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Appendix E:

Visual amenity impact assessment

Visual Amenity Impact Assessment

The Port Pirie (Regional Council) Development Plan is the primary statutory planning document that guides the appearance of proposed smelter.

As indicated in "Section 9.2 – Land Use" of this report, "special industry" in the form of a smelter already exists on the site and Policy Area 15 in the Development Plan clearly anticipates special industry continuing to be located here. This means that development that looks like industrial development is anticipated.

There are some Objectives within both Policy Area 15 and the Industry Zone that anticipate development, including special industry, having a high standard of visual amenity, as well as a visual buffer between land in adjoining Zones/areas:

Industry Zone

Objective 2: *A high standard of development which promotes good design, with high visual amenity to improve the character and appearance of the area, particularly along Zone interfaces and public roads. (underlining added)*

Objective 7: *The establishment and maintenance of a visual and acoustic buffer between development and zone interfaces. (underlining added)*

Policy Area 15: Pasminco Metals Policy Area

Objective 3: *The establishment and maintenance of a substantial visual and acoustic buffer between development and land in the adjacent Residential Zone, Rural Zone, Public Purposes Zone, Commercial Zone and the Port Pirie River. (underlining added)*

The Council Wide section of the Port Pirie (Regional Council) Development Plan also includes the following Principles of Development Control that are relevant to the appearance of the proposed smelter development:

Interface Between Land Uses

23 *Development at an interface between different land uses should provide an appropriate visual transition in terms of building scale, bulk, and materials. (underlining added)*

Industrial Development

Building Appearance and Siting

184 *Building appearance should be compatible with the desired future character of the locality and existing development in the locality and should add visual interest and differentiation between structures when viewed from the street, with a particular emphasis on the following elements:*

(a) *building mass and proportion;*

(b) *materials, patters, textures, colours and decorative elements;*

(c) *ground floor height above natural ground level;*

(d) *roof form and pitch;*

(e) *façade articulation;*

(f) *driveway crossovers, fence style and alignment. (underlining added)*

186 *Where industrial sites adjoin non-industrial properties, setbacks from side and rear boundaries should be progressively increased as building height increases to:*

(a) *reduce the visual impact of buildings from adjoining properties;*

(b) *reduce overshadowing effects on adjoining properties; and*

(c) *maintain adequate daylight to adjoining land uses. (underlining added)*

Landscaping

189 *Appropriate landscaping should be undertaken as part of an industrial development to reduce the visual impact of buildings and structures, particularly those which adjoin residential areas. (underlining added)*

It is significant that the proposal involves the demolition of a number of existing buildings/ plant/infrastructure within the site to make way for the proposed smelter upgrade. The lessens the visual impact of the proposed facility.

At the same time, the proposed smelter upgrade includes a combination of buildings and pipework/other infrastructure that can be reasonably anticipated with such a significant special industry. The tallest building proposed is approximately 70m high located towards the middle of the site, with most other plant/infrastructure being considerably lower than this. The appearance of the proposed infrastructure is appropriate for a special industry of this nature, satisfying Council Wide Principle of Development Control 184 and Objective 2 of the Industry Zone by incorporating:

- appropriately coloured exterior cladding materials to enclosed buildings
- appropriately coloured fencing materials.

The infrastructure associated with the proposed smelter upgrade is located towards the centre of the existing Nyrstar smelter facilities, more than 350 m from the southern boundary of the site. The land extending southwards from the Leahey Road boundary of the site within the Commercial Zone and the Public Purpose Zone is largely vacant (it is largely used for stormwater management). This substantial distance between the proposed smelter facilities and the nearest sensitive development to the south and west, which also partly includes a range of trees and other vegetation, satisfies Council Wide Principles of Development Control 23, 186 and 189, Objective 7 of the Industry Zone and Objective 3 of Policy Area 15 which seek visual buffers between development and adjoining Zones.

As is the case with the current smelter facilities, there is less separation distance between the proposed smelter facilities and the Port Pirie River. While the proposed smelter upgrade does not provide a "substantial visual buffer" between development and the Port Pirie River as sought by Objective 3 of Policy Area 15, the proposed smelter upgrade replaces existing infrastructure closest to the River and will not create any significant additional negative visual impact when viewed from the River.

The proposed smelter development also requires the following temporary facilities located within the smelter site between the smelter upgrade facilities and the southern boundary of the site:

- Shower building
- Project office buildings
- Two module laydown areas

Given the relatively small size of these buildings or areas, their context within the existing smelter site, the fact that they are opposite the Commercial Zone and the Public Purpose Zone that are largely vacant and their temporary nature (i.e. during the construction period for this project), the visual impact of these facilities will be negligible and acceptable.

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Appendix F:
Listed species potentially occurring in the Transformation area

Listed species potentially occurring in the study area

Habitat

Letters under column Hab. (C = Coastal, M = Marine, T = Terrestrial, W = Wetland)

Status

Letters under column AUS = the category of threat listed under the *Environment Protection and Biodiversity Conservation Act 1999* (CE = Critically Endangered, E = Endangered, V = Vulnerable, Mi = listed migratory species, Ma = listed marine species, W = whales and other cetaceans)

Letter under column SA = the category of threat listed under the *South Australian National Parks and Wildlife Act 1972* (E = Endangered, V = Vulnerable, R = Rare) or *Fisheries Management Act 2007* (P = Protected).

Likelihood of presence in study area

Unlikely - Never recorded in or near study area

Possible - Occasional records in the study area or suitable habitat and records near the study area

Probable - Regularly recorded in the study area or occasional records and suitable habitat

Species		**Hab.**	**Status**		**Distribution and/or habitat preference**	**Likelihood of presence in study area**
Scientific Name	**Common Name**		**Aus**	**SA**		
Birds						
Haliaeetus leucogaster	White-bellied Sea-Eagle	C	Mi, Ma	E	The White-bellied Sea-Eagle is found in coastal habitats (especially those close to the sea-shore) and around terrestrial wetlands in tropical and temperate regions of mainland Australia and its offshore islands. The habitats occupied by the sea-eagle are characterised by the presence of large areas of open water (larger rivers, swamps, lakes, the sea). The species is mostly recorded in coastal lowlands, but can occupy habitats up to 800 m above sea level in Tasmania and South Australia. Birds have been recorded at or in the vicinity of freshwater swamps, lakes, reservoirs, billabongs, saltmarsh and sewage ponds and also occur at sites near the sea or sea-shore, such as around bays and inlets, beaches, reefs, lagoons, estuaries and mangroves (DSEWPaC 2013). There is one record of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Possible

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Pandion cristatus (Listed Aus:Ma as *Pandion haliaetus*)	Osprey	C	Ma	E	Eastern Ospreys occur in littoral and coastal habitats and terrestrial wetlands of tropical and temperate Australia and offshore islands. They are mostly found in coastal areas but occasionally travel inland along major rivers, particularly in northern Australia. They require extensive areas of open fresh, brackish or saline water for foraging, and frequent a variety of wetland habitats including inshore waters, reefs, bays, coastal cliffs, beaches, estuaries, mangrove swamps, broad rivers, reservoirs and large lakes and waterholes (DSEWPaC 2013). Irregular visitor rarely recorded in Upper Spencer Gulf (BHP Billiton 2009b).	Possible
Phalacrocorax fuscescens	Black-faced Cormorant	C	Ma		Resident species uncommonly recorded in Upper Spencer Gulf, north to about 5km south of Port Augusta, but not reported breeding in region (Carpenter and Langdon 2013).	Possible
Thalasseus bergii (Listed Aus:Ma as *Sterna bergii*)	Crested Tern	C	Ma		Resident species uncommonly recorded in Upper Spencer Gulf (BHP Billiton 2009b, Carpenter and Langdon 2013).	Possible
Sternula nereis nereis (Listed SA:E as *Sterna nereis*)	Fairy Tern (Australian)	C	V	E	Within Australia, the Fairy Tern occurs along the coasts of Victoria, Tasmania, South Australia and Western Australia; occurring as far north as the Dampier Archipelago near Karratha. The Fairy Tern (Australian) nests on sheltered sandy beaches, spits and banks above the high tide line and below vegetation. The subspecies has been found in embayments of a variety of habitats including offshore, estuarine or lake islands, wetlands and mainland coastline (DSEWPaC 2013). Seven records of this species are included in the BDBSA. These records are from 2001-2012 and the closest recording of this species to the site is approximately less than 1 kilometre south of the site (Parsons Brinckerhoff 2013).	Possible
Diomedea antipodensis (Listed Aus:V as *Diomedea exulans antipodensis)*	Antipodean Albatross	M	V, Mi, Ma		There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Diomedea dabbenena (Listed Aus:E as *Diomedea exulans exulans*)	Tristan Albatross	M	E, Mi, Ma		There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	Common Name		Aus	SA		
Diomedea exulans (sensu lato)	Wandering Albatross	M	V, Mi, Ma	V	There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Macronectes giganteus	Southern Giant-Petrel	M	E, Mi, Ma	V	The Southern Giant-Petrel is widespread throughout the Southern Ocean. The Southern Giant-Petrel is marine bird that occurs in Antarctic to subtropical waters. In summer, it mainly occurs over Antarctic waters, and it is widespread south as far as the pack-ice and onto the Antarctic continent. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Macronectes halli	Northern Giant-Petrel	M	V, Mi, Ma		The Northern Giant Petrel breeds in the sub-Antarctic, and visits areas off the Australian mainland mainly during the winter months. The Northern Giant-Petrel is marine and oceanic. It mainly occurs in sub-Antarctic waters, but regularly occurs in Antarctic waters of the south-western Indian Ocean, the Drake Passage and west of the Antarctic Peninsula. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Puffinus carneipes	Flesh-footed Shearwater	M	Mi, Ma	R	Migrant species that visits Australia to breed in spring. The nearest breeding colony is Smith Island off the coast of Eyre Peninsula in South Australia (DSEWPaC 2013).	Unlikely
Thalassarche bulleri (Listed SA: V as *Diomedea bulleri*)	Buller's Albatross	M	V, Mi, Ma	V	Buller's Albatross breed in New Zealand (Snares, Solander and Chatham Islands), but are regular visitors to Australian waters. Buller's Albatross are marine and pelagic, inhabiting subtropical and subantarctic waters of the southern Pacific Ocean. Specific habitat requirements are poorly known, but they have been observed in association with fishing boats close inshore and over waters 180–360 m deep. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Thalassarche cauta (sensu stricto) (Listed Aus: V as *Thalassarche cauta cauta*; SA: V as *Diomedea cauta cauta*).	Shy Albatross	M	V, Mi, Ma	V	Shy Albatrosses appear to occur over all Australian coastal waters below 25° S. It is most commonly observed over the shelf waters around Tasmania and south-eastern Australia. It appears to be less pelagic than many other albatrosses, ranging well inshore over the continental shelf, even entering bays and harbours. The Shy Albatross is a marine species occurring in subantarctic and subtropical waters, reaching the tropics in the cool Humboldt Current off South America. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Thalassarche impavida (Listed Aus: V as *Thalassarche melanophris impavida* and SA: V as *Diomedea melanophris impavida*)	Campbell Albatross	M	V, Mi, Ma	V	The Campbell Albatross is a non-breeding visitor to Australian waters. Non-breeding birds most commonly seen foraging over the continental slopes off Tasmania, Victoria and New South Wales. Following breeding, birds move north and may enter Australia's temperate shelf waters. The Campbell Albatross is a marine sea bird inhabiting sub-Antarctic and subtropical waters from pelagic to shelf-break water habitats. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Acanthiza iredalei iredalei	Slender-billed Thornbill	T	V		Occurs in arid and semi-arid regions of southern WA, and south-western SA. The species generally inhabits treeless chenopod shrublands that are dominated by samphires or *Maireana* spp. (Bluebush) and *Atriplex* spp. (Saltbush) associations. It occasionally occurs in acacia shrublands and mangroves adjacent to more preferred habitat. Three records of this species since 1996 are captured in the BDBSA for the Port Pirie area; however, none of these records was positively identified to sub-species level. The closest of these records was approximately 2 km directly south of the site (Parsons Brinckerhoff 2013).	Possible
Apus pacificus	Fork-tailed Swift	T	Mi, Ma		In Australia, they mostly occur over inland plains but sometimes above foothills or in coastal areas. They often occur over cliffs and beaches and also over islands and sometimes well out to sea. They also occur over settled areas, including towns, urban areas and cities. They mostly occur over dry or open habitats, including riparian woodland and tea-tree swamps, low scrub, heathland or saltmarsh. They are also found at treeless grassland and sandplains covered with spinifex, open farmland and inland and coastal sand-dunes. The sometimes occur above rainforests, wet sclerophyll forest or open forest or plantations of pines. They forage aerially, up to hundreds of metres above ground, but also less then 1 m above open areas or over water. There were six records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Possible
Botaurus poiciloptilus	Australasian Bittern	T	E	V	Occurs from south-east Queensland to south-east South Australia, Tasmania and in the southwest of Western Australia. In South Australia, it is confined to the southeast, ranging north to the Murray River corridor and west to far southern Eyre Peninsula, and Kangaroo Island. It is most numerous in the swamps in the southeast of the state, notably Bool Lagoon. The Australasian Bittern occurs mainly in densely vegetated freshwater wetlands and, rarely, in estuaries or tidal wetlands. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Leipoa ocellata	Malleefowl	T	V, Mi	V	The Malleefowl inhabits semi-arid regions of southern Australia. In South Australia, the Malleefowl is distributed from the south-east, north to the Murray-Mallee region and west to Streaky Bay. The Malleefowl occurs in semi-arid and arid zones of temperate Australia, where it occupies shrublands and low woodlands that are dominated by mallee vegetation. It also occurs in other habitat types including eucalypt or native pine *Callitris* woodlands, acacia shrublands, Broombush *Melaleuca uncinata* vegetation or coastal heathlands. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Merops ornatus	Rainbow Bee-eater	T	Mi, Ma		There are 65 records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Probable
Myiagra cyanoleuca	Satin Flycatcher	T	Mi, Ma	E	Satin Flycatchers mainly inhabit eucalypt forests, often near wetlands or watercourses. They also occur in eucalypt woodlands with open understorey and grass ground cover. In South Australia, they are occasionally recorded, mostly in the lower south-east, occasionally as far north as Naracoorte, with a few other scattered records, e.g. Sandy Creek and near Kimba.	Unlikely
Neophema chrysogaster	Orange-bellied Parrot	T	CE, Mi, Ma	E	The Orange-bellied Parrot is endemic to south-eastern Australia. Its current non-breeding mainland distribution is from the mouth of the Murray River in South Australia, along the coast, to the east of Jack Smith Lake in South Gippsland, Victoria. In South Australia the most recent sightings have occurred around Canunda National Park and in the southern part of the Coorong National Park, located between the Victorian border and Port MacDonnell. Throughout the year Orange-bellied Parrots are found in salt marshes, coastal dunes, pastures, shrub lands, estuaries, islands, beaches and moorlands within 10 km of the coast. Vagrants have been recorded farther west, such as a single bird at Chinamans Creek, 23 km south of Port Augusta, in August/September 1992. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Pedionomus torquatus	Plains Wanderer	T	V	E	In South Australia, there have been recent records on the Willochra Plain north-east of Quorn, and in some adjacent areas of the southern Flinders Ranges, and north of the Barrier Highway (and west of Broken Hill) on Kalabity, Boolcoomatta and Mulyungarie Stations. The Plains-wanderer also irregularly occurs in the arid regions of northern South Australia during seasons of good rainfall. The Plains-wanderer inhabits sparse, treeless, lowland native grasslands. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Ardea alba	Great Egret	W	Mi, Ma		Resident species uncommonly recorded in Upper Spencer Gulf (BHP Billiton 2009b). There are six records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Possible

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Ardea ibis	Cattle Egret	W	Mi, Ma		Occurs as a vagrant to the Port Augusta area (BHP Billiton 2009b). There are nine[1] records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Probable
Arenaria interpres	Ruddy Turnstone	W	Mi, Ma	R	There are 19 records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Probable
Calidris acuminata	Sharp-tailed Sandpiper	W	Mi, Ma		There are 15 records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Probable
Calidris alba	Sanderling	W	Mi, Ma	R	Migratory shorebird that occurs in SA mostly from Sept–April. No records are known from Upper Spencer Gulf. The nearest reports are from sandy beaches south of Cowell and Wallaroo (BHP Billiton 2009b)	Unlikely
Calidris canutus	Red Knot	W	Mi, Ma		Migrant summer visitor uncommonly recorded in Upper Spencer Gulf, although several thousand have been observed at Ward Spit (BHP Billiton 2009b).	Probable
Calidris ferruginea	Curlew Sandpiper	W	Mi, Ma		Migrant summer visitor commonly recorded in Upper Spencer Gulf (BHP Billiton 2009b).	Probable
Calidris ruficolis	Red-necked Stint	W	Mi, Ma		Migrant summer visitor commonly recorded in Upper Spencer Gulf (BHP Billiton 2009b), with 57 records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Probable
Calidris tenuirostris	Great Knot	W	Mi, Ma	R	Migrant summer visitor uncommonly recorded in Upper Spencer Gulf (BHP Billiton 2009).	Unlikely
Charadrius mongolus	Lesser Sand Plover	W	Mi, Ma	R	There are three records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Possible
Charadrius ruficapillus	Red-capped Plover	W	Ma		Migrant summer visitor commonly recorded in Upper Spencer Gulf (BHP Billiton 200b9).	Probable
Gallinago hardwickii	Latham's Snipe	W	Mi, Ma	R	Migratory shorebird that occurs in SA mostly from Sept–April. It occurs in freshwater habitats and could possibly occur occasionally at sewage works/artificial freshwater lakes at Port Augusta and Whyalla (BHP Billiton 2009b).	Probable
Heteroscelus brevipes	Grey-tailed Tattler	W	Mi, Ma	R	Migrant summer visitor rarely recorded in Upper Spencer Gulf, with a few records near Point Jarrold (BHP Billiton 2009b).	Possible
Limosa lapponica	Bar-tailed Godwit	W	Mi, Ma	R	Migrant summer visitor uncommonly recorded in Upper Spencer Gulf, with a few records near Ward Spit and Point Jarrold (BHP Billiton 2009b).	Possible
Numenius madagascariensis	Eastern Curlew	W	Mi, Ma	V	Migrant summer visitor rarely recorded in Upper Spencer Gulf, with a few records near Ward Spit and Point Jarrold (BHP Billiton 2009b).	Possible

[1] Elsewhere Parsons Brinckerhoff (2013) state that there are no records of this species within 50 kilometres of the study area.

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Rostratula benghalensis (sensu lato) (Listed Aus:E as *Rostratula australis*)	Australian Painted Snipe	W	E, Mi, Ma	V	The Australian Painted Snipe has been recorded at wetlands in all states of Australia. The species generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. They also use inundated or waterlogged grassland or saltmarsh, dams, rice crops, sewage farms and bore drains. Typical sites include those with rank emergent tussocks of grass, sedges, rushes or reeds, or samphire; often with scattered clumps of *Muehlenbeckia* (lignum) or canegrass or sometimes *Melaleuca* (DSEWPaC 2013). There is one record of this species from 2001, from approximately 25 kilometres east of the site (Parsons Brinckerhoff 2013).	Possible
Tringa stagnatilis	Marsh Sandpiper	W	Mi, Ma		Migrant summer visitor rarely recorded in Upper Spencer Gulf, with a few records near Port Davis (BHP Billiton 2009b).	Unlikely
Mammals						
Arctocephalus forsteri	New Zealand Fur-seal	M	Ma	P	Isolated records of stray individuals (e.g. museum records from Pt Augusta power station outlet, and a couple from Whyalla area). Not a significant habitat for this species, compared with other parts of SA (BHP Billiton 2009a).	Unlikely
Arctocephalus pusillus	Australian Fur-seal	M	Ma	R, P	Unlikely in Upper Spencer Gulf. This is a cool water species that has rarely been recorded in the gulfs. There are no museum records from Upper Spencer Gulf (BHP Billiton 2009a).	Unlikely
Balaenoptera edeni	Bryde's Whale	M	Mi, W	R, P	Normally found in offshore waters, and Upper Spencer Gulf is not a significant habitat for this species. Isolated records (e.g. two SA Museum records from Curlew Point and Port Augusta area) of stray individuals that travelled into Upper Spencer Gulf (BHP Billiton 2009a).	Possible.
Caperea marginata	Pygmy Right Whale	M	Mi, W	R, P	Most strandings in SA are from the South-East; Kangaroo Island and southern Eyre Peninsula, with no records from Upper Spencer Gulf (BHP Billiton 2009a).	Unlikely
Delphinus delphis	Common Dolphin	M	W	P	Throughout SA waters. Populations within Whyalla and Fitzgerald Bay. Groups occupy home ranges, feeding on small fish and cephalopods (BHP Billiton 2009a).	Probable

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Eubalaena australis	Southern Right Whale	M	E, Mi, W	V, P	Southern Right Whales are seasonally present on the Australian coast between about May and November. Principally found around the southern coastline off southern Western Australia and far west South Australia, Southern Right Whales occur anywhere between Sydney and Perth, including off Tasmania (DSEWPaC 2013). Sightings of individuals and small groups in Upper Spencer Gulf include Port Augusta, Yarraville Shoal, Western Shoal (BHP Billiton 2009a). There are nine records of this species occurring within 50 kilometres of the site between 1983 and 2004. The closest of these records is 8 kilometres north of the site. However the geographic information for cetaceans are often recorded as the point at which the observer made the recording (i.e. from land), thus the actual location of the individual is likely to be within sight of the record location rather than directly at the location (Parsons Brinckerhoff 2013).	Possible
Lagenorhynchus obscurus	Dusky Dolphin	M	Mi, W	P	Very unlikely in Upper Spencer Gulf. In Australian waters the very limited data suggest that presence of Dusky Dolphin may be linked to Southern Oscillation events. Most of the sightings to date come from around Tasmania. However, there are confirmed sightings from Backstairs Passage area near Kangaroo Island (BHP Billiton 2009a).	Unlikely
Megaptera novaeangliae	Humpback Whale	M	V, Mi, W	V, P	During winter months, Humpback Whales migrate from their polar summer feeding grounds to their sub-tropical winter breeding grounds (DSEWPaC 2013). There have been sightings at Whyalla and Port Augusta. However this species is an infrequent visitor to SA coastal waters and records from Upper Spencer Gulf are incidental (BHP Billiton 2009a) There are two records of this species occurring within 50 kilometres of the size, between 1992 and 2005, the closest record being approximately 25 kilometres northwest of the site. However the geographic information for cetaceans are often recorded as the point at which the observer made the recording (i.e. from land), thus the actual location of the individual is likely to be within sight of the record location rather than directly at the location (Parsons Brinckerhoff 2013).	Unlikely
Neophoca cinerea	Australian Sea-lion	M	V, Ma	V, P	The Australian Sea-lion is the only pinniped endemic to Australia. The breeding range extends from Houtman Abrolhos, Western Australia (WA), to The Pages Island, east of Kangaroo Island, South Australia, including more than 50 offshore islands. Australian Sea-lions use a wide variety of habitats; Onshore habitats used include exposed islands and reefs, rocky terrain, sandy beaches and vegetated fore dunes and swales(DSEWPaC 2013). Australian Sea-lions seasonally visit Upper Spencer Gulf to feed on cephalopods and fish, and are regularly observed, particularly during winter and spring (BHP Billiton 2009a).	Possible

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Tursiops aduncus	Indian Ocean Bottlenose Dolphin	M	W	P	Distributed throughout SA waters, with populations near Whyalla and in Fitzgerald Bay. There are numerous museum records from Upper Spencer Gulf, including some from areas adjacent to Whyalla and Port Augusta (BHP Billiton 2009a).	Probable
Tursiops truncatus (sensu stricto)	Bottlenose Dolphin	M	W	P	Likely to occur in region occasionally, but most records are from further south, and out of the gulfs (it is more of an oceanic species than *T. aduncus*).	Possible
Plants						
Tecticornia flabelliformis (Listed SA: V as *Halosarcia flabelliformis*)	Bead Samphire	C	V	V	The Bead Glasswort is widespread but scattered in saltmarsh vegetation across southern mainland Australia. Bead Glasswort plants generally occur on the margins of salt lakes, saline flats, evaporation pans and coastal salt marshes over gypsum deposits. It is also reported from directly behind coastal dunes (DSEWPaC 2013). There are four records of this species from locations south of the site along the coast with the closest record being approximately 21 kilometres south of the site (Parsons Brinckerhoff 2013).	Unlikely
Zostera muelleri subspecies *mucronata*	Garweed	M		R	Dense on eastern shore of Spencer Gulf, in depths less than 10 m (BHP Billiton 2009a).	Probable
Acanthocladium dockeri	Spiny Everlasting	T	CE	E	The Spiny Everlasting is endemic to Australia and is currently only known from South Australia. In 1999, a population of Spiny Everlasting was discovered near Laura, in the mid-north of South Australia; a further four populations have since been located in the region. Extant subpopulations of Spiny Everlasting are confined to remnant grassland on low hills (altitude 270–350 m) and plains (altitude 180 m) in the mid-north of South Australia (DSEWPaC 2013). There are 67 records of this species from between 1999 and 2008. with the closest from approximately 15 kilometres northeast of the site whilst the majority of records are from 30 kilometres or more east of the site (Parsons Brinckerhoff 2013).	Unlikely
Caladenia gladiolata	Bayonet Spider-orchid	T	E	E	Herbarium records indicated that this species is endemic to South Australia, where it is now confined to the Mount Lofty and Southern Flinders Ranges in a distribution that extends as far north as Arden Vale via Quorn. The Bayonet Spider-orchid is known to grow in South Australian *Eucalyptus leucoxylon* (Blue Gum), *E. cladocalyx* (Sugar Gum) Woodland in the Mount Remarkable NP, and South Australian E. fasciculosa (Pink Gum) Woodland in Scott Creek CP (DSEWPaC 2013). There are two records of this species from 1986 and 2002 approximately 20 kilometres northeast of the site within the Flinders Ranges (Parsons Brinckerhoff 2013).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Caladenia macroclavia	Large-club Spider-orchid	T	E	E	This species is mostly confined to the Yorke Peninsula where it is poorly conserved and has a range of approximately 240 km². It is also rare on central Eyre Peninsula and has a single record from Telowie Gorge Conservation Park in the southern Flinders Ranges. The Large-club Spider-orchid grows in fertile shallow loams in mallee-boombrush woodland in sandy loam over limestone. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Caladenia tensa (Listed SA: E as *Caladenia dilatata*)	Greencomb Spider-orchid	T	E	E	In the early 1990s, the species was considered to be confined to western Victoria: in the Murray Mallee, Lowan Mallee and Wimmera Natural Regions. The species is also known from eastern and south-east South Australia where it is considered widespread but uncommon. Site examples include Telowie Gorge, Murray Bridge and Mt Boothby Conservation Parks (CP). It is also considered to be widespread in SA from the west coast, throughout Eyre Peninsula and adjacent pastoral zone, the Flinders Ranges, rare in the Mt Lofty Ranges and more common in the Murray and upper south-east. There are two records of this species occurring within 50 kilometres of the site from 1988 and 2004, the closest being approximately 17 kilometres southeast of the site (Parsons Brinckerhoff 2013).	Unlikely
Caladenia woolcockiorum	Woolcock's Spider-orchid	T	V	E	This species is endemic to South Australia and is known from 9 sub-populations within Mount Remarkable NP. Some evidence suggests that this species may respond to soil disturbance with many populations occurring in disturbed sites along roadsides and tracks (Quarmby 2010). There is one record of this species from 1999 from approximately 50 kilometres northeast of the site (Parsons Brinckerhoff 2013).	Unlikely
Caladenia xantholeuca	White Rabbits	T	E	E	This species is endemic to South Australia. It is known to have occurred in two sub-populations in Mt Remarkable NP and one in Telowie Gorge CP. It occurs in *Calitris glaucophylla* woodland and grows on south facing slopes of steep gorges (Quarmby 201). There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Prasophyllum pallidum	Pale Leek-orchid	T	V	R	This species is known singly or in groups in well-grassed open forests from the Flinders Ranges to Northern and Southern Lofty Regions of SA. The species occurs within the Adelaide and Mount Lofty Ranges and Northern and Yorke NRM regions. One record of this species from 1988 is included in the BDBSA. There is one record of this species from approximately 50 kilometres northeast of the site (Parsons Brinckerhoff 2013).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Pterostylis sp. *Halbury*	Halbury Greenhood	T	E	E	The Halbury Greenhood is thought to only occur in two small locations in South Australia: in the Halbury Parklands (surrounding the town of Halbury 90 km north of Adelaide) in an area of about 1 km²; and at a site near Moonta. Vegetation associated with the Halbury Greenhood include mallee form Peppermint Box (*Eucalyptus odorata*), Southern Cypress Pine (*Callitris preissii*) and Sea Box (*Alyxia buxifolia*). There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Swainsona pyrophila	Yellow Swainson-pea	T	V	R	This species occurs from the northern Eyre Peninsula east to north-western Victoria and south-western central NSW. It occurs in mallee vegetation communities on a variety of soil types including well-drained sands, sandy loam and heavier clay loams. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Reptiles						
Caretta caretta	Loggerhead Turtle	M	E, Mi, Ma	E	In Australia, the Loggerhead Turtle occurs in the waters of coral and rocky reefs, seagrass beds and muddy bays throughout eastern, northern and western Australia. Loggerhead Turtles nest on open, sandy beaches. Hatchlings enter the open ocean and begin feeding on small animals. Small Loggerhead Turtles live at or near the surface of the ocean and move with the ocean current (SEWPaC 2013)s. There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely
Chelonia mydas	Green Turtle	M	V, Mi, Ma	V	Green Turtles nest, forage and migrate across tropical northern Australia. Green Turtles spend their first five to ten years drifting on ocean currents. Once Green Turtles reach 30 to 40 cm curved carapace length, they settle in shallow benthic foraging habitats such as tropical tidal and sub-tidal coral and rocky reef habitat or inshore seagrass beds (SEWPaC 2013). There have been a few records in Upper Spencer Gulf (e.g. SA Museum records from 5 km off Lucky Bay, and also Port Pirie), but recorded uncommonly, as stray individuals. Upper Spencer Gulf is an incidental part of the range, and not significant (BHP Billiton 2009a).	Unlikely
Dermochelys coriacea	Leatherback Turtle	M	E, Mi, Ma	V	The Leatherback Turtle is a pelagic feeder, found in tropical, subtropical and temperate waters throughout the world. No major nesting has been recorded in Australia. The Leatherback Turtles is a highly pelagic species, venturing close to shore mainly during the nesting season SEWPaC 2013). There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	Common Name		Aus	SA		
Aprasia pseudopulchella	Flinders Worm-lizard	T	V		The Flinders Ranges Worm-lizard is known from the Flinders Ranges of South Australia, extending south to the western slopes and northern and central Mount Lofty Ranges. The Flinders Ranges Worm-lizard burrows freely in loose sand and soil, under rocks and litter. The species occurs in open woodland, native tussock grassland, riparian habitats and rocky isolates. It prefers stony soils, or clay soils with a stony surface, and has been found sheltering beneath stones and rotting stumps (SEWPaC 2013). There are ten records of this species from within 50 kilometres of between 1990 and 2004. All of the records occur from the Flinders Ranges region west of the site. The closest record is located approximately 15 kilometres east of the site (Parsons Brinckerhoff 2013).	Unlikely
Notechis ater ater	Krefft's Tiger Snake	T	V		Confined to several stream systems in the southern Flinders Ranges, SA and known to occur in Mount Remarkable NP. The current distribution appears to be restricted to the wetter parts of the Flinders Ranges. Restricted to the rocky, often steep margins of watercourses that may dry to become isolated pools during the summer, beginning in Sept. Riparian vegetation consists of woodland dominated by River Red Gum *Eucalyptus camaldulensis* and Sugar Gum *Eucalyptus cladocalyx* (SEWPaC 2013). There are five records of this species occurring within the region between 1984 to 2005. The closest record of this species occurring is from approximately 17 kilometres south of the project. Three of the records are from north of the site whilst two are from south of the site (Parsons Brinckerhoff 2013).	Unlikely
Fish and Sharks						
Carcharodon carcharias	Great White Shark	M	V, Mi	P	In Australia, Great White Sharks have been recorded from central Queensland around the south coast to north-west Western Australia. Great White Sharks can be found from close inshore around rocky reefs, surf beaches and shallow coastal bays to outer continental shelf and slope areas (SEWPaC 2013). There are no records of this species occurring within 50 kilometres of the site (Parsons Brinckerhoff 2013).	Possible
Lamna nasus	Porbeagle shark, mackerel shark	M	Mi		The species prefers the cool waters of the North Atlantic (less than approx. 18°C), but they are also found in the Mediterranean. In the southern hemisphere they have been observed in the southern part of the Indian Ocean around South Australia, off the coast of Chile and in additional regions of the subantarctic (Ritter 2009).	Unlikely
Fish						
Acentronura australe	Southern Pygmy Pipehorse	M	Ma	P	Unlikely in Upper Spencer Gulf. The few records to date in SA have mainly come from red algae in southern Gulf St Vincent and Investigator Strait. Also found in seagrass beds, in Western Australia (see Baker 2008 for summary of distribution and habitat, based on specimens recorded to date) (BHP Billiton 2009a).	Unlikely

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Filicampus tigris	Tiger Pipefish	M	Ma	P	Inhabits deep-water channels, and has been recorded during trawl surveys in Upper Spencer Gulf (BHP Billiton 2011).	Unlikely
Heraldia nocturna	Upside-down Pipefish	M	Ma	P	Unlikely in Upper Spencer Gulf – all SA records to date are from southern part of gulfs and Kangaroo Island (BHP Billiton 2009a).	Unlikely
Hippocampus breviceps	Short-head Seahorse	M	Ma	P	There are records from False Bay, Cowleds Landing, Port Davis and Moonta Bay (BHP Billiton 2009a).	Possible
Histiogamphelus cristatus	Rhino Pipefish/Macleay's Crested Pipefish/Ringback Pipefish	M	Ma	P	There are records from False Bay, Franklin Harbour, Shoalwater Point area, Plank Point area, Port Neill, Balgowan, and Cape Elizabeth (BHP Billiton 2009a).	Possible
Hypselognathus rostratus	Knifesnout Pipefish	M	Ma	P	There are records from False Bay and Port Broughton (BHP Billiton 2009a).	Possible
Kaupus costatus	Deep-bodied Pipefish	M	Ma	P	There are records from near Port Pirie (BHP Billiton 2009a).	Probable
Leptoichthys fistularius	Brushtail Pipefish	M	Ma	P	There are records from False Bay and Cowleds Landing (BHP Billiton 2009a).	Possible
Lissocampus caudalis	Smooth Pipefish	M	Ma	P	There are records from False Bay and Cowleds Landing (BHP Billiton 2009a).	Probable
Lissocampus runa	Javelin Pipefish	M	Ma	P	Possible, and there are verified records (SA Museum) at least as far north as Wallaroo (see Baker 2008).	Possible
Maroubra perserrata	Sawtooth Pipefish	M	Ma	P	Unlikely in Upper Spencer Gulf – all SA records to date are from southernmost part of gulfs and Kangaroo Island. It utilises rocks, ledges, fissures/crevices and caves, resting on sponges, or sheltering behind sea urchins (BHP Billiton 2009a).	Unlikely
Notiocampus ruber	Red Pipefish	M	Ma	P	There are no records from Upper Spencer Gulf to date, but might be found there, given general habitat requirements. The few records from SA have been from lower Gulf St Vincent, Kangaroo Island and south-east SA. It is associated with filamentous red macroalgae, sponges, and possibly seagrasses (BHP Billiton 2009a).	Possible
Phycodurus eques	Leafy Seadragon	M	Ma	P	Not a significant area for this species, but there are isolated records from Upper Spencer Gulf, from trawl bycatch, other bycatch surveys, and community observations (BHP Billiton 2009a).	Possible
Phyllopteryx taeniolatus	Weedy Seadragon	M	Ma	P	No records from further north than Moonta Bay (BHP Billiton 2009a).	Unlikely
Pugnaso curtirostris	Pug-nosed Pipefish	M	Ma	P	There are several dozen records from False Bay and Cowleds Landing (BHP Billiton 2009a).	Possible

Species		Hab.	Status		Distribution and/or habitat preference	Likelihood of presence in study area
Scientific Name	**Common Name**		**Aus**	**SA**		
Solegnathus robustus	Robust Pipehorse	M	Ma	P	Unlikely in Upper Spencer Gulf, given the depth and exposed habitat where it has been recorded to date, i.e. from trawl records in a limited area of eastern Great Australian Bight, but one record from bottom of Spencer Gulf (BHP Billiton 2009a).	Unlikely
Stigmatopora argus	Spotted Pipefish	M	Ma	P	There are more than eight hundred records from False Bay, Cowleds Landing, Port Pirie, Point Jarrold and Port Davis (BHP Billiton 2009a).	Probable
Stigmatopora nigra	Widebody Pipefish	M	Ma	P	There are records from Cowleds Landing and Port Pirie (BHP Billiton 2009a).	Probable
Stipecampus cristatus	Ringback Pipefish	M	Ma	P	There are few museum records with the nearest from south-central Spencer Gulf (BHP Billiton 2009a).	Unlikely
Urocampus carinirostris	Hairy Pipefish	M	Ma	P	Possible in Upper Spencer Gulf, given habitat, but there are only two known records in SA to date, both from the eastern Great Australian Bight (1965 and 2004, SA Museum data). This is a very small and inconspicuous species, and possibly more widespread in SA than records suggest ((BHP Billiton 2009a)	Possible
Vanacampus margaritifer	Mother-of-pearl Pipefish	M	Ma	P	There are few museum records, with the nearest being from southern Spencer Gulf (BHP Billiton 2009a).	Unlikely
Vanacampus phillipi	Port Phillip Pipefish	M	Ma	P	Example records include a few from False Bay, Cowleds Landing, Port Pirie and Port Davis area (BHP Billiton 2009a).	Probable
Vanacampus poecilolaemus	Long-snouted Pipefish	M	Ma	P	Example records include more than a hundred from False Bay and Cowleds Landing and SA Museum records from Port Pirie (BHP Billiton 2009a).	Probable
Vanacampus vercoi	Verco's Pipefish	M	Ma	P	Example records include a few from Cowleds Landing (BHP Billiton 2009a).	Possible

References

BHP Billiton 2009a. *Olympic Dam Expansion Draft Environmental Impact Statement*. Appendix O3 - Priority Marine Species. See also primary references within.

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DSEWPaC (Department of Sustainability, Environment, Water and Communities) 2013. *Species Profile and Threats Database*. http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl. See also primary references within.

Parsons Brinckerhoff 2013. *Port Pirie Smelter Transformation Development Application.* Report prepared for Nyrstar Pty Ltd. Appendix B - EPBC and BDBSA (Biological Database of SA) search results.

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Appendix G:
Risk assessment matrix

NYRSTAR PORT PIRIE TRANSFORMATION PROJECT
ENVIRONMENT RISK PROFILE

		Risk Profile: - Nyrstar Project PER Profile	RISK IDENTIFICATION				INHERENT LEVEL OF RISK (without controls)				RESIDUAL RISK LEVEL			RISK TREATMENT PLAN		
Ref	**Risk Number**	**Phase/Activity** *(During the course of this activity…)*	**Event description** *(…this could happen…)*	**Cause** *(… as a result of…)*	**Aspect** *(..which could impact these..)*	**Potential Impacts** *(…in this way…)*	**Consequence**	**Likelihood**	**Risk Level**	**Controls**	**Consequence**	**Likelihood**	**Risk Level**	**ALARP?**	**Expected Outcomes**	**Tracking mechanism**
1		**Stage 1 Oxidation Plant - Enclosed Bath Smelting Furnace (Sinter Replacement)**														
2	RSK-90001	Construction	Production of spoil	Preparation of land Not following procedures	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Dust and lead levels exceeding guidelines. Construction waste disposed incorrectly. Disturbing surface water and groundwater leading to contamination of surface water and groundwater	2 3 2 2 2	E E D C D	High	Earth moving plan (including dust suppression) Demolition plan Waste management and recycling plan	3	B	Medium	Yes	No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited
3	RSK-90002	Construction - Subsurface Geotechnical Testing for foundation design* (*The inherent level of risk is based on considering current process design)	Generation of contaminated material and Contaminant migration through interconnection of aquifers	Lack of appropriate material handling protocol Poor design Not following design	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Construction waste disposed incorrectly. Contamination to surface water and groundwater	3 3 1	E C C	High	Earth moving plan Waste management and recycling plan	3	B	Medium	Yes	Plans to be approved and implemented prior to construction phase. No contamination of surface water or groundwater. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited
4	RSK-90003	Construction - Installation of piles	Generation of contaminated material and Contaminant migration through interconnection of aquifers	Lack of appropriate material handling protocol Inappropriate pile design and installation plans	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Contamination to surface water and groundwater Noise exceeding EPA limits.	3 3 2 1	E C C C	High	Earth moving plan Waste management and recycling plan Curfew on construction of installation of piles (7am to 7pm) Development of pile design and installation plans with hydrogeological input	3	B	Medium	Yes	No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
5	RSK-90004	Construction - Pavements removed (*Intended to cut pavement for pile construction)	Excessive surface water recharge to open areas driving groundwater contamination migration/noise/waste	Pavements removed or not effectively maintained/drained for excessive periods	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Contamination to surface water and groundwater	3 3 2 1	B B B B	Medium	Construction plans to cater for surface water management and minimise open pavement area and time	3	B	Medium	Yes	No signficant impact on groundwater contamination migration or surface water contamination. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program
6	RSK-90005	Commissioning	Fugitive emissions exceed current baseline levels	Commissioning uncertainties Gas leakage from duct work/other systems.	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • **Odour** • **Sub-surface soil quality** • **Surface water quality** • Vibration • **Visual amenity**	SO2, Pb and particulates potentially affecting community health, emissions and with deposition affecting local environment.	3 3 1 1 1 1	C C C C C C	Medium	Commissioning plan	2	C	Low	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plan to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan implemented and audited
7	RSK-90006	Decommissioning	Dust levels exceeding current base line levels	Ineffective top-down wash	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Wind blown dust from existing sources	1 1	C C	Low	Procedures for top-down wash and post-wash inspections	1	B	Low	Yes	Reduced lead emissions from current levels. Procedure to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Procedure implemented and audited
8	RSK-90007	Operation - smelting	Fugitive emissions exceed proposed post-transformation levels	Plant upset condition Loss of negative pressure	• **Air quality** • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • **Visual amenity**	SO2, Pb and dust emissions lead to exceedances of guidelines at EPA monitoring sites. Visible plume emitted from the building.	2 1	D D	Medium	Process and Hygiene draughting system design Operations and maintenance plan	2	C	Low	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plan to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
9	RSK-90008	Operation - Pile Foundation maintenance (*inherent risk considers current design standards *Consequence may be different for costs to Nyrstar)	Acid attack on piles creating interconnection of aquifers	Facilitating effects of interconnected aquifers Inappropriate design for protection Inadequate contingency measures	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine flora/fauna)** • Noise • Odour • **Sub-surface soil quality** • Surface water quality • Vibration • Visual amenity	Degradation of piles leading to contamination of groundwater and soil Contamination flow between aquifers Flow of contaminated material to marine environment	3 3 1	B B B	Medium	Targeted testing and evaluation of pile design Inherent design of piles Operation and maintenance plan Operational Environmental Management and Monitoring Plan	2	B	Low	Yes	Geological testing and pile installation does not contaminate groundwater. Existing groundwater monitoring program upgraded to track pH in various aquifers. Plans to be approved and implemented prior to appropriate phase. Compliance with EPA requirements, guidelines and measures.	Refined groundwater monitoring program added to existing environmental monitoring program. Plans implemented and audited
10	RSK-90009	Operation - Bunding/drainage/paving	Spillage/leak to groundwater Spillage to surface water system	Inadequate pavement/bunding drainage design	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine environment)** • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Contamination to surface water and groundwater Results in 1M non compliance	2 2 2	C C C	Low	Design of pre-collection pits	2	B	Low	Yes	No contamination of surface water or groundwater. Inherently safe design implemented at design phase	Existing Environmental Monitoring Program. Pre-collection pits installed prior to starting operations
11	RSK-90010	Operation - maintenance	Fugitive emissions exceed proposed post-transformation levels	Process gas leakage from duct work/other systems during maintenance	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • **Odour** • **Sub-surface soil quality** • **Surface water quality** • Vibration • **Visual amenity**	SO2, Pb and particulates lead to exceedances of guidelines at EPA monitoring sites, potentially affecting community health, emissions and with deposition affecting local environment.	3 3 1 1 1 1	B B B B B B	Medium	Operational Environmental Management and Monitoring Plan Operation and maintenance plan	3	B	Medium	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plans to be approved and implemented prior to appropriate phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
12		**Stage 1 Oxygen Plant Facility**														
13	RSK-90011	Decommissioning	Waste generation	Drainage of molecular material (Alumina zeolite)	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Generation of waste	1	D	Low	Material handling procedures	1	C	Low	Yes	All waste generated by decommissioning will be handled in a safe and environmentally acceptable manner. Procedure to be approved and implemented prior to appropriate phase	Procedure implemented and audited
14	RSK-90012	Construction	Preparation of land	Not following procedures Production of spoil	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Dust and lead levels exceeding guidelines. Spoil disposed incorrectly. Disturbing surface water and groundwater leading to contamination of surface water and groundwater	2 3 2 2 2	E E D C D	High	Earth moving plan (including dust suppression) Demolition plan Waste management and recycling plan	3	B	Medium	Yes	No dust or metal levels exceeding air quality guidelines. No waste to be disposed incorrectly. No significant contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited
15	RSK-90013	Construction	Generation of contaminated material	Molecular Sieve Waste handled or disposed incorrectly.	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Construction waste disposed incorrectly. Contamination to surface water and groundwater	2 2 1	E C C	Medium	Earth moving plan Waste management and recycling plan	2	B	Low	Yes	No significant contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
16	RSK-90014	Operation	Generation of noise	Gas compressor operation	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • **Noise** • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Community complaint of noise. Exceeding EPA criteria	2 2	C C	Low	Communication/consultation with EPA Design standards in compliance with Environmental Protection Policy (Noise)	1	C	Low	Yes	Design standards ensure plant noise levels do not exceed EPA thresholds.	Sound monitoring during commissioning Phase meets design standards. Existing Environmental Monitoring Program
17		**Stage 2 Reduction Plants Enclosed Bath Smelting Furnace (Blast Furnace Replacement)**														
18	RSK-90015	Construction	Production of spoil	Preparation of land Not following procedures	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Dust levels exceed current levels. Waste generated by construction activities harming the environment. Disturbing surface water and groundwater leading to contamination of surface water and groundwater Noise levels exceeding EPA levels	2 3 2 2 2	E E D C D	High	Earth moving plan (including dust suppression) Demolition plan Waste management and recycling plan	3	B	Medium	Yes	Dust levels are within accepted guideline levels. No significant contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited
19	RSK-90016	Construction - Subsurface Geotechnical Testing for foundation design* (*The inherent level of risk is based on considering current process design)	Generation of contaminated material and Contaminant migration through interconnection of aquifers.	Lack of appropriate material handling protocol Poor design Not following design	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Spoil disposed incorrectly. Contamination to surface water and groundwater	3 3 1	E C C	High	Earth moving plan Waste management and recycling plan Design and implemenation includes appropriate controls to protect groundwater	3	B	Medium	Yes	All spoil is handled and disposed correctly. No significant contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

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20	RSK-90017	Construction - Installation of piles	Generation of contaminated material and Contaminant migration through interconnection of aquifers	Lack of appropriate material handling protocol Inappropriate pile design and installation plans	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Contamination to surface water and groundwater Community complaint of noise. Exceeding EPA criteria	3 3 2 1	E C C C	High	Earth moving plan Waste management and recycling plan Curfew on construction of installation of piles (7am to 7pm) Development of pile disign and installation plans with hydrogeological input	3	B	Medium	Yes	All spoil is handled and disposed correctly. No significant contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures. Noise levels do not exceed EPA thresholds.	Existing Environmental Monitoring Program. Plans implemented and audited
21	RSK-90018	Construction - Pavements removed (*Intended to cut pavement for pile construction)	Excessive surface water recharge to open areas driving groundwater contamination migration/noise/waste	Pavements removed or not effectively maintained/drained for excessive periods	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Spoil disposed incorrectly. Contamination to surface water and groundwater	3 3 2 1	B B B B	Medium	Construction plans to cater for surface water management and minimise open pavement area and time	3	B	Medium	Yes	No signficant impact on groundwater contamination migration or surface water contamination. Compliance with EPA requirements, guidelines and measures. Noise levels do not exceed EPA thresholds.	Existing Environmental Monitoring Program Plans implemented and audited
22	RSK-90019	Commissioning	Fugitive emissions exceed current baseline levels	Commissioning uncertainties Gas leakage from duct work/other systems.	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • **Odour** • **Sub-surface soil quality** • **Surface water quality** • Vibration • **Visual amenity**	SO2, Pb and particulates potentially affecting community health, emissions and with deposition affecting local environment.	3 3 1 1 1 1	C C C C C C	Medium	Commissioning plan	2	C	Low	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plan to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan implemented and audited
23	RSK-90020	Decommissioning	Dust levels exceeding current base line levels	Ineffective top-down wash	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Wind blown dust from existing sources	1 1	C C	Low	Procedures for top-down wash and post-wash inspections	1	B	Low	Yes	Reduced and lead emissions from current levels. Procedure to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Procedure implemented and audited

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24	RSK-90021	Operation - smelting	Fugitive emissions exceed proposed post-transformation levels	Plant upset condition Loss of negative pressure	• **Air quality** • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • **Visual amenity**	SO2, Pb and dust emissions lead to exceedances of guidelines at EPA monitoring sites. Visible plume emitted from the building.	2 1	D D	Medium	Process and Hygiene draughting system design Operations and maintenance plant	2	C	Low	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plan to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan implemented and audited
25	RSK-90064	Operation - smelting	COGEN machinery contributes to noise of plant	Plant item operation changes existing noise environment	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • **Noise** • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Community complaint of noise. Exceeding EPA criteria	2 2	C C	Low	Communication/consultation with EPA Design standards in compliance with Environmental Protection Policy (Noise)	1	C	Low	Yes	Design standards ensure plant noise levels do not exceed EPA thresholds.	Sound monitoring during commissioning Phase meets design standards. Existing Environmental Monitoring Program
26	RSK-90022	Operation - Pile Foundation maintenance (*inherent risk considers current design standards *Consequence may be different for costs to Nyrstar)	Acid attack on piles creating interconnection of aquifers	Facilitating effects of interconnected aquifers. Inappropriate design for protection. Inadequate contingency measures.	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine flora/fauna)** • Noise • Odour • **Sub-surface soil quality** • Surface water quality • Vibration • Visual amenity	Degradation of piles leading to contamination of groundwater and soil. Contamination flow between aquifers. Flow of contaminated material to marine environment	3 3 1	B B B	Medium	Targeted testing and evaluation of pile design Inherent design of piles Operation and maintenance plan Operational Environmental Management and Monitoring Plan	2	B	Low	Yes	Geological testing and pile installation does not contaminate groundwater. Existing groundwater monitoring program upgraded to track pH in various aquifers. Plans to be approved and implemented prior to appropriate phase. Compliance with EPA requirements, guidelines and measures.	Refined groundwater monitoring program added to existing environmental monitoring program. Plans implemented and audited
27	RSK-90023	Operation - Bunding/drainage/paving	Spillage/leak to groundwater Spillage to surface water system	Inadequate pavement/bunding drainage design	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine environment)** • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Contamination to surface water and groundwater results in 1M non compliance. Harm to marine habitat	2 2 2	C C C	Low	Design of pre-collection pits	2	B	Low	Yes	No contamination of surface water or groundwater. Inherently safe design implemented at design phase. No adverse impacts on marine habitats	Existing Environmental Monitoring Program. Marine habitat monitoring triggered if discharge quality at 1M exceeds licence conditions.

