ESPERANCE BAY

Dredging and Sand Backpassing Development

Reference: R-SOE-1505.01
Date: March 2019
Confidential

SHIRE OF ESPERANCE

ESPERANCE BAY

DREDGING AND SAND BACKPASSING DEVELOPMENT

Prepared for

By

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1 INTRODUCTION

1.1 Background

The Shire of Esperance has an ongoing erosion problem in the Esperance Bay. In particular, Castletown Beach requires an annual sand renourishment of 20,000 - 25,000 m^3 since the total trapping of the littoral sand volume by the port breakwater.

In the first half of 2018 the Shire engaged BMT to undertake a review of options for Castletown Beach erosion. After the appraisal of various management options and subject to the successful coordination of sand management activities in Esperance Bay between the Shire of Esperance Asset Management, the Department of Transport - Asset Management (Dredging) and the Department of Transport - Coastal Management (Erosion), a win-win solution was proposed that could be beneficial for all parties involved. As a result, the coordinated Bandy Creek Boat Harbour dredging & sand back-passing option was recommended for further development and received the “in-principle” support from the Department of Transport.

The Shire of Esperance now wishes to develop further the recommended option, including design, environmental planning and liaison with the Department of Transport.

Figure 1.1: Beach nourishment at Castletown Beach in coordination with the DoT’s Bandy Creek Boat Harbour dredging

1.2 Objectives of the study

The Shire of Esperance engaged coastal and maritime engineering and environmental science consultants BMT to develop the Esperance Bay coordinated Bandy Creek Boat Harbour dredging & sand back-passing solution.

1.3 Scope of services

The scope of services comprises the following:

- Review project definition
  - Review readily available report and site information (e.g. the Esperance Bay Coastal Erosion Options report July 2018)
  - Confirm design objectives and constraints

  - Confirm stakeholders' engagement approach
- Develop concept design of the proposal including:
  - Define options
  - Assess risks
  - Estimate cost
  - Select preferred option
- Prepare detailed design of the proposal, including:
  - Establish beach profile
  - Calculate sand volume requirements
  - Prepare pumping system specification
  - Prepare design drawings
  - Estimate cost
- Prepare an Environmental Impact Assessment and Environmental Management Plan including:
  - Sample analysis of sand
  - Potential impact on seagrass communities in the Esperance Bay
  - Native vegetation clearing permit preparation (if required)
- Liaise closely with the key stakeholders being Shire of Esperance and the Department of Transport
  - Inform and consult with key stakeholders to confirm design objectives and constraints
  - Involve and collaborate key stakeholders, including DoT dredging contractor

1.4 Scope of the report

The scope of the report comprises most of the scope of services, excluding

- Prepare detailed design of the proposal
- Prepare an Environmental Impact Assessment and Environmental Management Plan

These tasks will be reported separately, once the preferred concept option has been approved by the shire.

1.5 Structure of the report

This report is structured as follow:

- Section 2 provides a brief overview of the current sand management programs by the Shire and the DoT in Esperance Bay, highlighting their current sand relocation quantity and cost.
- Section 3 summarises the shoreline dynamic modelling undertaken to establish the target beach nourishment design and demonstrates that the design would sustain the local

erosion for two years on average, while minimising volume requirements and construction cost.

- Section 4 defines the proposed back-passing option, including an overview of key elements of the proposed methods, detailed description of options, indicative cost, early environmental considerations for each option.
- Section 5 presents the back-passing option appraisal, including a summary of the option multi-criteria assessment, the consultation conducted with the Department of Transport and the selection of the preferred options by the Shire.
- Section 6 concludes the concept design study with a summary of the outcomes and recommendations.

2 BACKGROUND

2.1 Castletown Beach sand nourishment program (every year - ongoing)

Castletown Beach sand nourishment areas stretches approximatively 700m between Esperance foreshore seawall and Esperance YHA hostel and encompasses Norseman Road groyne field (Figure 2.1).

The current sand nourishment method is summarised as follow:

- Sand is sourced from coastal dunes at Wylie Bay land fill
- Sand is carted 8.5km on road to site by trucks
- Sand is dumped over the erosion face
- Wheel loader spreads and levels the sand
- The top layer is stabilised with gravel to control the sand drift issue and facilitate truck movements

By continuously supplying sand in these areas, the sand nourishment program maintains the beach profile in semi-equilibrium (Figure 2.2). The sand volume placed is in the range 3,500 - 9,000m^3 per campaign (Figure 2.3).

On average, the sand nourishment program consists of placing 18,500m^3 per year at a cost of $10 per m^3 or $185,000 per year. The program is funded by the Shire with grant assistance from the Department of Transport - Coastal Infrastructure Business Unit - Coastal Management Branch.

Figure 2.1: Castletown Beach sand nourishment areas and survey location (Station 10).

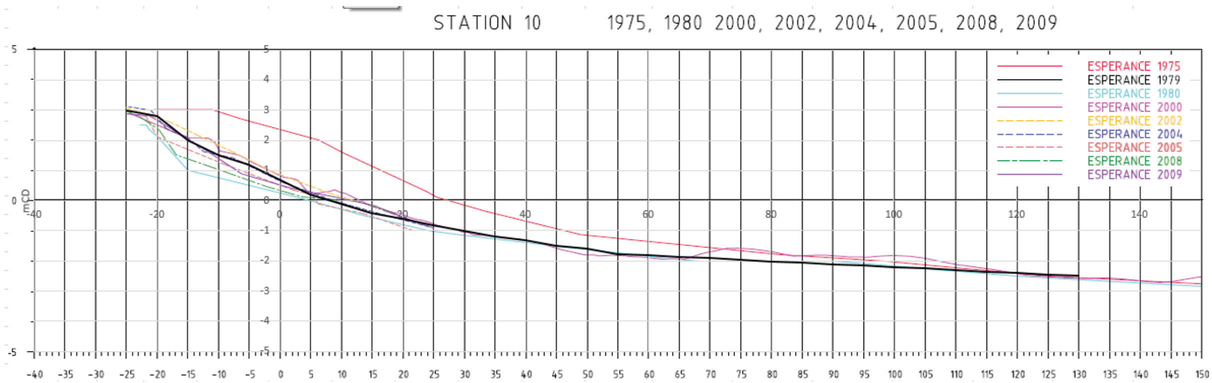


Figure 2.2: Castletown Beach cross-shore survey (Department of Planning and Infrastructure, Drawing 072-10-5, ESP07105).

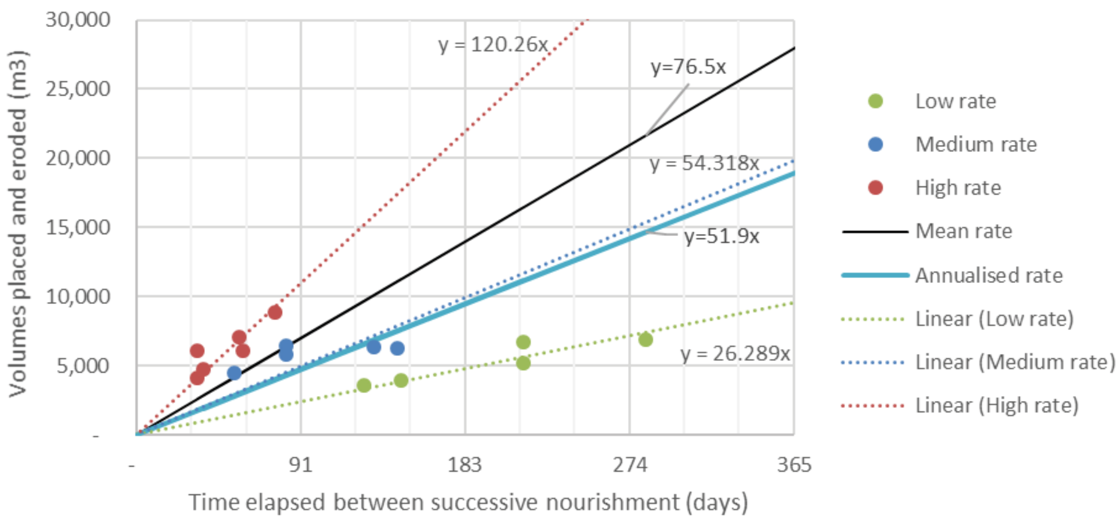


Figure 2.3: Castletown Beach erosion rates variability derived from the sand nourishment log (Jul-2013 to Feb-2018).

2.2 Bandy Creek Boat Harbor maintenance dredging program (two yearly - ongoing)

Bandy Creek Boat Harbour is located 3km downstream of Castletown Beach. The Department of Transport (DoT) regularly dredge the navigation channel to maintain the depth of the waterway for recreational and commercial users. Over the last 25 years, the dredged volumes have averaged approximately 60,000m^3 every two years. The maintenance dredging works is undertaken using a small cutter suction dredged. The dredged material is pumped hydraulically via a series of floating, submerged and onshore pipelines to a beach disposal site, located approximately 1.5km east of the Harbour (Figure 2.4).

The average cost of the Bandy Creek Boat Harbour maintenance dredging is approximately $1M every two years. The program is fully funded by the Department of Transport - Coastal Infrastructure Business Unit - Coastal Facilities Management Branch.

Figure 2.4: Aerial view of Bandy Creek Boat Harbour and surround during biennial maintenance dredging operation.

3 SHORELINE DYNAMIC MODEL

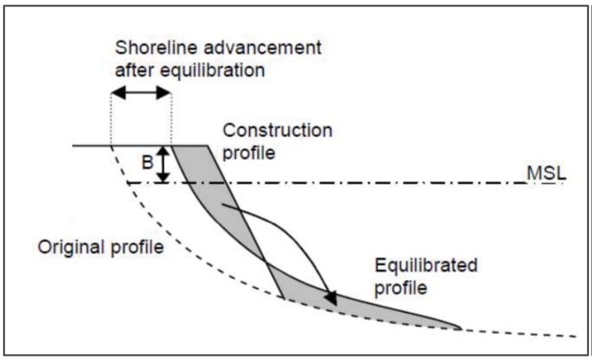
3.1 Sand nourishment dynamics model

The sand nourishment dynamics taking place at Castletown Beach can be characterised by two littoral sediment transport modes, which can happen concurrently (Figure 3.1).

First, a rapid change in the beach cross-shore profile can occur directly after placement. The relatively steep beach profile achieved after a sand nourishment campaign evolves rapidly toward a smoother and more natural beach profile (Figure 3.2). This phenomenon is considered to be largely dominated by cross-shore processes, which redistributes the sand in the cross-section without substantial loss of volumes.

Second, a slow(er) change in the shoreline position can occur overtime. The imbalance (deficit) in the longshore sediment budget translates into a cross-shore shift of the beach profile progressively leading to shoreline movement (retreat), as shown in Figure 3.1. This phenomenon is largely dominated by long-shore processes which drive the littoral drift. Any interruption of the flux of sand alongshore (e.g. no upstream supply) would result in a local loss of sand and an equivalent shoreline retreat unless some sand is locally supplied in sufficient quantity.

These sand nourishment dynamics principles have been used in our Castletown Beach shoreline evolution model to establish a suitable beach design at the site.



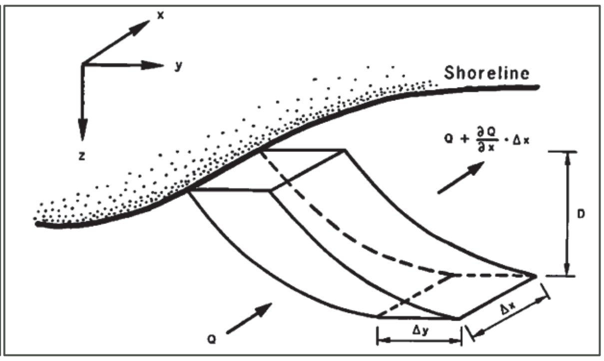


Figure 3.1: Schematic illustration of a hypothetical equilibrium beach profile (left, after Bodegom, 2014), used in one-line shoreline evolution model (right, after Larson et al 1987).

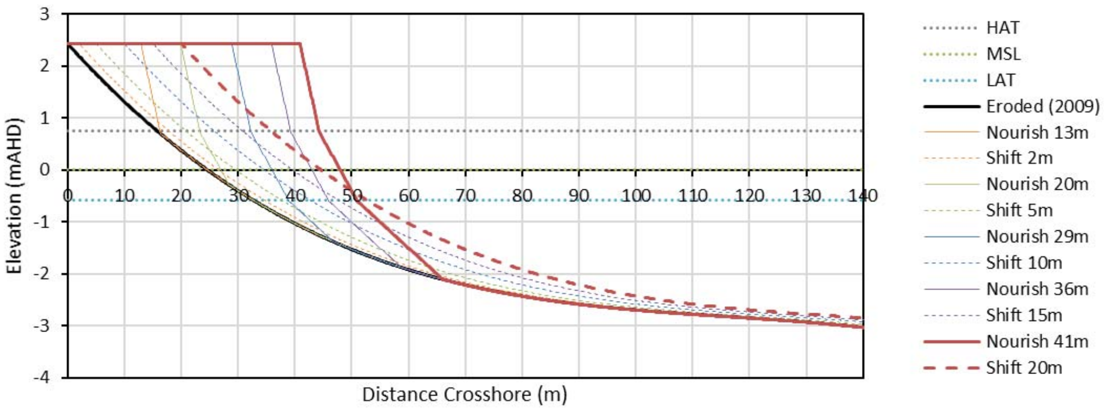


Figure 3.2: Castletown Beach volume estimation for various nourishment (solid line) and following "rapid" redistribution of sand in the cross section (dotted lines).

3.2 Castletown Beach shoreline evolution model calibration

The shoreline evolution model for Castletown Beach was developed and calibrated based on our understanding of local coastal processes, historical information of the site and project constraints.

A linear one-line shoreline evolution model (Larson et al 1987) was calibrated for area 1 of Castletown Beach using the sand nourishment dynamics principles (section 3.1), beach survey data (Figure 2.2) from the DoT and data from the Shire sand nourishment program log (Figure 2.3).

The shoreline evolution model calibration result for Castletown Beach Status-Quo quarterly nourishment option is shown in Figure 3.3. The model effectively represents the rapid erosion observed at Castletown Beach after the nourishment activities and demonstrates the need for ongoing and regular beach nourishment to prevent erosion of the foreshore.

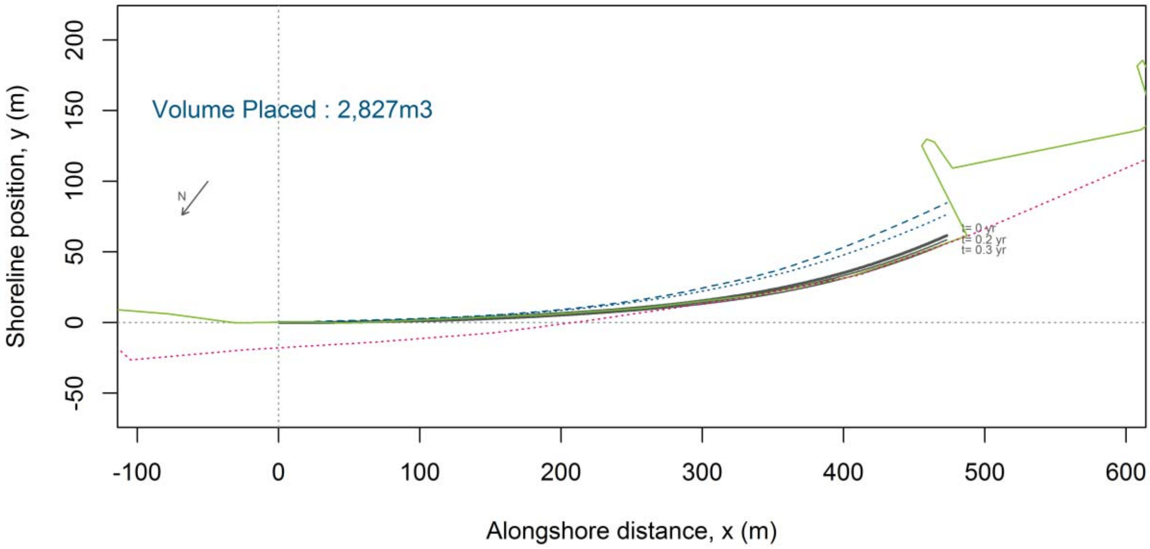


Figure 3.3: Castletown shoreline evolution (calibration) for Status-Quo quarterly nourishment option: Shoreline position (—), Footpath (…), Toeline after initial placement (---), Shoreline after initial placement (…), Effective shoreline after cross-shore redistribution (—).

