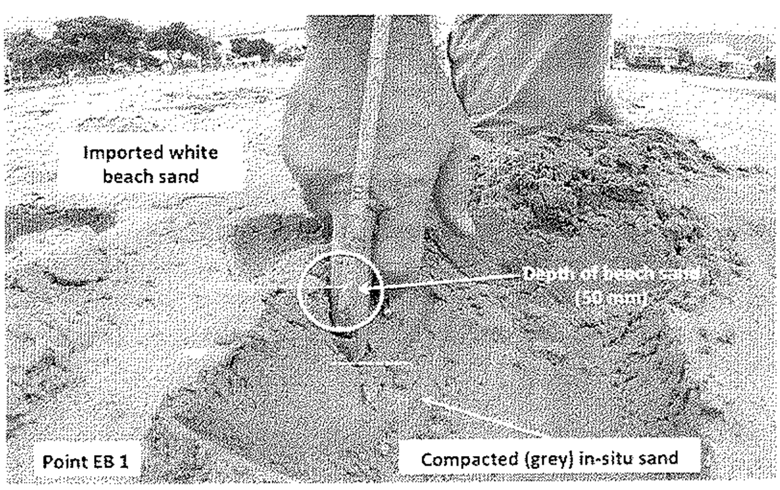


Figure 13: The white beach sand forms a relatively thin layer of between 20 mm and 260 mm above the compacted profile constructed with in-situ (grey) sand.

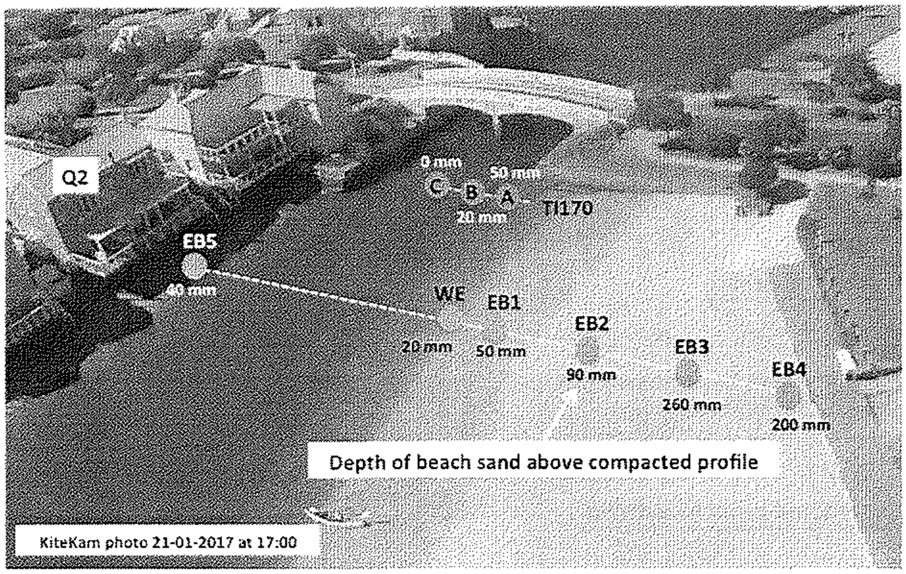


Figure 14: Position of survey points at the main beach opposite Erf Q2

Beach-use experience (upper beach)
Walking or running on the lower beach area and into the water, one experiences a 'soft, mushy' feel to the beach. As can be seen in Figure 14, your feet push through the mushy sand to the compacted profile below. The footprints can be as deep as 50 mm in places. The area is totally saturated and has a distinct upper and lower limit, which depends on the tide.