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28	RSK-90062	Operation	Generation of noise	Plant item operation changes existing noise environment	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • **Noise** • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Community complaint of noise. Exceeding EPA criteria	2 2	C C	Low	Communication/consultation with EPA Design standards in compliance with Environmental Protection Policy (Noise)	1	C	Low	Yes	Design standards ensure plant noise levels do not exceed EPA thresholds.	Sound monitoring during commissioning Phase meets design standards. Existing Environmental Monitoring Program
29	RSK-90024	Operation - maintenance	Fugitive emissions exceed proposed post-transformation levels	Process gas leakage from duct work/other systems during maintenance	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • **Odour** • **Sub-surface soil quality** • **Surface water quality** • Vibration • **Visual amenity**	SO2, Pb and particulates lead to exceedances of guidelines at EPA monitoring sites, potentially affecting community health, emissions and with deposition affecting local environment.	3 3 1 1 1 1	B B B B B B	Medium	Operational Environmental Management and Monitoring Plan Operation and maintenance plan	3	B	Medium	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plans to be approved and implemented prior to appropriate phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program
30		**Sulphur Capture (Acid) Plant**														
31	RSK-90025	Construction	Production of spoil	Preparation of land Not following procedures	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • **Sub-surface soil quality** • **Surface water quality** • Vibration • Visual Amenity	Excessive dust and incorrectly disposed spoil adversely effecting people and the environment. Disturbing surface water and groundwater leading to contamination of surface and groundwater.	2 3 2 2 2	E E D C D	High	Earth moving plan (including dust suppression) Demolition plan Waste management and recycling plan	3	B	Medium	Yes	No excessive dust generated. All spoil is disposed of correctly. No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
32	RSK-90026	Construction - Subsurface Geotechnical Testing for foundation design* (*The inherent level of risk is based on considering current process design)	Generation of contaminated material and Contaminant migration through interconnection of aquifers	Lack of appropriate material handling protocol Poor design Not following design	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Incorrectly disposed spoil degrades environment. Contamination to surface water and groundwater	3 3 1	E C C	High	Earth moving plan Waste management and recycling plan	3	B	Medium	Yes	All spoil is handled and disposed correctly. No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited
33	RSK-90027	Construction - Installation of piles	Generation of contaminated material and Contaminant migration through interconnection of aquifers	Lack of appropriate material handling protocol Inappropriate pile design and installation plans	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Incorrectly disposed spoil degrades environment. Contamination to surface water and groundwater Community complaint of noise. Exceeding EPA criteria	3 3 2 1	E C C C	High	Earth moving plan Waste management and recycling plan Curfew on construction of installation of piles (7am to 7pm) Development of pile design and installation plans with hydrogeological input	3	B	Medium	Yes	All waste and spoil disposed in correct manner. No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures. Noise levels do not exceed EPA thresholds.	Existing Environmental Monitoring Program. Plans implemented and audited
34	RSK-90028	Commissioning	Acid plant stack discharge to atmosphere	Acid plant upset	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • **Natural resources (flora)** • Noise • **Odour** • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Controlled discharge of SO2, SO3, acid mist to atmosphere from reduction furnace resulting in impact to vegetation and community	2 2 1 2	F E E E	Medium	Commissioning plan	2	E	Medium	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plan to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan implemented and audited
35	RSK-90029	Commissioning	Tall stack discharge to atmosphere	Acid plant upset	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • **Natural resources (flora)** • Noise • **Odour** • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Controlled discharge of SO2, SO3, acid mist to atmosphere from tall stack resulting in impact to vegetation and community	2 2 1 2	E D D D	Medium	Commissioning plan Communication plan	2	D	Medium	Yes	Reduced sulphur dioxide and lead emissions from current levels. Plans to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
36	RSK-90030	Decommissioning - existing acid plant	Spills/leakage of acid into secondary containment	Failure of equipment Incorrect operation of equipment	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources (flora) • Noise • Odour • **Sub-surface soil quality** • **Surface water quality** • Vibration • Visual amenity	Mobilisation of contamination in soil/groundwater/surface water	2 2 2 2	D D D D	Medium	Operation and maintenance plan (including operating procedure to manage bund levels)	2	C	Low	Yes	No significant contamination of surface water or groundwater. Inherently safe design implemented at design phase Plan to be approved and implemented prior to appropriate phase.	Existing Environmental Monitoring Program Plan implemented and audited
37	RSK-90061	Decommissioning - existing acid plant	Generation of waste product	Removal of Catalyst (Vanadium Pentoxide) removal	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • Groundwater • Natural resources (flora) • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Incorrectly disposed waste will degrade environment and reduce air and water quality.	1 1	D D	Low	Material handling procedures	1	C	Low	Yes	Waste handled in accordance with appropriate Standards Procedure to be approved and implemented prior to appropriate phase	Procedure implemented and audited
38	RSK-90031	Operation	Acid plant stack discharge to atmosphere	Acid plant upset	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • **Natural resources (flora)** • Noise • **Odour** • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Controlled discharge of SO2, SO3, acid mist to atmosphere from reduction furnace resulting in impact to vegetation and community	2 2 1 2	D D D D	Medium	Operation and maintenance plan	2	D	Medium	Yes	Not exceed new licensing conditions Plan to be approved and implemented prior to appropriate phase.	Existing Environmental Monitoring Program Plans implemented and audited
39	RSK-90032	Operation	Tall stack discharge to atmosphere	Acid plant upset	• **Air quality** • By-product/Waste generation • **Community health** • **Community amenity** • Greenhouse gas • Groundwater • **Natural resources (flora)** • Noise • **Odour** • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Controlled discharge of SO2, SO3, acid mist to atmosphere from tall stack resulting in impact to vegetation and community	2 2 2 1 2	D D D D D	Medium	Operation and maintenance plan	2	D	Medium	Yes	Not exceed new licensing conditions Plan to be approved and implemented prior to appropriate phase.	Existing Environmental Monitoring Program Plans implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
40	RSK-90033	Operation - Acid plant start up	Acid plant stack discharge to atmosphere	Insufficient operating temperatures during start up	• **Air quality** • By-product/Waste generation • **Community health** • **Community amenity** • Greenhouse gas • Groundwater • **Natural resources (flora)** • Noise • **Odour** • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Controlled discharge of SO2, SO3, acid mist to atmosphere from tall stack resulting in impact to vegetation and community	2 2 2 1 2	D D D D D	Medium	Operation and maintenance plan Start up procedures	2	D	Medium	Yes	Not exceed new licensing conditions Plan to be approved and implemented prior to appropriate phase.	Existing Environmental Monitoring Program Plans implemented and audited
41	RSK-90063	Operation	Generation of noise	Plant item operation changes existing noise environment	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • **Noise** • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Community complaint of noise. Exceeding EPA criteria	2 2	C C	Low	Communication/consultation with EPA Design standards in compliance with Environmental Protection Policy (Noise)	1	C	Low	Yes	Design standards ensure plant noise levels do not exceed EPA thresholds.	Sound monitoring during commissioning Phase meets design standards. Existing Environmental Monitoring Program
42	RSK-90034	Operation (*inherently safe design)	Spills/leakage of acid into secondary containment	Failure of equipment Incorrect operation of equipment	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources (flora) • Noise • Odour • **Sub-surface soil quality** • **Surface water quality** • Vibration • Visual amenity	Mobilisation of contamination in soil/groundwater/surface water	2 2 2 2	D D D D	Medium	Operation and maintenance plan (including operating procedure to manage bund levels)	2	C	Low	Yes	No contamination of surface water or groundwater. Plans to be approved and implemented prior to appropriate phase. Inherently safe design implemented at design phase	Existing Environmental Monitoring Program Plans implemented and audited

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43		**Materials Storage Area**														
44	RSK-90035	Operation - Storage of materials	Creation of fugitive dust emissions	drying of surface of pit due to change in water table height	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Pb dust emissions impacting surface water quality/public health	2 2 1	D D D	Medium	Earth moving plan (including dust suppression) Elimination of sinter and sinter returns Relocation of lead materials to co-treatment shed Reclamation and treatment of sludge through oxidation furnace	1	D	Low	Yes	Reduced lead emissions from current levels. Plan to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan implemented and audited
45	RSK-90036	Operations - material handling	Creation of fugitive dust emissions	Increased reclamation of sludge materials	• **Air quality** • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Dust emissions impacting on air quality	1	D	Low	Earth moving plan (including dust suppression) Handling procedures (non-windy days)	1	D	Low	Yes	Reduced lead emissions from current levels. Plan and procedure to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan and procedure implemented and audited
46		**Seawater Cooling Water Intake and Discharge Expansion**														
47	RSK-90037	Construction	Production of spoil	Preparation of land Not following procedures	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual Amenity	Dust generation will reduce air quality . Incorrectly disposed spoil may reduce soil quality and harm vegetation. Disturbing surface water and groundwater leading to contamination of surface and groundwater	2 3 2 2 2	E E D C D	High	Earth moving plan (including dust suppression) Demolition plan Waste management and recycling plan	3	B	Medium	Yes	Dust levels to within licence guidelines. All spoil will be disposed correctly. No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

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48	RSK-90038	Construction	Increased suspended sediment	Dredging to install new intake caisson	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater **• Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration **• Visual amenity**	Exceeding suspended metal and metalloids sediment guidelines in Port Pirie River	2 1	E E	Medium	Silt curtains	2	D	Medium	Yes	Suspended sediment in seawater will meet new licensing conditions. Compliance with EPA requirements, guidelines and measures.	Monitoring suspended sediment during construction phase
49	RSK-90039	Construction	Deposition of dredged material onsite	Dredging to install new intake caisson	• Air quality **• By-product/Waste generation** • Community health • Community amenity • Greenhouse gas **• Groundwater** **• Natural resources (marine)** • Noise • Odour • Sub-surface soil quality **• Surface water quality** • Vibration • Visual amenity	Creation of Pb and acid sulphate contaminated waste material from dredging. Generating suspended sediment plumes in seawater.	2 2 1 2	E D D D	Medium	Site location and design plan	2	C	Low	Yes	No contamination of surface water or groundwater. Suspended sediment levels to be within licence guidelines. Plan to be approved and implemented prior to appropriate phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Monitoring of suspended solids in seawater. Plan implemented and audited
50	RSK-90040	Construction	Increased suspended sediment	Installation of the diffuser on the channel floor	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater **• Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration **• Visual amenity**	Exceeding suspended metal and metalloids sediment guidelines in Port Pirie River	1 1	E E	Low	Installation management procedure (tide/current selection)	1	E	Low	Yes	Resuspension of sediment will meet new license conditions. Compliance with EPA requirements, guidelines and measures.	Monitoring suspended sediment during construction phase

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51	RSK-90041	Operation - Cooling water discharge	Cooling water discharge elevated temperature	Cooling plant upset	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater **• Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Increase in delta-T (thermal plume), salinity and dissolved oxygen with localised impacts on marine fauna (invertebrates)	2	C	Low	Diffuser design Operation and maintenance procedures Start up procedures Real-time discharge temperature monitoring system	1	B	Low	Yes	Thermal diffusion will meet new licensing conditions. Compliance with EPA requirements, guidelines and measures.	seawater temperature near diffuser to be included as part of existing Environmental Monitoring Program
52	RSK-90042	Operation - Cooling water discharge	Seabed erosion	Diffuser being damaged by anchor/fishing net	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater **• Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Re-suspension of contaminated sediments Increased turbidity Increased localised temperatures	2	C	Low	Channel markings	2	B	Low	Yes	Channel markings, where appropriate, are installed. Resuspended sediment will meet new licensing conditions	New monitoring program to be included as part of existing Environmental Monitoring Program
53	RSK-90043	Operation - Cooling water intake	Intake of water exceeds 0.6m/s	Inadequate design	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater **• Natural resources (marine fauna)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Marine organisms (including larvae) are entrained with cooling water	2	F	Medium	Design intake so that intake velocity is less than 0.6 m/s Operating procedures	2	C	Low	Yes	Design requirements implemented at relevant phase Procedure to be approved and implemented prior to appropriate phase	New monitoring program to be included as part of existing Environmental Monitoring Program Procedure implemented and audited

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
54		**Minor Infrastructure (incl Workshop, roads)**														
55	RSK-90044	Demolition	Asbestos is disturbed in the course of activities	Failure to follow procedures	• **Air quality** • **By-product/Waste generation** • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Increase in asbestos particulate in air will impact human health	2 2 2	B F B	Medium	Asbestos register Asbestos removal and disposal IAW Australian Standards.	2	F	Medium	Yes	Asbestos treated and managed in accordance with relevant standards	Post-activity asbestos audit/testing
56	RSK-90045	Decommissioning	Dust levels exceeding current base line levels	Ineffective top-down wash	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Wind blown dust from existing sources will impact human health	1 1	C C	Low	Dust management plan Procedures for top-down wash and post-wash inspections	1	B	Low	Yes	Reduced lead emissions from current levels. Plan and procedures to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan and procedure implemented and audited
57	RSK-90046	Construction	Preparation of land	Not following procedures Production of spoil	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • **Noise** • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Excess dust generation will impact human health. Disturbing surface water and groundwater leading to contamination of surface and groundwater	2 3 2 2 2	E E D C D	High	Earth moving plan (including dust suppression) Dust management plan Demolition plan Waste management and recycling plan	3	B	Medium	Yes	Dust levels to be within Licence conditions. No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited

NYRSTAR PORT PIRIE TRANSFORMATION PROJECT
ENVIRONMENT RISK PROFILE

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
58	RSK-90047	Construction - Subsurface Geotechnical Testing for foundation design* (*The inherent level of risk is based on considering current process design)	Generation of contaminated material and Contaminant migration through interconnection of aquifers	Lack of appropriate material handling protocol Poor design Not following design	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Contamination to surface water and groundwater	3 3 1	E C C	High	Earth moving plan Waste management and recycling plan	3	B	Medium	Yes	No contamination of surface water or groundwater. Plans to be approved and implemented prior to construction phase. Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plans implemented and audited
59		**Transportation and Logistics Management**														
60	RSK-90048	Construction - Transportation/Logistics of material	Increased frequency of traffic - construction	Increased mobilisation of staff, materials and plant	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • **Noise** • Odour • Sub-surface soil quality • Surface water quality • **Vibration** • Visual amenity	Delays to public road users on public roads (especially main road of Port Pirie)	2 2 2	F F F	Medium	Traffic management plan Schedule management Building dilapidation survey Community and Consultation Strategy	2	E	Medium	Yes	Plans to be approved and implemented prior to appropriate phase. Community informed of potential impacts in advance of activity	Plans implemented and audited Register of community consultation/engagement
61	RSK-90049	Construction - transportation/Logistics of material	Increased demand on parking spaces - construction	Increased mobilisation of staff, materials and plant	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Overflow from existing parking spaces onto roads and side streets impacting on public amenity	2	F	Medium	Traffic management plan Schedule management Designated overflow parking areas Community and Consultation Strategy	2	D	Medium	Yes	Plans to be approved and implemented prior to appropriate phase. Community informed of potential impacts in advance of activity	Plans implemented and audited Register of community consultation/engagement

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
62	RSK-90050	Construction - transportation/Logistics of material	Fugitive emissions - construction	Traffic movement onsite contributing to dust generation	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Pb dust emissions impacting surface water quality/public health	2 2 1	E E E	Medium	Dust management plan	2	C	Low	Yes	Reduced lead emissions from current levels. Plan and procedures to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan and procedure implemented and audited
63	RSK-90051	Construction and Operational Logistics	Introduction of foreign flora/fauna (incl. marine and terrestrial pests) construction and operation	International shipping incorrectly discharging of ballast water Failure to follow wet down procedures	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater • **Natural resources (marine and terrestrial)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Marine and terrestrial pests impacting local ecology	3	C	Medium	Flinders Port Authority Regulations Australian Quarantine Regulations	3	B	Medium	Yes	Liaison with Flinders Port Authority with shipping traffic	Records and documentation of meetings
64	RSK-90052	Construction and Operation - Transportation/Logistics of material	Additional winnowing of sediments and the generation of sediment plumes - construction and operation	Increased shipping size resulting in deeper draught.	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • Groundwater • **Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Re-suspension of contaminated sediments	2	F	Medium	Restriction of shipping sizes Consultation with Flinders Port Authority	1	E	Low	Yes	Liaison with Flinders Port Authority with shipping traffic	Records and documentation of meetings

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65		**Construction Workforce and Overflow Accommodation**														
66	RSK-90053	Shutdown during construction	Increased demand for personnel	Shutdown required during Transformation construction period	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Availability of health, utilities, accommodation and services impacting on local population resulting in unavailability of critical services	2	E	Medium	Schedule management Construction management plan Community and Consultation Strategy	2	B	Low	Yes	Demand on health utilities, accommodation and services will not impact local population. Plans to be approved and implemented prior to appropriate phase. Community informed of potential impacts in advance of activity	Project plan/schedule. Register of complaints and corrective actions. Register of community consultation/engagement
67	RSK-90054	Onsite-Waste Management - Sewage	Leakage of raw sewage (black or grey)	Inadequate design capacity of system, failure to fix existing leaks in plant	• Air quality • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • **Odour** • **Sub-surface soil quality** • Surface water quality • Vibration • Visual amenity	Sewage contamination of groundwater and driving head for contaminate migration	2 2 1 1	C D C D	Medium	Operation and contingency planning	2	B	Low	Yes	No contamination of surface water or groundwater. Plans to be approved and implemented prior to appropriate phase.	High-level alarms and triggers on plant Plans implemented and audited
68	RSK-90055	Accommodation	Anti-social behaviour in the community	Anti-social behaviour or pre-meditated behaviour of transient workforce (due to alcohol or drugs).	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • Visual amenity	Large workforce and antisocial behaviour impacting on community amenity	2	C	Low	Appropriate drug and alcohol policy Close liaison with local government authorities Public relations/liaison Community and Consultation Strategy	2	B	Low	Yes	Testing undertaken as part of drug and alcohol policy Liaison and cooperation with LGAs Community informed of potential impacts in advance of activity	Records and reporting on testing Register of community consultation/engagement

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Ref	Risk Number	Phase/Activity *(During the course of this activity…)*	Event description *(…this could happen…)*	Cause *(… as a result of…)*	Aspect *(..which could impact these..)*	Potential Impacts *(…in this way…)*	Consequence	Likelihood	Risk Level	Controls	Consequence	Likelihood	Risk Level	ALARP?	Expected Outcomes	Tracking mechanism
69		**Waste Management**														
70	RSK-90056	Construction	Stockpiling, handling and disposal of waste and recyclable resources	Demolition works Packaging materials Offcuts	• **Air quality** • **By-product/Waste generation** • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine)** • Noise • Odour • **Sub-surface soil quality** • **Surface water quality** • Vibration • Visual amenity	Contamination of groundwater and surface water, soil and marine environment	2 2 2 1 2 2	D D D D D D	Medium	Waste characterisation Waste management and recycling plan	1	C	Low	Yes	Waste characterised and prioritised for appropriate waste management Plan to be approved and implemented prior to appropriate phase.	Plan implemented and audited. Existing monitoring program upgraded to accommodate potential new impact sites.
71		**Other**														
72	RSK-90057	Construction and Operation	Flooding of site	Storm surge/ sea level variation/ high tide significant rainfall event Increased frequency of events	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Flooding removing contaminated material from site and depositing at sea	2 2 2	A A A	Low	Update site emergency response plan to ensure incorporation of extreme weather events (incl. inundation from river)	2	A	Low	Yes	Plans to be approved and implemented prior to appropriate phase.	Plans implemented and audited
73	RSK-90058	Construction and Operation	Increased fugitive emissions	Cumulative impact of multiple dust sources	• **Air quality** • By-product/Waste generation • **Community health** • Community amenity • Greenhouse gas • **Groundwater** • Natural resources • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • **Visual amenity**	Increased dust and lead emissions contributing to community health impacts. Increased wetting down of dust sources contributes to secondary impact on groundwater.	2 2 2 2 2	E D D D D	Medium	Schedule management Construction management plan Control of individual dust sources	1	C	Low	Yes	Reduced lead emissions from current levels. Plan and procedures to be approved and implemented prior to appropriate phase Compliance with EPA requirements, guidelines and measures.	Existing Environmental Monitoring Program. Plan and procedure implemented and audited

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74	RSK-90059	Construction and Operation	Multiple construction activities and operations together	Cumulative effect of: Flooding event, and/or Road wet down, and/or Rain during construction	• Air quality • By-product/Waste generation • Community health • Community amenity • Greenhouse gas • **Groundwater** • **Natural resources (marine)** • Noise • Odour • Sub-surface soil quality • **Surface water quality** • Vibration • Visual amenity	Increased contamination of surface water and groundwater or marine environment	3 3 3	C C C	Medium	Schedule management Construction management plan Control of individual source Housekeeping Internal environmental authorisation for placement of materials within known catchments Update site emergency response plan to ensure incorporation of extreme weather events (incl. inundation from river)	2	B	Low	Yes	No increased contamination of surface water and groundwater. Plans to be approved and implemented prior to appropriate phase.	Plans implemented and audited
75	RSK-90060	Operation	New infrastructure in prominent positions	Necessary infrastructure	• Air quality • By-product/Waste generation • Community health • **Community amenity** • Greenhouse gas • Groundwater • Natural resources • Noise • Odour • Sub-surface soil quality • Surface water quality • Vibration • **Visual amenity**	Prominent infrastructure visible from town of Port Pirie and surrounding areas	1 1	F F	Medium	Public engagement and consultation strategy	1	E	Low	Yes	Port Pirie skyline is not adversely affected by new structures beyond that outlined for development under Policy Area 15 of the Industry Zone, Port Pirie (Regional Council) Development Plan Liaison with LGA and public on issue	Records kept of engagement and agreed outcomes. Photo-point monitoring to document pre and post construction skyline of smelter from strategic view points.

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Resources for a changing world

Appendix H:

Port Pirie marine modelling assessment of cooling water discharges to the marine environment

A part of BMT in Energy and Environment

Port Pirie Marine Modelling Assessment of Cooling Water Discharges to the Marine Environment

R.B20232.001.01.RevisedReport.docx
July 2013

APPENDIX H

Port Pirie Marine Modelling Assessment of Cooling Water Discharges to the Marine Environment

Offices

Brisbane
Denver
Mackay
Melbourne
Newcastle
Perth
Sydney
Vancouver

Prepared For:	Nyrstar Port Pirie Pty Ltd.
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

DOCUMENT CONTROL SHEET

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	Client : ***Client Contact:*** ***Client Reference***	Nyrstar Port Pirie Pty Ltd. David Wiltshire

Title :	Port Pirie Marine Modelling Assessment of Cooling Water Discharges to the Marine Environment
Author :	Daniel Botelho
Synopsis :	This project details near and far field assessments of the temperature increase resulting from a series of scenarios taking into consideration different configurations of cooling water discharges.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
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BMT WBM Library	PDF	PDF		

EXECUTIVE SUMMARY

Study Briefing

Nyrstar Port Pirie Pty Ltd is currently undertaking pre-feasibility and bankable studies to upgrade its smelter in Port Pirie (South Australia) with a state-of-the-art operation. These new facilities would require an upgraded sea water intake and an expanded cooling water discharge system. The cooling water thermal effluent would be ultimately disposed in the marine environment of Spencer Gulf near Port Pirie (Nyrstar 2013).

Two main options for the discharge were put forward by the design engineers. The first option is to discharge the heated effluent to First Creek in the same location of an existing thermal effluent discharge. The second option is to construct a diffuser to be located in the Port Pirie River. A range of temperature increases between intake and outfall are being considered for these options. It is expected that the existing discharge will remain operational.

BMT WBM was commissioned to undertake a high-level study to support Nyrstar in coming to a decision on the pre-feasibility of each discharge option. In particular, the study briefing for the works reported in this document consisted of the following:

- To investigate whether a diffuser in the Port Pirie River could be successfully designed to meet South Australian EPA (SA EPA) water quality guidelines regarding temperature increase in the nearfield;
- To implement a single hydrodynamic numerical model framework to investigate the far field dispersion of the thermal effluent;
- To undertake hydrodynamic data collection to support the development of this model framework; and
- To use the model framework to quantify the temperature increases associated with the existing and proposed discharges, more specifically to identify whether and where the resulting temperature increases would be compliant with SA EPA water quality guidelines.

Commensurate with the conceptual nature of the study, the limited time available to undertake the scope of works, and limited existing hydrodynamic information near Port Pirie, BMT WBM elected to devise a flexible study methodology, which can be further refined as the plant upgrade design progresses from a conceptual stage through to increasingly more detailed phases.

As such, the adopted hydrodynamic model was only detailed to the point it could reasonably inform the temperature increases arising from each of the alternative discharge options. Results contained in this report were not produced with the intent of progressing detailed design of the proposed discharge.

Study components and outcomes are described below.

Data Collection

A targeted field measurement program was devised to inform model construction and advance model validation. Two types of instruments were deployed over approximately two full spring neap tidal cycles in May 2013. This period takes into account conditions associated with dodge tides, which are more prominent in the months of May and November each year. The measurements consisted of:

- Velocity data obtained from Acoustic Doppler Current Profilers (ADCPs) at two separate locations; and
- Conductivity-Temperature-Depth (CTD) data at four separate locations.

In particular, the ADCP measurements were undertaken near the main channel of Port Pirie River and in the subtidal areas offshore of First Creek. The CTD measurements were conducted in the same locations and other two locations further offshore in the subtidal areas of Germein Bay.

Average (0.09 and 0.10 m/s, respectively) and maximum velocities (0.59 and 0.60 m/s, respectively) measured by the ADCPs were similar between the two sites. In both sites, the three neap tide periods associated with the dodge tides indicated velocities remain below 0.1 m/s throughout the water column for a few days. Velocity magnitudes were relatively even between tide phases offshore of First Creek. Contrastingly, velocities in the Port Pirie River site were generally higher in the flooding tides and lower in the ebbing tides. Additionally, velocity directions showed the flow remained into the river appreciably longer than out of the river. This tidal asymmetry indicated the Port Pirie River is not well flushed, which is of particular importance for consideration if this location is chosen as the discharge alternative.

All sites present similar trends of decreasing salinities and temperature, as expected for this time of year. CTD measurements in the Port Pirie River showed stratification of salinity (up to approximately 2 units) and temperature (up to 1 ^{o}C), while sites offshore were relatively well mixed. Temperature in the Port Pirie River was generally lower and salinity was generally higher than offshore.

Discharge Assessments

Water Quality Guidelines

A central aspect of the study briefing was to investigate whether a diffuser in the Port Pirie River and the discharges to First Creek could be successfully designed to meet SA EPA water quality guidelines for temperature increases. While the existing Environment Protection (Water Quality) Policy 2003 (SA EPA 2003) does not have a specific guideline addressing temperature increases due to effluent discharges, precedent cases in South Australia required that temperatures resulting from the disposal of cooling water are no greater than 2 °C above the ambient temperature 20 m from the outfall (S Gaylard, SA EPA, *pers. comm.* 24 May 2013).

This water quality policy is under review such that a draft Environment Protection (Water Quality) Policy 2012 (SA EPA 2012), based on the ANZECC/ARMCANZ 2000 Water Quality Guidelines, is likely to replace the existing policy in 2014. The new policy requires that the resultant median water temperature does not exceed the 80th percentile (i.e. 20th percentile temperature exceedence) of the ambient water temperature at the edge of an agreed mixing zone.

Nearfield Assessment

Two well-established models were adopted to quantify the outfall discharge plume characteristics: CORMIX (Cornell Mixing Zone Model, Jirka et al. 1996) and Visual Plumes (Frick et al. 2003). Adoption of these configurations across two comparable models was undertaken to provide sensitivity and confidence in the modelling results. Based on ambient conditions and outfall characteristics, these models calculated temperature, dilution and plume geometrical characteristics at nominated distances from the diffuser. The modeled conditions assumed a discharge flow rate of 1.64 m^3/s and the maximum 10^{o}C temperature increase in relation to background ambient conditions.

Given the seminal nature of the project, no specific outfall diffuser plans or specifications (except for flow rate and temperature specifications) were provided. In order to approach the problem in a pragmatic fashion, two typical outfall design specifications were adopted in this nearfield investigation. The choice of these options were not intended to inform design but simply to demonstrate, as a proof-of-concept, that a typical outfall can be designed to comply with water quality guidelines.

Although the adopted modelling assumptions were generally conservative (i.e. considered the maximum proposed temperature increase above background and neglected surface heat exchange), it was shown that an outfall can be successfully designed to comply with the SA EPA water quality guidelines.

Taking into consideration the limited number of tests, the outfall design can be further optimised to achieve even more favourable conditions for the thermal effluent dilution.

Far Field Model Performance

The three dimensional hydrodynamic and transport model TUFLOW FV was set-up and executed for far field assessments of a subset of the alternative proposed discharges. The model comprised the whole of Spencer Gulf with high resolution in the areas of interest near Port Pirie. The model was shown to reproduce the tidal features throughout the Gulf and performed particularly well in terms of reproducing current velocities offshore of First Creek. Due to inaccuracies of the bathymetry in the intertidal areas, the model did not perform as well in the Port Pirie River area. The model, nevertheless, did reproduce the essential features of the hydrodynamics and was considered fit for the purpose of this conceptual study. Temperatures in the water column were particularly well reproduced.

Methodology for Comparison

A methodology was devised for comparisons between the discharge scenarios and the natural (unimpacted) baseline, so as to verify whether (and/or where) the discharges would meet water quality guidelines (both present and the proposed draft guidelines). In case guidelines were not met, these comparisons would serve to indicate which locations would be the worst affected by the discharge temperature increases.

The methodology consisted of calculating the percentile temperature exceedences for each surface cell of the model domain. The statistics were computed over one month of simulation, comprising the dodge tide period captured in the field data.

For verification of guidelines, each of the percentile exceedences obtained from the natural (unimpacted) baseline conditions were subtracted from a corresponding percentile exceedence obtained from the discharge scenarios. These differences were then mapped so as to obtain the locations and respective distances (or areas) from the discharge where they exceeded any given water quality criterion.

Proposed Discharges to First Creek

Results of the proposed alternative discharges were contrasted with natural and existing conditions. Natural conditions were simulated assuming there were no discharges in the model domain. Existing conditions assumed the existing thermal effluent discharge with a flow rate of 0.53 m^3/s and temperature increase between the intake and the discharge of 9^oC.

For the proposed discharge, different levels of temperature increase in relation to intake temperatures were considered (2^oC, 5^oC, and 10^oC). The discharge flow rate was 1.64 m^3/s.

The comparisons with natural conditions showed that any of the discharges into First Creek (either the existing or the existing with the combination of the proposed discharges) were not compliant with SA EPA water quality guidelines. When taking into consideration the proposed discharges, model results showed that for any of the cases most of First Creek would be non-compliant. In addition to First Creek, the intertidal area immediately offshore of the creek would be non-compliant with any of the guidelines. As expected, the extent of the non-compliant area would be reduced for smaller temperature increases between intake and discharge.

Proposed Discharge to the Port Pirie River

For the proposed discharge to the Port Pirie River, only a temperature increase of 10 ^oC in relation to the water intake temperatures was considered. The discharge input into the model did not consider the effects of mixing in the nearfield. Consistent with other discharge modelling studies, neglecting these effects produce very conservative dilutions (therefore, also temperature increase) in the vicinity of the diffuser. Adoption of this "unseeded" approach was preferred in view of the limited time available for the study. As a result, the far field assessment showed the discharge to the Port Pirie River would not be compliant over a significant area with either of the water quality guidelines. This result was immaterial in the sense that the near field model showed temperature increases below 2^oC can be achieved within 20 m from the diffuser.

Model results nevertheless were useful as they indicated an asymmetric plume, with tendency of movement during flood tides into the River, which was consistent with the ADCP measurements Port Pirie River. Given these results, the outfall in the Port Pirie River should be located as near as possible to the river mouth.

Comparisons with Existing Conditions

Comparisons with existing conditions were undertaken to quantify the effect of the increased heat load of the proposed discharges in the marine environment near First Creek. Despite the increased heat load, some of the proposed alternative discharges considered temperature increases (in relation to intake temperatures) smaller than the existing discharge. Model results showed that these scenarios would result, in comparison to existing conditions, in reduction of temperatures over significant lengths of First Creek. However, as advection and dispersion mechanisms in the creek are controlled by the tides, portions of the creek and the intertidal area immediately offshore would still present a temperature increase (in comparison to existing conditions). In particular, the areas near the mouth of the creek tended to present temperature increases, whilst a reduction was simulated near the discharge location.

For a discharge above 10 ^{o}C, the discharges into First Creek would always result in temperature increases, both along the entire First Creek stretch as well as in the intertidal area immediately offshore of First Creek. Such a temperature increase would therefore exacerbate the impacts of the existing discharge.

Recommendations

The alternatives of the thermal discharge to Port Pirie River or First Creek both have strengths and weaknesses, such that it is difficult to recommend the most viable option on environmental grounds alone.

Discharge to the Port Pirie River

For the proposed discharge to the Port Pirie River, it is possible to design an outfall capable of meeting existing water quality guidelines. However, in addition to the temperature increase in the Port Pirie River no abatement of the existing discharge conditions would occur in First Creek. As a result, the impact of the Nyrstar operations in the marine environment near Port Pirie would consist of two isolated zones. A possible solution to this outcome is to combine (pre-mix) both existing and proposed cooling water discharges for disposal through the outfall in the Port Pirie River. It should be noted that this suggestion did not consider any costs, design, or operational matters involved in this mixed approach.

If Nyrstar wishes to progress consideration of discharging to the Port Pirie River we suggest that:

1. A bathymetric field survey be undertaken in the intertidal areas within the Port Pirie River. Such a survey will allow further refinement of the hydrodynamic model in such a way as to improve predictive capability of the observed tidal asymmetry. This asymmetry is an important feature that relates to mixing processes so it is relevant here.

2. A pre-mixed approach with results from a nearfield model be adopted to “seed” the discharge into the far field model. Such an approach will allow the simulation of less conservative and more realistic far field plume characteristics within the Port Pirie River.

3. The nearfield analysis be upgraded with more detailed Computational Fluid Dynamics (CFD) modelling. Such an approach will allow improved understanding of the effects of tides in the nearfield dilutions and temperature increases as well as to provide reliable dilutions for the discharge “seeding” referred above.

Additionally, if both existing and proposed discharges are to be combined into a single disposal location, the nearfield study needs to be upgraded to reflect the increased heat load. This exercise should be taken in conjunction with a formal diffuser optimization study.

Discharge to First Creek

Considering the combination of existing and proposed discharges to First Creek will result in non-compliant conditions with SA EPA water quality guidelines.

In this case, any improvement in terms of temperature to First Creek would require a temperature increase in relation to intake temperatures significantly lower than the 9^{o}C increase assumed in the existing discharge. In particular, a 2°C increase in the proposed discharge resulted in significant improvement of overall conditions within some reaches of First Creek, with only relatively small deterioration in other locations.

If Nyrstar wishes to progress consideration of discharging to First Creek we suggest that:

1. A bathymetric field survey be undertaken in the intertidal areas within Germein Bay offshore of First Creek. Such a survey would allow further refinement of the hydrodynamic model in such a way as to improve predictive capability in the intertidal areas beyond the mouth of First Creek.

2. Collection of temperature and meteorological data be undertaken in First Creek and the adjacent intertidal areas. This data collection would allow increased understanding of the effects of the tidal dynamics on temperature within First Creek and allow improved model validation and predictive capability within the area.

3. The far field model be upgraded with increased resolution in the First Creek and immediately adjacent area. While sufficient resolution was adopted for this conceptual study, a more detailed investigation would benefit from increased resolution in the area.

Choice of Alternative

The advantages (and disadvantages) of each of the options need to be weighed in conjunction with other factors not necessarily related to the discharge itself (e.g. benefit to air quality, control of groundwater pollution). Once a decision is made on the way forward, the more detailed investigations addressed above should be undertaken to progress the chosen alternative.

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1 INTRODUCTION

Nyrstar Port Pirie Pty Ltd (hereafter Nyrstar) operates an integrated multi-metals recovery plant that can process a wide range of lead rich concentrates and smelting industry by-products, including lead, zinc, silver, gold, copper and sulphuric acid (Nyrstar 2013). The smelter has been in operation for more than 120 years, with its core production assets established some 60 years ago.

Nyrstar is currently undertaking pre-feasibility and bankable studies (including a Public Environmental Review – PER) to upgrade this facility to a state-of-the-art poly-metallic processing and recovery facility. More specifically, these studies are being undertaken to replace the existing sinter plant with a state-of-the-art oxygen enriched bath smelting furnace, coupled to an electricity cogeneration facility and a new sulphuric acid plant. These new facilities would require an upgraded sea water intake and an expanded cooling water discharge system. The cooling water thermal effluent would be ultimately disposed in the marine environment near Port Pirie (Nyrstar 2013).

This report describes and presents the results of near and far field numerical modelling undertaken to simulate the hydrodynamics of Spencer Gulf and the effects of the cooling water thermal discharge in the marine environment adjacent to Port Pirie.

1.1 Study Objectives

The objectives of this study were to:

- Assess the effects of different configurations of the cooling water discharge (i.e. location and temperature increase) and its compliance with existing and proposed water quality guidelines regarding temperature increase in the marine environment;
- Develop a three-dimensional numerical hydrodynamic model of Spencer Gulf, with resolution focused in the Port Pirie area;
- Collect physical oceanographic data with the view to establish, calibrate and validate this hydrodynamic model; and
- Support other assessments that require hydrodynamic information near Port Pirie.

1.2 Report Outline

This report is structured as follows:

- Section 2 presents a site description and relevant hydrodynamic information regarding the study area;
- Section 3 presents the data collected for the set-up, execution and validation of the near and far field models;
- Section 4 presents near and far field assessments of different cooling water discharge configurations in terms of comparisons with existing and proposed water quality guidelines; and
- Section 5 presents a brief discussion of the study findings, and
- Section 6 presents the study conclusions and recommendations.

2 SITE DESCRIPTION

2.1 Spencer Gulf

Spencer Gulf is a large (length approximately 300km, mean width approximately 60km) and relatively shallow (mean depth approximately 22m) semi-enclosed sea (Figure 2-1). The Gulf has an approximate triangular shape, bounded by the Yorke Peninsula to the east, the Eyre Peninsula to the west and the Southern Ocean to the south (Figure 2-1).

Flow in the Gulf is largely influenced by tides, which have significant spatial variation. In particular, the mouth in the southern end and the head in the northern end have a semidiurnal tidal elevation character, whereas at the centre of the Gulf, near Wallaroo, the tidal elevations are predominantly diurnal (Easton 1978). The tidal elevation range is relatively small at the mouth (0.6 m at Pondalowie Bay) of the Gulf and progressively increases up to 2.7 m in the head of the Gulf (BMT WBM 2011).

Predominant tidal harmonics in Spencer Gulf are the diurnal components K1 and O1, and the semi-diurnal components M2 and S2 (Nunes and Lennon 1986). Both diurnal and semi-diurnal components have similar amplitudes to each other. The semi-diurnal harmonics are phase-cancelling and enhancing at every 14.8 days, whilst the diurnal harmonics at every 13.7 days. As a result periods of low tidal amplitude occur approximately every 6 months, when both diurnal and semi-diurnal components cancel each other. These tides are a notorious feature of the South Australian gulfs, known as “dodge tides”. Due to the small tidal amplitudes, tidal flow becomes severely reduced over part of the neap cycle period (Easton 1978). However, it has been shown that during dodge tides flow velocities can still exceed 30 cm/s in some parts of the Gulf, such as near Port Bonython (BMT WBM 2011).

Temperature and salinity are predominantly influenced by the local meteorology and increased residence times within the northern areas of Spencer Gulf (Nunes and Lennon 1986). Over the annual cycle, mean water temperature ranges between 12 and 24°C Spencer Gulf. Salinity ranges over the annual cycle vary more widely spatially, from ~43 to 48 g/L at the head of the Gulf, to ~38 to 39 g/L at Wallaroo (Nunes and Lennon 1986), and ~35.5 to 37.0 at the mouth (Herzfeld et al. 2009). Strong evaporation north of Point Lowly drives these high salinities at the head of the Gulf and results in the development of a broadscale north-south salinity gradient during summer. This gradient is relaxed during autumn and winter due to the combined effects of reduced evaporation and a large scale ejection of salt from the Gulf (Nunes et al. 1990).

Given the Gulf’s width, the salt ejection is influenced by the Earth’s rotation forming a cyclonic (clockwise) gyre motion south of Port Bonython (Nunes and Lennon 1986). In autumn through winter, this gyre brings colder, less saline southern water up the Gulf along the western shore and more saline warmer water down the Gulf along the eastern shore (Nunes-Vaz et al. 1990). Nunes (1985) data shows temperature and salinity gradients that form across the Gulf between False Bay, off Whyalla, and Germein Bay, off Port Pirie (Figure 2-2).

2.2 Port Pirie

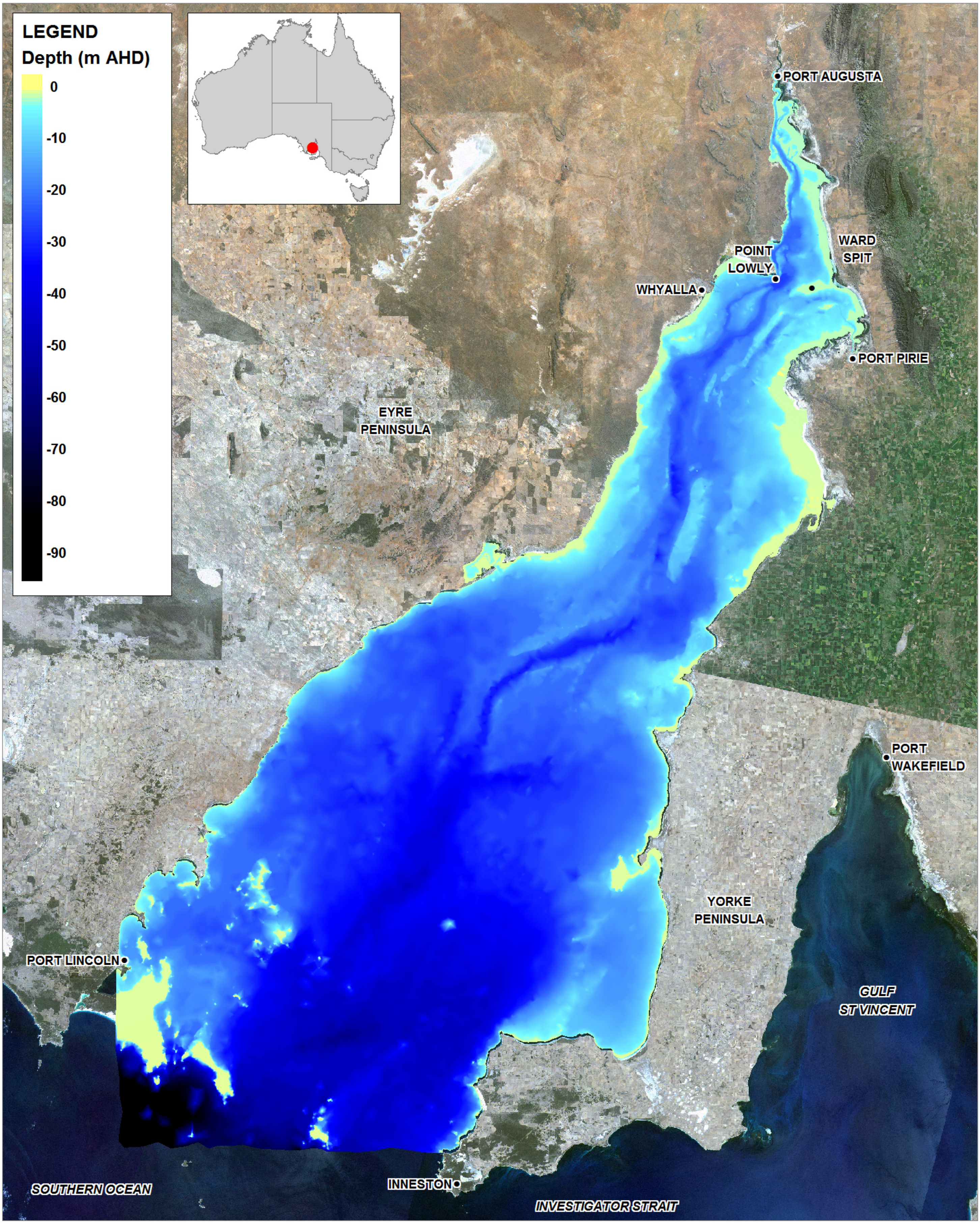
Port Pirie is a coastal town on the southern shore of Germein Bay located approximately 230 km north of Adelaide and approximately 37 km southeast across the Gulf from Whyalla (Figure 2-1). The city of Port Pirie and the Nyrstar smelter are located in the western margin of the Port Pirie River, where a port facility operates to receive concentrates used in the metal processing (Figure 2-3).