3.3 Castletown Beach modelled sand nourishment design profile

The objective of Castletown Beach sand nourishment design is to minimise the expectation of foreshore erosion in the area within a two-year timeframe, under the constraint to achieve an economical placement of approximately 40,000m^3 of sand (dredged from Bandy Creek Boat Harbour) along the current Castletown Beach renourishment zone.

3.3.1 Nourishment Area 1 – downdrift of terminal groin

The Castletown Beach shoreline evolution model was used to establish the renourishment profile in accordance with the above design objective and constraint. One possible solution to the design problem is shown in Figure 3.4. It shows that such placement of approximately 21,000 m^3 of sand could mitigate the foreshore erosion risk over the two years in Area 1.

Alternative test placements (with smaller and larger sand volume) were also modelled to assess model sensitivity (Figure 3.5), however some of these test placements failed to meet the design objective. In case 1, substantial foreshore erosion was expected to occur after one year. In case 2, excessive beach width would occur in some sections of the nourishment area 1. In case 3, excessive encroachment of the nourishment footprint on the subtidal area would occur. In case 4, a compact and balanced placement is achieved.

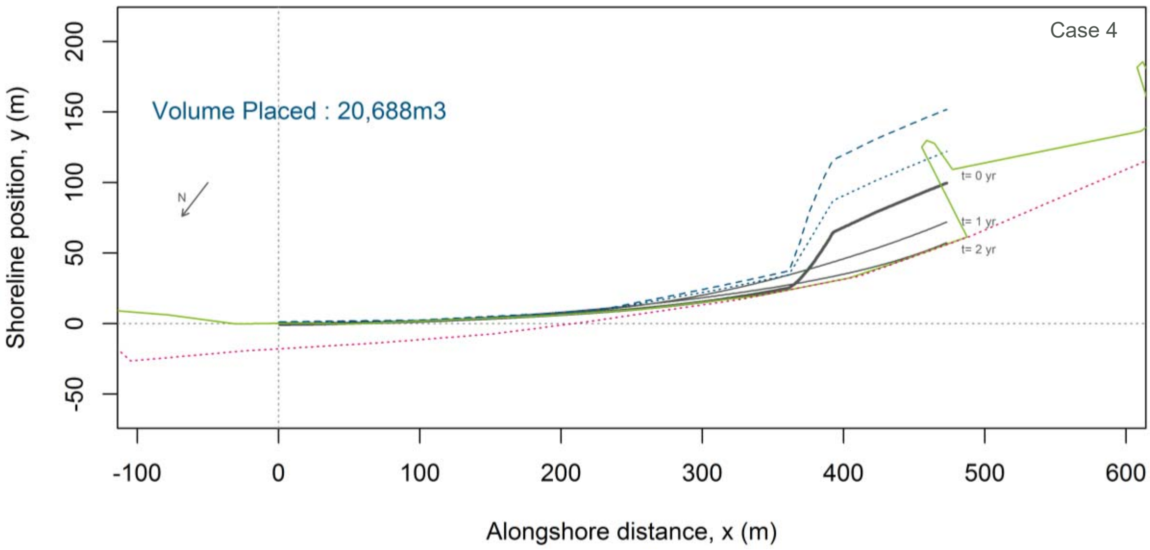


Figure 3.4: Castletown shoreline evolution (model result) for Sand back-passing two-yearly nourishment option: Shoreline position (—), Footpath (…), Toeline after initial placement (---), Shoreline after initial placement (…), Effective shoreline after cross-shore redistribution (—).

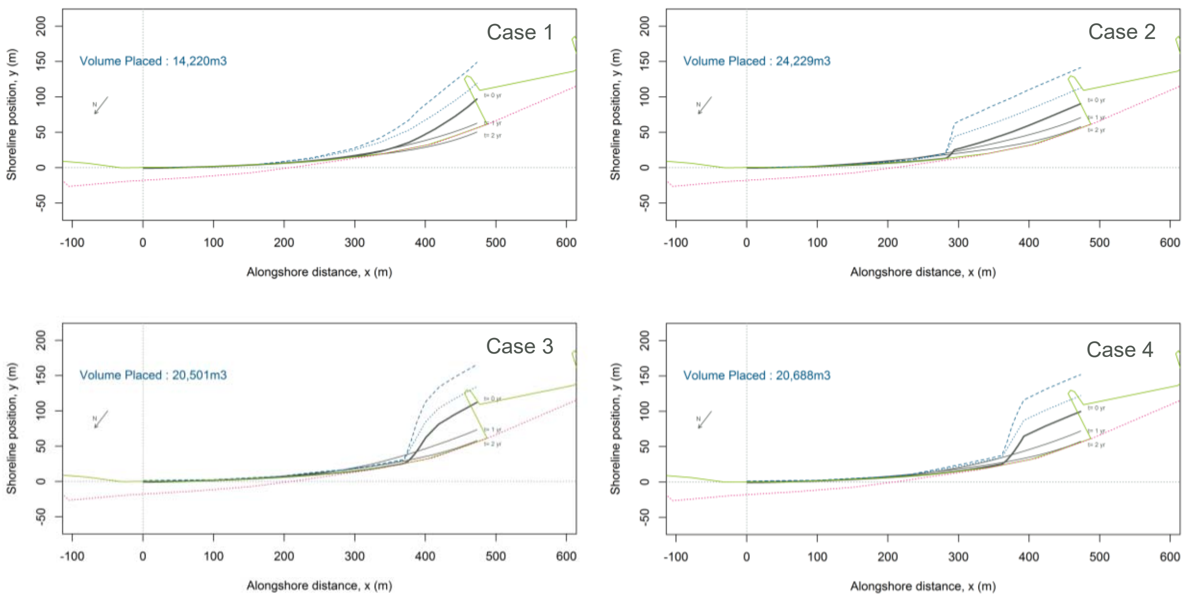


Figure 3.5: Castletown shoreline evolution (model sensitivity tests) for Sand back-passing two-yearly nourishment option: Shoreline position (—), Footpath (…), Toeline after initial placement (---), Shoreline after initial placement (…), Effective shoreline after cross-shore redistribution (—).

3.3.2 Nourishment Area 2, 3, 4 – between groins

The nourishment design problem between the groins was also solved using the Castletown shoreline evolution model. Model results were obtained for each area after calibrating the model for each segment independently (Figure 3.6). These results show that such placement of approximately 13,000m^3 of sand could mitigate the foreshore erosion risk over the two years in Area 2, 3 and 4.

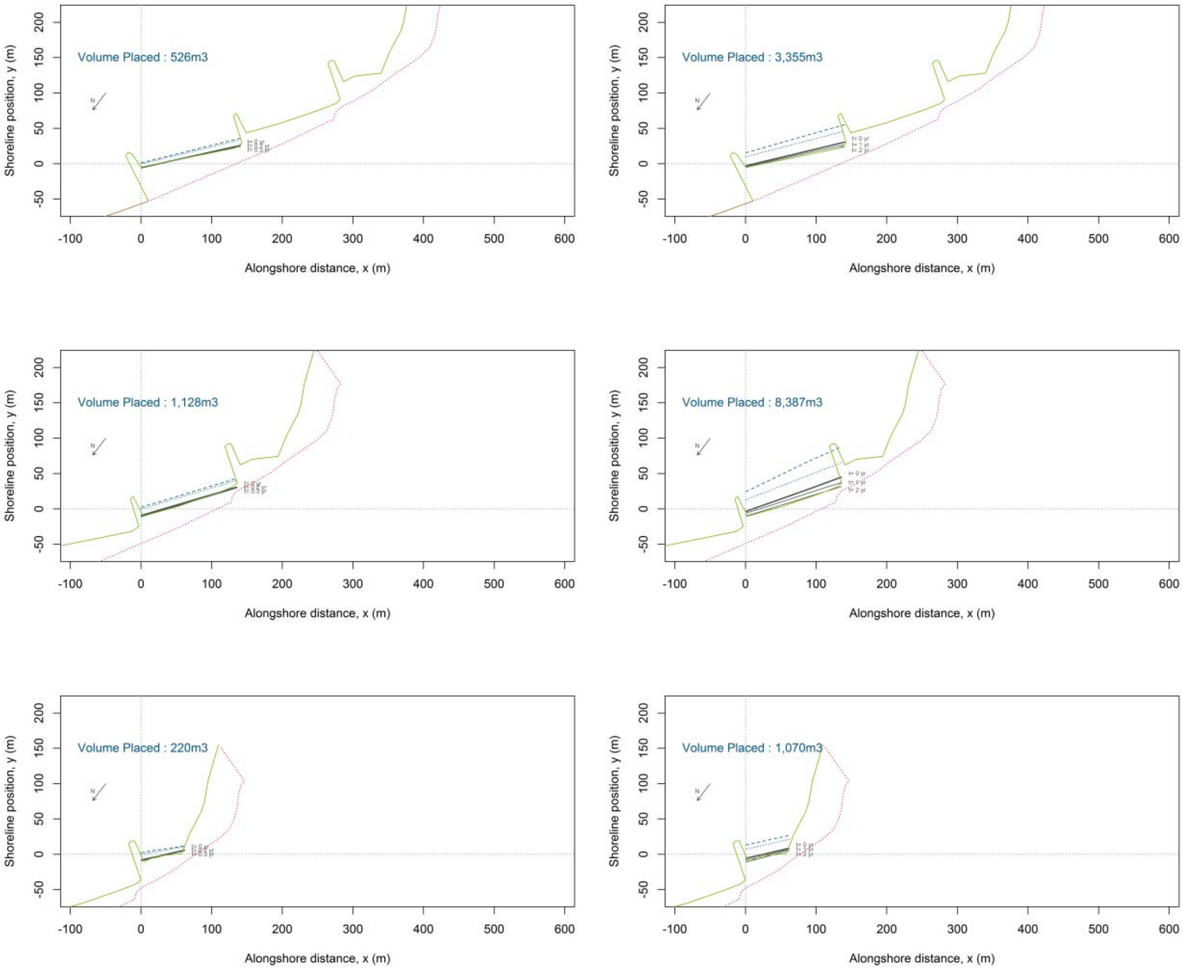


Figure 3.6: Castletown Beach shoreline evolution in Area 2 (top), Area 3 (middle), and Area 4 (bottom). Model calibration for Status-Quo quarterly nourishment option (left). Model results for Sand back-passing two-yearly nourishment option (right).

3.3.3 Total Nourishment Target

Considering the target renourishment volume estimated for Area 1, 2, 3 and 4, the total nourishment target volume is approximately 33,700m^3. The target volume would be placed in a single campaign, every two years and could mitigate the foreshore erosion risk over the two years on average in these areas. The footprint of the nourishment area is shown in Figure 3.7.

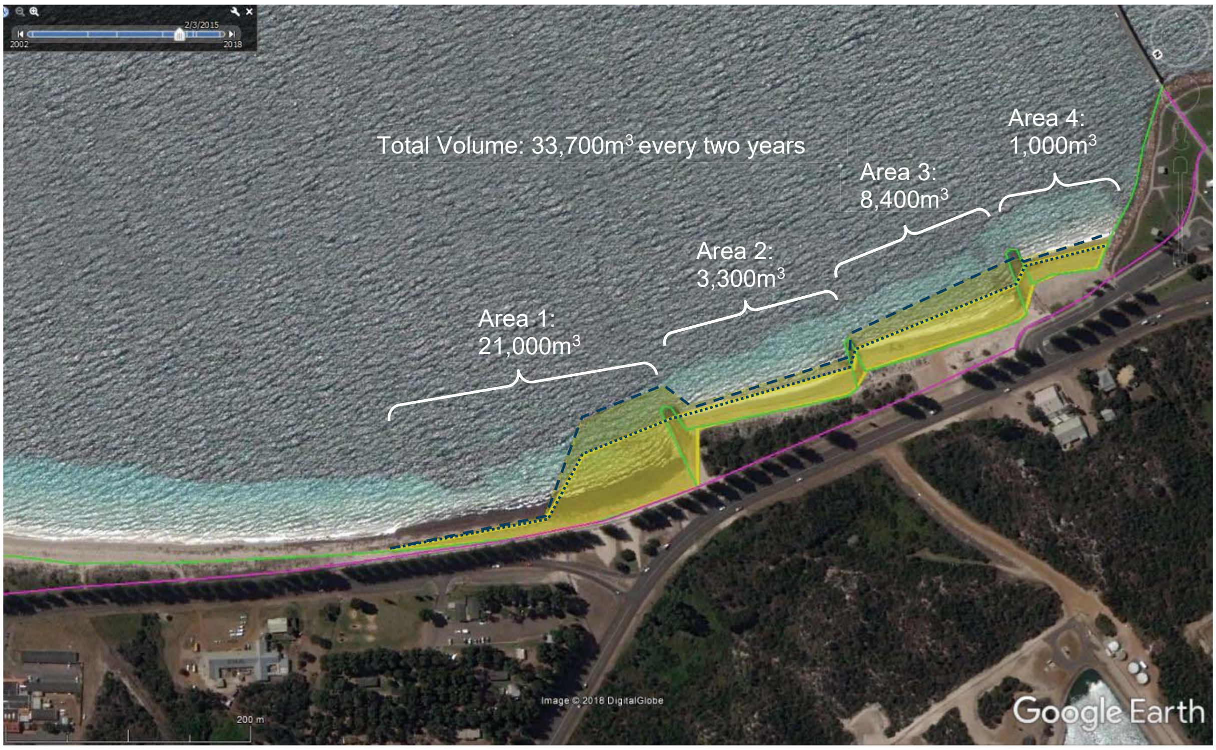


Figure 3.7: Castletown Beach nourishment profile. Shoreline position (—), Footpath (—), Toeline after initial placement (---), Shoreline after initial placement (…).

3.4 Management of residual risk of erosion

3.4.1 Weather variability and extreme events

As indicated previously, the erosion demand at the site may vary over time, so the average erosion rate and consequently the average shoreline retreat rate, may be exceeded from time to time. This irregularity is due to weather variability and extreme events occurrence. First, there is a risk of excessive erosion between two nourishment campaigns posed by the weather inter-annual variability. Second, there is a risk of extreme shoreline retreat in response to extreme storm events, so-called "storm bite". Therefore, residual erosion risk may still exist, and some mitigation should be considered to enhance the efficacy of the nourishment program.

3.4.2 Responsive nourishment

In the case of current nourishment program, the residual risk of erosion after nourishment is only partially mitigated. Indeed, one of the upside of current nourishment program at Castleton, is that the "flexible" nourishment approach provides some opportunities for sporadic interventions, when some renourishment of the beach can be undertaken "as needed" in response to weather variability. However, the downside of this strategy is that only a thin sand buffer is present at all times, which means that the extreme events erosion risk, is much higher on average than with the proposed two yearly back-passing strategy. For example, a large storm bite in the order of 30m has been reported in the CHRMAP for a rare event (1 in 100 year). Although, this type of the extreme erosion event is very unlikely over a two-year window (less than 2% probability of occurrence), should such a large event occur, a wider beach would perform better than a narrow beach which would offer less protection.

3.4.3 Wider sand buffer

In the case of the proposed two-yearly nourishment strategy, the beach is expected to be wider than the current beach (under current nourishment program) most of the time, so intrinsically the proposed strategy offers better erosion protection. Furthermore, a possible solution to manage the erosion rate variability would consist of placing additional sand along the proposed nourishment area, thus more effectively mitigating excess erosion due to both weather variability and extreme events occurrence. This “extra” sand buffer would widen the beach further and could be designed following a similar optimisation process as undertaken previously to establish the average nourishment profile, with the objective and constraint to effectively place as much extra sand as possible within the project budget to reduce extreme events erosion risk.

Alternatively, another solution to manage the erosion rate variability would be to reserve some fractions of the budget for sporadic intervention in the later stage of the two-year nourishment cycle, to respond to weather variabilities in the same way as the current approach and until the next scheduled two-yearly nourishment campaign.

3.5 Castletown Beach sand management strategy

3.5.1 Sand relocation process

The volume of sand required to achieve the nourishment target needs to account for volume changes and losses during the material handling processes between BCBH dredging area and Castletown Beach nourishment area (Figure 3.8), as detailed hereafter.