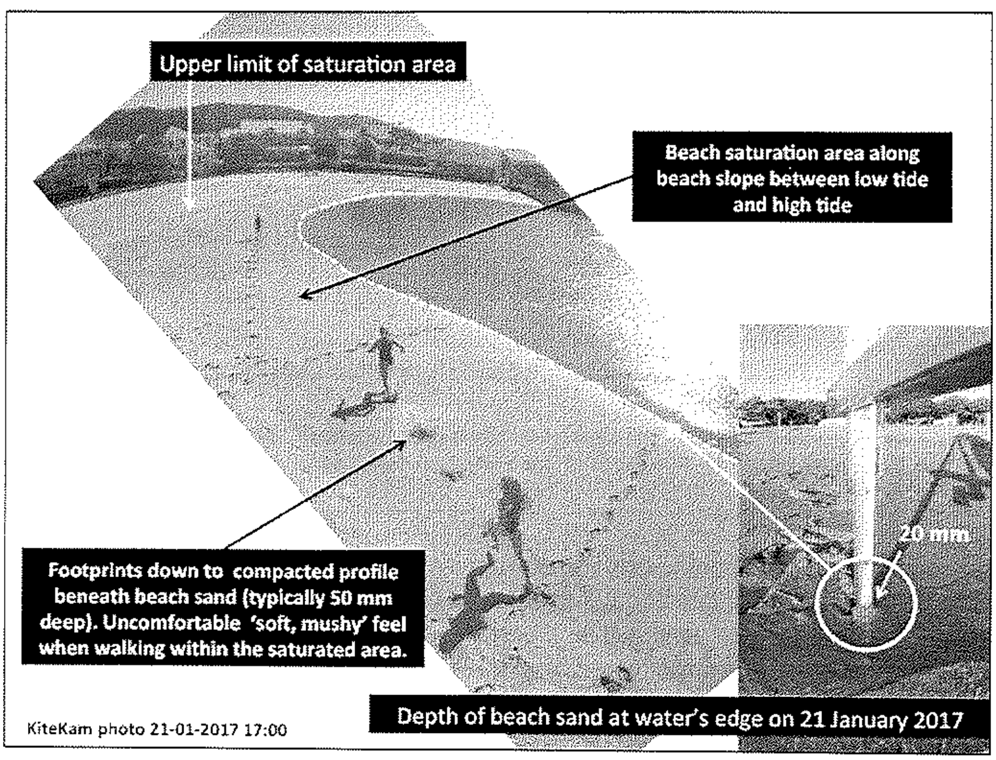


Figure 15: The saturated beach has a 'soft-and-mushy' feel to it.

As depicted in Figures 16a and 16b, it is concluded that the compacted surface beneath the imported beach sand prevents outgoing tidal water from draining sufficiently. This leaves an ever-present saturated area on the beach in the form of a layer of beach sand between 20 mm thick at the average low-tide mark and 50 to 100 mm at the average high-tide mark that is soft and 'mushy' underfoot. Storm water draining onto the beach off the adjacent high areas during rains will extend and add to the spatial extent of the saturated area.

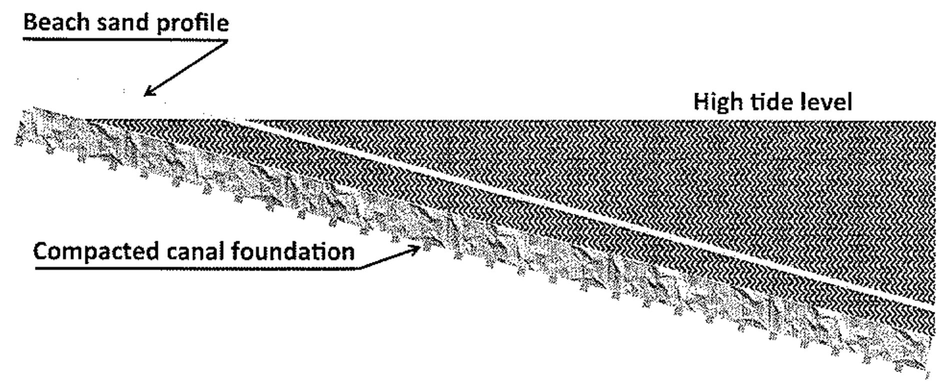


Figure16a: Schematic of beach profile at high tide.

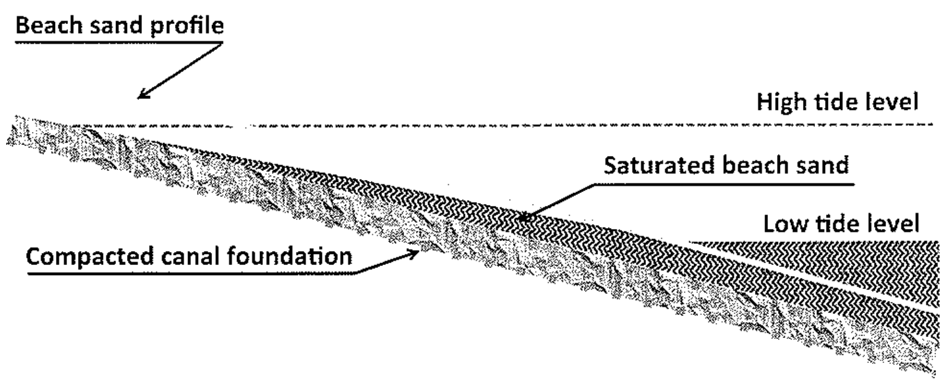


Figure16b: Schematic of beach profile at low tide.

