Assessment of Pipers Head beach characteristics

produced by

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Report for

Bellingham Progress Association

George Town Coastal Management Group

and Tamar NRM

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Abstract

To aid the local community of Bellingham to maintain this unique area, this idiographic study aims to assess the coastline's characteristics for erosion and coastal stability. Community members were surveyed asking about beach history and trends, and historical research was carried out to find any written records. Using beach shape and profile techniques, surveys of the beach were performed to assess geomorphic information for future area studies. Sand samples were collected from strategic dune and beach locations and analysed for physical properties. This was to enable the community and government agencies to create effective enhancement and management programs for the beach and dune system of Pipers Head.

Results showed that from 1909 to 1940 the river mouth changed from a westerly exit to a northerly exit. During the last hundred years, the topography of the present mouth exit has been constantly modified through Aeolian processes in the area, as confirmed by the community survey and photographs. As well as seaward transportation indicators of sediment are evident in two transects, with three transect results providing evidence of land sedimentation. The river transects show no sign of rice grass, but instead, we find an infestation of sea spurge on the dunes and back beach areas. The river transects had concave characteristics of erosion, and the seaward transects had a neutral position of erosion/accretion.

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Acknowledgments

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Flo Mc Auley and Gary Mondon

Thank you for your voluntary assistance with the surveying and soil sampling, as well for our long discussions about the area's history which provided me much useful insight re doing the historical research.

Betty Viney

A huge thank you to you for your tremendous help with historical photographs which I was able to effectively compare with present day photographs of the area, and for our tremendously helpful discussion about Bellingham and its foreshore, which provided evidence re environment change, and the erosion we are seeing today.

The George Town Council

I would like to thank The George Town Council for providing illustrative information and imagery of Bellingham and Pipers Head. My hope is that this project's analysis will be useful in implementing future programs.

Peter Cox and the Low Head Pilot House Museum

Thank you for our informative interview and your insight into Bellingham's history, which filled in some missing pieces re the area's historical establishment.

LINC library, Launceston

Thank you to the level two Launceston staff for your tremendous help in finding archival documents of Pipers River, its port activity and survey maps.

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Chapter 1 Introduction

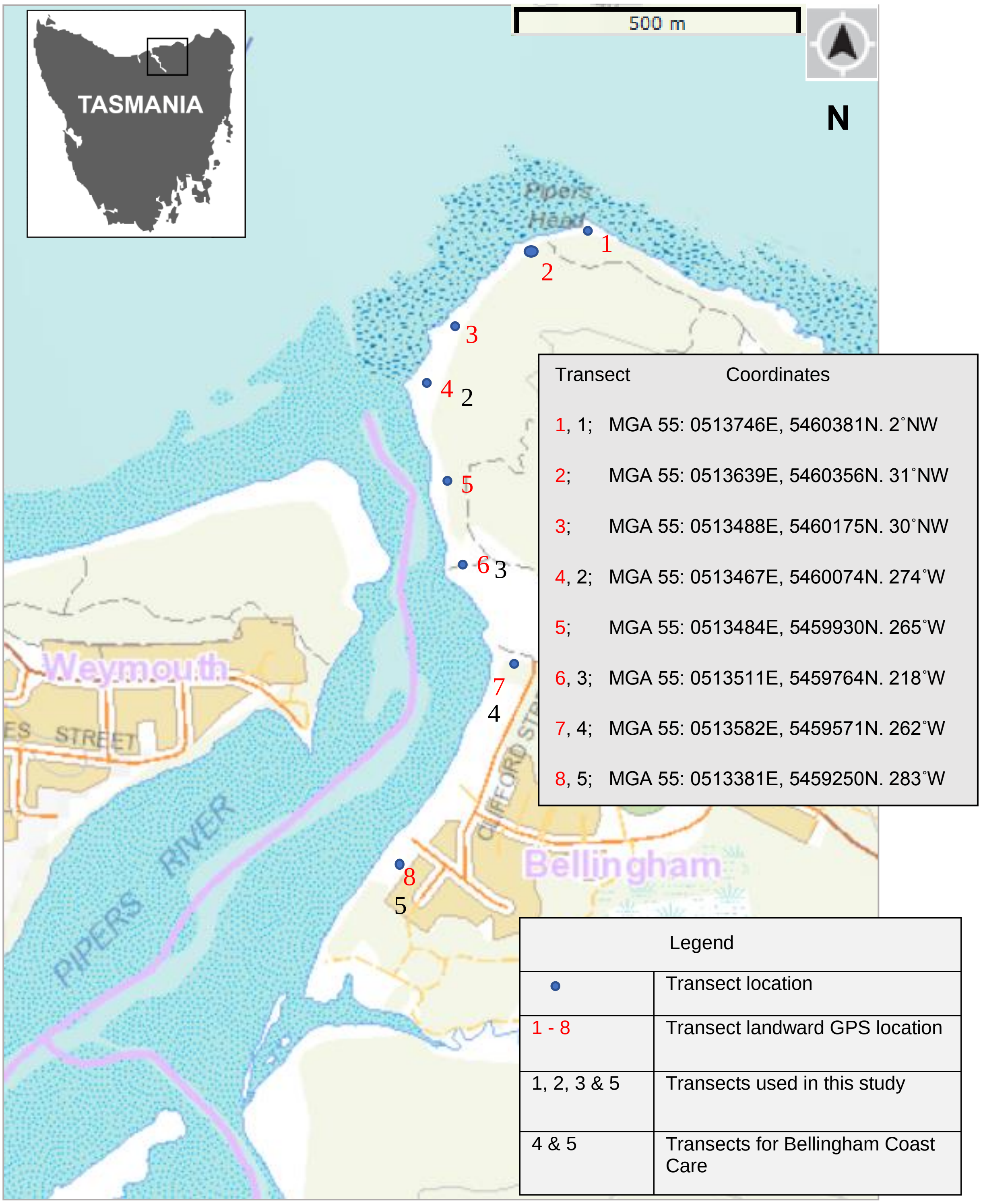
1.1 The role of sand dunes in making healthy beaches

Australia is a large continent with a culture that has grown around its wealth of sandy beaches, its major cities being either on or close to these vast areas, with a climate that induces their usage. Stresses from human impact affect these ecosystems more than the Aeolian processes of wind and sea. More frequent access to this vast beach area in recent times has made the culture more aware of its impact and has encouraged people to become more involved in environmental issues (James, 2000).

1.1.1 Bellingham

Pipers River is an estuary located on the northern coast of Tasmania. It enters Bass Strait at Nolans Bay, and with two townships on each river bank. On the western bank is Weymouth, (Skinner, 2015), and on the eastern bank is Bellingham, (Fig.1). Pipers Head shelters Bellingham from Bass Strait by breaking the force of strong north-westerly swells caused by the region's roaring 40's latitude. The east facing side is sheltered and not affected by the weaker north-easterly sea and wind action during summer low pressure systems from the north. Short (2006) described the beach around Pipers Head as being "a low rocky sand-draped headland with narrow tidal beach, with intertidal rock flats of steeply dipping greywacke". The beach width varies from 50 m to 200 m, with transgressive dunes and 60 m high slopes.

The north-westerly side of Pipers Head causes Bellingham residents the greatest concern, and they have clearly voiced their opinion in the past and more recently re the coastal area's alarming erosion rate. When viewed on Google maps, the coordinates of G55 513358E, 5459965N, Bellingham boasts a population of approximately 60 permanent residents and approximately 200 seasonal residents in summer.



Transect	Coordinates
1, 1;	MGA 55: 0513746E, 5460381N. 2˚NW
2;	MGA 55: 0513639E, 5460356N. 31˚NW
3;	MGA 55: 0513488E, 5460175N. 30˚NW
4, 2;	MGA 55: 0513467E, 5460074N. 274˚W
5;	MGA 55: 0513484E, 5459930N. 265˚W
6, 3;	MGA 55: 0513511E, 5459764N. 218˚W
7, 4;	MGA 55: 0513582E, 5459571N. 262˚W
8, 5;	MGA 55: 0513381E, 5459250N. 283˚W

Legend	
●	Transect location
1 - 8	Transect landward GPS location
1, 2, 3 & 5	Transects used in this study
4 & 5	Transects for Bellingham Coast Care

Figure 1. SE corner is at MGA 55: 512671E, 5458332N. Map of Bellingham, east side of Pipers River Estuary displaying profile location and survey points for intended benchmark survey and ongoing monitoring program to establish beach life cycle, purple line indicating estuarine thalweg (deepest channel) in 2017

1.1.2 Previous surveys

A few Tasmanian studies have focused on an overall view of coastline beaches in a broad context, but have not gone into enough detail re individual beaches. Most of the studies have gaps re specific areas as they do not fit the parameters of those studies (Graddon, 1997, Meikle, 2014, Sanders, 1968). To date, no “beach processes” survey has been done in Bellingham, and past surveys were only concerned with mineral wealth or land capacity, development of the townships, agriculture and port facilities at Weymouth (Fig. 2). Lack of Tasmanian beach profiling is a critical issue when dealing with beach environments and understanding of beach characteristics. Most past and present programs have proved to be mostly ineffective in assisting beach resilience (Thom and Hall, 1991).

International reviews, such as Defeo et al. (2009), have highlighted the impacts upon the fauna and ecosystem in more depth, and state that management programs will not elevate ecosystem threats in the short term. Regular surveys of coastal processes over a range of years allow for distinction between hearsay, long term and short term occurrences of beach morphology incidents (Thom and Hall, 1991), thus may produce a clear determination of what is actually happening at Bellingham. Without regular studies, it has been difficult for the community to elicit assistance from government agencies regarding establishing effective coastal care or conservation programs.

Beach profiling determines whether a beach is in either an “accretion dominated period” or an “erosion dominated period”. Studies such as Thom and Hall (1991) and Johnston and Ellison (2014) have increased the community’s awareness of the impact of human and animal activity, as well as storm and sea level impacts on sedimentary type coasts. A recent 2015 study by Skinner at Weymouth, the township on the western bank of Pipers River, was one of the recent beach surveys designed to gather beach geomorphology, to assist communities and government agencies in maintaining the beach environments. Skinner suggested that there is a need for further analysis of Tasmanian beaches and more consistent surveys over

longer time periods to establish beach characteristics for effective coastal care. An in-depth beach profile and coastal process study which provides a broad gathering of information would enable the community and government agencies to develop an effective management program for Pipers River Estuary system, and for the beach at Pipers Head. As is the case with most studies being restricted to certain guidelines, this one also has similar parameters to adhere to in its Pipers Head beach research information gathering, there so much raw material available to research around Pipers River it would be easy to become distracted from the original goal of this study.

1.1.3 The study of Bellingham

From the 1800's to 1909 the evidence from archival survey maps showed a constant direction of river flow, but between 1909 and 1940 a major environment event happened which changed the course of Pipers River, flowing westward in front of Weymouth to flowing northward, (Fig. 1 & 2). Seventy years on, the area is displaying possible changed characteristics. It was decided that beach characteristics would be the focus of this study, because of the communal benefits to Bellingham and because of its crucial importance in communicating with government agencies.

Without this empirical type of study it is difficult to determine beach characteristics which relate to resilience in the ecosystem and its reaction to disturbances forced upon it by either weather events, enhanced climate change or human impact processes, such as 4x4 driving, horse riding, motorbike and quad bike riding, non-designated track walking, camping and burning of natural habitat (Defeo et al., 2009). With ongoing monitoring of the area, using the GPS markers in situ (Fig. 3), a clearer picture of how the coastline is changing due to weathering will emerge which will help determine the beach's main vulnerability points.

The main reason for proposing this study is to establish a database of information collected via in-depth research, which hopefully, could be

increased over the next five to ten years, thus enabling a recognition of dominant prevailing issues.

1.1.4 Aims

The proposed study would undertake an idiographic approach (the study or discovery of scientific facts and processes) suitable for a baseline survey, undertaking descriptive and inductive interpretation of beach characteristics. The objective would be to investigate the characteristics of beaches at Bellingham from the estuary to the foreshore, and to reconstruct past conditions such as changes to the river mouth and dune system, using archival and community interview methods.

Figure. 2. Pipers River Weekly Courier 1909, photograph from on top of Pipers Head dunes, courtesy of Betty Viney

Chapter 2 Methods

2.1 What is the study area and plan?

This study has researched the history of Pipers River Estuary, the township of Bellingham, the mouth of the estuary and Pipers Head, including the fore and back beach, sand dunes, and the rock formation at the northern end of Pipers Head. A handheld GPS device was used to locate several positions along the headland and river bank, (Fig. 3), and these positions were then selected by different terrain criteria and contours, as well as their position pertaining to the sea and river, as per map (Fig. 1).

Two types of research were conducted;

Firstly, an ethics approved two-part community survey:

> Part one, was a quantitative question set, which asked for specific data, so it could be mathematically analysed, and with a second part which asked qualitative questions about the person's beliefs and general memories describing the how and what of events that happened in the community.
>
> Part two, was an interview conducted with volunteers who wished to share their valuable history and photographs of Bellingham and Pipers River, (some of which had never been previously revealed).

Secondly, quantitative research was conducted to gather information by means of beach profile surveys and sediment sample testing, which would provide a benchmark for future area studies.

2.2 Qualitative research methods

2.2.1 Community survey

The ethics approved two-part community survey was accomplished by delivering printed questionnaires through the new Bellingham Progress Society. The questionnaire consisted of twenty four quantitative questions and seven qualitative questions (all involvement was voluntary and anonymous), (Tables 1 and 2).

	What do you believe are the causes for erosion at this beach?
1	Storms
2	High tide wave action
3	Tsunami
4	Sea level rise
5	Sand removal for construction/road building
6	Human footprints damaging the shore
7	Vehicles/motorbikes damaging the shore
8	Horses damaging the shore
9	Coastal vegetation dieback
10	Wind blowing the sand off the beach
	Coastal management at this beach over the last decade
11	Have the coastal management works been appropriate
12	Were public walkways successful in preventing foot traffic over the dunes
13	Was the revegetation with native grasses and shrubs successful
14	Was fencing of the dunes successful in reducing erosion
15	Was the placement of rocks on the shoreline successful in reducing erosion
16	Was the placement of groynes on the shoreline successful in reducing erosion
17	Was the placement of any artificial reefs on the shoreline successful in reducing erosion
18	Was the placement of information signs successful in reducing erosion
19	Was the placement of vehicle control barriers successful in reducing erosion
20	Have you observed any changes around the coastal infrastructure since its installation
21	Have the coastal works been maintained
22	Has there been support to maintain them

Table 1. Quantative question from the community survey 2017

1	How long have you lived near this beach
2	Are you involved with the local Coastcare Group/ Progress Association? If so for how long
3	How would you describe the history of coastal change, e.g.; erosion events
4	Would you like to comment on why actions were successful or not in each case
5	How successful have the coastal management practices been overall
6	Any suggestions regarding the improvement of coastal management at this beach
7	Is there any other information you would like to share about coastal changes and management at this beach

Table 2. Qualitative question from the community survey 2017

When the surveys were returned (by August 30th, 2017), they were collated into tables for ease of analysis, providing evidence of community opinions and general beliefs regarding the cumulative effects on Bellingham's coastline.