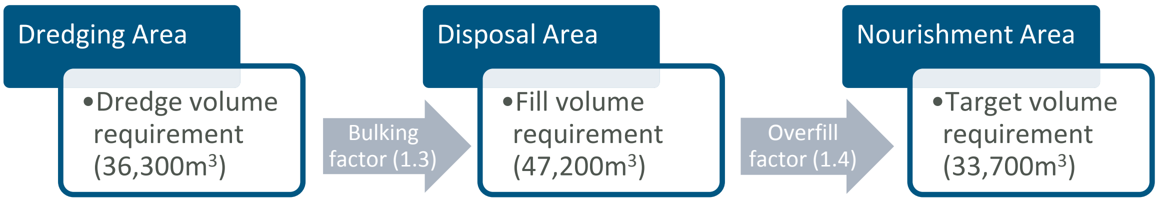


Figure 3.8: Castletown Beach sand relocation process.

3.5.2 Target volume requirement

The target beach nourishment profile was developed for Castletown Beach based on the result of the calibrated Castletown Beach shoreline evolution model (section 3). The estimated total nourishment target volume is approximately 33,700m^3. This forms the basis to estimate fill volume and the dredged volume requirements.

3.5.3 Fill volume requirement

It is anticipated that more sand than the renourishment target volume will be required to achieve the construction profile. Typically, an overfill factor of 1.4 is considered to account for losses due to washout of fines in the swash zone during the construction period and the presence of steeper initial profiles after nourishment (van Rijn, 2014). So, the required fill volume is estimated to be approximately 47,200m^3. This required fill volume is comparable to the average sand volume placed by the Shire as part of its ongoing nourishment program at Castleton (i.e. 20,000-25,000m^3 per year, or 40,000-50,000 m^3 every two years).

3.5.4 Dredge volume requirement

It is proposed to use the dredged sand from BCBH maintenance dredging as a source of sand for the Castletown Beach nourishment. A bulking factor of 1.3 is considered to account for the structural disruption and entrainment of water during dredging. So, the required dredged volume is estimated to be approximately 36,300m^3.

3.5.5 Excess dredge volume management

Keeping a wholistic view of sand management operations in Esperance Bay, including DoT and the Shire operations, it is important to note that the DoT dredging volume requirement for BCBH (60,000m^3) are higher than the dredged volume requirement for Castletown Beach nourishment (36,300m^3). This is because BCBH traps both, the eastward and the westward components of the littoral drift, while Castletown Beach sediment deficit is only unidirectional and related to the eastward components of the littoral drift at Bandy Creek.

As a result, there is an excess volume of dredged sand of approximately 23,700m^3 (or 30,800m^3 of fill equivalent) which requires to be managed. So, another branch for the "excess dredge volume" has been added to the Castletown Beach sand relocation process (Figure 3.8) as illustrated in Figure 3.9. The excess dredged material disposal strategy may involve:

- Placement of sand in the beach nourishment area (above target design volume)
- Stock piling sand in the disposal area (for future use)
- Beach disposal/dispersion of sand

These strategies have different pros and cons, so the preferred strategy will need to be selected in collaboration with key stakeholders.

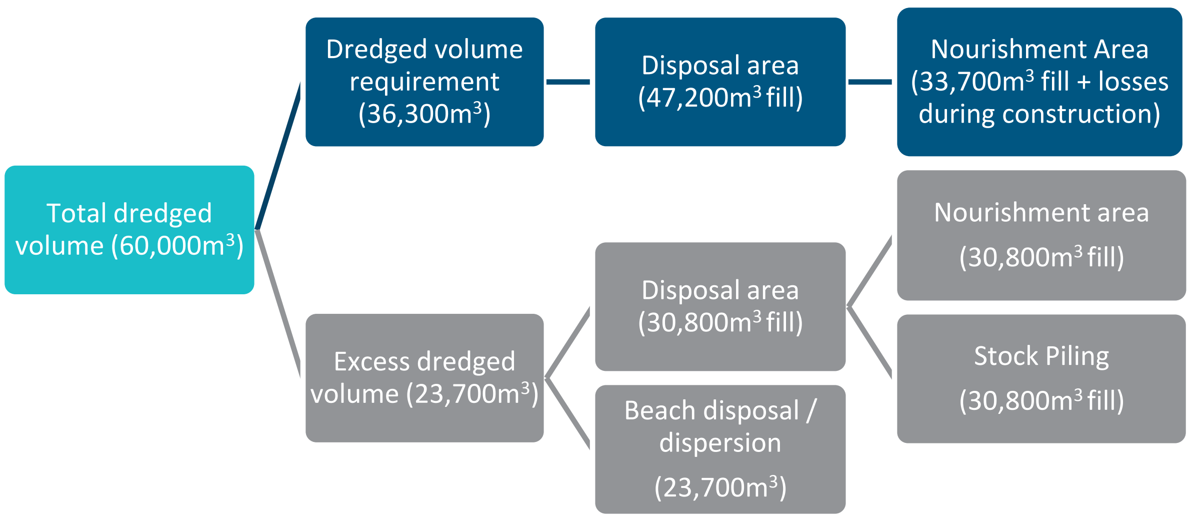


Figure 3.9: Holistic dredged material management process in Esperance bay. Grey branch to be defined in collaboration with DoT.

4 BACK-PASSING OPTION DEFINITION

A holistic sand management solution in Esperance Bay must consider the individual needs, objectives and constraints of both the Shire of Esperance and the Department of Transport, as defined previously in Section 2 and 3.

This section presents a number of solutions which address the holistic sand management problem. These solutions range from the Status-Quo option, which involves trucking on one hand and on the other dredging with temporary slurry pipes, to the fully integrated option, which involves only a dredging and sand back-passing system using permanently buried slurry pipes (i.e. no trucking).

Elaborating on the Castletown Beach sand management process introduced before (Figure 3.8), these options not only consider the supply of sand to the designated nourishment area, but also potential excess material disposal solution, e.g. onshore stock pile and beach dispersal at various distances (east and westward) form Bandy Creek Boat Harbor.

A brief description of the key activities encompassed in each option is provided hereafter, followed by a more detailed description of each individual option, including spatial representation and cost estimate. General environmental considerations applicable for each option are also provided.

4.1 Option summary

The options considered are summarised in Table 4-1, including CAPEX , OPEX and net present cost.

A comparative breakdown of activities for each option is also shown in Table 4-2

Layouts for each option are illustrated in Table 4-3

Table 4-1: Option summary

Category, option and description		CAPEX	OPEX (yearly eq.)	NPC (30yr, @1.7%)
Independent pumping (temporary pipes) & Trucking				
Option 0)	8.5km trucking + 1.4km pumping (temporary) + full beach dispersion @1.4kmEast	$0	$602,178	$14,139,056
Coordinated pumping (temporary pipes) & Trucking				
Option 1)	4.7km trucking + 0.3km pumping (temporary) + excess stock pile @0.3km	$0	$501,163	$11,767,235
Option 2)	2.4km trucking + 1.0km pumping (temporary) + excess beach dispersion @1.0kmWest	$0	$538,233	$12,637,620
Option 3)	2.0km trucking + 1.4km pumping (temporary) + excess beach dispersion @1.4kmWest	$0	$613,541	$14,405,856
Coordinated pumping (temporary pipes)				
Option 4a)	3.5km pumping (temporary) + excess beach dispersion @3.5kmWest	$211,000	$663,923	$15,799,801
Option 4b)	3.5km pumping (temporary) + excess beach dispersion @1.4kmWest	$211,000	$584,651	$13,938,505
Option 4c)	3.5km pumping (temporary) + excess beach dispersion @1.0kmWest	$211,000	$557,043	$13,290,279
Option 4d)	3.5km pumping (temporary) + excess beach dispersion @0.3kmWest	$211,000	$566,788	$13,519,098
Option 4e)	3.5km pumping (temporary) + excess beach dispersion @1.0kmEast	$211,000	$587,077	$13,995,469
Option 4f)	3.5km pumping (temporary) + excess beach dispersion @1.4kmEast	$211,000	$615,330	$14,658,859
Coordinated pumping (permanent buried pipes)				
Option 5a)	3.5km pumping (permanent) + excess beach dispersion @3.5kmWest	$1,416,843	$557,634	$14,509,990
Option 5b)	3.5km pumping (permanent) + excess beach dispersion @1.4kmWest	$1,416,843	$490,569	$12,935,325
Option 5c)	3.5km pumping (permanent) + excess beach dispersion @1.0kmWest	$1,416,843	$462,236	$12,270,061
Option 5d)	3.5km pumping (permanent) + excess stock pile @0.3km	$1,416,843	$481,642	$12,725,728
Coordinated pumping (permanent pipes)				
Option 5e)	3.5km pumping (permanent) + excess beach dispersion @1.0kmEast	$1,416,843	$481,493	$12,722,218
Option 5f)	3.5km pumping (permanent) + excess beach dispersion @1.4kmEast	$1,416,843	$520,688	$13,642,507

Table 4-2: Summary breakdown of activities and options

Scenario		Placing	Trucking	Excavating	Stock piling	Beach disposal	Hydraulic pumping (West)	Hydraulic pumping (West)	Dredging (BCBH)	Hydraulic pumping (East)	Beach disposal
Category	Option	Nourishment area (700m long)	Local road or beach	Disposal area	Disposal area	Free outfall	Booster pump #2 (2.2 - 3.5km)	Booster pump #1 (1.0 - 2.2km)	Dredge pump (0 - 1.0km)	Booster pump #1 (1.0 - 2.2km)	Free outfall
Independant pumping (temporary pipes) & Trucking	0	47,200m^3 Castletown Beach	47,200 m^3 8.5km	47,200 m^3 Land fill at Wylie Bay	47,200 m^3 Land fill at Wylie Bay				60,000m^3 1.4km		Beach east of Bandy Creek
Coordinated pumping (temporary pipes) & Trucking	1	47,200m3 Castletown Beach	47,200m3 4.7km	47,200m3 Hind dunes at BCBH near Daw Dr	78,000m3 0.3kmWest - Hind dunes at BCBH near Daw Dr				60,000m^3 0.3km		
	2	47,200m^3 Castletown Beach	47,200m^3 2.4km	47,200m^3 1.0kmWest - Hind dunes near Ormonde Cl	47,200m^3 1.0kmWest - Hind dunes near Ormonde Cl	23,700m^3 1.0kmWest - Beach near Ormonde Cl			60,000m^3 1.0km		
	3	47,200m^3 Castletown Beach	47,200m^3 2.0km	47,200m^3 1.4kmWest - Fore dunes at near Chaplin St	47,200m^3 1.4kmWest - Fore dunes at near Chaplin St	23,700m^3 1.4kmWest - Beach near Chaplin St		60,000m^3 1.4km			
Coordinated pumping (temporary pipes)	4a	78,000m^3 Castletown Beach				60,000m^3 3.5kmWest - Beach near Goldfields Rd	60,000m^3 3.5km				
	4b	47,200m^3 Castletown Beach					36,300m^3 3.5km				
						23,700m^3 1.4kmWest - Beach near Chaplin St		23,700m^3 1.4km			
	4c	47,200m^3 Castletown Beach					36,300m^3 3.5km				
						23,700m^3 1.0kmWest - Beach near Ormonde Cl			23,700m^3 1.0km		
	4d	47,200m^3 Castletown Beach					36,300m^3 3.5km				
					30,800m^3 0.3kmWest - Hind dunes at BCBH near Daw Dr				23,700m^3 0.3km		
	4e	47,200m^3 Castletown Beach					36,300m^3 3.5km				
									23,700m^3 1.0kmEast		23,700m^3 1.0kmEast - Beach east of Bandy Creek
	4f	47,200m^3 Castletown Beach					36,300m^3 3.5km				
									23,700m^3 1.4kmEast		23,700m^3 1.4kmEast - Beach east of Bandy Creek
Coordinated pumping (permanent burried pipes)	5a	78,000m^3 Castletown Beach				60,000m^3 3.5kmWest - Beach near Goldfields Rd	60,000m^3 3.5km				

Scenario		Placing	Trucking	Excavating	Stock piling	Beach disposal	Hydraulic pumping (West)	Hydraulic pumping (West)	Dredging (BCBH)	Hydraulic pumping (East)	Beach disposal
Category	Option	Nourishment area (700m long)	Local road or beach	Disposal area	Disposal area	Free outfall	Booster pump #2 (2.2 - 3.5km)	Booster pump #1 (1.0 - 2.2km)	Dredge pump (0 - 1.0km)	Booster pump #1 (1.0 - 2.2km)	Free outfall
	5b	47,200m^3 Castletown Beach					36,300m^3 3.5km				
						23,700m^3 1.4kmWest - Beach near Chaplin St		23,700m^3 1.4km			
	5c	47,200m^3 Castletown Beach					36,300m^3 3.5km				
						23,700m^3 1.0kmWest - Beach near Ormonde Cl			23,700m^3 1.0km		
	5d	47,200m^3 Castletown Beach					36,300m^3 3.5km				
					30,800m^3 0.3kmWest - Hind dunes at BCBH near Daw Dr				23,700m^3 0.3km		
Coordinated pumping (mixed pipes)	5e	47,200m^3 Castletown Beach					36,300m^3 3.5km				
									23,700m^3 1.0kmEast		23,700m^3 1.0kmEast - Beach east of Bandy Creek
	5f	47,200m^3 Castletown Beach					36,300m^3 3.5km				
									23,700m^3 1.4kmEast		23,700m^3 1.4kmEast - Beach east of Bandy Creek

