Seaspray Flood Study – Data Review (R01)

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Cover Photo: Floodway Regulator, Seaspray

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1. INTRODUCTION

Water Technology was commissioned by the West Gippsland CMA to undertake the Seaspray Flood Investigation. This project includes detailed hydrological and hydraulic modelling of Merriman Creek, taking into account the influences of ocean generated flooding and potential inflows from Lake Reeve, flood mapping of the Seaspray township and will provide recommendations for flood mitigation actions and works.

As part of the initial scoping work, the data required for modelling and mapping was collated and reviewed. This report documents the data review findings and identification of gaps in the data. It also outlines the proposed hydrological and hydraulic modelling scope and methodology.

2. STUDY AREA

Seaspray is a coastal town with 320 permanent residents which rises to more than 1,000 during summer. The township lies at the western end of the Ninety Mile Beach west of the Gippsland Lakes and approximately 200 km east of Melbourne. As detailed in the Urban Design Framework developed for the township by Wellington Shire Council (Wellington Shire Council, 2007), Seaspray is an important access point to the 90 Mile Beach Area and the extensive areas of small lot subdivision that extend easterly for 28km to Golden Beach and Paradise Beach.

The town is located at the downstream end of the Merriman Creek catchment, with the creek flowing along the western boundary of the township, before it passes through the 90 Mile Beach coastal dunes system and enters the ocean. The study area and significant watercourses or flood related influences are shown in Figure 2-1.

Figure 2-1 Seaspray Study Area

3. FLOOD RELATED STUDIES

Following extensive flooding in Seaspray in May and then June 1978, the State Rivers and Water Supply Commission published a flood report for the floods. The report included mapping of approximately 18 surveyed flood levels from the May 1978 flood and 27 flood levels from the June 1978 flood, as well as aerial photography of the June 1978 flood.

The Seaspray Flood Study was then commissioned by the State Rivers and Water Supply Commission in 1980 (Camp Scott Furphy, 1980). A flood frequency analysis was undertaken with limited gauge data and a 1% AEP peak discharge of 330 m^3/s was adopted, equal to the June 1978 peak discharge. Flood modelling and damage assessment was undertaken and a flood mitigation scheme recommended, which included the following works and measures:

- Proclamation of flood-prone lands and drainage courses and incorporation into local planning scheme.
- Construction of an approved flood mitigation scheme including levees along Merriman Creek and Lake Reeve Floodway, excavation of the Lake Reeve Floodway and construction of a regulating structure between the Lake Reeve Floodway and Merriman Creek.
- Operation and maintenance arrangements including the clearing of Merriman Creek mouth and operation of the Lake Reeve Floodway.
- Improved flood warning arrangements.

The construction of the scheme was completed in 1987. A levee audit in 1996 (Findlay Irrigation Design Services and BM Consulting Civil Engineers, 1996) found the levees in generally good condition, however in many cases the levee crest was below the design level by up to 0.3 m, and in one area there was a gap in the levees that had allowed floodwaters into the protected area in the 1993 flood.

A flood report was also published for the 1993 flood (Hydrotechnology, 1995), which contained comprehensive details of flood extents, heights and impacts in Seaspray. The flood review of 2007 (EGCMA and WGCMA, 2010) contained a brief reference to the coastal erosion that occurred in Seaspray.

A minor investigation was undertaken for the Duke Energy track crossing of the Lake Reeve floodway in 2002 (ID&A 2002). A Coastal Hazard and Vulnerability Assessment and Flood Study was undertaken for the Seaspray Caravan Park in 2010 (Cardno Lawson Treloar, 2010), which found the existing levee system only protected land up to the 70 year ARI flood event, primarily due to a revision of the 1% AEP flow estimate to more than double the 1980 estimate (679 m^3/s). The study also assessed flooding under a range of storm surge and sea level rise conditions, finding that vulnerability to coastal flooding was low.

The recently completed Gippsland Lakes/90 Mile Beach Local Coastal Hazard Assessment Project (Water Technology, 2014a) assessed the sensitivity of Seaspray to flooding from the Gippsland Lakes under present and future sea level rise conditions based on hydrodynamic modelling. The work found that the floodplains around Seaspray only became inundated during the 10% AEP flood event under the +0.8 m sea level rise scenario. Flood levels did not overtop the existing levees. Coincident flooding from Merriman Creek was not considered. However, coastally driven inundation of the township due to overwash of the dune barrier system was also assessed.

4. HYDROLOGICAL DATA

4.1 Rainfall Data

The average annual rainfall at Seaspray is 620 mm. A steep rainfall gradient exists over the catchment with average annual rainfall reaching 1500 mm in the headwaters. At the catchment centroid the average annual rainfall is around 670 mm.

Numerous daily rainfall sites are in operation in and around the catchment. Key stations, including current stations and stations operating over the 1978, 1993 and 1995 floods, are listed in Table 4-1.

Table 4-1 Daily rainfall stations around Merriman Creek catchment

Gauge No.	Location	Period	Years	Distance from catchment centroid
85006 226017	Le Roy (Taylors Rd Quarry)	2000-2009	9	34
85009 226815	Traralgon Epa	2000-2014	14	34
85017	Callignee South	1932-1985	54	26
85033	Giffard	1906-2014	108	21
85071	Rosedale	1878-2005	124	20
85072	East Sale Airport	1943-2014	72	30
85073	Seaspray (Burong)	1989-2014	112	25
85076	Stradbroke West (Inglenook)	1891-1982	91	6
85101	Tarra Valley	1952-1990	10	34
85105	Hazelwood North	1939-1990	37	35
85148	Woodside (Lake View)	1952-1997	46	23
85152	Won Wron Prison	1967-2005	38	27
85160	Darriman (Tarralangi)	1952-2014	62	13
85170	Traralgon L.V.W.& S.B.	1967-1990	23	33
85236	Callignee North	1956-2014	57	28
85281	Traralgon Creek At Koornalla	2000-2014	14	31
85298	East Sale Comparison	1996-2005	9	31
85299	Koornalla Traralgon Ck Rd	2000-2014	14	31

Pluviograph (sub-daily rainfall) stations in and around the Merriman Creek catchment are listed in Table 4-2. The 1993 and 1995 events were captured at East Sale Airport and Calignee North pluviographs. The 1978 events were captured at all listed stations.

Table 4-2 Pluviograph stations around Merriman Creek catchment

Gauge No.	Location	Period	Years	Distance from catchment centroid (km)
85072	East Sale Airport	1953-2011	58	30
85236 226817	Calignee North	1961-2013 1999-2014	51 15	28

Gauge No.	Location	Period	Years	Distance from catchment centroid (km)
85170	Traralgon LVW & SB	1961-1979	18	33
85265	Macks Creek	1975-1978	3.4	26
85264	Novacs	1968-1978	6.8	24
85007 226818	Balook	1999-2014	15	33
585047 227239	Stradbroke West	2006-2014	8	10
585186 226814	Mount Tassie	1998-2014	16	30