Little is known about the hydrodynamics near Port Pirie; more specifically, to our knowledge no hydrodynamic modelling studies have been undertaken in the area. Recently, hydrodynamic studies have been conducted as a result of environmental studies for a desalination plant outfall near Port Bonython in the opposite margin of the Gulf (BMT WBM 2011). These studies show that bathymetric features are very important in determining the intensity and direction of the flow resulting from the tides. For example, flow is quite vigorous (up to 1.5 m/s, mean 0.50 m/s) through a deep channel known as "the Rip" between Point Lowly and Ward Spit (BMT WBM 2011 - see Figure 2-2 for locations). On the other hand, vortices form on the lee side of Point Lowly, considerably reducing the flow intensity (maximum of approximately 0.3 m/s during ebb tides, BMT WBM 2011).

The existing smelter cooling system extracts water at the intake location shown in Figure 2-3. Cooling water is discharged at an average 0.62 m^3/s flow rate to a flume (PP02 in Figure 2-3) that serves as conduit to First Creek, approximately 1.6 km downstream. Cooling water is ultimately delivered to Spencer Gulf according to the tidal motion within First Creek. A five year monitoring study showed that the increased temperatures associated with the cooling water is confined to First Creek, while little difference in temperature was found between the mouth of First Creek and control sites offshore (NRS 2007).

2.2.1 Proposed Discharge

Four potential outfall locations as indicated by points PP02 to PP05 in Figure 2-3 are under consideration in the upgraded operations. The existing discharge, also at PP02, discharges via First Creek, whilst the potential outfalls at PP03 to PP05 would discharge cooling water directly to Port Pirie River. Port Pirie River channel is maintained in excess of 8.0 m for the Port Pirie activities which, in comparison to the shallower waters in First Creek, would provide an opportunity for mixing if delivered via a diffuser near the seabed (Figure 2-2). The proposed discharge considers a 1.54 m^3/s cooling water flow rate.



Title:

Spencer Gulf Location and Bathymetry

Figure: 2-1

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0 30 60km

Approx. Scale

BMT WBM

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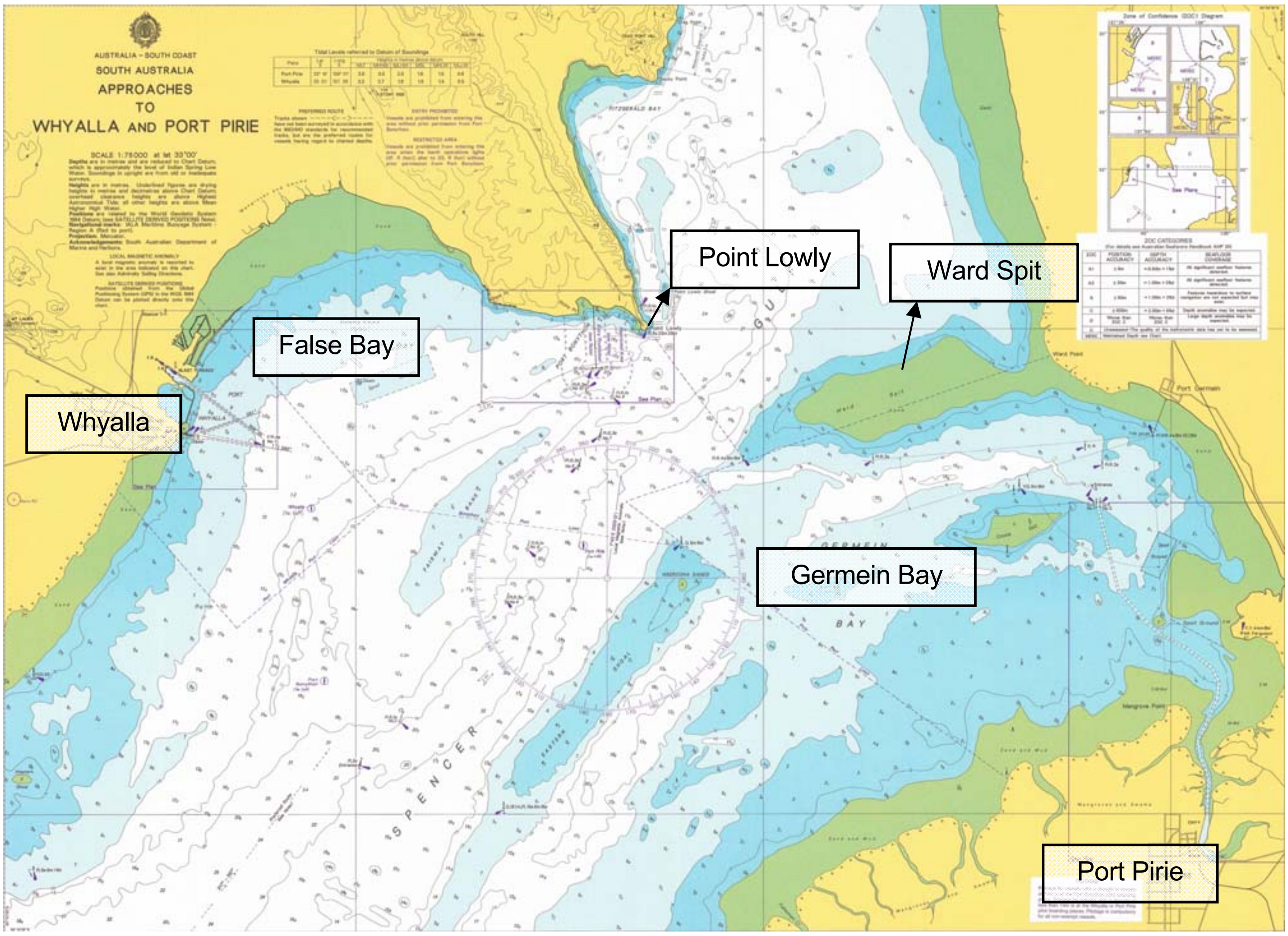

Figure 2-2 Approaches to Whyalla and Port Pirie (Chart AUS 136, AHS 2000). Scale shown does not apply.

Title:

Port Pirie, Nyrstar Facilities and Sampling Stations

Figure: 2-3

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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3 DATA COLLECTION

A targeted field measurement program was undertaken specifically for model validation purposes. The instruments were deployed between 04 April and 08 May 2013, inclusive of approximately two full spring neap tidal cycles. This period was chosen as to capture conditions during dodge tides, which are prevalent during neaps in the months of May and November each year. The measurements consisted of:

- Velocity data obtained from Acoustic Doppler Current Profilers (ADCPs) at two separate locations; and
- Conductivity-Temperature-Depth (CTD) data at four separate locations.

A description of these measurements is given below and a summary is provided in Table 3-1. The deployment locations are presented in Figure 2-3.

3.1 ADCP Measurements

ADCP measurements were undertaken at two separate locations to provide hydrodynamic conditions associated with the proposed outfall locations. Site 1 was located next to the Port Pirie River main channel at the mouth of Magazine Creek. Although not directly positioned at any of the proposed outfall locations in the Port Pirie River the site was chosen so as not to interfere with shipping traffic. Site 2 was located in approximately 7 m depth just offshore of First Creek.

Measurements at Site 1 and 2 are presented respectively in Figure 3-1 and Figure 3-2. Average (0.09 and 0.10 m/s, respectively) and maximum velocities (0.59 and 0.60 m/s, respectively) were similar between the two sites. However, it can be seen that velocities at Site 1 were generally higher in the flooding tides and lower in the ebbing tides. Contrastingly, velocities were more even between tide phases at Site 2, with only slightly higher velocities during ebbing tides. In both sites, the three neap tide periods indicate velocities remain below 0.1 m/s throughout the water column for a few days. These low velocity intensities, representative of the dodge tides, were particularly prominent with the low water elevations observed around 05 May (Figure 3-1 and Figure 3-2).

The velocity directions at Site 1 were oriented in the NW-SE directions, with markedly abrupt changes in direction with the change in tidal phases (Figure 3-1). On the other hand, velocity directions at Site 2 varied more gradually from one phase to another. The predominant directions at the peak velocities at Site 2 were East (flood tides) and West (ebb tides - Figure 3-2).

3.2 CTD Measurements

CTD temperature and salinity measurements are presented in Figure 3-3 and Figure 3-4, respectively. In most locations, measurements were collected near the top and bottom of the water column, with the exception of measurements at Site 2 (Table 3-1). Some conductivity sensors when deployed for over a week are known to present problems associated with drifting and biofouling. Such samples that were deemed unreliable at the end of the records were therefore discarded.

All sites present similar trends of decreasing salinities and temperature, as expected for this time of year. Site 1, inside the estuary, presented stratification of salinity (up to approximately 2 units) and temperature (up to 1 °C), while sites offshore (Sites 3 and 4) were relatively well mixed. Temperature inside the estuary (Site 1) was generally lower than offshore and salinity was higher (Figure 3-5 and Figure 3-6). Sites 3 and 4 presented a larger rate of salinity reduction with time, which are unlikely to be real and probably resulted from excessive sensor drifting.

Table 3-1 Summary of measurements specifically undertaken for model development

Measurement Type	Station	Location		Measurement Interval	Measured Variables
		Longitude	Latitude		
Vertical Velocity Profile (ADCP)	1 (~7 m depth)	138° 0’ 58.1’’ E	33° 9’ 12.2’’ S	05/04/2013 to 08/05/2013	Current speed and direction (and backup water depth)
	2 (~6 m depth)	137° 58’ 49.3’’ E	33° 5’ 32.8’’ S		
Conductivity Temperature and Depth (CTD)	1 (~7 m depth) top and bottom	138° 0’ 58.1’’ E	33° 9’ 12.2’’ S	05/04/2013 to 08/05/2013	Temperature, conductivity (salinity and density), and pressure (depth)
	2 (~6 m depth)	137° 58’ 49.3’’ E	33° 5’ 32.8’’ S	05/04/2013 to 05/05/2013	
	3 (~5 m depth) top and bottom	137° 56’ 20.2’’ E	33° 0’ 00.1’’ S	05/04/2013 to 08/05/2013	
	4 (~6 m depth) top and bottom	137° 57’ 18.5’’ E	33° 6’ 52.4’’ S	05/04/2013 to 08/05/2013	

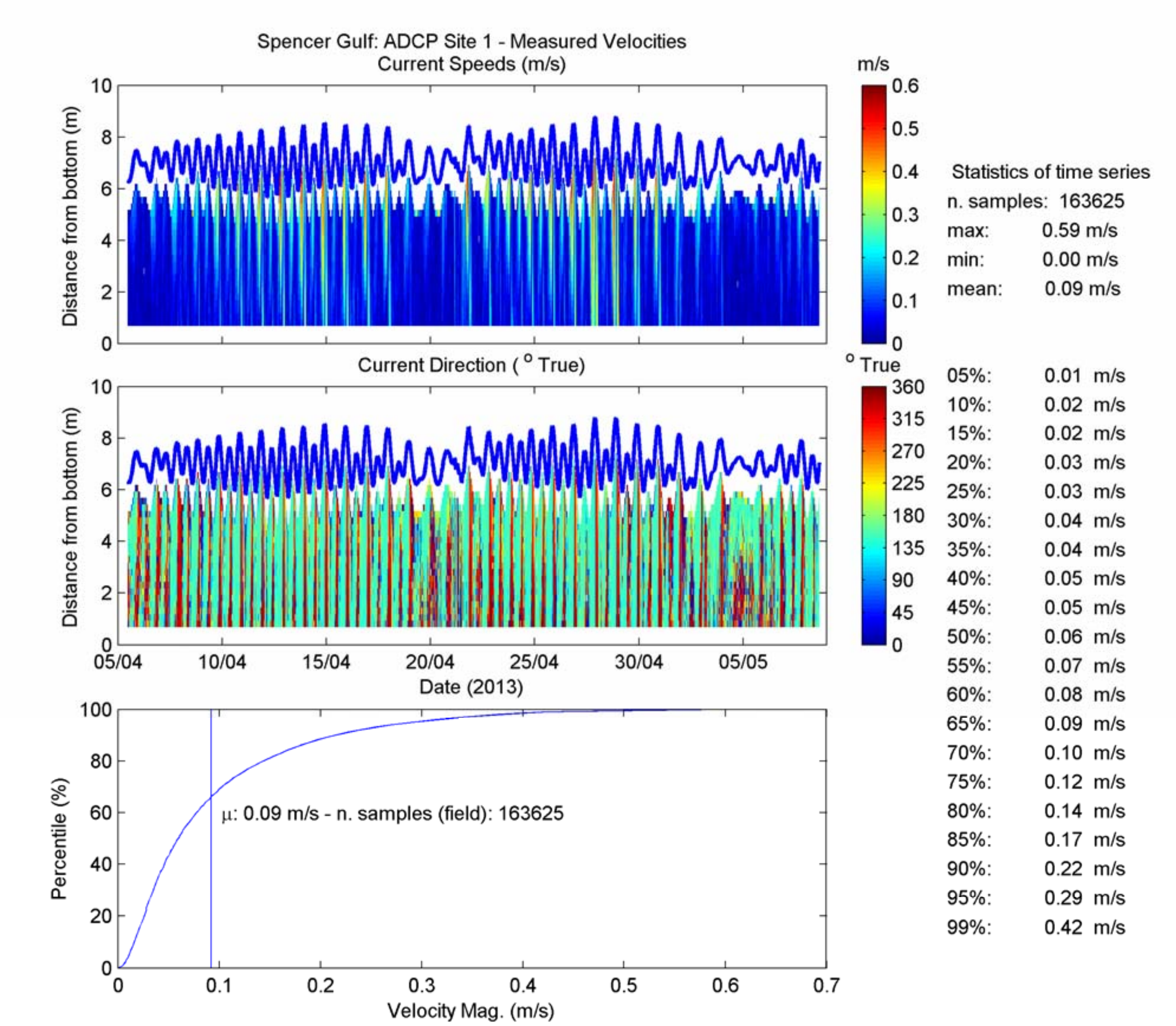


Figure 3-1 ADCP Measurements at Site 1

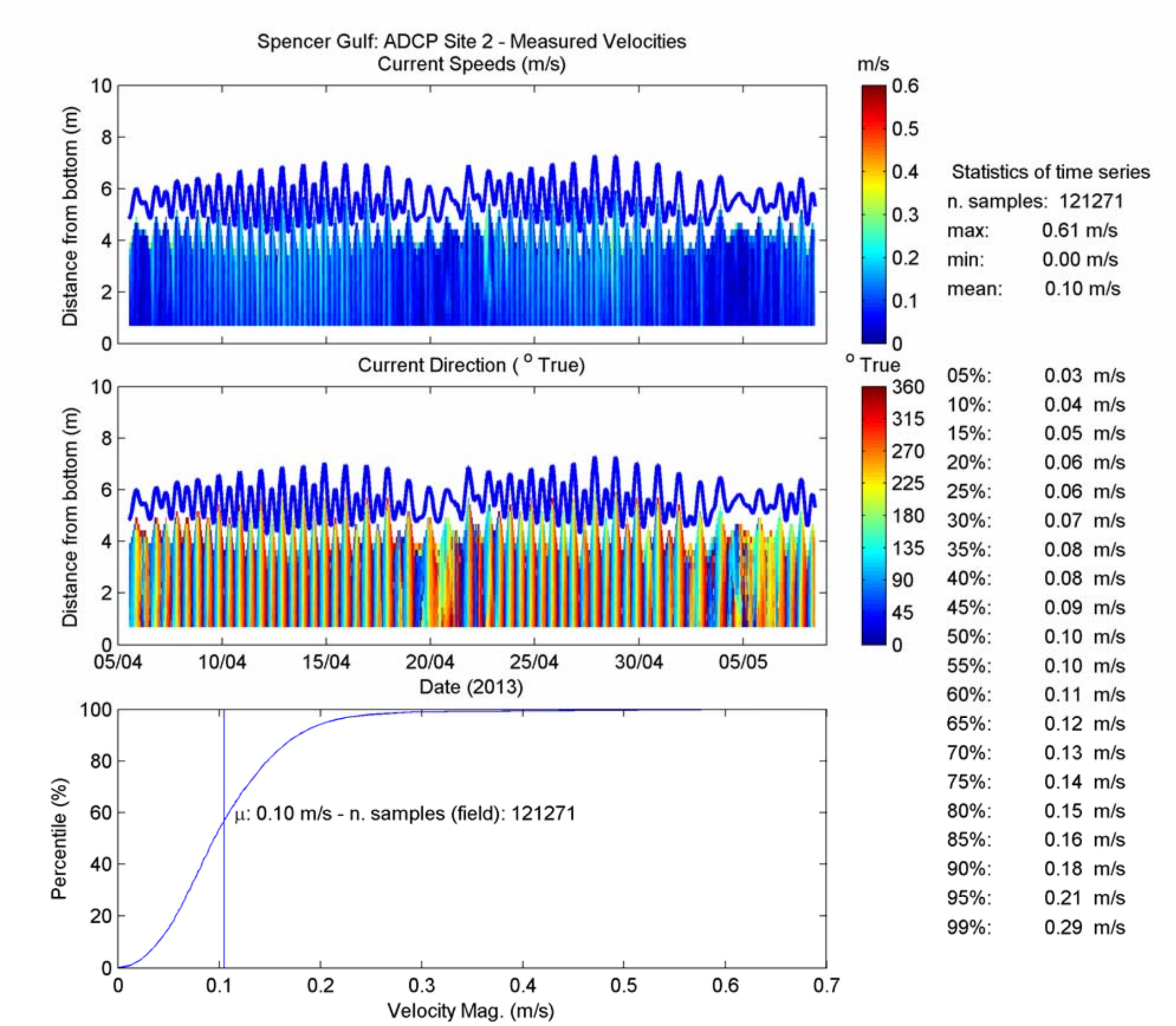


Figure 3-2 ADCP Measurements at Site 2

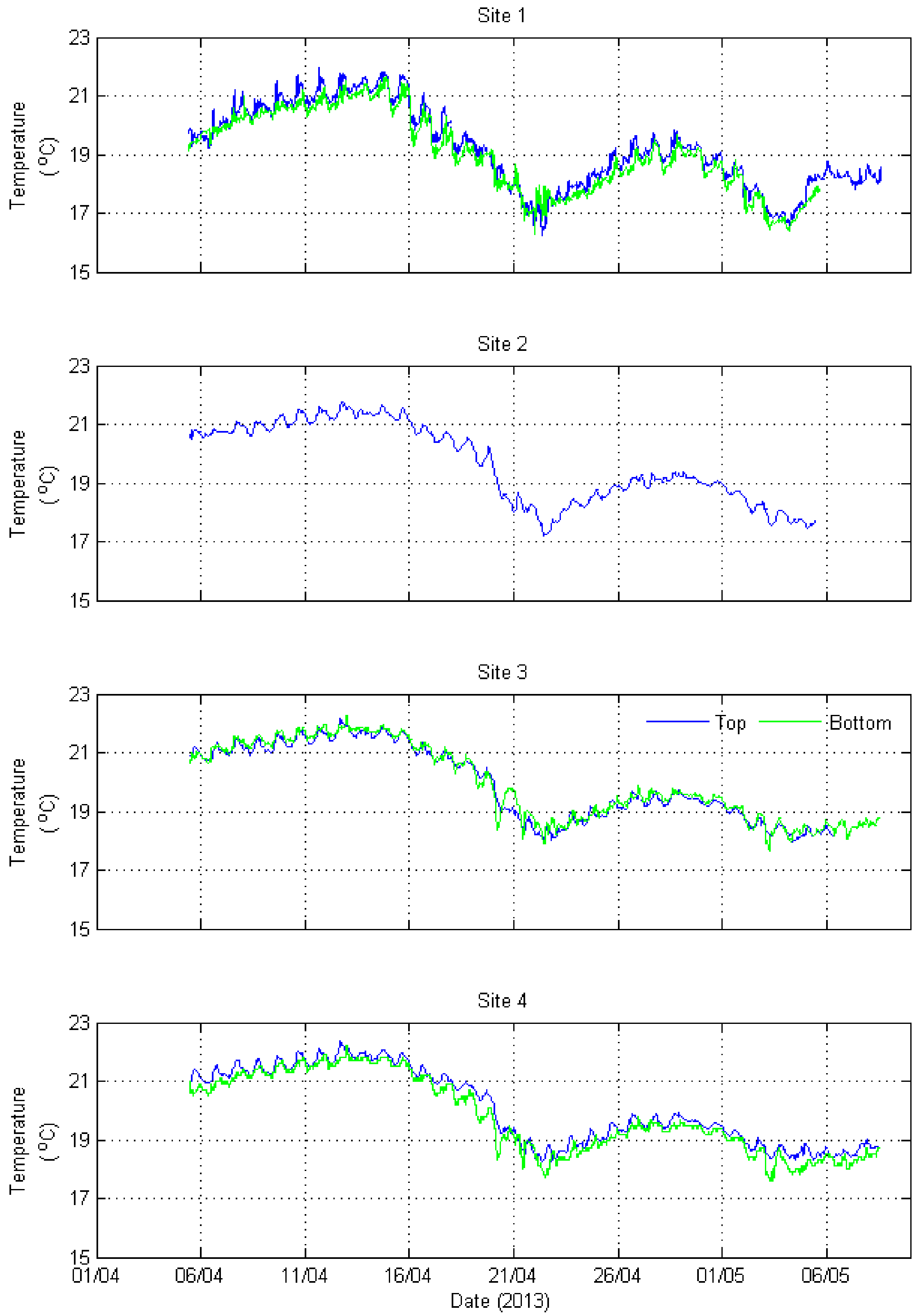


Figure 3-3 CTD Temperature Measurements

BMT WBM

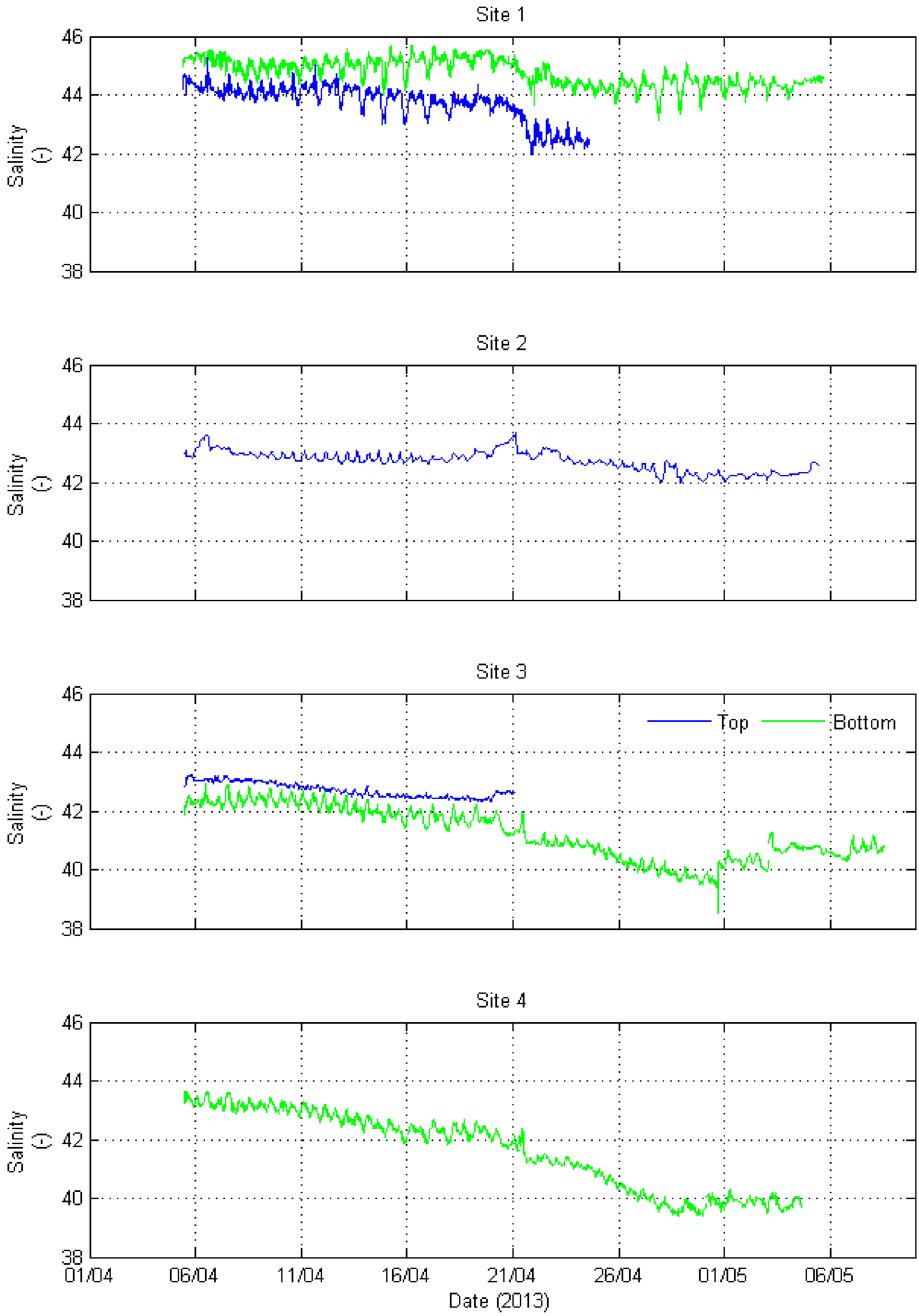


Figure 3-4 CTD Salinity Measurements

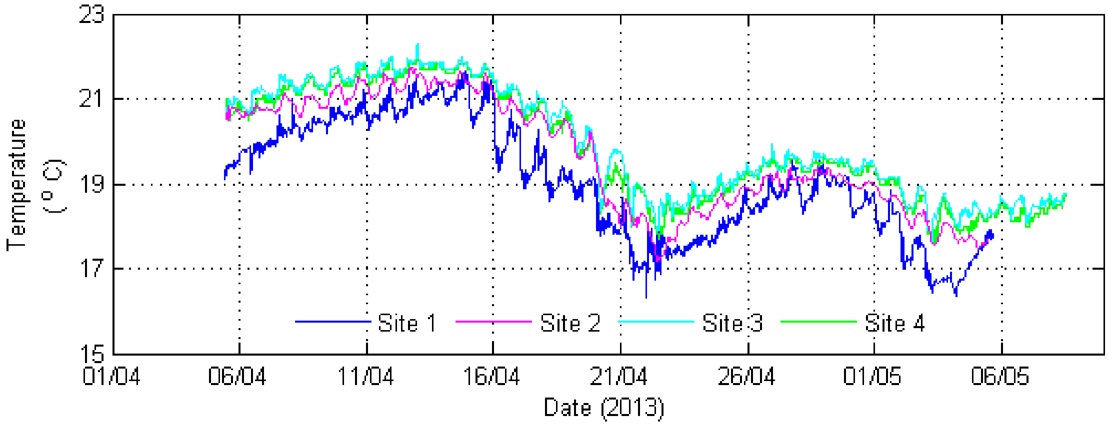


Figure 3-5 CTD Temperature Measurements – Comparisons at Surface between All Sites

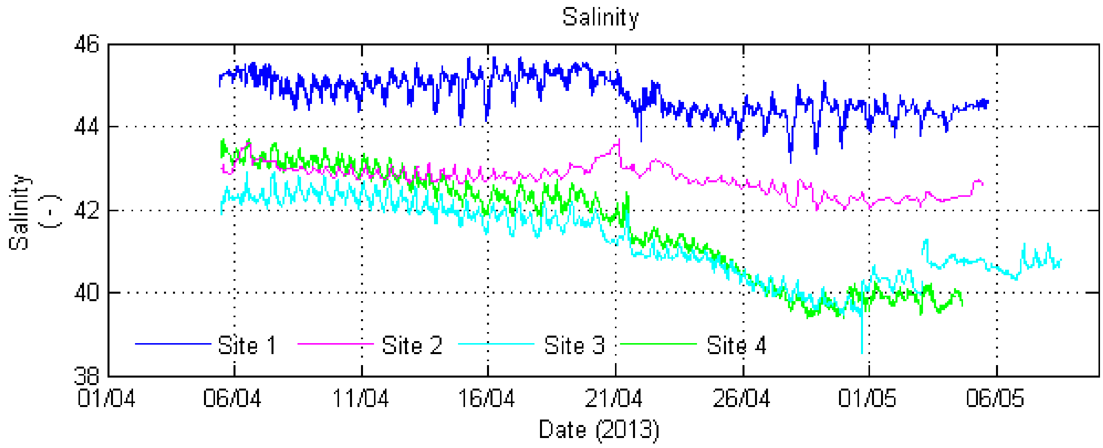


Figure 3-6 CTD Salinity Measurements – Comparisons at Surface between All Sites

4 DISCHARGE MODELLING

For cooling water discharges, the effluent will be warmer than the receiving water, therefore less dense, and will accelerate upwards due to buoyancy. In the near field, the acceleration is counteracted by entrainment of ambient water into the plume and it is this entrainment that produces mixing and dilution of the plume. Depending on the local conditions and outfall design characteristics, the plume can present distinctive behavior, as summarised by Jirka et al. (1996).

Before the assessments are described, it is convenient to address a few basic terminologies and concepts adopted in this study.

Nearfield - is defined as an area of the receiving environment near the point of discharge where the effluent jet trajectory and dilution is governed by the momentum flux, buoyancy flux and geometry of a diffuser/outlet.

Far field - is the region of the receiving water where the plume trajectory and dilution are controlled by horizontal buoyant spreading and the ambient flow.

The near field is therefore the region where the outfall design can exert control of the effluent dilution and the far field is the area where the ambient mixing processes dominate (Jirka et al. 1996).

Mixing zone - is a stipulated area or distance in the immediate vicinity of the point of discharge where a certain quality criteria can be exceeded. The mixing zone is often defined in such a way to specify criteria associated with regulatory compliance.

4.1.1 Water Quality Guidelines

The existing Environment Protection (Water Quality) Policy 2003 (SA EPA 2003) does not have a specific guideline addressing temperature increases due to effluent discharges. As a general rule, the SA EPA negotiates appropriate guidelines on a case by case basis. Based on precedents in South Australia, the SA EPA is likely to require that temperatures resulting from the disposal of cooling water into the Port Pirie River are no greater than 2 °C above the ambient temperature 20 m from the outfall (S Gaylard, SA EPA, *pers. comm.* 24 May 2013). This guideline is hereafter referred to as present guideline.

It is also relevant that a draft Environment Protection (Water Quality) Policy 2012 (SA EPA 2012), based on the ANZECC/ARMCANZ 2000 Water Quality Guidelines, is likely to replace the existing policy in 2014. The new policy requires that the resultant median water temperature does not exceed the 80th percentile (i.e. 20th percentile temperature exceedence) of the ambient water temperature at the edge of an agreed mixing zone. This mixing zone is likely to be specified at 20 m from the outfall, as per the present guidelines, however this is yet to be confirmed.

4.2 Conceptual Alternatives

As mentioned in Section 2, four conceptual locations are being considered for the upgraded facility outfall, as shown in Figure 2-3. PP02 is to be co-located with the existing discharge. PP03 to PP05 will be located in the Port Pirie River. PP05 is located closest to Germein Bay approximately 4.7 km from the river mouth. PP04 is the furthest, about 5.6 km from the mouth. PP03 is near the existing and proposed intakes (~100 m), approximately 5.1 km from the Port Pirie River mouth.

The expected temperature and salinity changes in the cooling water effluent will depend on the characteristics of the cooling water system. This information was provided by Nyrstar and is presented in Table 4-1.

For all the configurations, the cooling water flow rate will be 1.64 m^3/s. The water intake will be located with the existing intake. However, water will be withdrawn at depth approximately 1.0 m from the seabed. The existing intake withdraws water at about 2.0 m below mean sea water level (David Wiltshire, pers. comm.).

Table 4-1 Conceptual Outfall Characteristics

Outfall location	Coordinates		Temp. increase (°C)	Salinity increase (%)
	Latitude	Longitude		
PP02:	33° 09' 39.50'' S	138° 00' 20.93'' E	10	0
			8	0.35
			5	0.88
			2	1.41
PP03	33° 10' 03.15'' S	138° 00' 50.96'' E	10	0
			8	0.35
			5	0.88
			2	1.41
PP04:	33° 10' 19.27'' S	138° 00' 46.02'' E	10	0
			8	0.35
			5	0.88
			2	1.41
PP05:	33° 09' 51.91'' S	138° 00' 51.97'' E	10	0
			8	0.35
			5	0.88
			2	1.41

4.3 Nearfield Assessment

Two well-established models were adopted to quantify the outfall discharge plume characteristics: CORMIX (Cornell Mixing Zone Model, Jirka et al. 1996) and Visual Plumes (Frick et al. 2003). These models were chosen as they are widely used for outfall design and both are tools recommended by the United States EPA. Based on ambient conditions and outfall characteristics, the models output temperature, dilution and plume geometrical characteristics at nominated distances from the diffuser. The main aspect of the present assessment is investigation of the dilution factor and associated temperature increase at 20 m from the diffuser as required by the water quality guidelines described above.

It is noted that the sole objective of this assessment is to demonstrate an outfall at the proposed sites can be successfully designed to meet the EPA criteria, and as such results presented in this report should not be used for any other purpose (i.e. basis of engineering design). Further works will be required (such as CFD modelling) to support more detailed design works.

4.3.1 Model Configurations

For each outfall specification (i.e. number of ports) and ambient condition (i.e. 7 ambient velocities and 2 ambient temperatures), a series of CORMIX and Visual Plumes models were set-up and executed, including the following configurations:

- CORMIX assuming a single port;
- CORMIX assuming multiple ports (slot line discharge) far away from the bank;
- CORMIX assuming multiple ports (slot line discharge) at 10 m from the bank;
- Visual Plumes assuming a single port; and
- Visual Plumes assuming multiport diffusers.

Adoption of these configurations across two comparable models was undertaken to provide sensitivity and confidence in the modelling results.

4.3.2 Model Assumptions and Limitations

For multiple-port diffusers (as adopted in this assessment) CORMIX assumes the configuration as a rectangular (2 dimensional) slot discharge, as if the discharge plumes were completely merged from exiting the port nozzles. This assumption neglects significant amount of mixing along the interface of the plumes of each individual port prior to merging. Visual Plumes, on the other hand, does not make this assumption and it allows for true merging of the individual port discharges. In order to compare both models under similar conditions, we have also compared the models using a single port configuration. These allowed us to define a reasonable spacing between ports, so as to determine the total diffuser length.

CORMIX model schemes were validated against numerous laboratory and field measurements (Jirka et al. 1996), however, CORMIX has less reliable results under low or no ambient velocity conditions. To overcome this limitation we extrapolated results from other ambient velocities to estimate the dilutions under stagnant conditions. This procedure of extrapolating CORMIX dilutions has been adopted in other discharge studies (BMT WBM 2011).

As Visual Plumes is unable to predict conditions resulting from bank attachment, the effects of potential bank attachment was explored with CORMIX only. Additionally, Visual Plumes does not provide outputs beyond the point where the plume reaches the surface. In the case these distances are shorter than 20 m, these values are reported.

The models' configurations did not assume surface heat exchange. This is a generally conservative condition, assuming warmer water would lose heat to the atmosphere, therefore cooling more than the predictions presented here.

The models did not include the influence of the unsteady nature of tidal flow. A more sophisticated approach using Computational Fluid Dynamics (i.e. CFD) needs to be adopted to investigate the unsteady flow effects in the plume, as well as to support detailed engineering design works, should these be required.

4.3.3 Outfall Characteristics

As discussed above, the proposed upgraded cooling water discharge will be designed for:

- Flow rate of up to 1.64 m3/s; and
- No more than 10 ^{o}C above background temperature at point of discharge.

For present water quality guidelines (2 ^{o}C above background), this temperature corresponds to a dilution factor of 5.0 at 20 m from the discharge location, neglecting effects of surface heat exchange (as described above).

Nearfield assessments were conducted for configurations applicable to outfalls PP03 to PP05. All of these are proposed to be located at similar depths and under similar ambient conditions.

Consistent with the conceptual phase of this project, no specific outfall diffuser plans or specifications (exception to flow rate and temperature increase) were provided. In order to approach the problem in a pragmatic fashion, two typical outfall design specifications were adopted for this nearfield investigation. They consisted of a major pipe aligned with the Port Pirie River western shoreline installed under the seabed. Twelve and eighteen equally-spaced ports raising 20 cm from the seabed and pointing towards the centre of the Port Pirie River were assumed. The ports were also assumed to be pointing at 45^{o} angle from the vertical. These configurations were chosen as to:

- avoid contact of plume with the seabed, therefore maximising dilutions;
- minimise plume bank attachment, therefore maximising dilutions; and
- avoid interference with shipping traffic.

For this preliminary assessment, a typical port diameter of 15 cm was assumed. The number of ports was chosen so as to maintain the nozzle exit velocities below 8.0 m/s and a total diffuser length shorter than 80 m. Although arbitrarily chosen, these conditions were adopted as they are generally in the operation range to avoid cavitation and damage to nozzles. No specific consideration was given to available hydraulic head or pumping requirements for the discharge, however this could be examined at a later stage in the project if required.

Ambient conditions were chosen as to replicate the annual temperature extremes (12 and 25 ^{o}C) and the measured currents presented in Figure 3-1. For the purpose of this analysis, the water column was assumed to be homogeneous in terms of temperature, salinity and velocity. This assumption was based in the field observations presented in Section 3. The maximum observed density stratification was about 1 kg/m^3 over the water column (but it was typically much less). The density difference induced by a 10 ^{o}C temperature increase is more than four times larger than this maximum stratification observed in the field.

Figure 4-1 shows a schematic of the outfall configuration assumed in the present assessment, whilst Table 4-2 summarises the assumed outfall characteristics and ambient conditions. Distances were measured from the downstream edges of the diffuser.

For a single port diffuser CORMIX computed a (gaussian) width when the plume reaches the surface (i.e. the plume diameter) to be approximately 3.0 m. A typical port spacing of 4.0 m was chosen in such a way to avoid significant plume interaction, thus maximising the plume mixing potential.

PP02 was not considered in these nearfield assessments as it delivers cooling water to a very shallow receiving environment (< 2.0 m depth), therefore little mixing is expected from it until the cooling water reaches Spencer Gulf. This is consistent with diver observations throughout the length of First Creek (David Wiltshire, pers. comm.). Mixing from PP02 will therefore be controlled by far field conditions, which is explored later in this report (see Section 4.4).

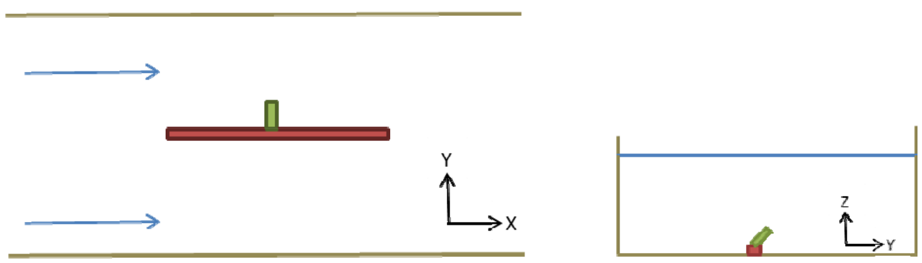


Figure 4-1 Outfall Configuration Schematic. Left Panel: Plan View. Right Panel: Side View.

Table 4-2 Assessed Outfall Characteristics and Ambient Conditions

Discharge Flow Rate (m^3/s)	Temperature Increase (^oC)	Nozzle Diameter (cm)	Port Spacing (m)	Number of Ports (-)	Total Diffuser Length (m)	Port Exit Velocity (m/s)	Ambient Temperature (^oC)	Ambient Velocities (m/s)
1.64	10	15	4.0	12	48.0	7.7	12	0.00 0.02 0.05 0.10 0.20 0.25 0.50
							25	0.00 0.02 0.05 0.10 0.20 0.25 0.50
				18	72.0	5.2	12	0.00 0.02 0.05 0.10 0.20 0.25 0.50
							25	0.00 0.02 0.05 0.10 0.20 0.25 0.50

4.3.4 Nearfield Results

For each of the executed models, results are presented for both temperature and dilution factor as ranges that encompass the results of all model configurations described above. In general, CORMIX results assuming a single port diffuser were the least conservative; they tended to present the highest dilution and lowest temperature results. Contrastingly, CORMIX results assuming multiple ports at 10 m from the bank were the most conservative.

The effect of ambient temperature was shown to have negligible effects in the resulting dilutions. These results occurred because the discharged water is heated up relative to the background conditions, and as such the buoyancy of the discharge was essentially the same for all cases. Thus, a similar level of dilution (and temperature increases) can be assumed throughout the year for a same temperature difference between ambient and the discharge. For brevity only results for 25 ^{o}C ambient temperature are reported.

4.3.4.1 Temperature at 20.0 m from Diffuser

Temperatures at 20 m from the diffuser are shown in Figure 4-2. CORMIX did not produce results for 0.0 m/s ambient velocities (as discussed above). We linearly extrapolated the results for these conditions from the results of the 0.02 m/s and 0.05 m/s. Visual Plumes did not produce results 20 m from the diffuser; therefore we adopted the results as the plumes reach the surface, which in all Visual Plumes runs were less than 20.0 m from the diffuser.

For both 12 and 18-port diffusers the minimum, mean, and average values for all ambient velocities produced temperatures well below the existing guideline values. The mean of all models varied between 25.3 and 26.0 ^{o}C for all ambient velocities considered.

For relatively strong ambient currents (> 10 cm/s), only the results of CORMIX assuming the discharge 10 m from the bank produced temperatures near or above the guideline. The results of the 12-port diffuser met the guidelines for all ambient velocities with temperatures between 26.9 and 27.0 ^{o}C for ambient velocities larger or equal 10 cm/s.

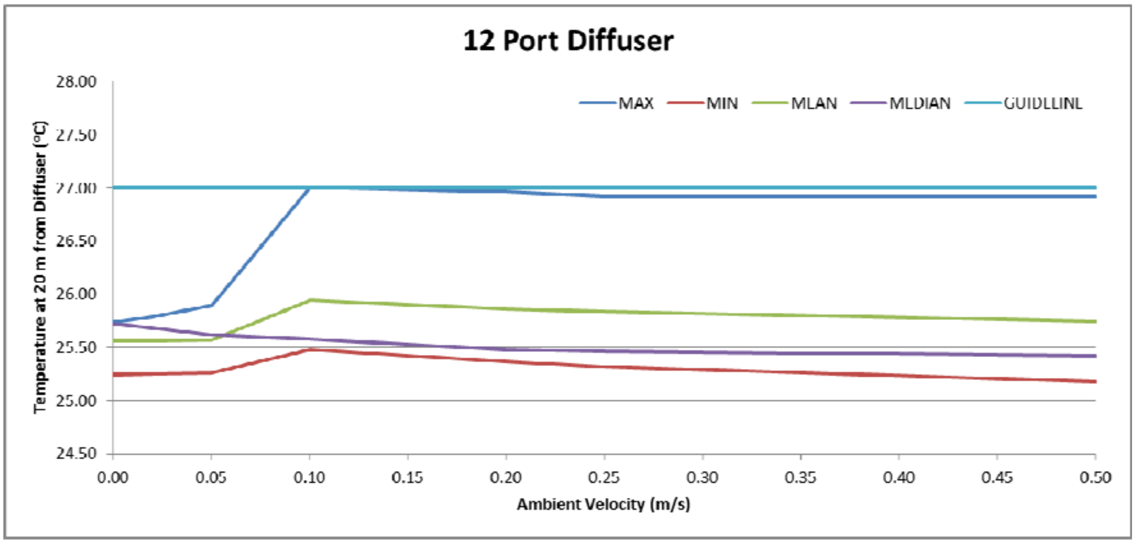
For the 18-port diffuser (and same CORMIX configuration), temperatures at 20 m from the diffuser for velocities above 5 cm/s exceeded the guideline values. In these cases temperatures varied between 27.4 and 27.8 ^{o}C.

4.3.4.2 Dilution at 20.0 m from Diffuser

Dilutions at 20 m from the diffuser are shown in Figure 4-3. Reflecting the temperature results, both 12 and 18-port diffusers the maximum, mean, and average values for all ambient velocities produced dilutions well above the requisite dilution factor for the effluent to meet the existing temperature guideline values (5.0). Mean values varied between 14.1 and 34.0 for all cases studied.

For relatively strong ambient currents (> 10 cm/s), only the results of CORMIX assuming the discharge 10 m from the bank produced dilutions near or below the existing guidelines. The results of the 12-port diffuser met the guidelines for all ambient velocities with dilution factors between 5.0 and 5.2 for ambient velocities larger or equal 10 cm/s.

For the 18-port diffuser (and same CORMIX configuration), dilutions at 20 m from the diffuser for velocities above 5 cm/s exceeded the guideline values. In these cases dilution factors varied between 3.6 and 4.2. Reasons why the 12 port diffuser performed better than the 18 port diffuser are discussed later in the text (Section 5).



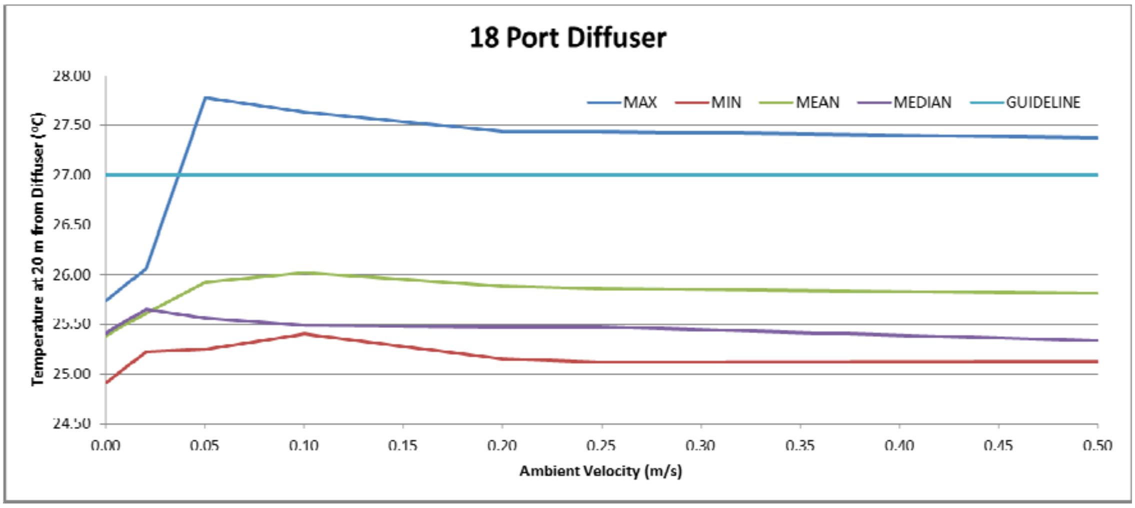
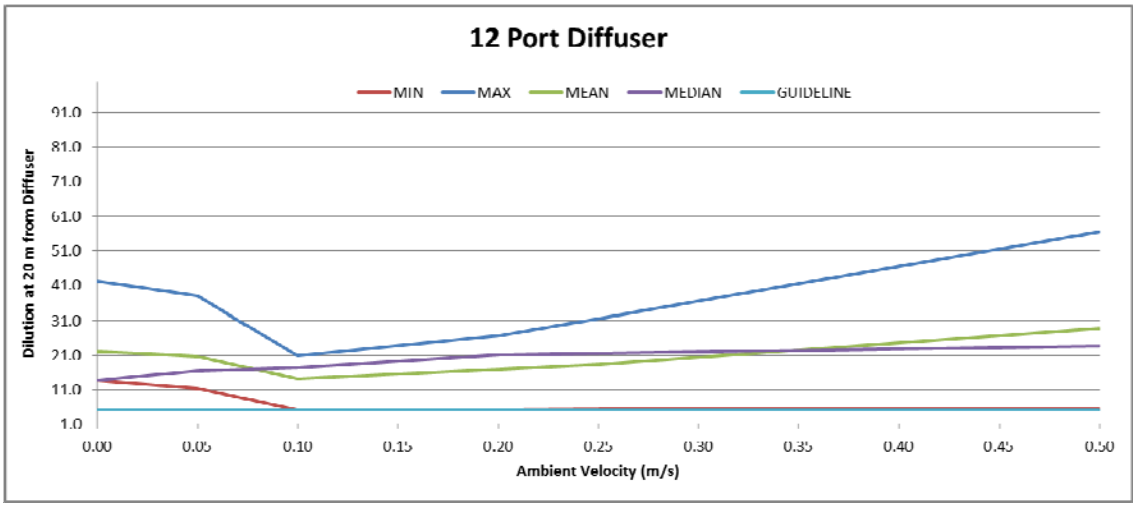


Figure 4-2 Range of Temperature 20 m from Diffuser Results from All Outfall Models. Top Panel: 12-port diffuser. Lower Panel: 18-port diffuser.



