Seaspray Flood Study - Summary Report (R05)

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PROJECT DETAILS

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Cover Photo: Flooding in Seaspray in 1993

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EXECUTIVE SUMMARY

This report details the input data, approach and outcomes for the Seaspray Flood Study and is intended to be read as an accompaniment to the previous reports:

- Seaspray Flood Study – Data Review (R01)
- Seaspray Flood Study – Hydrology (R02)
- Seaspray Flood Study – Hydraulics (R03)
- Seaspray Flood Study – Assess and Treat Risk (R04)

The Seaspray Flood Study has been initiated by the West Gippsland Catchment Management Authority (WGCMA) in order to define the extent and characteristics of flooding in the township of Seaspray so that future planning decisions may be soundly based and measures may be put in place to minimise risk to the community.

The study provides information on flood behaviour and flood intelligence in and round the township of Seaspray. The study involved a rigorous technical analysis of the drivers for flooding, which included coastal, riverine and stormwater flooding, and provides confidence in the use of this information to guide emergency management and future floodplain management in the catchment.

Community consultation was undertaken at various stages of the study, primarily in order to gather data and accounts of flooding and to benchmark the outputs of the calibration and preliminary design event mapping. The flood information provided by residents was invaluable in the development of the study outcomes.

A hydrologic analysis of Merriman Creek and the associated catchment was undertaken to determine design flood hydrographs for the 10%, 5%, 2%, 1% and 0.5% annual exceedance probability (AEP) flood events which affect the township as well as the probable maximum flood (PMF). A rigorous approach has been applied to test and validate the design flows by utilising a number of hydrologic approaches including Flood Frequency Analysis, and development of a detailed hydrologic (RORB) model. The adopted design flood inflows for the study are listed in Table 1.

Table 1 Design peak flows at Prospect Road

AEP	Flow (ML/day)
10%	10,280
5%	19,790
2%	29,030
1%	41,130
0.5%	55,640

To place the design peak flows in a historical context, the approximate AEP (and Average Recurrence Interval, ARI) of significant historical flood events are provided in Table 2. Widespread flooding occurred throughout Seaspray during the September 1993 event. The November 1995 event is the largest gauged event recorded at the Prospect Road Gauge. Despite the 1995 event being the largest on record, flood mitigation works following the 1993 prevented flooding in Seaspray.

Table 2 Merriman Creek, Approximate AEP/ARIs for significant historical flood events

Historical event (year)	Approximate AEP/ARI (based at Prospect Road)
September 1993	2% / 50 years
November 1995	2% / 50 years
June 2012	<10% / 10 years

A digital elevation model (DEM) was developed from available LiDAR survey. Using the DEM, a hydraulic model was established to simulate flood behaviour within the study area. Flood behaviour was assessed for flooding originating from tributaries as well as local catchment runoff within the floodplain. The hydraulic model was calibrated to one historic flood event (September 1993). The completion of the Flood Mitigation Scheme for the town in 1987 significantly altered the flood behaviour through Seaspray. The introduction of flood defence levees and the construction of the Lake Reeve Floodway as part of this scheme, removed the ability to achieve any relevant calibration to flood events prior to the scheme's implementation. Additionally, the more recent changes to flood levees and culvert upgrades following the 1993 flood event have shown a positive influence in reducing flood impacts within Seaspray. As such, more recent flood events have resulted in limited impact on properties and infrastructure, and has led to insufficient data with which model comparisons can be based.

Flood maps of all the design flood events and output data for all events have been produced as a key deliverable of this study.

A flood risk analysis was undertaken, including extraction of flood intelligence and flood warning information, review of the operation of the existing flood management scheme, and development of a Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO). Recommendations for improved management and maintenance are provided in the Flood Risk Report (R04) and include operational controls for the manual opening of the entrance berm if closed prior to a flood event, maintenance of the floodway, and operation of the existing regulator structure.

Conceptual design and feasibility assessment was undertaken for several mitigation options to further improve the flood resilience of Seaspray. Improvement works to the existing levee network, and the extension of Griffioens Levee has been shown to provide considerable reduction in flood damages for the 1% AEP flood event and a positive return from a benefit-cost analysis.

The model resolution of this study is suitable to inform land use planning and flood insurance pricing at a property scale. The timing of the flood peak and associated data is suitable to inform emergency response services.

ACKNOWLEDGEMENTS

Numerous organisations and individuals have contributed both time and valuable information to the Seaspray Flood Study. The study team acknowledges the contributions made by these groups and individuals, in particular:

- Wayne Gilmour and Adam Dunn (West Gippsland CMA)
- Rebecca Lett (Department of Environment Land Water and Planning)
- John Inglis (Wellington Shire Council)
- Wayne Ross (Thiess/Ventia Hydrographic Services)
- Louise Haughton, Ken Bodinnar, Merryn Henderson (VicSES)
- Karen Hudson, Elma Kazazic (Bureau of Meteorology)

The study team also wishes to thank all those stakeholders and members of the public who participated in the steering group and community information sessions and provided valuable records (including historic photos) and discussed their experiences and views on flooding in Seaspray.

GLOSSARY OF TERMS

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.

Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
MIKE FLOOD	A hydraulic modelling tool used in this study to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.

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1. INTRODUCTION

1.1 Overview

The West Gippsland Catchment Management Authority (WGCMA) commissioned Water Technology to undertake the Seaspray Flood Study. This study involved detailed hydrological and hydraulic modelling of the township of Seaspray, the adjacent floodplain areas from Prospect Road on Merriman Creek to Lake Reeve and took into account the downstream ocean conditions.

The objective of the Seaspray Flood Study was to define the extent and characteristics of flooding in and around Seaspray so that emergency management and future planning decisions may be soundly based and measures may be put in place to minimise risk to the community.

The study addressed the following aspects:

- Examine contributing factors to flood events around Seaspray including Merriman Creek, Lake Reeve, stormwater and the ocean;
- Assess the sensitivity of the impacts of climate change, bushfire, sea level rise and Lake Reeve influences;
- Determine flood levels and extents for a range of flood modelling scenarios within the study area;
- Provide detailed flood intelligence outputs;
- Develop conceptual design of feasible flood mitigation options.

1.2 Study Catchment and Floodplain

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 90 Mile Beach, and the areas of small lot subdivision that extend easterly for 28 km to Golden Beach and Paradise Beach.

The town is located on the estuarine floodplain of the Merriman Creek catchment. Merriman Creek flows along the western boundary of Seaspray before it passes through the 90 Mile Beach coastal dune system and enters Bass Strait. As part of the flood mitigation scheme completed in 1987, an engineered floodway running through the middle of the town, has the ability to distribute water from the Merriman Creek estuary to Lake Reeve in the east.

The study area includes Merriman Creek downstream of Prospect Road, the lagoon entrance with Bass Strait, and the floodway extending all the way to the western end of Lake Reeve as shown in Figure 1-1.

In this study area, flooding can occur as a result of a range of potential mechanisms, including;

- Overbank flows from Merriman Creek,
- Coastal inundation due to elevated ocean levels,
- Flooding from the Gippsland Lakes via Lake Reeve,
- Localised stormwater flooding.

Each of these flooding mechanisms have been evaluated during this project.

Figure 1-1 Study Area

1.3 Supporting Documents

A number of reports were prepared at each stage of the study. These reports were produced as separate standalone volumes, and a summary of each is provided in Table 1-1. In addition to these documents, flood intelligence outputs and GIS layers have been provided for each of the design flood events.