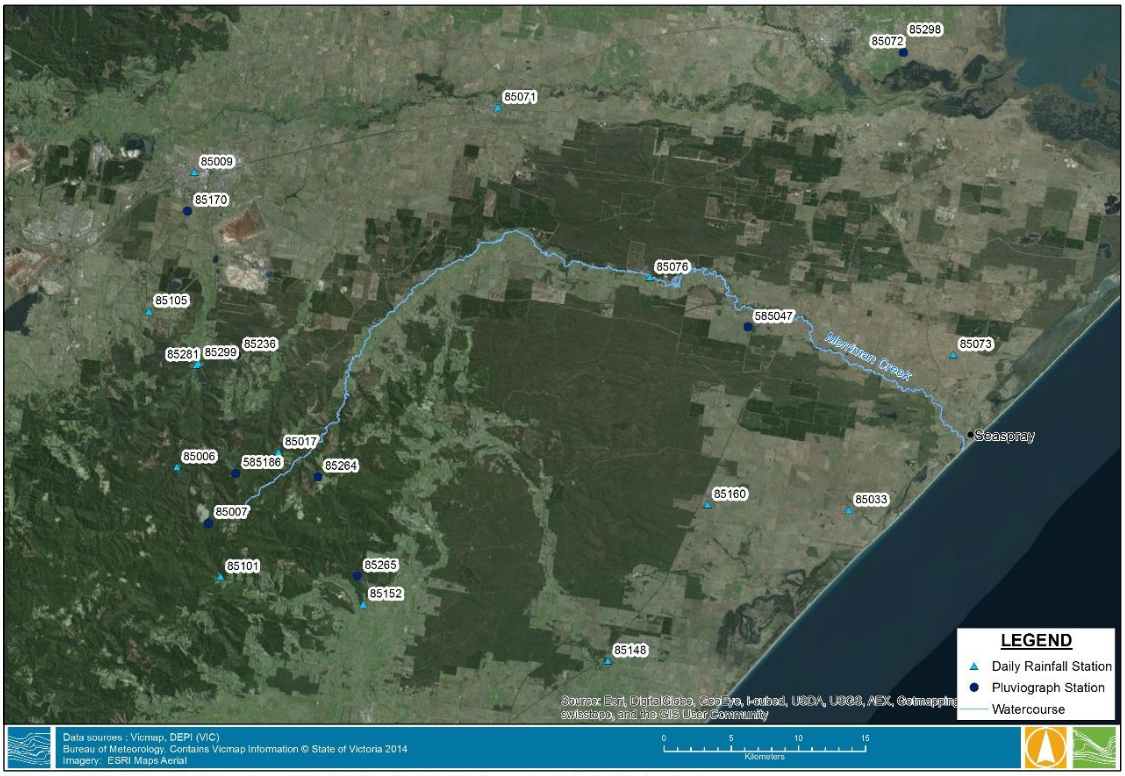

Figure 4-1 Rainfall Stations in and around the Merriman Creek Catchment

4.2 Streamflow Data

Four streamflow gauges operate in the catchment (Table 4-3). The Prospect Road gauge is located close to the town of Seaspray and captures most of the catchment. The Stradbroke West gauge is located upstream and captures just under half of the catchment. The ungauged Monkey Creek joins Merriman Creek between the Stradbroke West and Prospect Road gauges. The Calignee South gauge is located in the headwaters of the catchment, capturing around 7% of the catchment.

Table 4-3 Streamflow gauges in Merriman Creek catchment

Gauge No.	Location	Period	Years	Catchment Area (km^2)
227240	Merriman Creek @ Prospect Road Seaspray	1983-2014	31	529
227001	Merriman Creek @ Seaspray (old Prospect Road site)	1966-1971	5	525
227239	Merriman Creek @ Stradbroke West	1983-2014	31	256
227205	Merriman Creek @ Calignee South	1946-1952 and 1965-2014	54	36
227242	Merriman Creek @ Seaspray Township	1984-2014	31	

The rating curve for the Prospect Road gauges (227240) is shown in Figure 4-2. The rating curve is considered to have only limited reliability up to 3.5 m (8170 ML/d, 95 m^3/s), as shown by the scatter in the figure.

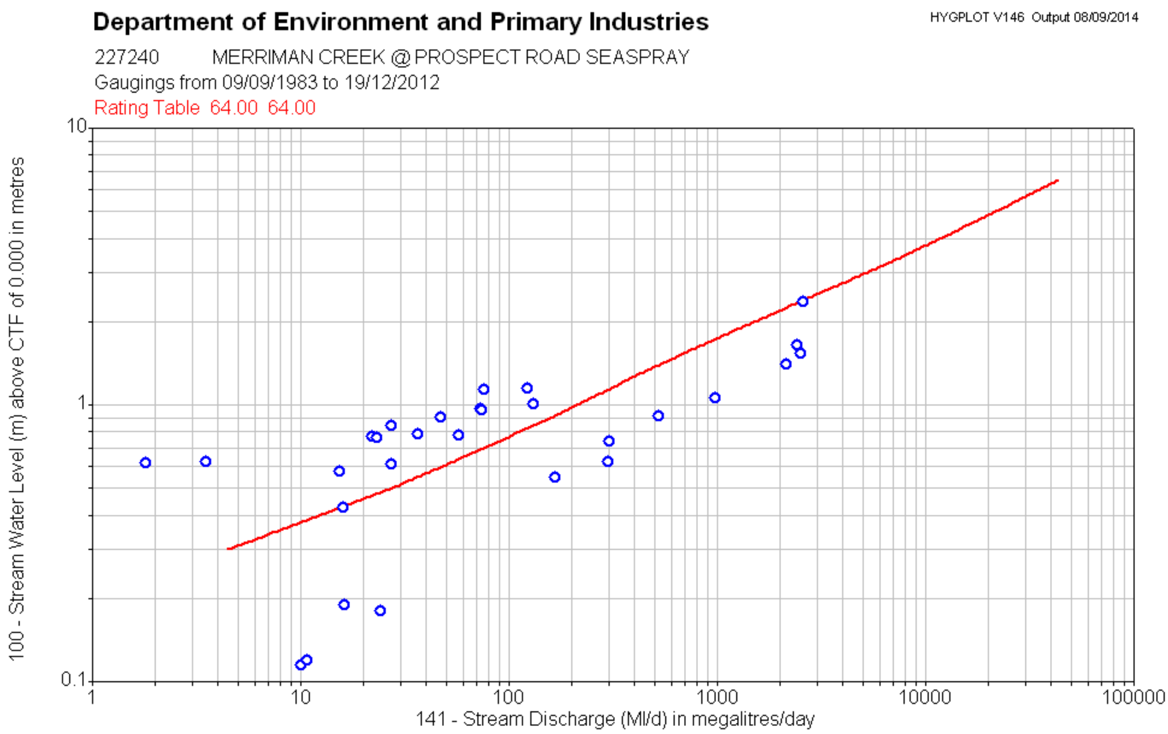

Figure 4-2 Rating Curve for 227240 Merriman Creek @ Prospect Road

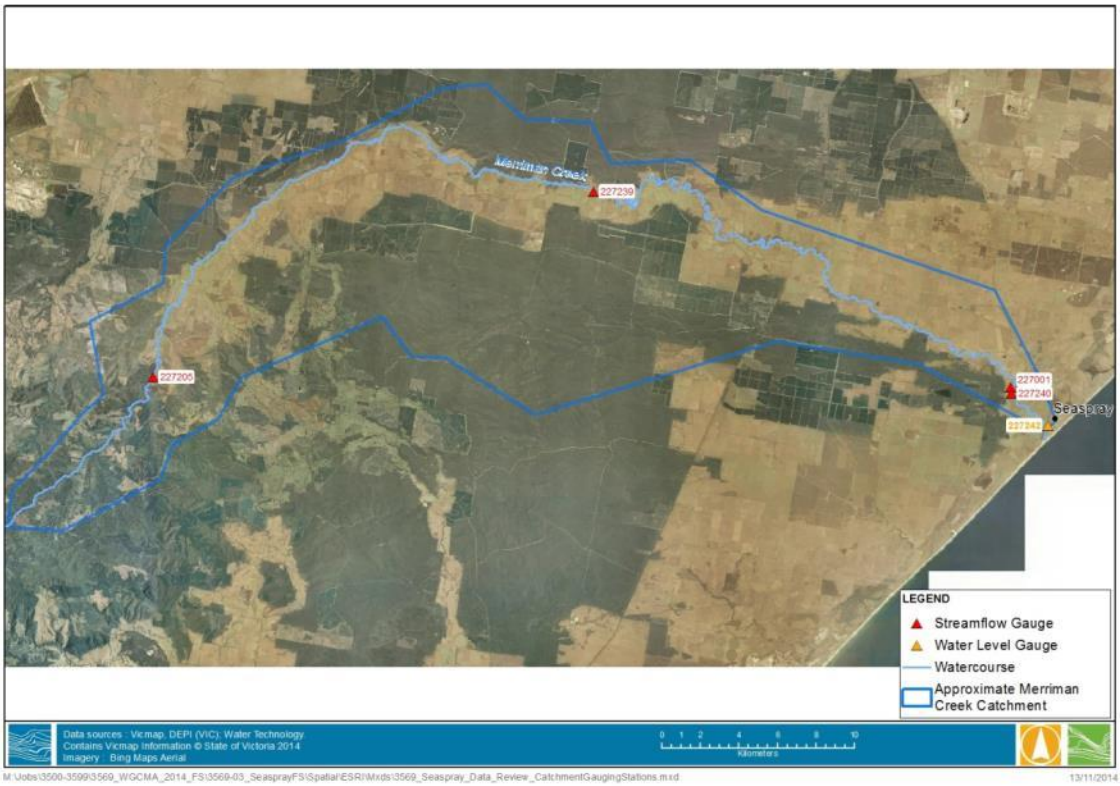

Figure 4-3 Merriman Creek Catchment and Gauging Stations

The Stradbroke West gauge has more high-flow gaugings and less scatter, and might therefore be considered more reliable in high flow estimation. It is considered reliable up to 6.4 m (6790 ML/d, 79 m^3/s).

Both the Stradbroke West gauge and Prospect Road gauge ratings are discussed in detail in the accompanying Hydrology Report (Report 2).