Figure 16a (High tide) and 16b (Low tide): The beach sand becomes saturated because the rate of drainage of tidal water is restricted due to the relatively thin layer of uncompacted beach sand on the highly compacted foundation profile.

This phenomenon is not uncomfortable or dangerous and beach users soon get used to it even though it does seem 'not beach-like'. If it is deemed necessary to improve the 'look-and-feel' of the lower beach, a phased management intervention is possible. Some consultation with residents is recommended to determine the need for an intervention. More beach sand can be added to the middle and upper beach without impacting on the functioning of the 'pocket beach'.

However, as the sea level rises in time (projected to be 25 cm by 2030 and 35 cm by 2050 in response to climate change[10]) the saturation area will extend across the whole beach with little if any dry upper beach left by 2050.

A practical response will be to construct a pole retaining structure at a point parallel to the high-water mark to form a 'perched' dry beach with a greater volume of beach sand brought in. This intervention is common at upmarket resort hotels in, for example,Mauritius, where the availability of natural beach sand is limited.

Beach-use experience (upper beach)
The well-compacted profile beneath the shallow beach sand in the upper beach area forms a physical barrier when beach users dig into the sand (for example to build sand-castles or put up beach umbrellas). The sand depth is 200 to 260 mm deep in this area. Much digging and sand-castle building will eventually result in the (white) beach sand being mixed with the underlying (grey) in-situ sand, which may be aesthetically unpleasing. However, it will not impact on the physical functioning of the beach.

A practical intervention is to place more sand in identified areas, thereby creating specific 'sandbox' type play areas that will enhance the beach-use experience. It will also be easy to keep the sandbox areas clean of glass pieces, charcoal and hazardous materials such as dog and cat excrement by implementing a regular manual sand sifting exercise as part of the Maintenance Management Plan. In time the construction of the 'perched' dry beach as discussed above will be necessary in any case.

Loss of beach sand (storm water wash-away)
Storm water draining across the beach area increases the saturated beach area and may result in a more rapid wash-away of the thin layer of beach sand above the compacted profile. This washed away beach sand is deposited into the adjacent deeper canal. This is currently noticeable in the area on the southwestern side of the beach where a storm-water drain discharges onto the beach. An insignificant amount of this washed away sand leaks westwards under the bridge and along the Reno mattress alongside Erf P117.

Loss of beach sand (wind-induced alongshore sand movement)
The incoming tidal currents are enhanced at times when wind-waves and wind induced surges penetrate the beach area through the canal below the bridge at P117 from the southern Drymill canal. This wind surge, wind-wave energy and incoming tidal current can churn up and redistribute the beach sediment eastwards along the beach-canal interface in the form of alongshore sediment movement. This action effectively keeps the beach sand within the beach area. The opposing easterly wind-wave energy and outgoing tidal current is significantly less and thus a net eastwards movement of sediment is expected.

The energy associated with the strong northerly and north-northwesterly wind-waves superimposed onto outgoing tidal flow currents in the canal between Quill and Plantation Islands can result in sediment being transported southwards and alongshore at the beach-canal interface. This also effectively counters the leaking of beach sand north-eastwards along the canal beneath the bridge at Erf Q1.

Loss of beach sand (wind-blown)
The northerly and north-northwesterly winds blowing across the dry (unsaturated) areas of the upper beach result in wind-blown sand movement towards the southern sector. This sand is seen to accumulate under the existing wooden walkway. In places the sand has blown across the walkway into the vegetation

[10] Theron, A.K., Rossouw, M., Barwell, L., Maherry, A., Diedericks, G., De Wet, P. (2010). Quantification of risks to coastal areas and development: wave run-up and erosion. CSIR 3rd Biennial Conference 2010. Science Real and Relevant, CSIR International Convention Centre, Pretoria 30 August – 01 September 2010, South Africa. http://hdl.handle.net/10204/4261.

on the southern side of the walkway. If left unchecked, the sand will eventually blow onto the lawn and kill off the grass. This volume of wind-blown sand is easily managed through periodically manually placing it back on the beach or by establishing a low concave wooden barrier on the beach side of the walkway from where it can occasionally be scraped back onto the beach as part of the Maintenance Management Plan. A more natural approach would be to establish a narrow band of indigenous dune vegetation next to the walkway to trap the wind-blown sand on the beach in a small foredune, thereby reducing the need to manually move the sand back onto the beach.