Table 4-3: General layouts for each option

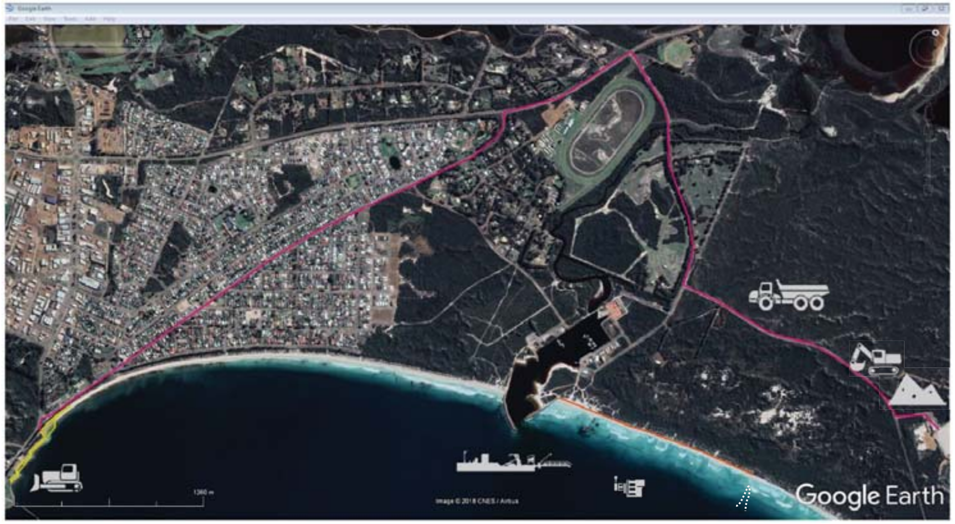
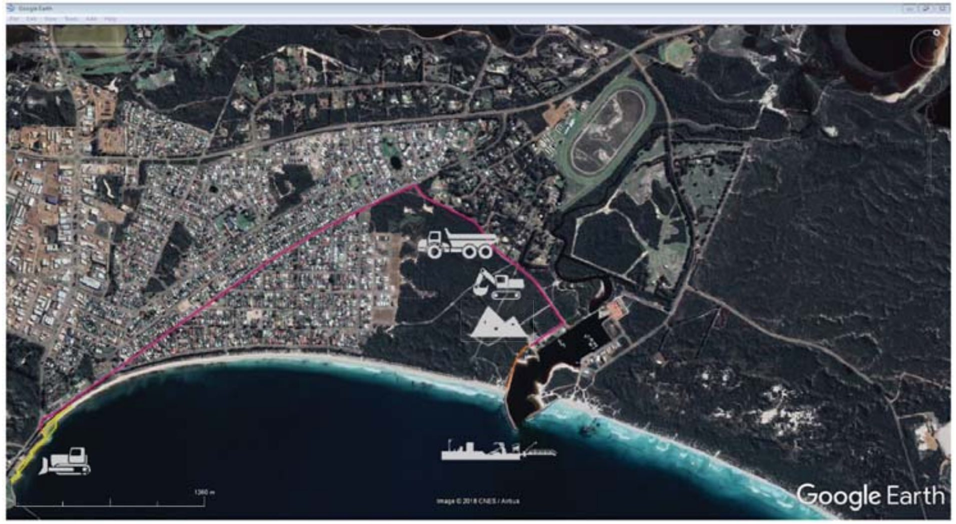
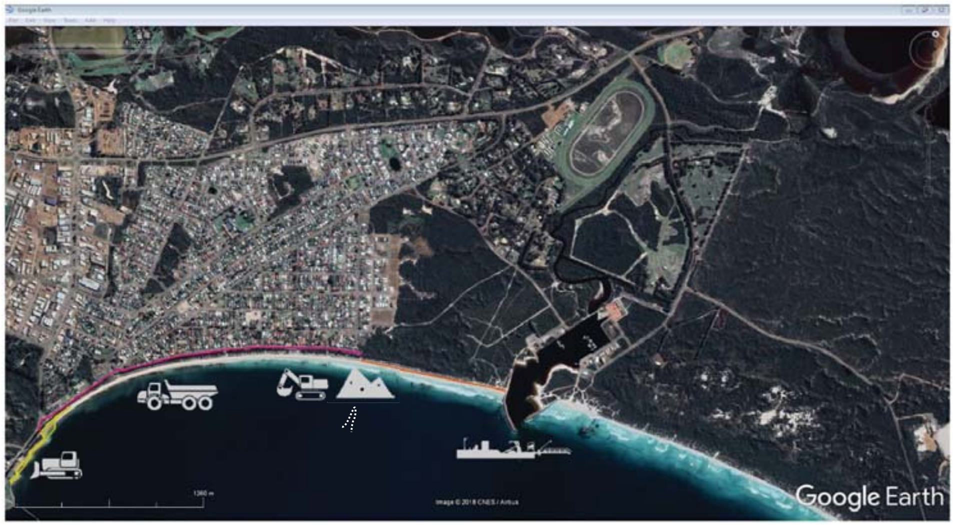
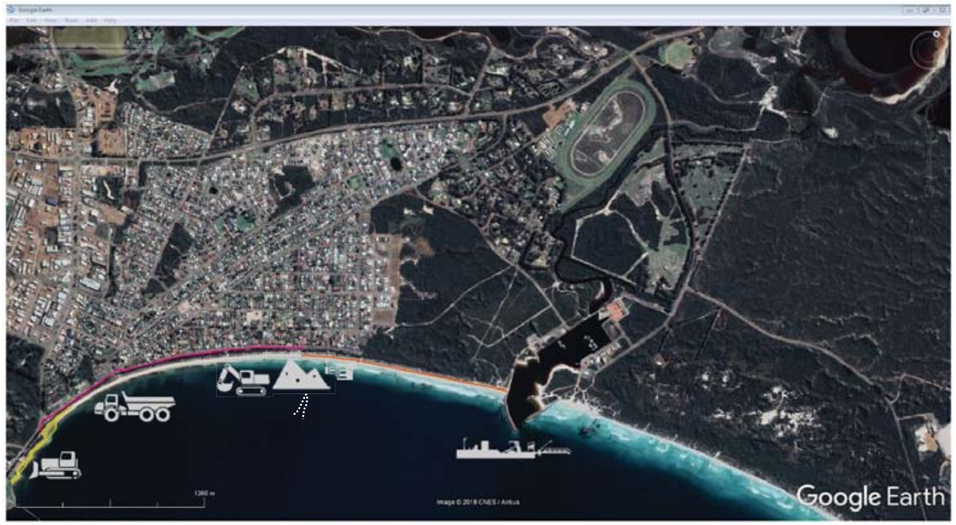
 **Option 0) 8.5km trucking + 1.4km pumping (temporary) + full beach dispersion @1.4kmEast**	 **Option 1) 4.7km trucking + 0.3km pumping (temporary) + excess stock pile @0.3km**
 **Option 2) 2.4km trucking + 1.0km pumping (temporary) + excess beach dispersion @1.0kmWest**	 **Option 3) 2.0km trucking + 1.4km pumping (temporary) + excess beach dispersion @1.4kmWest**

Table 4-3 (cont.)

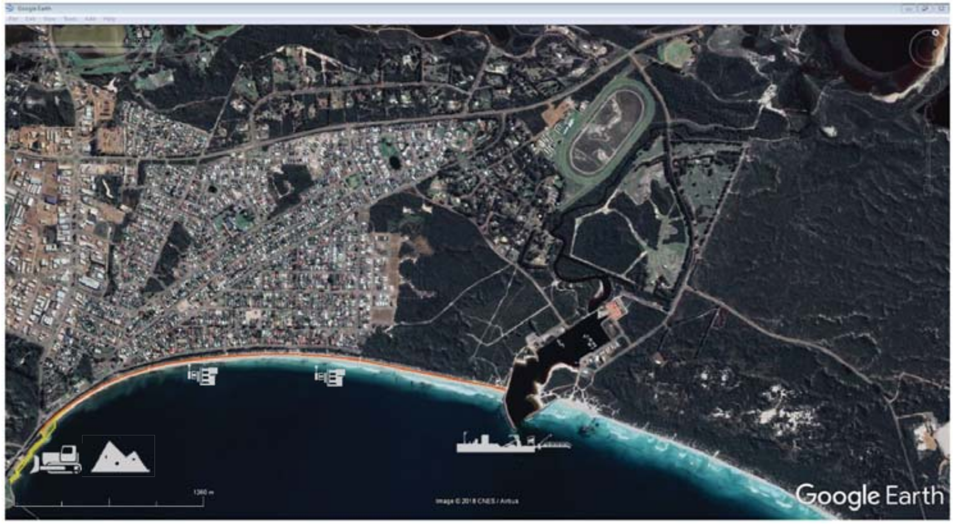
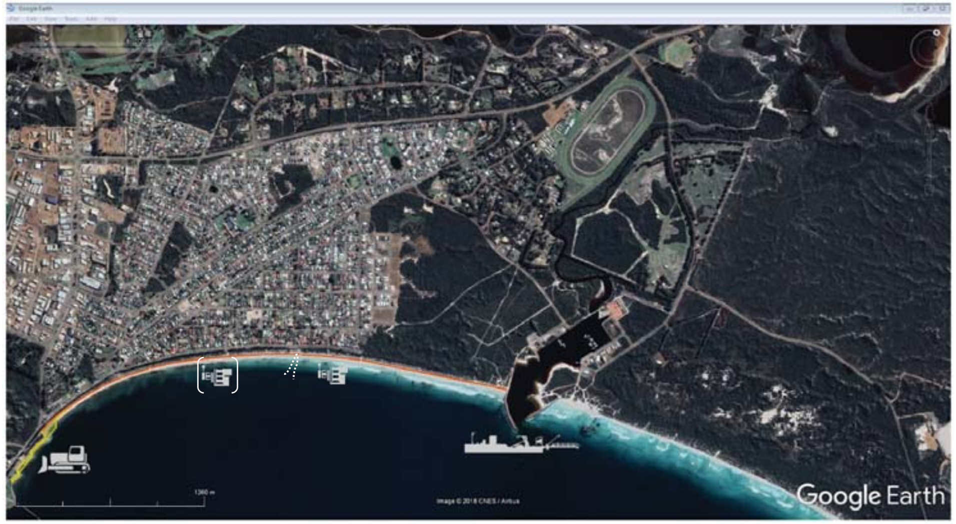
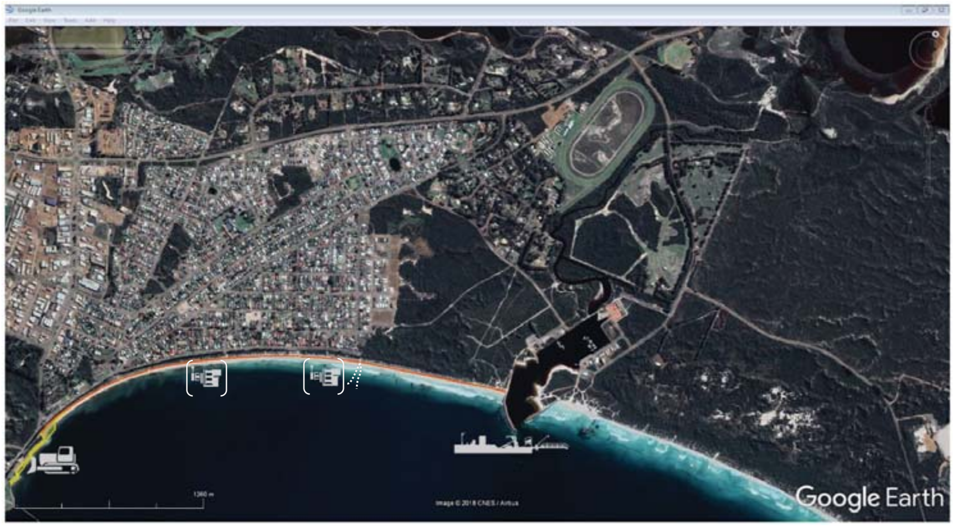
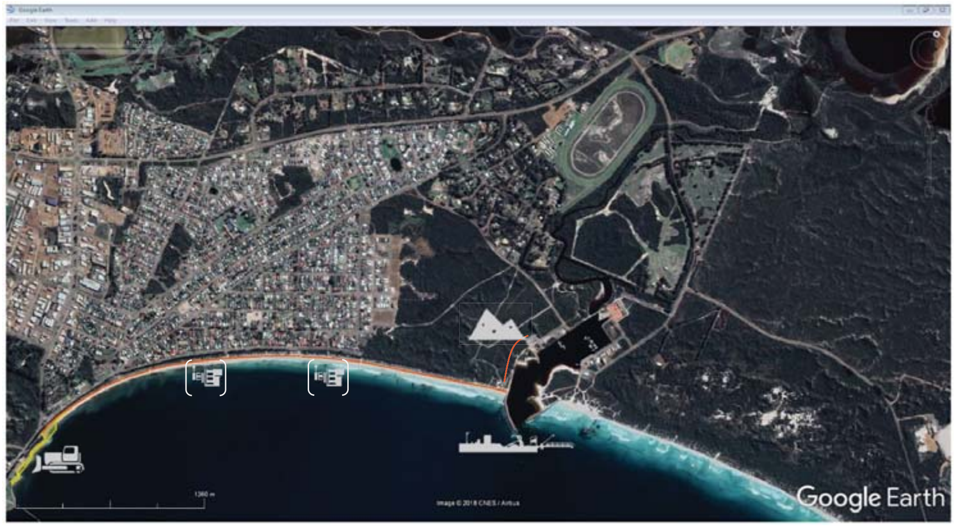
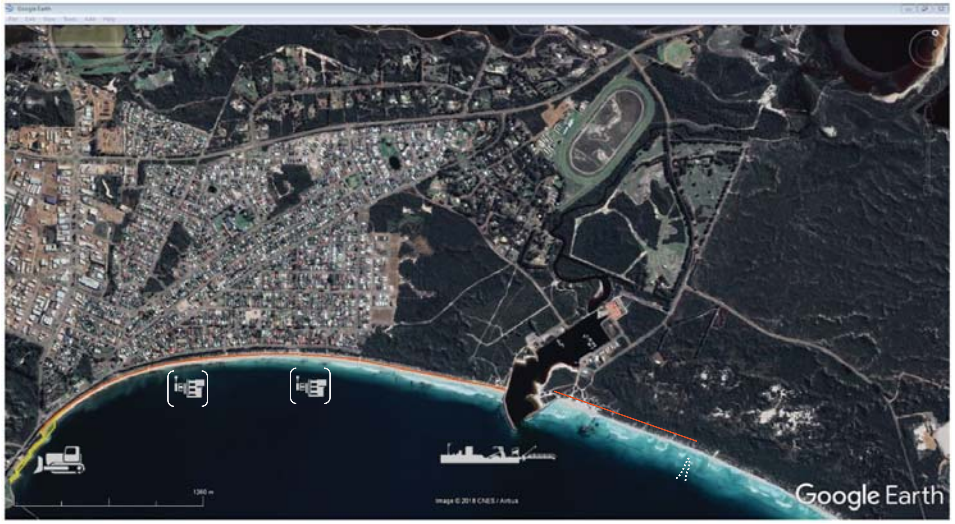
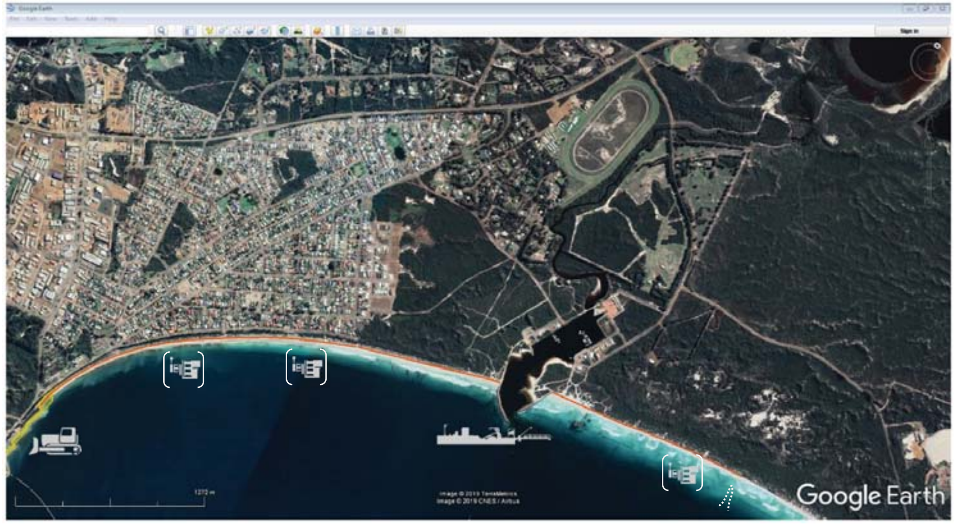
 Option 4a) 3.5km pumping (temporary) + excess beach dispersion @3.5kmWest	 Option 4b) 3.5km pumping (temporary) + excess beach dispersion @1.4kmWest
 Option 4c) 3.5km pumping (temporary) + excess beach dispersion @1.0kmWest	 Option 4d) 3.5km pumping (temporary) + excess beach dispersion @0.3kmWest

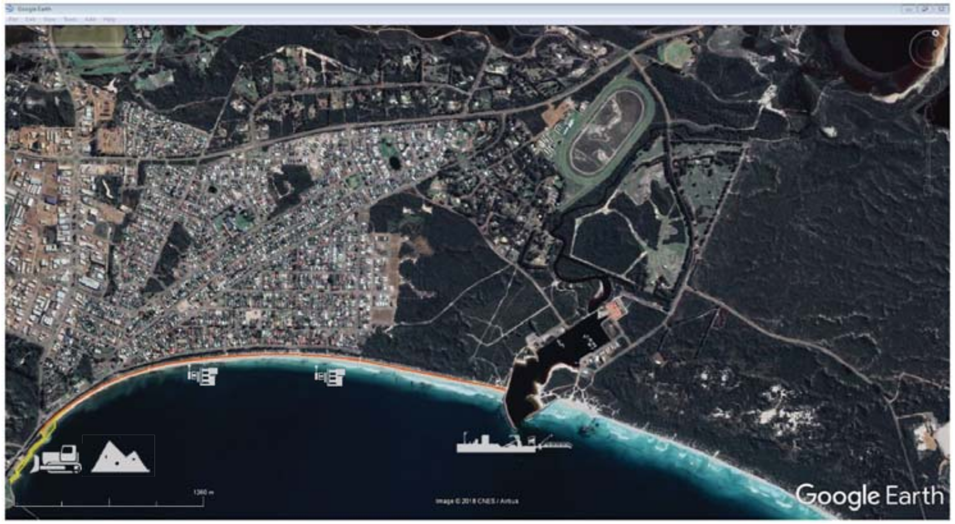
Table 4-3 (cont.)