Historical information was gathered through the archives of government departments, such as library and online databases. Local history was collected by interviewing Bellingham residents and frequent visitors to Bellingham and gazetted articles from local papers. The historical information was noted and assessed for tabling into a timeline of events.

2.2.2 Archival history

An archival search through the Tasmanian State Launceston LINC library and through the TROVE web site.

2.2.3 Reconstructed history

This area of study included interviews with several community members who either live / lived in the area, with other qualitative history being gathered through the community survey questions and interviews. All this information was reviewed and time-lined and presented in table form, as this helps to analyse the area's history and establishes guidelines for dealing with probable causes of existing issues.

2.3 Quantitative research methods

2.3.1 Fieldwork

A study area was reconnoitred and suitable positions for transecting dune and beach terrain were located and GPS coordinates were logged in, and volunteers from the Bellingham Progress Society helped create and establish semi-permanent markers at GPS points, (Fig. 3).

Figure 3. GPS marker in place, courtsey of Bellingham Progressive Society volunteers, photo by R Smith

Figure. 4. Greg Morrison and researcher plotting GPS positions for study (photo: D Ballenden)

Two Bellingham residents volunteered to assist in surveying transects; achieved by using a standard surveyor's dumpy level, tripod, and a five metre height survey staff. Also, a handheld GPS device to locate position markers, and a Silva compass with a one

hundred metre measuring tape for distance and direction of transect. Starting at a position landward from the dune face, two back marker positions were logged, then moving seaward during the astronomical low tide period, forward markers were logged at important variances of terrain.

MSL (Mean Sea Level): MSL is the average level of the sea surface over a period (preferably 19 years), or the average level which would exist in the absence of tides.

AHD heights of LAT, HAT and MSL

Port	**Ref BM & Height**	**HAT**	**MSL**	**LAT**
Hobart	SPM 194 1.859	0.86	0.05	-0.83
Spring Bay	SPM 8521 7.236	0.69	-0.02	-0.76
Low Head	SPM 9214 1.863	1.62	-0.03	-2.02
Stanley	SPM 6235 3.430	1.60	-0.07	-2.06
Burnie	SPM 8857 3.553	1.64	-0.01	-1.96

Table 3. Bureau of Meterology (BOM) data for mean sea level calculations

tide @ Low Head

28th Aug 2017		29th Aug 2017		30th Aug 2017	
421	3.25	503	3.2	544	3.15
1036	0.91	1115	1.01	1153	1.09
1632	3.37	1710	3.27	1745	3.23
2259	0.77	2337	0.8		

Table 4. Tide levels from BOM website for the days of survey

Geomorphic field drawings were compiled on site showing various contours and water levels at different times. Copies of maps from the Listmaps.gov.au site were taken and used as base drawings, and then symbols from the geomorphic field manual by Dackombe and Gardiner (1983) captured the contours of beach characteristics, an artist's impression was created in a 2D picture to show the contours of all profiles

Soil sampling was achieved by collection, with assistance from two Bellingham residents, at three points along each transect. Starting at the foredune base, the transect was intersected by a line 90˚ on either side, and along these lines at ten intervals of 100 mm span, and a scoop of no more than 2 cm deep of sediment was then collected into a bag at each point. These soil samples were identified by transect and position along that line, then returned to the laboratory for analysis.

Figure. 5. Orange line is the transect line showing depth of sample procurement technique used to collect sediment sample, photo by R Smith

Figure. 6. Flo Mc Auley assisting in sediment sample collection, photo by R Smith

2.3.2 Laboratory testing

The laboratory tests as follows;

2.3.2.1 Particle shape analysis was achieved by placing a sample of sediment in a petri dish under a scanning microscope, then classified according to the Wadell roundness chart to determine the shape of particles.

2.3.2.2 Dominant mineral composition was performed using a scanning microscope and a portion of sediment sample in a petri dish. 10% Hydrochloric Acid (HCl) solution was then placed onto the sediment. A visual analysis of the ratio of chemical reaction allowed for a determination of the percentage of quartz and carbonate quantities.

2.3.2.3 Half of the sediment was placed into an oven at 60˚ C for four days, then, using cascade sieves, with a range of 4.00 to 0.063 mm, the sediment was separated into different size fractions, and each fraction was then weighed and catalogued. Sample data was then calculated into the phi scale, from which a histogram and cumulative frequency curve was constructed. This made it easier to describe the grain size, and afterwards it was converted to millimetres for general viewing.

Chapter 3 Results

3.1 Community Survey

Forty-five ethically approved survey forms were presented to the community (30% returned), which recorded from 80 to 15 residential years in the area. Twelve of the twenty-two questions returned a ‘no’ vote (highest) (Tables 1,2 & 5), overall 37.3% of the cumulative percentage. A 22.7% overall count of ‘maybe’ from six questions, with 23.3% ‘yes’ votes on three questions. Question 11 revealed 40% voted, ‘unsure’, (Tables 1, 2 & 5). In summary, results show the community believes that past/present coast care groups have been mostly ineffective, and that any implemented programs are not, nor have they been effective in reducing human impact and erosion of the ecosystem.

question	yes	%	no	%	maybe	%	unsure	%	abstain	%	N/A	%
Storm 1	13	87	0		2	13	0		0		0	
High tide 2	15	100	0		0		0		0		0	
3	0		11	73	2	13	2	13	0		0	
4	3	20	4		6	40	2	13	0		0	
5	0		11	73	4	27	0		0		0	
Footprints 6	2	13	11	73	2	13	0		0		0	
Vehicles 7	6	40	1		7	47	1	7	0		0	
Horses 8	2	13	8	53	5	33	0		0		0	
9	5	33	4	27	6	40	0		0		0	
Wind 10	11	73	1		3		0		0		0	
11	0		4		4	27	6	40	0		1	7
Re-veg 13	1	7	9	60	2		1		0		2	13
Fencing 14	2	13	7	47	1		2	13	1		2	13
15	2	13	5	33	2		1	7	3	20	2	13
Groynes 16	1	7	6	40	4	27	2		0		2	13
Art-reefs 17	1	7	6	40	1	7	1		3		3	20
18	1	7	5		4	27	2	13	0		3	20
Barriers 19	3	20	5	33	6	40	0		0		1	
20	4	27	7		1	7	2	13	0		1	7
CC work 21	2	13	6	40	4	27	2	13	0		1	7
22	0		5		6	40	3	20	0		1	7

Table 5. Ethics approved community survey results, 2017

In summary, the main erosion factors are; the various Aeolian processes, human activity, and ineffective management plans (Table 5).

3.2 Historical research

3.2.1 Archival history

The archival search produced several early survey maps and one geomorphological survey. This latter survey covered minerals and their monetary value to the state of Tasmania ("Anon", 1974). The earlier surveys were of land and water boundaries, and indicated most suitable locations for agriculture and ports, and proclaimed Tasmania as being part of the English Empire, so the French could not claim it. (from state archives at the Launceston LINC library, and from Trove web site).

Figure. 8. First known survey map of Bellingham, surveyor Mr Lewis circa 1810.

Fig. 7 is part of an 1810 survey map by a Mr Lewis and company, showing a wide mouthed estuary flowing from an easterly inland beginning to westerly outpouring into the sea. Also, Pipers River can be seen entering at the western side of the estuary mouth. By 1811 the area had become dissected into allotments and the township of Weymouth was surveyed (Fig. 8), the map

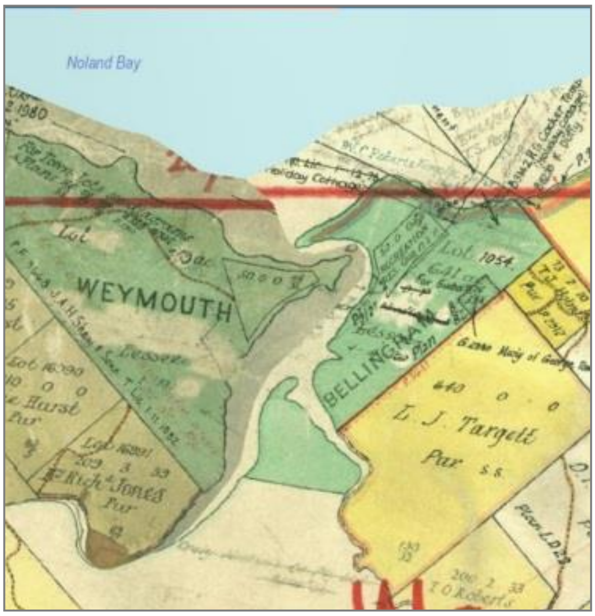


Figure. 7. Pipers River estuary dated 1811, (www.listmap.gov.au)

being in colour suggest that it was updated around the early 1900's, to emphasis the different usages of land.

Fig. 9 A. photograph was taken in 1909, from the dune bank looking towards Bellingham, taking in the jetty and the point on the Weymouth side. The figures in the picture give a rough guide as to how high the dune bank was and how far into Pipers River Estuary the jetty protruded. Fig. 9 B. photograph was taken in 2017 from the river bank on the Bellingham side; not an exact position, but it still shows the difference due to sediment movement.

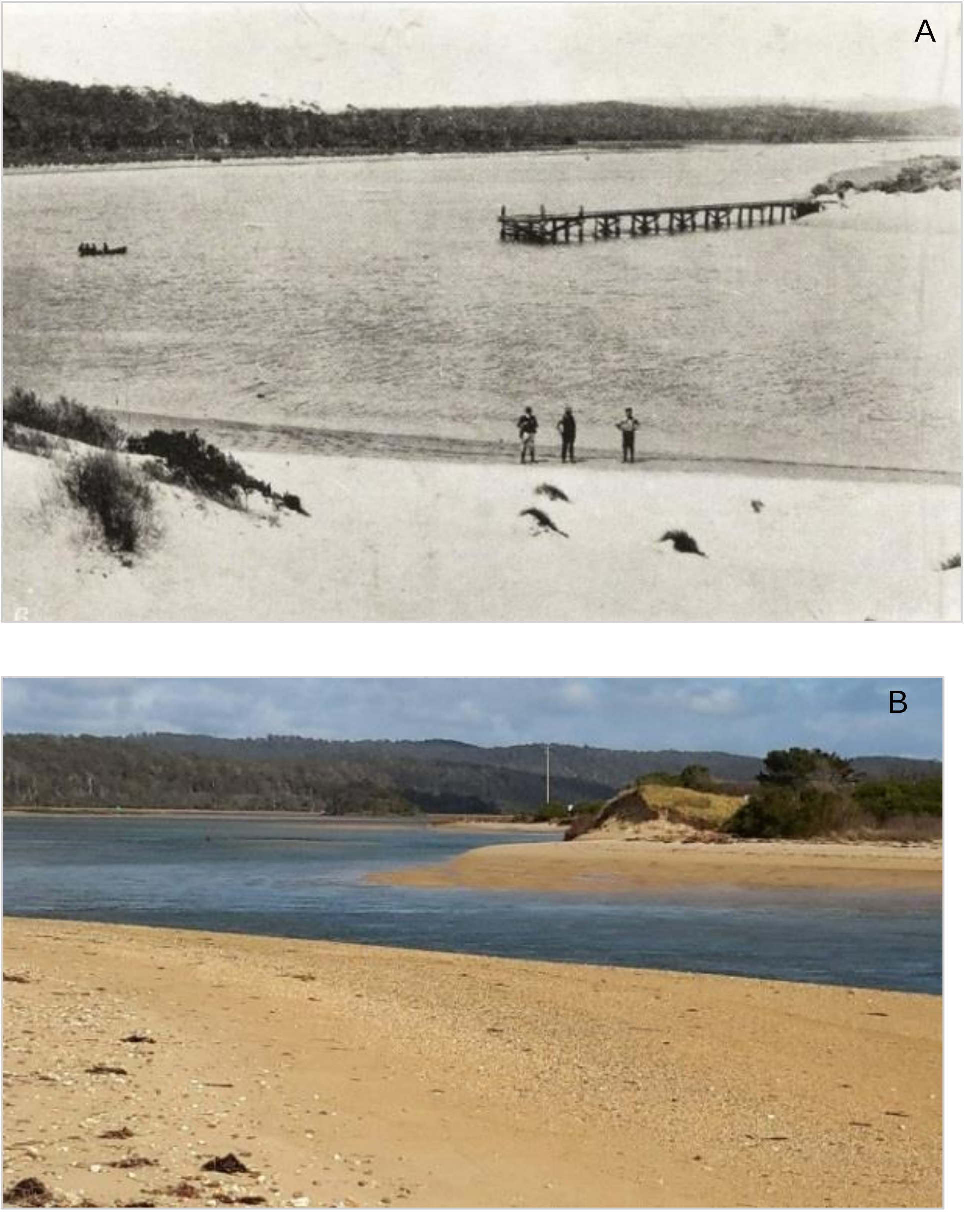


Figure. 9. Comparison photographs between 1909, A, (photo: B Viney), and 2017, B, (photo: R Smith)