Table 1-1 Supporting documents

Report	Document Number	Title	Summary
1	R01	Data Report	Review of flood related information for the study area, a review of available topographic and structure data (bridges and culvert information), and verification of topographic data. The report also provided a proposed outline of the hydrologic analysis and hydraulic modelling methodology
2	R02	Hydrology Report	Hydrologic modelling and analysis report, summarising results of flood frequency analysis, RORB modelling, estimation of design event, and probable maximum flood hydrographs
3	R03	Hydraulics Report	Hydraulic modelling report providing details of hydraulic model construction and calibration, sensitivity tests, and results of design event simulations.

Report	Document Number	Title	Summary
4	R04	Assess and Treat Risk Report	Flood risk report detailing the flood intelligence, flood mitigation options and associated flood damages for a range of design events.

2. DATA REVIEW

On inception of the project a detailed review was undertaken of all available flood related information as well as topographic data, structure information, and hydrological data. Details of this review are provided in Report 1, while a short overview is provided herein.

2.1 Flood Information

2.1.1 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.

2.1.2 Historic Flood Information

Significant historic flood events have been compiled from available sources and are listed in Table 2-1. 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 2-1 Historic Flood Events

Event	Description	Data available
1880	Whole area flooded with fresh water	Gippsland Times letter from A.G. Futcher
1895	Salt water flooding of whole area	Gippsland Times letter from A.G. Futcher
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 1971		Gauged streamflow at 227001 (peak discharge 326 m3/s)
May 1975	Tidal flooding	
May 1978	Overflow from Merriman Creek and Blind Creek	Digitised flood extent (VFD)

Event	Description	Data available
	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	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.

2.1.3 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 2-2 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).

2.1.4 Existing 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.

2.2 Topographic Data

2.2.1 Available Datasets

Aerial LiDAR (Light Detection and Ranging) survey was 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')

It was identified during the data review that further bathymetric data information was required for the lower sections of Merriman Creek and also for the new caravan park area which was relocated to its present location after the LiDAR data capture. Field survey was subsequently obtained for the areas within lower Merriman Creek and Wellington Shire Council provided design levels and layout drawings for the caravan park.
For ocean areas, VicMap 20m bathymetry dataset was available. Details of each of the topographic data sets are provided in the Data Report (R01).

2.2.2 DEM Development

The model topography was developed from four data sources as shown in Figure 2-1. The Coastal DEM (green) was used where available, with the exception of the main river channel where surveyed bathymetric levels collected for this project were used (red). VicMap 20m bathymetry (blue) was used seaward of the shore line and the Rivers DEM (pink) was used in a small area of the upstream section of the model where the Coastal DEM did not have coverage. Modifications were made directly to the mesh for the various entrance conditions representation. Further discussion on the quality and availability of LiDAR is provided in the Data Report (R01).

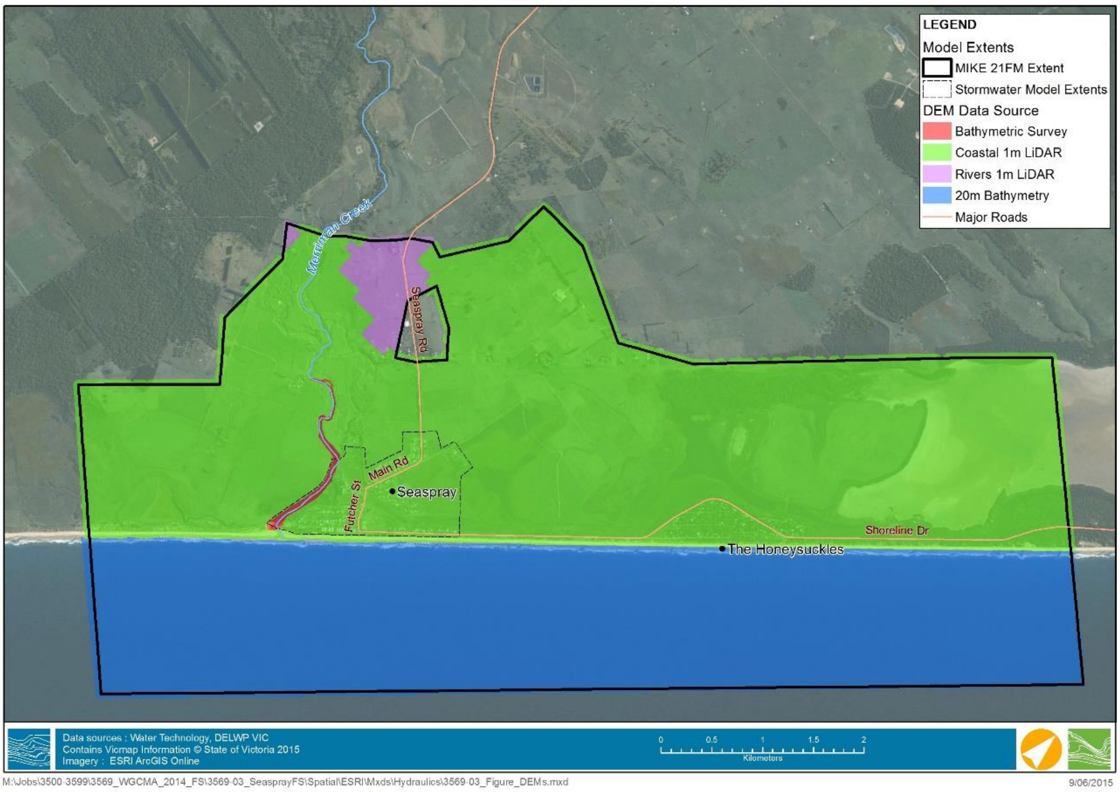

Figure 2-1 Extent of DEM Data Sources Used in Model.

2.3 Structure Information

The following structures are those that have been identified for incorporation to the hydraulic model.

2.3.1 Drainage Information

GIS layers of local pits and pipes were provided by Wellington Shire (Figure 2-2). 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. Details of the caravan park infrastructure including pit and pipe layout, and detention basin locations was provided by Wellington Shire Council.

Figure 2-2 Drainage system at Seaspray

2.3.2 Levees

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 2-3. The levees labelled 2000 Levee are from the Victorian Flood Database (VFD).