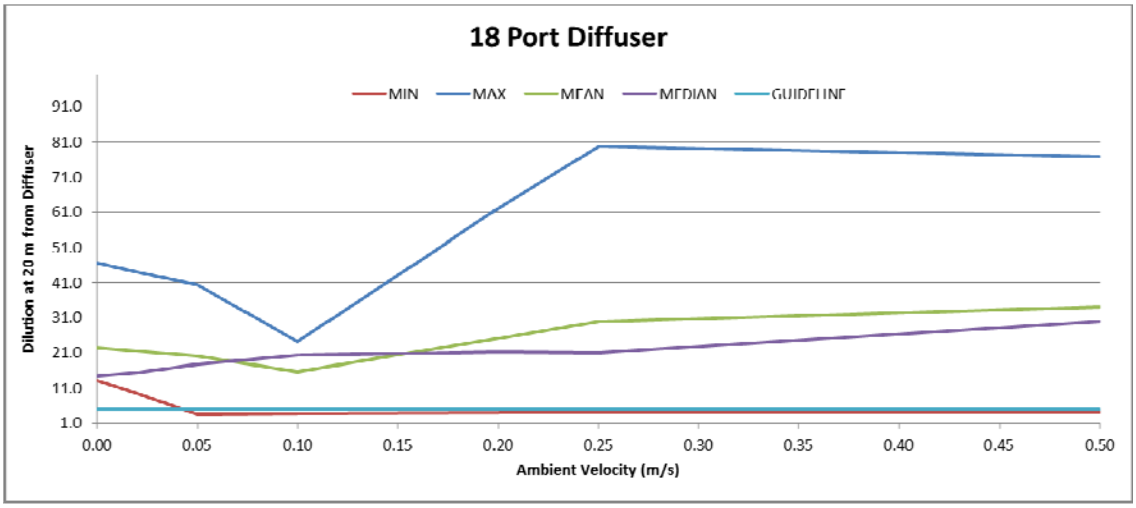


Figure 4-3 Range of Dilution 20 m from the Diffuser Results from All Outfall Models. Top Panel: 12-port diffuser. Lower Panel: 18-port diffuser.

4.3.4.3 Draft Water Quality Guidelines

The ability of the outfalls to meet the new draft Environment Protection (Water Quality) Policy 2012 guidelines was tested by adopting the following procedure:

1. The lowest dilutions obtained at 20 m from the diffuser were used to produce a look-up table (assuming linear interpolation) of dilution as a function of ambient velocities (Figure 4-4);

2. Temperature as measured by the CTD (Figure 3-3) were used to represent ambient conditions;

3. Cooling water discharges temperatures were calculated by adding 10 ^{o}C to the ambient conditions;

4. Temperatures at 20 m from the diffuser were calculated using the ADCP measurements (Figure 4) to represent ambient velocities and the dilutions look-up table (Figure 4-4);

5. The 50th percentile temperature at 20 m from the diffuser and the 80th percentile dilution from the data presented in Figure 3-3 (Site 1) were calculated, so comparisons could be made with guidelines. .

The analysis was performed for one month of data collected between 06 April and 06 May 2013 (bottom temperatures) and between 06 April and 05 May 2013 (top temperatures).

Results of the analysis are presented in Figure 4-5 for the 12 port diffuser, considering the temperature measured at the top of the water column. The values for comparisons with the new draft guidelines are presented in Table 4-3. For both top and bottom temperatures (April 2013), the 12-port diffuser would meet the draft proposed guidelines. Contrastingly, the 18-port diffuser would not meet the guidelines (Table 4-3). The reasons for the differences between diffuser designs are discussed later in Section 6.

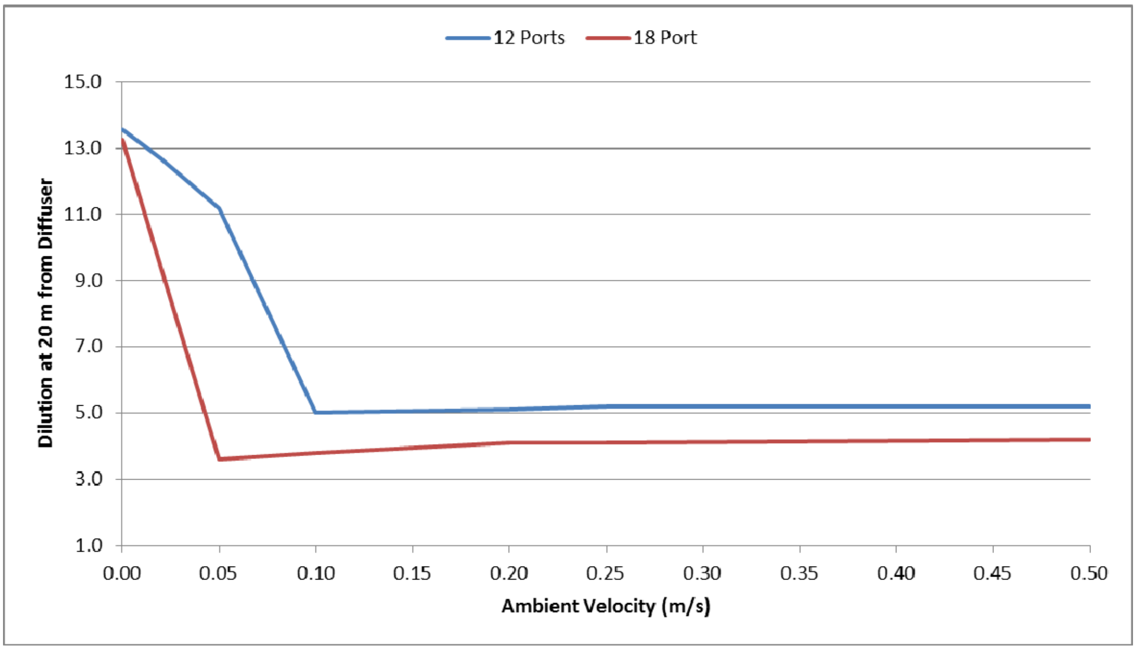


Figure 4-4 Minimum Dilution at 20 m from Diffuser as a Function of Ambient Velocity Magnitude

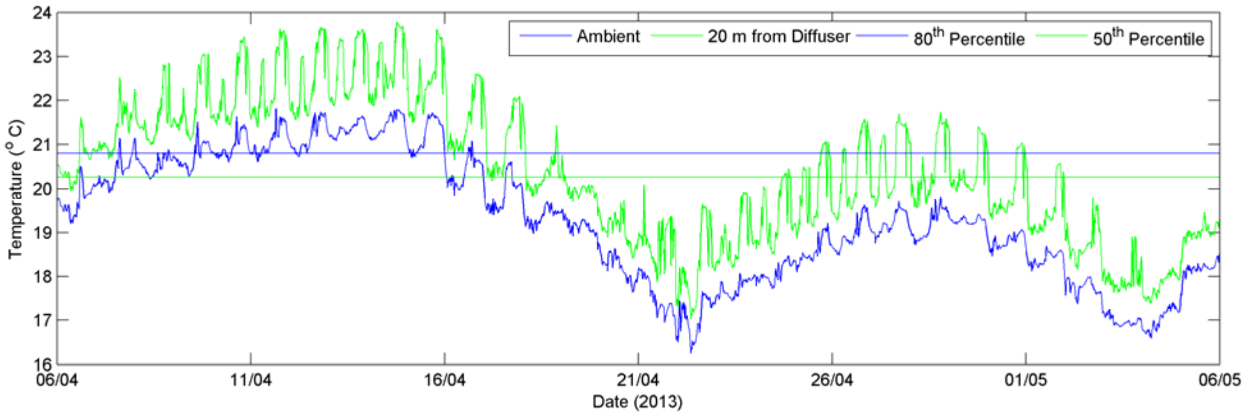


Figure 4-5 Comparison of Ambient Temperatures (blue) and Temperatures at 20 m from Diffuser (green) for April 2013. Straight Lines refer to 80th percentile ambient temperature (blue) and 50th percentile temperatures 20 m from diffuser (green).

Table 4-3 Temperature Values for Adoption in the New Proposed Guidelines

Number of Ports	Measurement Location	80th Percentile Ambient Temperature	50th Percentile Temperature 20 m from Diffuser	Acceptable
12	Top	20.80 °C	20.26 °C	Yes
	Bottom	20.56 °C	20.08 °C	Yes
18	Top	20.80 °C	21.18 °C	No
	Bottom	20.56 °C	20.92 °C	No

4.4 Far Field Assessment

A hydrodynamic model was developed with the objectives of undertaking far field assessments of the cooling water discharge. The details of the adopted model framework, model set-up and comparison with the field measurements described in Section 3 are presented below. These sections are followed by analysis of alternative discharge scenarios.

4.4.1 Model Description

The numerical modelling framework adopted in the present study was based on the three-dimensional TUFLOW FV modelling suite. TUFLOW FV is a coupled 3D hydrodynamics (HD) and advection-dispersion (AD) model that adopts a flexible mesh to define the computational domain. A baroclinic model configuration with density coupling from both temperature and salinity fields was applied in order to represent stratification processes that occur within Spencer Gulf. TUFLOW FV has been used by BMT WBM on several studies in Australia and overseas, including:

- Gladstone Western Basin Dredging and Disposal Project (coastal studies);
- Murray River Mouth, Coorong & Lower Lakes Environmental & Morphological Modeling;

- MetOcean and Sedimentation Study for LNG Import Terminal, Pipavav Port, India;
- Hawkesbury-Napean River System Water Quality Modelling, NSW, and
- Townsville Port Expansion EIS Project (coastal studies).

Adoption of a flexible mesh model allowed adjustment of the spatial resolution of the computational domain to apply high resolution in the Port Pirie River and areas immediately offshore of First Creek. Variable spatial resolution is important in the current study given the relatively large extent of the Gulf in comparison to the intricate details in the areas of interest near the proposed cooling water discharges. Computational efficiency was achieved by progressively reducing model resolution away from these areas of interest.

4.4.2 Model Extent and Mesh Definition

The Spencer Gulf model domain extended over an area of approximately 22,000 km^2. The southern limit of the domain extended from West Cape (Inneston) to Wedge Island, and from Wedge Island to Thistle Island. The land boundaries extended along the Eyre and Yorke Peninsulas to the head of the Gulf at Port Augusta. The model coverage area is presented in Figure 4-6.

The mesh resolution varied between 40 m inside the Port Pirie to approximately 3 km near the Gulf's mouth (Figure 4-6 and Figure 4-7). Horizontal cell sizes near First Creek were maintained below 100m, typically between 60 and 80 m. Careful consideration was given to delineate the navigation channel approaching Port Pirie as well as the several tidal creeks surrounding Port Pirie. However, the reach of First Creek between PP02, where effluent is delivered, for about 2.0 km towards the ocean is too narrow to be reasonably resolved by the model (without a very large computational expense), and as such was not included in the domain. The model mesh is shown in Figure 4-6 and Figure 4-7.

The model adopted a z-coordinate scheme with layer thicknesses of 1 m between -3.0 and -8.0 m AHD, and progressively increasing to 10 metres between -50.0 and -60.0 m AHD. Five sigma layers were used to between -3.0 m and the model free surface. A maximum of 21 layers were resolved in the deeper sections of the model domain.

4.4.3 Bathymetry

The bathymetry data was obtained from a Digital Elevation Model (DEM) of Spencer Gulf, which was produced from a combination of local navigation charts (AUS 136, AUS 776 to 778). This DEM was then referenced to AHD (Australian Height Datum) to provide for a consistent vertical datum over the entire domain. The resulting bathymetry is presented in Figure 2-1.

A shortcoming of the bathymetry based on the navigation charts is the lack of specification of bed elevations in the intertidal areas, which were initially specified at 0.0 m LAT (approximately -1.7 mAHD – see Figure 2-2 and Figure 4-8 below). As can be seen in the Google Earth image in Figure 2-3, the underwater relief nearshore and in the Port Pirie River is not flat as suggested in the navigation charts (Figure 4-8).

The specification of bathymetry within intertidal areas is of particularly importance for the performance of hydrodynamic models. In the absence of more refined information, we undertook an adjustment of the bathymetry in an attempt to obtain a more realistic description in the intertidal areas of the model. The Google Earth image was used to define regions associated with mangroves and sand banks in the intertidal areas surrounding Port Pirie (i.e. roughly a few km east of First Creek up to the latitude of the Spoil Ground shown in Figure 4-8). The bathymetry levels were then assigned as follows:

- A constant bathymetry level of -0.5 m AHD was applied to the regions associated with the mangroves;
- A constant bathymetry level of -0.8 m AHD was assigned to the regions associated with sand banks;
- A constant bathymetry level of 0.0 mAHD was assigned to the intertidal tributary creeks to the Port Pirie River;
- A constant bathymetry of -1.7 mAHD was assigned to First Creek. This was in line with spot depth measurements undertaken by divers in First Creek (David Wiltshire, pers. comm.); and
- A constant bathymetry of -1.0 mAHD was assigned to the upstream end of the Port Pirie River.

The resulting bathymetry adopted in the modelling is shown in the right panel of Figure 4-9. While we acknowledge such an approximation is not ideal, resources were not available to undertake a bathymetric survey within the time constraints of this project. For progressing this conceptual project phase to more detailed stages, a bathymetric survey will be required.

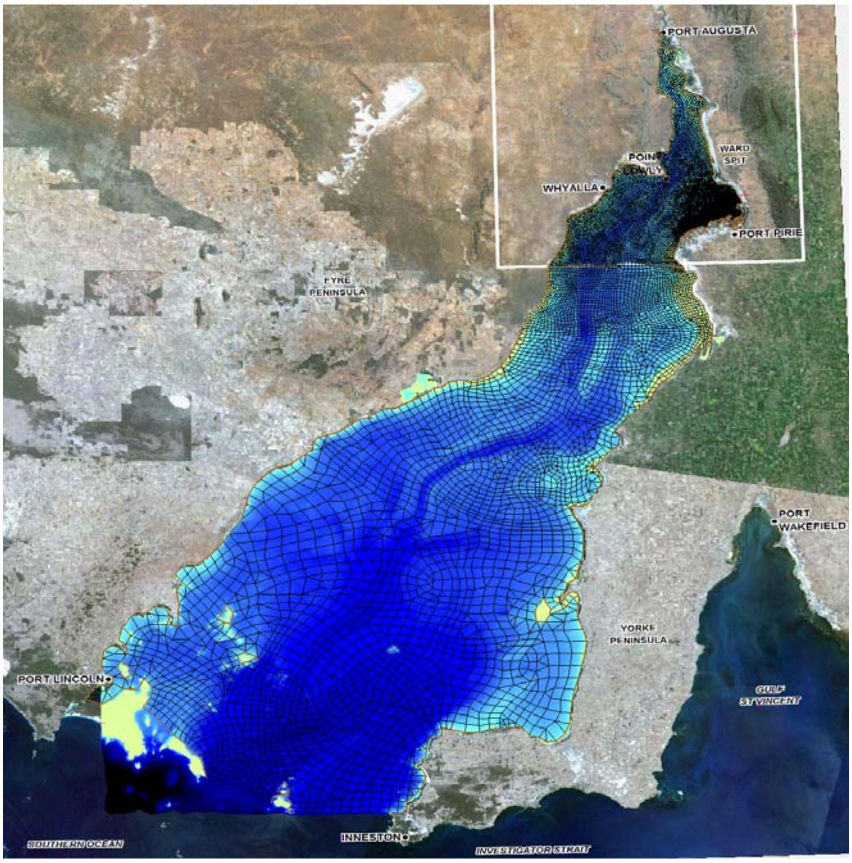


Figure 4-6 Model Extent and Numerical Mesh

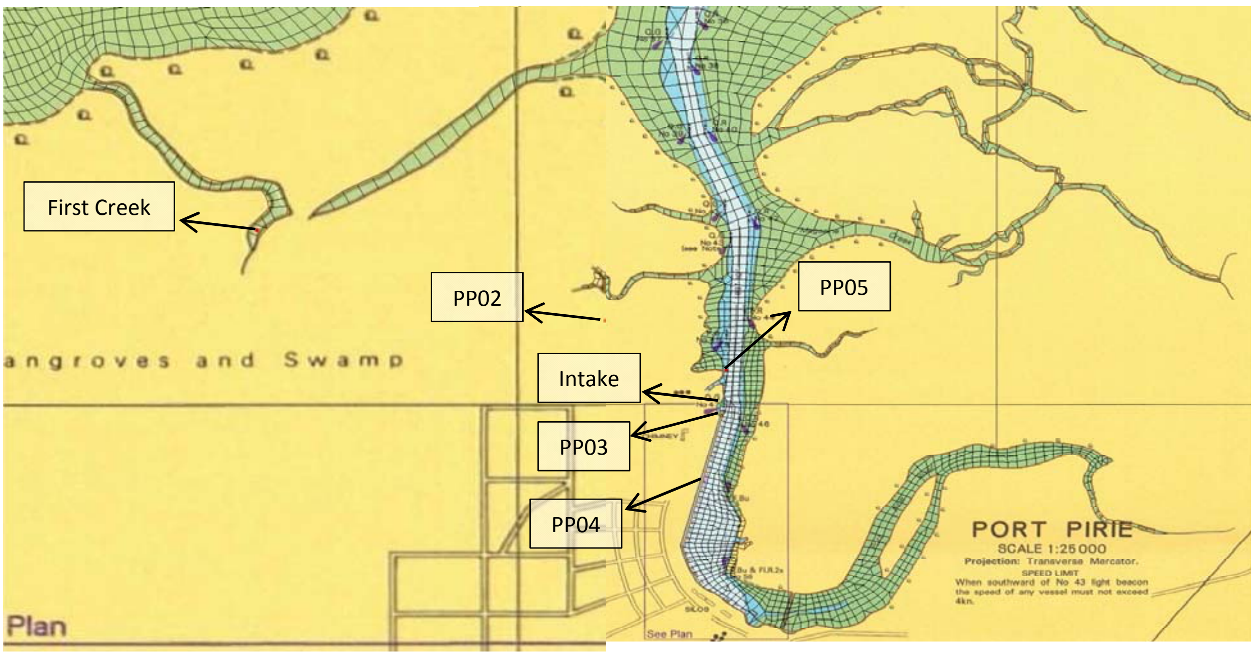


Figure 4-7 Numerical Mesh near Port Pirie. The mesh is superimposed on AUS 136 charts (AHS 2000). The images are a composite of the Approaches to Whyalla chart and Port Pirie chart and the Port Pirie chart. Scale shown does not apply.

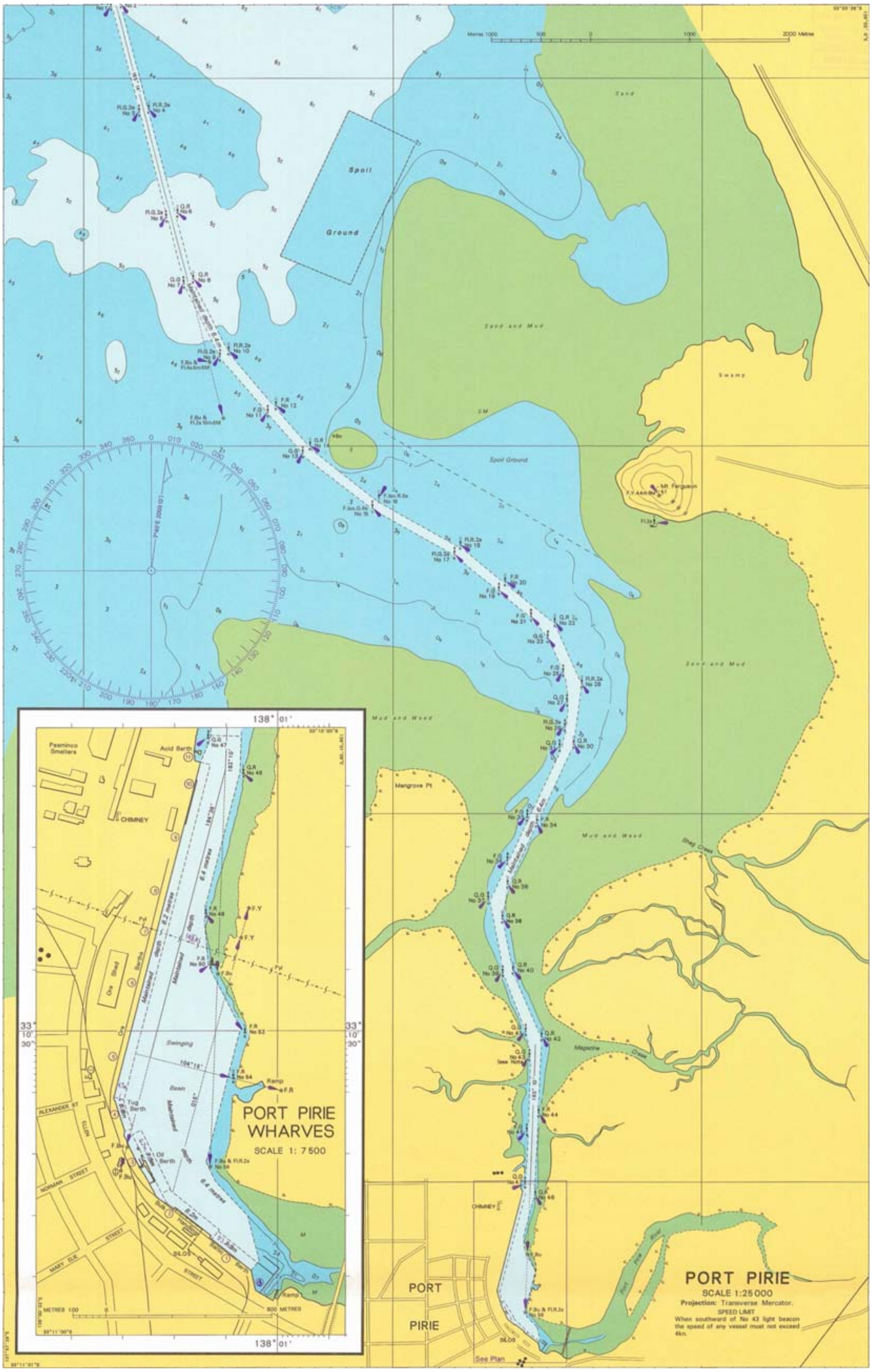


Figure 4-8 Bathymetry within Port Pirie and Port Pirie Wharves (Chart AUS 136, AHS 2000). Scales shown do not apply.

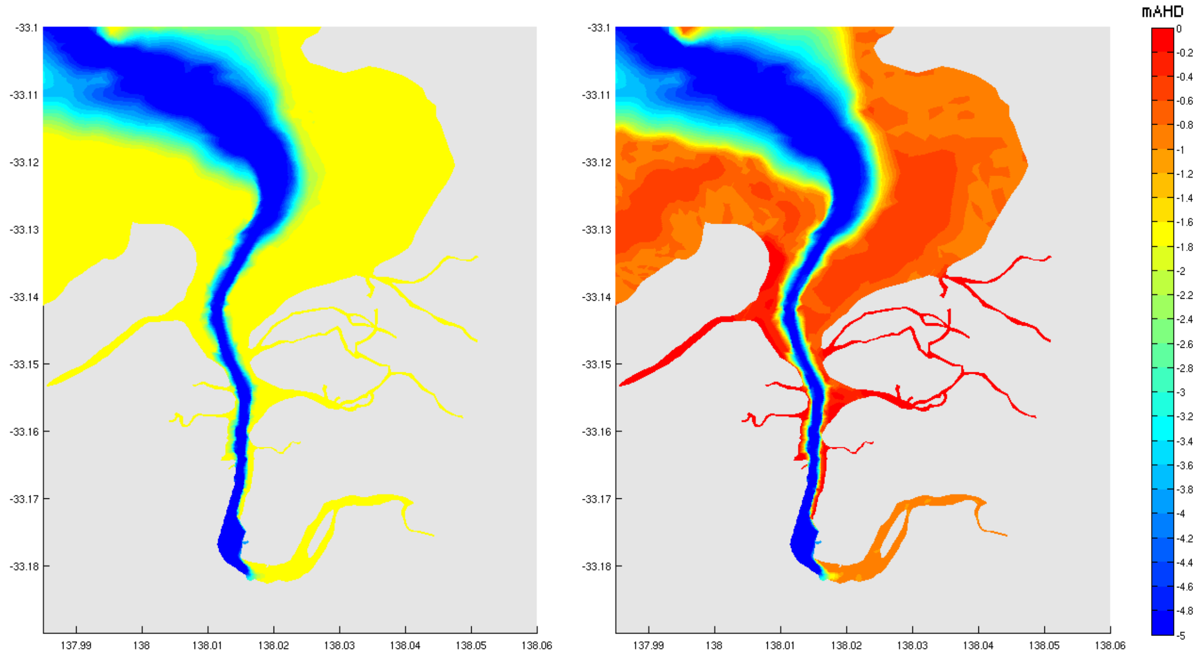


Figure 4-9 Development of Bathymetry in the Intertidal Areas near Port Pirie. Left Panel: Intertidal areas at a constant elevation corresponding to 0.0 m LAT (~ -1.7 m AHD). Right Panel: Adjusted bathymetry.

4.4.4 Comparisons with Field Data

4.4.4.1 Simulation Period

For comparisons with the field data described in Section 3, a simulation starting on 01 February 2013 and finishing on 10 May 2013 was executed. Approximately two months were used for spin-up and the remaining days were used for data analysis.

4.4.4.2 Boundary Conditions

The hydrodynamic model was forced by tides at the ocean boundaries, wind stresses and other meteorological variables at the free surface, and the existing and proposed cooling water discharges (when applicable).

Tides – tidal forcing was comprised of surface water elevations specified at the southern boundary of the domain. The elevations were derived from harmonic constituents at Pondalowie Bay using the Seafarer Tides software. Tidal levels were provided at every 15 minutes. For each of the tidal locations, daily temperature and salinity obtained from data assimilation global circulation models were adopted.

Meteorology – meteorological forcing at the free-surface consisted of wind speed and direction, air temperature, relative humidity, cloud cover (to estimate long wave radiation) and short wave radiation. With exception of solar radiation, data was sourced from the BoM station 018120 (Whyalla Aero). Solar radiation was available from BoM station 023304 (Adelaide Airport). Solar radiation at

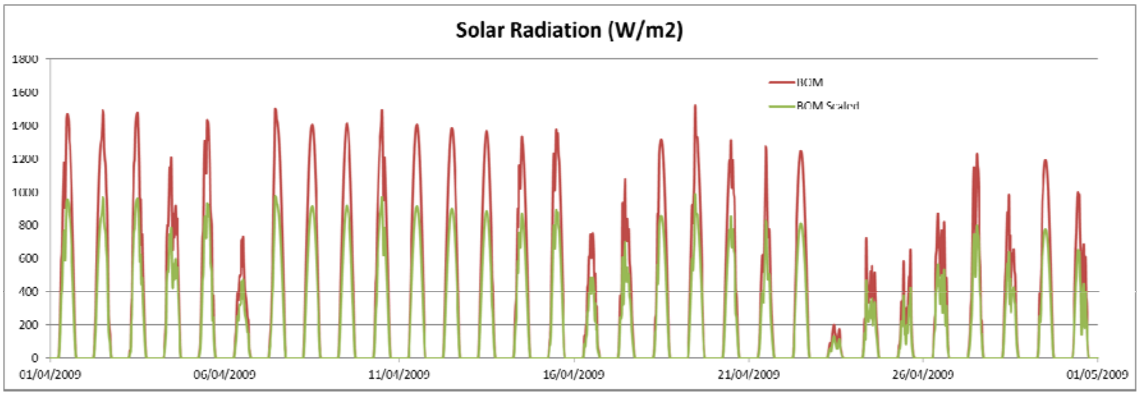
Adelaide Airport was deemed excessively high when contrasted with May-2009 data collected at Port Bonython (see BMT WBM 2011). While the data at Port Bonython peaked between 600 and 800 W/m^2, the Adelaide Airport data peaked above 1000 W/m^2. A scale factor of 0.65 was therefore applied to the Adelaide Airport data before adoption in the model. All meteorological data were available at every hour.

Existing Intake and Discharge – The existing intake and the discharge at First Creek ("Intake" and "First Creek" points annotated in Figure 4-7) were considered in the simulation by adopting a constant flow rate of 0.73 m^3/s. A temperature increase of 8 ^{o}C between the intake and the point of insertion of the discharge in the model was assumed. This assumption was based on spot measurements undertaken by Nyrstar, which indicated a temperature difference between intake and point PP02 (Figure 4-7) of approximately 9 ^{o}C (David Wilsthire, *pers. comm.*). Another 1 ^{o}C loss was assumed between point PP02 and the point of insertion in the model, again based on spot measurements undertaken by Nyrstar personnel at First Creek (David Wiltshire, *pers. comm.*). Further measurements are recommended to check this assumption.

4.4.4.3 Drag Coefficient

A constant Mannings coefficient of 0.022 was adopted to parameterise the bottom drag in TUFLOW FV. While this value is relatively large, particularly for the offshore areas, its specification had relatively little sensitivity at Site 1, where model results are in agreement with the field data (see below). For Site 2 in the Port Pirie River, the effects of the Manning's coefficient had very little sensitivity in comparison to the effects of the local bathymetry. Further adjustment of the coefficient was therefore unwarranted without a more proper specification of the bathymetry within the intertidal areas of the model domain.

Figure 4-10 Meteorological Boundary Conditions at Whyalla Aero



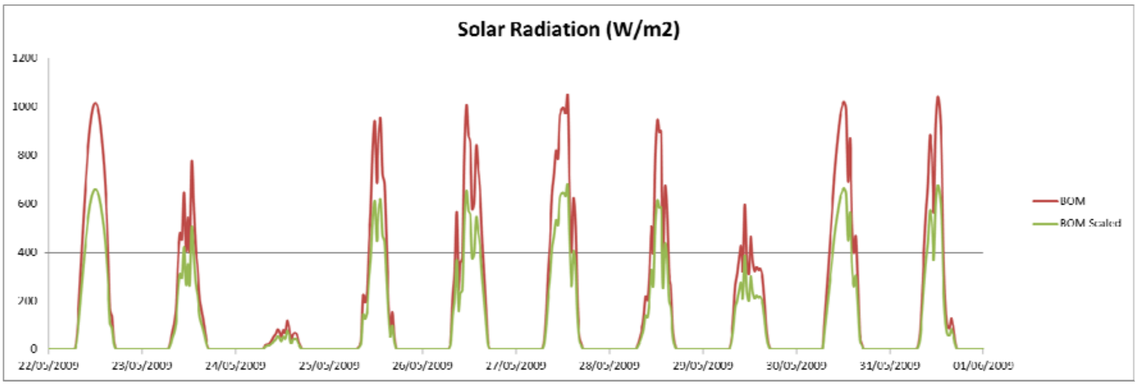


Figure 4-11 Solar Radiation at Adelaide Airport (Raw and Scaled). Top Panel: Modelling Period. Bottom Panel: May –June 2009 (for contrasting with BMT WBM 2011)

4.4.4.4 Initial Conditions

A cold start was adopted for velocity and water levels. Initialisation of salinity and temperature data was based on data collected by Dr. Rick Nunes-Vaz (Nunes 1985) on February 1983. Additionally, the same data from global assimilation models adopted at the open ocean boundary were used to complement the model initial conditions.

The initial temperature and salinity fields at the surface are given in Figure 4-12 and Figure 4-13, respectively.

In First Creek, a constant stratification of 7 ^{o}C was imposed along its length (top and bottom). Again, this was based on spot measurements along the Creek (David Wiltshire, pers. comm.). Model results (not shown) indicated that this stratification was stronger near the discharge and progressively reduced towards the mouth of the creek. However, the period of stratification was not permanent, particularly at low tides when the water column was well mixed. It is recommended that temperature measurements be continuously undertaken in First Creek in order to capture the effects of the tides on the stratification regime within the creek.

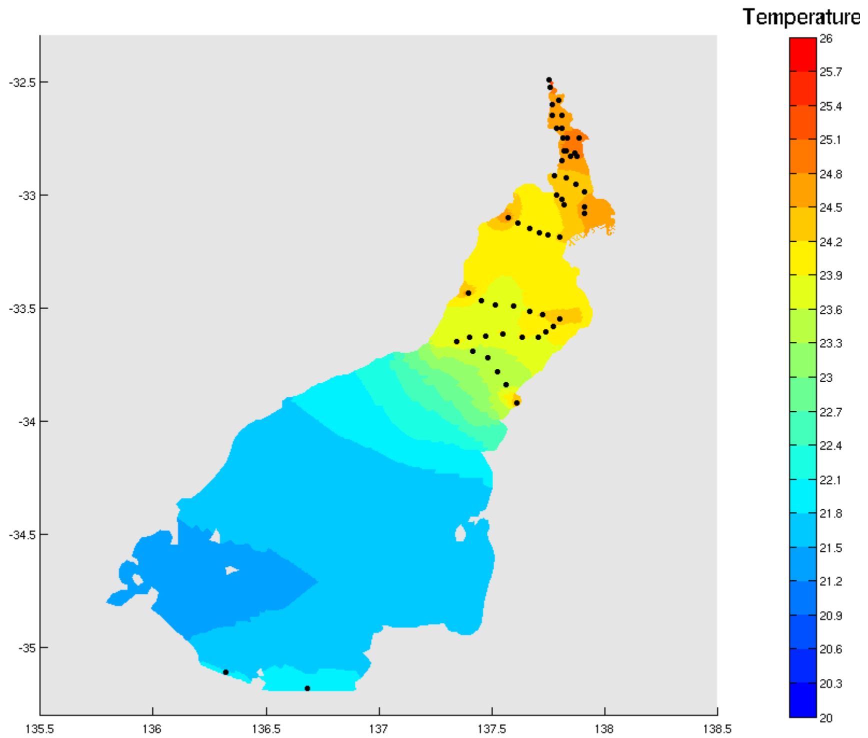


Figure 4-12 Temperature Initial Conditions for Autumn Simulations (February 2013)

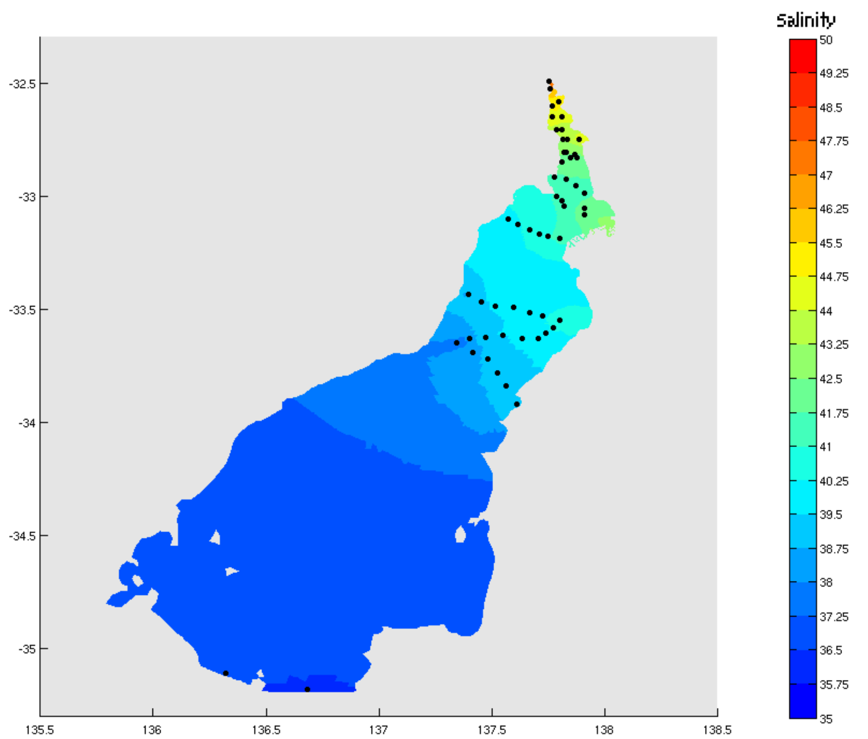


Figure 4-13 Salinity Initial Conditions Conditions for Autumn Simulations (February 2013)

4.4.5 Model Comparisons

4.4.5.1 Tidal Elevations

To verify the model's ability in propagating the tides from throughout the Gulf, tidal elevations were compared at four standard port locations, including Port Lincoln, Wallaroo, Whyalla, Port Pirie, and Port Augusta. These standard port tidal data were obtained from tidal signals reconstructed from harmonic components at these ports. Comparisons of the tidal data with model results are presented in Figure 4-14.

Three major features of the tides are present in the results shown in Figure 4-14:

- The tidal amplification between Port Lincoln and Port Augusta;
- The phasing of the tides between Port Lincoln and Augusta; and
- The relatively small semi-diurnal component associated with the (semi-diurnal) nodal point near Wallaroo.

In addition to the reproduction of these general tidal features along the Gulf, the model also reproduced with relatively good skill the amplitude and phase of the tides at Port Pirie. The mean absolute error and root mean square errors between 05 April and 05 May 2013 were 0.07 m and 0.13 m, respectively.

4.4.5.2 Temperature and Salinity

Comparisons of temperature and salinity model results with CTD measurements are shown in Figure 4-15 and Figure 4-16, respectively. The following general trends could be observed in temperature comparisons:

- The model presented the cooling trends observed in the field data, particularly in the offshore sites directly offshore of First Creek (Site 2 and Site 3). Temperatures at these sites were generally well within 0.5 ^{o}C from the measurements;
- The model predicted lower temperatures in the Port Pirie River (Site 1) in comparison to the other sites. Predictions from 14 April onwards were generally within 1 ^{o}C from measurements, whilst temperatures at the earlier part of the record were under-predicted by up to 2^{o}C.
- Further offshore at Site 4, the model did not reproduce the lowest temperatures around 20-25 April, over-predicting them by up to 2^{o}C. Simulated temperatures nevertheless very closely matched the prior and ensuing periods (5-20 April, and 25 April – 5 May), with differences generally well within 1^{o}C.

For salinity, the following trends could be observed:

- The model results (and field data) predicted lower salinities at the offshore sites (Sites 2 to 4) in comparison to Site 1 (Port Pirie River).
- The model could not reproduce the high-frequency variations (i.e. associated with the tides) revealed in the records. This is a known feature associated with relatively short spin-up times for development of accurate salinity gradients (see e.g. BMT WBM 2011). This feature is however of importance to the large scale circulation dynamics in the Gulf. As it will be shown below, the

effects of the cooling water discharge are rather localised, such that predictive capability in terms of salinity should have only a minor and secondary effect for the simulation of temperature.

- The model did not reproduce the decreasing salinity trend at Sites 2 and 3, which, as discussed previously, were likely a result of conductivity sensor drifting.

4.4.5.3 Current Velocities

Site 2 (Offshore of First Creek)

Comparison of velocities magnitude and direction at Site 2 obtained by the model and from the ADCP measurements are presented in Figure 4-17 to Figure 4-23.

Figure 4-17 show measured and modelled velocities magnitudes over the water column throughout the entire measurement period whilst Figure 4-18 shows the velocity directions. These figures show that the model reproduced the hydrodynamics at Site 2. In particular, the model predicted the gradual transition between flood and ebb tides seen in the field data and the overall velocity magnitude range. The model predictive capability is further reinforced by the close match between field and modelled velocity magnitude distributions shown in Figure 4-23. Average velocity magnitudes were 0.10 m/s (model) and 0.11 m/s (Figure 4-23).

Figure 4-19 to Figure 4-22 show a zoomed in version of the velocity magnitudes and directions through the water column during spring and neap tide periods. These comparisons show more clearly that the model replicating the observed intensities and predominantly E-W direction of the flow at the times of peak velocity magnitudes. There were some instances, however, in which modelled directions did not exactly match the measurements. These differences were generally immaterial, as they occurred during slack water at very low intensities, particularly during neaps (Figure 4-20).

Site 1 (Port Pirie River)

Comparison of velocity magnitudes and directions at Site 1 obtained by the model and from the ADCP measurements are presented in Figure 4-24 to Figure 4-30.

Figure 4-24, Figure 4-26 and Figure 4-30 shows that the model produced velocity magnitudes within the ranges observed in the field. Also, the predominant abrupt changes between North (ebbs) and South (floods) directions were simulated by the model (Figure 4-25, Figure 4-27, and Figure 4-29). However, the timing of the velocity peaks, particularly during spring tides, occurred earlier than the measurements (Figure 4-27). The measurements also presented relatively large velocity intensity for longer in comparison to the model. During neap tides, water was quiescent at Site 1, and this was well resolved by the model.

Another interesting feature in the field data, is that the tides remained flowing South after the high tides' slack water and before the low tides' slack water (note in Figure 4-25, Figure 4-27, and Figure 4-29 that the light green areas in the measurements were much broader than the red areas). The model did not reproduce this feature, likely as a result of its inability to properly incorporate the effects of the unresolved intertidal bathymetry in the hydrodynamic model.

Average velocity magnitudes were however very similar (Figure 4-30).

Considering the model replicated the overall trends in tidal elevations, temperature, and velocity fields, the model predictions were considered fit for the purpose at this conceptual stage and thus could be used for assessing the relative impacts of the proposed cooling water discharge (i.e. temperature changes with respect a baseline condition). Model predictive capability, particularly within the Port Pirie River area, can be improved by undertaking a more detailed bathymetric survey in intertidal areas of the Port Pirie River and Germein Bay.