4.3 Water Level Data

A water level gauge operates in the Merriman Creek lagoon at Seaspray (Table 4-4). The gauge record spans from 1984-2014 but is incomplete, with 1986-1989 and 1993-1995 missing and a patchy record from 2011-2014. None of the major floods are recorded at this gauge.

Table 4-4 Water Level Gauge in Seaspray

Gauge No.	Location	Period	Years
227242	Merriman Creek @ Seaspray Township	1984-2014 (incomplete)	~20

5. FLOOD RECORDS

5.1 Historic Flood Information

Significant historic flood events have been compiled from available sources and are listed in Table 5-1. The largest flood on record at the Prospect Road gauge, just upstream of Seaspray, was the October 1995 flood, however very little information is available for that event. More information is available for the 1993 event, including digitised flood extent, surveyed flood levels, floor levels and numerous flood photographs, collated for Hydrotechnology's report on the 1993 Gippsland flood. A large amount of data is also available for the 1978 floods which were the largest on record when they occurred, but were later exceeded in 1993 and 1995.

Table 5-1 Historic Flood Events

Event	Description	Data available
1880	Whole area flooded with fresh water	Gippsland Times letter
1895	Salt water flooding of whole area	Gippsland Times letter
1900	Town flooded by salt water	Gippsland Times article
March 1908	Salt water flooding of camping reserve	Gippsland Times article
September 1916		
1930	Two salt water flooding events in the first half of 1930	Gippsland Times article
April 1932	Creek overflowed and swamped a large portion of Seaspray	Gippsland Times article
December 1934	"Flood of unusual magnitude"	Gippsland Times article
April 1935	Every house in north end of town surrounded by water	
July 1936	Flood covering both ends of township	Gippsland Times article
May 1944	Mouth blocked	
July 1949	Mouth blocked	
February 1951	Reported as the worst flood in 60 years. 75% of homes in Seaspray were flooded	Gippsland Times articles
June 1952	Reported as a "record flood" Overflow from Merriman Creek and Blind Creek, with Monkey Creek also in flood Mouth opened readily as floodwaters rose. 75% of homes in Seaspray were flooded	Discharge estimated at 194 m3/s in 1980 Flood Study (Camp Scott Furphy 1980) One flood level (VFD) Gippsland Times articles
January 1962	Tidal flooding	
February		Gauged streamflow at 227001 (peak

Event	Description	Data available
1971		discharge 326 m3/s)
May 1975	Tidal flooding	
May 1978	Overflow from Merriman Creek and Blind Creek 12 out of 55 permanently occupied residential properties were flooded at or above floor level 9 out of 42 seasonally occupied residences were flooded at or above floor level	Digitised flood extent (VFD) Approx. 18 surveyed flood levels (Camp Scott Furphy 1980)
June 1978	42 out of 55 permanently occupied residential properties were flooded at or above floor level 38 out of 42 seasonally occupied residences were flooded at or above floor level Complete inundation of over 180 built-on allotments Only 15 to 20 allotments out of 320 were not subject to any inundation	Peak discharge estimated at 330 m3/s in 1980 Flood Study (Camp Scott Furphy 1980) Digitised flood extent (VFD) Approx. 27 surveyed flood levels
April 1990		Digitised flood extent (VFD)
September 1993	1.5 times larger than the previous largest flood and previous 1% AEP estimate. Land affected by flooding from Blind Creek and overtopping/outflanking of levees. 44 houses flooded above floor level Around 140 built-on allotments affected by flooding in total	Peak discharge estimated at 450 m3/s Digitised flood extent (VFD) Approx. 12 surveyed flood levels CFA logs and transcripts 44 surveyed floor levels Numerous flood photographs (Hydrotechnology 1995)
October 1995	Second-largest flood on record.	Flood peak 370 m3/s
2007	Coastal erosion of dunes	
June 2012		Digitised flood extent (VFD) Lake Reeve western end only.

Historic flood data recorded in the Victorian Flood Database (VFD) is summarised in Figure 5-1, Figure 5-2 and Figure 5-3 below. Note that flood heights for the May 1978 flood are not recorded in the VFD but are available in the 1978 Flood Report (SRWSC 1978). Some inconsistencies have been noted between the VFD data and the original data recorded in the 1978 and 1993.

Figure 5-1 May 1978 flood information in VFD

Figure 5-2 June 1978 flood information in VFD

Figure 5-3 1993 flood information in VFD

5.2 Imagery

Non-flood aerial imagery is available for April 1965 (B&W), July 1974 (Colour), 1976 (B&W), 1977 (B&W), May 1984 (Colour), January 1992 (Colour), and 2010 (Colour orthophoto).

Flood aerial photography is available for the May 1978 event in Colour and Colour Infrared (CIR) and the June 1978 event in CIR only. An example is shown in Figure 5-4 below. Aerial photography is also available for the aftermath of the 1993 event (28 September 1993) in the Hydrotechnology (1995) flood review.

Figure 5-4 **CIR Imagery of May 1978 event**

6. PHYSICAL FEATURES

6.1 Topographic and Physical Survey

6.1.1 LiDAR Datasets

Aerial LiDAR (Light Detection and Ranging) survey is available for the Seaspray area from two difference sources:

- Vicmap Elevation Coastal 1m DEM (referred to as the 'Coastal DEM')
- 2009-10 Victorian State Wide Rivers LiDAR Project - West Gippsland CMA (referred to as the 'Rivers DEM')

The entrance and lagoon arrangements are different in the two datasets as they were captured at different times. The lagoon water level and entrance berm are lower in Coastal DEM.

The extents of the two datasets are shown in Figure 6-1. A comparison of the two datasets where they overlap (Rivers DEM minus Coastal DEM) is shown in Figure 6-2. A slight vertical offset is discernible between the two datasets in flat floodplain areas. In these areas, the Rivers DEM is around 0.1 m lower than the Coastal DEM. A comparison between the surveyed levee heights from the Urban Levees Review (SKM, 2014) showed that both LiDAR datasets were 0.05 m higher on average than the levee survey, with a standard deviation of 0.13-0.15 m. A survey transect in a flat area would be valuable to further verify the LiDAR datasets and assist in the selection of datasets for modelling. Key metadata for the two datasets is given in Table 6-1.

As the Coastal DEM is rated to a higher accuracy, covers a greater extent and has lower lagoon levels, it is envisaged that it will be used as the primary dataset for modelling.

A coarse (10 m resolution) DEM is available from VicMap for the whole Merrimans Creek catchment for catchment delineation purposes.

Table 6-1 Key metadata for LiDAR datasets

Dataset	Source	Date of Capture	Vertical accuracy (1 sigma)	Resolution
Vicmap Elevation Coastal 1m DEM (Coastal DEM)	LiDAR	Sep 2007-Sep 2009	0.10 m	1 m
2009-10 Victorian State Wide Rivers LiDAR Project - West Gippsland CMA (Rivers DEM)	LiDAR	Feb-Nov 2010	0.20 m	1 m