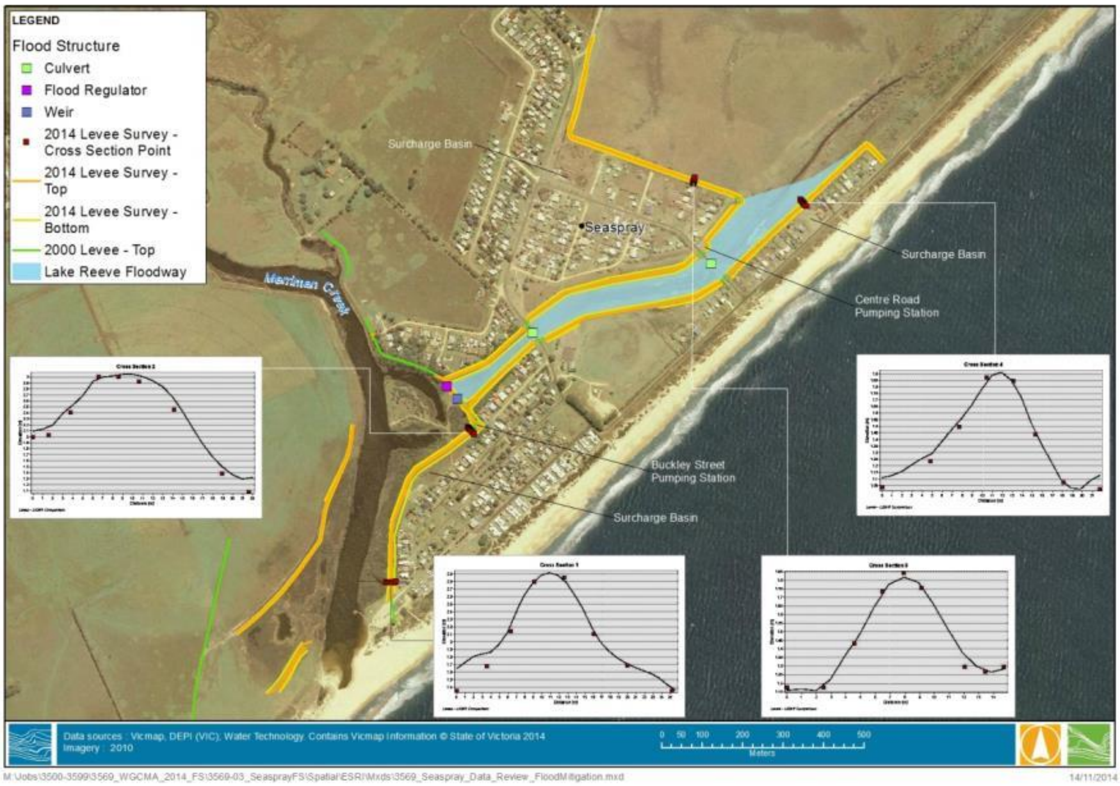

Figure 2-3 Location of Levees and Flood Mitigation Structures within and around Seaspray

2.3.3 Bridges and Culverts

The main bridges and culverts were included in the model as structures defined by their dimensions. The dimensions for the bridges and culverts were determined during a site visit as listed in the Data Review Report (R01).

For the 1993 calibration event, the Eastern Prior culvert under Seaspray Road was a single 450 mm reinforced concrete pipe. After the flood, this was replaced with five 2000 x 1500 mm reinforced concrete box culverts. The modelling of the 1993 event therefore applied a 450 mm pipe culvert, while the sensitivity and design runs applied the new box culvert dimensions.

2.3.4 Regulator and Adjacent Weir

There is a regulator and weir structure at the western end of the Lake Reeve Floodway. The minimum level of the weir is 2.2 m AHD. It is the current operating practice to retain all boards within the structure, raising the overall elevation to 2.7 m AHD. This level, representing the highest setting of the regulator, preferentially directs flow toward the lagoon entrance and away from the Lake Reeve Floodway. The impact and control of the regulator structure has been investigated within a sensitivity analysis, which is described in detail in Report 3 (R03).

2.4 Hydrological Data

Hydrological data required for the study included streamflow, rainfall, along with river water level information.

2.4.1 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 2-2.

Table 2-2 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 2-3. 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 2-3 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
85170	Traralgon LVW & SB	1961-1979	18	33
85265	Macks Creek	1975-1978	3.4	26

Gauge No.	Location	Period	Years	Distance from catchment centroid (km)
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

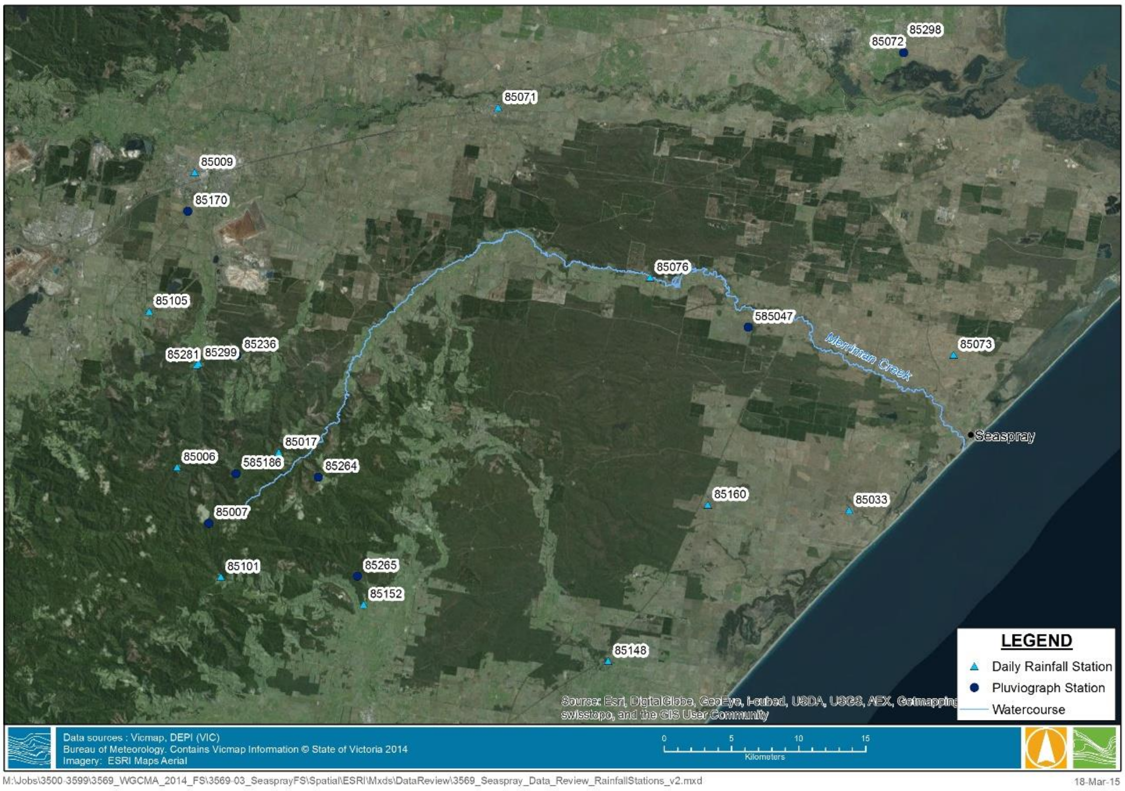

Figure 2-4 Rainfall Stations in and around the Merriman Creek Catchment

2.4.2 Streamflow Data

Gauge Locations

Four streamflow gauges operate in the catchment (Table 2-4). 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 2-4 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 @ Callignee South	1946-1952 and 1965-2014	54	36
227242	Merriman Creek @ Seaspray Township	1984-2014	31	

Rating Curves

Prospect Road Seaspray is the closest gauge to the Seaspray Flood Study mapping area, and the design flows determined at this location provide the design event inflows to the hydraulic model. Therefore a detailed review of the Prospect Road Gauge rating curve was undertaken prior to completion of the hydrologic assessment.

The Merriman Creek at Prospect Road gauge (227240) has 31 years of instantaneous flow data. There were also 5 years of data from 1966-1971 at a previous gauging station (227001, referred to as Merriman Creek at Seaspray) located near the current Prospect Road gauge. Little is known about the reliability of the rating at the old gauge site, although numerous physical gauging measurements were undertaken for flows up to around 1,470 ML/d. The rating for the current gauge is officially considered reliable up to flows of 8,210 ML/d, however the small number of physical gauging measurements show considerable scatter across the whole range, particularly for low flows. Therefore flow estimates are likely to have a high degree of uncertainty.