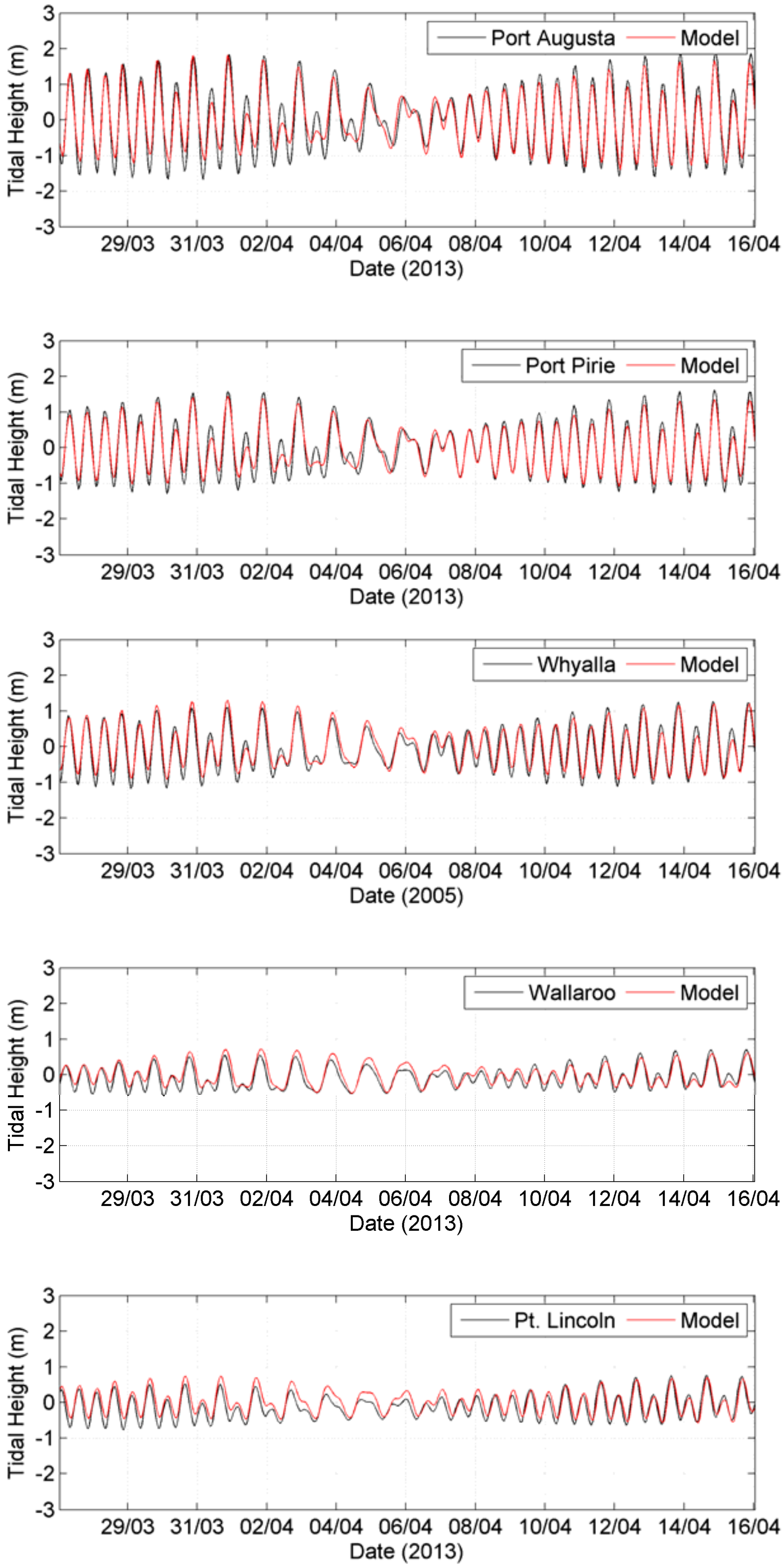


Figure 4-14 Comparison of Field and Model Tidal Elevations at Different Standard Ports throughout the Gulf

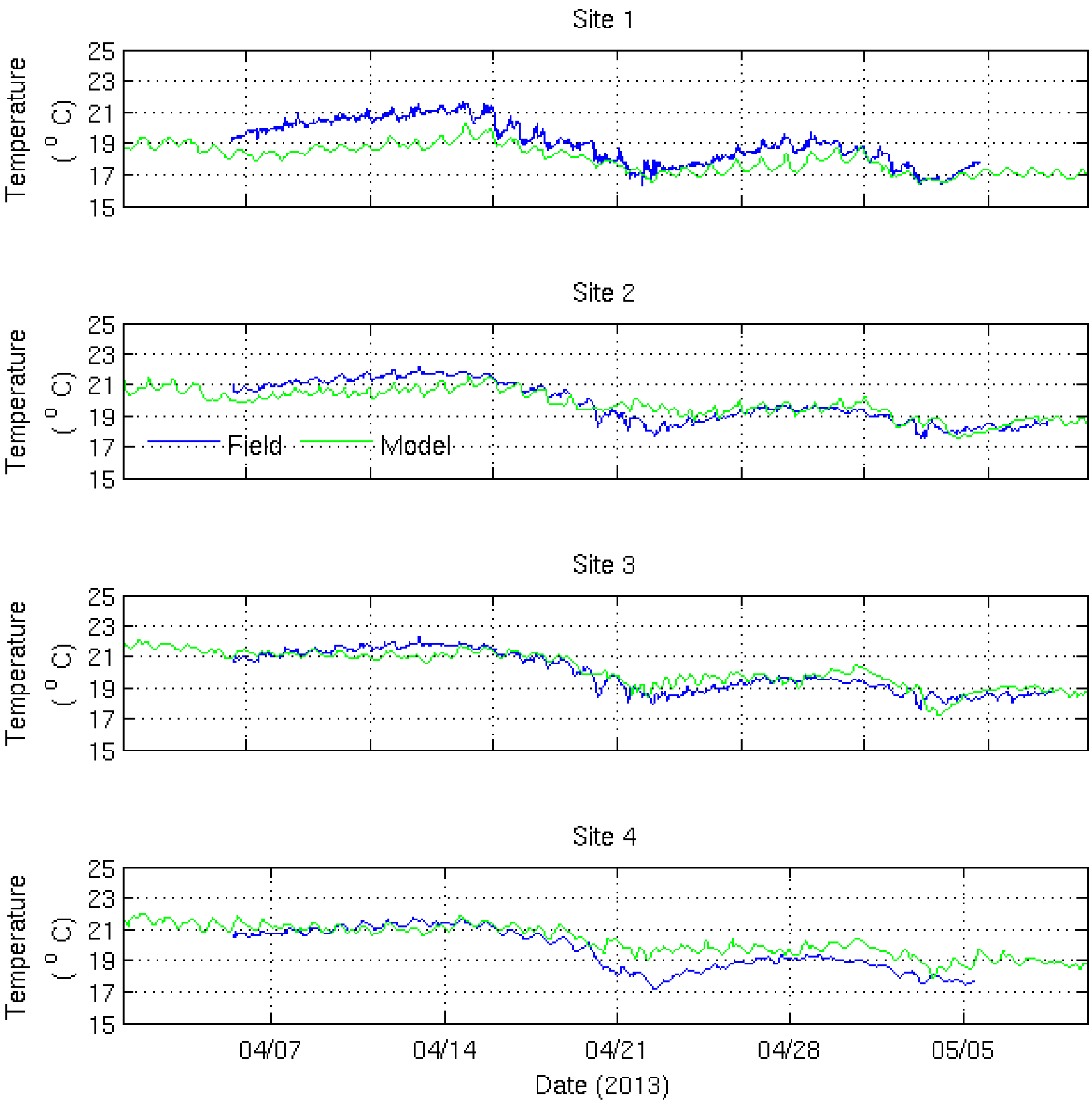


Figure 4-15 Comparison of Field (CTD) and Model Temperatures

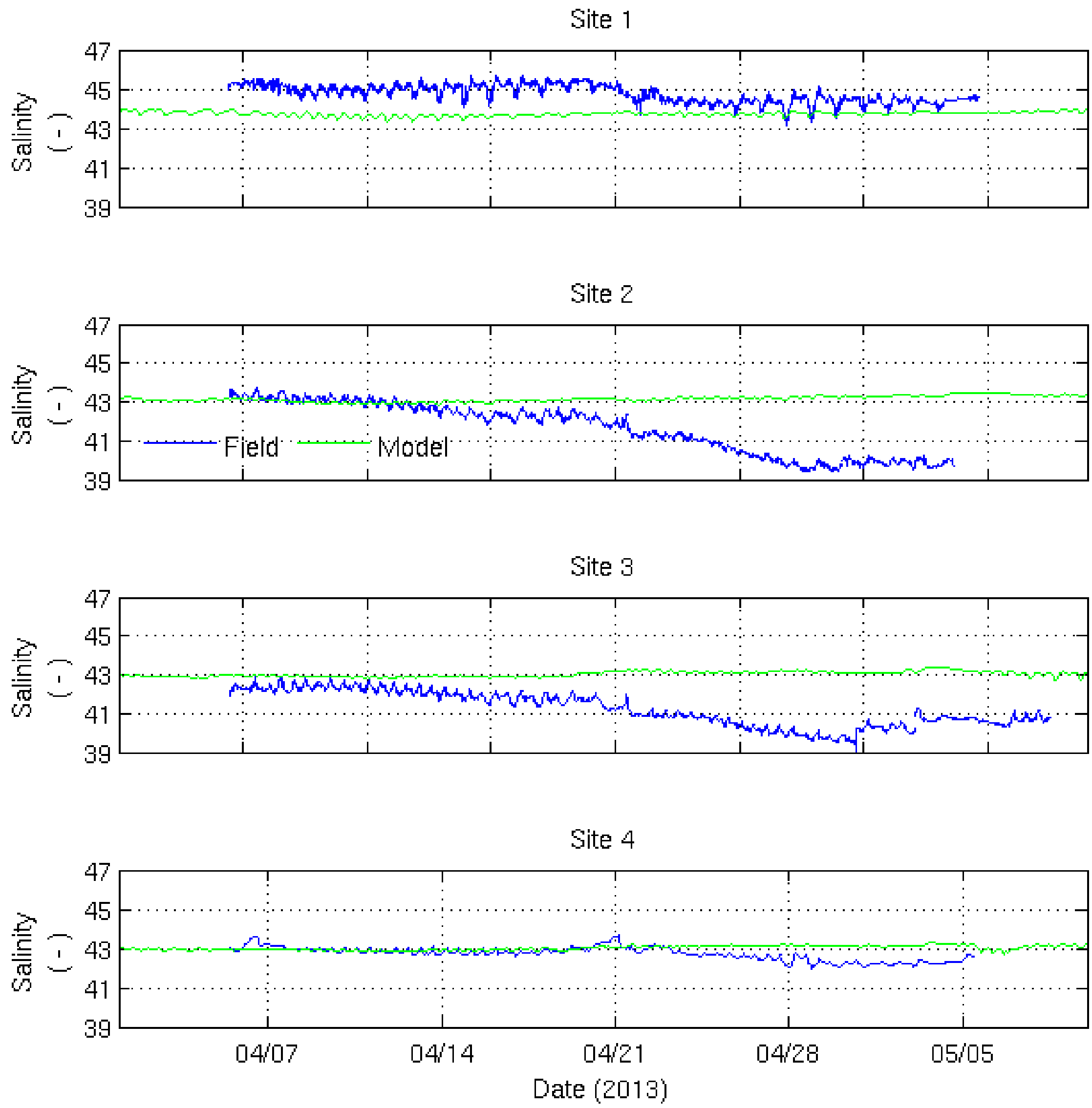


Figure 4-16 Comparison of Field (CTD) and Model Salinities

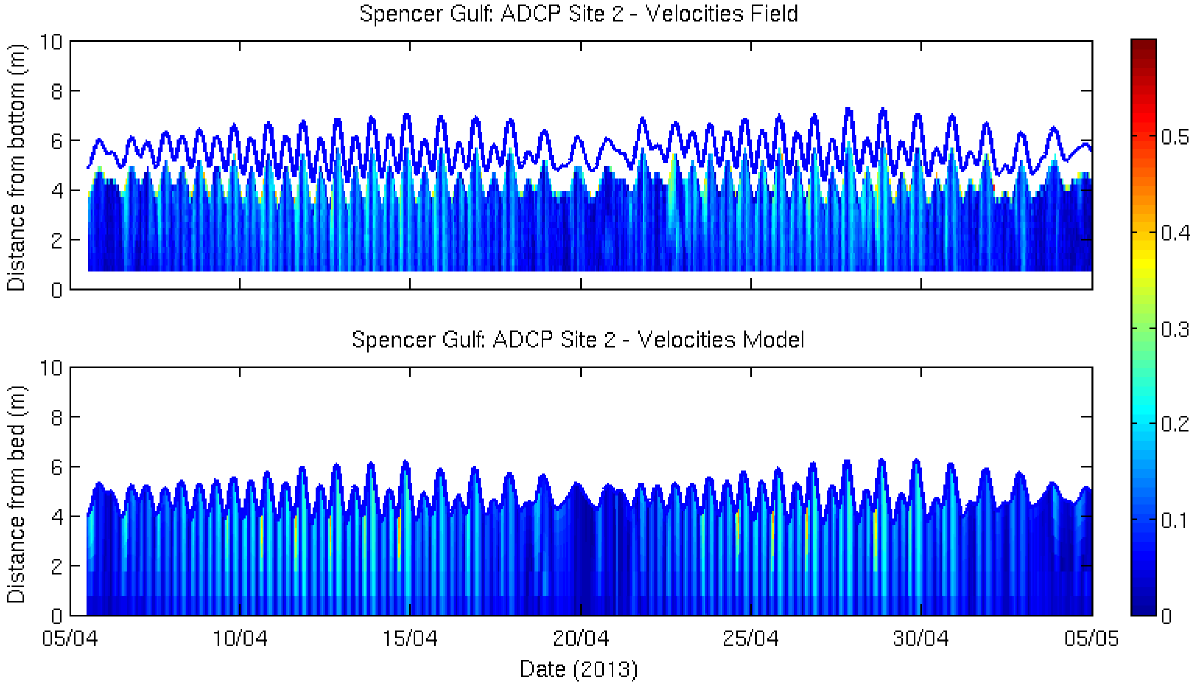


Figure 4-17 Velocity Magnitudes at Site 2

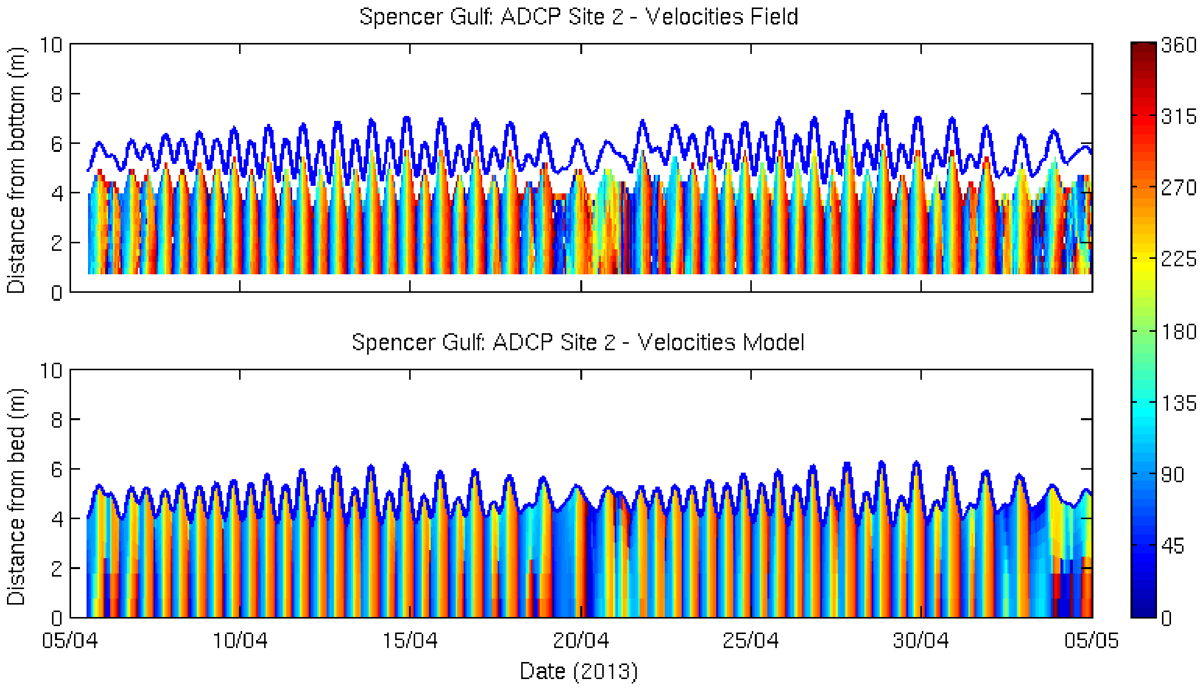


Figure 4-18 Velocity Directions at Site 2

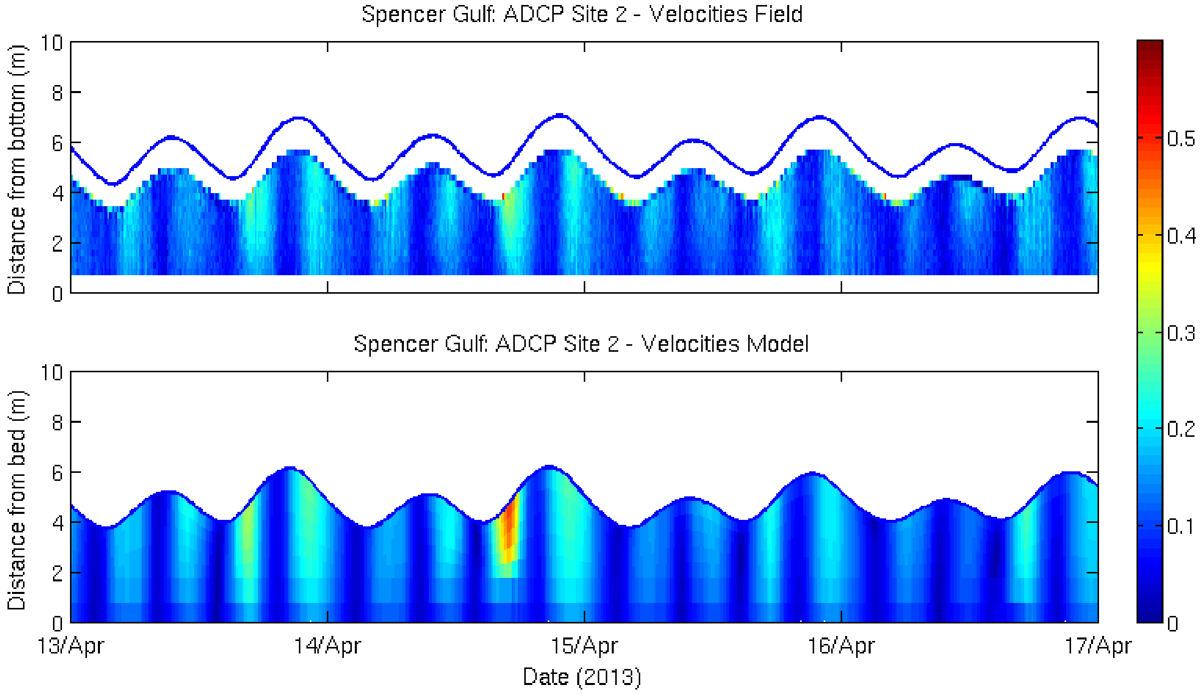


Figure 4-19 Velocity Magnitudes during Spring Tides at Site 2

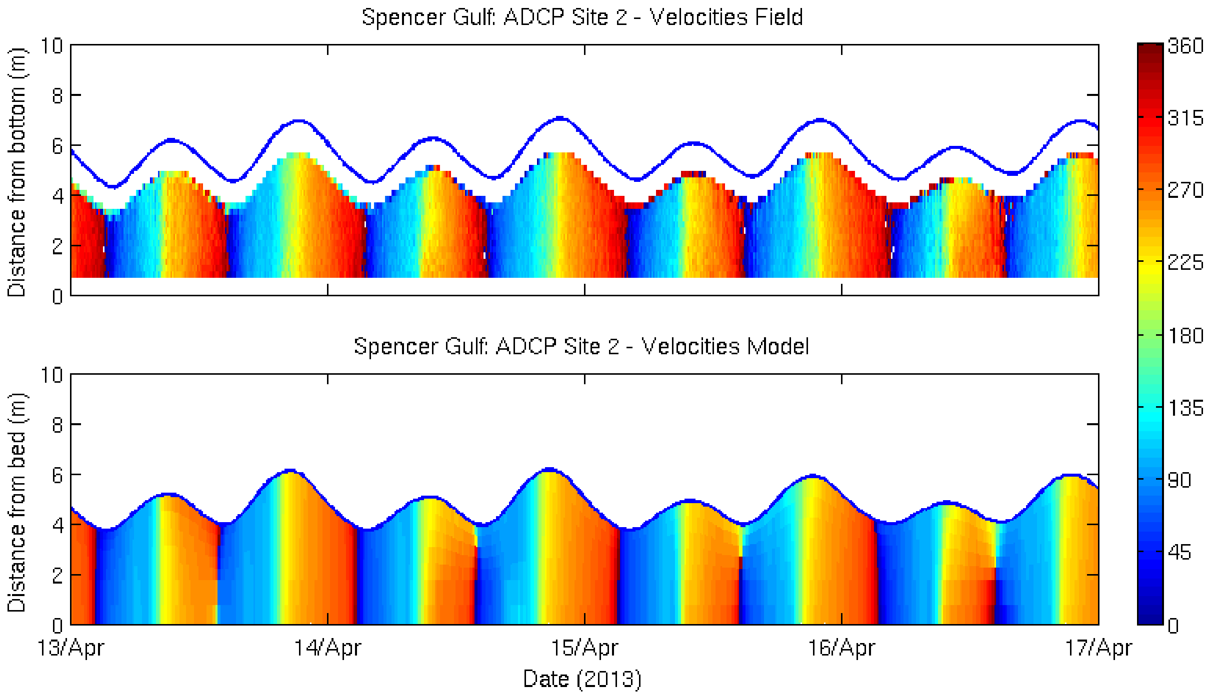


Figure 4-20 Velocity Directions during Spring Tides at Site 2

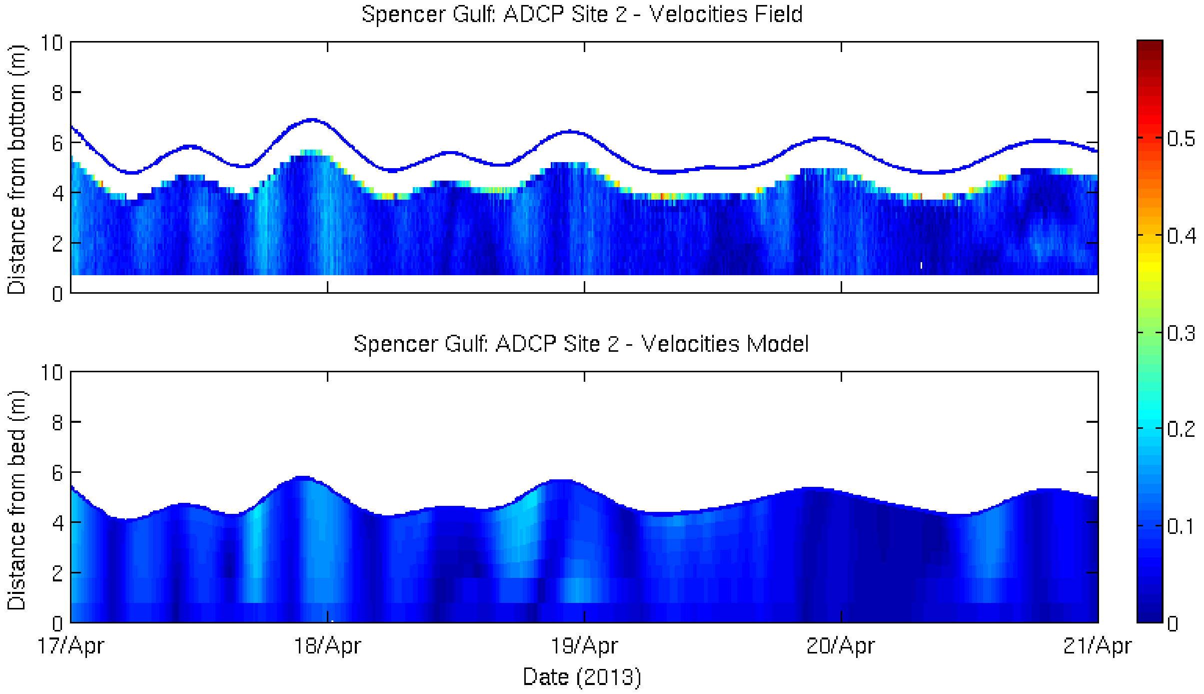


Figure 4-21 Velocity Magnitudes during Neap Tides at Site 2

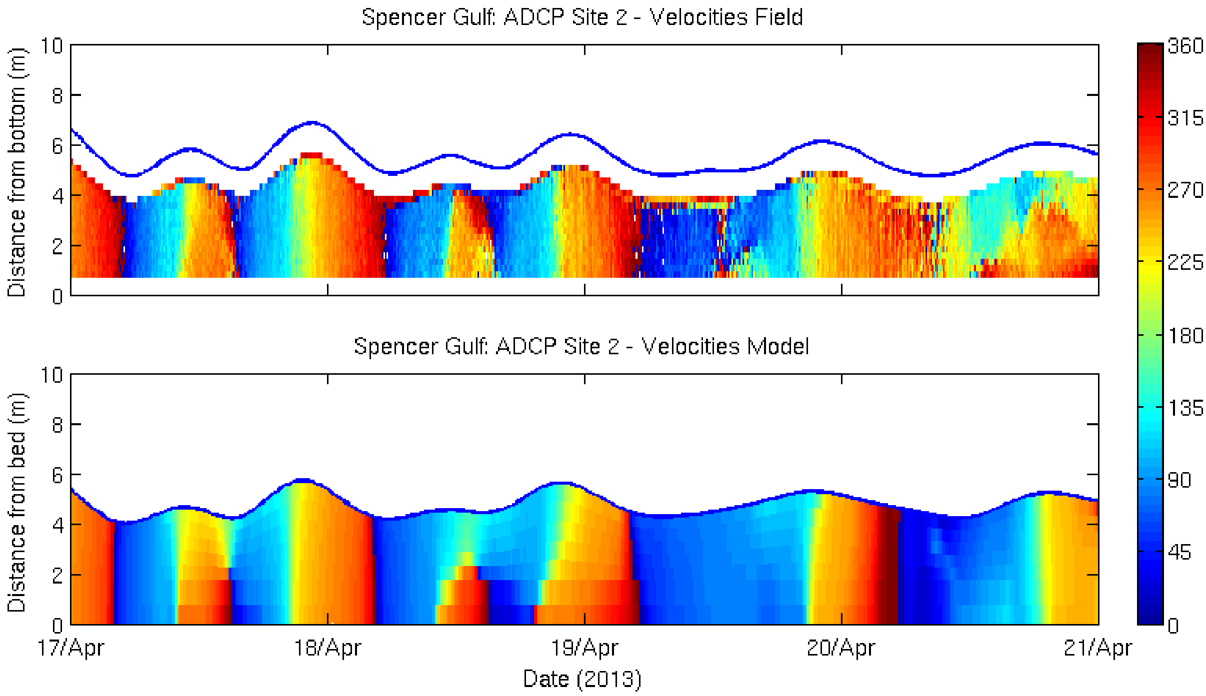


Figure 4-22 Velocity Directions during Neap Tides at Site 2

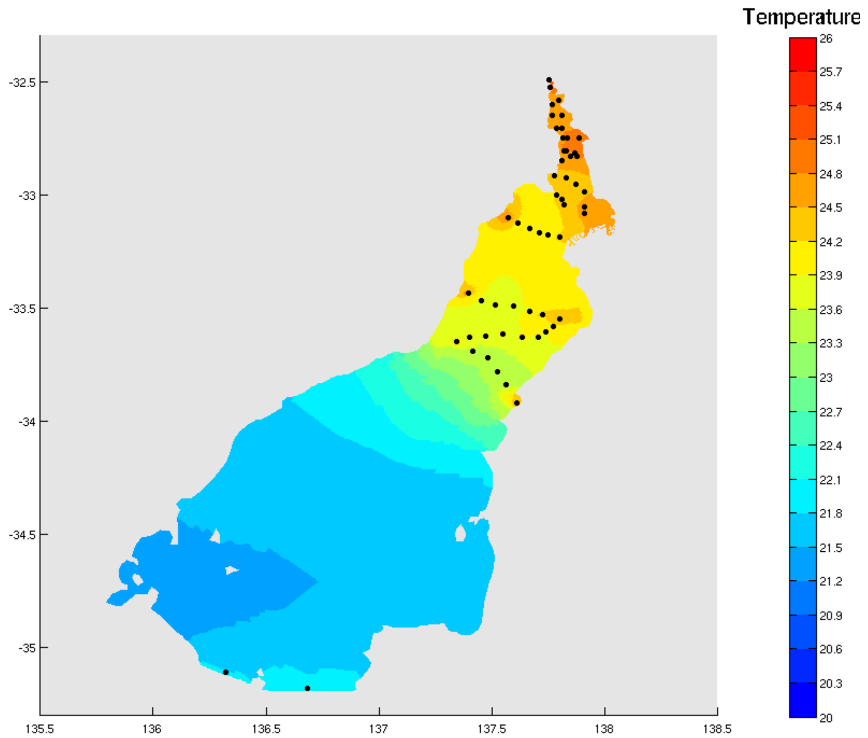


Figure 4-12 Temperature Initial Conditions for Autumn Simulations (February 2013)

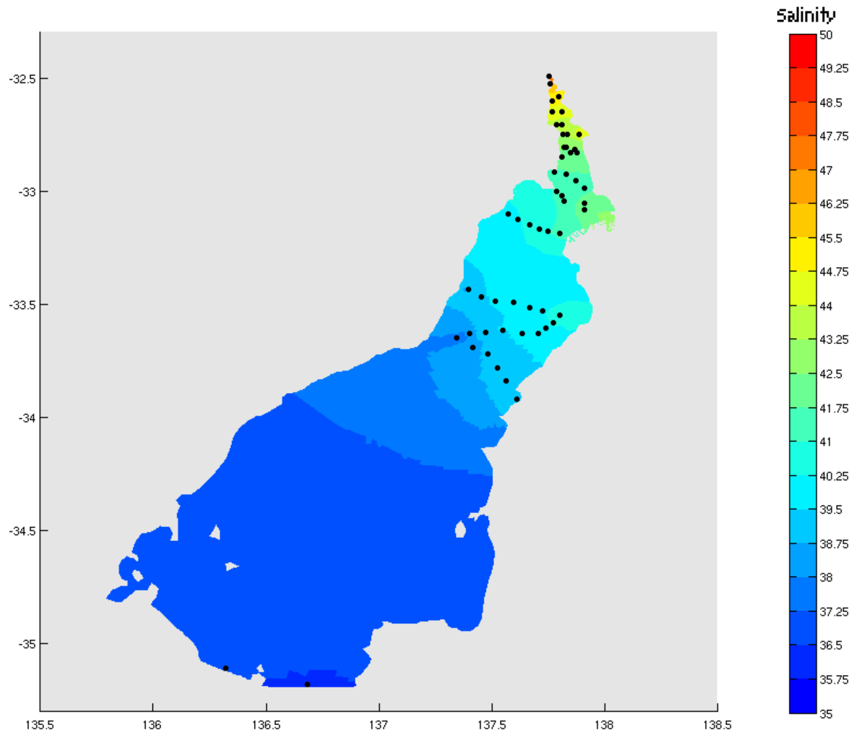


Figure 4-13 Salinity Initial Conditions Conditions for Autumn Simulations (February 2013)

4.4.5 Model Comparisons

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Comparison of velocities magnitude and direction at Site 2 obtained by the model and from the ADCP measurements are presented in Figure 4-17 to Figure 4-23.

Figure 4-17 show measured and modelled velocities magnitudes over the water column throughout the entire measurement period whilst Figure 4-18 shows the velocity directions. These figures show that the model reproduced the hydrodynamics at Site 2. In particular, the model predicted the gradual transition between flood and ebb tides seen in the field data and the overall velocity magnitude range. The model predictive capability is further reinforced by the close match between field and modelled velocity magnitude distributions shown in Figure 4-23. Average velocity magnitudes were 0.10 m/s (model) and 0.11 m/s (Figure 4-23).

Figure 4-19 to Figure 4-22 show a zoomed in version of the velocity magnitudes and directions through the water column during spring and neap tide periods. These comparisons show more clearly that the model replicating the observed intensities and predominantly E-W direction of the flow at the times of peak velocity magnitudes. There were some instances, however, in which modelled directions did not exactly match the measurements. These differences were generally immaterial, as they occurred during slack water at very low intensities, particularly during neaps (Figure 4-20).

Site 1 (Port Pirie River)

Comparison of velocity magnitudes and directions at Site 1 obtained by the model and from the ADCP measurements are presented in Figure 4-24 to Figure 4-30.

Figure 4-24, Figure 4-26 and Figure 4-30 shows that the model produced velocity magnitudes within the ranges observed in the field. Also, the predominant abrupt changes between North (ebbs) and South (floods) directions were simulated by the model (Figure 4-25, Figure 4-27, and Figure 4-29). However, the timing of the velocity peaks, particularly during spring tides, occurred earlier than the measurements (Figure 4-27). The measurements also presented relatively large velocity intensity for longer in comparison to the model. During neap tides, water was quiescent at Site 1, and this was well resolved by the model.

Another interesting feature in the field data, is that the tides remained flowing South after the high tides' slack water and before the low tides' slack water (note in Figure 4-25, Figure 4-27, and Figure 4-29 that the light green areas in the measurements were much broader than the red areas). The model did not reproduce this feature, likely as a result of its inability to properly incorporate the effects of the unresolved intertidal bathymetry in the hydrodynamic model.

Average velocity magnitudes were however very similar (Figure 4-30).

Considering the model replicated the overall trends in tidal elevations, temperature, and velocity fields, the model predictions were considered fit for the purpose at this conceptual stage and thus could be used for assessing the relative impacts of the proposed cooling water discharge (i.e. temperature changes with respect a baseline condition). Model predictive capability, particularly within the Port Pirie River area, can be improved by undertaking a more detailed bathymetric survey in intertidal areas of the Port Pirie River and Germein Bay.

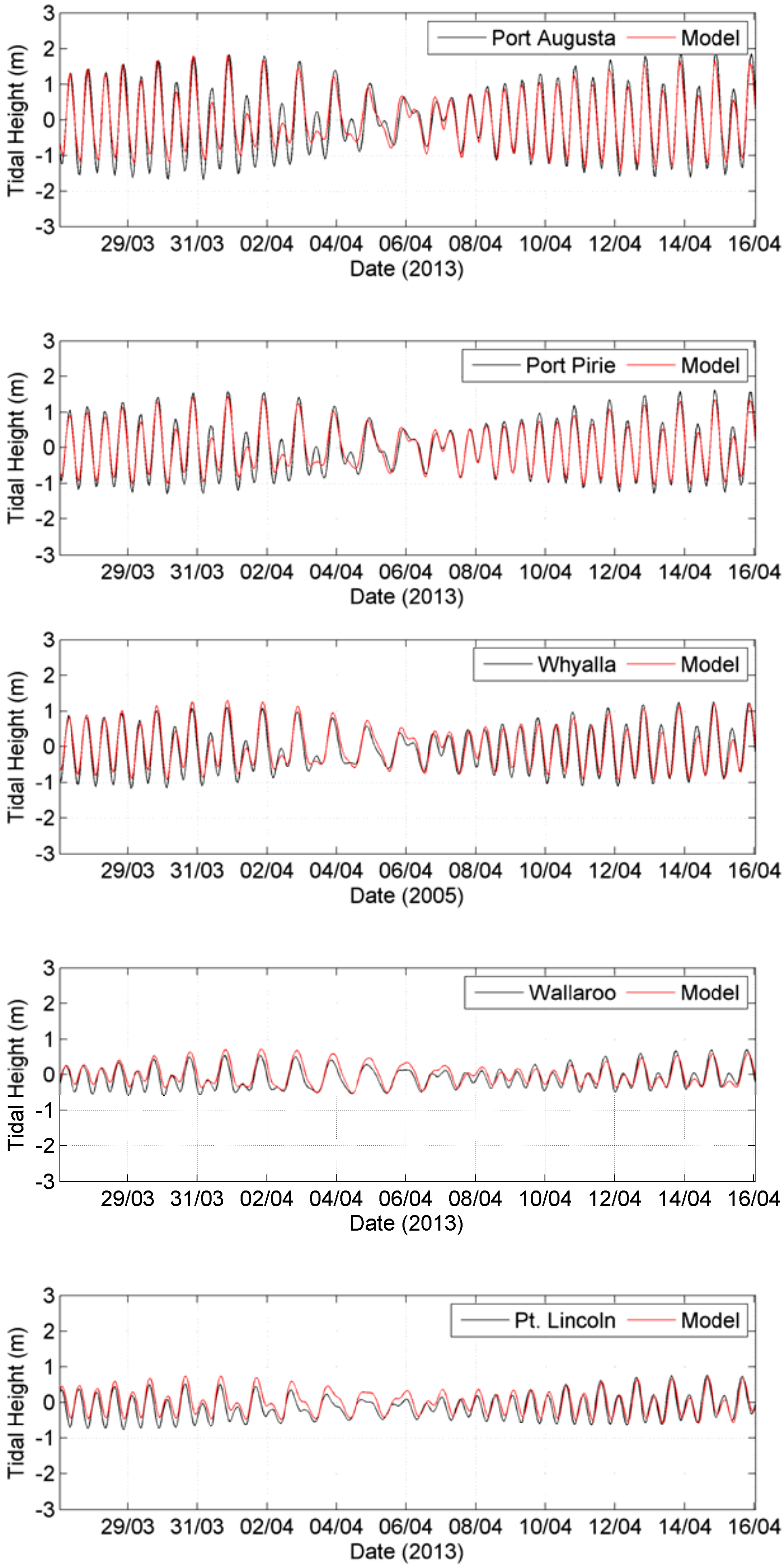

Figure 4-14 Comparison of Field and Model Tidal Elevations at Different Standard Ports throughout the Gulf