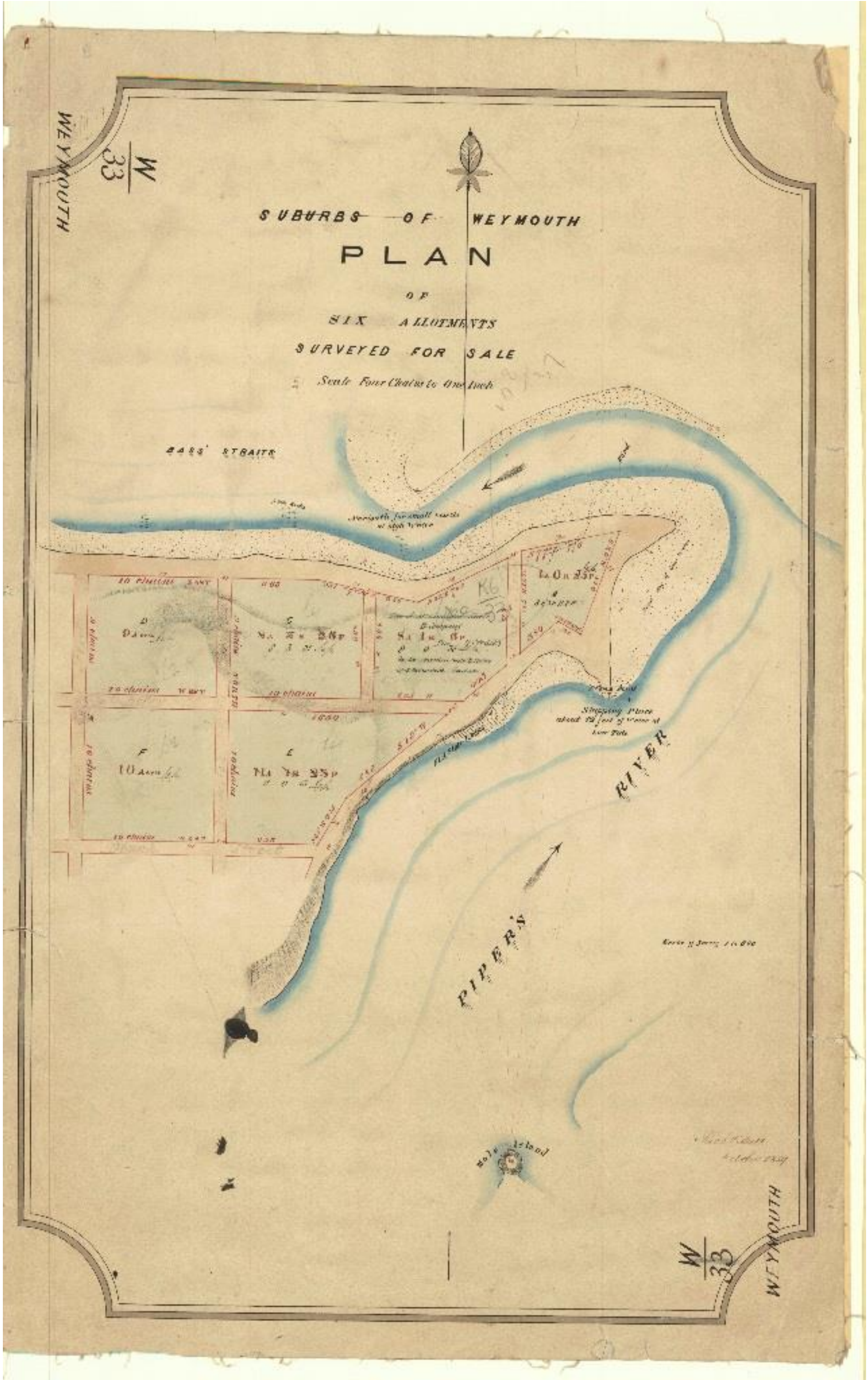


Figure. 10. Township of Weymouth circa 1859, surveyor Rich McHall

Fig. 10. 1859 survey map by Rich McHall, displaying the course the estuary took towards the west in front of Weymouth; the river depth was 12 feet at Stoney Point, suitable for shipping at low tide. This is the present-day site of the Weymouth boat ramp.

Fig. 11 A. 1940 photograph taken from Pipers Head dunes looking southward toward Weymouth, Fig. 11 B, taken on the same day, but looking westward, shows the low sand bar in front of the township and the river flowing in a northerly direction. Fig. 11 C. is a 2017 photograph for comparison with Fig. 11 B.

Figure. 11. Pipers River mouth showing new direction of river and sand. A & B from 1940, (Photo: B Viney). C from 2017 (Photo: R Smith)

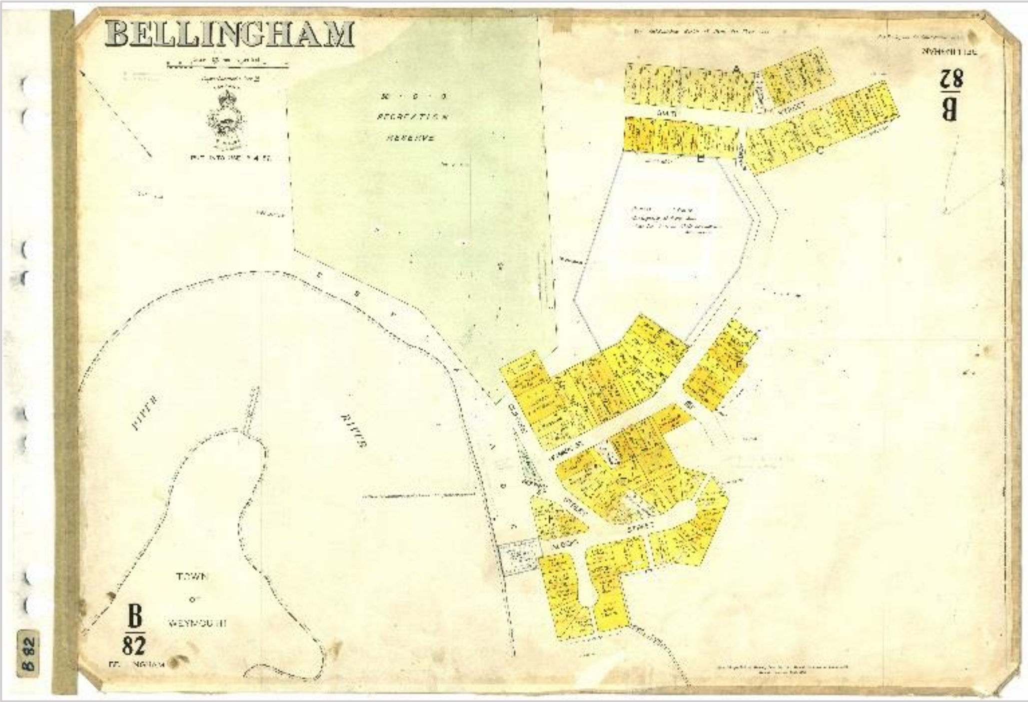


Figure. 12. Council map circa 1957 used for land ownership changes

In 1957 a map was commissioned, (Fig. 12), which unfortunately, was proven false when compared with Fig 9. A & B which shows no jetty existing in 1940. Also, some land holders claim that they owned land there in 1970, not 1957. Still it does show what the estuary was like before 1940, with the dune system and an intact jetty at Weymouth.

3.2.2 Reconstructed history

The reconstructed history was gathered by conducting interviews with community members and via archive research at Launceston LINC library and via the www.trove.nla.gov.au website (Table 4).

To 1800	Indigenous population encampment on the east side of Wattra Karoola River	Flo Mc Auley
1805	Wattra Karoola River was discovered by English surveyors and was renamed Pipers river after Ensign Piper, the first member to sight the river opening.	TROVE web site
Unsure time	Whalers and Sealers would frequent this river as it was a safe harbour, to process their catch (and with the hope of indigenous female company). The indigenous tribe would place a lookout on crab island to thwart this idea.	Flo Mc Auley
1810	Thomas Lewis improved the survey and charted Pipers River as coming through the marsh area (known as ‘the flats’ at the present-day Bellingham township).	LINC library
1859	Rich McHall surveyed the western bank to establish the Township and port of Weymouth.	TROVE web site
1873 to 1909	Pipers River became a well-used port for the transport of agricultural goods and mining goods to Launceston, Tasmania.	TROVE web site
1909 to 1940	Unable to find written evidence of the changed Pipers River mouth, (photographic evidence from 1940 shows a change to the north and directly out into Bass Strait).	Discussions with residents
1950 to 1960	Bellingham township surveyed on ‘the flats’.	LINC library
1960 to 1980	Boat ramp installed at Bellingham.	Discussions and photos from residents
1980 to 1990	High power boats towing skiers frequented the river as it became a recreational area.	Discussions with residents
1990 to 2005	Power jet skis became the preferred mode of entertainment on the river with fewer powerboat skiers.	Discussions with residents
2005 to 2017	Present day use is lessened to small power boats for fishing.	Discussions with residents

Table 6. Reconstructed historical timeline from 1800 to present day, (information gathered through community interviews and state archival search)

3.3 Fieldwork

3.3.1 Field mapping

Copies of maps from the Listmaps.gov.au site were used as base drawings, and then symbols from the geomorphic field manual by Dackombe and Gardiner (1983) captured the contours of beach characteristics, and the artist's impression below presents a 2D picture of the contour of all profiles, as seen in Figs. 13 to 16.

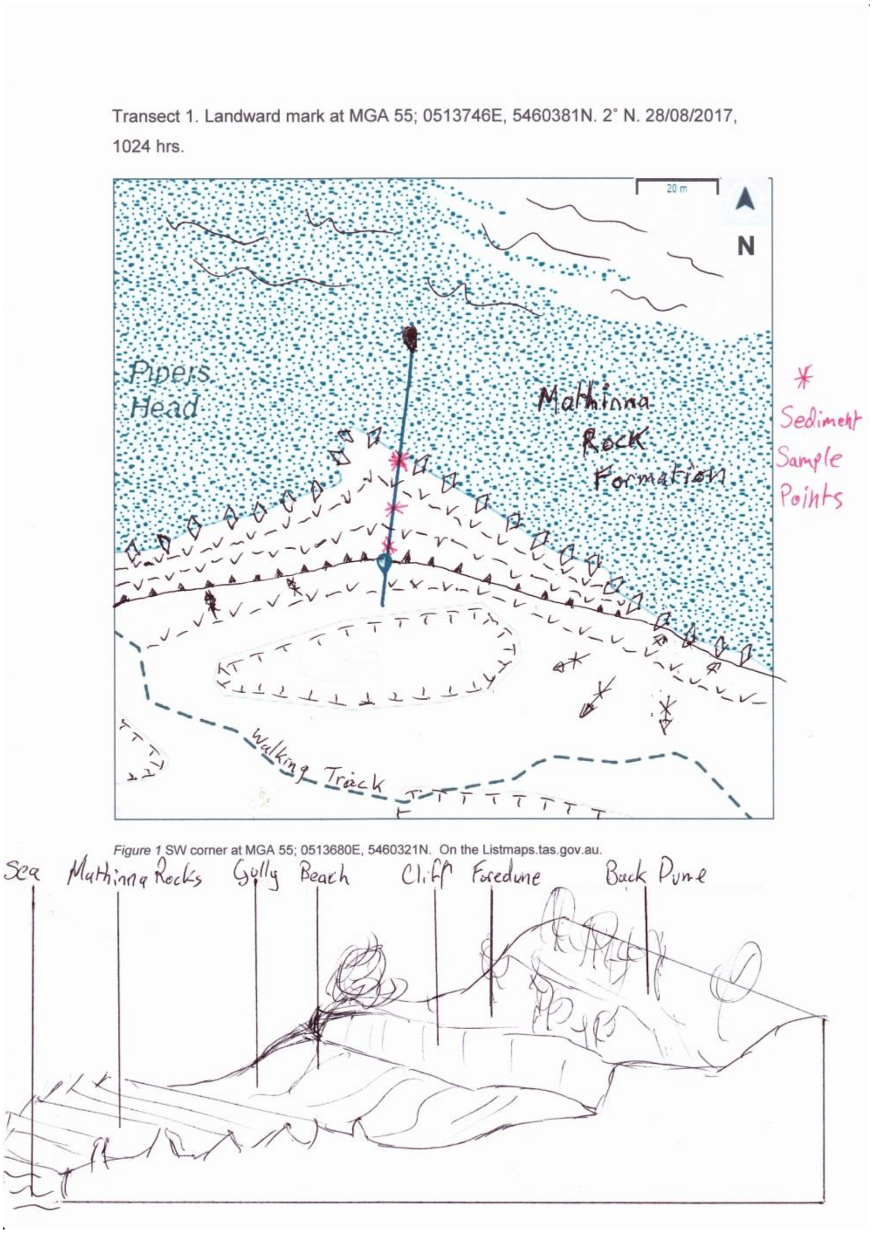


Figure 13. Geomorphic diagram and artist site drawing of transect 1, displaying contours and beach aspects, R Smith 2017

Transect 2. Landward mark at MGA 55; 0513467E, 5460074N. 284° W. 28/08/2017, 1115 hrs.

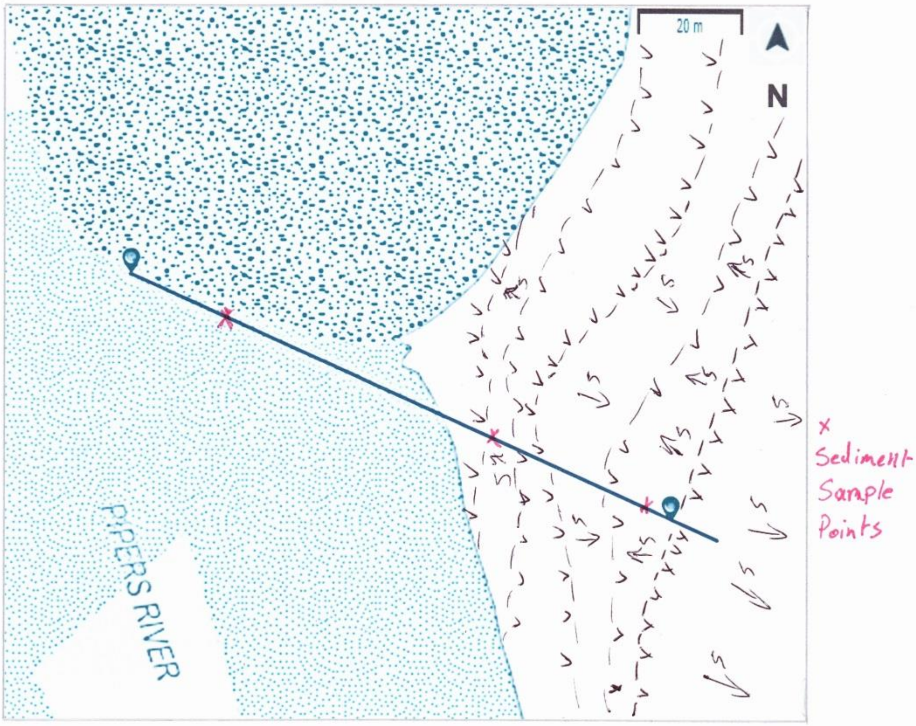


Figure 2 SW corner at MGA 55; 0513319E, 545600030N. On the Listmaps.tas.gov.au.