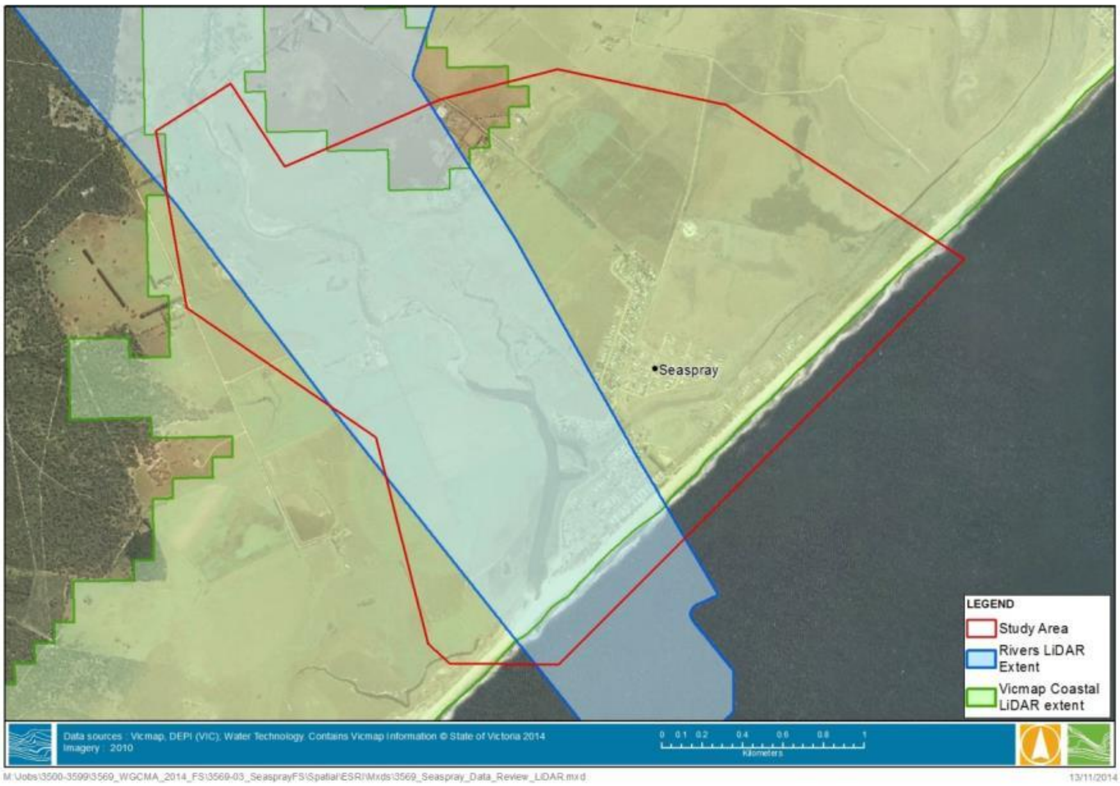

Figure 6-1 DEM extents

Figure 6-2 LiDAR comparison - Rivers LiDAR DEM minus Coastal DEM

6.1.2 Levee Survey

The Urban Levees Review (SKM, 2014) identified the following four levees within Seaspray, which were subsequently surveyed along with a preliminary condition assessment:

- Levee A – situated along the west bank of Merriman Creek between the floodway and Ninety Mile Beach.
- Levee B and C – situated along the north bank of the floodway (to the east of Merriman Creek) between Merriman Creek and the end of Catton Street, where it runs parallel to Centre Road to Main Road (Seaspray Road) and then along Main Road to the junction with Tip Road.
- Levee D – situated along the south bank of the floodway (to the east of Merriman Creek) between Merriman Creek and the most easterly house along Shoreline Drive.

An additional section of levee (Levee E), which is an extension of Levee C, was not surveyed. Each of the surveyed levees is shown in Figure 6-3. The levees labelled 2000 Levee are from the VFD.

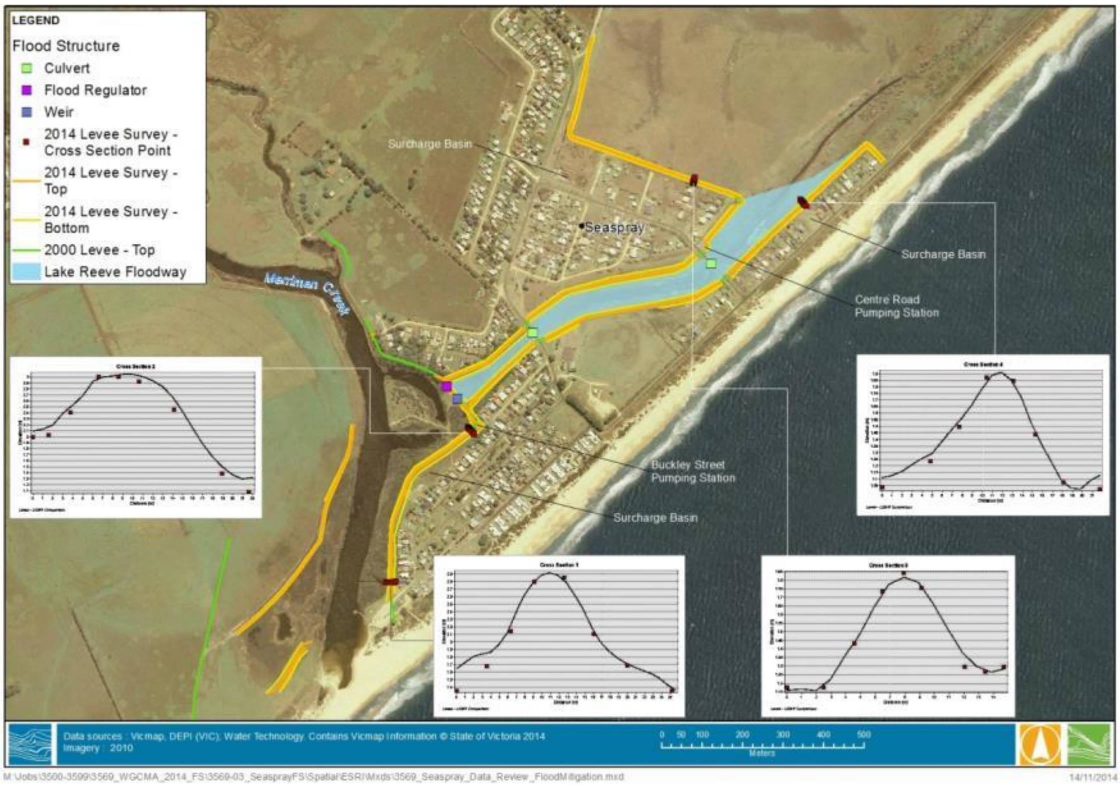

Figure 6-3 Location of Levees and Flood Mitigation Structures within and around Seaspray

6.1.3 Road Survey

West Gippsland CMA provided a road survey that was undertaken for a sub-division near the new caravan park in the Seaspray township. The survey extended around a path joining Futcher Street, Main Road, Centre Road, and Shoreline Drive. The levels from the survey were compared to, and found to agree with, the Coastal DEM. The average difference (survey – Coastal DEM) was -0.04 m with a standard deviation of 0.03 m.

6.2 Drainage Information

GIS layers of local pits and pipes were provided by Wellington Shire (Figure 6-4). from Wellington Shire provided advice on the reliability of the pipe layer and additional/altered pipes. The town of Seaspray is divided into two separate drainage areas. The area east of Futcher Road drains to a pump station on Centre Road on the northern side of the floodway, which pumps stormwater out to the floodway. The area west of Futcher Road drains to a pump station on Irving Street, which pumps to Merriman Creek. Each pump station has two pumps which have a maximum capacity of 170 L/s each. During a high rainfall event both pumps can be operated together giving a maximum discharge rate from each pump station of 340 L/s.

The caravan park has been constructed recently on the site of the former oval and has significant internal drainage infrastructure, including grated pits and pipes running along internal roads, and two retarding basins.

Figure 6-4 Drainage GIS layers (Wellington Shire Council) and additional/altered pipes as advised by

6.3 Bridges and Culverts

Bridge and culvert dimensions were surveyed by Water Technology on 26 November 2014. The locations of the surveyed culverts are shown in Figure 6-5 and key details are given in Table 6-2.