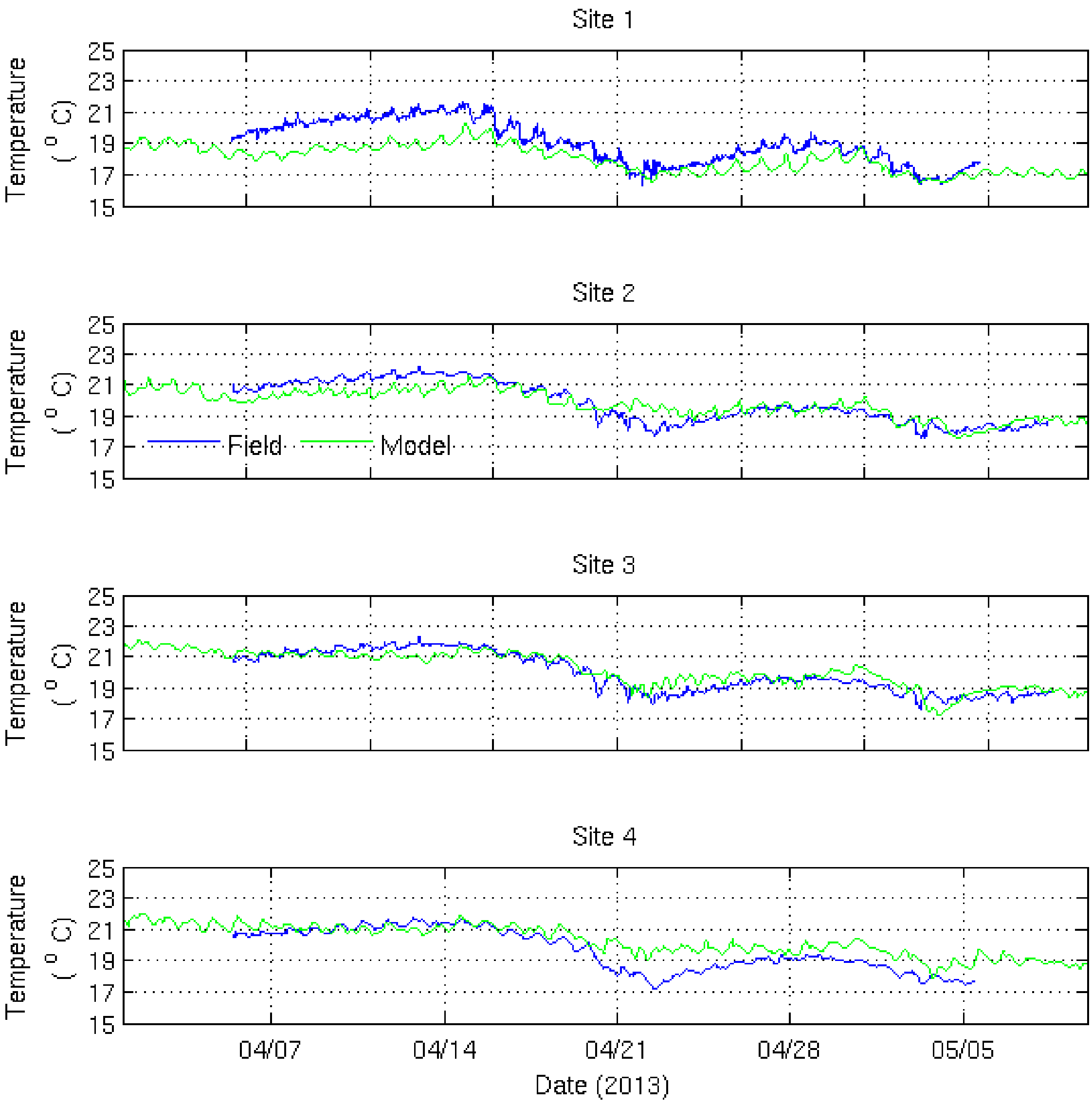

Figure 4-15 Comparison of Field (CTD) and Model Temperatures

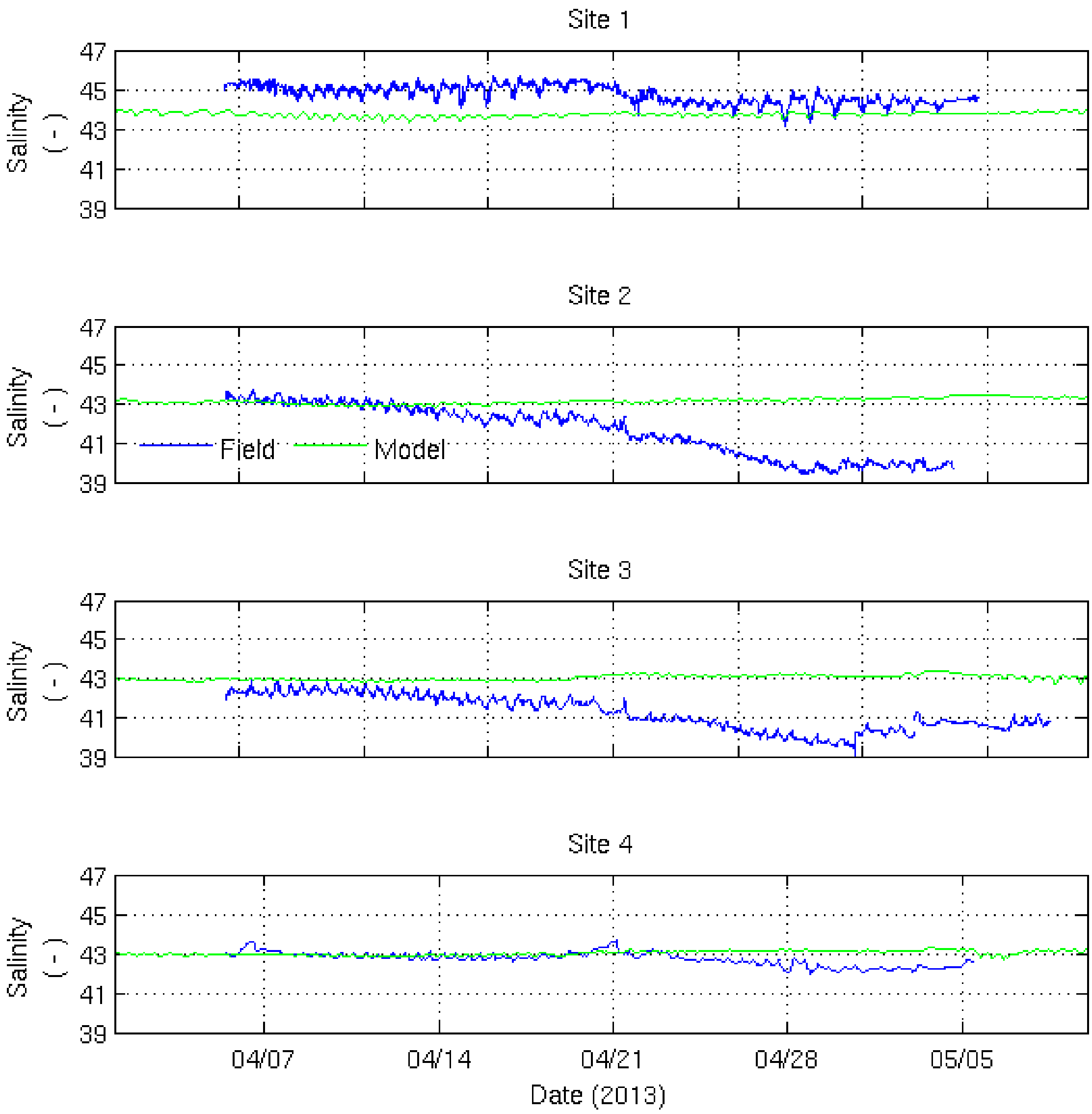

Figure 4-16 Comparison of Field (CTD) and Model Salinities

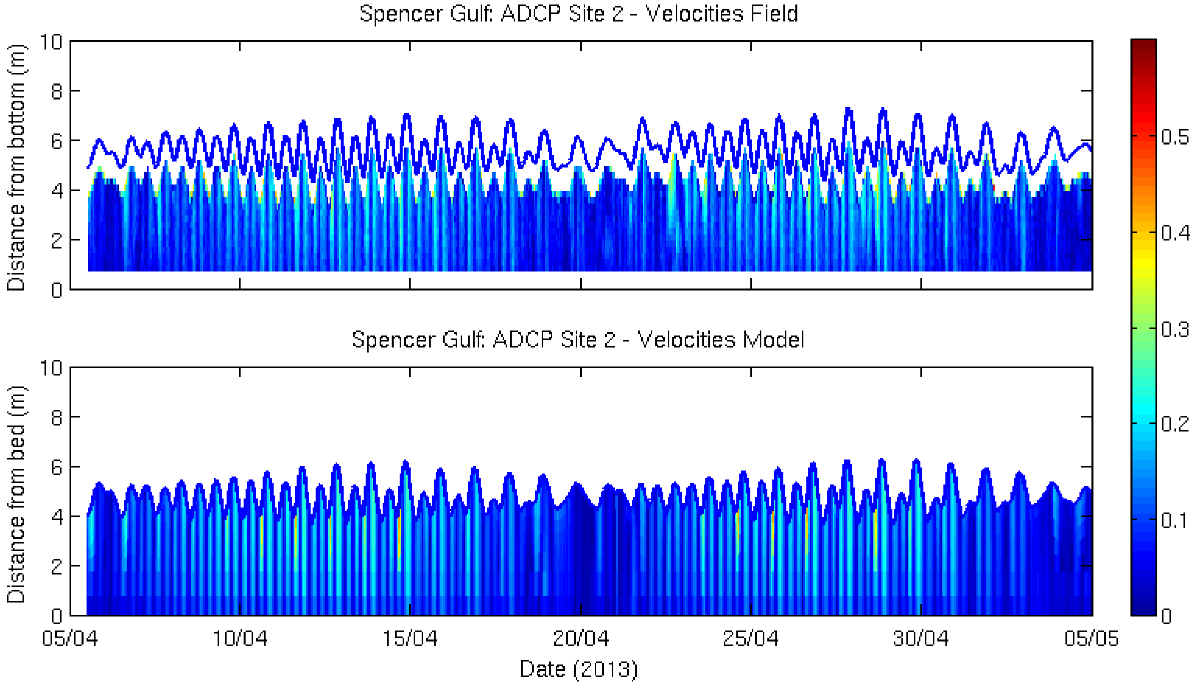

Figure 4-17 Velocity Magnitudes at Site 2

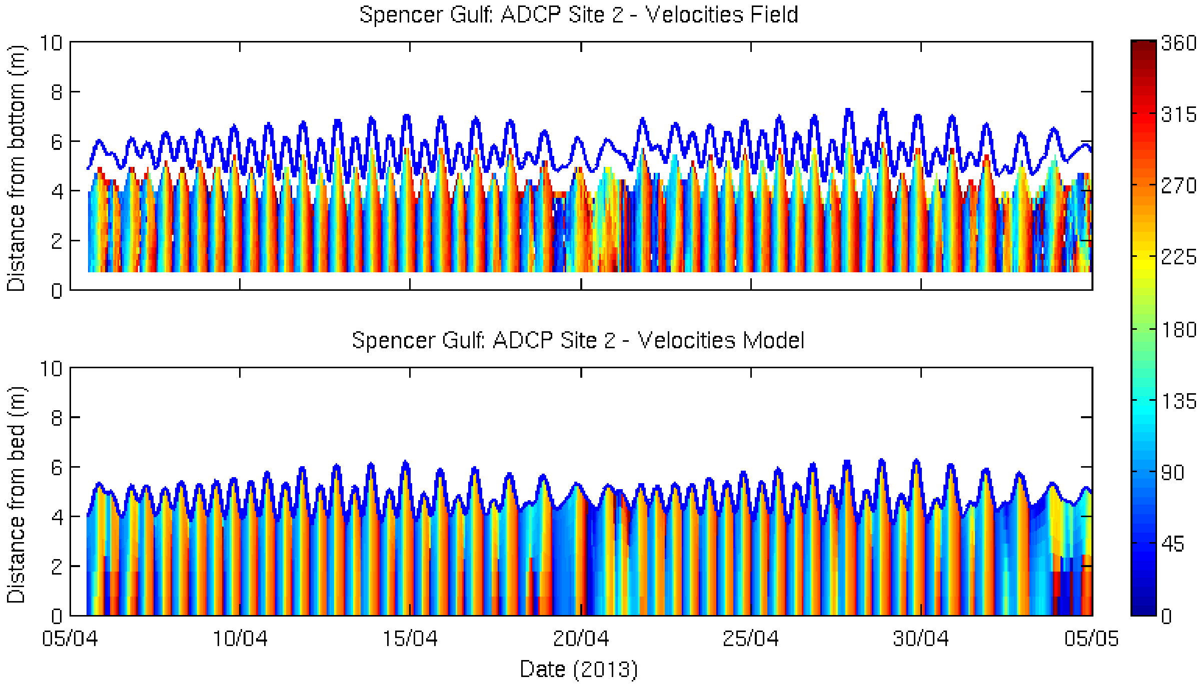

Figure 4-18 Velocity Directions at Site 2

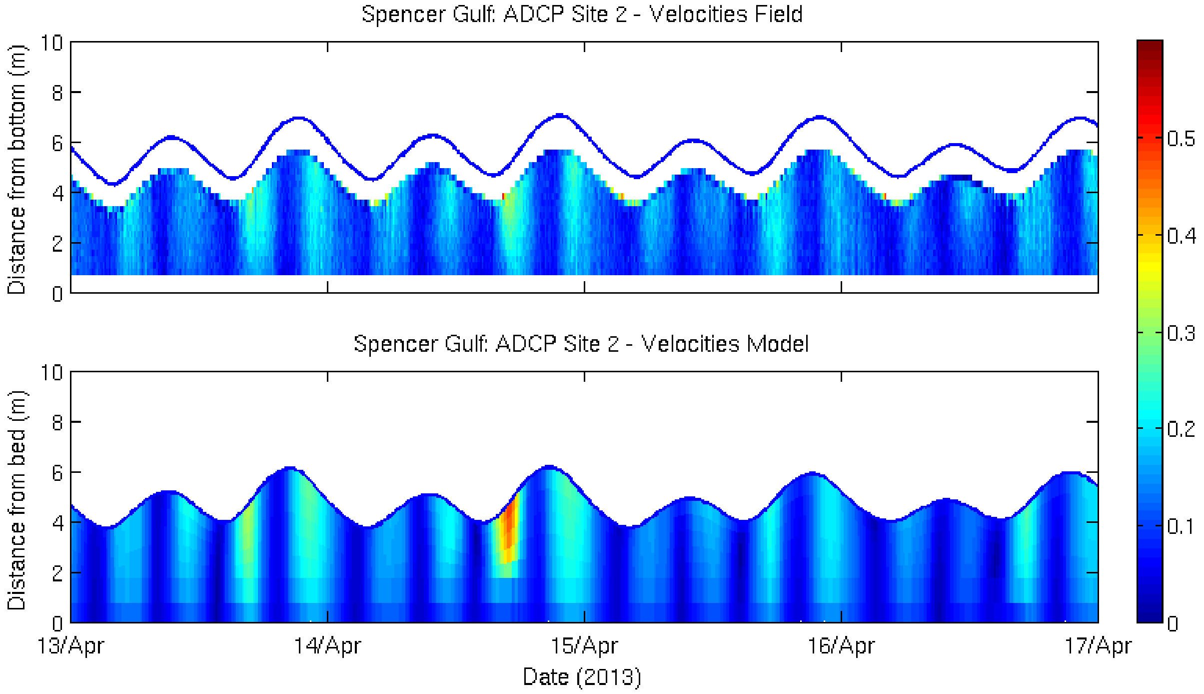

Figure 4-19 Velocity Magnitudes during Spring Tides at Site 2

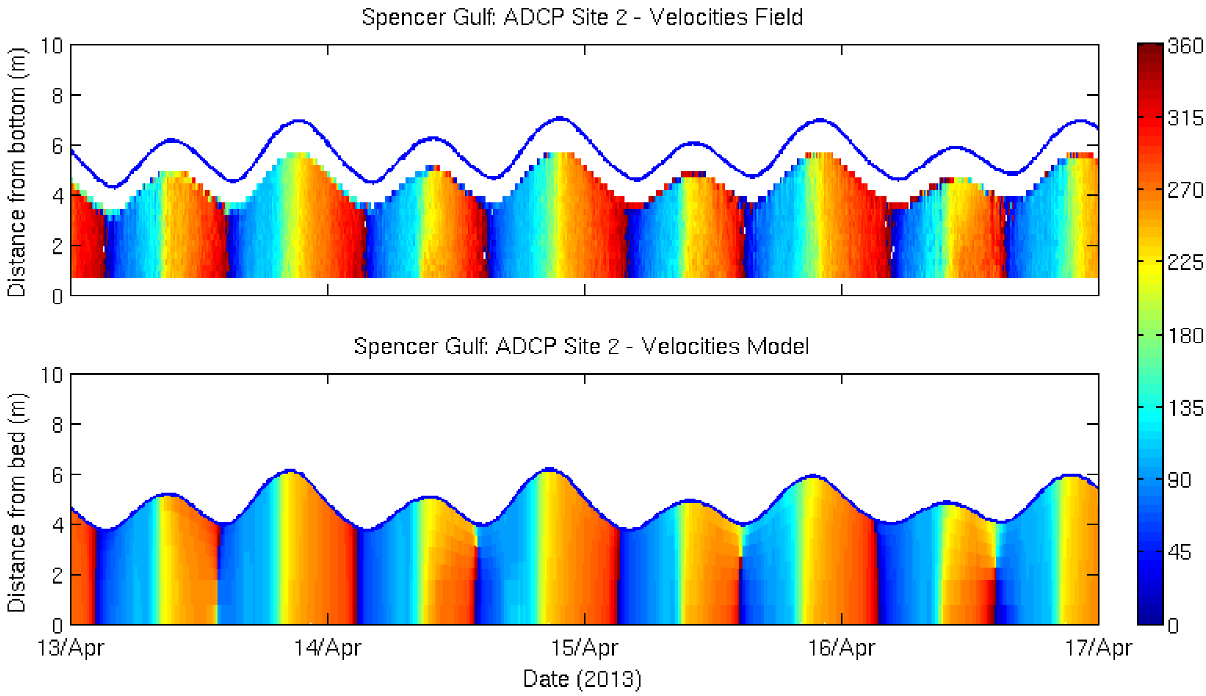

Figure 4-20 Velocity Directions during Spring Tides at Site 2

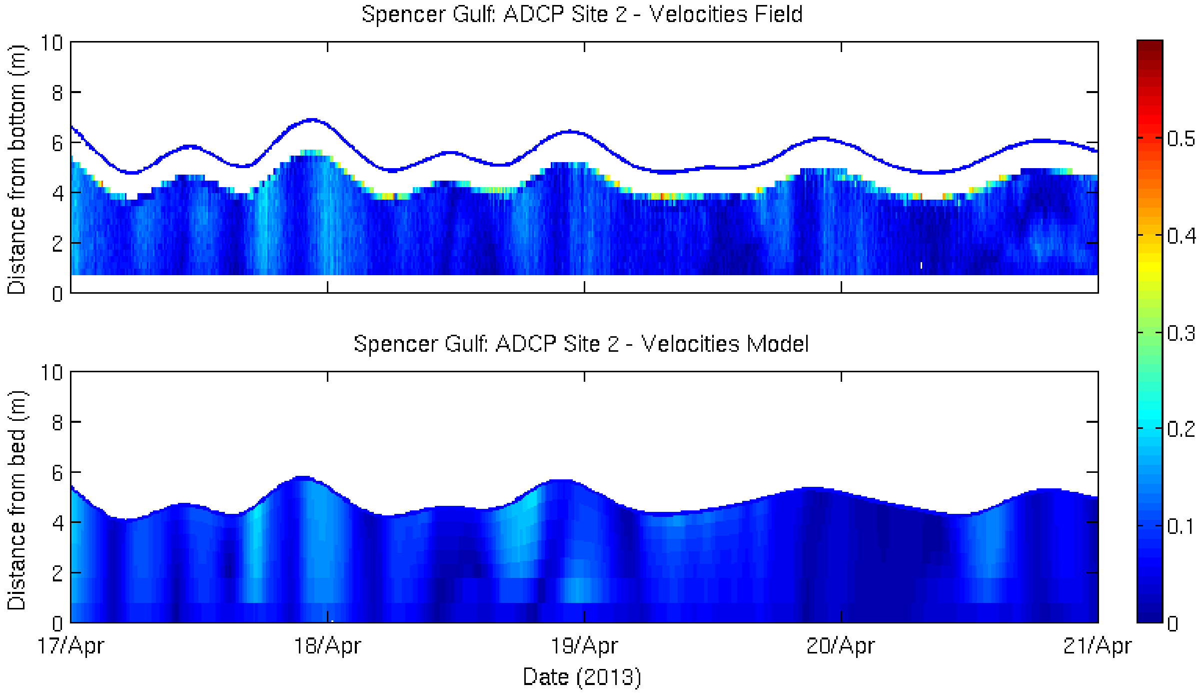

Figure 4-21 Velocity Magnitudes during Neap Tides at Site 2

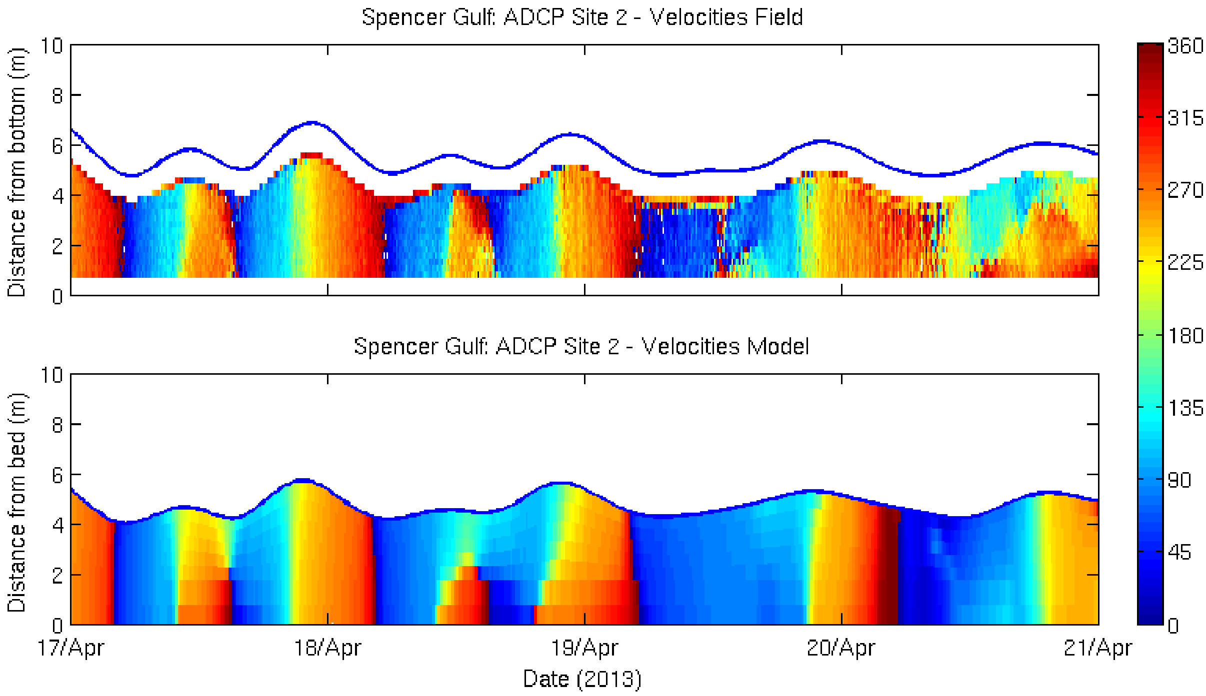

Figure 4-22 Velocity Directions during Neap Tides at Site 2

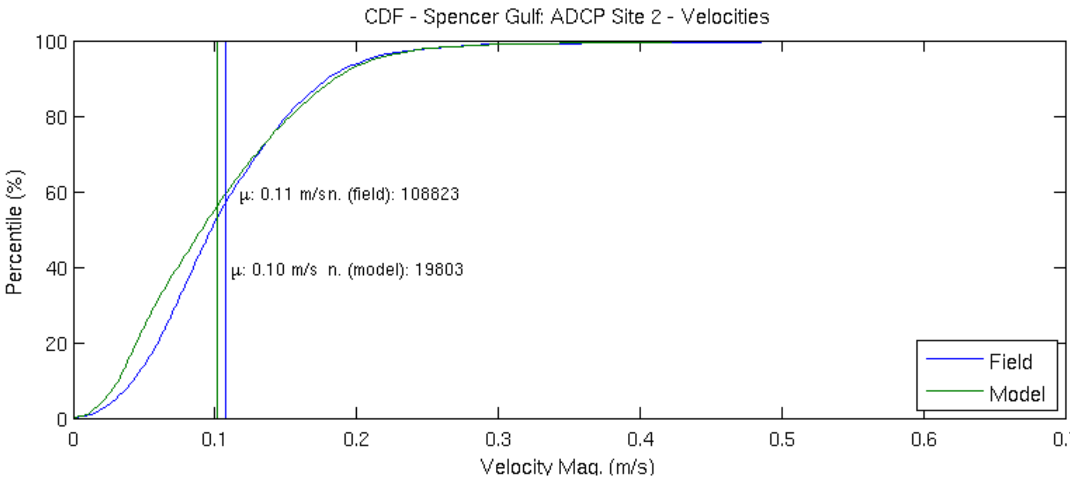

Figure 4-23 Distribution of Velocity Magnitudes at Site 2 over the Measurement Period

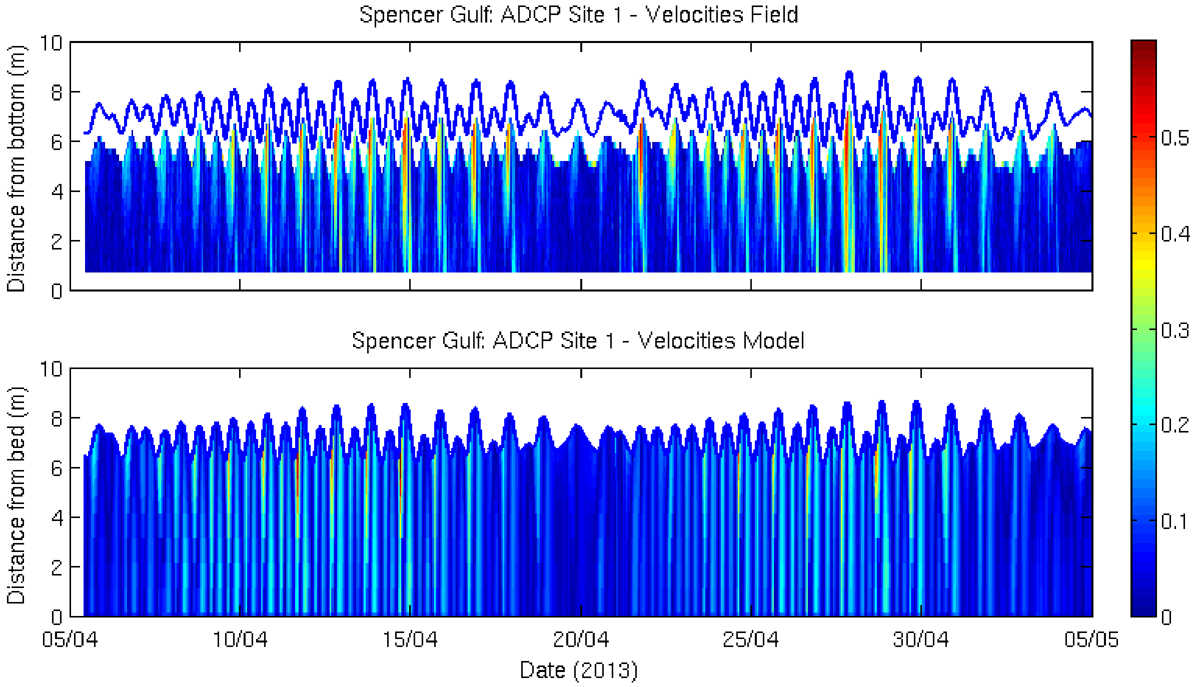

Figure 4-24 Velocity Magnitudes at Site 1

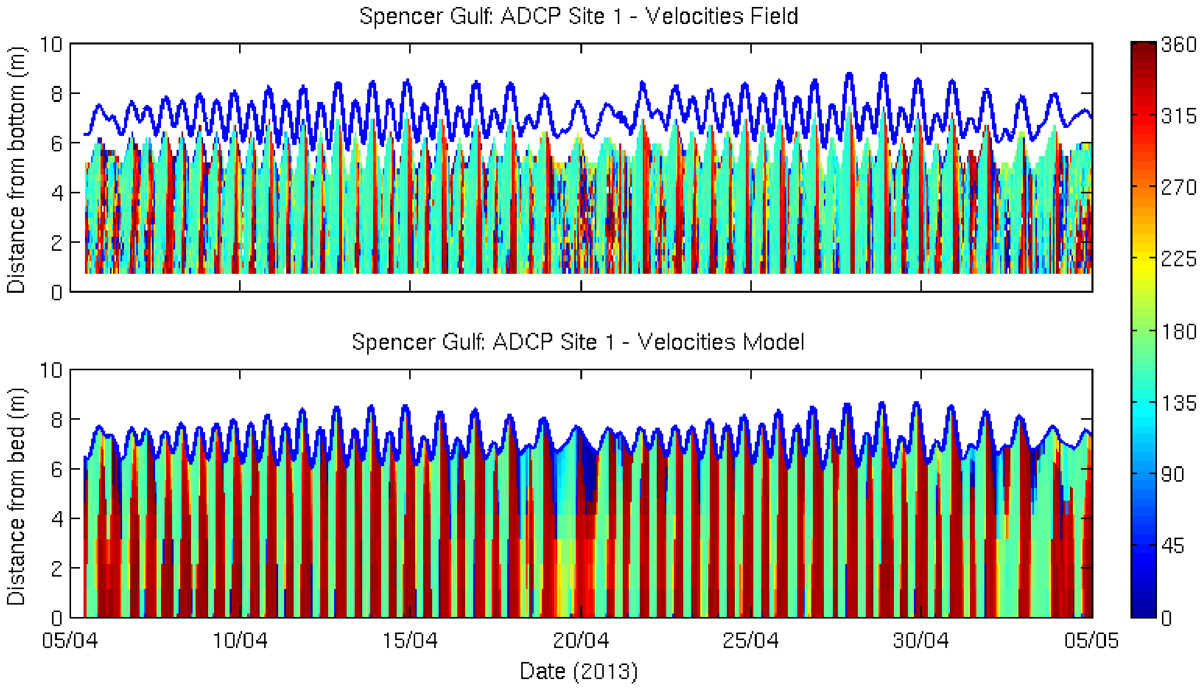

Figure 4-25 Velocity Directions at Site 1

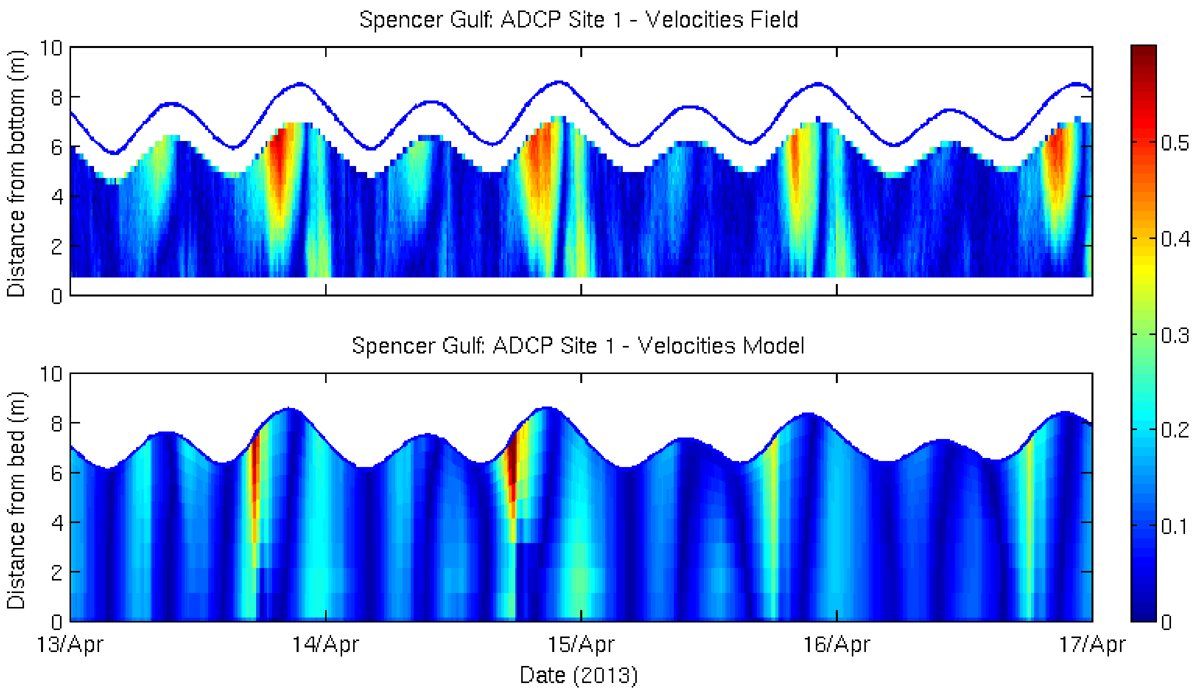

Figure 4-26 Velocity Magnitudes during Spring Tides at Site 1

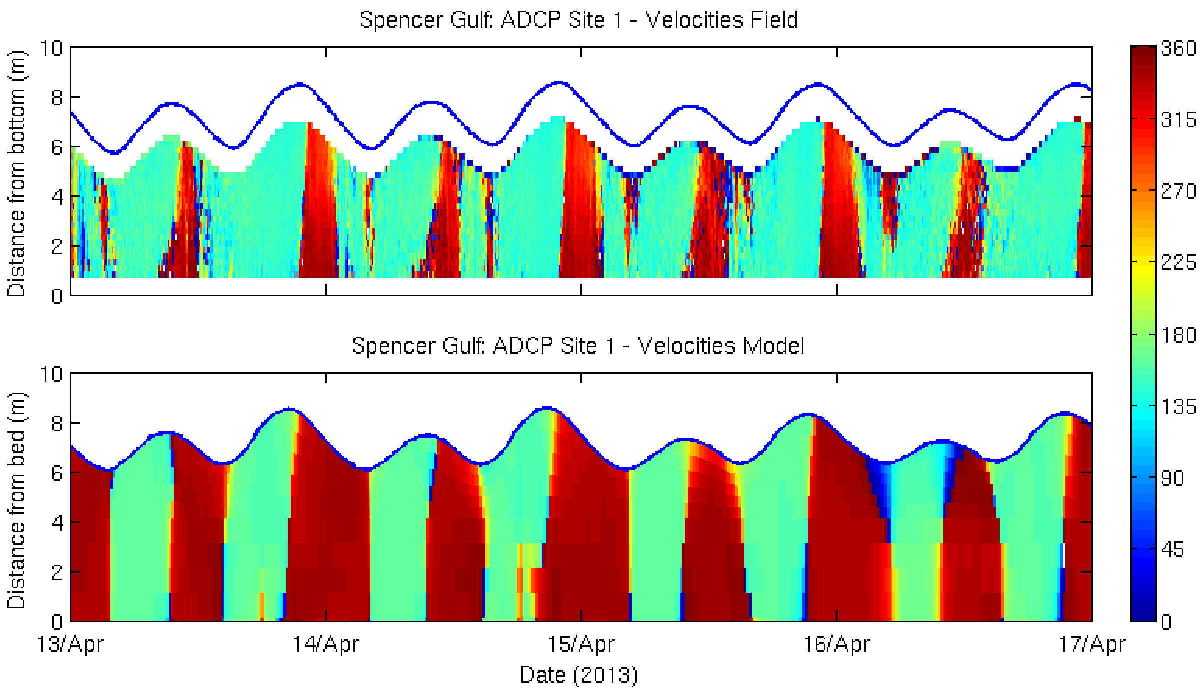

Figure 4-27 Velocity Directions during Spring Tides at Site 1

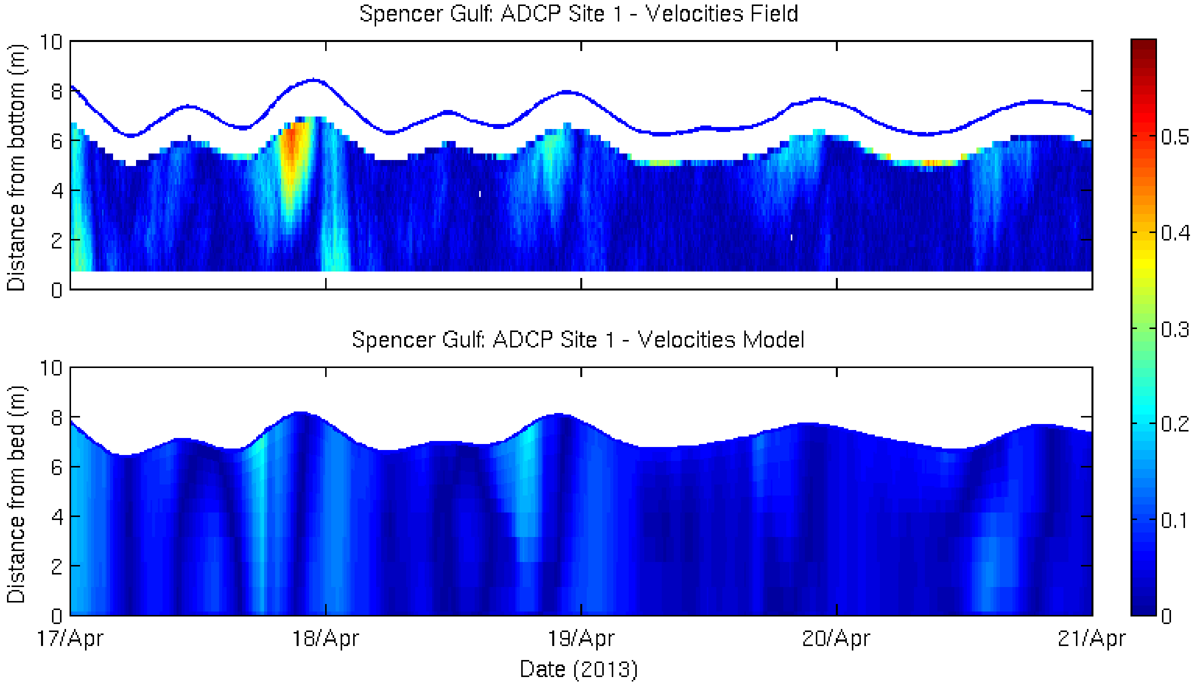

Figure 4-28 Velocity Magnitudes during Neap Tides at Site 1

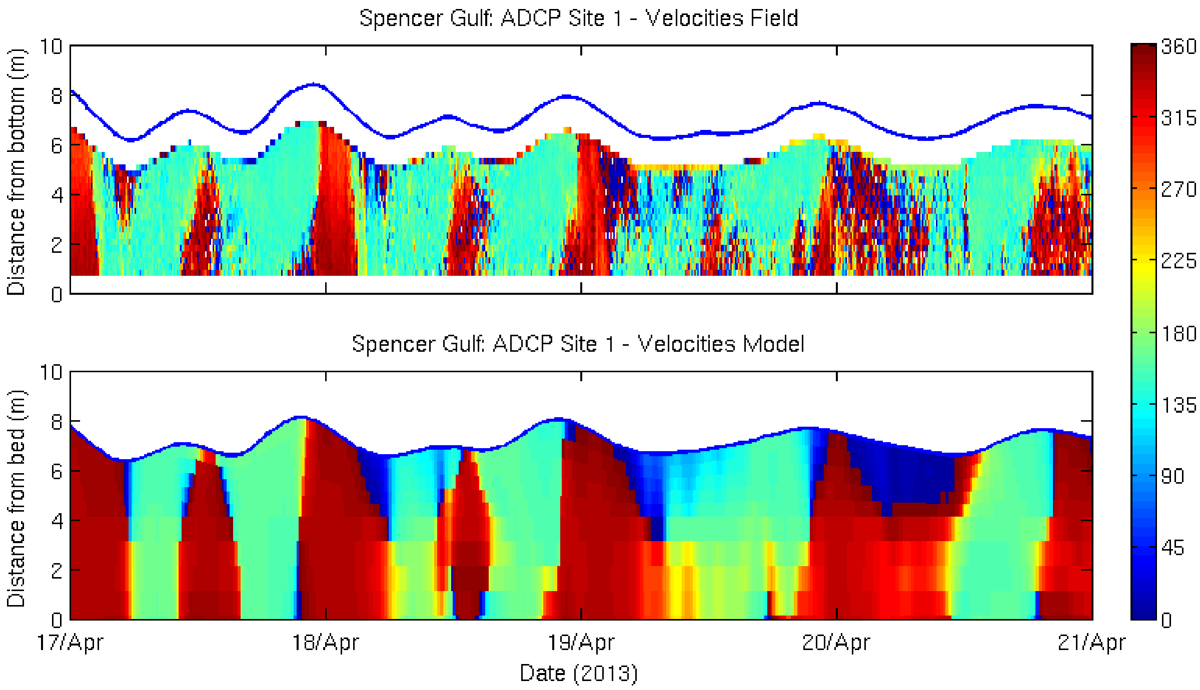

Figure 4-29 Velocity Directions during Neap Tides at Site 1

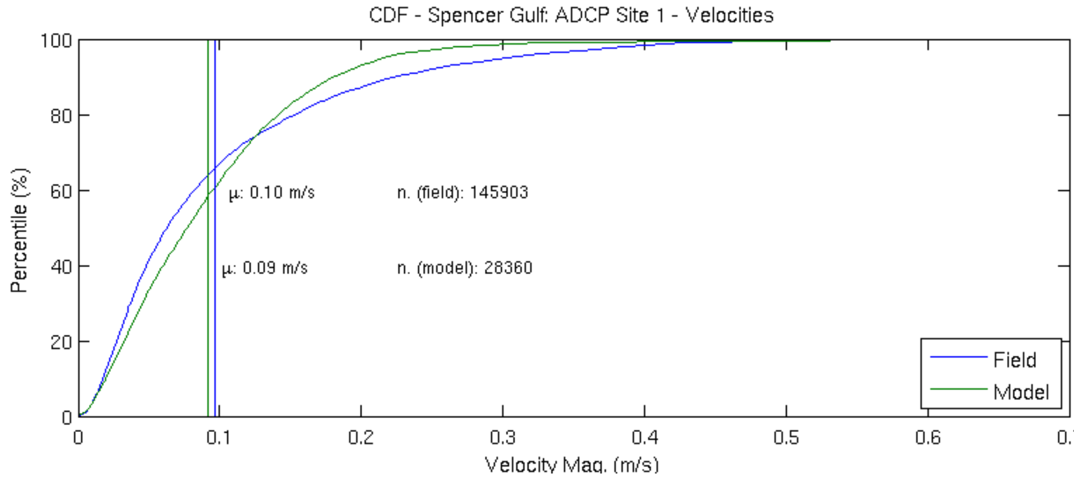

Figure 4-30 Distribution of Velocity Magnitudes at Site 1 over the Measurement Period

4.4.6 Discharge Scenarios

Discharge scenarios were designed to investigate the resulting temperature increase in the marine environment resulting from the proposed cooling water discharge alternatives. In order to assess the temperature increase, suitable baseline conditions were stipulated. These are described below before a description of the cooling water discharge scenarios is given.

4.4.6.1 Baseline Conditions

Two baseline conditions were assumed in the study. The first baseline was designed to quantify the temperature increases (or reductions) associated with the effect of the cooling water discharge in relation to a natural environment without any prior existing discharge. This baseline assumed the same simulation set-up adopted in the model verification, with the exception of the First Creek discharge and initial stratification. Hereafter this baseline is referred to as natural or unimpacted baseline.

The second baseline was designed to quantify the temperature increases (or reductions) associated with the effect of the cooling water discharge in relation to existing conditions. This baseline assumed the same simulation set-up adopted in the model verification, including the First Creek discharge and initial stratification. Hereafter this baseline is referred to as existing baseline.

4.4.6.2 Simulations Period

The periods of analysis corresponded to 01 April to 01 May 2013. Similarly to the approach adopted in the model verification, the simulations were spun-up for approximately two months.

4.4.6.3 Methodology for Comparisons

A methodology was devised for comparisons between the discharge scenarios and the natural (unimpacted) baseline, so as to verify whether (and/or where) the discharges would meet water quality guidelines (both present and the proposed draft guidelines). In case guidelines were not met, these comparisons would serve to indicate which locations would be the worst affected by the temperature increases. A step by step of the methodology is provided below:

For each of the simulations performed, 0th (maximum), 10th, 20th and 50th (median) percentile temperature exceedences were calculated in each surface cell of the model domain. The calculation of statistics was obtained from time series corresponding to the period of analysis in each of these locations.

Present Guideline Comparisons

For verification of present guidelines, each of the 0th, 10th and 50th percentile exceedences obtained from the natural (unimpacted) baseline conditions were subtracted from the corresponding percentile exceedence obtained from the discharge scenarios. For example, the baseline 0th temperature percentile exceedence was subtracted from the scenario 0th percentile temperature exceedence, and so on.

These differences, obtained in each surface cell of the model domain, were then mapped so as to obtain the locations and respective distances (or areas) from the discharge where they exceed any given temperature. It is important to note that 2 ^{o}C was of most interest in view of the definition of the present guidelines.

Proposed Guideline Comparisons

For verification of the proposed draft guidelines, the 20th percentile exceedences obtained from the natural baseline conditions was subtracted from the 50th percentile exceedence obtained from the discharge scenarios.

Again, these differences were obtained in each surface cell of the model domain and subsequently mapped so as to obtain the locations and respective distances (or areas) from the discharge where they exceed the proposed water quality guidelines. It is important to note that in this case a temperature increase results in non-compliance.

Comparisons with the Existing Baseline

In addition to the comparisons with the unimpacted baseline, a similar methodology was employed for comparisons between the simulations including the proposed discharge (in conjunction with the existing discharge) and the existing baseline (i.e. only the existing discharge to First Creek). These comparisons were used to provide an indication of the effects of the proposed discharge in relation to existing conditions.

4.4.6.4 Discharges to First Creek

In addition to the existing discharge to First Creek (0.73 m^3/s and a temperature increase in relation to the intake of 9 ^{o}C), three other discharge scenarios into First Creek were considered. These are summarised below in Table 4-4. The last column indicates the temperature stratification assumed in First Creek as part of the set-up of initial conditions.

4.4.6.5 Discharge to Port Pirie River

Given the nearfield assessments indicated an outfall can be successfully designed to meet the water quality guidelines, only one outfall configuration was considered in the Port Pirie River in addition to the existing discharge to First Creek (0.73 m^3/s and a temperature increase in relation to the intake of 9 ^oC).

Table 4-4 Alternative Discharges to First Creek and Port Pirie River

Scenario	Outfall location	Flow Rate m^3/s	Temp. increase (^oC)	Salinity increase (%)	Initial Stratification in First Creek ^oC
1	PP02	1.64	10	0	7.0
3			5	0.88	4.0
4			2	1.41	2.0
13	PP05	1.64	10	0	7.0

It is noted that the discharge input into the model did not consider the effects of mixing in the nearfield. Consistent with other discharge modelling studies, neglecting these effects produce very conservative dilutions and temperature increases in the vicinity of the diffuser. This occurs because the model cells are very coarse in comparison to the scales of the plume (and its associated mixing mechanisms) near the diffuser. As such, assessments in this region should rely on nearfield assessments (see e.g. Botelho et al. 2013). Adoption of this “unseeded” approach was however preferred in view of the limited time available for the study.

4.4.6.6 Baseline Maps

The 0th, 10th, 20th and 50th percentile temperature exceedence maps for the natural (unimpacted) baseline are respectively shown in Figure 4-31 to Figure 4-34, whilst for the existing case baseline are respectively shown in Figure 4-35 to Figure 4-38. They are presented as they were subsequently used in all comparisons with the proposed discharge scenarios. The following general features can be seen in these maps:

1. As expected, the higher the temperature exceedence percentile, the lower the temperatures in the model domain;

2. The higher the temperature exceedence percentile, the larger the differences in temperature between the deep areas (e.g. main channel of the Port Pirie River) and the shallow intertidal areas. The temperatures in the deeper areas were generally higher than the intertidal areas. This is a reflection of the period of analysis, which has a cooling trend. The effect of the atmospheric heat exchange in the relatively low volumes of the intertidal areas lead to further temperature reductions in comparison to the deeper parts of the domain.

3. For the existing case baseline, there is a clear influence of the existing discharge in the temperatures at First Creek in all percentile exceedences. Visually, temperatures at the mouth were very similar to offshore temperatures, and they progressively increased further

into the creek. This result was consistent with the Nyrstar five year temperature monitoring program (NRS 2007).