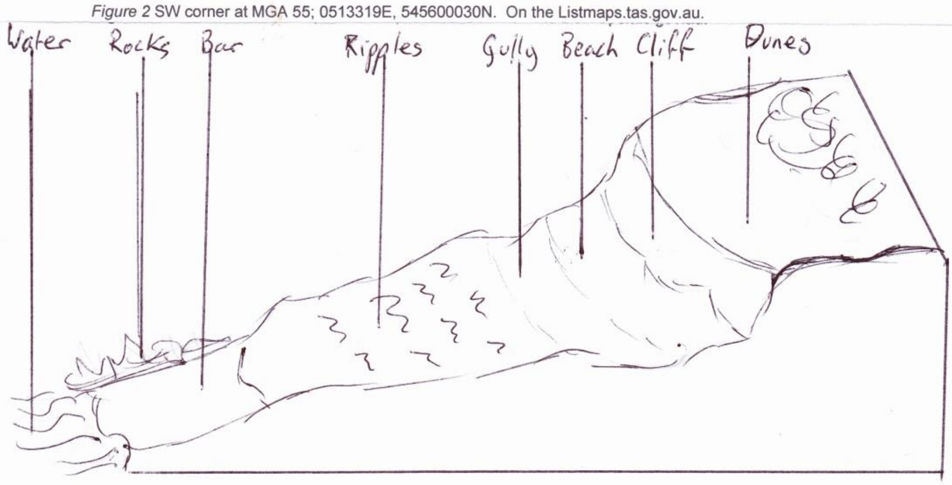


Figure 14. Geomorphic diagram and artist site drawing of transect 2, displaying contours and beach aspects, R Smith 2017

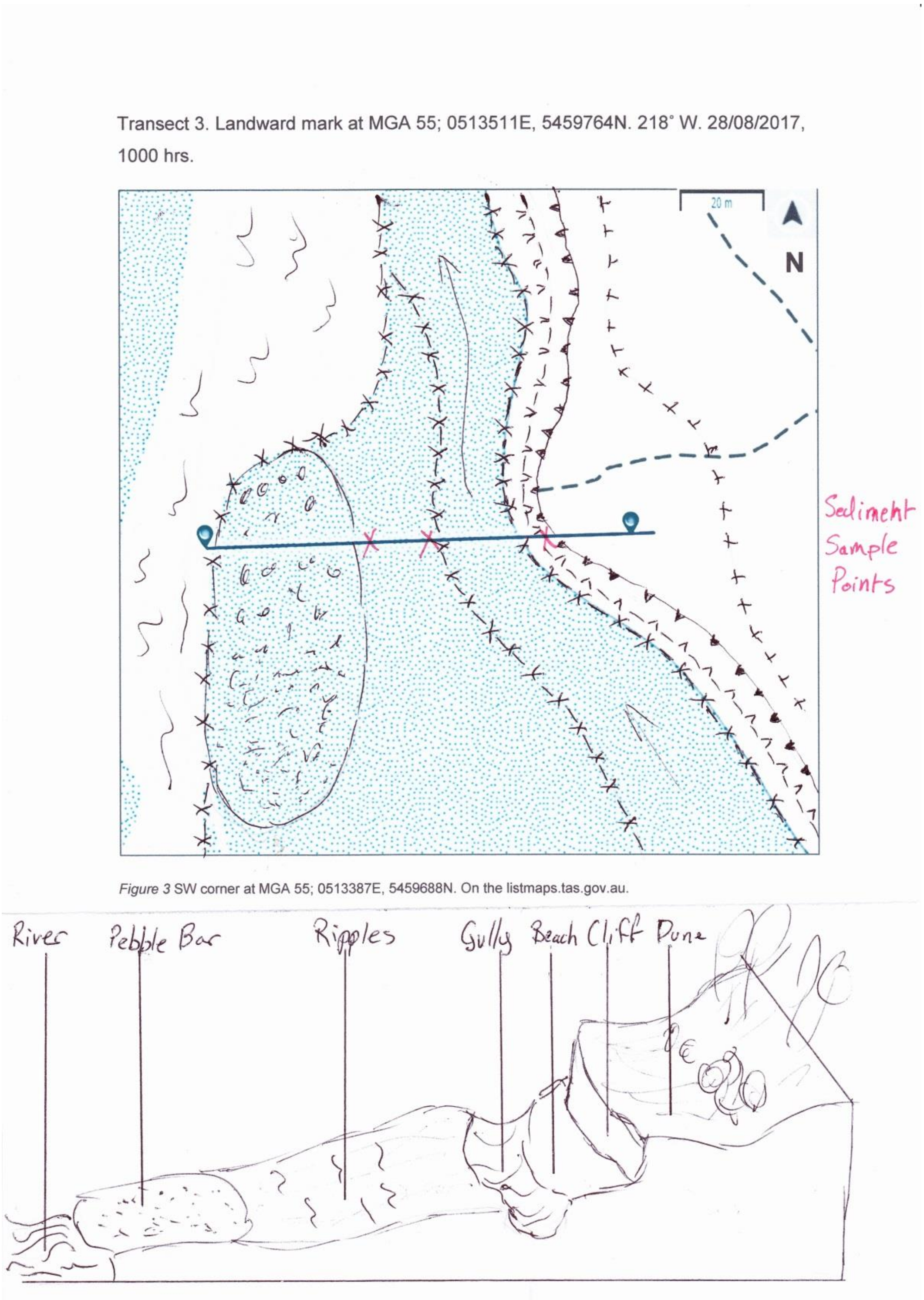


Figure 15. Geomorphic diagram and artist site drawing of transect 3, displaying contours and beach aspects, R Smith 2017

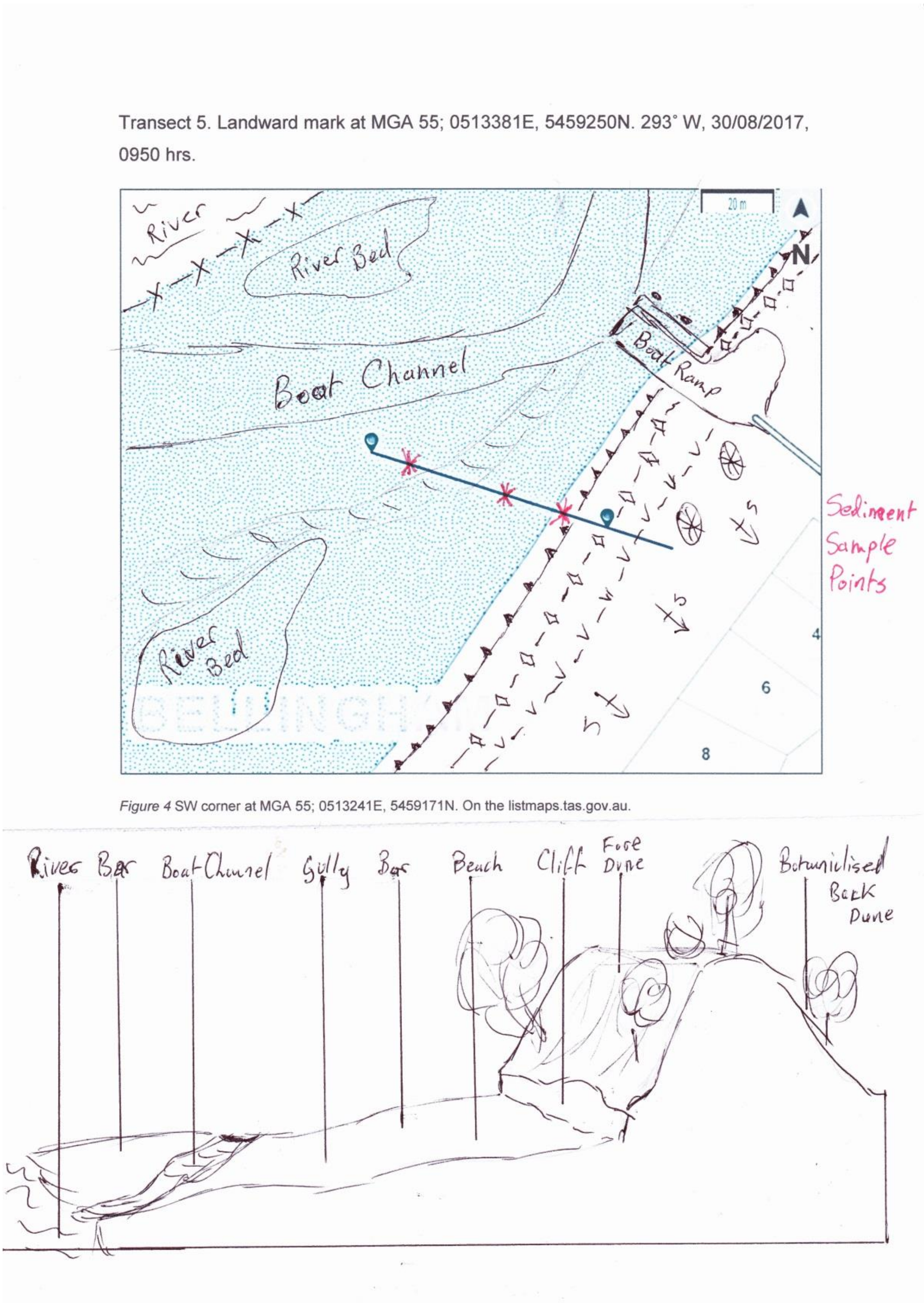


Figure 16. Geomorphic diagram and artist site drawing of transect 5, displaying contours and beach aspects, R Smith 2017

3.3.2 Transect profiles

Transects 1, 3 and 4 showed a downward slope of -1 metres toward mean sea level (MSL) and a foredune upward slope height range of 3.5 to 5.5

metres, whereas transect 2 slopes to -2.5 metres to MSL with a foredune slope height of 4 metres, and transect 5 records a slope reduction of 0.8 and foredune slope height of 3.5 metres on the day. Transect 5's record is skewed by the fact that it was conducted approximately 2 hours before the forecast low astronomical tide for that day, and it also ended at the first channel of water as it was too deep to traverse safely on foot. Figs. 18 and 21 display a variety of convex (upward) and concave (downward) contours in the back and fore beach area, respectively, where Figs. 17, 19 and 20 have a concave and then convex slope profile, (opposite to Fig. 18 and 21).

All transect profile data was adjusted to mean sea level (MSL) by calculating from the Australian Height Datum (AHD) for Low Head, Tasmania, (Figs. 17 to 21).