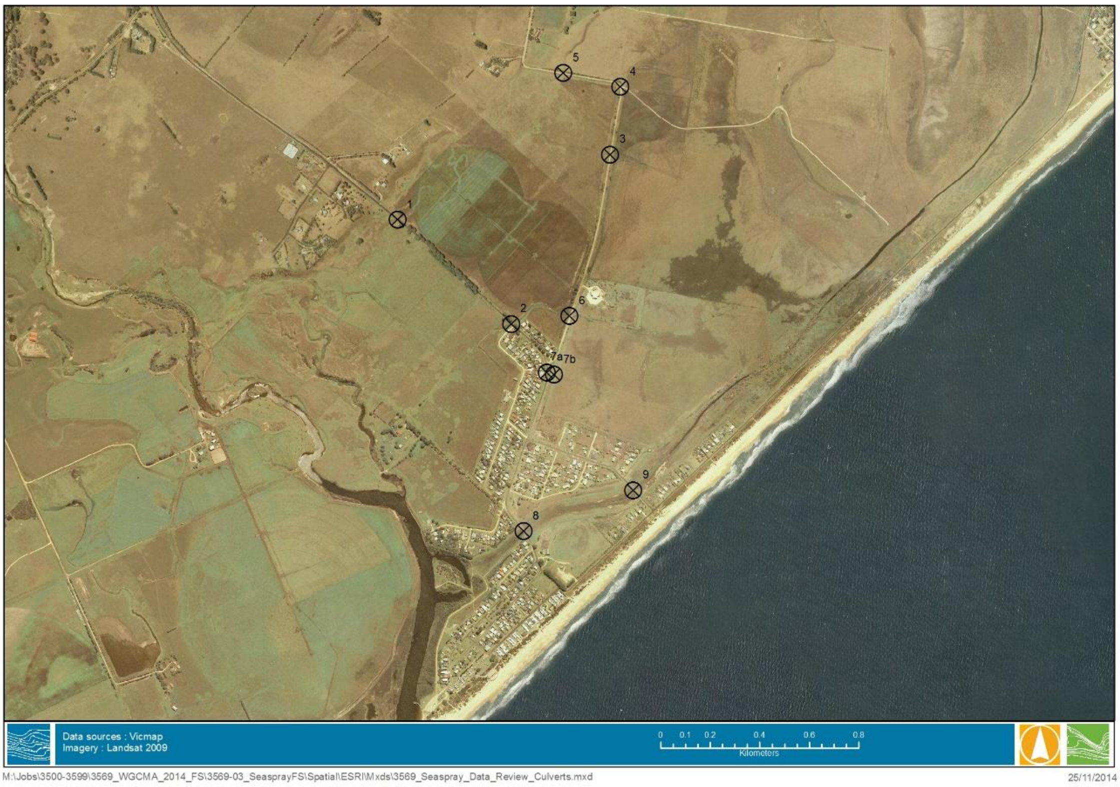

Figure 6-5 Surveyed bridges and culverts

Table 6-2 Key details for surveyed bridges and culverts

Culvert ref.	Type	No.	Dimensions	Notes
1	Angled RCBC	5	2000 x 1500 mm	Debris grates on upstream side.
2	RCP	3	450 mm	Heavily overgrown with kikuyu
3	culvert not found			Heavily overgrown with Phragmites
4	RCP	1	300 mm	
5	RCP	3	450 mm	
6	RCP	2	300 mm	
7a	RCBC	1	450 x 150 mm	Upstream end cracked, appears fully blocked, Downstream end eroded.
7b	RCP	1	450 mm	Flap gate on downstream side, blocked by soil to one third of its height.
8	Clear span		2 x 8.2 m span, total span 17 m	1 x central rectangular pier 600 mm wide, sitting on square 300 mm piers
9	RCBC	4	1200 x 750 mm	Standing water in culverts to approx. halfway

RCP = reinforced concrete pipe

RCBC =reinforced concrete box culverts

6.4 Estuary Entrance Conditions

The coastal morphology in the vicinity of the township of Seaspray was examined in detail in the recently completed Gippsland Lakes/90 Mile Beach Local Coastal Hazard Assessment Project (Water Technology, 2014a).

Seaspray is located behind the Outer Barrier of the Gippsland Lakes coastal barrier system. The outer barrier extends continuously from the sand islands of eastern Corner Inlet to Red Bluff east of Lakes Entrance. It is the youngest of the coastal barriers and the morphology and present dynamics are highly variable.

Merriman Creek exits to the ocean through this barrier at Seaspray. The Merriman Creek estuary is defined as an ICOLL (intermittently closed and open lake or lagoon) whereby under low creek flows and/or on-shore wave conditions the entrance channel is small or closed off from the ocean by the sand berm. When the entrance is closed, the water level in the estuary will be elevated and can influence flood extents.

Available aerial imagery (Section 5.2) indicates that the location and form of the entrance channel varies over time.

Estuary conditions have also been influenced by the flood mitigation scheme, described in Section 8.1, which included the remodelling of Merriman Creek including the cut-off of the meander bend upstream of the entrance (now known as The Island).

An artificial entrance channel has at times been constructed through the sand berm to allow the water level in the estuary to be lowered prior to a flood event in Merriman Creek. This work is undertaken by Wellington Shire Council; however no formal entrance channel opening procedure exists.

Based on the available gauged water levels (Gauge 227242) the water level in the estuary varies between 1 m AHD to around 2 m AHD, Figure 6-6.

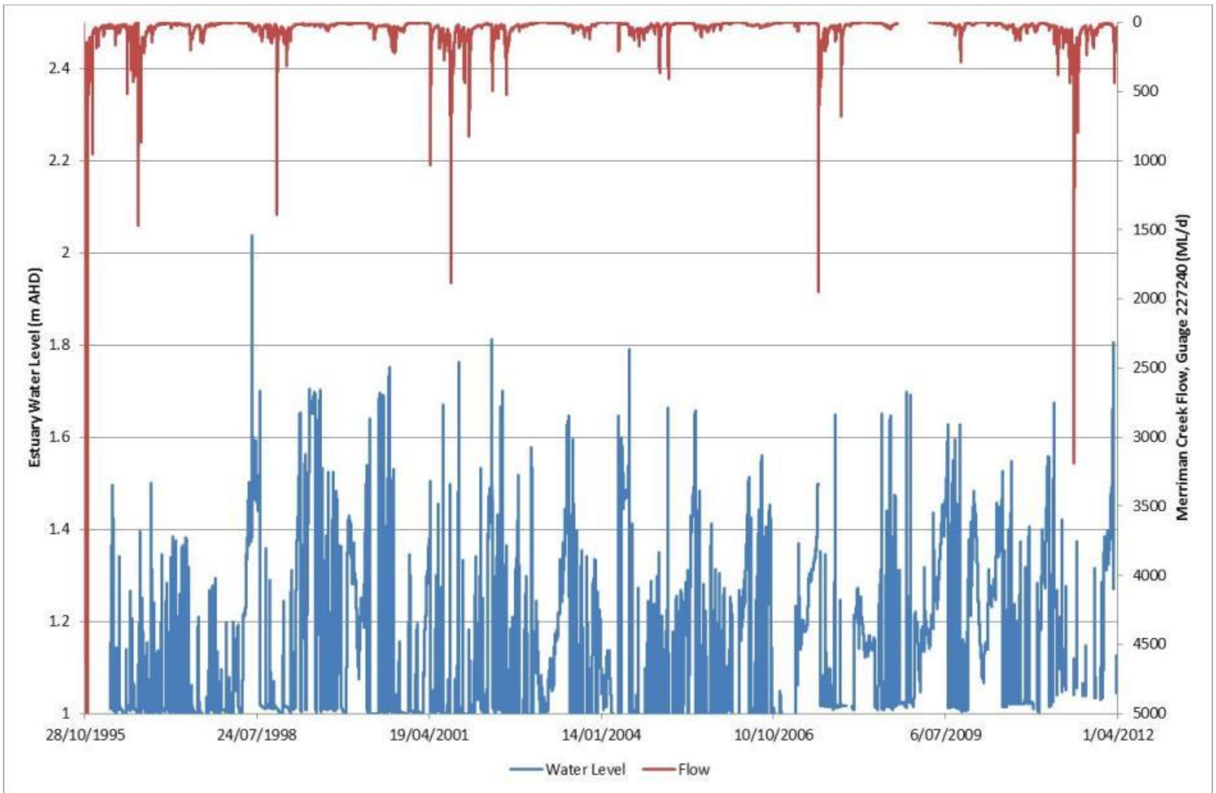

Figure 6-6 Estuary Water Level and Merriman Creek Flows

7. METOCEAN CONDITIONS

7.1 Wind Climate

Along the coastline at Seaspray, winds are predominantly westerly, with minor southerly and easterly components. As the broad orientation of the Outer Barrier is to the NE, the majority of the strongest and most persistent winds blow offshore, however, there is some variation along the study area. At Seaspray the shoreline is aligned to the NE (45^0) such that only winds from the south to east have appreciable onshore components.

7.2 Wave Climate

Waves and the variability associated with their height, period and direction comprise the principle source of energy for mobilising the sediments along the shoreline at Seaspray, which influences the conditions at the Merriman Creek entrance.

The wave climate of the East Gippsland coast is largely sheltered from direct exposure to the highly energetic wave climate of the Southern Ocean by the Tasmanian landmass, although waves from this source do refract around the eastern side of Tasmania. Larger waves are therefore principally generated within eastern Bass Strait by south westerly to southerly winds and in the South Tasman Sea by east to south-easterly winds. For the recent coastal hazard study (Water Technology, 2014a), the wave climate along Ninety Mile Beach was simulated over a 63 year period (1948 to 2011).

The percentage exceedance of significant wave heights from the 63 year wave simulation found that significant wave heights are generally between 0.5 and 1.0 m. Significant wave heights exceed 2.0 m less than approximately 1% of the time at Seaspray.

The mean wave directions were found to be principally from the south and south-east with minor contribution from south-westerly and easterly waves. Towards the south-west at Seaspray, the slightly greater easterly aspect of the coastline results in a slightly greater percentage of waves arriving from the east compared to the more south-east facing coastline at Lakes Entrance.

7.2.1 Storm Wave Climate

An analysis of the storm wave climate along the Gippsland Coast (Water Technology, 2014a) found that storm wave events are not distributed evenly over the historical record but display significant clustering on an approximate decadal scale. Relationships between storm intensity and frequencies on the east coast of Australia have been identified as potentially being modulated by the Interdecadal Pacific Oscillation (IPO) and El Niño-Southern Oscillation (ENSO) by You & Lord (2008) and Shand et al. (2010).