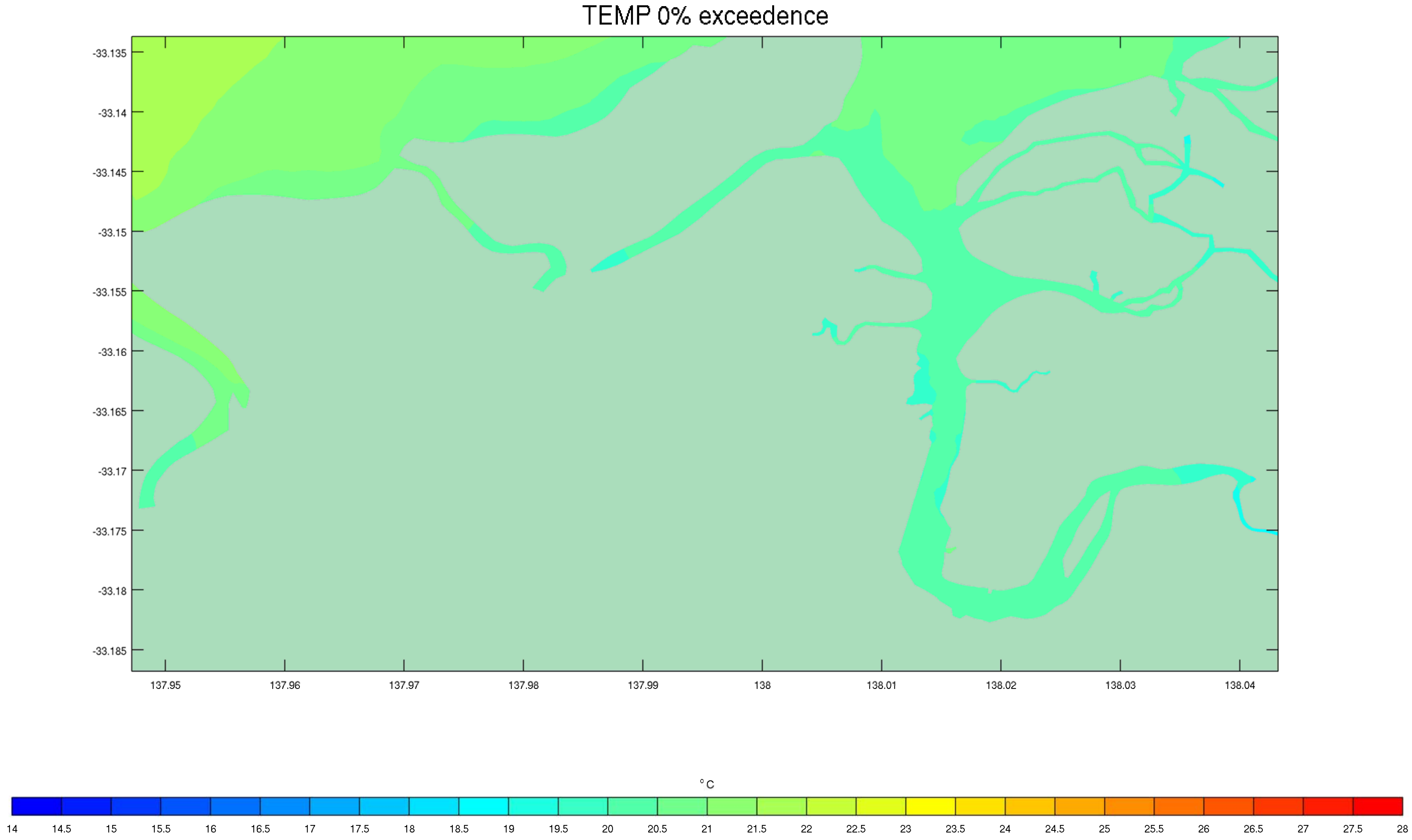

Figure 4-31 0th Percentile Temperature Exceedences – Natural Baseline

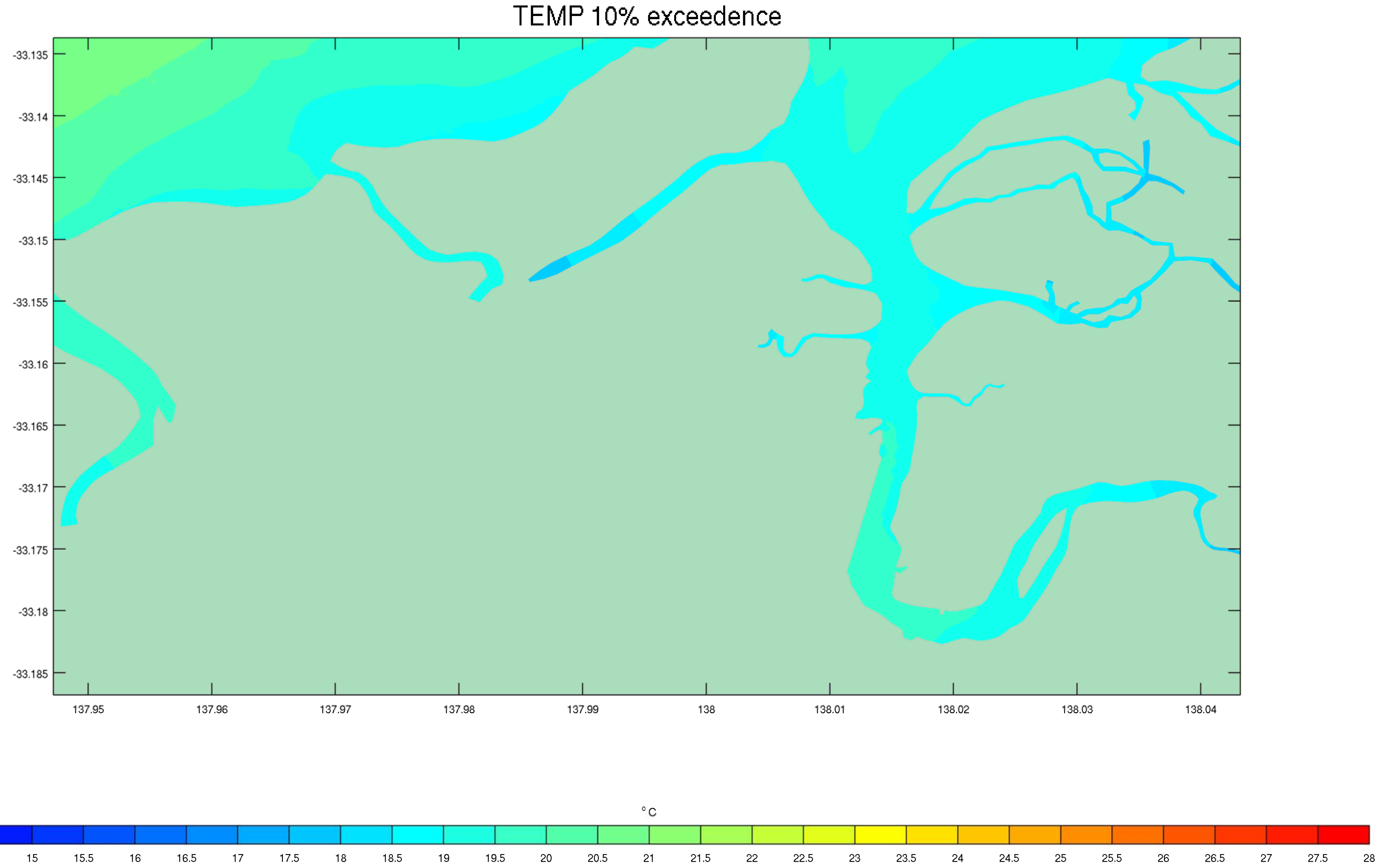

Figure 4-32 10th Percentile Temperature Exceedences – Natural Baseline

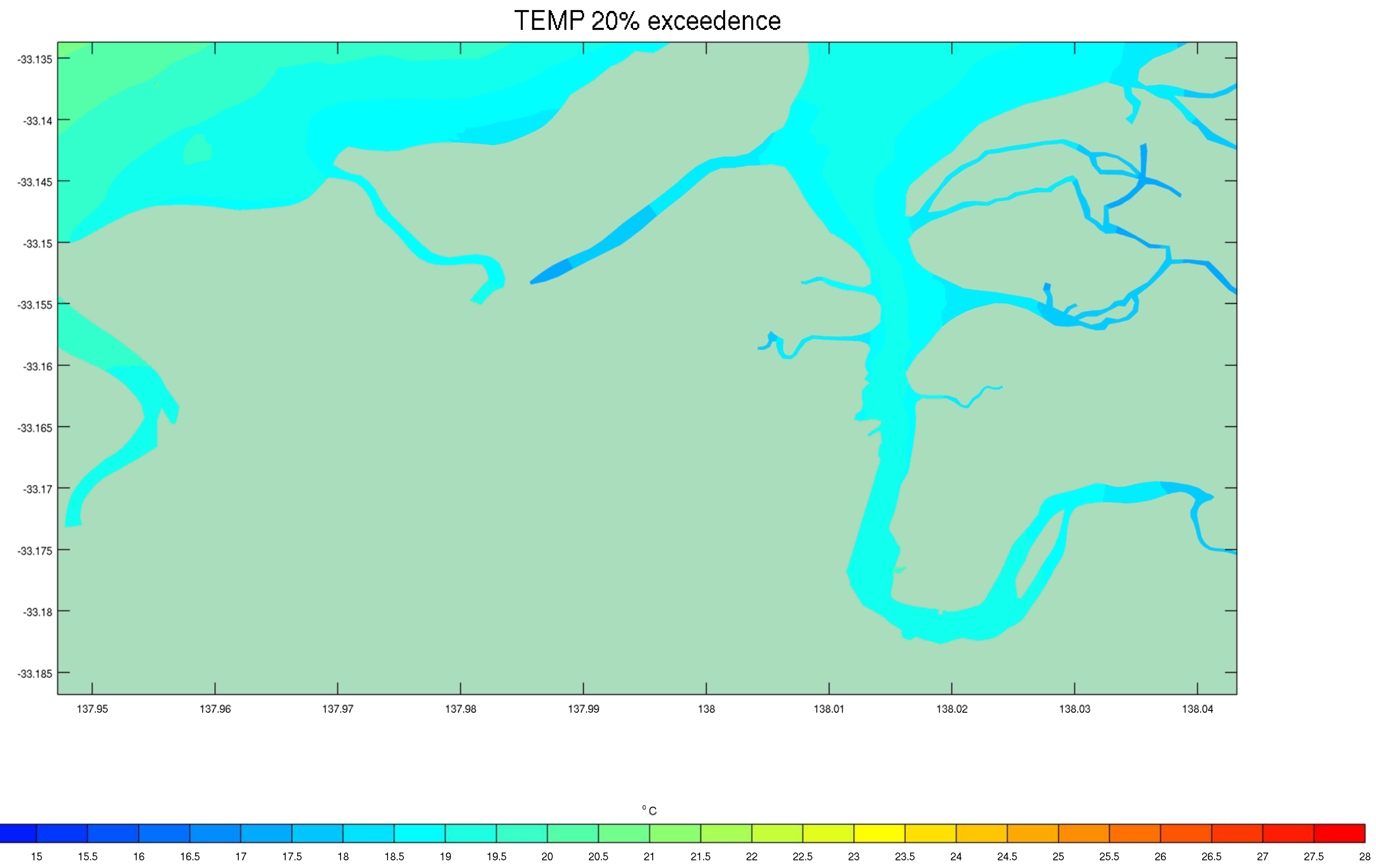

Figure 4-33 20th Percentile Temperature Exceedences – Natural Baseline

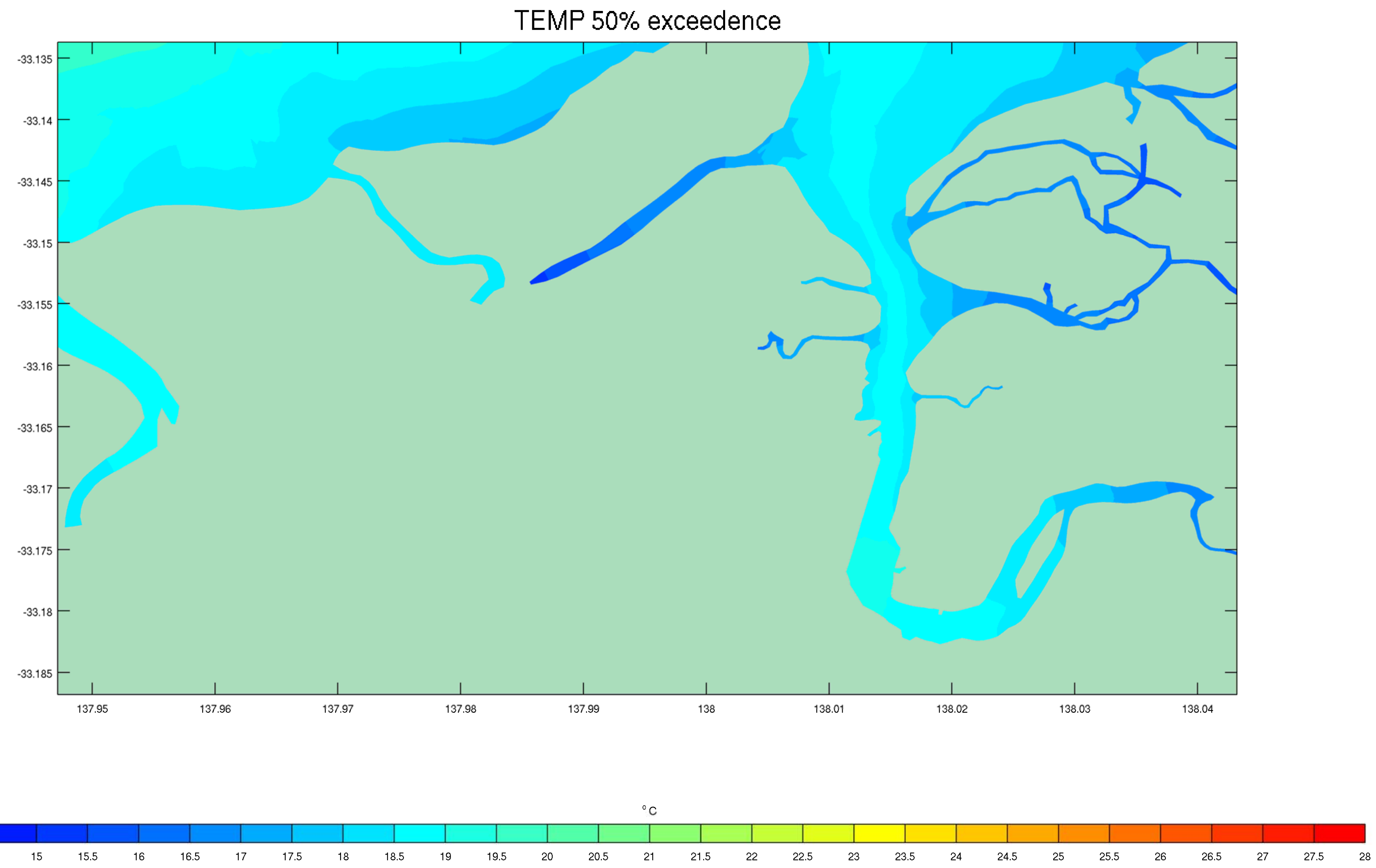

Figure 4-34 50th Percentile Temperature Exceedences – Natural Baseline

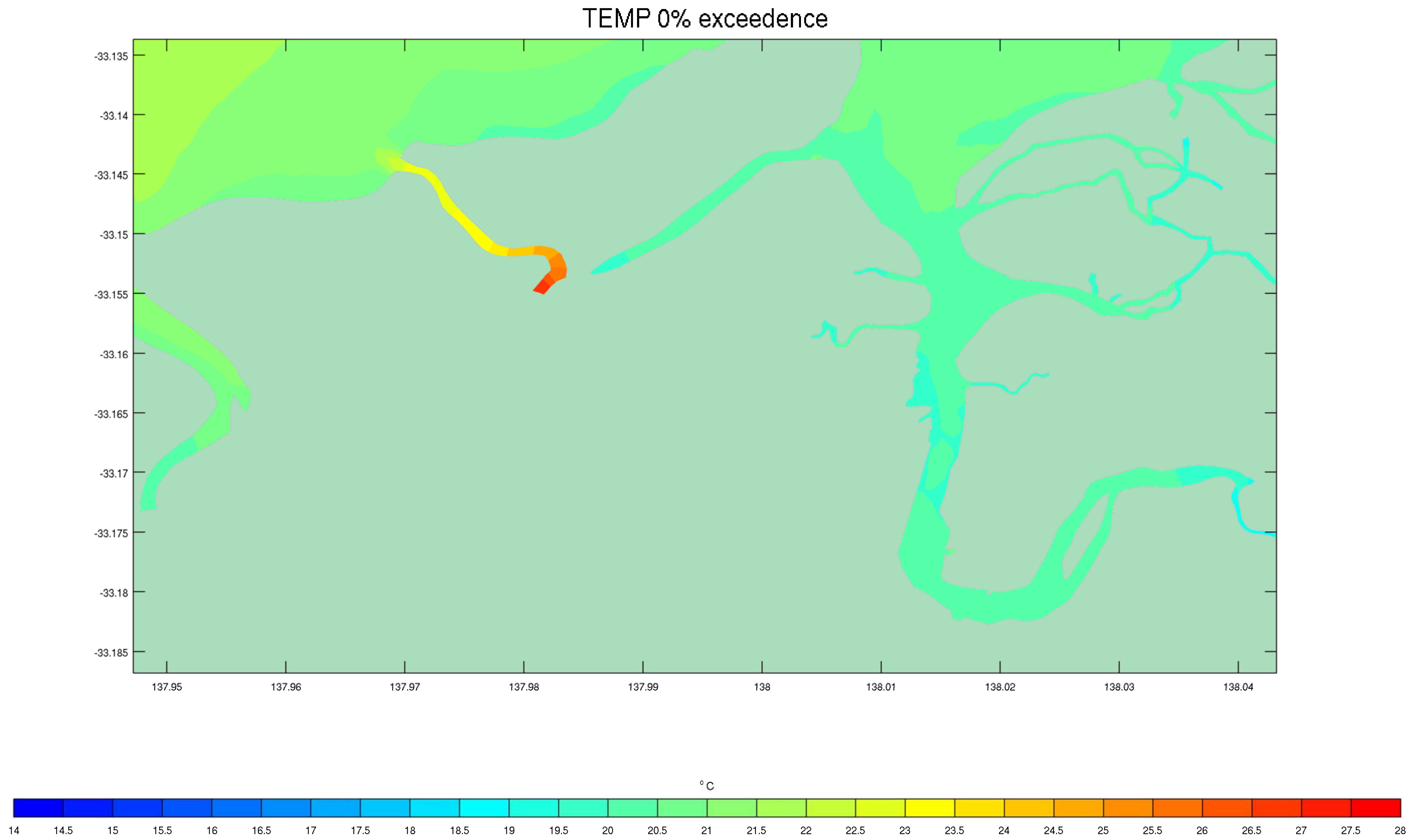

Figure 4-35 0th Percentile Temperature Exceedences – Existing Discharge Baseline

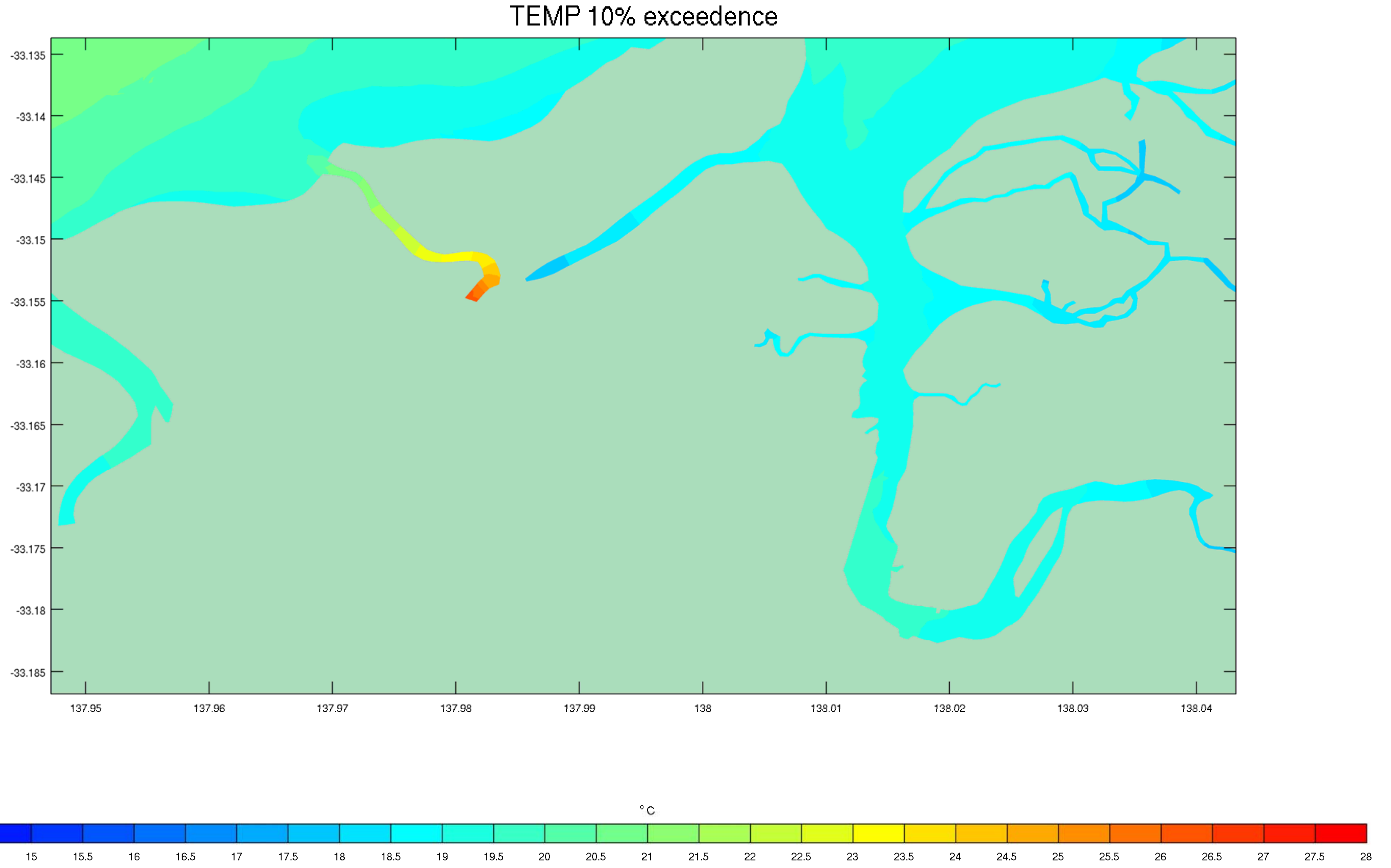

Figure 4-36 10th Percentile Temperature Exceedences – Existing Discharge Baseline

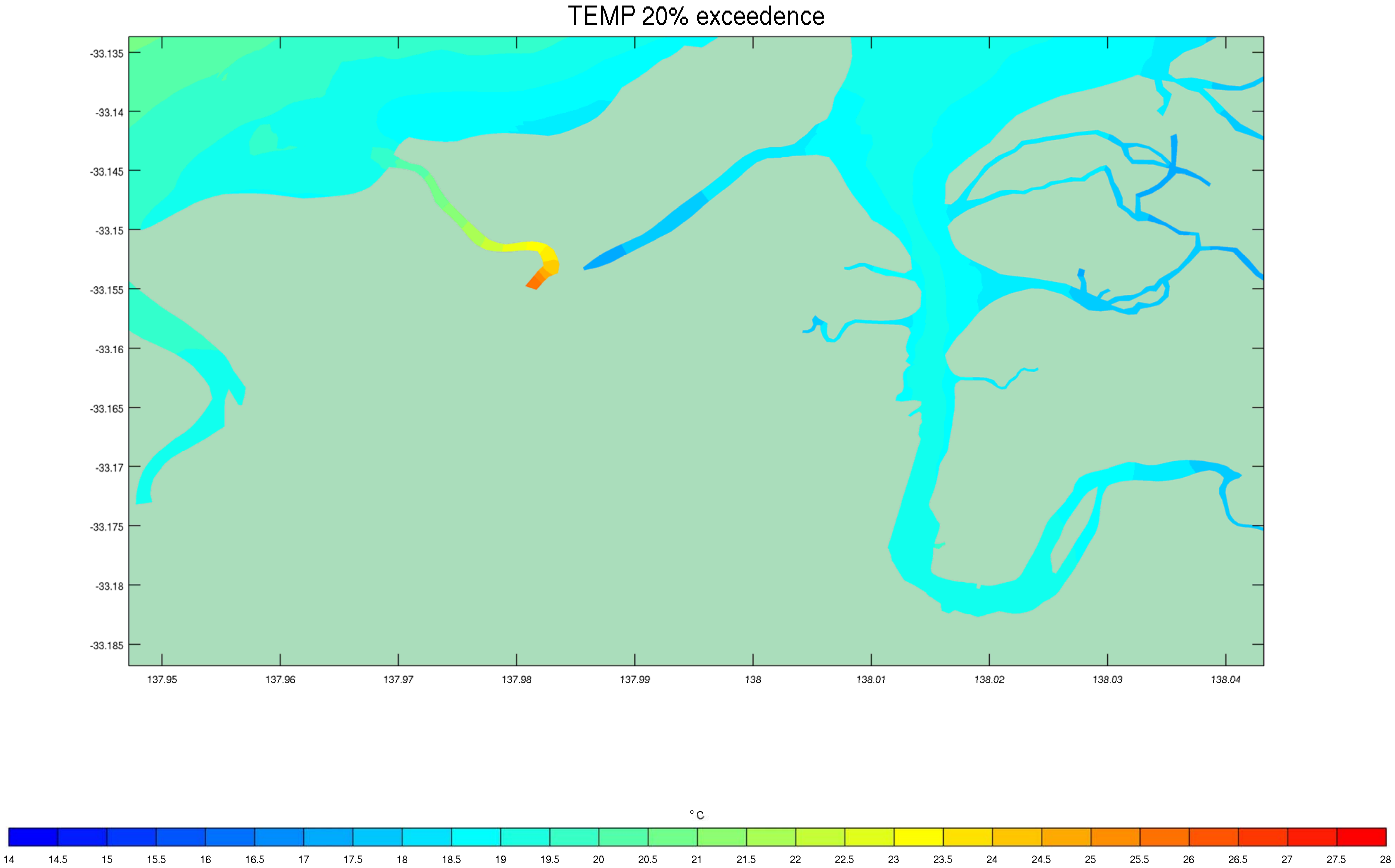

Figure 4-37 20th Percentile Temperature Exceedences – Existing Discharge Baseline

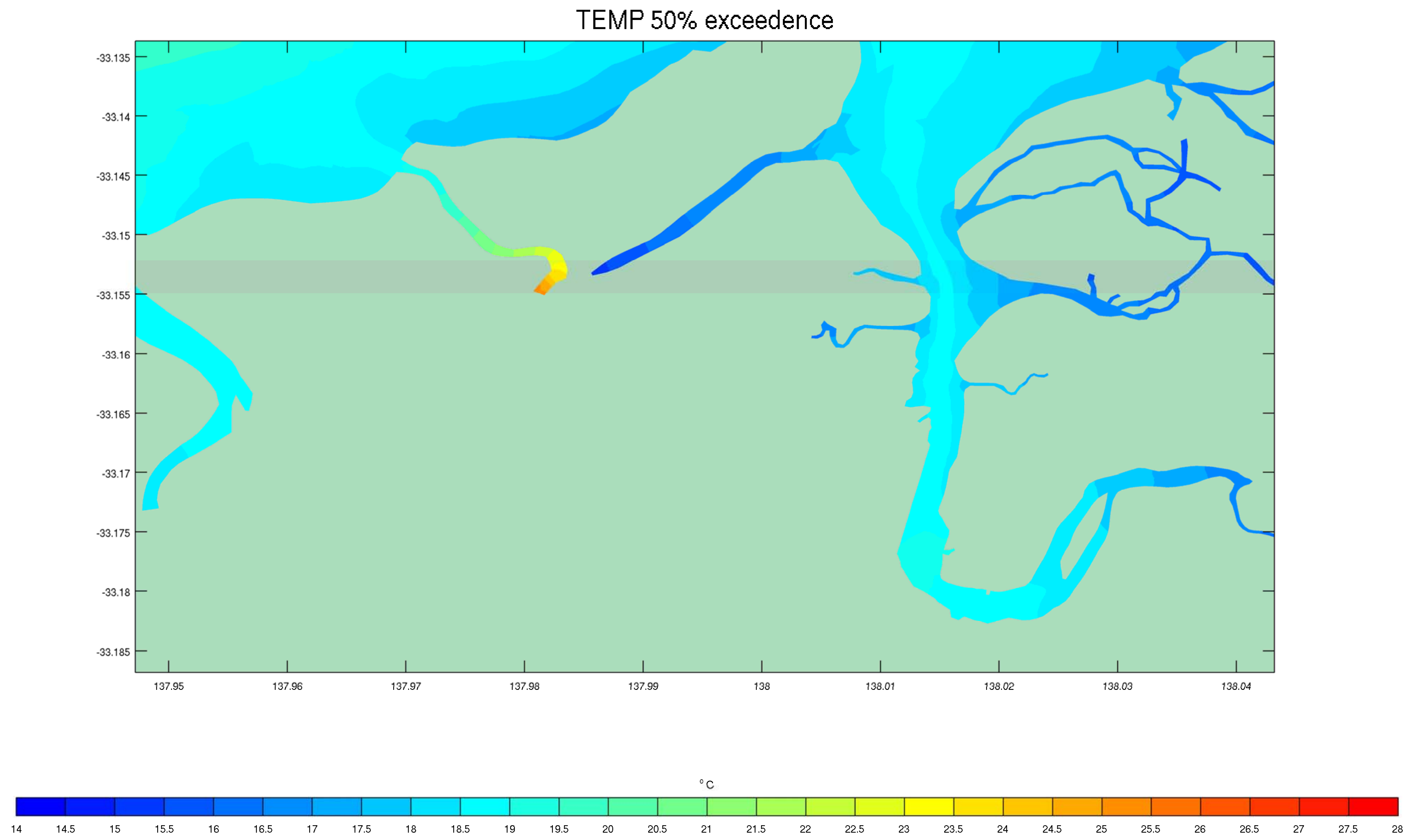

Figure 4-38 50th Percentile Temperature Exceedences – Existing Discharge Baseline

4.4.6.7 Discharge Alternative Maps

Scenario 1

The 0th, 10th, 20th and 50th percentile temperature exceedence maps for Scenario 1 are respectively shown in Figure 4-39 to Figure 4-42. They are presented as they were subsequently used in all comparisons with the existing discharge baseline, and the natural (unimpacted) baseline (to determine compliance with the present and draft proposed SA EPA guidelines for temperature increase). The following general features can be seen in these maps:

1. In contrast to both baselines, the effects of the combination of existing and proposed discharges created a more appreciable temperature increase throughout First Creek. This is so to the point the effects of the discharge extend beyond the mouth of First Creek in all percentiles.

2. For increasingly higher temperature exceedences percentiles, there was a more pronounced gradient of temperatures along First Creek. This is expected as the higher the percentiles the larger the influence of the tidal exchange with First Creek on the results.

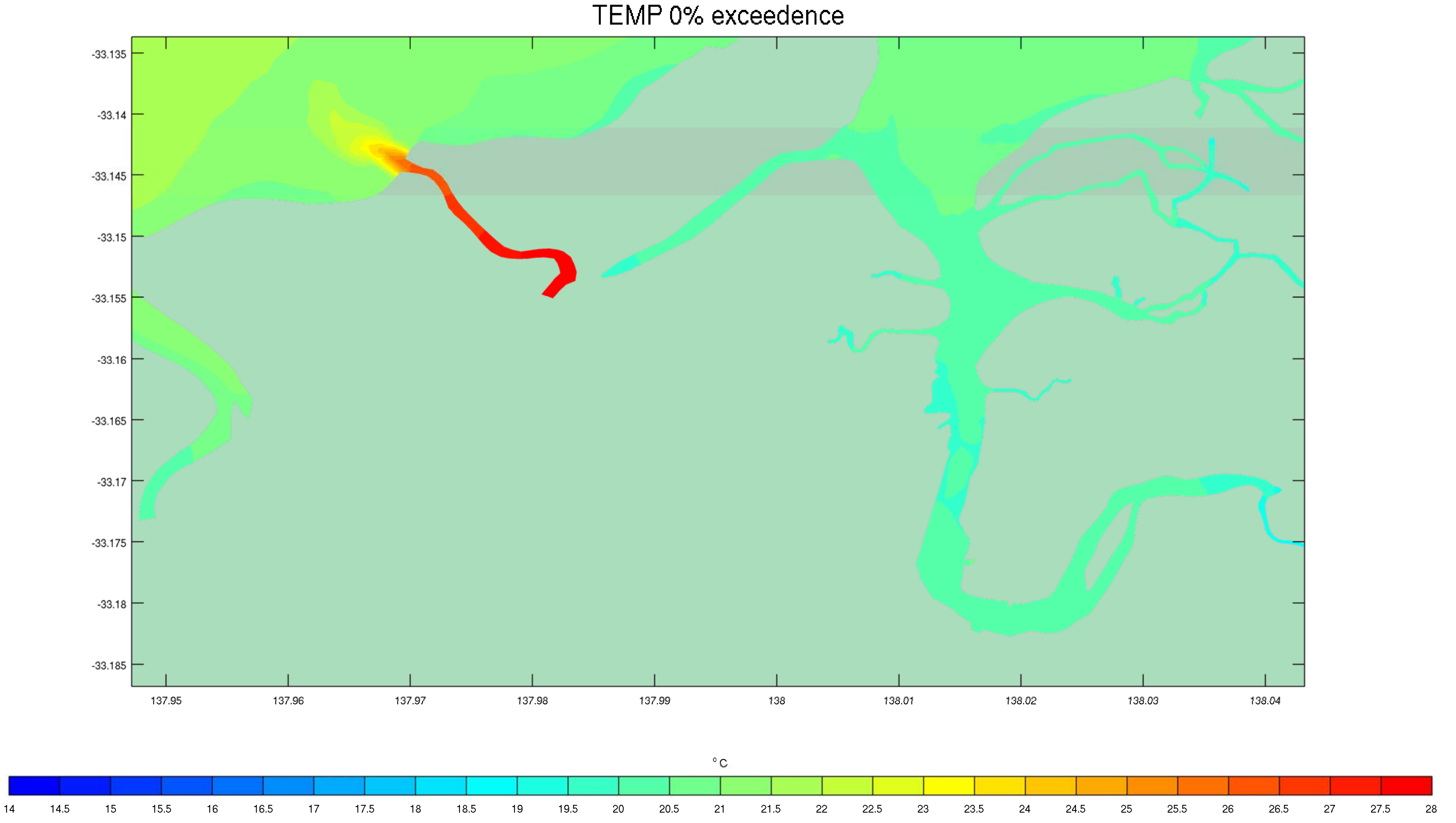

Figure 4-39 0th Percentile Temperature Exceedences – Scenario 1 Discharge

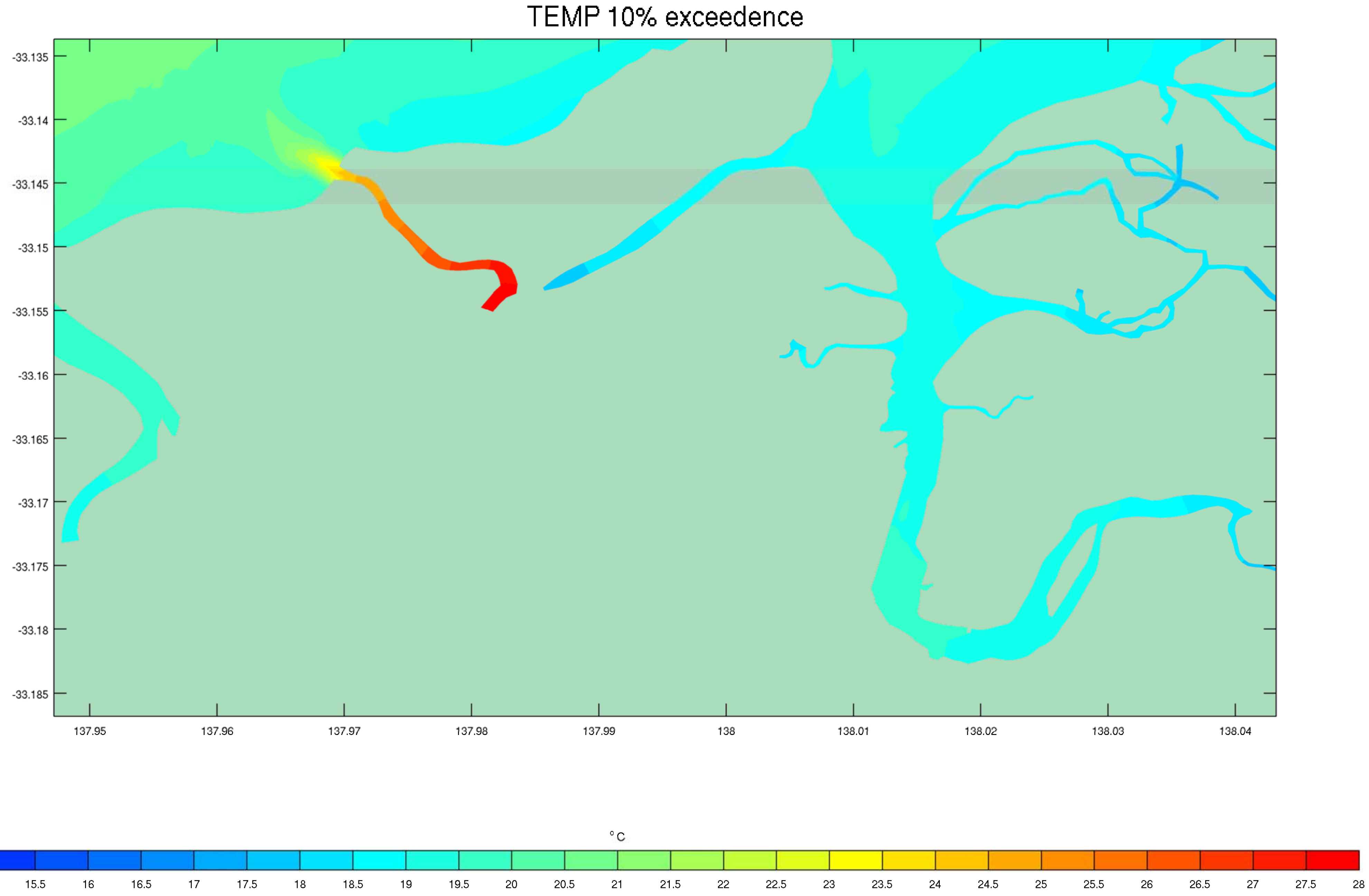

Figure 4-40 10th Percentile Temperature Exceedences – Scenario 1 Discharge

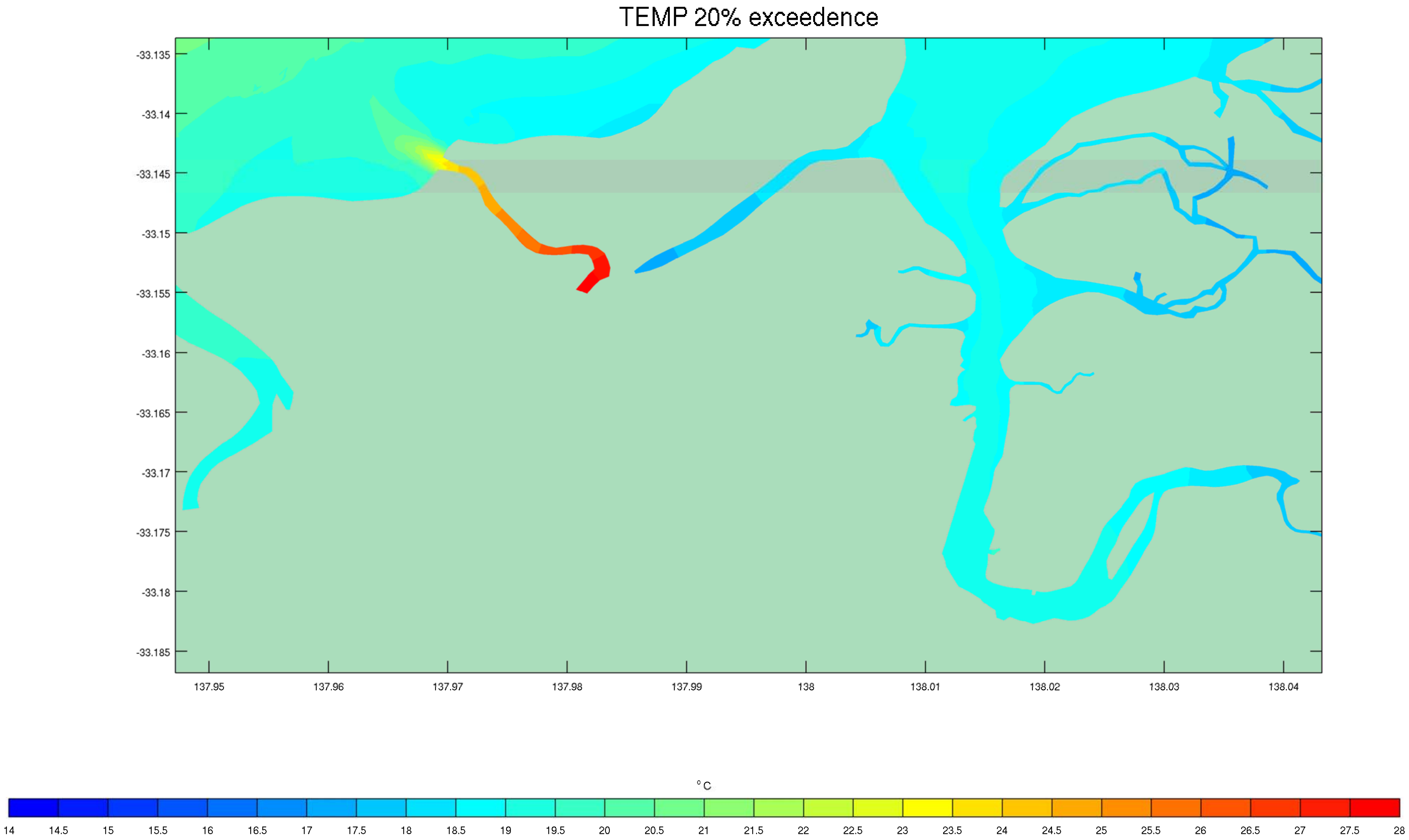

Figure 4-41 20th Percentile Temperature Exceedences – Scenario 1 Discharge

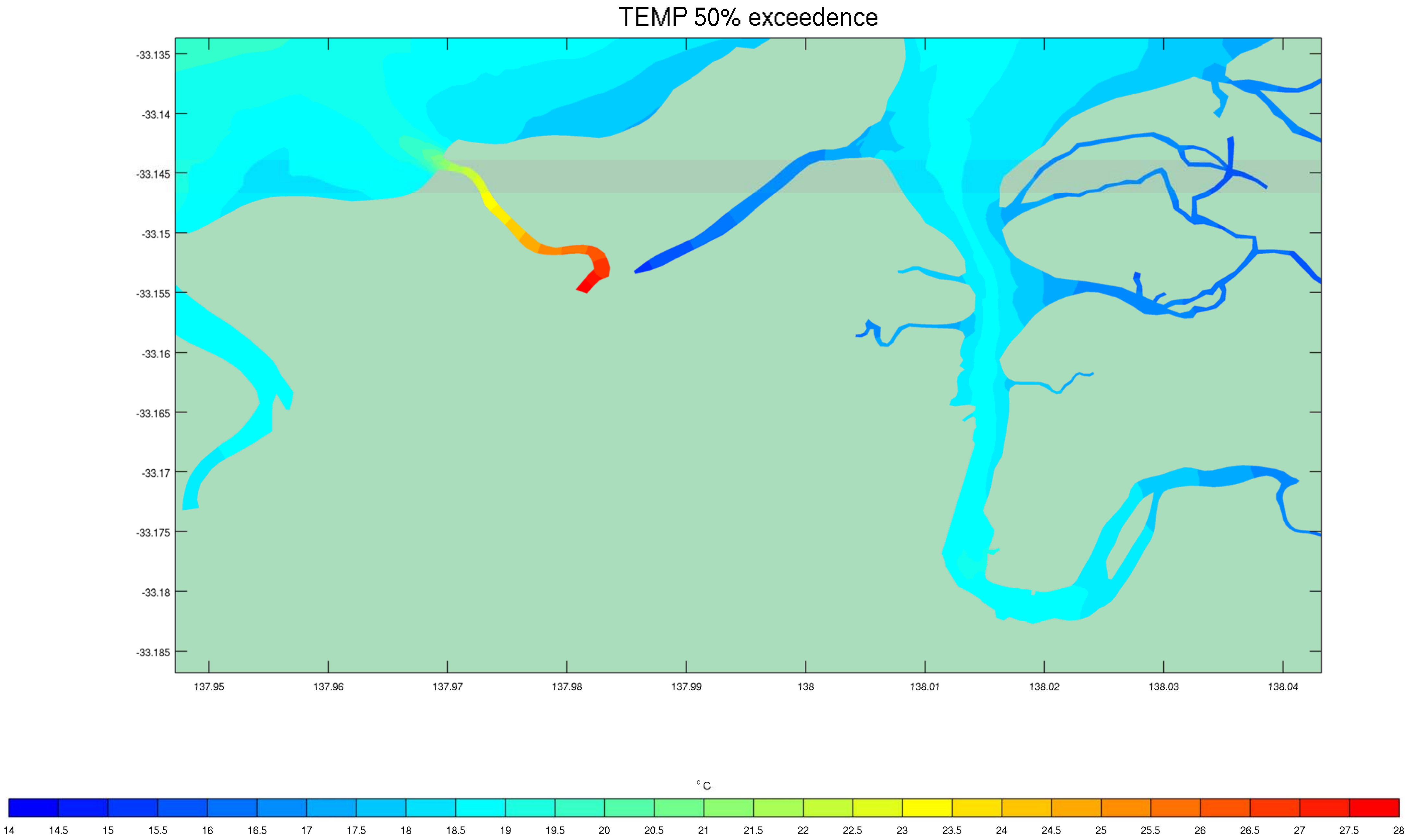

Figure 4-42 50th Percentile Temperature Exceedences – Scenario 1 Discharge

Scenario 3

The 0th, 10th, 20th and 50th percentile temperature exceedence maps for Scenario 3 are respectively shown in Figure 4-43 to Figure 4-46. Again, they are presented as they were subsequently used in all comparisons with the existing discharge baseline, and the natural (unimpacted) baseline (to determine compliance with the present and draft proposed SA EPA guidelines for temperature increase). The following general features can be seen in these maps:

1. In contrast to the natural baseline, it can be seen that the effects of the combination of existing and proposed discharges have an appreciable effect throughout First Creek. This effect was obvious for all percentiles, and as before, more prominent for the lowest temperature exceedences.

2. In contrast to the existing case baseline and Scenario 1, the effects of the combination of existing and proposed discharges created a less appreciable temperature increase throughout First Creek. Although the heat load for Scenario 3 increased in comparison to the existing discharge, the effects in terms of temperature were less pronounced, given that the assumed Scenario 3 temperature increases were lower than the existing discharge.

3. Visually, the effects of the discharge on temperature in comparison to offshore extended beyond the mouth of First Creek for the lower percentiles (0th and 20th). This effect was less obvious for the higher percentiles (20th and 50th).

4. Again, for increasingly higher temperature exceedences percentiles, there was a more pronounced gradient of temperatures along First Creek. This is expected as the higher the percentiles the larger the influence of the tidal exchange with First Creek on the results. Given the relatively low temperatures assumed in the Scenario 3 discharge, this gradient was softer than the gradients shown in the existing case baseline and in Scenario 1.

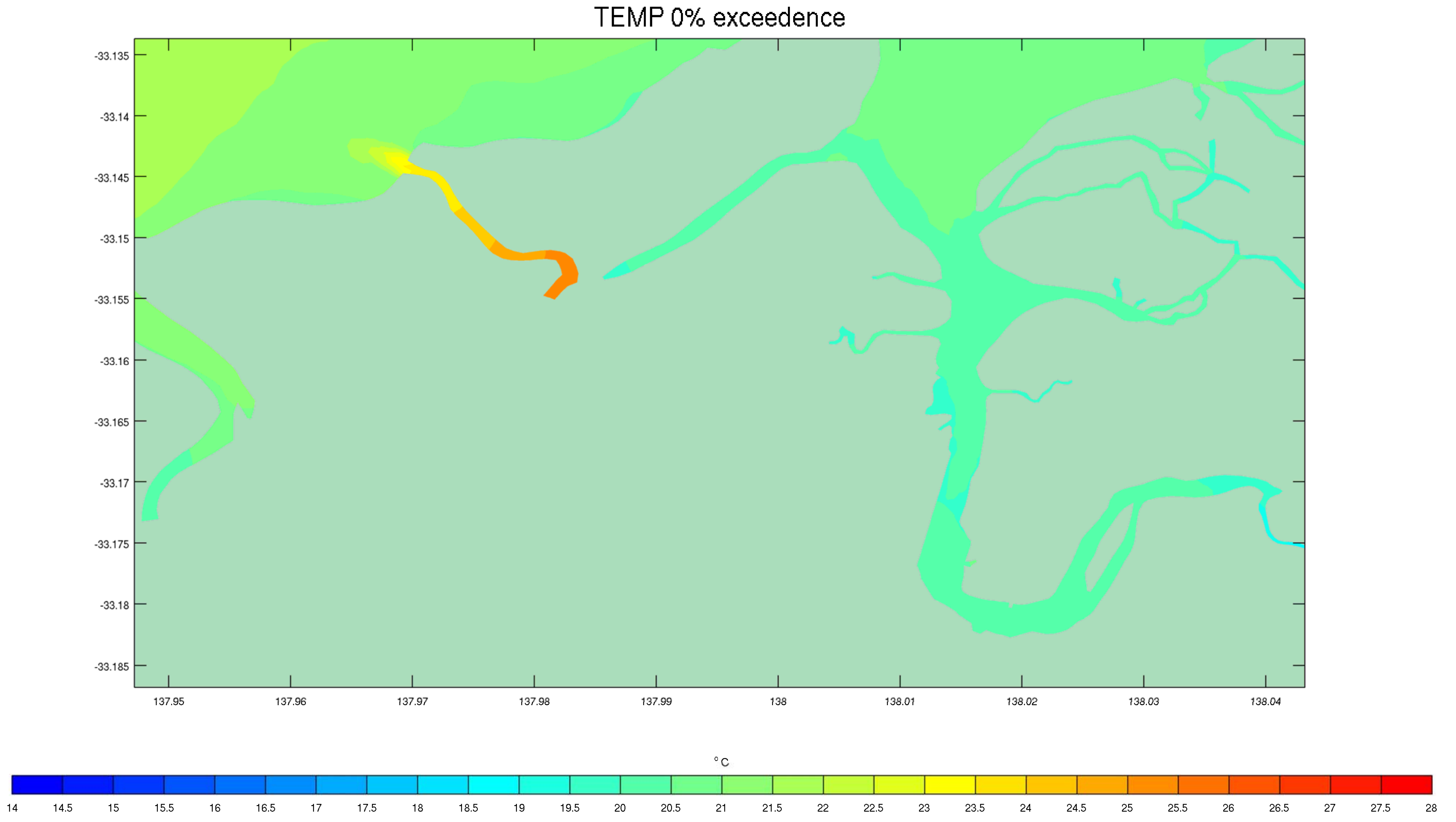

Figure 4-43 0th Percentile Temperature Exceedences – Scenario 3 Discharge

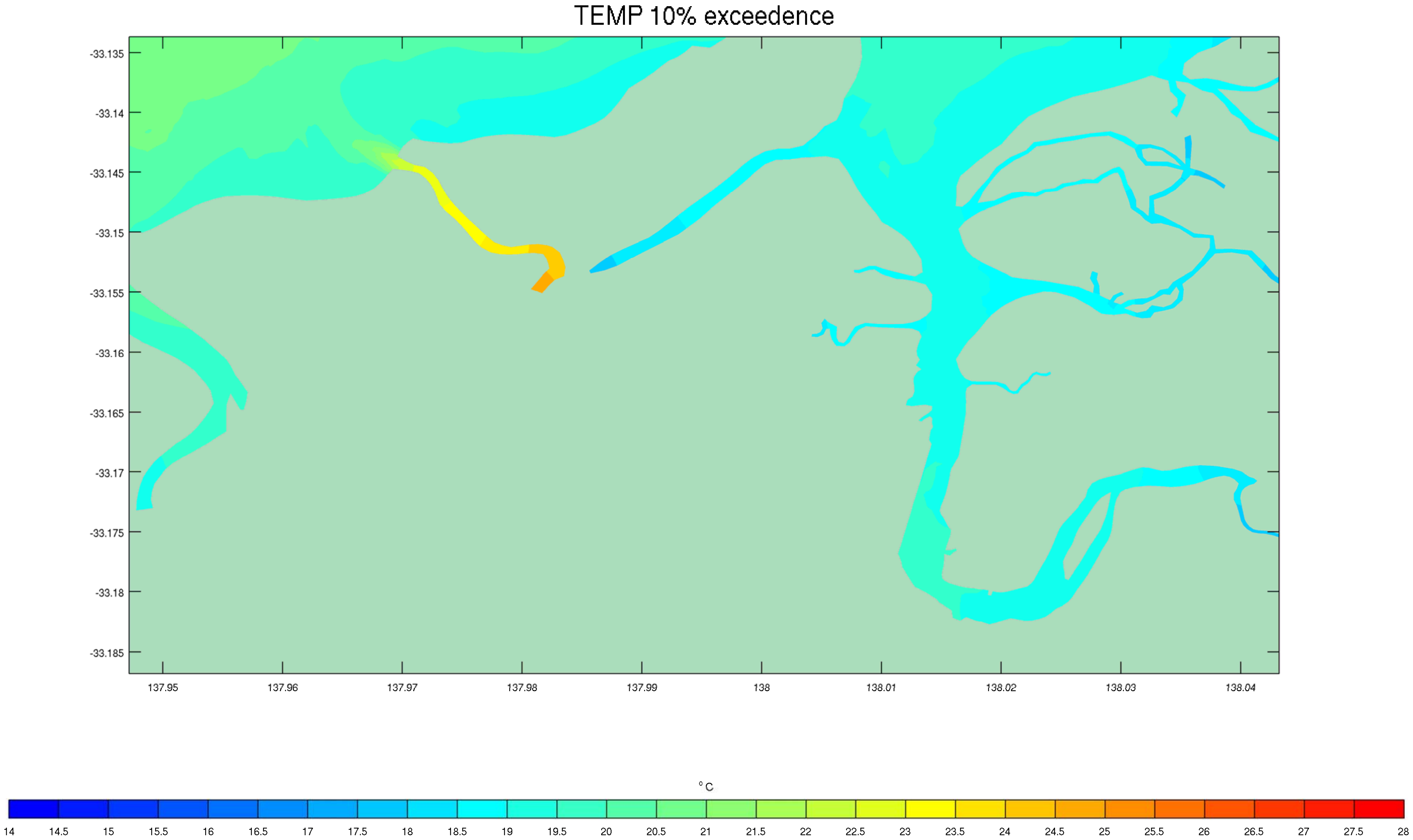

Figure 4-44 10th Percentile Temperature Exceedences – Scenario 3 Discharge

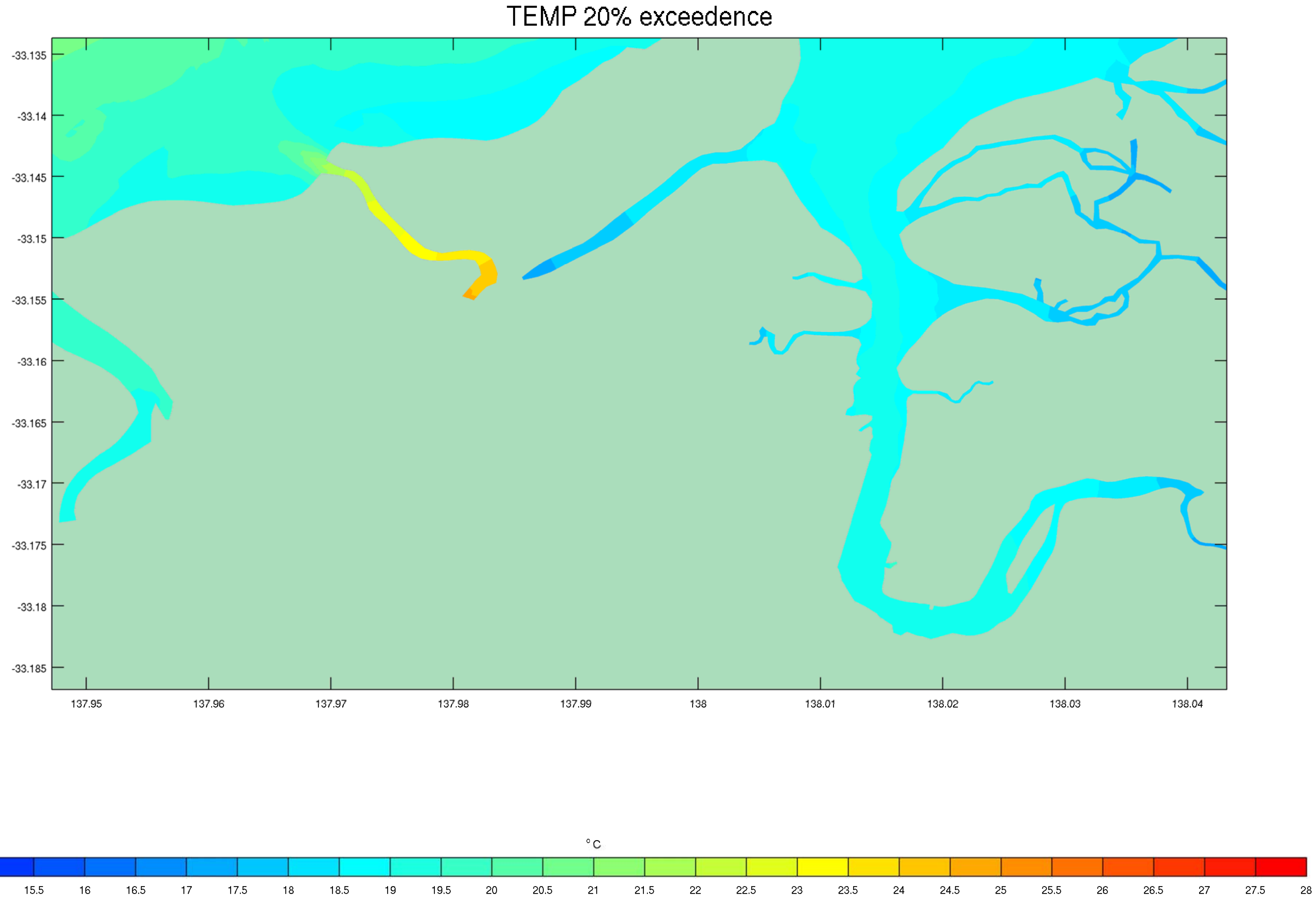

Figure 4-45 20th Percentile Temperature Exceedences – Scenario 3 Discharge

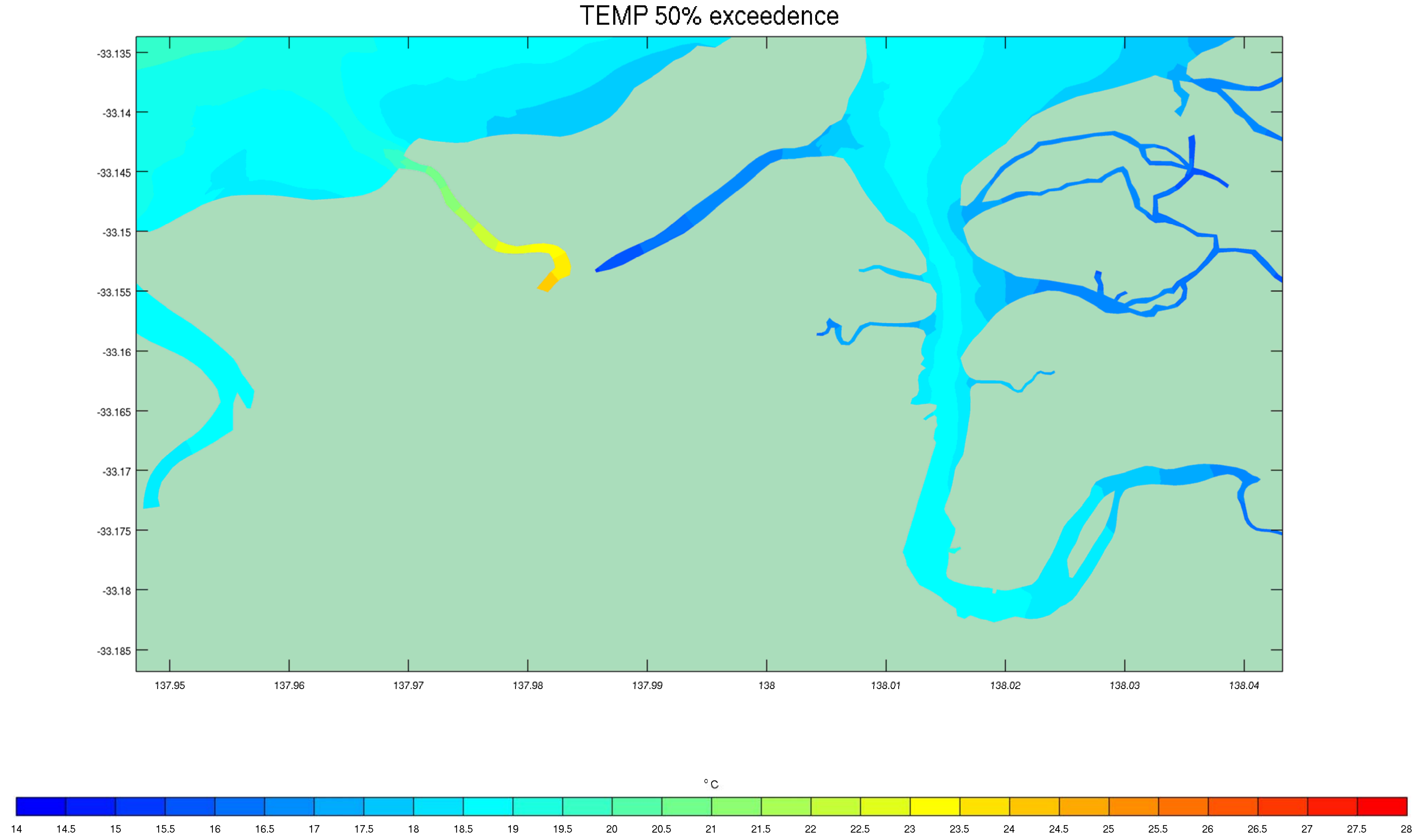

Figure 4-46 50th Percentile Temperature Exceedences – Scenario 3 Discharge

Scenario 4

The 0th, 10th, 20th and 50th percentile temperature exceedence maps for Scenario 4 are respectively shown in Figure 4-47 to Figure 4-50. Again, they are presented as they were subsequently used in all comparisons with present and draft proposed SA EPA guidelines for temperature increase. The following general features can be seen in these maps:

1. The temperature exceedences in Scenario 4 produced a further reduction of temperatures in First Creek in comparison to Scenarios 1 and 3. This is so because Scenario 4 assumed the lowest temperature in the proposed discharge. It is still important to note, though, that the heat load for Scenario 4 was increased in comparison to the existing case baseline.