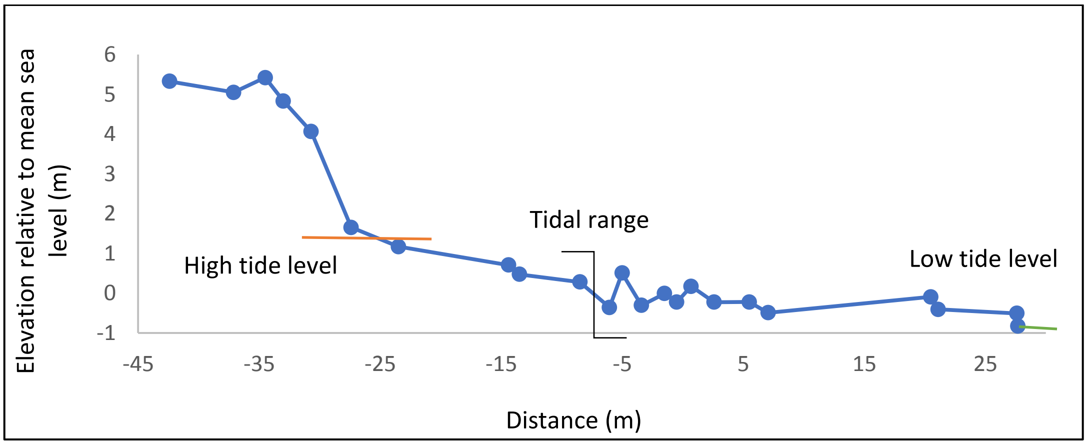


Figure 17. Transect 1 beach profile

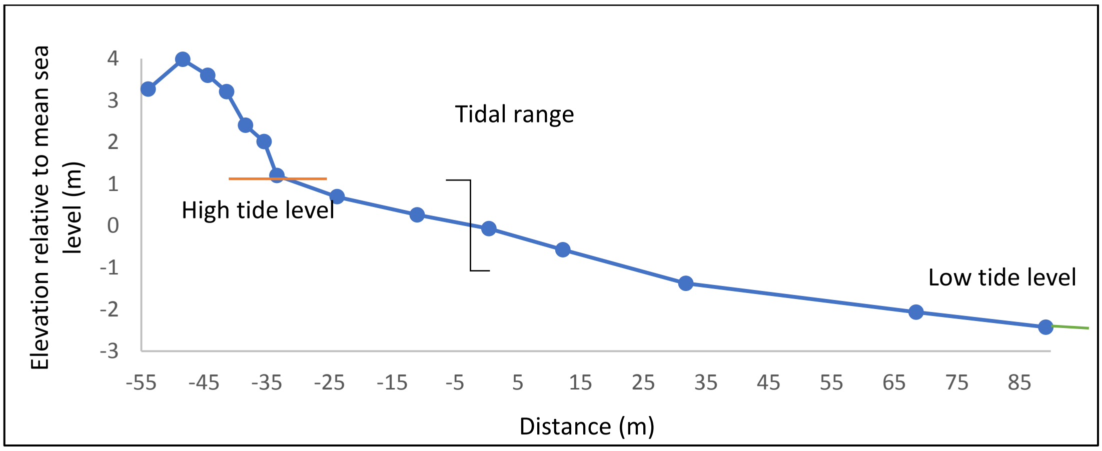


Figure 18. Transect 2 beach profile

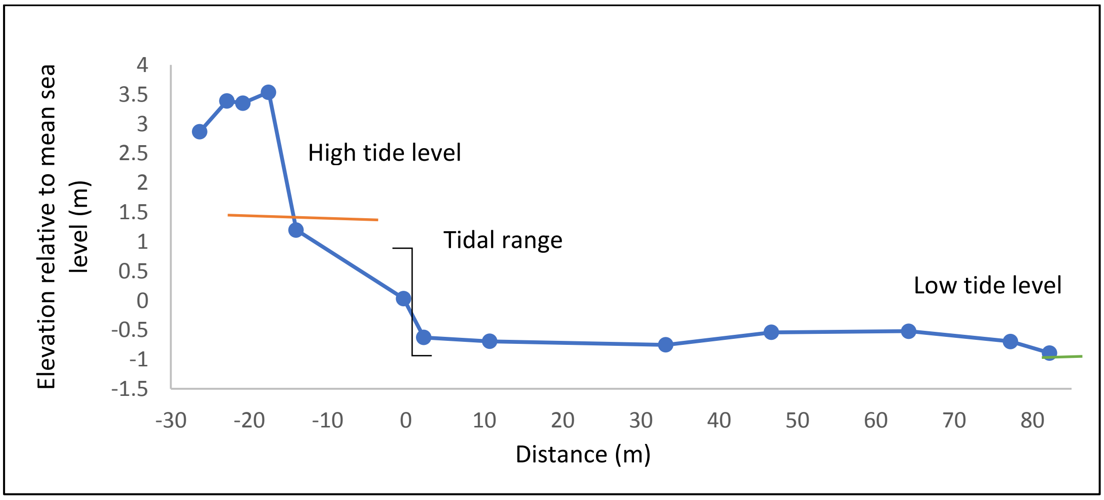


Figure 19. Transect 3 beach profile

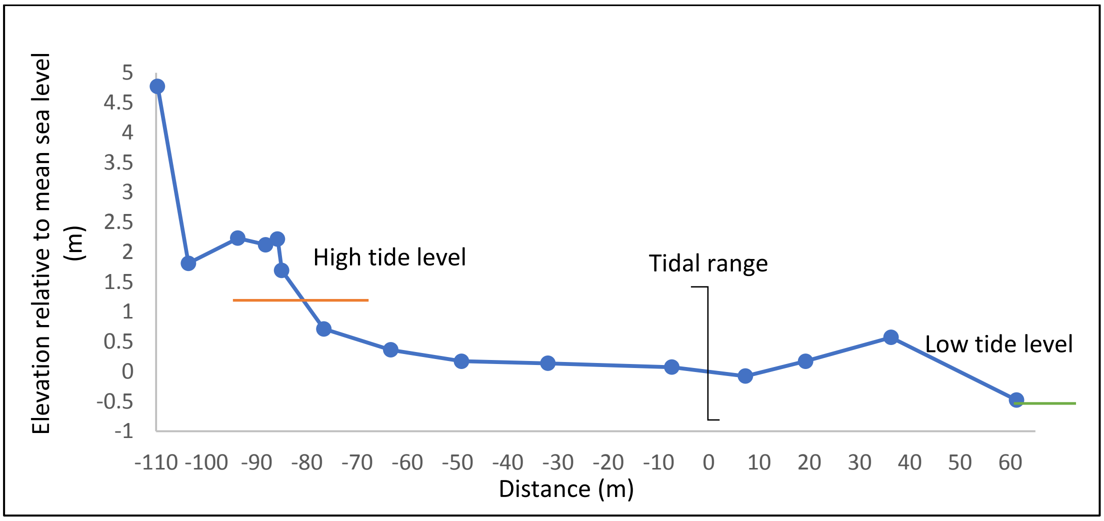


Figure 20. Transect 4 beach profile

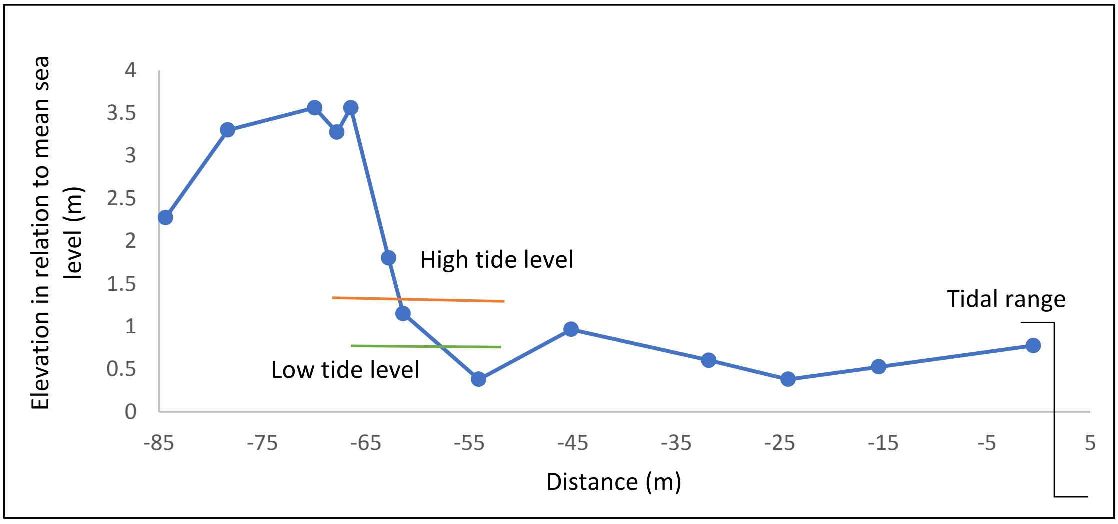


Figure 21. Transect 5 beach profile

3.4 Laboratory testing

Transect 4 was not used in the sediment sample testing. Points on each transect are shown in Figs. 13 – 16, with point numbers increasing from the dune to seaward.

3.4.1 Particle shape analysis

The particle shape of all transects sediment samples had a variety of roundness or angularity, close to being evenly spread throughout the sample points. Although the trend is for the sediment to be angular on the seaward transects to a sub-rounded particle in the river transects, with the middle being a mix of both, as seen in Table 7.

	Transect			
point	1	2	3	5
1	Sa-Sr	Sa	Sa-Sr	Sr
2	Sa	Sr	Sa	Sr
3	A	Sr	R	A

Wr	well rounded
R	rounded
Sr	sub-rounded
Sa	sub-angular
A	angular
Va	very angular
Sa-Sr	Sub-angular/sub-rounded

Table 7. Particle shape as based on Powers (1953)

3.4.2 Dominant mineral composition

Transect 1 majored in carbonate dominate particles except at point 1.
Transect 2 majored in carbonate dominate particles (mixed at point 3).
Transect 3 majored in quartz dominant sediment (mixed at point 1).
Transect 4 (not used).
Transect 5 contained all three types of mixture; point 1 was quartz dominant, point 2 was mixed, point 3 contained carbonate dominant particles.

So, carbonate sediment dominates the seaward facing transects, and the river facing transects are quartz dominant. Between transects 2 and 3 the dominant minerals change places, (Table 8).

	Transect			
point	1	2	3	5
1	Q-d	C-d	M	Q-d
2	C-d	C-d	Q-d	M
3	C-d	M	Q-d	C-d

Q-d	Quartz dominant
C-d	Carbonate dominant
M	neither quartz or carbonate dominant

Table 8. Mineral dominant composition

3.4.3 Sediment grain size

Most sediment samples are comprised of fine particles, (under 0.25 mm). Transect points 1 and 3 were symmetrical in sediment particle distribution. Transect points 6, 8, 9 and 10 skewed strongly toward fine particles. Transect points 4, 7, 11 and 12 produced fine skewed particles. Transect points 2 and 5 were skewed toward coarse particles. Overall, the transect data displays a movement from 'strongly sorted toward fine' particles to 'strongly sorted toward large' particles at points 8 to 10 and then back to 'strongly sorted toward fine' particles, (Fig. 22).

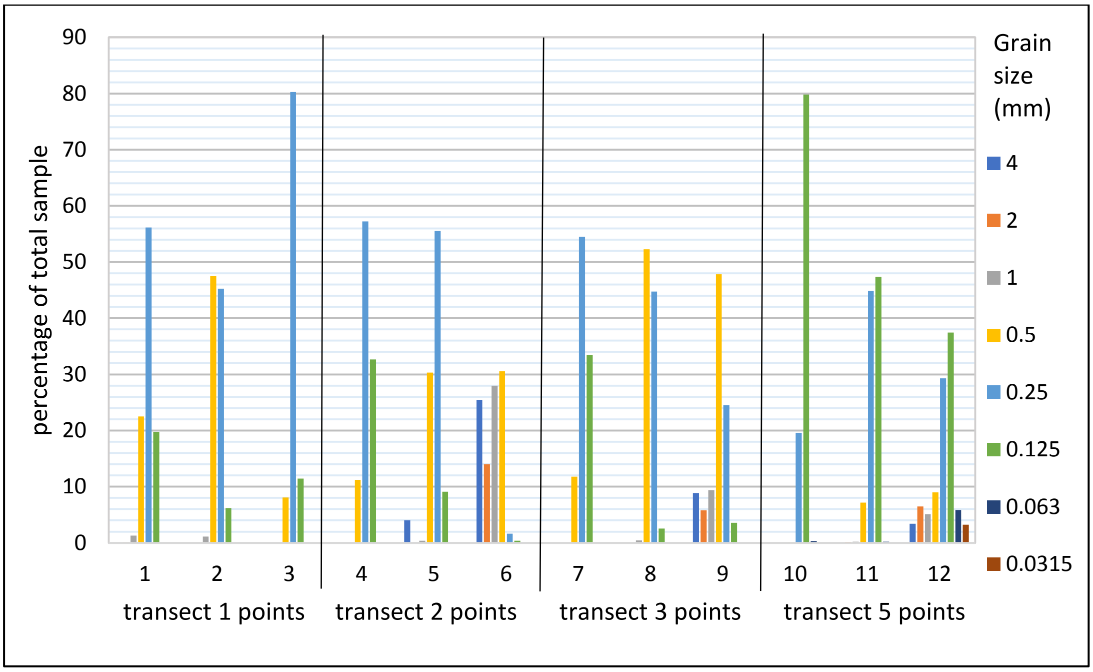


Figure 22. Sediment comparison between all transect samples

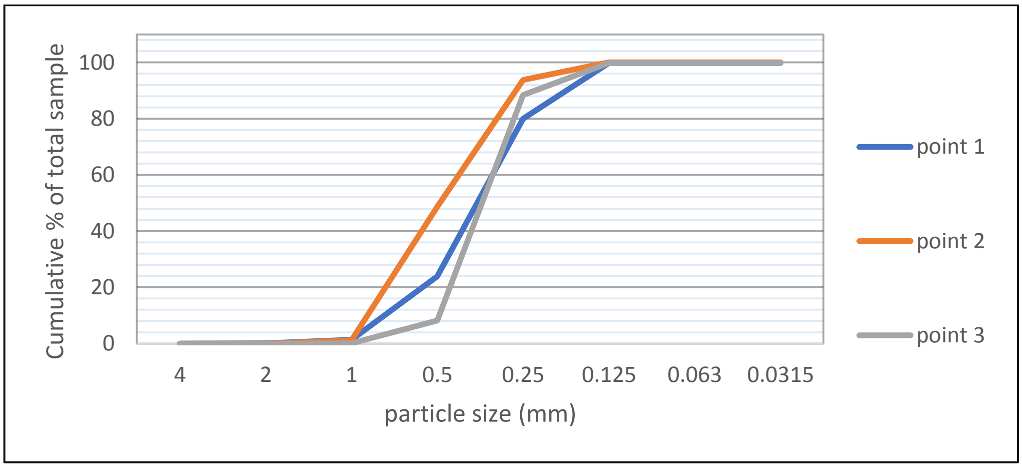


Figure 23. Transect 1 sediment samples with point 1 being at the beach and point 3 being at waters edge.

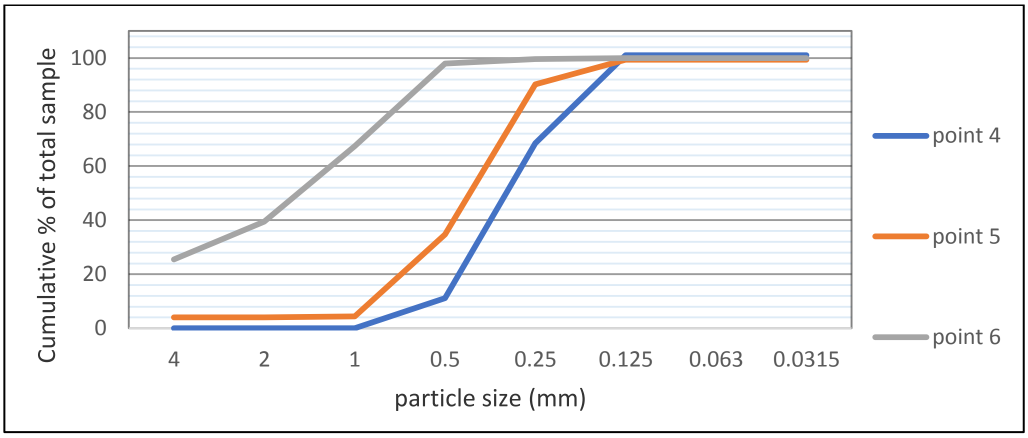


Figure 24. Transect 2 sediment samples with point 4 being at the beach and point 6 being at waters edge.

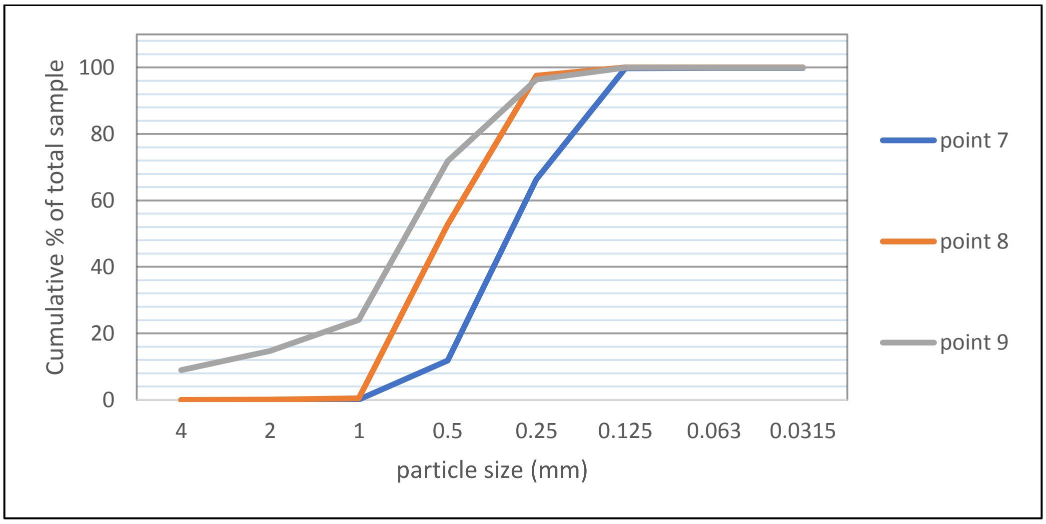


Figure 25. Transect 3 sediment samples with point 7 being at the beach and point 9 being at waters edge.