Based on the clustering of storm wave events, periods of heightened wave storminess were interpreted as 1950-1956; 1964-1967; 1974-1978; 1984-1987; 1995-2001; and 2007-2011. The study then analysed the frequency of the large storm events to provide a statistical estimate of storm wave recurrence interval.

7.3 Coastal Water Levels

Ocean water level variations are primarily caused by a combination of the inverse barometric pressure affect, coastally trapped waves and astronomical tides.

7.3.1 Astronomical Tides

The gravitational interactions associated with the sun and moon on the earth's oceans generate regular water level variations commonly referred to as the tide. The Eastern Bass Strait coastline experiences a micro-tidal climate with the tidal range increasing slightly towards the south-west of the study area due to resonance of the tide within Bass Strait. Table 7-1 displays the main astronomical tidal planes at Lakes Entrance and Seaspray relative to Lowest Astronomical Tide (LAT).

Table 7-1 Astronomical Tidal Planes for Lakes Entrance (Outer) and Seaspray (ref. to LAT)

	HAT (m)	MHHW (m)	MLHW (m)	MSL (m)	MHLW (m)	MLLW (m)
Lakes Entrance (Outer)	1.4	1.2	0.8	0.8	0.7	0.3
Seaspray[1]	1.6	1.4	1.0	0.9	0.8	0.2

[1] Approximated from tidal constituents at McGauran's Beach (Hinwood J. &., 1986)

7.3.2 Storm Surges

Storm surge is the common term used to describe variations in coastal water levels that exceed that which can be attributed to the astronomical tide. Storm surges are generated by a combination of the inverse barometric pressure affect, coastally trapped waves and wind setup.

Estimated recurrence intervals of peak storm surge and storm tide levels for the open coast at Seaspray for relevant sea level rise scenarios have been developed by the CSIRO and are displayed in Table 7-2.

Table 7-2 Estimated Storm Surge and Storm Tide Recurrence Intervals for Open Coast at Seaspray, based on the IPCC 2007 A1FI Scenario 2, from McInnes, et al. (2009)

Period (years)	Storm Tide (m)			
	Current Climate	+0.15 m SLR	+0.47 m SLR	+0.82 m SLR
10	1.22 ±0.12	1.42	1.87	2.33
20	1.32 ±0.12	1.54	1.98	2.44
50	1.43 ±0.12	1.66	2.09	2.53
100	1.50 ±0.14	1.73	2.18	2.64

The synoptic weather systems responsible for significant storm surge events on the East Gippsland coast were investigated by the CSIRO (2005). A synoptic typing technique was utilised that generated three generic weather systems giving rise to storm surges on the East Gippsland Coast. The three generic weather systems were termed Cold Fronts, Tasman Lows and East Coast Lows.

The study determined that from a population of storm surges greater than 0.4 m at Lakes Entrance, 77% were associated with cold fronts at various stages of progression across Bass Strait. Only around 23% of significant storm surges were identified as being generated from either Tasman Low or East Coast Low weather systems.

8. FLOOD MITIGATION AND WARNING

8.1 Flood Mitigation Scheme

The Seaspray flood mitigation scheme was constructed in response to the 1978 flooding following the 1980 flood study. The flood mitigation scheme was originally intended to protect residential land and allow extra time to get the entrance open. The scheme consists of:

- Levees along Merriman Creek and surrounding developed areas
- Excavation of the Lake Reeve Floodway
- Regulating structure and spillway between Merriman Creek and the Lake Reeve Floodway
- Remodelling of Merriman Creek including cut-off of the meander (now The Island)

Figure 6-3 shows the location of the levees and floodway structures.

Wellington Shire Council is responsible for the operation of the floodway. The opening of the entrance is considered the first priority when a flood alert is issued. If the mouth is not open then it must be mechanically excavated. At times the mouth has been difficult to get open and has tended to reclose due to wave conditions. If the mouth cannot be opened then flows exceeding 45 m^3/s are likely to overtop the levees.

The regulator structure can be lowered to allow flood flows to flow towards Lake Reeve to allow additional time to get the entrance open. The capacity of the floodway is 15 m^3/s. In recent years the regulator has been kept closed in all events, with the aim to allow flood levels to build up in the lagoon to help drive entrance scouring.

A low flow bypass pipe connects Merriman Creek with the Lake Reeve end of the floodway, but is not currently operable due to corrosion.

The flood mitigation scheme refers to a fixed spillway at 2.4 m to Masons Creek to the south west of the lagoon. However there is no evidence of this spillway on the ground or in the DEM. The ground surface has an overflow level of approximately 2.3 m to Masons Creek. The scheme also refers to filling of the land west of the lagoon to compensate for increased flood levels, however the land appears to have been protected with a levee with crest height approximately 1.9 m to 2.5 m AHD rather than fill.

The construction of the scheme was completed in 1987. Some additional works were undertaken after the 1996 audit (Findlay Irrigation Design Services and BM Consulting Civil Engineers 1996) including the levee extension up to Blind Creek and the Eastern Prior Stream culvert upgrade. The levees were surveyed for the Urban Levee Review project (SKM, 2014).

8.2 Flood Warning Arrangements

Bureau of Meteorology gauges at Prospect Road and Stradbroke West were installed following the 1980 flood study for flood warning purposes. Flood alert flow levels at the Prospect Road gauge are listed in the Mitigation Scheme Operating Procedure but it is unknown whether these have been formally implemented by the Bureau of Meteorology. No flood class levels have been defined for either gauge.

The Mitigation Scheme Operating Procedure also includes recommendations for opening of the estuary entrance when flood conditions are expected in Merriman Creek, based on the upstream gauge flows.

9. SITE INSPECTION

A site inspection was undertaken by representatives from Water Technology, West Gippsland CMA and Wellington Shire Council on 16 October 2014. Key locations visited are shown in Table 9-1.

Table 9-1 Key locations visited by project staff, 16 October 2014

Location/Notes	Photo
Centre Road Pump Station • All stormwater drains to 2 pump stations. Some stormwater from the northern levee area drains to the southern area via pipes under the floodway.	
Southern Pump Station	
Water Level Gauge • Lagoon quite high, 1.3 m on gauge	

Location/Notes	**Photo**
Regulator • All boards were in. Boards come up to top of concrete walkway. • (Wellington Shire Council) advised that current practice is to leave all boards in at all times, which deviates from the operating procedure. The rationale behind this is that the priority during a flood is to get the entrance open, and if the floodway is open it can create conditions where the entrance is less likely to scour out properly when opened. The regulator would only be opened if water was required to top up Lake Reeve. In a typical flood it can be assumed to remain closed.	
Low flow gate at Regulator (closed) • Small regulators on each side of the regulator are intended to allow low flow through to Lake Reeve. The floodway side should be kept open but is currently closed and cannot be operated. The lagoon side was also closed. The low flow pipe runs to an outlet at the Centre Road crossing of the floodway.	
Spillway beside regulator • Next to the regulator is a wide spillway at a lower level than the top of the boards. The weir is constructed of rock gabions or rock covered with mesh)	

Location/Notes	Photo
Merriman Creek Lagoon • Entrance closed • Large lagoon on ocean side of dunes, stretching toward surf club • Phragmites along fringes of lagoon, some swamp paperbark around The Island	
Floodway (looking west from Futcher Road) • High grass in Floodway	
Floodway (looking west from Centre Road)	

Location/Notes	Photo
Levee north of The Island • Levees have recently been surveyed by SKM. A section north of The Island was missed. • All levees appeared in good condition	
Levee between lagoon car park and regulator	

Local historical knowledge was provided on site by John Inglis of Wellington Shire Council, including the following remarks:

- The west regulator/levee (west of Merriman Creek) was never finished. Some flow would head down to Lake Denison under high flood conditions.
- The Prospect Road gauge was moved earlier this year to a more stable location. Previously it had to be re-rated many times due to channel change. The Stradbroke West gauge is in a stable location and provides good flood warning (~24 hours).
- In 1993-1995 Blind Creek was blocked with an unauthorised levee. The levee was rectified after the 1995 flood.
- Usually the entrance is easy to open, but in 1995 and 1998 wave conditions made it hard to get the entrance open. The entrance usually opens up towards the surf club due to the prevailing wind direction
- After the 1995 flood a new culvert was installed on Eastern Prior Stream.

10. MODEL DEVELOPMENT AND SCHEMATISATION

10.1 Hydrologic Modelling Approach

Hydrologic modelling will be undertaken to quantify the catchment generated flows in Merriman Creek at the hydraulic model boundaries as well as stormwater inflows within the hydraulic model extent.