The beach is well protected from the dominant winds and wind-blown sand related movement is easily manageable.

4. SEDIMENTATION OF THE CANALS

A concern expressed by the TIHOA and boat owners is the perceived shallowing of the canals in places within the canal network.

To determine the extent and source of the perceived siltation, a rapid assessment survey was done as described and discussed in this section.

4.1 Design parameters

To determine whether siltation has actually taken place, it is of course important to know what the 'starting' situation was, so as to form a baseline against which to assess any measured changes in time.

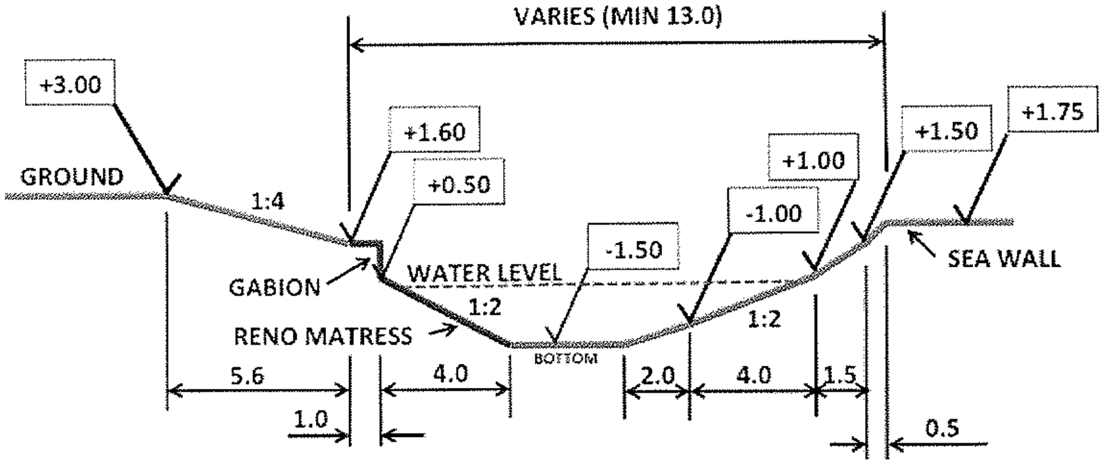
Unfortunately no 'as-built' data are available for the canal cross-sections. The design profiles[11] were therefore used as the baseline and it is assumed that the construction was done as close to the design parameters as possible. This is a fair assumption since the canals were shaped and finished off 'in-the-dry', thereby enabling a high degree of accuracy. Furthermore, the work took place within the framework of an Environmental Management Plan where progress of the various construction methods and elements were documented, as presented in the comprehensive Date Report.

As shown in Figure 17 below, the cross-sectional design for both narrow canals and the wider canals are shown. The key parameter to note is that the bottom level of the canals is set at -1,5 m MSL. This, together with the width of the canal, is an important factor for ensuring the water flow during tidal exchange is within the design specification.