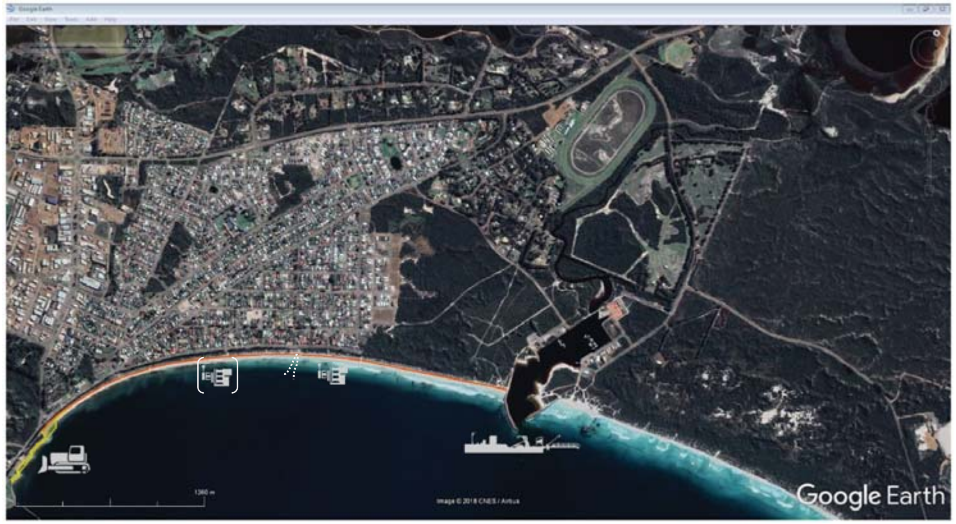
Option 4e) 3.5km pumping (temporary) + excess beach dispersion @1.0kmEast



Option 4f) 3.5km pumping (temporary) + excess beach dispersion @1.4kmEast

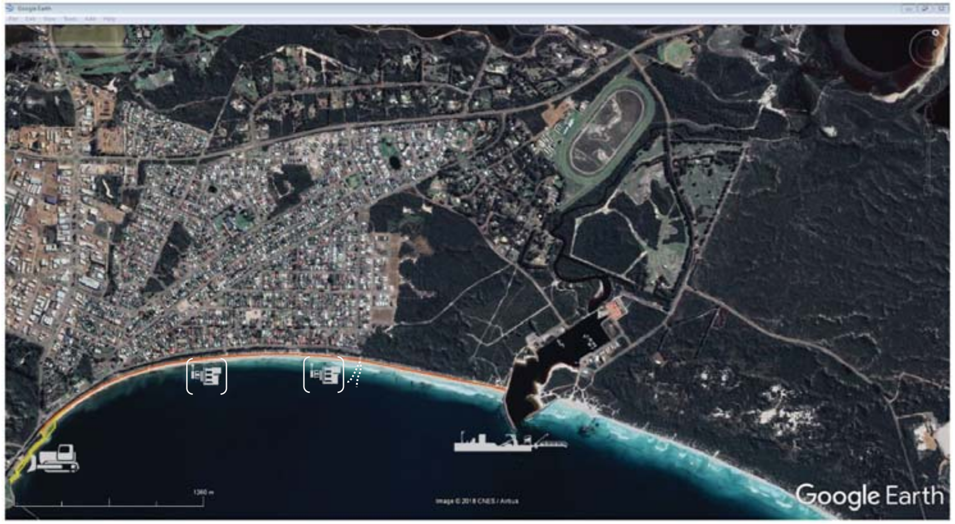
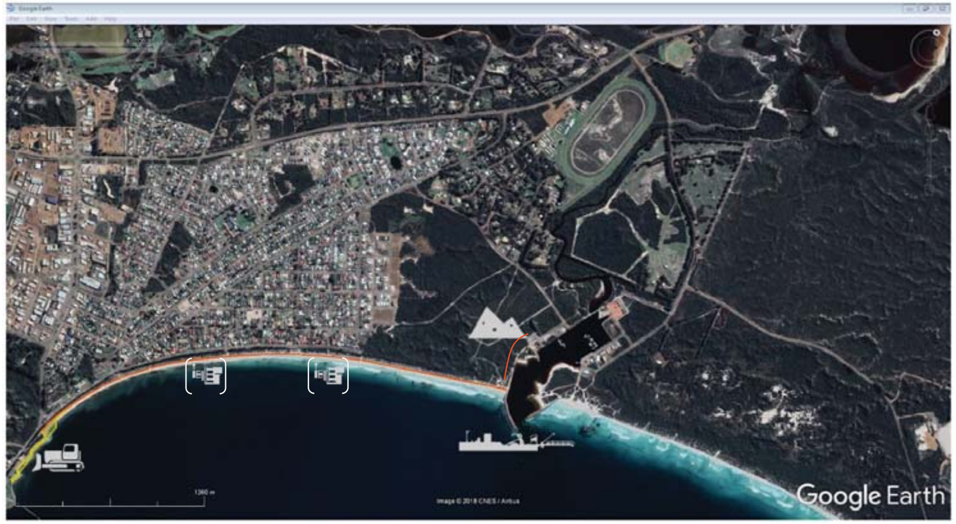
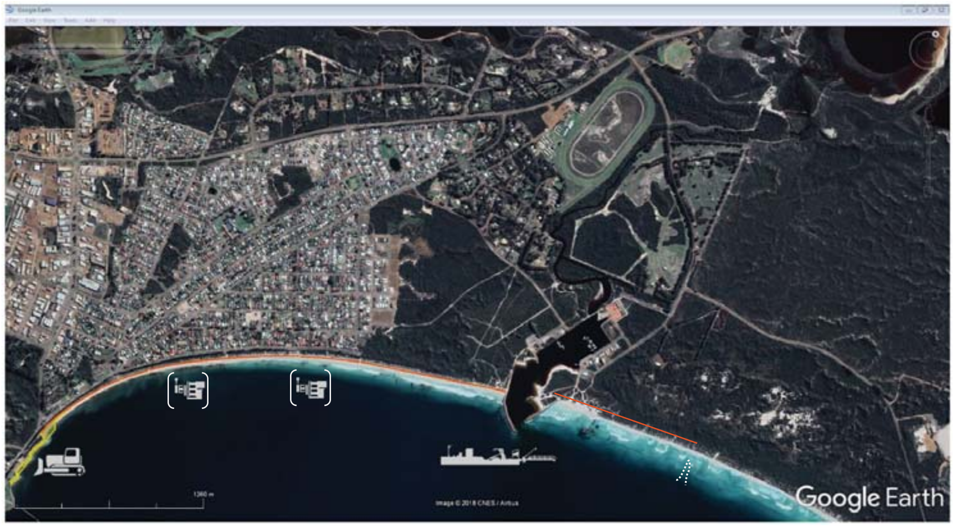
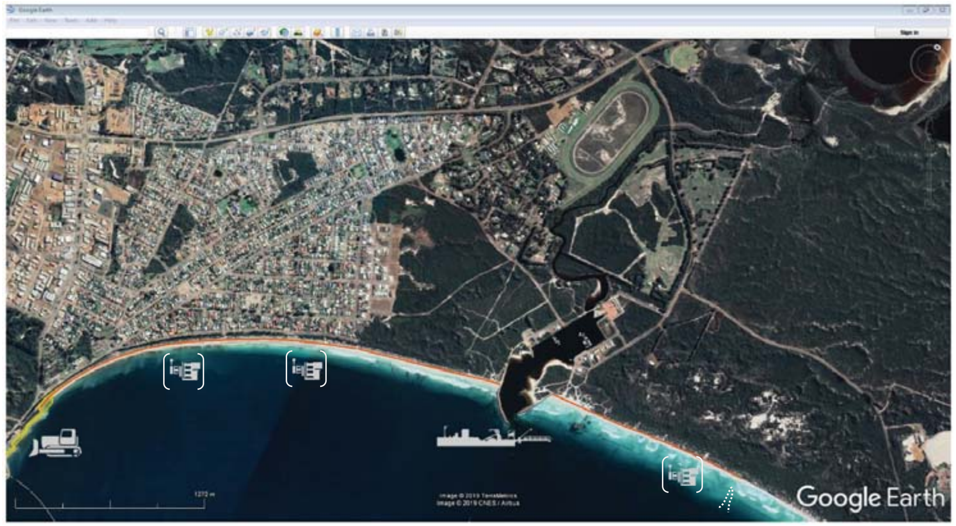


Option 5a) 3.5km pumping (permanent) + excess beach dispersion @3.5kmWest



Option 5b) 3.5km pumping (permanent) + excess beach dispersion @1.4kmWest

Table 4-3 (cont.)

 Option 5c) 3.5km pumping (permanent) + excess beach dispersion @1.0kmWest	 Option 5d) 3.5km pumping (permanent) + excess stock pile @0.3kmWest
 Option 5e) 3.5km pumping (permanent) + excess beach dispersion @1.0kmEast	 Option 5f) 3.5km pumping (permanent) + excess beach dispersion @1.4kmEast

4.2 Typical activities

4.2.1 Dredging and hydraulic pumping

Dredging and hydraulic pumping activities are core activities to undertake required maintenance dredging of Bandy Creek Boat Harbour. For example, dredging and hydraulic pumping is currently implemented by DoT (Option 0) and involves a small cutter suction dredge, one booster pump and 1.4km of temporary pipes with the capability to pump 60,000m^3 of sand to the East of Bandy Creek Boat Harbour – a two yearly operation estimate at [redacted] pa equivalent.

Dredging and hydraulic pumping activities are present across all the options considered, with the pumping distance may vary between 0.3km and 3.5km. So, the overall dredging cost may also vary, reflecting the cost of mobilisation/demobilisation and running cost of the dredged, boosters and pipes. In addition to the cost of mobilising the equipment, the method can offer the possibility to use temporary pipes, permanent buried pipes or a combination of both.

The baseline specification of the dredging and pumping method is well understood at the site, however some alteration of the method implemented by DoT will be required to reflect potential changes in pumping distance, disposal method and the permanent use of buried infrastructure.

4.2.2 Beach disposal/dispersion

Beach disposal/dispersion consists of discharging the sand slurry directly on the beach in a controlled but uncontained manner, so the dredged materials freely return to the beach and get dispersed by local coastal processes. In addition, the beach disposal option enables disposal of lower quality sand and seagrass mixtures. This is the disposal method adopted by DoT during the maintenance dredging at BCBH, where the dredged sand is dispersed 1.4km to the East of Bandy Creek Boat Harbour.

It is assumed that no additional cost (excluding the dredging and pumping cost) is incurred for implementing beach disposal/dispersion.

4.2.3 Stock piling

Stock piling may be required to optimise the sand management process or simply to enable further use of the dredged material at a later stage. This method would consist of creating a bunded area to receive the sand slurry and enable excess water to return to the sea, thus retaining quality sand fill in a contained area for later use. The dewatered sand can later be rehandled and transported to the site of interest site (using an excavator and truck). Defining a strategic location for siting the stock pile is therefore paramount as it should enhance the sand management process and be accepted be key stakeholders.

A nominal cost allowance for the preparation of the site was assumed when considering stock piling.

4.2.4 Excavating, trucking & placing

Excavating and trucking activities are required to load and transport sand from the sand supply area (e.g. pit, stock pile) to the disposal or nourishment area. Placing activities are required to move the sand fill in accordance with proposed nourishment area construction profile. As shown in Table 4-2, the placement method in the nourishment area is common to all the options considered hereafter, so it is not a differentiator between options in this study.

For example, excavating, trucking and placing is currently implemented by the Shire (Option 0). It involves excavating from Wylie Bay land fill, trucking sand 8.5km to Castleton Beach, and placing in the nourishment area, which is done in parallel of the supply of sand fill. This currently a frequent operation taking place every 3-4 months and estimated at $185,000pa (for a volume of fill of 18,500m^{3}pa).

Excavating and trucking activities are included is some of the options considered, with the trucking distance varying between 8.5km and 2.0km. Options involving no trucking at all are also considered. Placing activity is included as a cost in all option, but it is not a differentiating activity.

The baseline cost basis of the excavating, trucking and placing activities is well understood at the site, however some alteration of the method implemented by the Shire will be required to reflect trucking distance and adjusted for the volume of fill placed, as required.

4.3 Environmental considerations

4.3.1 All options

For all options presented, the following approvals and/or consultation with Determining Authority are required:

- Native Vegetation Clearing Permit (NVCP) from Department of Water and Environmental Regulation (DWER) for the destruction/killing of native vegetation for access, laydown areas, stockpiling sand etc. The requirement to obtain a NVCP can be assessed following detailed design and the approval timeframe is ~3–6 months – previously the Shire of Esperance mentioned there was an existing native vegetation purpose permit available for Shire maintenance that allowed clearing of up to 1 ha (to be confirmed).
- Esperance Tjaltjraak Native Title Aboriginal Corporation (ETNTAC) approval – Proponents operating with the ETNTAC Determination Area of an Indigenous Land Use Agreement (see below Figure) are required to consult and obtain approval from ETNTAC. This could involve ethnographic/archaeological surveys. Proponents are required to submit an Activity Notice providing details of the Scope of Works to the ETNTAC. Within 28 days the ETNTAC will advise if the works can proceed with or without conditions, or if Heritage surveys are required prior to excavation/disturbance. If Heritage surveys are required, this may take an additional 2-3 months to complete and is a variation to the initial scope.
- The Boat Harbour was recently listed as a Registered Aboriginal Heritage Site and it is now protected under the *Aboriginal Heritage Act 1972* (AH Act). Department of Transport (DoT) was required to obtain an exemption (from the AH Act) to facilitate maintenance dredging campaigns for the life of the Boat Harbour through a Section 18 notice. Approval is pending, however; DoT obtained ETNTAC approval (dot point 1) and it is likely the Section 18 approval will also be provided, with conditions to have in place cultural monitors or contractors with appropriate training in identification of artefacts. Consultation may be required with Department of Planning, Lands and Heritage (DPLH) to discuss the scope changes with the Shires proposed design.

Figure 4.1: Esperance Tjaltjraak Native Title Aboriginal Corporation (■).

4.3.2 Stock piling

Stockpiling onshore may require a licence or works approval under the Environmental Protection Regulations 1987. This can be further considered following detailed design.

4.3.3 Placement

It is preferable to place the material landward of the low water mark to avoid flagging Sea Dumping requirements. The low water mark for the Shire of Esperance project area is shown in Figure 4.2. The data is collected from Landgate. Any operations landward of the low water mark **will not** flag the requirement for permit under the *Environmental Protection (Sea Dumping) Act 1981.*

There is potential to smother nearshore seagrass communities with the placement of material at the disposal area. If direct impacts (through removal or smothering) are anticipated with placement of material, a NVCP may be required (seagrass is protected aquatic native vegetation). Alternatively, if it is anticipated material will be entrained with natural sediment transport processes and unlikely to smother habitats, this can be monitored through surveys.

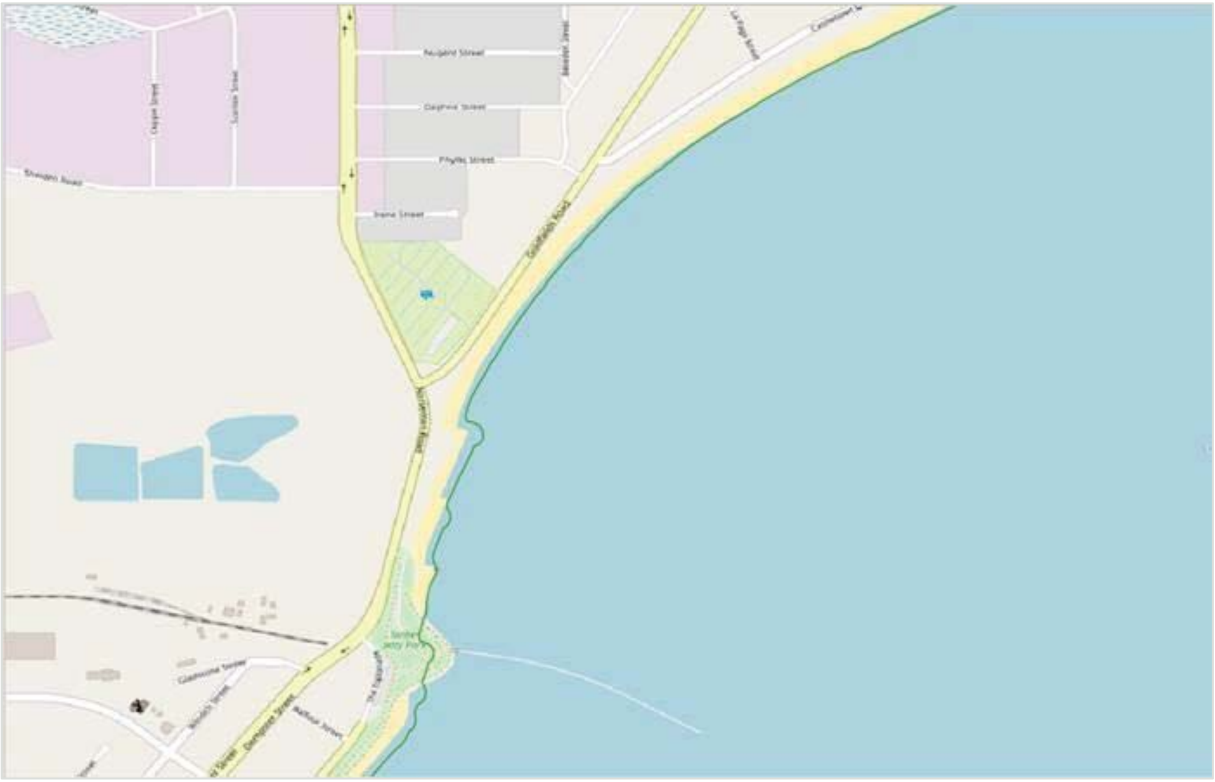


Figure 4.2: Low water mark (—).