Plotting of the published water levels and flows from the gauge clearly showed a number of rating curves were used over the 32 year period (refer Report 2, R02). This is because the creek at this location has a sand bed which has been subject to significant instability over the record period. A changing water level – discharge relationship occurs as the sand bed accretes and erodes. The long term water level record was also reviewed and it was found that following the flood event in 1993, gauged levels were elevated, even during low flow periods, for a number of years. The low flow water level, after suddenly increasing in 1993, slowly settled back to current levels over a period of around ten years. This is indicative of sand accretion in the channel after the 1993 event. The 1995 rating curve had a lower predicted flow for a given water level than the rating curve used in 1993, such that the recorded 1995 peak flow was lower than the 1993 peak, even though the water level was higher.

Two dimensional hydraulic modelling of the reach of Merriman Creek around the gauge site was undertaken to verify the appropriateness of the rating curves for the calibration events. This is detailed in Report 2 (R02).

2.4.3 Water Level Data

A water level gauge operates in the Merriman Creek lagoon at Seaspray (Table 2-5). 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 2-5 Water level gauge at Seaspray

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

2.5 Metocean Conditions

2.5.1 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.

2.5.2 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.

2.5.3 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.

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. The astronomical tidal planes for Seaspray are detailed in Report 1 (R01).

Storm Tides

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. The combination of storm surge and astronomical tide is referred to as the "storm tide".

Estimated recurrence intervals of peak storm tide levels for the open coast at Seaspray for various sea level rise scenarios have been developed by the CSIRO (McInnes et. al., 2009) and are displayed in Table 2-6.

Table 2-6 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

3. PROJECT CONSULTATION

3.1 Overview

An important element of the flood mapping study was the active engagement of residents in the study area. This engagement was developed over the course of the study through community consultation sessions and meetings with a Steering Committee. The aims of the community consultation were as follows:

- To raise awareness of the study and to identify key community concerns; and
- To provide information to the community and seek their feedback/input regarding the study outcomes including the existing flood behaviour and proposed flood mapping extents.

3.2 Steering Committee

The flood mapping study was led by a Steering Committee consisting of representatives from West Gippsland Catchment Management Authority (WGCMA), Department of Environment Land Water and Planning (DELWP), Wellington Shire Council (WSC) and Victorian State Emergency Service (VicSES).

The Steering Committee met on three occasions at key points throughout the study, to review and manage the development of the study.

3.3 Community Consultation

The main aim of the community engagement process was to provide information regarding the development of the study and to seek feedback, both verbally and through the use of online methods. All community meetings were supported by media releases to local papers and meeting notices.

The public consultation process was coordinated by the West Gippsland Catchment Management Authority. The following community meetings were held as part of the consultation process:

- Initial community meeting, 26th November 2014. This first public meeting was held to outline the objectives of the study to the community and to receive any flood information the community may be able to provide;
- Second community meeting, 1st April 2015. This meeting presented the results of the calibration event flood modelling. Community feedback was sought on the flood modelling results, particularly the flood behaviour aspects.
- Third community meeting, 14th September 2015. This meeting presented the results of the design event modelling and proposed mitigation options.

The community provided knowledge of a range of previous floods. Many of those present were able to provide specific flood intelligence for the 1993 flood, and also provided information on how the entrance channel across the berm is managed.

4. FLOOD BEHAVIOUR

4.1 Overview

Flooding at Seaspray occurs as a result of floodwaters from Merriman Creek upstream, local stormwater flows, elevated ocean water levels and potentially through flooding from the Gippsland Lakes via Lake Reeve.

The flood behaviour associated with these flooding mechanisms has been assessed using a range of industry standard approaches and tools:

- Hydrological analysis – this involves the analysis of the magnitude of previous flood events in the catchment, the development of a rainfall-runoff model for the Merriman Creek catchment, and the prediction of the likelihood of future flood events of a given magnitude,
- Hydraulic analysis – the physical understanding of what a given flood event may look like in and around Seaspray was assessed through a hydraulic analysis. A hydraulic model was used to predict the extent of flooding, flood depths and flow velocities for a range of possible future flood events.

The different flood mechanism and the results of the hydrologic and hydraulic analysis for the study area are discussed in detail in the following sections. Detailed discussions are also provided in Report 2 & 3.

4.2 Hydrology

4.2.1 Streamflow Gauging

There are two streamflow gauge stations available for use in flood frequency analysis and calibration data for the hydrologic and hydraulic models. A detailed analysis of each gauge was undertaken and is presented in the Section 3.4 of Report 2, the Hydrology report.

4.2.2 Flood Frequency Analysis

A flood frequency analysis was used to estimate the magnitude of flood events at the four selected gauges in terms of a probability of occurrence. This allows the quantification of previous flood events and also enables the estimation of the frequency of future flood events.

The flood frequency analysis was based on an annual series of maximum flows at each gauge for the full record of data. Historic flood peaks were also included based on flood information received for each of the gauges and relationships between the gauges. Comparison to previous estimates and regional equations was also undertaken. Further details are provided in Section 3.5 of Report 2.

4.2.3 Hydrologic Modelling

A hydrological model of the catchment was developed for the purpose of extracting design flows to be used as boundary conditions in the hydraulic model. The rainfall-runoff program, RORB (Version 6) was used for this study.

RORB is a non-linear rainfall runoff and streamflow routing model which is used for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Specified losses are then deducted, and the excess routed through the reach network. The RORB model layout is shown in Figure 4-1.

The two streamflow gauges within the catchment were used to calibrate the RORB model. Parameter selection was based on calibration to both gauges and comparison to accepted regional methods, and the design flows were validated against the flood frequency analysis.

Design flow hydrographs were developed using the calibrated routing parameters, and loss parameters adjusted to reconcile the flood peak to the flood frequency analysis. The adopted peak design flows are provided in Table 4-1.

Table 4-1 Adopted Peak Flows for Merriman Creek at Prospect Road

AEP	RORB Design Flow (ML/d)	Critical Duration
10%	10,280	48hr
5%	19,790	48hr
2%	29,030	36hr
1%	41,130	48hr
0.5%	55,640	48hr

4.2.4 Sensitivity Analysis

Climate Change

The impacts of climate change were tested by increasing the rainfall intensity by 5% per degree of warming, in line with latest guidance from Australian Rainfall and Runoff (Engineers Australia 2014). A scenario of 2°C of warming (i.e. 10% increase in rainfall intensity) was adopted for this sensitivity test. This is consistent with 'Climate Change in Australia Projections' (CSIRO, 2015) report which suggests for an intermediate climate scenario a temperature increase of between 1.1 °C to 2.0 °C is likely for the Southern Slopes region, which includes Merriman Creek catchment.

The 10% increase in rainfall intensity was to the RORB model. Due to the hydrologic response of the catchment, the proportional increases in catchment flows are significantly larger than the applied percentage increase in rainfall. This is most notable in the more frequent events where the 10% AEP design flood event produces a 46% increase in flow. As the magnitude of the design event increases, the percentage increases in flow are reduced to a value more closely aligned to the percentage increase in rainfall. Further detail is provided in Report 2.