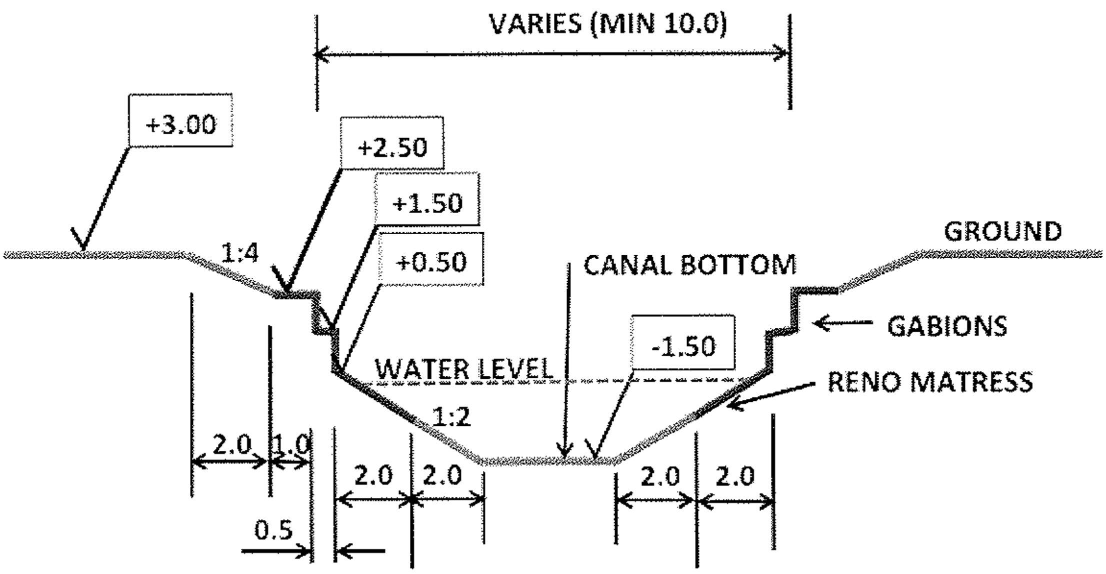
The assumption for measuring the degree of siltation that has taken place is therefore to check if the bottom levels of the canals are at least -1,5 m MSL or lower.

Furthermore, by assessing the sediment grain size characteristics and observing the consistency of a sample of the sediment/silt taken from the bottom profile, an idea of the source of the measured sediment/silt build-up can be derived.

[11]Thesen Islands Development: Data Report. Pieter Badenhorst Professional Services cc, (PBPS) October 2006



CROSS SECTION: WIDE CANAL



CROSS SECTION: NARROW CANAL

Figure 17: The design profile of the canals is used as the baseline for assessing the degree of sedimentation/siltation that has occurred in the canals. The key parameter is the bottom level of -1,5 m MSL.

4.2 Assessment methodology

The specific points where observations were made were provided by the TIHOA in consultation with specific home owners and boat owners.

The points are shown in Figure 18 below. The reference numbers relate to the particular erf number as depicted on the official Thesen Islands, Knysna, property layout plan.

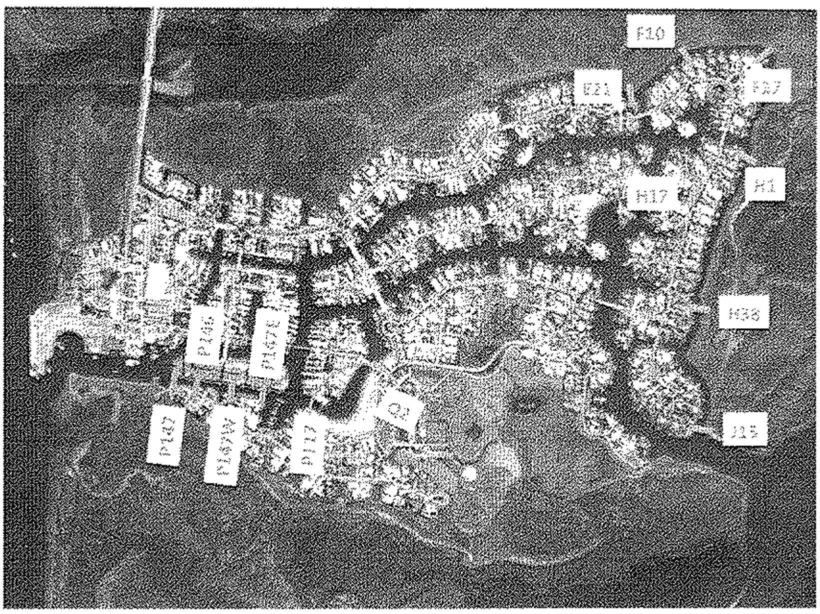


Figure 18. Positions of the points where the surveys were done and reference to the nearest erf number.

Use was made of a measuring tape attached to a vertical probe to which a GoPro™ video camera was attached. The survey was carried out from a canoe. The horizontal position across the canal was determined by a graduated rope attached to the Gabion™ retaining structures on either side of the canal. The width of the canal at the particular point was measured off the Google Earth™ image and a percentage across the distance calculated. The time of the survey was noted each time and the measuring probe pushed down into the sediment until the probe hit the compacted bottom profile. The water depth at that point at the specific time was recorded so as to enable the level of the horizontal reference baseline to be determined from the tidal record at the specific time. The video recorded the depth of the sand/silt at the specific time. Observations of the organic content of the silt could also be made from the video clip when the probe was withdrawn.