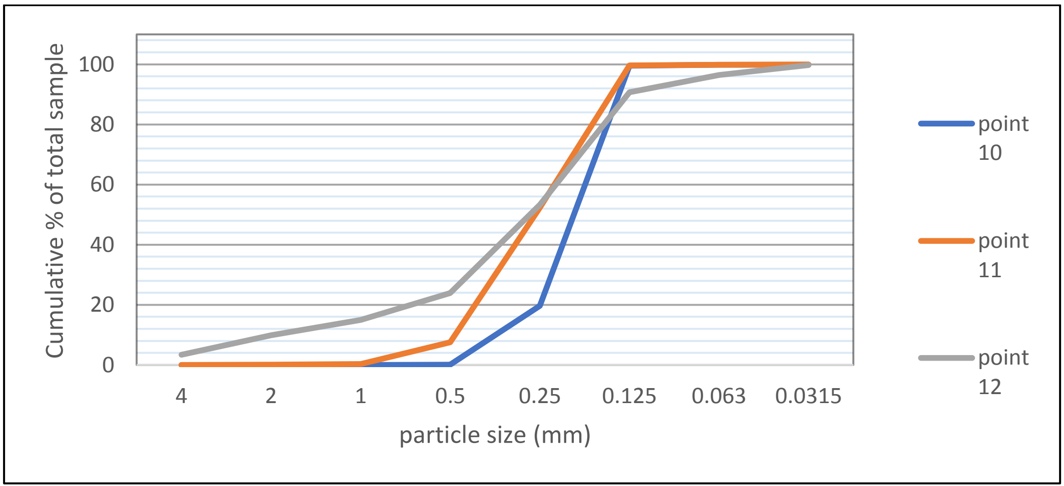


Figure 26. Transect 5 sediment samples with point 10 being at the beach and point 12 being at waters edge.

Transects 1, 3 and 5 all show similar trends in sediment distribution (Figs. 23, 25 & 26), whereas transect 2 shows a wider distribution of sediment (Fig. 24).

		Transect points					
Phi value	sieve size (mm)	1	2	3	4	5	6
-2	4	0	0	0	0	4	25.45
-1	2	0.09	0	0	0	0.05	13.98
0	1	1.28	1.13	0.04	0	0.35	28
1	0.5	22.5	47.48	8.08	11.19	30.34	30.57
2	0.25	56.15	45.23	80.28	57.21	55.54	1.63
3	0.125	19.79	6.2	11.44	32.66	9.12	0.36
4	0.063	0.01	0.005	0.01	0	0.02	0.02
5	0.0315	0	0	0	0	0	0
	Skewness	-0.03	-0.3	0.01	0.13	-0.14	-1.09
		sym	cs	sym	fs	cs	sstcp
	Kurtosis	-2.53	-2.36	-2.74	-2.51	-2.53	-0.6
		VL	VL	VL	VL	VL	VP

Table 9. % mass of sediments from transects 1 & 2 points

		Transect points					
Phi value	sieve size (mm)	7	8	9	10	11	12
-2	4	0	0	8.9	0	0	3.4
-1	2	0	0.04	5.8	0	0.14	6.45
0	1	0.06	0.43	9.37	0	0.21	5.11
1	0.5	11.77	52.28	47.81	0.1	7.15	8.98
2	0.25	54.51	44.75	24.48	19.59	44.83	29.31
3	0.125	33.46	2.52	3.59	79.81	47.38	37.42
4	0.063	0.06	0.02	0.02	0.32	0.19	5.83
5	0.0315	0	0	0	0.04	0.06	3.25
	Skewness	0.14	-0.34	-0.52	0.58	0.29	0.27
		fs	sstcp	sstcp	sstfp	fs	fs
	Kurtosis	-2.49	-2.33	-2.11	-2.23	-2.36	-2.2
		VL	VL	VL	VL	VL	VL

Table 10. % mass of sediments from transects 3 & 5 points

SSTFP	strongly skewed towards fine particles	VP	very platykurtic < 0.67
FS	fine skewed	P	platykurtic 0.67 - 0.90
SYM	symmetrical	M	mesokurtic 0.90 - 1.11
CS	coarse skew	L	leptokurtic 1.11 - 1.50
SSTCP	strongly skewed toward coarse particles	VL	very leptokurtic 1.50 - 3.00
		EL	extremely leptokurtic > 3.00

Table 11. Legend for Tables 9 and 10

Phi value	Sieve size (mm)	Transect points 1	2	3	4	5	6
-2	4	0	0	0	0	4	25.45
-1	2	0.09	0	0	0	4.05	39.42
0	1	1.37	1.13	0.04	0	4.4	67.42
1	0.5	23.87	48.6	8.12	11.19	34.73	97.99
2	0.25	80.02	93.83	88.4	68.4	90.27	99.62
3	0.125	99.81	100.02	99.83	101.05	99.39	99.97
4	0.063	99.82	100.03	99.84	101.05	99.4	99.99
5	0.0315	99.82	100.03	99.84	101.05	99.4	99.99

Table 12. Cumulative % mass of sediments from transects 1 & 2 points

Phi value	Sieve size (mm)	Transect points 7	8	9	10	11	12
-2	4	0	0	8.9	0	0	3.4
-1	2	0	0.04	14.7	0	0.14	9.84
0	1	0.06	0.47	24.07	0	0.34	14.95
1	0.5	11.83	52.75	71.87	0.1	7.49	23.93
2	0.25	66.33	97.5	96.35	19.69	52.31	53.24
3	0.125	99.79	100.02	99.93	99.49	99.69	90.66
4	0.063	99.85	100.03	99.95	99.81	99.87	96.48
5	0.0315	99.85	100.03	99.95	99.85	99.93	99.73

Table 13. Cumulative % mass of sediments from transects 3 & 5 points

Sediment samples from all transect points were very leptokurtic, except for point 6, which was very platykurtic, (Fig. 24). All the sediment samples are very evenly spread in sediment size, except in position 6 which exhibits a broader spread of sediment size.

Transect	Point	Median	Scatter	Skewness		Kurtosis	
	1	1.4	0.83	-0.02	SYM	-2.53	VL
1	2	1	0.7	-0.3	CS	-2.36	VL
	3	1.5	0.56	0.01	SYM	-2.74	VL
	4	1.5	0.739	0.13	FS	-2.51	VL
2	5	1.1	0.84	-0.13	CS	-2.52	VL
	6	-0.6	-1.08	-1.09	SSTCP	-0.6	VP
	7	1.6	0.78	0.14	FS	-2.49	VL
3	8	0.9	0.66	-0.34	SSTCP	-2.33	VL
	9	0.4	0.002	-0.52	SSTCP	-2.11	VL
	10	2.3	0.54	0.58	SSTFP	-2.23	VL
5	11	1.8	0.75	0.29	FS	-2.36	VL
	12	1.7	1	0.27	FS	-2.19	VL

Table 14. Sediment sample results in pyhsical properties

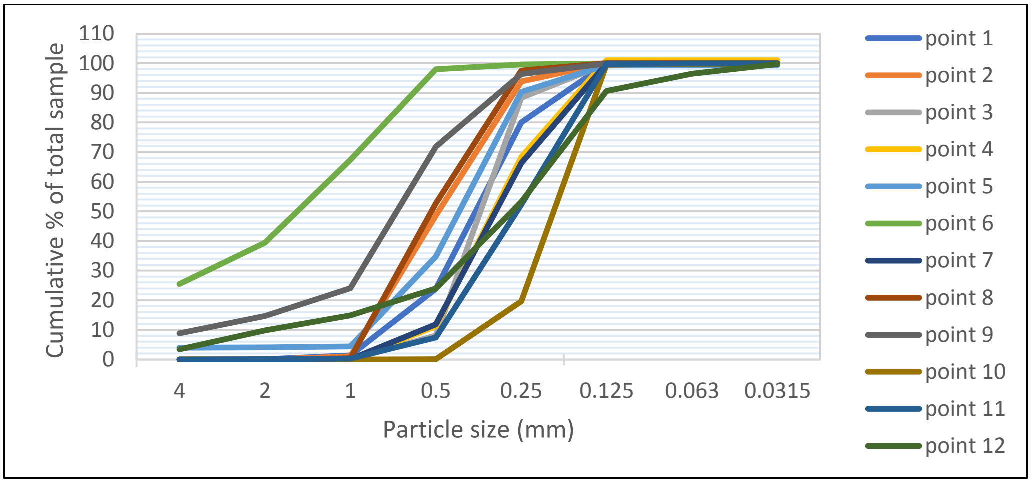


Figure 27. Graph of all sediment samples showing point 6 different range of sediment size

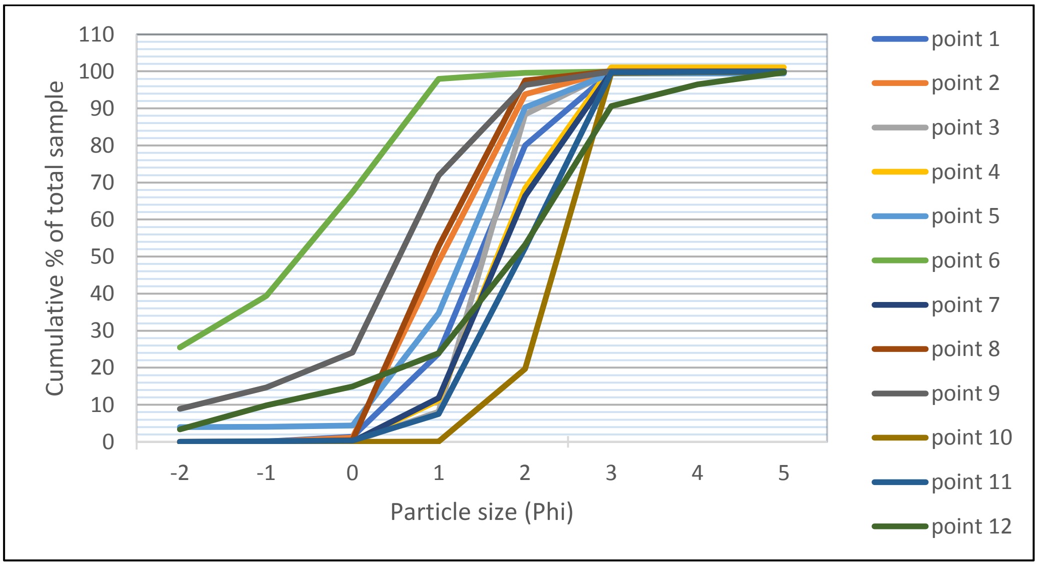


Figure 28. same as Fig. 25 except in sizes of Phi

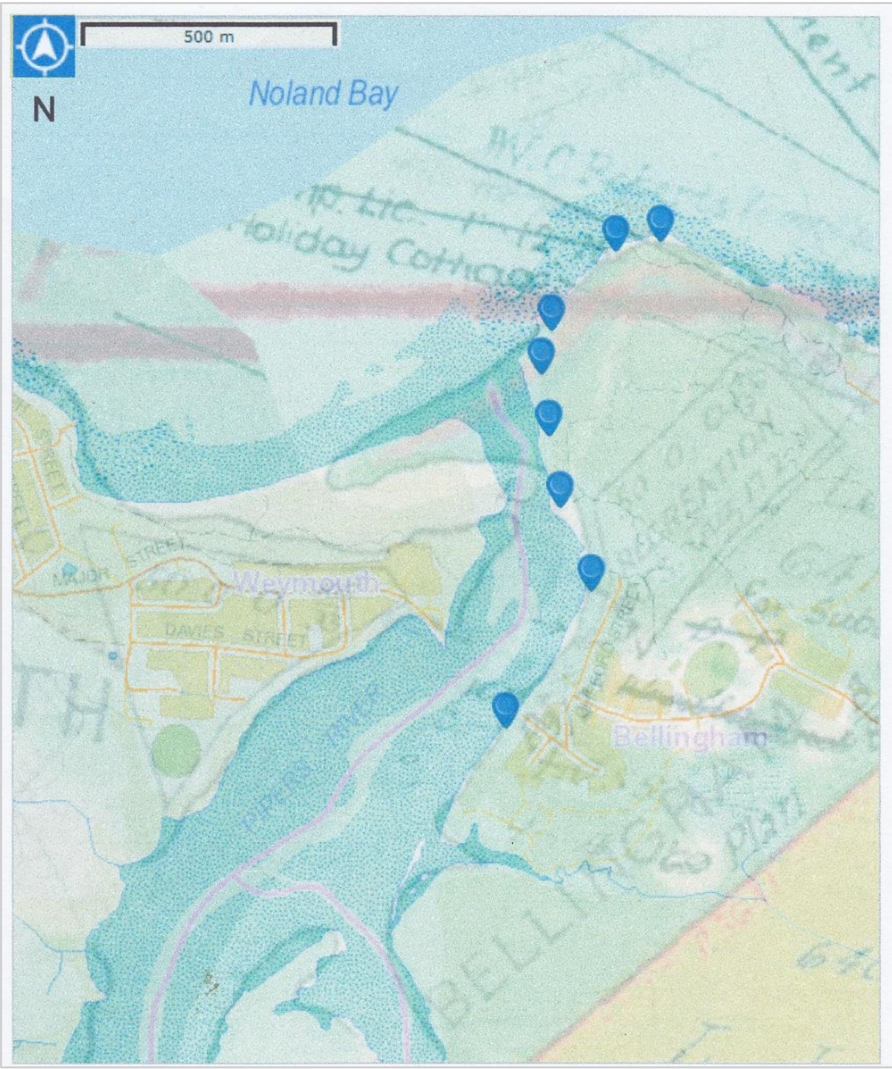


Figure 29. 1811 map overlaid on a 2017 map displaying change of river and sediment deposition in the Pipers River Estuary, (Listmap.gov.au).