Bushfires

The impacts of bushfires were tested by adjusting the fraction impervious values 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). This involved increasing the impervious fraction for all Farming Zone (Forestry) and Public Conservation and Resource Zone areas across the catchment.

As these land use types constitute a significant proportion of the catchment area the increase of impervious fraction due to bushfire had a significant impact on the peak flows generated from the catchment at the catchment outlet. For example, for the 1% AEP flood event, a high intensity bushfire event could increase the flow in Merriman Creek at Prospect Road by 82%. Further detail is provided in Report 2.

4.2.5 Probable Maximum Flood

The Probable Maximum Flood (PMF) is the flow generated from the theoretical maximum precipitation for a given duration under current climate conditions. A PMF Estimate for Merriman Creek at Seaspray (at the lagoon mouth) was prepared using the Quick Method of Nathan et al. (1994). This method applies a set of empirical equations to compute a triangular PMF hydrograph.

The equations are applicable to southeast Australian catchments from 1 to 10,000 km^2 that do not have large lakes or storages. As the Merriman Creek catchment contains a reasonably large swamp storage (around 35 ha in area increasing to around 90 ha when full), a correction to the catchment area was required before the equations are applied.

The resulting PMF peak flow estimate is given in Table 4-2.

Table 4-2 PMF peak flow estimates at Seaspray

	Design Flow (m^3/s)	Time to Peak (hrs)
PMF	5,818	8.1

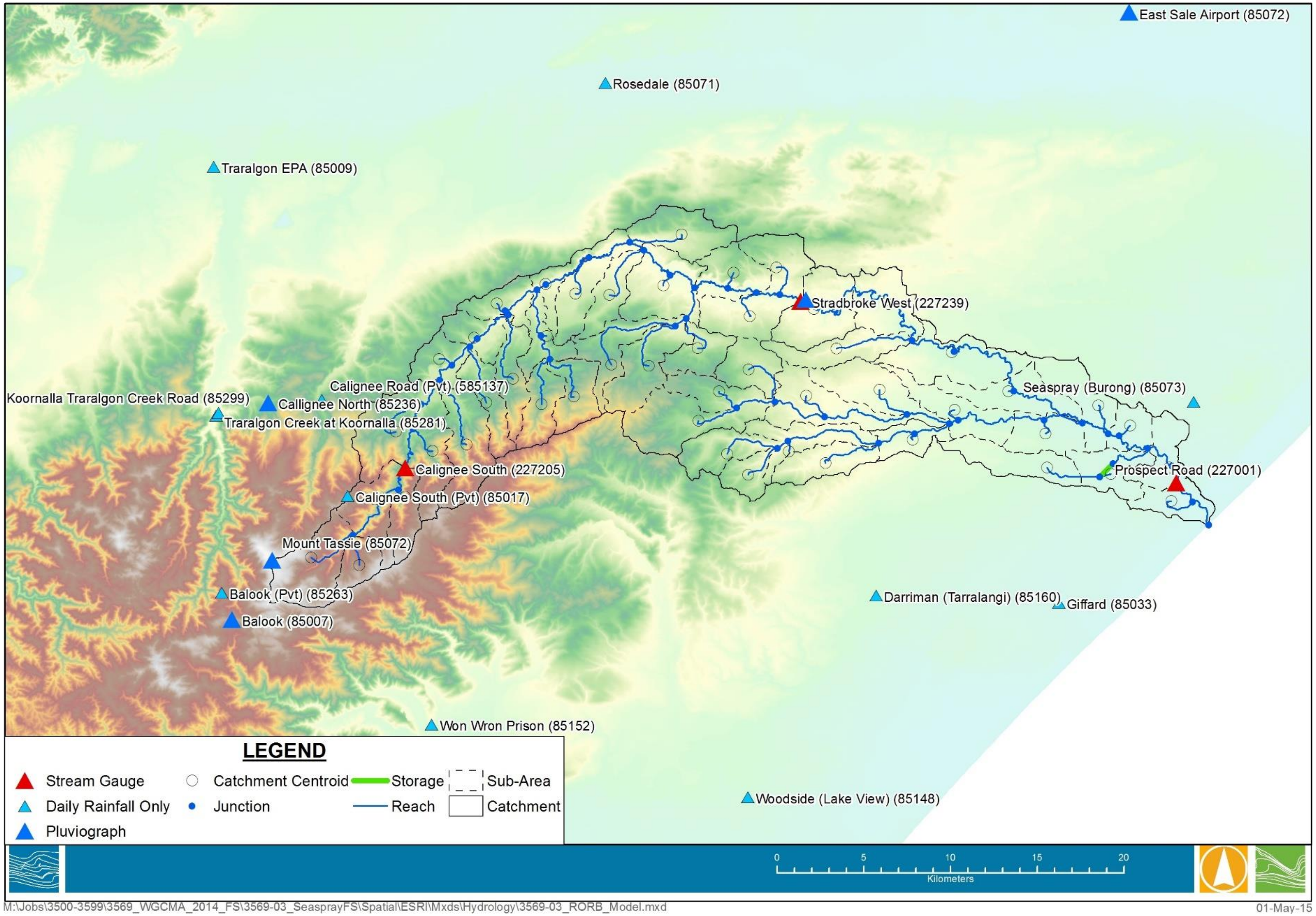

Figure 4-1 RORB Model Structure

4.3 Hydraulics

4.3.1 Overview

This section discusses the application of the hydraulic model to simulate flood behaviour (extents, depth, velocities) for a range of flood magnitudes. The study area experiences a range of different flood mechanisms, including:

- Overbank flows from Merriman Creek,
- Coastal inundation due to elevated ocean levels,
- Flooding from the Gippsland Lakes via Lake Reeve,
- Localised stormwater flooding.

Each of these mechanisms has been assessed in detail during the hydraulic modelling component of the study.

The hydrologic analysis previously discussed, provided flood inflow hydrographs for the hydraulic model. These inflow hydrographs were routed through the calibrated hydraulic model. Ocean boundary levels were applied as a boundary condition. Stormwater influences were modelled independently and then incorporated into the broader assessment. This enabled the modelling of flood depths, extents and velocities over a range of flood magnitudes and conditions. It also provided a tool for understanding the flood behaviour across the study area.

A detailed description of the hydraulic model setup, calibration, validation, sensitivity tests and design event simulation is provided in Report 3. This section summaries the general model development and key outcomes from the hydraulic modelling investigation.

4.3.2 Hydraulic Modelling

A two dimensional (2D) flexible mesh hydraulic model was developed for the study area using MIKE21FM (Mike by DHI). MIKE21FM two-dimensional flexible mesh model systems is a 2D state-of-the-art tool for floodplain modelling. Further details on the capabilities of the MIKE modelling system can be found at http://www.dhisoftware.com.

Adopting a flexible mesh modelling approach allowed the hydraulic model to incorporate greater detail in areas of importance, whilst maintaining computational efficiency through a larger element size in less sensitive regions of the modelled area. This allows features within the broader floodplain and the township area to be resolved in varying detail in the same model whilst maintaining appropriate run times.

The model extent covered the full study area, as shown in Figure 1-1, and inflows were included from Merriman Creek, as well sensitivity tests with flows from Lake Reeve. Ocean levels provided the downstream boundary of the model. Topography data was provided by LiDAR and field survey.