The table below shows the results for Point P146 located in the Drymill south canal.

P146			
Distance across profile (%)	Soft bottom level (m MSL)	Hard bottom level (m MSL)	Sediment depth (mm)
0%	-1,46	-1,46	0
29%	-1,56	-1,73	170
57%	-1,53	-1,65	120
93%	-1,26	-1,26	0
100%	-1	-1	0

It shows that the constructed hard profile level was located between -1,65 and -1,73 m MSL at 30% and 60% across the profile. This is compared to the design level of -1,5 m MSL. The silt collected at the bottom of the canal profile, defined as the 'soft bottom', shows that the levels are still within the design specification of -1,5 m MSL. The sediment depth is calculated as between 120 and 170 mm at that point. Similarly the table below shows the results for Point F17 located in the top northeastern corner of the Ashmead perimeter canal.

F17			
Distance across profile (%)	Soft bottom level (m MSL)	Hard bottom level (m MSL)	Sediment depth (mm)
0%	-0,89	-0,89	0
6%	-1,03	-1,09	60
19%	-1,51	-1,57	60
50%	-1,75	-1,81	60
63%	-1,37	-1,41	40
88%	-1,08	-1,11	30
100%	-0,76	-0,76	0

Here the canal foundation profile bottom level and the soft bottom profile are still well within the design specification.

The results for the rest of the points surveyed are shown in summary on Figure 19.