10.1.1 Model Build / Development

A RORB hydrological model will be developed of the entire Merriman Creek catchment to the creek entrance, which includes the hydraulic model extent. ESRI's ArcHydro will be used to delineate the catchment, with a minimum of 3 to 5 sub-areas schematised upstream of any required streamflow hydrograph. Print locations will be included at all locations where flow is required such as at tributaries, streamflow gauges and model boundaries.

10.1.2 Model Calibration

The model will be calibrated to the 1993, 1995, and 2011 flood events for which gauged information is available. Local daily rainfall gauges will be used to construct a spatial pattern of rainfall for the historic events. Local sub-daily rainfall gauges will be used as temporal patterns for the historic storm event. Model parameters *kc*, *m*, *IL* and *CL* will then be developed for each event by calibrating to the available streamflow gauge. The *kc* and *m* will most likely be consistent across events with the losses varied to represent different antecedent conditions.

The design events 0.5%, 1%, 2%, 5% and 10% AEP will be simulated for a range of storm durations.

10.1.3 Hydrological Design Modelling

A flood frequency analysis will be undertaken for the Prospect Road gauge to determine peak flow and volume for the design annual exceedance probabilities specified in the brief.

At this stage is the proposed that the current IFD curves will be utilised for design rainfalls. Presently, the revised curves are not recommended to be used in practice until the revised AR&R manual is finalised. The revised IFD curves will be modelled, however, as part of a sensitivity analysis.

RORB model design parameters (*kc, m, IL, CL*) will be determined. The *kc* and *m* values adopted for design modelling will most likely be the same as that adopted for verification, given the calibration approach will utilise design estimates, but will be compared to nearby model values as well as values from Australian Rainfall and Runoff and the RORB *kc* prediction equations.

A number of estimation techniques will be tested for design losses, with the flows at Seaspray compared for the various methods:

- Hill *et. al.*
- Australian Rainfall and Runoff
- Other models from nearby catchments
- Losses from verification historic events

Further verification of design flows will be undertaken using regional prediction equations and methods such as the Probabilistic Rational Method. However it must be noted that the recently released draft version of the updated Australian Rainfall and Runoff – A Guide to Flood Estimation, recommends that the Probabilistic Rational Method is no longer used, and goes on to provide an alternative approach. Both methods will be used to provide verification for the RORB design flow estimates.

The design events will consider a range of durations with a focus on critical durations for Merriman Creek at Seaspray. All critical durations will be simulated in the hydraulic model and results enveloped for the final design event mapping.

The final adopted design model parameters will be utilised to produce hydrographs at all hydraulic model boundaries for the 0.5%, 1%, 2%, 5%, and 10%, AEP flood events.

The probable maximum flood (PMF) discharge will be estimated using the rapid assessment method developed by Nathan *et. al.* (1994).

The impacts of climate change will also be tested by increasing the rainfall intensity by an agreed amount in line with available literature, most likely an increase of 32% as advised in the report *Climate Change in Australia* (CSIRO, 2005).

The impacts of bushfires will be tested by adjusting the fraction impervious of the Merriman Creek sub-catchments to reflect an agreed severity of bushfire. For example Blackham et al (2012) provides values of equivalent percentage impervious for different levels of burn severity, based on BAER (2009).

10.1.4 Stormwater

Stormwater modelling will use ARR87 IFD and temporal pattern information for input to the direct rainfall model. The ARR87 information will be compared to any updated information available for the ARR update, and if there are significant differences a sensitivity test may be justified.

No calibration data is available for stormwater flooding.

Loss values will be adopted to be consistent with those applied in the RORB model for design flood estimation.

10.2 Hydraulic Modelling Approach

10.2.1 Overview

Water Technology has previously developed both a MIKE21 Flexible Mesh and MIKE21 Fixed Grid model of Seaspray to assess ocean inundation as a result of a breach of the coastal barrier and overflows from Lake Reeve as a result of catchment flooding, Figure 10-1 and Figure 10-2.

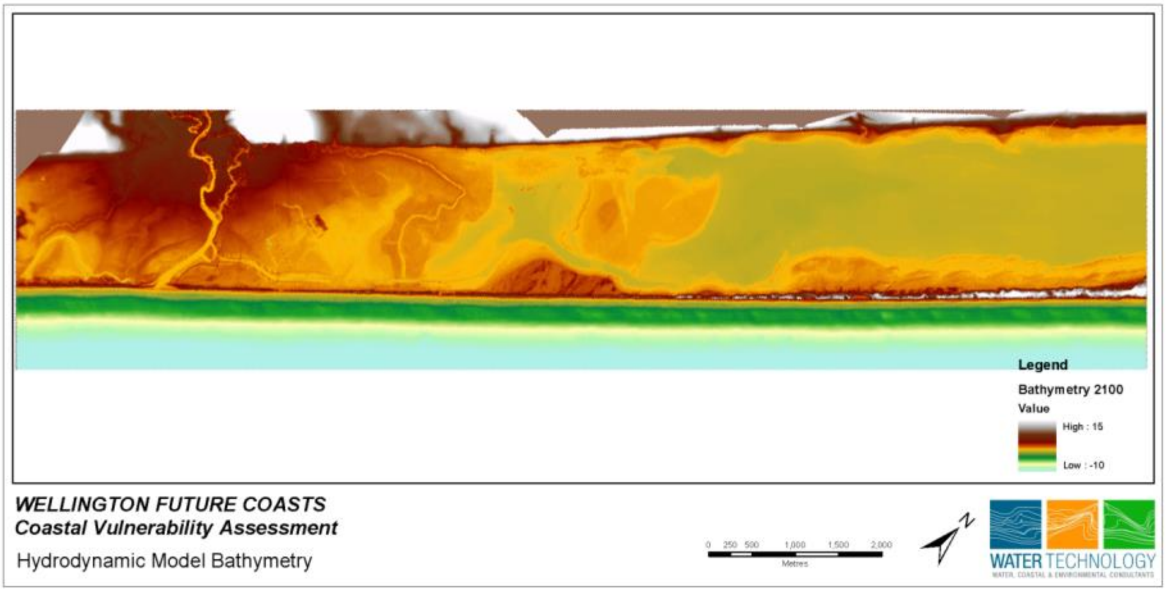

Figure 10-1 Model Extent of Existing MIKE21 Fixed Grid Model

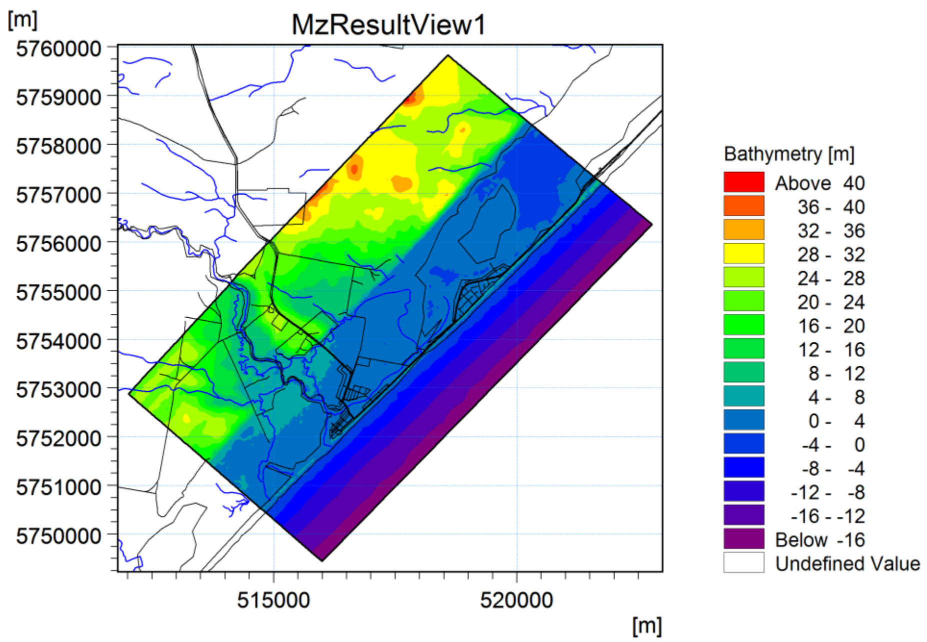

Figure 10-2 Model Extent of Existing MIKE21 Flexible Mesh Model

Both models cover essentially the same study area extent, from approximately the 10m offshore isobath to the higher elevation areas associated with the marginal bluff inland (a former marine cliff), and in the longshore direction from just north of Lake Dennison to Lake Reeve.

The fixed grid model has a 5m grid resolution, with levee features specifically incorporated, while the flexible mesh model has a variable mesh resolution across the model domain, with 10-20m in the township. The flexible mesh model resolution is currently too coarse for detailed flood modelling, however the advantage of the flexible mesh model is that it can be increasingly refined to accurately represent small topographic features in areas of interest without having to alter the size of the grid elements in other locations. This allows greater detail with less impact on model runs times. Neither of the models currently includes pipes or the regulating structure. Both types of model can include rainfall on grid as well as the more standard point source inflows.