To assess specific stormwater flooding mechanisms, a separate local 1D-2D TUFLOW rainfall-on-grid model was established for Seaspray itself. TUFLOW was chosen due to the ease of incorporating pipes and pits within the model. The localised TUFLOW model incorporated inflow boundaries extracted from the larger MIKE21FM model with the addition of rainfall-on-grid excess across the TUFLOW model area. Stormwater drainage assets were included within the model, incorporating key pipes, pits and pumps.

The modelling process involved the following stages:

- Model setup and calibration,
- Validation and sensitivity tests,
- Design flood simulations,

The calibration, validation, and sensitivity assessments are an iterative investigative process and all outcomes from these stages inform the final design flood simulations.

4.3.3 Understanding Flood Behaviour

Table 4-3 describes the key flood characteristics at Seaspray and surrounds for each design event.

Table 4-3 Design Flood Events and Associated Flood Consequences

Design Flood Event (% AEP)	Gauge Height at Prospect Road (m)	Flood Consequences
10	3.78	River flooding confined to banks of Merriman creek and Blind creek and the urban floodway toward Lake Reeve. There is some flow across the floodplains west of Merriman Creek at the Estuary. There is some pooling throughout the town due to localised rainfall with minor impacts houses along Foreshore Rd and Rowley St. Depths of around 200mm on parts of Foreshore Rd and Futchers St. **Total Properties Flooded = 56** **Properties Flooded above floor level = 0**
5	4.82	River flooding confined to banks of Merriman creek and Blind creek and the urban floodway toward Lake Reeve. Some breakout to the north of the Urban Floodway, East of the town, into undeveloped farmalnd. Pooling throughout Seaspray due to localised rainfall. Depths of around 200mm on Foreshore Rd and parts of Futchers St and Centre Rd. Around 25 houses are within the flood extent. Properties along Rowley St begin to become inundated. **Total Properties Flooded = 57** **Properties Flooded above floor level = 0**
2	5.57	River mostly confined to banks with some flow breaking the banks but remaining close to the main channels. Larger breakouts occurring to the east of the town, to the north of the urban floodway onto low lying farmland. Localised rainfall causing flooding within town. Around 45 houses within the flood extent. Properties along Shoreline Dr and Catton St road begin to become impacted. Deeper flooding along Foreshore Rd, Futchers St and Centre Rd. **Total Properties Flooded = 58** **Properties Flooded above floor level = 0**
1	6.36	River breaking from banks of Merriman creek and Blind Creek adjacent to Griffioens Levee. Breakouts from the Urban Floodway also occur, leading to flow over Government Road Levee from the urban floodway. Deep flows to the east of Seaspray flowing towards Lake Reeve. Overland flow to the west of the Merriman creek towards the estuary. Localised rainfall causing pooled water over a number of properties. Around 195 houses within the flood extent, many between Main Rd and Catton St. Inundation of a large number of roads, with deep water on Centre Rd, Catton St and Hansen

		St. **Total Properties Flooded = 177** **Properties Flooded above floor level = 37**
0.5	NA*	Breakout at turn in Merriman Creek North east of Buckleys Rd. Breakouts from Blind Creek and Merriman Creek adjacent to Griffioens Levee. Breakouts to the west of Merriman Creek moving westward. Seaspray Rd inundation, north of the town, potential isolation. Shoreline drive inundated between Seaspray and The Honeysuckles, causing potential isolation of the Honeysuckles. All houses within Seaspray township within the flood extent except for several along Seaspray Rd, north of Tip Rd, and the south of Bearups St between Lyons St and Bock St. **Total Properties Flooded = 322** **Properties Flooded above floor level = 180**

5. FLOOD RISK AND TREATMENT

5.1 Flood Risk

Flood risk is the product of the consequence and the frequency of a flood event occurring. To assess the flood risk within Seaspray, the hydraulic modelling outputs (depth and velocity) can be used to identify both the frequency of flood impacts (in terms of annual exceedance probability) and the consequence of the magnitude of the flood impacts.

The method used to delineate high flood hazard is broadly based on the new Australian Rainfall and Runoff Project 10 'Appropriate Safety Criteria for People'. Criterion for delineating the flood overlay considers both vehicle and people safety, and are as follows:

- Depth > 0.3 m
- Velocity > 1.5 m/s
- Depth x velocity > 0.3 m^2/s.

If any of the above criteria is exceeded, the area is considered to be High Hazard. Low Hazard areas are locations within the flood extent, but do not exceed any of the above criteria. The maximum flood hazard for the 1% AEP flood event is shown in Figure 5-1.

Figure 5-1 High and Low Hazard Areas in the 1% AEP flood event

5.2 Flood Risk Treatment

5.2.1 Flood Warning

Two streamflow gauges located upstream of the township (Prospect Road and Stradbroke West) provide valuable information on the approaching streamflow towards Seaspray. This information can be used to provide a warning to an approaching flood to the Seaspray Township. The time between peak flows at the two gauges can provide a good indication of the travel time and the available flood warning time, this is outlined in Table 5-1.

While Table 5-1 shows the time between peak flows at the streamflow gauges, flood impacts in Seaspray can occur well before the flood peak arrives at the Prospect Road gauge. Localised rainfall can lead to stormwater flooding within Seaspray independently of any catchment flooding in Merriman Creek. High Risk areas, including Centre Road between Catton Street and Newton Street can be inundated from local rainfall, well before the flood peak from the catchment reaches Seaspray. The source of flooding is important to consider for emergency response procedures such as road closures, sandbagging and if required, evacuation.

Table 5-1 Historical Travel Time between Flood Peaks (based on gauge flows)

Historical Event	Time from Peak at Stradbroke West to Peak at Prospect Road
1993	~ 4 Hours
1995	~ 9 Hours
2012	~ 26 Hours

There are currently no flood warning gauge levels for Seaspray despite the presence of stream flow gauges at Prospect Rd and further upstream at Stradbroke West. Based on the analysis undertaken for this study, recommendations are provided in Table 5-2 to establish flood warning levels at the Prospect Road gauge.

Table 5-2 Proposed Flood Warning Levels

Flood Warning Level	Prospect Rd Height
Minor	2.0m
Moderate	3.0m
Major	4.5m

5.2.2 Flood Management Scheme Operation

Regulator Structure

The existing operating procedure for the Seaspray flood mitigation scheme, including the floodway regulator and manual opening of the estuary entrance is detailed in the operating manual maintained by Wellington Shire Council (Wellington Shire Council, 1996).

The intention of the regulator structure is to provide flood protection from both riverine and coastal flooding. In practical terms, if the sand berm is closed the regulator should maintain a pool level at 2.0 m AHD to 2.2 m AHD, which will preferentially direct river flows down the floodway to limit flows overtopping the berm and scouring an entrance channel. This therefore would prevent ingress of water from the ocean during extreme storm tide events. However, the analysis of coastal flooding reported in the Hydraulics Report R03 has concluded that under existing conditions, there is no risk posed to Seaspray from coastal flooding as the 1% AEP storm tide elevation at Seaspray is 1.5 m AHD under existing mean sea level and therefore the existing levees along Merriman Creek would prevent inundation for storm tides, regardless of the operation of the regulator structure.

The existing operating procedure (Wellington Shire Council, 1996) recommends that for riverine flooding events the regulator structure is to have boards incrementally added manually throughout the duration of the event to limit and control flow down the floodway. In practice this has proven dangerous and impractical, as reported in the failed attempts to place flood boards during the 1993 flood event. Maintaining all boards in place within the regulator structure does however force flood water towards the estuary entrance and encourage earlier natural scouring of the entrance berm if the entrance channel is initially closed.