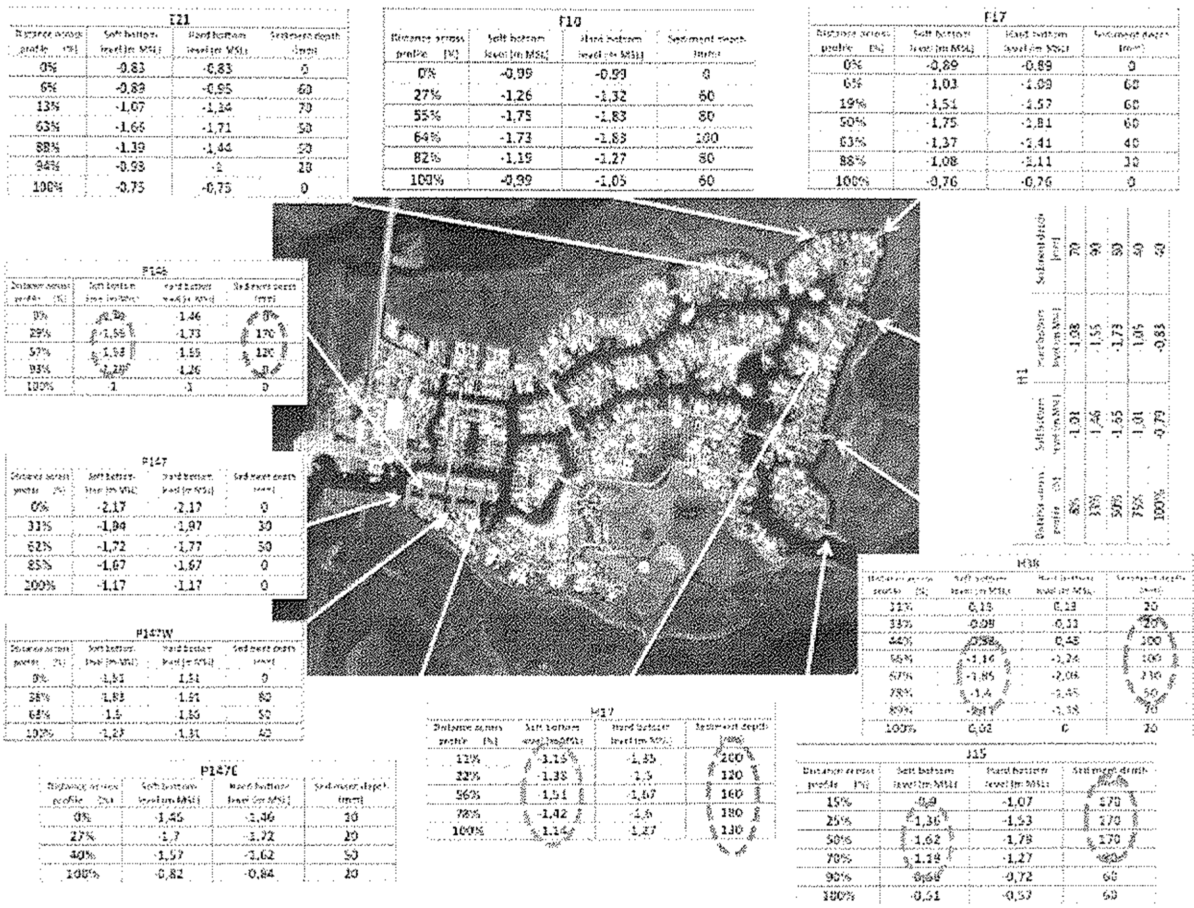


Figure 19. The actual level of the soft bottom is still well within the design profile level of -1,5 m MSL in the surveyed canals.

5. FINDINGS AND CONCLUSIONS

The findings from the rapid assessment analyses in the sections above lead to the following conclusions that should be considered:

1. The analysis of aerial images for the period of 2003 to 2016 shows that the beach is functioning as a typical 'pocket beach' with no net loss or gain of sediment due to the prevailing hydrodynamic processes. It is important to understand that the system is still dynamic and that seasonal changes do occur locally as discussed.

2. Storm-water runoff draining onto the beach increases the saturated beach area and may result in a more rapid wash-away of the thin layer of beach sand above the compacted foundation profile. This washed away beach sand is deposited into the adjacent deeper canal. This sediment is redistributed within the pocket beach system.

3. The wind surge, wind-wave energy and incoming tidal currents entering the beach canal area from the canal at P117 can churn up and redistribute the beach sediment eastwards along the beach-canal interface in the form of alongshore sediment movement. This action effectively keeps the beach sand

within the beach area. The opposing easterly wind-wave energy and outgoing tidal current is significantly less and thus a net eastwards movement of sediment is expected.

4. The energy associated with the strong northerly and north-northwesterly wind-waves superimposed onto outgoing tidal flow currents in the canal between Quill and Plantation Islands can result in sediment being transported southwards and alongshore at the beach-canal interface. This also effectively counters the leaking of beach sand northeastwards along the canal beneath the bridge at Erf Q1.

5. The beach is well protected from the dominant winds, and wind-blown sand related movement is easily manageable as part of a Maintenance Management Plan.

6. The compacted surface beneath the imported beach sand prevents outgoing tidal water from draining sufficiently. This leaves a saturated area on the beach in the form of a layer of beach sand between 20 mm thick at the average low-tide mark and 50 to 100 mm at the average high-tide mark that feels soft and 'mushy' underfoot. This phenomenon is not uncomfortable or dangerous and beach users easily get used to it. Some consultation with residents is recommended to determine the need for an intervention. More beach sand can be added to the middle and upper beach without impacting on the functioning of the 'pocket beach'.

7. As the sea level rises in time (in response to climate change) the saturation area will extend across the whole beach with little if any dry upper beach left by 2030 (even at low tide). A practical response will be to construct a pole retaining structure at a point parallel to the high-water mark to form a 'perched' dry beach with a greater volume of beach sand brought in.

8. The well-compacted foundation profile beneath the shallow beach sand in the upper beach area forms a physical barrier when beach users dig into the sand (for example to build sand-castles or put up beach umbrellas). The sand depth is up to 260 mm deep in this area. A practical intervention is to place more sand in identified areas, thereby creating specific 'sandbox' type play areas that will enhance the beach-use experience in the upper beach area. In time the construction of the 'perched' dry beach as discussed above will be necessary in any case.

9. No significant sedimentation of adjacent canals has taken place along the beach-canal, or in the canals to the west or northeast of the beach. The beach dynamics stabilised after 2010 and it is functioning as a typical 'pocket beach', secure between the hard Gabion™ structures on the western and northeastern edges of the beach.

10. The rapid assessment concluded that no abnormal sediment movement or siltation has occurred at the surveyed points within the study area. The bottom level of the canal at the surveyed canal profiles are all still at (or below) the design level of -1,5 m MSL even though an accumulation of organic rich sediment of up to 200 mm has occurred in places.

11. Observations from available aerial images taken at low tide indicate some specific areas (not surveyed during this study) that may require further investigation and monitoring. A high-definition, drone-based aerial survey of the whole Thesen Islands canal network will greatly assist in establishing a baseline for prioritising possible sediment removal as part of the Maintenance Management Plan.