After reviewing both models, we propose to refine and update the flexible mesh model for this study. This is due to the ability of the flexible mesh model to be refined in areas of interest while minimising impacts on model run times.

The model will predominantly be a 2D model with hydraulic structures such as culverts, bridges and pipes modelled in 1D. The selection of the 2D model extent is a compromise between geographical coverage and model grid resolution.

Preliminary testing during this review has indicated that in the township areas and other locations of specific interest a fine mesh element size can be used (3-5m). In other areas the mesh resolution will be increased up to 10-12m depending on the location and the requirements to resolve specific topographic features. Mesh resolutions will be refined during the model development to optimise model run times.

The model's inflow boundaries will vary depending on the flood mechanism(s) being assessed. For instance, for a catchment generated flood event the model's upstream boundaries will use flow hydrographs generated from the RORB model for Merriman Creek and local tributaries. The model's downstream boundary will use a time series ocean boundary condition.

Hydraulic roughness parameters will be adopted using industry standard values that represent the creek and floodplain vegetated condition, and will be adjusted as required to calibrate the models.

Sensitivity analysis will be performed on hydraulic roughness to assess the model's sensitivity to the adopted parameters.

A 2D roughness map will be developed including appropriate roughness values for residential/commercial/industrial properties, roads and car parks, waterways, public open space, dense vegetation and sparse vegetation.

10.2.2 Ocean Water Levels

The Australian Rainfall and Runoff Revision Project 18 is currently investigating the interaction between coastal processes and severe weather events. As detailed in the Project 18 Stage 2 report, where the level of dependence between extreme rainfall and storm surge has not been determined it recommends assessing whether accounting for dependence would result in significant change to the flood level for the area of interest. We therefore propose to do this through modelling the following events for an open entrance condition:

- 1% AEP catchment generated flood event with a 1% AEP storm tide (peak storm tide elevation based on McInnes et al., 2009 under present mean sea level, Table 7-2)
- 1% AEP catchment generated flood event with an astronomical tide only,
- 1% AEP storm tide (peak storm tide elevation based on McInnes et al., 2009 under present mean sea level, Table 7-2) with no catchment flood event (assumed baseflow condition).

These three simulations are slightly different to those proposed in the original proposal and reflect the latest guidance from Project 18, which recommends testing the level of dependence between catchment flows and storm tide in this way ( ). Depending on the outcomes of these simulations we may undertake additional sensitivity test to select an appropriate downstream boundary condition for the design event simulations.

The offshore water level boundary will be generated using the following approach:

- Apply a cosine wave with an amplitude equal to that of the 1% AEP storm surge at Seaspray (McInnes et al., 2009),
- Add to this the predicted astronomical tidal water levels for Seaspray (Table 7-1),
- Analyse the resultant time series and select a suitable period where the peak water level is equal to the 1% AEP storm tide level for Seaspray (Table 7-2).
- Apply the selected time series of the model boundary, with further adjustments as required to ensure the correct storm tide elevation at Seaspray.

The process is then repeated for the estimated 10% AEP storm surge and storm tide peak values. This is the same approach as used to develop a storm tide boundary condition for the Corner Inlet Storm Tide Assessment (Water Technology, 2014b) and for previous storm tide assessments at Seaspray (Water Technology, 2010 and 2014a).

Based on the outcomes of this assessment and discussions with WGCMA, suitable ocean water level conditions will be adopted for the remaining design flood events.

A sensitivity analysis will be undertaken for the 10% catchment generated flood event with a 1% storm tide including +0.8m sea level rise.

10.2.3 Lake Reeve Water Levels

To assess flooding impacts from Lake Reeve, boundary conditions will be extracted from the Gippsland Lakes hydrodynamic model, used in the Coastal Hazard Assessment (Water Technology, 2014a) and applied as an inflow boundary to the local Seaspray model.

The previous modelling of Gippsland Lakes including Lake Reeve was undertaken for the estimated 10% AEP catchment flood under present, +0.2, +0.4 and +0.8 m sea level rise conditions and 1% AEP catchment flood under present and a +0.2 m sea-level rise condition. A key result of this analysis was that the floodplains around Seaspray only became inundated during the 10% AEP flood event under the +0.8 m sea level rise scenario. However, the flood levels did not reach a height sufficient to overtop the levees surrounding Seaspray.

For this study, it is proposed that boundary conditions for the 10% AEP flood with +0.8 m of sea level rise will be extracted from the Gippsland Lakes model and used as input to the local refined Seaspray flood model. This will allow more detailed assessment of the impacts of this event on the township and surrounds.

10.2.4 Entrance Conditions

Merriman Creek estuary is an ICOLL (intermittently closed and open lake or lagoon) whereby under low creek flows and/or on-shore wave conditions the entrance channel is small or closed off from the ocean. When the entrance is closed the water level in the estuary will be elevated and can influence flood extents, particularly for more frequent events. It is understood that the entrance is mechanically opened during flood events, although in some events it tends to be resistant to opening. In large floods it is likely the entrance will open naturally.

Under low creek flows and/or strong on-shore wave conditions, the entrance channel of Merrimans Creek is small or closed off from the ocean. Under such conditions the water level in the creek at Seaspray increases until the flows overtop the sandy berm at the entrance or the creek flows are sufficient to erode an entrance channel through the berm. In order to understand the opening and closing regime of the Merriman Creek entrance, the water level gauge at Seaspray will be analysed along with creek inflow record to ascertain under what river flow condition the entrance is open, closed or perched. An initial review of the water level information indicates that when closed the estuary water level increases up to around 1.6 m AHD, after which an opening is initiated. The conditions at the ocean entrance of Merriman Creek are likely only important for more frequent flood events as during rare events (i.e. 1 % AEP flood) an entrance will scour rapidly to the size required to convey the flood through the entrance berm.

For a given design flow, the likely resultant entrance channel dimensions will be estimated. Sediment size information is available for Seaspray from the Local Coastal Hazard Assessment and this will allow calculation of the critical velocity for erosion of the entrance channel. Typical outlet dimensions are also visible in flood aerial photography of the 1978 and 1993 events.

The MIKE FM sand transport module will be run coupled to the flood model for the 10% AEP event to dynamically simulate the effect of flood flows on the entrance channel. This will provide an indication of the rate of scour and changes in flood levels as a result of the entrance channel forming.

Based on the results of the analysis an appropriate entrance channel configuration will be adopted for each design flood event. The choice of ocean water level conditions for the design events will be determined based on the outcome of the catchment and ocean flooding sensitivity assessment (described below). It is anticipated that the downstream ocean boundary condition for the catchment flood design scenarios will be based on a typical tidal condition, and sensitivity tests will be conducted for +0.2m, +0.5m and +0.8m sea level rise.

10.2.5 Stormwater Modelling

Stormwater modelling will be undertaken using a direct rainfall on grid approach. For this type of hydraulic modelling, the design rainfall estimates are applied directly to the hydraulic model surface. Land planning layers, cadastral and aerial imagery will be used to identify unique fraction impervious and loss characteristics for each land parcel in the study area. A representation of Wellington Shire Councils pipe and pit network will be included in the model as 1D elements.

11. DATA GAPS

The following data gaps were identified:

- Merriman Creek bathymetry
- Caravan Park topography and drainage information

11.1 Merriman Creek and Lagoon Bathymetry

LiDAR data does not capture the bathymetry of rivers and waterbodies below the water surface. In the case of the Merriman Creek lagoon, it is fortunate that the Vicmap Elevation Coastal LiDAR dataset was captured when the water level was relatively low (0.8 m AHD), however there remains some uncertainty around the bathymetry of the lagoon below this water level. Since the lagoon is a backwater area, the bathymetry is not of critical importance, however some information on typical bathymetry near the entrance would be valuable.

Following completion of the draft preliminary report additional bathymetric survey of the lower sections of the lagoon was undertaken to fill this data gap. This is discussed in the Hydraulics Report (R03).

11.2 Caravan Park Topography and Drainage

Since the collection of the various LiDAR datasets the Seaspray caravan park has been relocated to an area that was formally the football oval, as shown in Figure 11-1. The ground surface levels in this area have been raised and significant drainage infrastructure has been installed. Information was requested from the Seaspray Foreshore Committee for any “as-built” survey or drainage plans, however no information was available. Wellington Shire Council provided design information including ground levels and drainage layout and this information has been adopted for the study.

Figure 11-1 Location of Seaspray Caravan Park

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