It is therefore recommended that the operating procedure be updated so that in future all boards remain in place to provide protection against riverine flooding, as there is no flood benefit to removing them during an event.

Entrance Opening

Estuary closure as a result of sedimentation of the entrance and creation of a sand berm is a continued concern for local residents, with pooling of water within the estuary a perceived flood risk if riverine flooding is to occur. Results of sensitivity analysis within the Hydraulics Report (R03) showed that once overtopped, the sand berm will naturally erode within 1-3 hours through natural erosion processes. A safe operating height of 2.1m AHD is proposed as a maximum berm level crest for the sand berm to open naturally without negative flood impacts in Seaspray. It is proposed that the berm be maintained at a maximum height of 2.1m AHD which allows 100mm of freeboard before the earthen weir adjacent the regulator structure is overtopped and water is diverted down the floodway. The height of 2.1m AHD also provides 400mm of freeboard to the crests of the levees along Merriman Creek. If the entrance sand berm is greater than 2.1m AHD, manual opening of the entrance is recommended if weather warnings indicate significant rainfall is likely to occur in the catchment. This differs from the existing operating procedure for the structure as detailed in the operating manual. It is therefore recommended that the operating manual be updated to reflect this revised information.

There is currently no accurate measure of the berm height, although the water level behind the berm is recorded by the gauge at Seaspray. A water level gauge board located at the boat ramp or on the berm would allow Council, WGCMA and the local community to have up to date information on the sand levels and provide a trigger for implementing potential artificial openings of the entrance prior to predicted flood events.

5.2.3 Land Use Planning

The Victoria Planning Provisions (VPPs) contain a number of controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

For the study area, FO and LSIO overlays have been developed based on accepted safety criteria (refer Report 4 for details). The resultant draft FO and LSIO maps are provided in Figure 5-2.

Figure 5-2 Draft LSIO and FO Map for Existing Conditions

5.2.4 Structural Mitigation Options

Three structural mitigation options were presented to the steering committee and community meeting held in September. The three options are listed below, and are described in further detail in Report 4.

1. **Increase Conveyance of Eastern Prior Stream** – It was proposed to assess whether deepening of Eastern Prior Stream to the inverts of the culvert at Seaspray Road would allow water to flow along Eastern Prior Stream and reconnect with Lake Reeve. This aimed to reduce the flood flows directly towards Seaspray.
2. **Increase flood storage along Mason Creek** – It was proposed that additional storage of flood waters could be achieved by utilising the natural depression along Mason Creek towards Lake Denison. The aim was to reduce flood levels within the Merriman Creek estuary and consequently overtopping of the adjacent levees.
3. **Increase Existing Flood Levee Function** - The existing network of levees constructed around Seaspray as part of the flood mitigation scheme have ensured that Seaspray was not impacted during the 1995 or 2012 floods. Design modelling of the 1% AEP flood event, does however, show that the existing levee scheme remains vulnerable to overtopping and breakout flows during a 1% AEP event. Raising of levees in specific locations could be undertaken to eliminate this overtopping.

Modelling results indicated that Options 1 and 2 provide negligible reduction in flood risk to Seaspray and are not effective flood mitigation options.

The levee assessment (Option 3) has identified locations across the levee network in and around Seaspray that are vulnerable to overtopping (Figure 5-3) and how much the vulnerable sections of levee should be raised to provide the required level of flood protection. This work allows a targeted approach to raise underperforming sections of the levee and improve the levee network to mitigate flood levels in the 1% AEP flood event.

Figure 5-3 Vulnerability of existing levees in the 1% AEP flood event

5.3 Flood Damages Assessment

A flood damages assessment was undertaken on existing conditions and is shown in Figure 5-4. The 1% AEP damage calculated was **$2,259,374** with 36 residential properties flooded above floor and 1 commercial property also flooded above floor. The average annual damage (AAD), a measure of the flood damage, per year over an extended period was estimated for existing conditions to be **$46,124**. The AAD is an estimate of the cost of flooding to the community that includes both public and privately owned assets.

Damages were costed for mitigation Option 3, the upgrade of the existing levee mitigation scheme. This option aims to prevent flooding of Seaspray under the 1% AEP design flow from Merriman Creek. It does not address local stormwater flooding. The results (Figure 5-5) showed that the number of residential properties flooded above floor in a 1% AEP event are reduced to 4, and no commercial properties are now flooded above floor level. The flooding of these properties is limited to localised rainfall and stormwater flooding. This reduced the flood damage estimate for a 1% AEP flood event to **$429,895**. The AAD was also reduced to **$33,413**.

EXISTING CONDITIONS					
ARI (years)	200yr	100yr	50yr	20yr	10yr
AEP	0.005	0.01	0.02	0.05	0.1
Residential Buildings Flooded Above Floor	166	36	0	0	0
Commercial Buildings Flooded Above Floor	14	1	0	0	0
Properties Flooded Below Floor	142	177	58	57	56
Total Properties Flooded	**322**	**214**	**58**	**57**	**56**
Direct Potential External Damage Cost	$1,218,495	$738,020	$60,090	$48,791	$48,733
Direct Potential Residential Damage Cost	$9,992,403	$1,997,493	$0	$0	$0
Direct Potential Commercial Damage Cost	$170,813	$3,779	$0	$0	$0
Total Direct Potential Damage Cost	**$11,381,711**	**$2,739,292**	**$60,090**	**$48,791**	**$48,733**
Total Actual Damage Cost *(0.8*Potential)*	**$9,105,369**	**$2,191,434**	**$48,072**	**$39,033**	**$38,986**
Infrastructure Damage Cost	**$160,563**	**$67,940**	**$35,906**	**$32,534**	**$19,876**
Indirect Clean Up Cost					
Indirect Residential Relocation Cost					
Indirect Emergency Response Cost					
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$9,265,932**	**$2,259,374**	**$83,978**	**$71,567**	**$58,862**

Figure 5-4 Existing Condition Flood Damages Summary

MITIGATION CONDITIONS					
ARI (years)	200yr	100yr	50yr	20yr	10yr
AEP	0.005	0.01	0.02	0.05	0.1
Residential Buildings Flooded Above Floor	158	4	0	0	0
Commercial Buildings Flooded Above Floor	1	0	0	0	0
Properties Flooded Below Floor	125	212	58	57	56
Total Properties Flooded	**284**	**216**	**58**	**57**	**56**
Direct Potential External Damage Cost	$462,331	$324,188	$60,090	$48,791	$48,733
Direct Potential Residential Damage Cost	$11,480,148	$168,532	$0	$0	$0
Direct Potential Commercial Damage Cost	$19,781	$0	$0	$0	$0
Total Direct Potential Damage Cost	**$11,962,260**	**$492,720**	**$60,090**	**$48,791**	**$48,733**
Total Actual Damage Cost *(0.8*Potential)*	**$9,569,808**	**$394,176**	**$48,072**	**$39,033**	**$38,986**
Infrastructure Damage Cost	**$100,203**	**$35,719**	**$35,906**	**$32,534**	**$19,876**
Indirect Clean Up Cost					
Indirect Residential Relocation Cost					
Indirect Emergency Response Cost					
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$9,670,011**	**$429,895**	**$83,978**	**$71,567**	**$58,862**

Figure 5-5 Levee Mitigation Flood Damages Summary

The levee improvement mitigation option shows a positive benefit to cost ratio due to the relatively limited extent of levee raising required and associated costs compared to the reduction of flood impacted properties in the 1% AEP flood event (Table 5-3). The magnitude of the 0.5% AEP flood event is such that raising the existing levees is not able to prevent Seaspray from becoming inundated. Overbank flow from Blind Creek continues to outflank the existing levee arrangement with breakout flows occurring all the way along Blind Creek to Eastern Prior stream.