4.3.4 Sediment quality

Sediment samples were collected in numerous locations in Bandy Creek Boat Harbour in 2013 and on the eastern beach in 2018, as shown in Figure 4.3 respectively. These samples were collected two years after the dredging campaigns that took place in 2011 and 2015 respectively.

The sediment samples are representative of the sediment quality to be dredged in the harbour channel (as part of the main scope of dredging and proposed to be used for Castleton beach nourishment) and of the natural beach sand found on Esperance Bay beaches (including Castleton beach).

Samples were analyzed for particle size distributions (PSD) as shown in Figure 4.4. The PSD results shows strong similarities, with most sediment being classified as Medium Sand.

So, there is a good compatibility between the sand proposed for the beach nourishment and the natural beach sand.

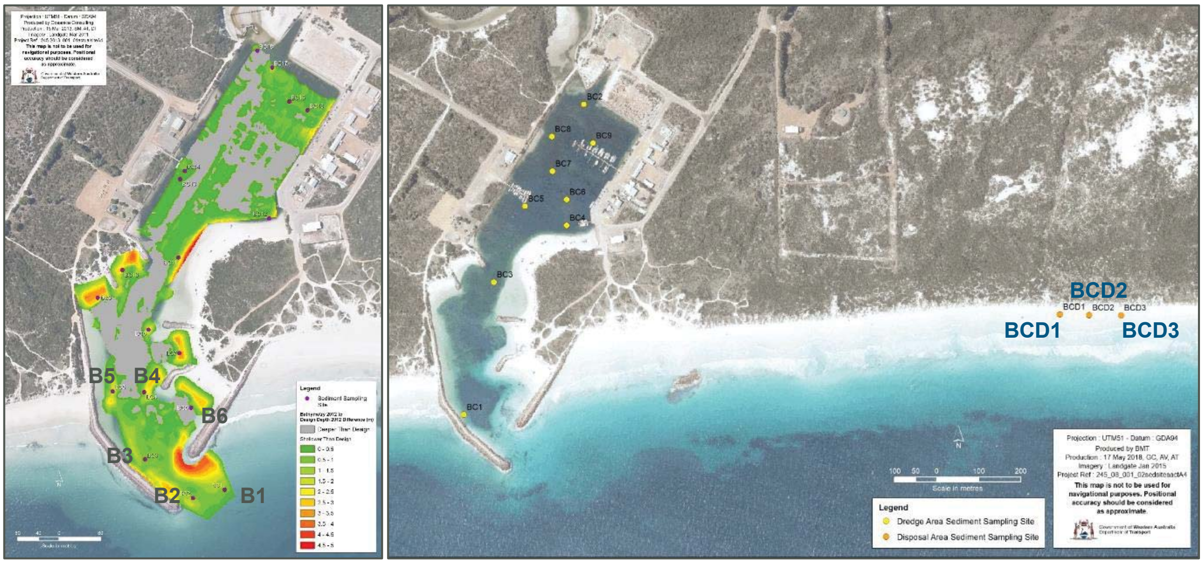


Figure 4.3: Sediment sample locations for 2013 (left) and 2018 (right) survey.

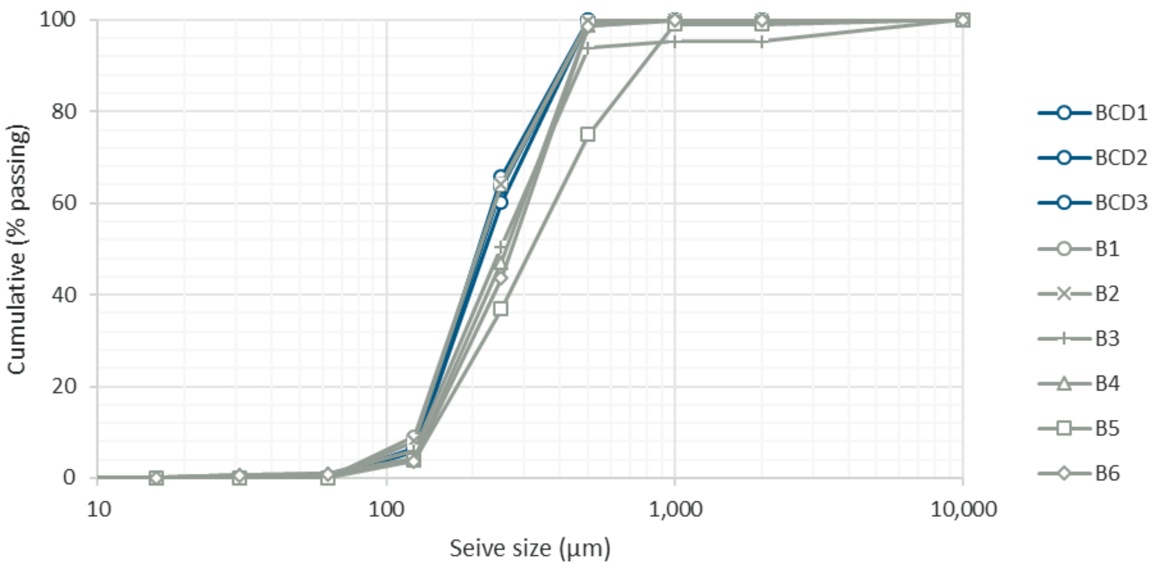


Figure 4.4: Particle size distribution in the harbour (channel area, B_i) and beach (disposal area, BCD_i).

4.4 Cost estimates

4.4.1 Benchmark

Cost for all the option considered were estimated based on the cost of equipment (e.g. dredging, pumping, pipes, trucking, placement) and activities (e.g. mobilisation, installation and operation) inferred from similar projects and site-specific contractor estimates.

Costs were also benchmarked against the DoT contract and the Shire recent experience. For example, the range of volume considered, a nominal $10/m^3 for loading, trucking 8.5km and placement was used and adjusted for methodology variation. Also, dredging rates were varying in the range $6.5-$16 per m^3 and mobilisation/demobilisation cost ranged between $95,000 and $270,000, depending on the dredging & pumping configuration.

Although most of the dredging & pumping operation could be undertaken within the current DoT contractor capability, addition capital items had to be considered included:

- Temporary pipe extra length (1.5km): $211,000
- Permanent pipeline and installation (3.5km): $1,417,000

These costs are preliminary estimates and they should be refined based on more detailed scope and specifications when available.

4.4.2 Baseline adjustments

The cost estimate of the status quo option was adjusted to reflect the required nourishment volume as per the proposed design i.e. 47,200m^3 of sand fill (a 27% increase from the 37,000m^3 historically placed every two years), thereby forming the baseline scenario to compare alternative options against.

Also, the total dredged volume costed was for the main scope of work in the navigation channel, i.e. 60,000m^3. The cost of managing the dredged volume in excess of the required nourishment volume were also considered in the costs, by adjusting pumping methodology and cost accordingly.

4.4.3 Cost comparison

The Net Present Cost over 30 years (NPC) was calculated, including initial Capex and operational cost at the given frequency (i.e. two yearly for dredging and one yearly for baseline trucking operations). The real discount rate applied was 1.7%, which corresponds to a nominal rate of 4.2% when adjusting for 2.5% inflation. The OPEX was back calculated (using the NPC value) as a yearly OPEX equivalent to enable comparison between options.

Figure 4.5 illustrates the economics differences between the OPEX vs. NPC of each option. This graph shows a wide range of economic benefits, with the options sitting in the lower left corner enjoying better saving potential. For example:

- Option 5c - 3.5km permanent pumping and excess beach dispersion at 1.0km West of BCBH [CAPEX: $1,416,843] - has the lowest OPEX of all options and the second lowest NPC. Option 5c would result in saving of $139,943 (23%) annually and over $1.8M (13%) over the project's life. Despite the $1.4M CAPEX, this option is very cost effective by displacing the ongoing mob/demob cost via use of a permanent pipeline installation and removing all boosters (dredge only) to pump the excess dredged volume. The main source of uncertainty in this option is the impact of the excess beach dispersion (located at 1.0km west of BCBH) on the siltation regime in the harbour.
- Option 1 - 4.7km trucking and 0.3km temporary pumping and excess stock pile at 0.3km West of BCBH [CAPEX: $0] - has the second lowest OPEX of all options and the lowest NPC. Option 1 would result in savings of $101,015 (17%) annually and over $2.3M (17%) over the project's life. Despite an appealing economic profile and no CAPEX, Option 1 involves trucking through town and stock piling in BCBH area, which is not the most appealing option from a social and environmental stand point.

These extreme examples illustrate both the benefit of considering both the OPEX and whole of life cost when evaluating option economics, while stressing the importance of other criteria, such as stakeholder impact, when assessing options.

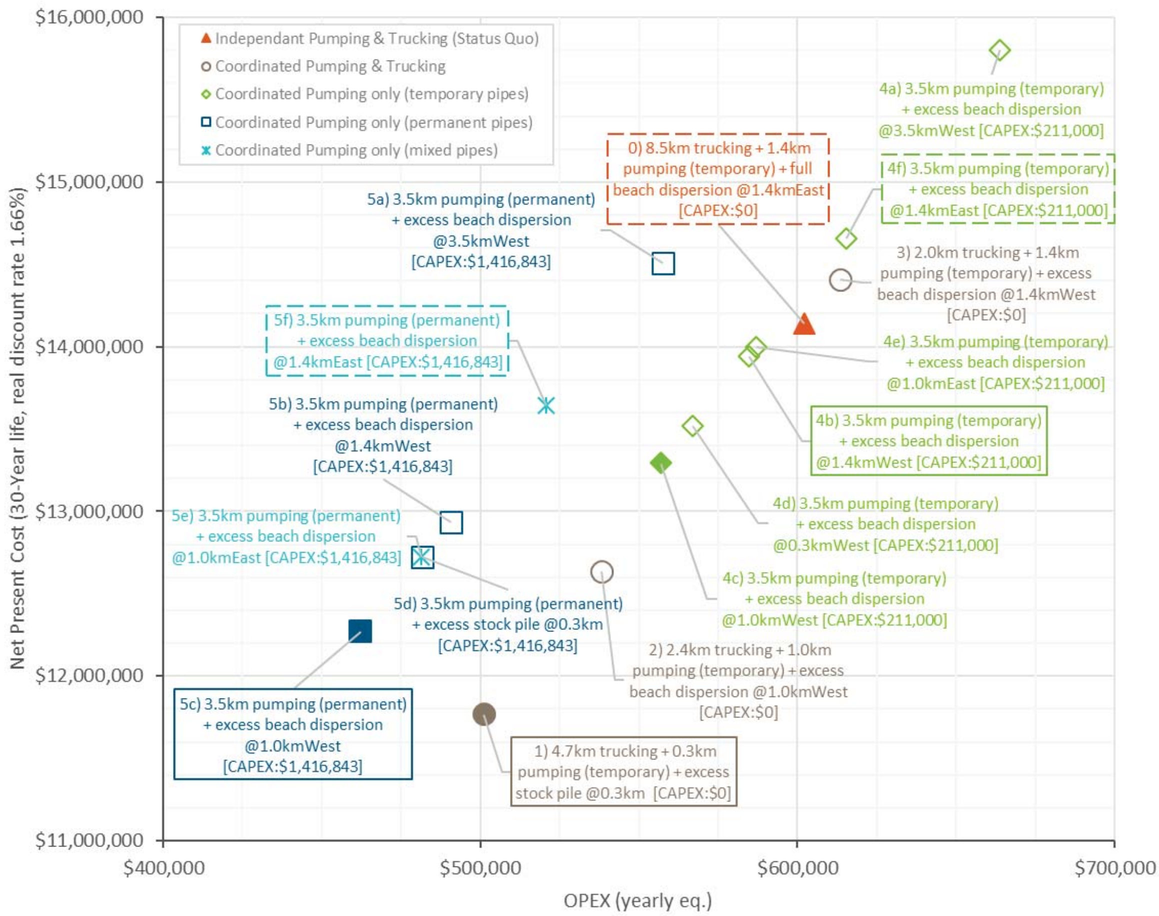


Figure 4.5 Option cost comparison: OPEX versus Net Present Cost.

4.5 Cost/benefit sharing indication

An indicative economic cost/benefit sharing estimate for the cheapest OPEX option was undertaken. This was obtained by calculating the Shapley value for the characteristic function given for the various coalitions formed by DoT Maintenance Dredging, DoT Coastal Management and Shire of Esperance, as shown in Table 4-4.

This exercise demonstrates the substantial economic benefits for all the parties involved, i.e. approximately $280,000 savings every two years, e.g. $130, 000 savings for DoT and $150,000 savings for the Shire. This approach illuminates the high-level cost structure of the deal and where the savings are coming from, but it does not capture the full value received by the members of the coalition, such as social and political benefits (e.g. removing trucking operation in town, inter-governmental agency collaboration, cost effective).

Table 4-4: Indicative cost saving potential and benefit sharing*: Orange cells obtained from project data and engineering estimates; Grey cells inferred from Shapely value for the given characteristic function.

Status Quo - Independent operations	OPEX (every two years)	Department of Transport	Shire of Esperance	Total
	Maintenance Dredging	[redacted]	[redacted]	[redacted]
	Coastal Management	$200,000	$267,948	$467,948
	Total	[redacted]	[redacted]	[redacted]

Option 5c) 3.5km pumping (permanent) + excess beach dispersion @1.0kmWest [CAPEX : $1,416,843]	OPEX (every two years)*	Department of Transport	Shire of Esperance	Total
	Maintenance Dredging	[redacted]	[redacted]	[redacted]
	Coastal Management	$85,458	$119,432	$204,890
	Total	[redacted]	[redacted]	[redacted]

Indicative economic benefits of the coalition*	OPEX* saving	Department of Transport	Shire of Esperance	Total
(*) Cost/benefit sharing using Shapley value	Total	$129,084	$148,516	$277,601

Characteristic function	
Member	**Description**
A	DoT Maintenance Dredging
B	Shire of Esperance
C	DoT Coastal Management
Coalitions	**Cost**
A	[redacted]
B	$267,948
C	$200,000
AB	[redacted]
BC	$467,948
AC	[redacted]
ABC	[redacted]

5 SAND BACK-PASSING OPTION APPRAISAL

5.1 Multi-criteria assessment

A multi-criteria assessment was undertaken to appraise each option against various dimensions, including social, technical, environmental, economic, political, legal and ethical.

5.1.1 Rating scale

A common rating scale was developed in the process, ensuring robustness and consistency of the results across options, as shown in Table 5-1.Essentially, the social criteria considered the issues of Beach access, Public safety, Community perception and Noise impact, which are largely biased against trucking operations and temporary installation.

The technical criteria considered the performance, complexity and risk inherent to the design and construction. They tend to penalize mobilization and demobilization activities, the use of bund and siltation risk related to beach disposal in proximity of the BCBH.

The economic criteria are quantitatively based on the cost estimated previously for CAPEX , OPEX, and NPV.