3.5 Other results

Overlaying the 1811 and 2017 maps also provides the answer to another question, namely, why is the environment behaving the way it is? (Fig. 29). Evidence of a major flood event was disclosed during discussions with community members, which purportedly happened around the 1920’s, (this has not been confirmed at time of writing).

Chapter 4 Discussion

4.1 River usage and course change

As shown in Skinner (2015) Fig. 7 and Fig. 9 A & B of this report, by 1940 the river had its course changed towards the north, away from its westerly exit in front of Weymouth (1909). The remnant of the original river course and its usage are visible today at low tide with only one of the landward anchor posts of the jetty remaining, as circled in red in Fig. 30.

Figure 30. The only remaining jetty anchor post, circled in red, photo courtesy of B Viney

From the 1940s up to the 1980s, river usage changed from mainly commercial to recreational (Table 6), as more families frequented the area

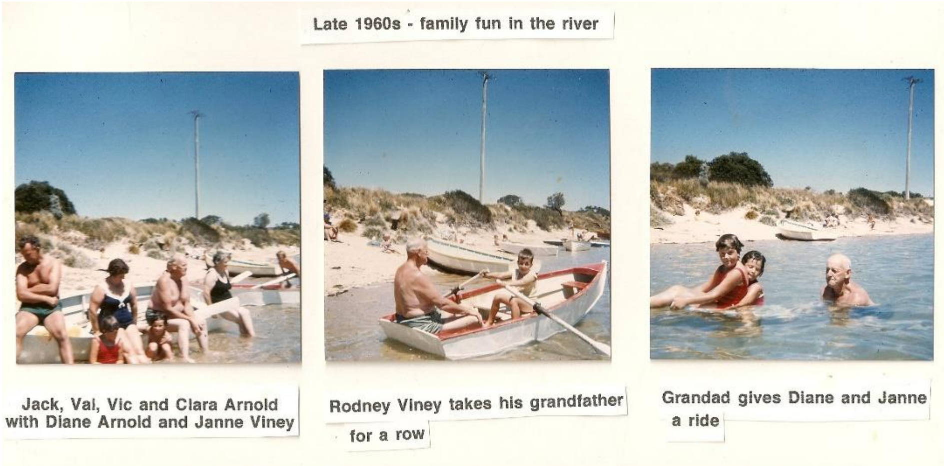


Figure 31. Photos courtesy of B Viney of persons at Bellingham beach in the 1960s

for camping, holiday and eventually permanent settlement.

Around the 1980's and late 1990's the use of high powered speed boats became a frequent sight with persons skiing in tow, at times as many as six or eight boats on the water at the same time. In 2000, power skis grew in popularity vs. usage of speed boats and skiers. These activities may have contributed to heavier sedimentation in the river bed, e.g. in places like north of the Bellingham boat ramp, as well as at the northern side of Weymouth's boat ramp. These activities have reduced in frequency to the present day, (2017), where now only a few small power boats use the ramps to access the sea mainly for fishing purposes. Historical evidence confirms that the estuary mouth between Bellingham and Weymouth beaches shallowed considerably after 1909 (Table 6) up to which time it was deep enough for commercial vessels. This coincided with the eastern movement of the river mouth, and may be concentrated by catchment erosion delivering sediment to the estuary.

4.2 Present-day study

Nowadays there is a greater realisation that ecosystem services have a value, and an impact on humans. An

Figure 32. Part of Mathinna Bed formation on the northern shore of Pipers Head, photo by R Smith

increasing number of studies are now indicating indirect human impacts to the coast and river zones, (Defeo et al., 2009, Skinner, 2015, Johnston and Ellison, 2014), whereas in the past, there were numerous studies on the formation of the substructure in the Dorset County (Sanders, 1968), that dealt with the 'Mathinna Bed' formation and river course and catchment, and agricultural impacts on the environment (Edgar et al., 1999) (Fig. 32). Other areas around the Tasmanian coastline have recently drawn local interest, focusing primarily on the direct and indirect results of climate and human impacts (Johnston and Ellison, 2014, Short, 2006). This has assisted coastal care groups to become informed and to produce and implement effective conservation measures. This study has highlighted areas of concern at Bellingham of beach erosion, through the ongoing studies, transect profiles, and sediment testing. In the next ten years, accumulating knowledge of this coastline's characteristics will produce a better understanding of the ecosystem and a greater awareness of protecting the environment.

4.2.1 Transect comparison

Although these transects have fore dunes with visible concavity, they also have steep declining faces, (Figs.17 to 21). Along with this, the back beach and fore beach areas are also slightly concave with areas being convex, as in sand or pebble bars. When the transect profiles 1 to 5 in Figs. 17 to 21 are compared with profiles by Bird (2008) (Fig. 34), and those of Johnston and Ellison (2014) at Turners Beach, and Skinner (2015) at Weymouth beach, the Bellingham profiles have evidence of some build up to become new dunes and beaches. So, although, all transects have areas of convexity and concavity, as well as channels close to the dune system, the beach characteristics display some accretion in progress.

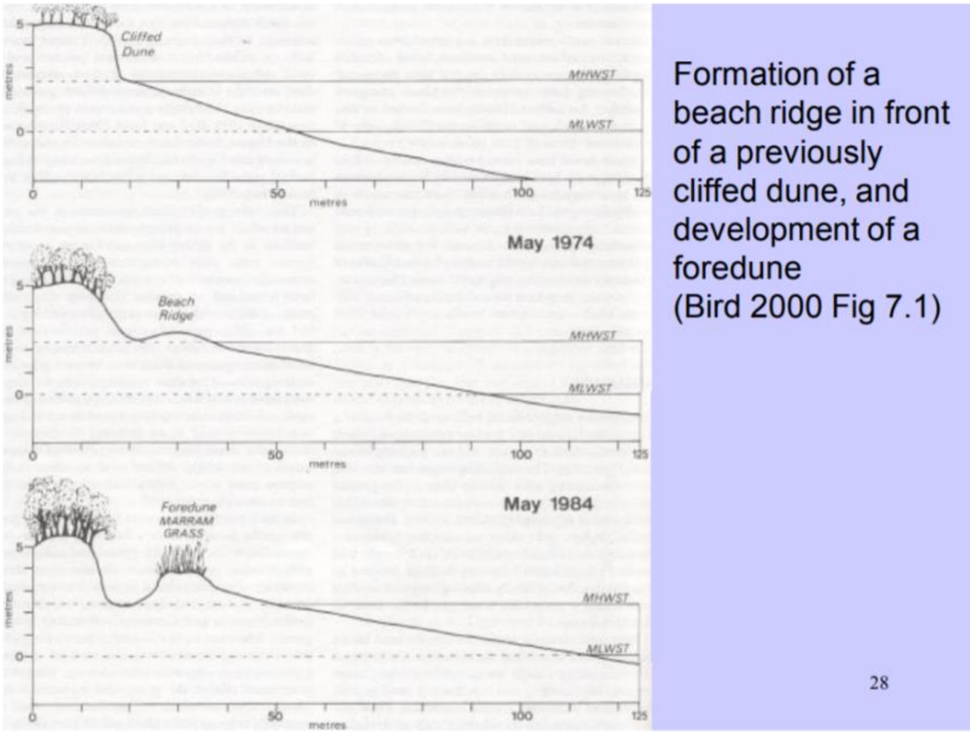


Figure. 33. beach formations by Bird (2008)

Transects 3 and 4 (Figs.19 and 20) demonstrate respectively at c 60 m and c 45 m distance a contour that is building up, these close to shore and the long expanse of sediment that is slightly convex shaped and the slightly concave fore beach area near the rivers mouth, similar to Bird (2008) second profile in Fig. 34. Transect 5, (Fig. 21) gully near the cliff face at c-55, followed by a ridge of sediment buildup at c-45, similar to both profile 3s in Figs.19 and 34. Whereas transect 1 has a short sand beach, with a slight convex shape between c-25 and -15, (Fig. 17), providing evidence for sediment depletion at time of study. Transect 2 has a convex contour to begin at c 5, and then ends with a concave contour at c 35 to near low tide, (Fig. 18). There are signs of sediment buildup in the back beach area, similar to profile one in Fig. 34.

As this is the first study of the Bellingham area, further long term research is needed to determine whether the beach is accreting or eroding, this study is a baseline survey. Future surveys using the permanent points that the Progess Association has now estabilshed will confirm trends of sediment movment.

4.2.2 Sediment comparison

As indicated in the concave beach profiles in the results (Figs. 17 – 21), and historical records discussed in section 4.1, sediment erosion depostion is a feature at Bellingham. Sediment analysis performed in a laboratory establishes a range of differences between all sample points, from finely sorted to coarsely sorted grains of sediment and mineral compostion, resulting in a definite changing point from carbonate to quartz domination in the sediment samples. This manifests between transects 2 and 3, respectively.

Davies and Hudson (1987) concluded that a high proportion of carbonate being present indiates that the sediment comes from marine origins, and a quartz dominant sediment is derived from land origins. The sediment results showed a transition from carbonate dominant in transect 1 and 2, towards a quartz dominant sediment in transect 3 and 5 (Table 8), showing variation in fluvial to marine influences along these transect locations. Whereas the roundness test showed a mix, with transects 1 and 3 being more angular than transects 2 and 5, (which were inclined towards roundness), (Table 7). This, along with the sediment size anaylsis of ‘strongly sorted towards fine’ particles, is evidence of high wind and wave energy within the Pipers Head and Pipers River environs (Bird, 2008, Davies and Hudson, 1987).

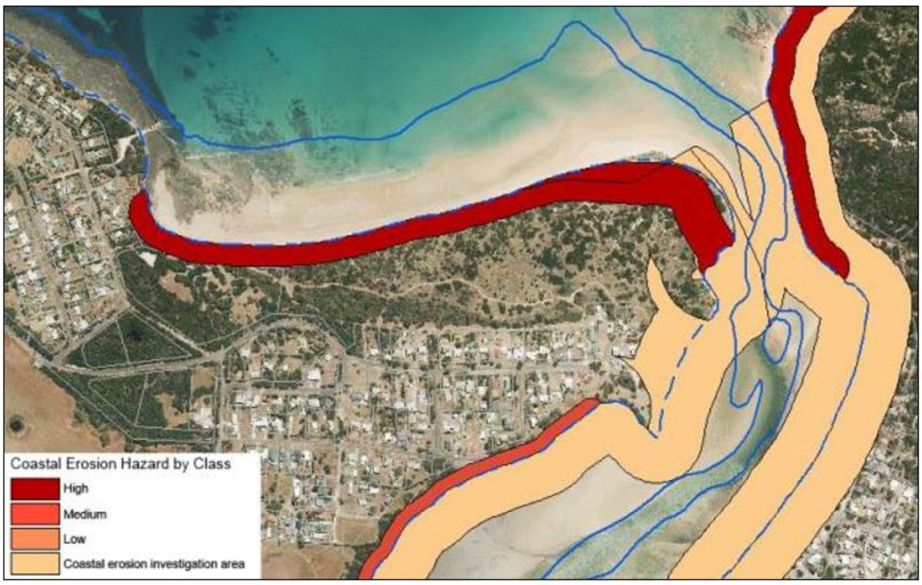


Figure 34. Coastal erosion risk, by class, courtesy of The George Town Council (Skinner, 2015)

Fig. 33 shows both transects 2 and 3 (Fig. 1) are within the red zone, which is where the greatest amount of hydraulic action is experienced, due to dominant wave energy direction into the river mouth. And with the position of the rock outcrop at Pipers Head, this funnels the longshore drift into Pipers River from the Weymouth beach, adding to the siltation of the estuarine and inhibiting estuarine vegetation growth. The depositing of fine sediment on top of large sediment, as seen in transect 2 results, (behind a rock outcrop), and as seen in transect 5, (furthest away from wave pressure), provides evidence of increasing siltation. At transect 3 at the tail-end of the red zone, there is a greater layer of fine sediment in the form of sand bars, depicting an accretion dominant period of sediment movement, (Thom and Hall, 1991).

To enhance this sediment comparison it is suggested that what Friedman (1961) described as a process of separating the different weighted minerals, which increases the defining ratio of the quartz content to that of specific heavy minerals, thus greatly defining the origins of the sediments come from, be utilised by future researchers to determine whether the sediment has come from dunes, river or sea material with greater accuracy.

4.3 Impacting history of the area

4.3.1 From indigenous to European control

Around 1805, (Fig. 1), the indigenous people called the river Wattra Karoola; later renamed ‘Pipers River’. At that time the river entered the sea parallel to the shoreline following a westerly course. In 1810, another surveyor named Thomas Lewis (Fig. 7), mapped the course of Pipers River as coming from the east through a marsh area, known today as the township of Bellingham. 1859 brought Rich McHall to the area; he surveyed the west bank for the establishment of the Weymouth Township at Pipers River, (Fig. 10), (archives from trove.nla.gov.au and state library).

4.3.2 Port establishment

During the 1800's, ships frequented the estuary area as it provided a safe and sheltered anchorage where they could process their catch of whale blubber and seal furs. The impact on the indigenous community was drastic; by 1873 the river was transformed into a busy port, where slate and other goods were transported back and forth daily, which continued up to circa 1909, (Fig. 3). This change of area usage may have had an impact on the dune zone of Pipers Head, for in the period between 1909 to 1940 the river course was altered by either a flood or manmade actions. This destroyed the port area and increased the inbound flow of offshore sand deposits, creating a greater erosion effect on the Pipers Head beach zone, as shown in Fig. 7 of the Skinner (2015) study, (as per community interviews and photos and state archives).

4.3.3 Recommendations

The community survey results (Tables 1 & 5) (sections 2.2.1 & 3.1) highlighted the lack of effective coast care programs and ongoing management, evidenced by site observations of the area (Figs. 13 to 16). Hence, this report recommends that taking no action will result in further damage, as found by Skinner (2015). Skinner's proposal for Weymouth and the west side of Pipers River, could also be considered for Bellingham or Pipers Head. Not only management programs, but inclusion of native vegetation rehabilitation programs of areas infested with marram grass and sea spurge need to be established. To retain sand sediment and help regrowth of native vegetation, fencing and thatching will reduce the wind and wave movement erosion.