Table 5-3 Benefit-Cost Analysis of Levee Mitigation Scenario

	Existing Conditions	Levee Mitigation Option
Annual Average Damages	**$46,124**	**$33,413**
Annual Maintenance Cost		**$1,559**
Annual Cost Saving		$11,152
Net Present Value (6%)		**$156,821**
Capital Cost of Mitigation		**$83,781**
Benefit-Cost Ratio		**1.87**

6. STUDY DELIVERABLES

6.1 Overview

The study deliverables provide a comprehensive set of data that support the study outcomes. The deliverables are supplied on a study USB and consist of background data and outputs as listed below:

- Digital copies of study reports in PDF format.
- Study survey data (LIDAR, structures, cross-sections and floor levels)
- Other input data including rainfall and flow data
- A property database including flood information
- Digital copies of the maps (PDF format)
- GIS datasets for the model results (ArcGIS format)
- The hydrologic and hydraulic model input files

There is a readme.txt file on the disk that describes the directory structure of the data contained on the disk.

6.2 Mapping Outputs

Details are provided of the study outputs for emergency response, and land use planning mapping including:

- Data sets: grids and shapefiles
- Planning layer
- Flood response inundation maps
- VFD layer updates

6.2.1 Data Sets

The following datasets have been provided. All GIS files were provided in ESRI format.

Grids

Gridded datasets of model results were provided for the following:

- PMF – maximum hazard and water surface elevation,
- Design events (10%, 5%, 2% 1% & 0.5% AEP events) – maximum depth, hazard, velocity and water surface elevation.
- September 1993 Calibration event – maximum depth, water surface elevation and extent

Shapefiles/Tabfiles

ERSI shapefiles were provided for the following:

- Flood depth contours
- Flood extents
- Floor levels
- Mapping limits
- Water surface elevation (flood level) contours

6.2.2 Maps

The flood response inundation maps have been produced for the following design flood events:

- PMF – maximum depth and hazard,
- Flood Hazard - 10%, 5%, 2% 1% & 0.5% AEP events,
- Flood Depth - 10%, 5%, 2% 1% & 0.5% AEP events,
- Flood Velocity - 10%, 5%, 2% 1% & 0.5% AEP events,
- Flood Levels - 10%, 5%, 2% 1% & 0.5% AEP events.

Each map includes:

- Flood extent,
- Flood level contour at 0.2 m and 1m intervals,
- Depth of inundation,
- Identification of essential services,
- Road/street names
- Cadastral base
- Land marks, including all physical man-made features particularly those affecting flood flows and distribution.

Soft copies were provided as PDFs. Related GIS files were provided in ESRI format.

6.2.3 Flood Extent Mapping (VFD Compliant)

All flood mapping data was prepared to the VFD metadata specifications.

6.2.4 Land Use Planning Maps

A draft FO and LSIO map has been produced. A copy of this map is included on the study USB.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Overview

The Seaspray Flood Study provides a comprehensive analysis and review of flood risk in and around the township of Seaspray. The study has involved:

- Collection and review of a range of data relevant to the definition of flooding within the study area.
- A rigorous hydrologic analysis to develop robust design flood estimates for the study.
- Development of a detailed hydraulic model that is capable of predicting flood impacts from a range of mechanisms across the entire floodplain under a range of conditions.
- Thorough sensitivity testing of the hydraulic results including the assessment of relative impacts associated with the different flood mechanisms including riverine flooding, elevated ocean water levels, stormwater and flooding from the Gippsland Lakes via Lake Reeve.
- Design and calibration model result outputs.
- Examination of a range of potential risk management options including structural mitigation measures for Seaspray.
- Quantification of flood risk in terms of flood damages.

7.2 Key Outcomes

In undertaking this study a number of important aspects of flood risk relevant to Seaspray have become apparent. These are summarised as follows.

Hydrology & Flooding Mechanisms – flooding in the Merriman Creek catchment is primarily a function of sustained, high intensity rainfall events in the upper catchment over a period of 36 – 48 hours. Coastal flooding and flooding from the Gippsland Lakes through increased water levels in Lake Reeve are successfully mitigated through the existing levee network and do not result in inundation of Seaspray under existing conditions. Stormwater flooding from local rainfall can create localised pooling of water within Seaspray for events of greater magnitude than the 10% AEP rainfall event.

Hydraulic Characteristics of Flooding at Seaspray – Peak flood levels in 2% AEP and smaller flood event are well confined within Merriman Creek and the floodway. The existing levee network prevents overbank flows from Merriman Creek inundating Seaspray in events equal to and smaller than the 2% AEP flood event. The 1% AEP event results in breakout flows flanking Griffioens Levee at the junction of Merriman Creek and Blind Creek, leading to inundation of Seaspray and water ponding on the inside of flood mitigation levees. Government Road levee is also overtopped from the floodway. Severe levee failure and inundation across most of Seaspray occurs in the 0.5% AEP flood event.

Flood Risk Treatment & Mitigation – locations along the existing levee network that are vulnerable to overtopping in the 1% AEP flood event have been identified. A targeted approach to raising vulnerable sections, in addition to an extension of Griffioens Levee along the bank of Blind Creek, can result in significant reduction of flood damages for the 1% AEP flood event.

Operation of the existing regulator structure and an updated entrance opening procedure would also aid the management of flood risk to the community.

7.3 Recommendations

Following the investigations undertaken for the study and the conclusions reached it is recommended that:

- The WGCMA and Wellington Shire undertake a planning scheme amendment process to incorporate new LSIO and FO mapping into the Wellington Planning Scheme as soon as possible .
- The WGCMA and Wellington Shire consider all recommendations provided within the accompanying "Wellington Planning Scheme Flood Controls Review – Seaspray Flood Investigation" provided by Planning and Environmental Design, for inclusion into a revision of the Wellington Planning Scheme.
- Hydraulic modelling be undertaken to assist Ventia in developing 'level to level' correlation between the Gippsland Water pump location gauge and the existing Prospect Road gauge
- Wellington Shire Council update the existing operating procedure for the regulating structure at Seaspray to reflect the learning from this study and confirm responsibilities for implementation of the procedure during flood events. This may include installation of a new water level/berm height gauge near the Merriman Creek entrance area.
- The Wellington Shire Council and WGCMA continue to engage the community in the treatment of flood risks through regular flood awareness programs such as the VICSES FloodSafe program, starting with the development of a local flood guide.
- The Wellington Council and WGCMA explore further the recommendations for enhanced flood response through co-operation with SES and Police, utilising the flood inundation maps and flood intelligence tools included in the Municipal Flood Emergency Plan (MFEP). Consideration should be given to the use of the MFEP during an emergency.
- The Wellington Shire Council and WGCMA explore further the recommendations for the development of community portal for flood information at Seaspray in conjunction with the BoM and SES.

8. REFERENCES

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