The environmental criteria cover aspects related to sea dumping, native vegetation clearance, waste regulation, heritage & native title. These are weakly differentiating between options. They tend to penalize stock piling and “oversized” nourishment, which may flag onerous permitting or licensing requirements.

The political criteria favor meaningful inter-governmental collaboration, money well spent, good story potential.

The ethical criterion focused on the sustainability of the method, thus penalizing the use of landfill and unidirectional (to the West only) pumping.

5.1.2 Core analysis

A core analysis was performed based on our specialist understanding of what each individual option entails and considering the perspective of key stakeholders, as shown inTable 5-1 and Table 5-2.

In the core analysis, each individual criterion was equally weighted with a value of 1, so the equal normalized weight was 5.9% (1/17). The top 5 highest ranking options identified from the core analysis were:

- Rank 1st: Option 5e) 3.5km pumping (permanent) + excess beach dispersion @1.0kmEast [CAPEX: $1,416,843]
- Rank 2nd: Option 5c) 3.5km pumping (permanent) + excess beach dispersion @1.0kmWest [CAPEX :$1,416,843]
- Rank 3rd: Option 5f) 3.5km pumping (permanent) + excess beach dispersion @1.4kmEast [CAPEX: $1,416,843]
- Rank 4th: Option 5b) 3.5km pumping (permanent) + excess beach dispersion @1.4kmWest [CAPEX: $1,416,843]
- Rank 5th: Option 5d) 3.5km pumping (permanent) + excess stock pile @0.3km [CAPEX: $1,416,843]

5.1.3 Sensitivity analysis

A sensitivity analysis (as shown in Table 5-3) was also undertaken to evaluate the robustness of the core analysis results.

In the sensitivity analysis, the weight of each individual criteria was randomly assigned a value between 1 and 10 to reflect the diversity of possible preferences by various stakeholders. The averaged normalized weight remained 5.9% (1/17), but the minimum (resp. maximum) weight assigned to an individual criterion was 0.8% (resp. 16.9%). The top 5 highest ranking options were similar as the one identified by the core analysis. The sensitivity analysis also shows that the potential rank spread is relatively narrow for the top 4 options, while the option rank 5th spread is broader. The overlap between the spreads is also relatively small.

5.2 Preferred option(s)

5.2.1 MCA results

The MCA results indicate that the absolute and relative ranking of the options considered is robust, and swings induced by stakeholder preferences re-weighting are unlikely for the highest-ranking options.

The permanent pumping methods rank overwhelmingly higher than the other option involving trucking. The top two options seem particularly appealing:

- Rank 1st: Option 5e) 3.5km pumping (permanent) + excess beach dispersion @1.0kmEast [CAPEX : $1,416,843]
- Rank 2nd: Option 5c) 3.5km pumping (permanent) + excess beach dispersion @1.0kmWest [CAPEX : $1,416,843]

The key difference between these options is the location of the beach disposal for the excess dredged material. This leads to small distinctions in the MCA:

- Technically, from a design standpoint, the risk of increased siltation in the dredged channel is theoretically lower when disposing excess material to the east of BCBH; from a construction standpoint however disposing of excess material to the west of BCBH is more efficient and would not require the mobilisation (and demobilisation) of temporary pipes.
- Economically, the mobilisation (and demobilisation) of temporary pipes required for disposing excess material to the east of BCBH is more expensive than discharging the excess material from the permanent pipeline to the west of BCBH.
- Ethically, returning the excess material to the eastern beach of BCBH would be preferable and would reflect its contribution to the littoral drift in Esperance Bay.

So, if the siltation rate in BCBH and dredging rates are not significantly affected by the beach disposal activities taking place within 1km of BCBH, then there is a practical and economic incentive to pump the excess dredged material to the West using the dredge only (no booster).

Again, the key difference between the top two options and the options rank 3rd and 4th is the location of the beach disposal for the excess dredged material. In these cases, the beach disposal activities are taking place at 1.4km of BCBH, which is a similar distance as previously done for the regular BCBH dredging campaign, so it would alleviate concerns about the change in siltation rate in the harbour, especially those related to the beach disposal to the East of BCBH. For the beach disposal situated at 1.4km to the West of BCBH, the siltation risk is also lower than for the beach disposal situated at 1.0km to the West of BCBH. However, there will a need for a booster (in addition to the dredged) to achieve the pumping distance, thus penalising this option both in terms of social impact (noise) and economics (higher cost).

Finally, the option ranked 5th which involves stock piling at BCBH, should not be completely ruled out. Although it is currently penalised due to potentially onerous permitting and licensing requirements, it is one of the most cost-effective solution. In addition, there is potential revenue from the sale of sand from the stock pile. This could change the economics of this option by offsetting the cost of the operation with a 30,800m^3 sand resource valued at approximately $46,200, which is a potential yearly net gain of $23,100 not accounted for.

5.2.2 Department of Transport engagement

A stakeholder engagement meeting took place on the 28/02/2019 with the Department of Transport. The meeting presentation and minutes are attached in appendices.

The participant included:

- [redacted]: Manager Facility Operations | Department of Transport
- [redacted]: Manager Asset Management | Department of Transport
- [redacted]: Manager Coastal Management | Department of Transport
- [redacted]: Regional Facilities Coordinator | Department of Transport
- [redacted]: Maintenance Dredging Program Manager | Department of Transport / BMT
- [redacted]: Environment Permit & Approval | Department of Transport / BMT
- [redacted]: Project Manager | BMT / Shire of Esperance

The purpose of the meeting was to continue the engagement with the Department of Transport in relation to the Coordinated Bandy Creek Boat Harbour dredging & sand back-passing proposal. First, a brief update on the concept development was provided, including design, cost (saving) estimate and environmental considerations for various implementation options. Then, these options were discussed, and preferred options shortlisted. Finally, a number of recommended actions were outlined.

It is expected that this process will ensure the Department of Transport concerns and aspirations are understood, considered and reflected in the proposal being developed by the Shire of Esperance.

The DoT participants recognized a win-win scenario and acknowledged the value of collaborating with the Shire to better manage the sand in Esperance Bay. As a result, it was proposed to organise a sand back-passing trial in 2020, by bringing forward by one year the scheduled dredging campaign. This is to validate the performance and to demonstrate the benefit of the sand back-passing to stakeholders and community.

The DoT recommended focusing on “April 2020 Back-Passing Trial” as a first step, which would involve:

- Full-length pumping from BCBH to Castleton Beach nourishment area (i.e. 3.5km)
- Temporary pipes set-up on the beach (installed along the toe of the dune, as previously done for the regular BCBH dredging campaign), with 2 boosters and 1 dredge.
- Half the "regular" dredged volume (i.e. approximately 30,000m^3 dredged sand or 39,000m^3 of fill material equivalent); no excess material disposal will be required due to the lower expected siltation volume in the BCBH channel taking place over 1 year (instead of 2 years)
- All the necessary planning and approvals, including community consultation.
- All the necessary monitoring to record progress, evaluate performance, learn from experience and improve the method going forward.

The following key actions were listed in the minutes of meeting:

- Inform the Shire of strong alignment with DoT
- Open discussions between DoT and Shire regarding agreement framework outlining the terms of the understanding, including intended common line of action, funding arrangement and each party's requirements and responsibilities.
- Get estimate of the additional cost for the trial for consideration in next financial year budget
- Revise maintenance dredging campaign budget to enable April 2020 Trial for 1/2 volume (~36,000m^3)
- Confirm the particle size distribution of dredged sand vs. the dune sand in terms of better retainment on the beach.
- Plan booster location(s) and noise management
- Develop community consultation plan

Table 5-1: Multi-criteria assessment: rating scale.

		Rating scale					
#	Criteria	0 (poor)	1	2	3	4	5 (good)
1	Social - Beach access	Pipe or truck on beach					Buried pipes
2	Social - Public Safety	Truck in town		Temporary pipe			Buried pipes
3	Social - Community Perception	Trucks					Buried pipes
4	Social - Noise impact	Trucks or 2 booster	1.4km west		1.4km east	1km east or west	Minise boosters
5	Technical - Design Performance, Complexity	Bund	siltation risk @1km west	siltation risk @1.4km west	siltation risk @1km east	Permanent stock pile,siltation risk @1.4km east	No Bund, Max fill, siltation reduced
6	Technical - Construction Performance, Complexity		3.5km temp	1.4km temp	1.0km temp	1.0km/1.4km West perm	0.3km/ 3.5km permanent
7	Economics - CAPEX	$1.5m		$211,000		$0	$0
8	Economics - OPEX	$664k					$460k
9	Economics - NPV	$15.8m					$11.7m
10	Enironmental - Sea Dumping	needed					not needed
11	Enironmental - Native Vegetation Clearance	Permanent bund		temporary bund			
12	Enironmental - Waste Regulation	Permanent bund					
13	Enironmental - Heritage & Native Title						
14	Political - Inter-governmental collaboration	trucking independent					permanent buried
15	Political - money well spent, good story						
16	Legal						
17	Ethical		land fill source	West excess beach disposal	East excess beach disposal		
18							
19							

Table 5-2: Multi-criteria assessment: core analysis.

				Options															
#	Criteria	Weight	Normalised Weight	0) 8.5km trucking + 1.4km pumping (temporary) + full beach dispersion @1.4kmEast [CAPEX:$0]	1) 4.7km trucking + 0.3km pumping (temporary) + excess stock pile @0.3km [CAPEX:$0]	2) 2.4km trucking + 1.0km pumping (temporary) + excess beach dispersion @1.0kmWest [CAPEX:$0]	3) 2.0km trucking + 1.4km pumping (temporary) + excess beach dispersion @1.4kmWest [CAPEX:$0]	4a) 3.5km pumping (temporary) + excess beach dispersion @3.5kmWest [CAPEX:$211,000]	4b) 3.5km pumping (temporary) + excess beach dispersion @1.4kmWest [CAPEX:$211,000]	4c) 3.5km pumping (temporary) + excess beach dispersion @1.0kmWest [CAPEX:$211,000]	4d) 3.5km pumping (temporary) + excess beach dispersion @0.3kmWest [CAPEX:$211,000]	4e) 3.5km pumping (temporary) + excess beach dispersion @1.0kmEast [CAPEX:$211,000]	4f) 3.5km pumping (temporary) + excess beach dispersion @1.4kmEast [CAPEX:$211,000]	5a) 3.5km pumping (permanent) + excess beach dispersion @3.5kmWest [CAPEX:$1,416,843]	5b) 3.5km pumping (permanent) + excess beach dispersion @1.4kmWest [CAPEX:$1,416,843]	5c) 3.5km pumping (permanent) + excess beach dispersion @1.0kmWest [CAPEX:$1,416,843]	5d) 3.5km pumping (permanent) + excess stock pile @0.3km [CAPEX:$1,416,843]	5e) 3.5km pumping (permanent) + excess beach dispersion @1.0kmEast [CAPEX:$1,416,843]	5f) 3.5km pumping (permanent) + excess beach dispersion @1.4kmEast [CAPEX:$1,416,843]
1	Social - Beach access	1	5.9%	2	2	0	0	0	0	0	0	0	0	5	5	5	5	5	5
2	Social - Public Safety	1	5.9%	0	0	1	1	2	2	2	2	2	2	5	5	5	5	5	5
3	Social - Community Perception	1	5.9%	0	0	0	0	2	2	2	2	2	2	5	5	5	5	5	5
4	Social - Noise impact	1	5.9%	0	0	0	0	0	1	2	5	4	3	0	1	4	5	4	3
5	Technical - Design Performance, Complexity	1	5.9%	0	0	0	0	5	2	1	4	3	4	5	2	1	4	3	4
6	Technical - Construction Performance, Complexity	1	5.9%	2	4	3	2	1	1	1	1	1	1	5	4	4	5	3	2
7	Economics - CAPEX	1	5.9%	4	4	4	4	2	2	2	2	2	2	0	0	0	0	0	0
8	Economics - OPEX	1	5.9%	1	4	3	1	0	2	3	2	2	1	3	4	5	4	5	3
9	Economics - NPV	1	5.9%	2	5	4	1	0	2	3	3	2	1	1	3	5	4	4	3
10	Enironmental - Sea Dumping	1	5.9%	5	5	5	5	0	5	5	5	5	5	0	5	5	5	5	5
11	Enironmental - Native Vegetation Clearance	1	5.9%	5	0	2	2	5	5	5	0	5	5	5	5	5	0	5	5
12	Enironmental - Waste Regulation	1	5.9%	5	0	5	5	5	5	5	0	5	5	5	5	5	0	5	5
13	Enironmental - Heritage & Native Title	1	5.9%	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Political - Inter-governmental collaboration	1	5.9%	0	2	2	2	3	3	3	3	3	5	5	5	5	5	5	5
15	Political - money well spent, good story	1	5.9%	0	1	1	1	4	4	4	4	4	4	5	5	5	5	5	5
16	Legal	1	5.9%	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
17	Ethical	1	5.9%	1	2	2	2	2	2	2	2	3	3	2	2	2	2	3	3
18																			
19																			
	Normalised Rating	17	100.0%	1.82	1.94	2.12	1.76	2.06	2.47	2.59	2.29	2.76	2.76	3.24	3.53	3.82	3.41	3.88	3.65
	Rank			**15**	**14**	**12**	**16**	**13**	**10**	**9**	**11**	**7**	**7**	**6**	**4**	**2**	**5**	**1**	**3**

Table 5-3: Multi-criteria assessment: sensitivity analysis.

Probable Rank	Options: 0) 8.5km trucking + 1.4km pumping (temporary) + full beach dispersion @1.4kmEast [CAPEX:$0]	1) 4.7km trucking + 0.3km pumping (temporary) + excess stock pile @0.3km [CAPEX:$0]	2) 2.4km trucking + 1.0km pumping (temporary) + excess beach dispersion @1.0kmWest [CAPEX:$0]	3) 2.0km trucking + 1.4km pumping (temporary) + excess beach dispersion @1.4kmWest [CAPEX:$0]	4a) 3.5km pumping (temporary) + excess beach dispersion @3.5kmWest [CAPEX:$211,000]	4b) 3.5km pumping (temporary) + excess beach dispersion @1.4kmWest [CAPEX:$211,000]	4c) 3.5km pumping (temporary) + excess beach dispersion @1.0kmWest [CAPEX:$211,000]	4d) 3.5km pumping (temporary) + excess beach dispersion @0.3kmWest [CAPEX:$211,000]	4e) 3.5km pumping (temporary) + excess beach dispersion @1.0kmEast [CAPEX:$211,000]	4f) 3.5km pumping (temporary) + excess beach dispersion @1.4kmEast [CAPEX:$211,000]	5a) 3.5km pumping (permanent) + excess beach dispersion @3.5kmWest [CAPEX:$1,416,843]	5b) 3.5km pumping (permanent) + excess beach dispersion @1.4kmWest [CAPEX:$1,416,843]	5c) 3.5km pumping (permanent) + excess beach dispersion @1.0kmWest [CAPEX:$1,416,843]	5d) 3.5km pumping (permanent) + excess stock pile @0.3km [CAPEX:$1,416,843]	5e) 3.5km pumping (permanent) + excess beach dispersion @1.0kmEast [CAPEX:$1,416,843]	5f) 3.5km pumping (permanent) + excess beach dispersion @1.4kmEast [CAPEX:$1,416,843]
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27%	2%	73%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	2%	26%	11%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	15%	12%	15%	1%	56%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	46%	2%	19%	0%	28%
5	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	23%	37%	0%	33%	0%	5%
6	0%	0%	0%	0%	0%	0%	0%	0%	4%	5%	63%	2%	0%	25%	0%	0%
7	0%	1%	0%	0%	0%	0%	4%	1%	47%	47%	3%	0%	0%	1%	0%	0%
8	0%	0%	0%	0%	0%	0%	12%	2%	46%	34%	2%	0%	0%	2%	0%	0%
9	0%	1%	0%	0%	1%	2%	69%	11%	2%	12%	1%	0%	0%	1%	0%	0%
10	0%	1%	2%	0%	1%	66%	14%	13%	0%	1%	1%	0%	0%	0%	0%	0%
11	0%	4%	22%	0%	14%	26%	1%	32%	0%	0%	0%	0%	0%	0%	0%	0%
12	4%	17%	25%	0%	30%	4%	0%	21%	0%	0%	0%	0%	0%	0%	0%	0%
13	8%	23%	42%	2%	12%	1%	0%	12%	0%	0%	0%	0%	0%	0%	0%	0%
14	26%	24%	8%	16%	20%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%
15	34%	13%	0%	42%	9%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%
16	28%	17%	0%	40%	13%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

5.2.3 Preferred sand back-passing option(s)

Following the MCA and key stakeholder engagement, the preferred sand back-passing options comprise a first step trial followed by the installation of a permanent infrastructure, subject to a successful trial.