Introducing boardwalks and more effective signage through Crownland and coastal areas to encourage tourism, and integrated management that encompasses all stakeholders and environmental concerns needs to be greatly stimulated. What affects one side will affect the other, so, an all-encompassing approach by communities, government agencies and councils will result in encouraging the ecosystem to become more

resilient. This is not helped by the local council and NRM boundary separating the two communities at governance levels, for it is important that Bellingham and Weymouth value and understand their shared ecosystem and work together to preserve it. To achieve this, it is recommended that Tamar NRM fully "adopts" Bellingham into its region, as already proposed by including Bellingham in George Town coastal planning meetings.

4.4 Conclusion

It is becoming more evident that the conditions of sediment transport at Bellingham are the result of it losing its natural barrier to the sea, turning it from a restricted and sheltered harbour with a deep basin in 1909, into a free-flowing tidal estuary exiting directly into the sea. The results for the community survey and transect data show issues of erosion by wind and sea pressures, human impact over the last hundred years is having its effects, with the dune system shifting at Pipers Head and increasing flood erosion from the Pipers River catchment area.

Increasing community usage of the beach area at Pipers Head has increased the value of the ecosystem services, and its stability value is thereby increased, not only as a recreational place, but also as a sheltered environment. As Table.3 has shown there is an uncertainty of what is causing the erosion, as the more obvious possible causes believed are dominant, whereas the underlying issues of erosion are not believed to be apparent. As Skinner discussed, it is important to manage the dune system, as it provides protection for the ecosystem environment behind the fore dune, and to the local community, (Skinner, 2015). It is unknown whether doing nothing will result in greater harm than good, or 'vice-versa'. But then again, doing something, may forestall future disasters for Bellingham and Pipers Head environs, relying as it does on its dune system for protection.

The area of Bellingham and Weymouth would benefit from a long-term study focusing on the impact of the dominant characteristics in Nolans Bay and Pipers Head. Scientific in-depth analysis of accumulated information is crucial in determining how to manage the habitat more efficiently, and will assist all Tasmanian Coastcare agencies.

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Appendix

Transect 1. MGA 55 0513746E, 5460381N, 2˚ NW 28/08/2017, 1024 hrs				Mean Sea level adjustment 1.2 m	
Position	Distance (m)	Height (m)	Description	Distance (m)	Height (m)
back 2	7.9	0.07		-42.4	5.33
back 1	2.6	-0.35		-37.1	5.05
survey	0	0	sand dune top	-34.5	5.42
1	1.5	-0.535		-33	4.835
2	3.8	-1.335	cliff top	-30.7	4.065
3	7.1	-3.75	beach base (0 and 1.47)	-27.4	1.65
4	4	-4.23	High tide mark	-23.5	1.17
5	13	-4.665	rock ridge line	-14.4	0.705
6	14	-4.928	seaward side of rock ridge	-13.5	0.472
7	19	-5.122	rock ridge	-8.5	0.278
8	21.35	-5.76	gully	-6.05	-0.36
9	22.6	-4.895	rock ridge	-5	0.505
10	24	-5.708	gully	-3.4	-0.308
11	26	-5.388	rock ridge	-1.5	-0.012
12	27	-5.63	gully	-0.5	-0.23
13	28.1	-5.23	rock ridge	0.7	0.17
14	30	-5.63		2.6	-0.23
15	33	-5.625		5.5	-0.225
16	34.45	-5.895	rock platform	7.05	-0.495
17	48	-5.495	last rock ridge	20.5	-0.095
18	48.5	-5.78		21.1	-0.41
19	55	-5.88	edge of rock formation	27.6	-0.51
20	55.1	-6.28	sea level	27.7	-0.83

Table 15. Survey field data for transect 1

Transect 2. MGA55G: 0513467E, 5460074N. 274˚ W. 28/08/2017, 1115 hrs.				Mean Sea Level adjustment 1.2 m	
Position	Distance (m)	Height (m)	Description	Distance (m)	Height (m)
back 2	-9.5	-0.392	first rearward gully	-53.9	3.268
back 1	-4	0.318	ridge on backslope of foredune	-48.4	3.978
survey	0	0	top of foredune	-44.4	3.6
1	3	-0.45		-41.4	3.21
2	6	-1.255	foredune cliff face	-38.4	2.405
3	9	-1.65	beach (next survey points 0, 1.45)	-35.4	2.01
4	11	-2.46		-33.4	1.2
5	20.2	-2.97		-23.8	0.69
6	33	-3.4	repositioned level	-11	0.26
7	44.4	-3.73		0.4	-0.07
8	56.2	-4.235		12.2	-0.575
9	75.8	-5.04	repositioned tape	31.8	-1.38
10	112.5	-5.73	rock outcrop	68.5	-2.07
11	133.2	-6.09	channel marker	89.2	-2.43

Table 16. Survey field data for transect 2

Transect 3. MGA 55: 0513511E, 5459764N. 218˚ W, 29/08/2017, 1000 hrs.				Mean Sea Level adjustment 1.15 m	
Position	Distance (m)	Height (m)	Description	Distance (m)	Height (m)
back 2	-5.5	-0.485	gully	-26.3	2.87
back 1	-2.05	-0.016	dune slope off	-22.85	3.39
survey	0	0	survey level/dune flat	-20.8	3.355
1	3.27	0.185	dune cliff top	-17.53	3.54
2	6.8	-2.155	dune cliff bottom	-14	1.2
3	20.5	-3.32	start of shale bed, 1.59 m high 0	-0.3	0.035
4	23.1	-3.98	nearside channel edge	2.3	-0.625
5	31.5	-4.045	far-side channel edge	10.7	-0.69
6	54	-4.105	nearside shale bar	33.2	-0.75
7	67.5	-3.895		46.7	-0.54
8	85	-3.875		64.2	-0.52
9	98	-3.895		77.2	-0.695
10	103	-4.245	water’s edge	82.2	-0.89

Table 17. Survey field data for transect 3

Transect 4 MGA 55: 0513582E, 5459571N. 262˚ W, 29/08/2017, 1045 hrs.				Mean Sea Level adjustment 1.15 m	
Position	Distance (m)	Height (m)	Description	Distance (m)	Height (m)
back 2	-16	2.54	back dune top	-109.7	4.77
back 1	-9.85	-0.42	end of plateau	-103.55	1.81
survey	0	0	middle of plateau	-93.7	2.23
1	5.5	-0.11	ridge	-88.2	2.12
2	7.9	-0.015	end of plateau cliff edge	-85.8	2.215
3	8.7	-0.542	cliff base, beach level	-85	1.688
4	17.1	-1.518	end of soft sand, hard sand with ripples	-76.6	0.712
5	30.4	-1.87	ridge	-63.3	0.36
6	44.5	-2.06	dip	-49.2	0.17
7	69.7	-2.095		-32	0.135
8	86.4	-2.16		-7.3	0.07
9	101	-2.31		7.3	-0.08
10	113	-2.06		19.3	0.17
11	130	-1.66	sand bar	36.3	0.57
12	155	-2.71	water's edge	61.3	-0.48

Table 18. Survey field data for transect 4

Transect 5. MGA 55: 0513381E, 5459250N. 283˚ W, 30/08/2017, 0950 hrs.				Mean Sea Level adjustment 1.15 m	
Position	Distance (m)	Height (m)	Description	Distance (m)	Height (m)
back 2	-17.4	-1.285	Pine tree	-84.35	2.275
back 1	-8.4	-0.26	ridge on backslope of dune	-78.35	3.3
survey	0	0	survey level position, flat of dune	-69.95	3.56
1	2.15	-0.286	top of dune	-67.8	3.274
2	3.5	0	dune face/cliff	-66.45	3.56
3	7.15	-1.79	dune base	-62.8	1.8
4	8.55	-2.41	high tide undercut of dune	-61.4	1.15
5	15.85	-3.18	previous night's high tide	-54.1	0.38
6	24.8	-2.595	end of beach/ river bed	-45.15	0.965
7	38.1	-2.957	nearside of old river channel	-31.85	0.603
8	45.75	-3.18	far-side of old river channel	-24.2	0.38
9	54.4	-3.035	sandbar/riverbed	-15.45	0.525
10	70.45	-2.785	main channel east-side water's edge	-0.5	0.775
11	70.5	-2.9	water height	0	0

Table 19. Survey field data for transect 5

	Sieve mesh size (microns)							
-	>4000	>2000	>1000	>500	>250	>125	>63	<63
Transect 1								
point 1	0	0.18	2.56	45	112.3	39.58	0.02	0
point 2	0	0	2.25	94.95	90.45	12.39	0.01	0
point 3	0	0	0.08	16.16	160.55	22.87	0.02	0
Transect 2								
point 4	0	0	0	22.37	114.42	65.31	0	0
point 5	8	0.09	0.7	60.67	111.07	18.24	0.03	0
point 6	50.89	27.95	56	61.13	3.26	0.71	0.03	0
Transect 3								
point 7	0	0	0.11	23.54	109.01	66.91	0.12	0
point 8	0	0.08	0.86	104.56	89.49	5.04	0.03	0
point 9	17.8	11.59	18.74	95.61	48.95	7.17	0.04	0
Transect 5								
point 10	0	0	0	0.2	39.17	159.61	0.64	0.07
point 11	0	0.27	0.41	14.29	89.65	94.75	0.37	0.12
point 12	6.79	12.89	10.22	17.95	58.62	74.84	11.65	6.49

Table 20. Grain size results from all study transects (grams)

Point 1

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0.18	0.09	0.09
>1000	0	2.56	1.28	1.37
>500	1	45	22.5	23.87
>250	2	112.3	56.15	80.02
>125	3	39.58	19.79	99.81
>63	4	0.02	0.01	99.82
<63		0	0	99.82

Table 21. % of individual sieve mass and cumilative mass amounts for transect 1

Point 2

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0	0	0
>1000	0	2.25	1.13	1.13
>500	1	94.95	47.48	48.6
>250	2	90.45	45.23	93.83
>125	3	12.39	6.2	100.02
>63	4	0.01	0.005	100.03
<63		0	0	100.03

Table 22. % of individual sieve mass and cumilative mass amounts for transect 1

Point 3

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0	0	0
>1000	0	0.08	0.04	0.04
>500	1	16.16	8.08	8.12
>250	2	160.55	80.28	88.4
>125	3	22.87	11.44	99.83
>63	4	0.02	0.01	99.84
<63		0	0	99.84

Table 23. % of individual sieve mass and cumilative mass amounts for transect 1

Point 4

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0	0	0
>1000	0	0	0	0
>500	1	22.37	11.19	11.19
>250	2	114.42	57.21	68.4
>125	3	65.31	32.66	101.05
>63	4	0	0	101.05
<63		0	0	101.05

Table 24. % of individual sieve mass and cumilative mass amounts for transect 2

Point 5

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	8	4	4
>2000	-1	0.09	0.045	4.05
>1000	0	0.7	0.35	4.4
>500	1	60.67	30.34	34.73
>250	2	111.07	55.54	90.27
>125	3	18.24	9.12	99.39
>63	4	0.03	0.02	99.4
<63		0	0	99.4

Table 25. % of individual sieve mass and cumilative mass amounts for transect 2

Point 6

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	50.89	25.45	25.45
>2000	-1	27.95	13.98	39.42
>1000	0	56	28	67.42
>500	1	61.13	30.57	97.99
>250	2	3.26	1.63	99.62
>125	3	0.71	0.36	99.97
>63	4	0.03	0.015	99.99
<63		0	0	99.99

Table 26. % of individual sieve mass and cumilative mass amounts for transect 2

Point 7

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0	0	0
>1000	0	0.11	0.055	0.055
>500	1	23.54	11.77	11.83
>250	2	109.01	54.51	66.33
>125	3	66.91	33.46	99.79
>63	4	0.12	0.06	99.85
<63		0	0	99.85

Table 27. % of individual sieve mass and cumilative mass amounts for transect 3

Point 8

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0.08	0.04	0.04
>1000	0	0.86	0.43	0.47
>500	1	104.56	52.28	52.75
>250	2	89.49	44.75	97.5
>125	3	5.04	2.52	100.02
>63	4	0.03	0.02	100.03
<63		0	0	100.03

Table 28. % of individual sieve mass and cumilative mass amounts for transect 3

Point 9

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	17.8	8.9	8.9
>2000	-1	11.59	5.8	14.7
>1000	0	18.74	9.37	24.07
>500	1	95.61	47.81	71.87
>250	2	48.95	24.475	96.35
>125	3	7.17	3.59	99.93
>63	4	0.04	0.02	99.95
<63		0	0	99.95

Table 29. % of individual sieve mass and cumilative mass amounts for transect 3

Point 10

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0	0	0
>1000	0	0	0	0
>500	1	0.2	0.1	0.1
>250	2	39.17	19.59	19.69
>125	3	159.61	79.81	99.49
>63	4	0.64	0.32	99.81
<63		0.07	0.035	99.85

Table 30. % of individual sieve mass and cumilative mass amounts for transect 5

Point 11

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	0	0	0
>2000	-1	0.27	0.135	0.14
>1000	0	0.41	0.205	0.34
>500	1	14.29	7.15	7.49
>250	2	89.65	44.83	52.31
>125	3	94.75	47.38	99.69
>63	4	0.37	0.19	99.87
<63		0.12	0.06	99.93

Table 31. % of individual sieve mass and cumilative mass amounts for transect 5

Point 12

Sieve size, µm	Phi value	Mass retained by this sieve, g	% mass	Cumulative % mass
>4000	-2	6.79	3.4	3.4
>2000	-1	12.89	6.45	9.84
>1000	0	10.22	5.11	14.95
>500	1	17.95	8.98	23.93
>250	2	58.62	29.31	53.24
>125	3	74.84	37.42	90.66
>63	4	11.65	5.83	96.48
<63		6.49	3.25	99.73

Table 32. % of individual sieve mass and cumilative mass amounts for transect 5

question	highest answer	question	highest answer
1	yes	11	unsure
2	yes	12	no
3	no	13	no
4	maybe	14	no
5	no	15	no
6	no	16	no
7	maybe	17	no
8	no	18	maybe
9	no	19	maybe
10	maybe	20	yes
		21	no

Table 33. Highest answers to community survey questions

	yes	no	maybe	unsure	abstain	N/A
total answered	77	123	75	28	7	20
% of total	23.3	37.3	22.7	8.5	2.1	6.1

Table 34. Total percentages of community survey questions

Figure 35. Willy weather report for the days of Aug 26th to Aug 30th, 2017. This was used as a local guide as it displays the Aeolian conditions