First step option - April 2020 Back-Passing Trial

The First step - April 2020 Back-Passing Trial is DoT preferred solution at present. It is a full-length (3.5km) sand back-passing trial, using similar installation as used by DoT for the regular maintenance dredging at BCBH, and pumping approximately half the volume of a "regular campaign" over approximately 2 months.

The dredging/pumping cost estimate for the "one-off" trial may differ from the cost established before for such activities, as they were estimated assuming long-term contract rates. Here, an allowance for new capital items not readily available as part of current contractor capability should be considered.

The indicative cost for the April 2020 Back-Passing Trial is approximately [redacted] which is about [redacted] more than the cost of [redacted] for a "regular campaign" adjusted for the trial volume (see details in Table 5-4, Table 5-5 and Table 5-6).

The cost increase between the April 2020 Back-Passing Trial and a "regular campaign" is attributed to items, such as:

- Mobilisation/demobilisation of 1 additional booster
- Mobilisation/demobilisation of 2.1km of additional pipe
- Supply of 0.7km of additional pipe
- Purchase of 1.4km of additional pipe*
- Refurbishing of 1 booster*
- Pumping an additional 2.1km distance in pipes of mixed ownership

where the (*) denotes capital item not readily available as part of current contractor capability.

The cost saving between the April 2020 Back-Passing Trial and a "regular campaign" is attributed to the removal of items no longer required, such as:

- Supplying and loading of sand
- Trucking over 8.5km

An indicative sharing of the extra cost ($211,309) associated with running the April 2020 Back-Passing Trial is detailed in Table 5-7. Assuming an initial 50/50 split between the DoT and the Shire for the funding of coastal management activities, this analysis suggests a 82/18 cost split between the DoT and the Shire to cover the $211,309 extra expenses.

Table 5-4: Indicative cost for the April 2020 Back-Passing Trial.

Item	Quantity	Rate	Cost estimate
Preliminaries, including: a) Mobilisation/demobilisation of 1 dredge b) Mobilisation/demobilisation of 2 boosters c) Mobilisation/demobilisation of 3.5km of pipe d) Supply of 2.1km of pipe e) Refurbishing of booster #2*	1	[redacted]	[redacted]
Additional item: f) Purchase of 1.4km of pipe*	1	[redacted]	[redacted]
Dredging and pumping g) 1 dredge, 2 boosters, 3.5km to the west of BCBH (2.1km contractor owned + 1.4km Shire/DoT owned) h) -	30,000m3	[redacted]	[redacted]
Nourishment activity i) - j) - k) Placement	39,000m3	[redacted]	[redacted]
Total			[redacted]

(*) denotes capital item not readily available as part of current contractor capability

Table 5-5: Indicative cost for the "regular campaign" (trial adjusted volume).

Item	Quantity	Rate	Cost estimate
Preliminaries, including: a) Mobilisation/demobilisation of 1 dredge b) Mobilisation/demobilisation of 1 booster c) Mobilisation/demobilisation of 1.4km of pipe d) Supply of 1.4km of pipe e) -	1	[redacted]	[redacted]
Additional item: f) -	-	-	-
Dredging and pumping g) 1 dredge, 1 booster, 1.4km of pipe to the east of BCBH (1.4km contractor owned) h) -	30,000m3	[redacted]	[redacted]
Nourishment activity i) Supply and loading of sand j) Trucking over 8.5km k) Placement	39,000m3	$10.00	$390,000
Total			[redacted]

Table 5-6: Indicative cost difference between the trial and the "regular campaign".

Item	Quantity	Rate	Cost difference
Preliminaries, including: a) - b) Mobilisation/demobilisation of 1 booster c) Mobilisation/demobilisation of 2.1km of pipe d) Supply of 0.7km of pipe e) Refurbishing of booster #2*	1	[redacted]	[redacted]
Additional item: f) Purchase of 1.4km of pipe*	1	[redacted]	[redacted]
Dredging and pumping g) 1 booster, 2.1km of pipes of mixed ownership (0.7km contractor owned, 1.4km Shire/DoT owned) h) -	30,000m3	[redacted]	[redacted]
Nourishment activity i) Supply and loading of sand j) Trucking over 8.5km k) -	(39,000m3)	[redacted]	[redacted]
Subtotal cost increase			**$525,064**
Subtotal cost saving			**($313,755)**
Total net cost			**$211,309**

(*) denotes capital item not readily available as part of current contractor capability

Table 5-7: Indicative cost sharing distribution for the trial (30,000m3 dredged volume)

	Cost (one-off)	Department of Transport	Shire of Esperance	Total
"regular campaign" (status-quo, volume adjusted)	Maintenance Dredging	[redacted]	**$0**	[redacted]
	Coastal Management (50/50)	$195,000	$195,000	**$390,000**
	Total	[redacted]	$195,000	[redacted]

	Cost (one-off)	Department of Transport	Shire of Esperance	Total
April 2020 Back-Passing Trial	Maintenance Dredging	[redacted]	$0	[redacted]
	Coastal Management	$242,482	$297,936	$540,418
	Total	[redacted]	$297,936	[redacted]

Indicative shares of the coalition*	Cost Sharing	Department of Transport	Shire of Esperance	Total
(*) Cost/benefit sharing using Shapley value		-$108,372	-$102,936	**-$211,309**

Characteristic function	
Member	Description
A	DoT Maintenance Dredging
B	Shire of Esperance
C	DoT Coastal Management
Coalitions	Cost
A	[redacted]
B	$195,000
C	$195,000
AB	[redacted]
BC	$390,000
AC	[redacted]
ABC	[redacted]

Long-term option - Permanent Back-Passing every two years

Following the multi-criteria analysis and subject to a successful trial, the preferred long-term back-passing solution is Option 5e. It involves the installation of a full-length (3.5km) permanent pipeline buried at the toe of the dunes to pump 36,300m^3 of dredged sand to the nourishment area, and dispose of the excess material (i.e. 23,700m^3) on the beach 1.0km East of BCBH (i.e. within pumping distance of the dredge alone).

The adoption of this solution is also subject to the confirmation that there is a low risk of increased siltation in the harbour channel, relative to the status quo, and caused by:

- A small reduction of the distance between BCBH and the excess material beach disposal site from 1.4km to 1.0km; and

- A significant reduction of dredged material volume dispersed on the beach from 60,000m^3 to 23,700m^3.

The indicative two-yearly OPEX for Option 5e is approximately [redacted] which is about $240,000 less than the cost of [redacted] for the Option 0 (status-quo), as detailed in Table 5-8 and Table 5-9. These savings are realized by materially reducing the beach nourishment cost by switching to a permanent back-passing system, which only marginally increases the dredging and pumping cost. These overall saving in OPEX is however contingent upon investing into a permanent back-passing system, which has an estimated CAPEX of $1,416,843 for the supply and installation of the permanent buried pipeline.

An indicative sharing of the resulting savings ($239,401 every two years) associated with the adoption of Option 5e is detailed in Table 5-10. Assuming an initial 42/58 split between the DoT and the Shire for the funding of coastal management activities, this analysis suggests a 43/57 split between the DoT and the Shire to share the $239,401 two-yearly OPEX savings.

Table 5-8: Indicative cost for Option 5e (every two years).

Item	Quantity	Rate	Cost estimate
Preliminaries, including: a) Mobilisation/demobilisation of 1 dredge b) Mobilisation/demobilisation of 2 boosters c) Mobilisation/demobilisation of 1.0km of pipe d) Supply of 1.0km of pipe	1	[redacted]	[redacted]
Additional capital item: e) Purchase of 3.5km of pipe* f) Installation of 3.5km of pipe*	1	$1,416,843	$1,416,843
Dredging and pumping g) 1 dredge, 2 boosters, 3.5km of pipes to the west of BCBH h) 1 dredge, 1.0km of pipes to the east of BCBH	36,292m3 23,708m3	[redacted] [redacted]	[redacted]
Nourishment i) - j) - k) Placement	47,180m3	$1.96	$92,237
Total OPEX (two yearly)			[redacted]
Total CAPEX *			**$1,416,843**

(*) denotes capital item not readily available as part of current contractor capability

Table 5-9: Indicative cost for Option 0) status-quo (every two years).

Item	Quantity	Rate	Cost estimate
Preliminaries, including: a) Mobilisation/demobilisation of 1 dredge b) Mobilisation/demobilisation of 1 booster c) Mobilisation/demobilisation of 1.4km of pipe d) Supply of 1.4km of pipe	1	[redacted]	[redacted]
Additional capital item: e) - f) -	-	-	-
Dredging and pumping activity g) - h) 1 dredge, 1 booster, 1.4km of pipes to the east of BCBH	60,000m3	[redacted]	[redacted]
Nourishment activity i) Supply and loading of sand j) Trucking over 8.5km k) Placement	47,180m3	$10.00	$467,948
Total OPEX (two yearly)			[redacted]
Total CAPEX			-

Table 5-10: Indicative cost sharing distribution for Option 5e (60,000m^3 dredged volume).

Status Quo - Independent operations	OPEX (pa)	Department of Transport	Shire of Esperance	Total
	Maintenance Dredging	[redacted]	**$0**	[redacted]
	Coastal Management	**$200,000**	**$267,948**	$467,948
	Total	[redacted]	$267,948	[redacted]

Option 5e) 3.5km pumping (permanent) + excess beach dispersion @1.0kmEast [CAPEX :$1,416,843]	OPEX (pa)*	Department of Transport	Shire of Esperance	Total
	Maintenance Dredging	[redacted]	$0	[redacted]
	Coastal Management	$98,191	$132,165	$230,356
	Total	[redacted]	$132,165	[redacted]

Indicative shares of the coalition*	Cost Sharing	Department of Transport	Shire of Esperance	Total
(*) Cost/benefit sharing using Shapley value		$103,618	$135,783	**$239,401**

Characteristic function	
Member	Description
A	DoT Maintenance Dredging
B	Shire of Esperance
C	DoT Coastal Management
Coalitions	Cost
A	[redacted]
B	$267,948
C	$200,000
AB	[redacted]
BC	$467,948
AC	[redacted]
ABC	[redacted]

6 CONCLUSION AND RECOMEMENDATION

After the review of a range of coastal management and coastal protection options to address the on-going erosion issue at Castletown Beach (BMT, 2018), the Shire engaged BMT coastal engineers to develop the Bandy Creek Boat Harbour (BCBH) dredging & sand back-passing solution, in coordination with the Department of Transport two-yearly dredging campaign at BCBH.

The beach nourishment profile was designed to provide sufficient sand capacity in the eroded area to sustain the action of coastal process for two-years on average. A shoreline model was developed that takes into account both the cross-shore and long-shore sediment dynamic. The model was calibrated at the site using prior sand nourishment observations. The beach profile was adjusted to offer a tight sand placement, that minimises encroachment of the nourishment area seaward of the breakwater. Although, the constructed beach will get eroded over its two-year life, the resulting beach is expected to be broader most of the time, leading to better amenity for the community and better protection against storm erosion, hence improving the Shire current nourishment performance.

Sand management in Esperance Bay was looked at holistically. The nourishment volume target requirement was estimated at 33,700m^3, which corresponds to a dredged volume requirement of 36,300m^3, including bulking and overfill factors allowance. Given that the main scope of the two-yearly dredging in BCBH is 60,000m^3 of quality sand located in the entrance channel, only 60% of it is proposed to be back-passed to Castletown Beach for nourishment purpose, so the balance (i.e. 40%, or 23,700m^3) requires alternative disposal location. This holistic approach to sand management is important to extract the maximum synergies between DoT and the Shire.

Sand back-passing implementation options were defined in more detailed and evaluated. Broad categories of options were considered ranging from a combination of hydraulic pumping and trucking, hydraulic pumping only using temporary pipes, hydraulic pumping only using permanent buried pipe, and hydraulic pumping using both permanent buried pipes for the nourishment and temporary pipes for the excess dredged sand disposal to the east of BCBH. A rigorous breakdown of key activities, including pumping, stock piling, beach disposal, excavating, trucking and placing, enabled clear definition and differentiation between the 16 options considered. Subsequent multi-criteria analysis facilitated the appraisal and relative ranking of options in accordance with stakeholder preferences and across a broad range of aspects, including social, technical, environmental, economic, political, legal and ethical. Thus, the preferred long-term options were shortlisted.

The preferred long-term option shortlisted was Option 5e. It involves the installation of a full-length (3.5km) permanent pipeline buried at the toe of the dunes to pump 36,300m^3 of dredged sand to the nourishment area, and dispose of the excess material (i.e. 23,700m^3) on the beach 1.0km East of BCBH (i.e. within pumping distance of the dredge alone). This solution removed all trucking operations and relies solely on sand slurry transport, from the dredged located in BCBH, with the assistance of two booster stations located approximately 1km and 2km away along the pipeline route. It is one of the most cost-effective solution considered, with a potential cost saving of approximately $240,000 every two years to be shared between the Shire and the DoT. This solution is contingent upon investing into a permanent back-passing system, which has an estimated CAPEX of approximately $1,420,000 for the supply and installation of the permanent buried pipeline.

A stakeholder engagement meeting took place on the 28/02/2019 with the Department of Transport, involving managers of facility operations, asset management, coastal management, and representatives of the regional facilities, maintenance dredging and environment. This meeting built on previous engagement activities with the DoT undertaken in 2018 in relation to the Coordinated Bandy Creek Boat Harbour dredging & sand back-passing proposal. This process not only ensures continuity in the engagement with the Department of Transport but also it makes sure that their concerns and aspirations are understood, considered and reflected in the proposal being developed by the Shire of Esperance.

The Department of Transport representatives unanimously recognized a win-win scenario and acknowledged the value of collaborating with the Shire to better manage the sand in Esperance Bay, thus leading the Department of Transport to recommend, as a first step, organizing a sand back-passing trial in 2020 to validate the performance. This is to demonstrate the benefit of the sand back-passing to stakeholders and community, before committing to a more permanent solution requiring more capital investment, such as the preferred long-term solution Option 5e.

Notwithstanding the above recommendations and findings favoring a long-term solution (e.g. Option 5e), "April 2020 Back-Passing Trial" is DoT preferred solution at present. It is a full-length (3.5km) sand back-passing trial, using similar installation as used by DoT for the regular maintenance dredging at BCBH, and pumping approximately half the volume of a "regular campaign" over approximately 2 months. No excess dredged sand is expected for the trial. The indicative cost for the April 2020 Back-Passing Trial is approximately [redacted], which is about $210,000 more than the [redacted] cost for a "regular campaign" adjusted for the trial volume. This solution is contingent upon acquiring 1.5km of pipe, which has an estimated CAPEX of approximately [redacted], and refurbishing a second booster pump to supplement DoT's dredging contractor capability.

Accordingly, to progress the April 2020 Back-Passing Trial, it is recommended for the Shire to:

- Open discussions between DoT and Shire regarding an agreement framework outlining the terms of the understanding, including intended common line of action, funding arrangement and each party's requirements and responsibilities.
- Continue the engineering definition of the recommended trial, including detailed design and environmental planning in accordance with DoT's framework, including consideration for booster locations and noise mitigate strategy, as required.
- Develop a community consultation plan to ensure adequate engagement with the community before, during and after the trial.
- Develop a trial coastal monitoring plan to maximise learning during and after construction of nourishment beach profile and facilitate future improvement of the back-passing system design and construction.
- Seek funding assistance for the trial from the DoT CAP grant program.

7 REFERENCES

BMT (2018) Esperance Bay Coastal Erosion Options. BMT report R-J18004.00 prepared for the Shire of Esperance, pp.70, June 2018.

Bodegom (2004) Beach Nourishment: an evaluation of equilibration design methods, pp.287. TU Deflt, MSc thesis, April 2004.

Shire of Esperance (2018) Castletown beach nourishment works close out data. Shire of Esperance Asset Management (Personal Communication).

Van Rijn (2014) Beach Nourishment, https://www.leovanrijn-sediment.com/ papers/ Beachnourishment2014.pdf [accessed 10 Dec 2018].