2. Visually, the effects of the discharge on temperature in comparison to offshore were less obvious than Scenarios 1 and 3, but they still extended beyond the mouth of First Creek for the lower percentiles (0th and 10th). This effect was less obvious for the higher percentiles (20th and 50th).

3. Again, for increasingly high temperature exceedences percentiles, there was a more pronounced gradient of temperatures along First Creek. Given the relatively low temperatures assumed in the Scenario 4 discharge, this gradient was softer than the gradients shown in the existing case baseline and in Scenarios 1 and 3.

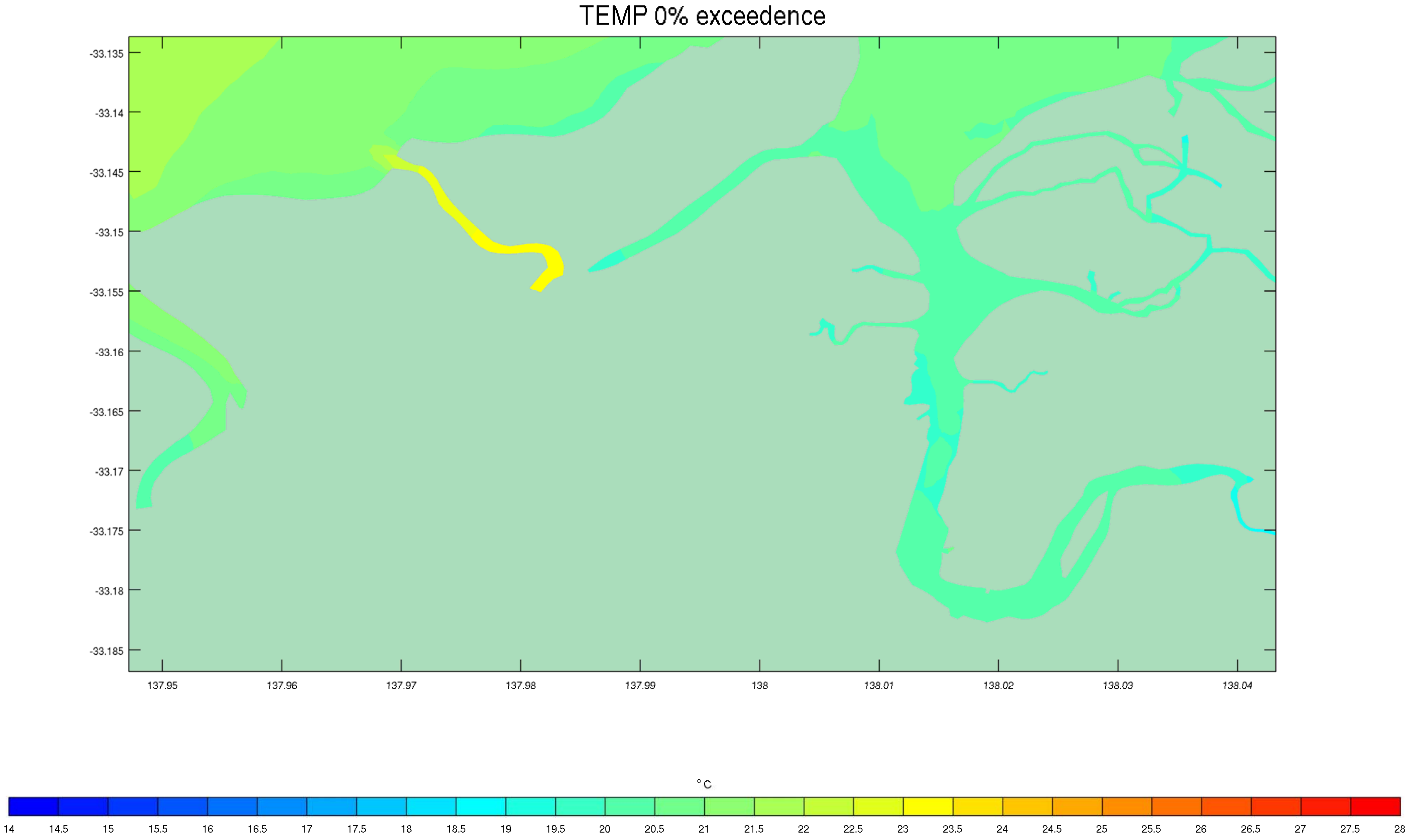

Figure 4-47 0th Percentile Temperature Exceedences – Scenario 4 Discharge

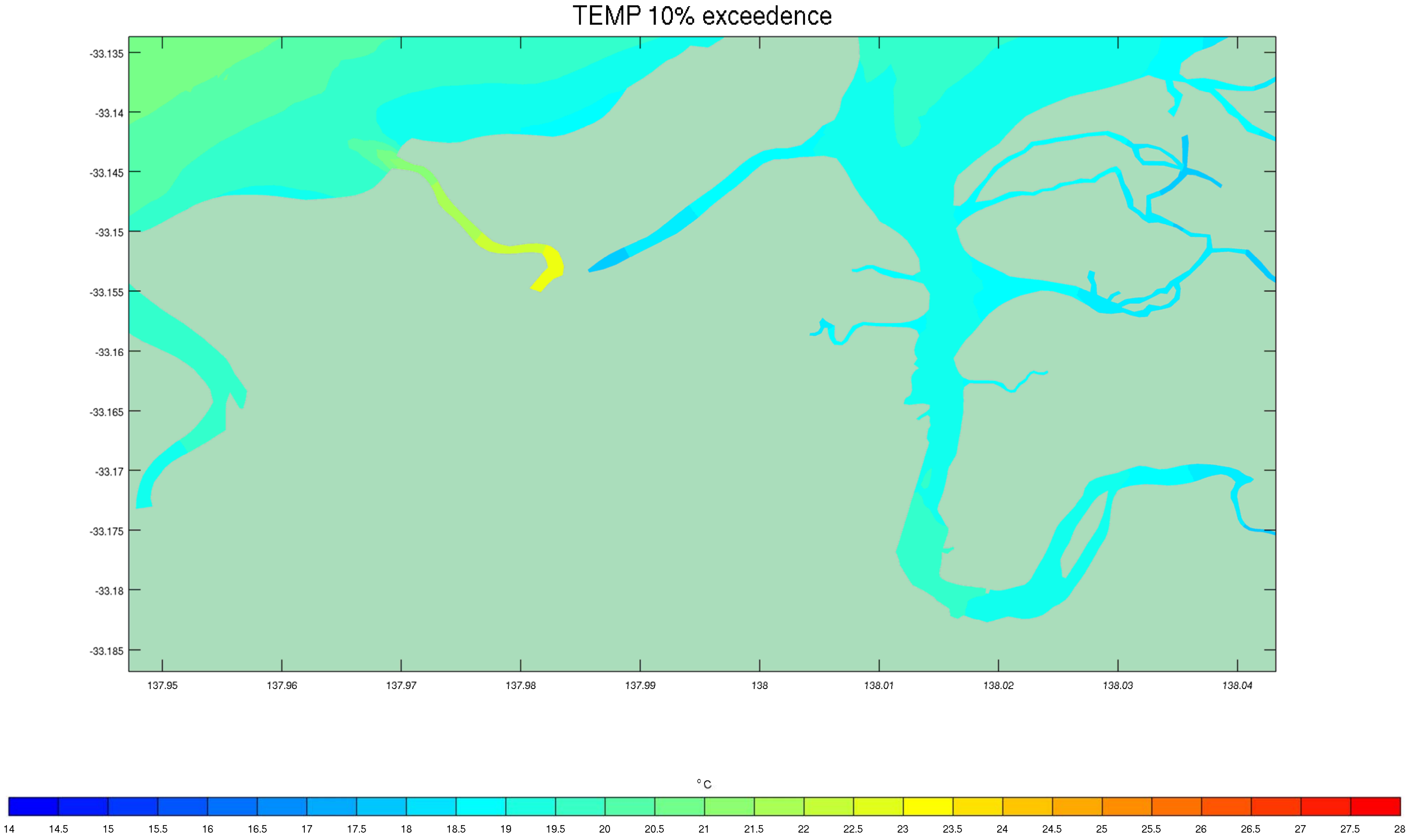

Figure 4-48 10th Percentile Temperature Exceedences – Scenario 4 Discharge

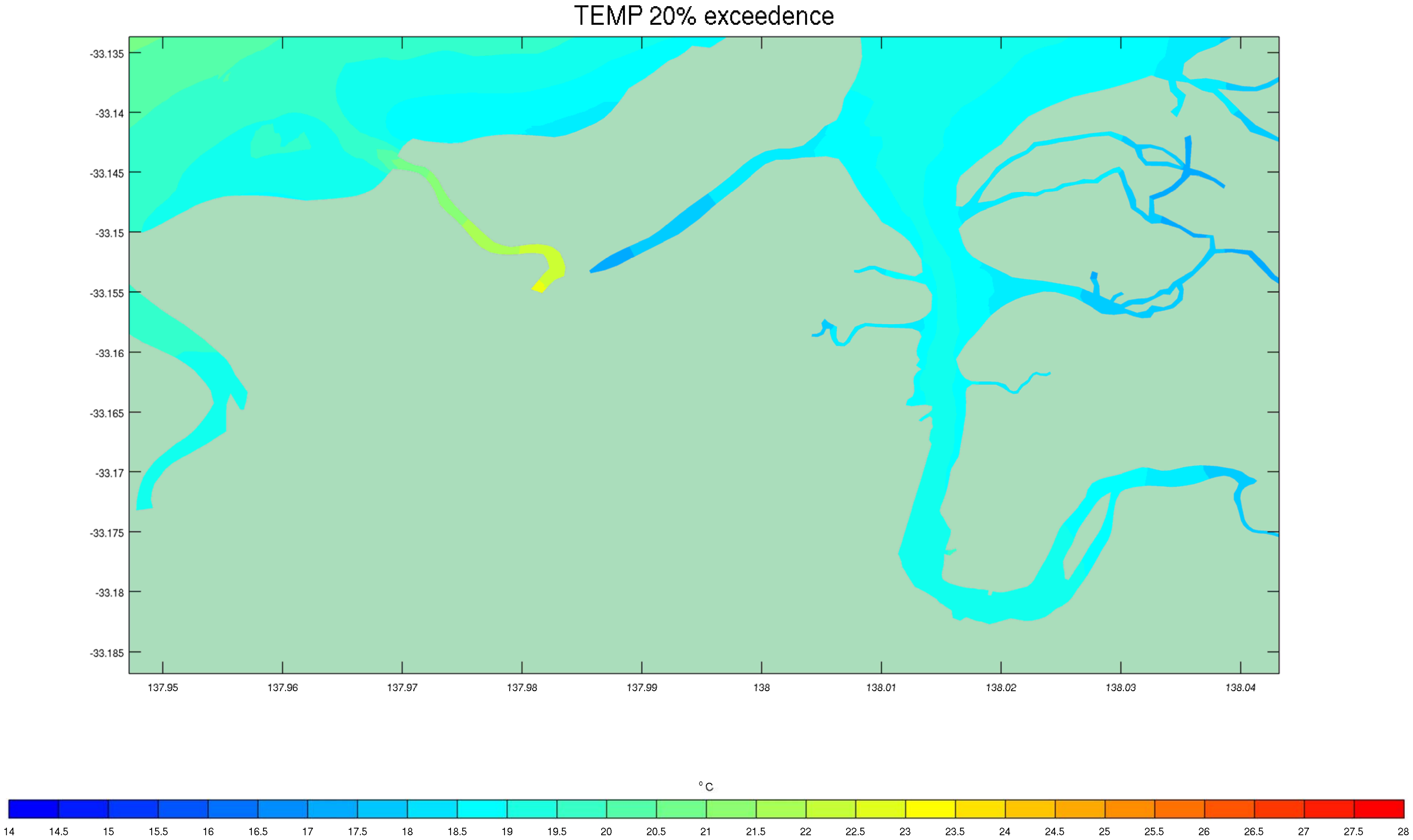

Figure 4-49 20th Percentile Temperature Exceedences – Scenario 4 Discharge

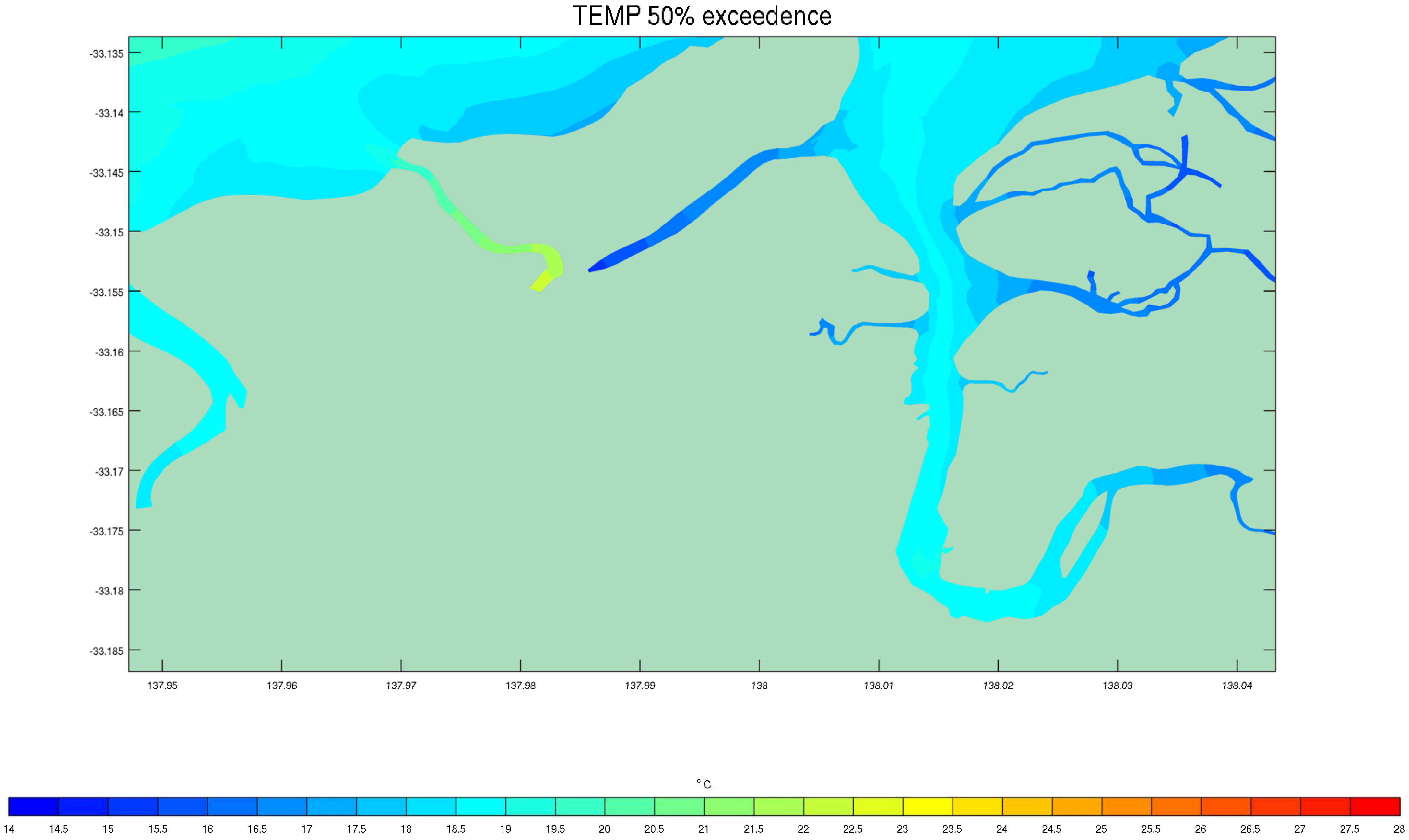

Figure 4-50 50th Percentile Temperature Exceedences – Scenario 4 Discharge

Scenario 13

The 0^{th}, 10^{th}, 20^{th} and 50^{th} percentile temperature exceedence maps for Scenario 13 are respectively shown in Figure 4-51 to Figure 4-54. Again, they are presented as they were subsequently used in all comparisons with the existing discharge baseline, and the natural (unimpacted) baseline (to determine compliance with the present and draft proposed SA EPA guidelines for temperature increase). The following general features can be seen in these maps:

1. The most obvious feature of Scenario 13 discharges is the distribution of the heat load to the Port Pirie River. The effects of the discharge on temperatures in the Port Pirie River were confined to the western shore;

2. Particularly for the lower percentiles, the shape of the plume in the Port Pirie River was asymmetric, being elongated in the tidal flow direction associated with flood tides (i.e. into the river). North of the location of the discharge, the plume was elongated in the direction transversal to the tidal flow, as the plume was attached to the river bank. As a result the plume did not extend as much towards the mouth as it did into the Port Pirie River. This pattern suggested the Port Pirie River is poorly flushed.

3. The effects of the existing discharge on temperatures in First Creek were essentially the same as the effects depicted in the existing baseline case.

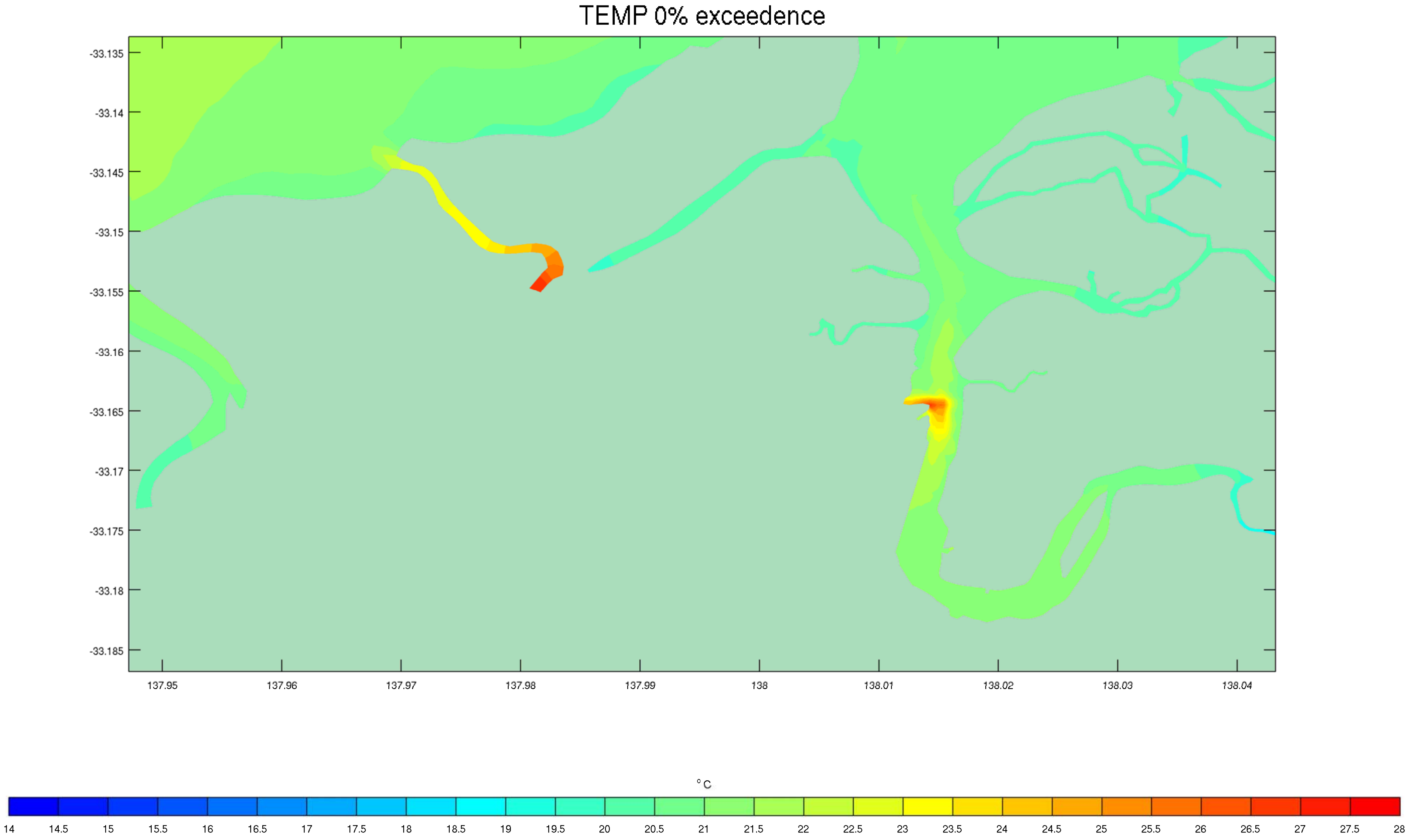

Figure 4-51 0th Percentile Temperature Exceedences – Scenario 13 Discharge

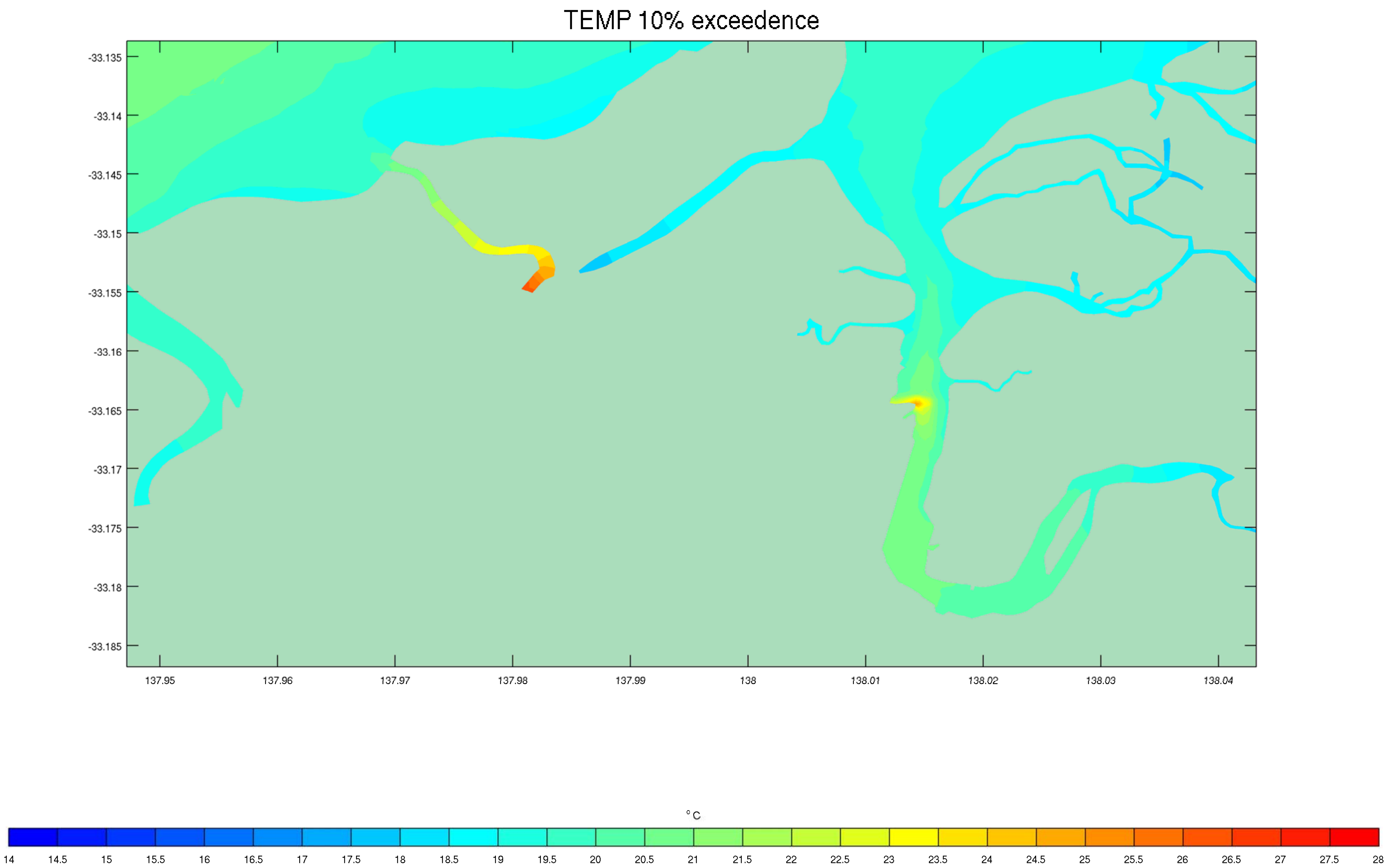

Figure 4-52 10th Percentile Temperature Exceedences – Scenario 13 Discharge

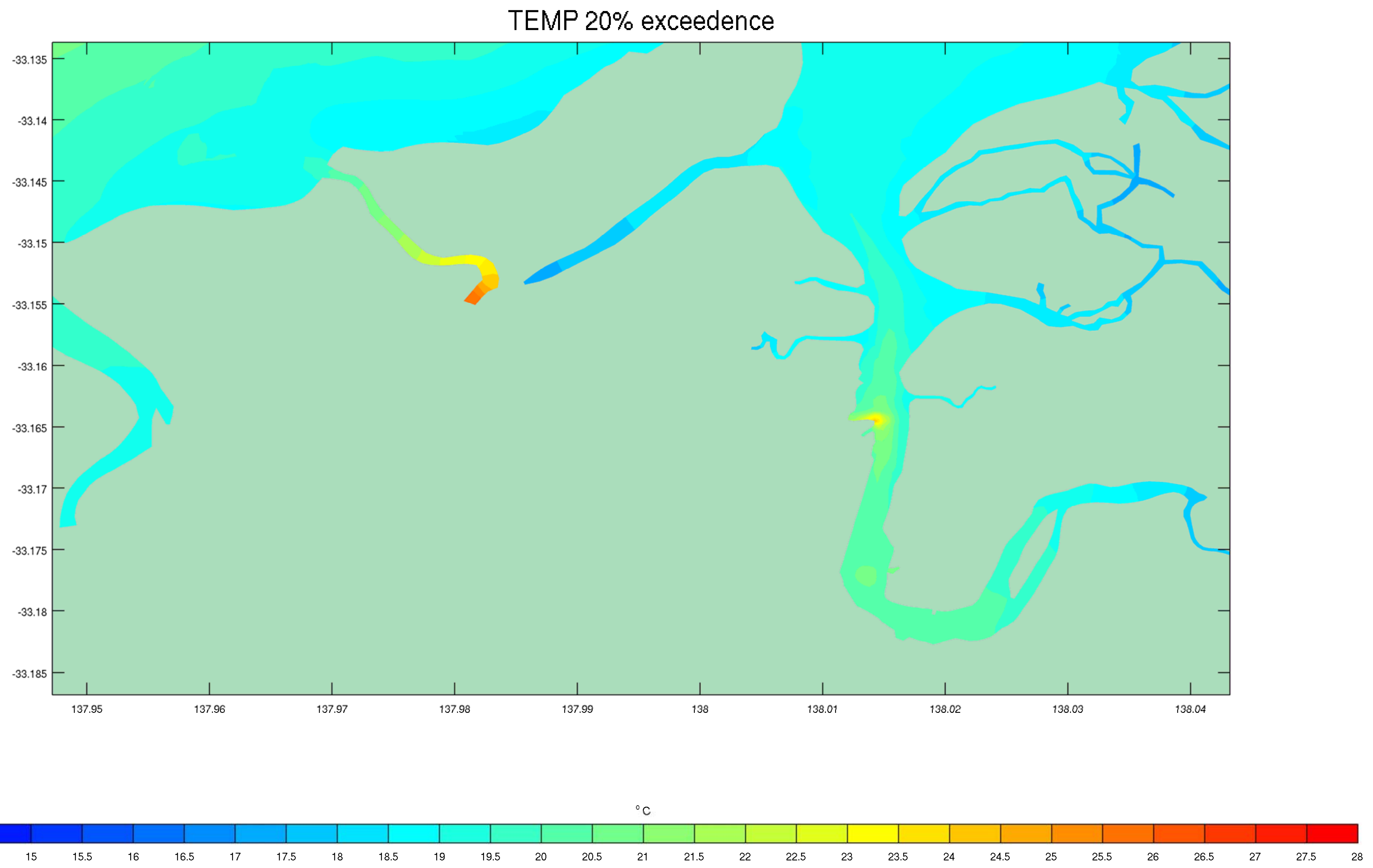

Figure 4-53 20th Percentile Temperature Exceedences – Scenario 13 Discharge

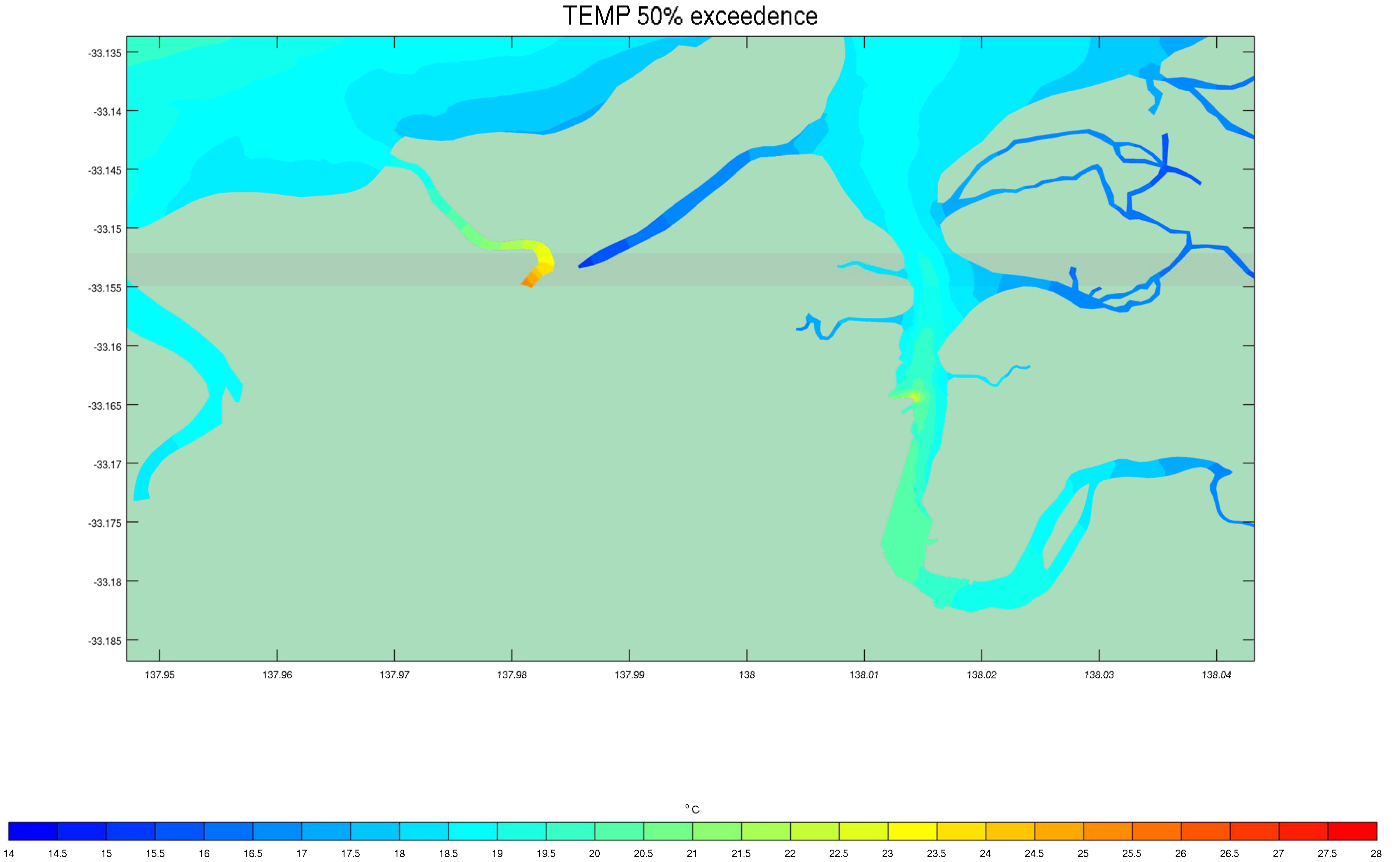

Figure 4-54 50th Percentile Temperature Exceedences – Scenario 13 Discharge

4.4.6.8 Comparisons of Discharge Alternatives with the Natural Baseline

Results of the temperature exceedence differences between the alternative discharge scenarios and the natural (unimpacted) baseline are presented below. These include the maps for:

1. the differences between the 10^{th} percentile temperature exceedences resulting from the discharge scenarios and the corresponding natural (unimpacted) baseline temperature exceedence percentile; for comparison with present SA EPA guidelines; and
2. the differences between the discharge scenarios 50^{th} percentile exceedences and the natural (unimpacted) baseline 20th percentile exceedences; for comparison with the draft SA EPA 2012 guidelines;

For the purpose of comparisons to the natural baseline, these results were sufficient to illustrate the total extent of the area of influence of the different discharge alternatives (including the existing discharge).

The reader is referred to the Appendices A to D for all temperature exceedence difference maps:

- Appendix A: Temperature exceedence differences between Scenario 1 and natural baseline;
- Appendix B: Temperature exceedence differences between Scenario 3 and natural baseline;
- Appendix C: Temperature exceedence differences between Scenario 4 and natural baseline; and
- Appendix D: Temperature exceedence differences between Scenario 13 and natural baseline.

Scenario 1 – Comparison with Present Guidelines

The differences between Scenario 1 and the baseline 10^{th} percentile temperature exceedences are presented in Figure 4-55. The other percentiles (0^{th} and 50^{th}) are presented in Appendix A. For this scenario a temperature exceedence difference above 8°C occurred near the discharge point and progressively decreased towards the mouth of First Creek. At this location the temperature exceedence differences were above 5°C for the lowest exceedence percentiles (see Appendix A).

Temperature percentile exceedences above 2°C within the plume extended approximately 140 m to 450 m beyond the mouth of First Creek. The maximum width of the plume with temperature exceedences above 2°C was approximately 140 to 260 m, depending on exceedence percentile. The largest distances and widths were associated with the lowest exceedence percentiles. This shows that a reach consisting of the extent of First Creek to a few hundred metres beyond its mouth would be exceeding present SA EPA guidelines.

It is worth to note here that the shape of the plume beyond the mouth of First Creek was influenced by the local bathymetry. While aerial imagery suggests a reasonable approximation of the bathymetry, more detailed assessments should rely on proper bathymetric survey in the area.

Scenario 1 – Comparison with Draft Proposed Guidelines

The differences between the Scenario 1 50^{th} percentile exceedences and the baseline 20^{th} percentile exceedences are presented in Figure 4-56 (also in Appendix A). For this comparison with the draft proposed guidelines, the entire First Creek would not be compliant. Although all temperatures exceedence differences beyond the mouth were smaller than 2^{o}C, a reach of approximately 280 m beyond the mouth of First Creek presented temperature exceedences differences above 0.5^{o}C. We note that the non-compliant area would extend further beyond this distance however, given model uncertainty (e.g. solar radiation not being measure locally, etc.), the model results were deemed not sufficiently accurate to capture these small temperature differences.

Scenario 3 – Comparison with Present Guidelines

The differences between Scenario 3 and the baseline 10th percentile temperature exceedences are presented in Figure 4-57. The other percentiles (0th and 50th) are presented in Appendix B. For this scenario a temperature exceedence difference above 6^{o}C occurred near the discharge point and progressively decreased towards the mouth of First Creek. At this location the temperature exceedence differences were above 3^{o}C for the lowest exceedence percentiles (see Appendix B).

Temperature percentile exceedences above 2^{o}C within the plume extended approximately 140 m beyond the mouth of First Creek (for the 0th and 10th exceedence percentiles). The 50th exceedence percentile showed a non-compliant over most of the length of First Creek up to approximately 70 m from its mouth. This shows that a reach consisting of the extent of First Creek to a couple of hundred metres beyond its mouth would be exceeding present SA EPA guidelines.

It is also noted that the areas associated with smaller temperature exceedences differences (i.e. 1^{o}C) were largest for the highest percentiles.

Scenario 3 – Comparison with Draft Proposed Guidelines

The differences between the Scenario 3 50th percentile exceedences and the baseline 20th percentile exceedences are presented in Figure 4-58 (also Appendix B). For this comparison with the draft proposed guidelines, the entire First Creek length plus an area extending approximately 140 m beyond its mouth would be non-compliant (temperature exceedences differences larger than 0.5^{o}C). As for Scenario 1, this area was probably larger, but the simulation results were likely not sufficiently accurate to resolve such small temperature differences.

Scenario 4 – Comparison with Present Guidelines

The differences between Scenario 4 and baseline 10th percentile temperature exceedences are presented in Figure 4-59 (also Appendix C). For this scenario a temperature exceedence difference above 3^{o}C extended over a significant length (at least 890 m) of First Creek.

Temperature percentile exceedences above 2^{o}C within the plume extended over most of First Creek, from the point of discharge to between 150 and 500 m up from the mouth, depending on exceedence percentiles. This shows that for Scenario 4 a reach consisting of the extent of First Creek to approximately hundred metres up from its mouth would be exceeding present SA EPA guidelines.

Scenario 4 – Comparison with Draft Proposed Guidelines

The differences between the Scenario 4 50th percentile exceedences and the baseline 20th percentile exceedences are presented in Figure 4-60 (also Appendix C).

For this comparison with the draft proposed guidelines, the entire First Creek length would be non-compliant. A small reach (extending approximately 70 m offshore from the creek mouth) would present temperature exceedences differences larger than 0.5^{o}C. As for Scenarios 1 and 3, this area was probably larger, but the simulation results were likely not sufficiently accurate to resolve such small temperature differences.

Scenario 13 – Comparison with Present Guidelines

The differences between Scenario 1 and baseline 10th percentile temperature exceedences are presented in Figure 4-61 (Also Appendix D). The comparison maps show the effects of the proposed discharge in the Port Pirie River, as well as the temperature effects of the existing discharge to First Creek. For the purposes of this analysis it was assumed that the discharge to Port Pirie River had negligible temperature effects near First Creek.

At First Creek, the existing discharge was not compliant with present guidelines (i.e. temperature exceedences larger than 2^{o}C) over a significant length of First Creek, extending from the point of discharge to between 370 m and 880 m from its mouth, depending on exceedence percentile. It is noted that this non-compliance would still occur under the proposed discharges to Port Pirie River.

As discussed above, not taking into consideration the degree of mixing obtained in the nearfield prior to insertion of the discharge into the model, lead to very conservative temperature increases in the vicinity of the diffuser. Consequently, for this scenario, a temperature increase above 2^{o}C was simulated in the Port Pirie River. These areas are unrealistic, based on the nearfield results obtained in Section 3.

Scenario 13 – Comparison with Draft Proposed Guidelines

The differences between the Scenario 13 50th percentile exceedences and the baseline 20th percentile exceedences are presented in Figure 4-62 (also Appendix D). Again, for this comparison with the draft proposed guidelines, an unrealistic area was shown to be non-compliant with the draft proposed guidelines.

Nevertheless, these results further indicated that the Port Pirie River is not well flushed. If a diffuser is to be constructed at that location, careful design must be undertaken to maximise dilution in the nearfield.

In First Creek, the non-compliant area (i.e. with exceedence percentile differences larger than 0.5 ^{o}C) extended from the point of discharge down to approximately 300 m up from its mouth. Again, this area of non-compliance was likely larger, maybe extending over the entire First Creek length. However, model results are likely not accurate enough to resolve these small temperature differences.

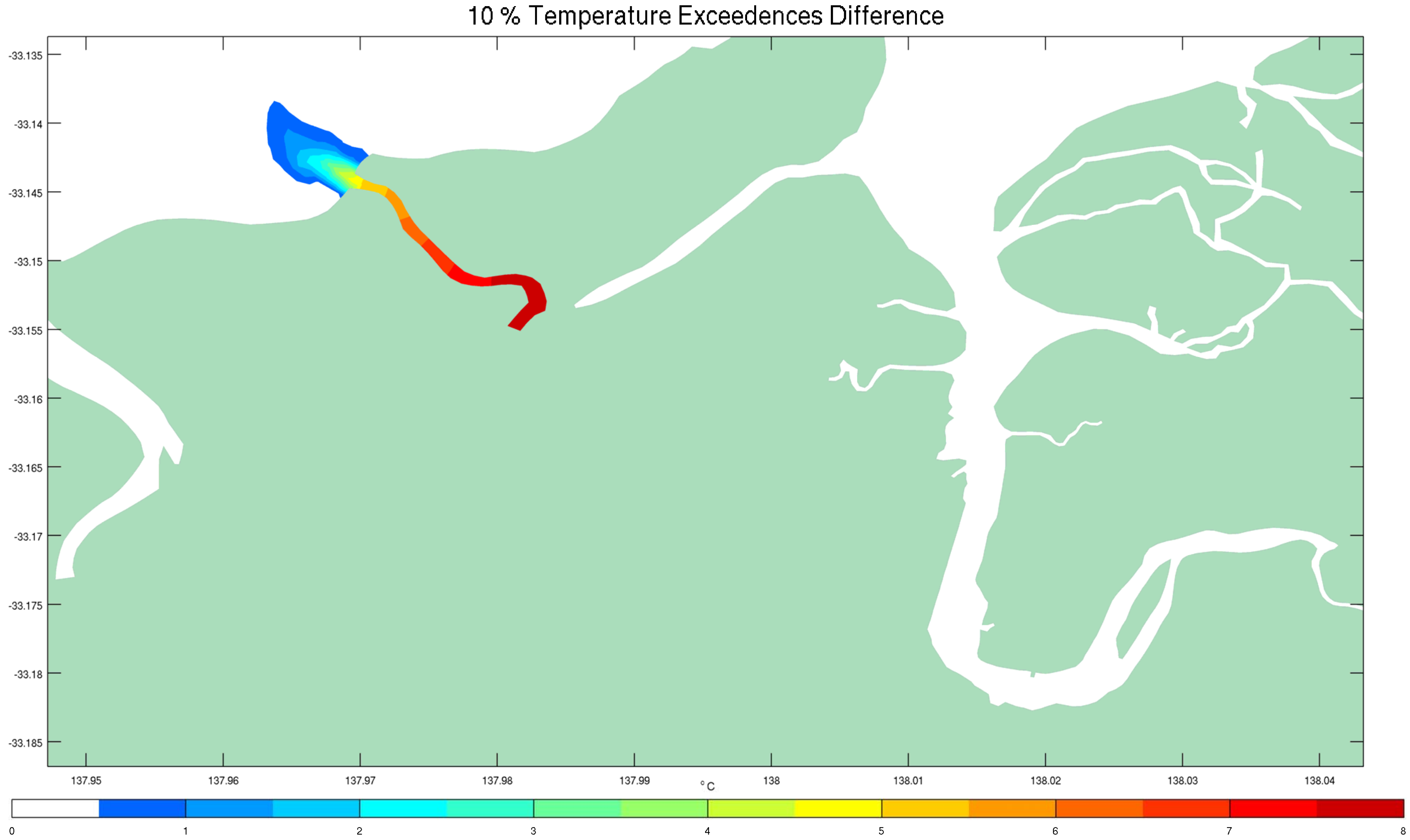

Figure 4-55 10th Percentile Temperature Exceedences Differences – Scenario 1 Discharge and Natural Baseline

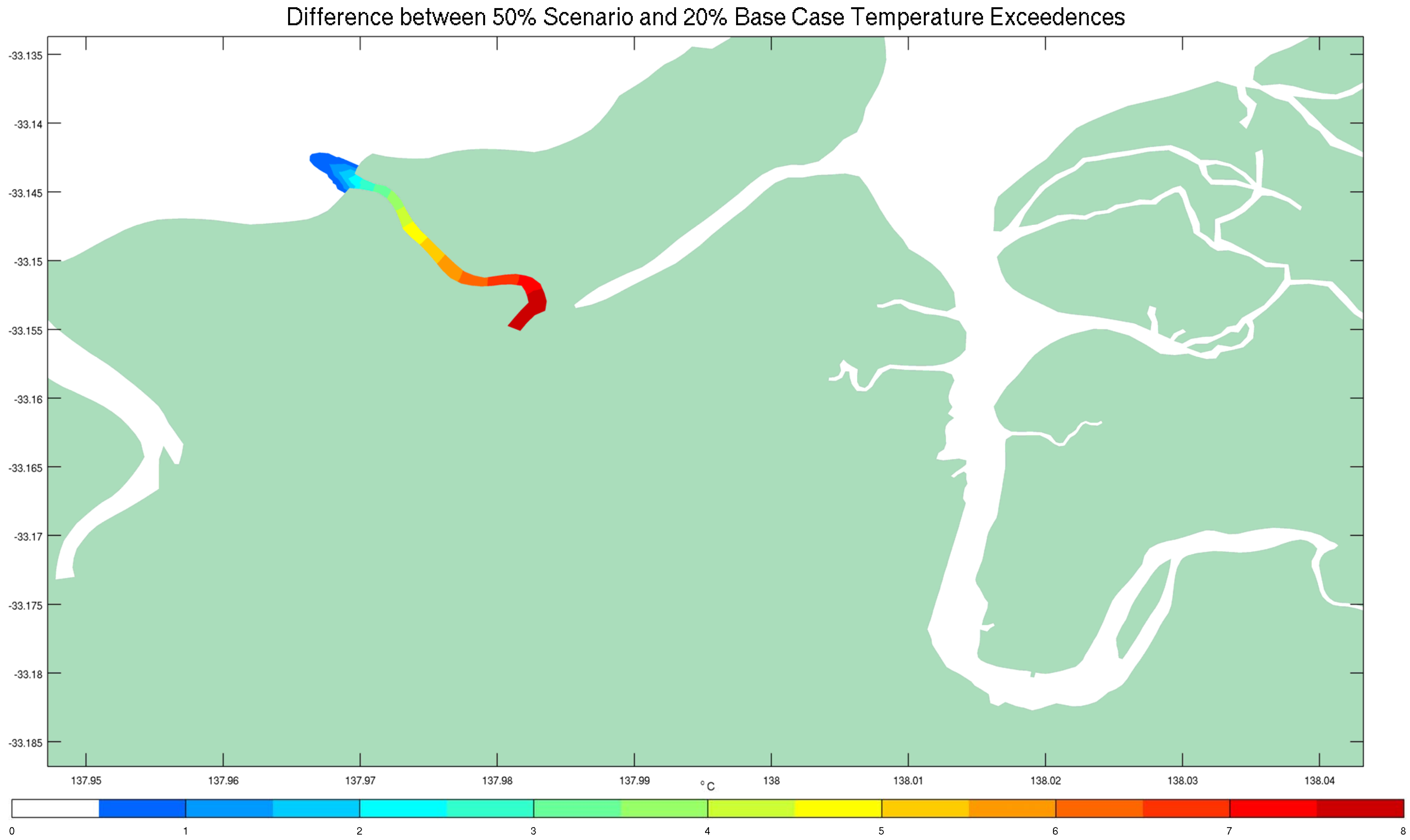

Figure 4-56 Differences between Scenario 1 50th Percentile Temperature Exceedences and Natural Baseline 20th Percentile Temperature Exceedences

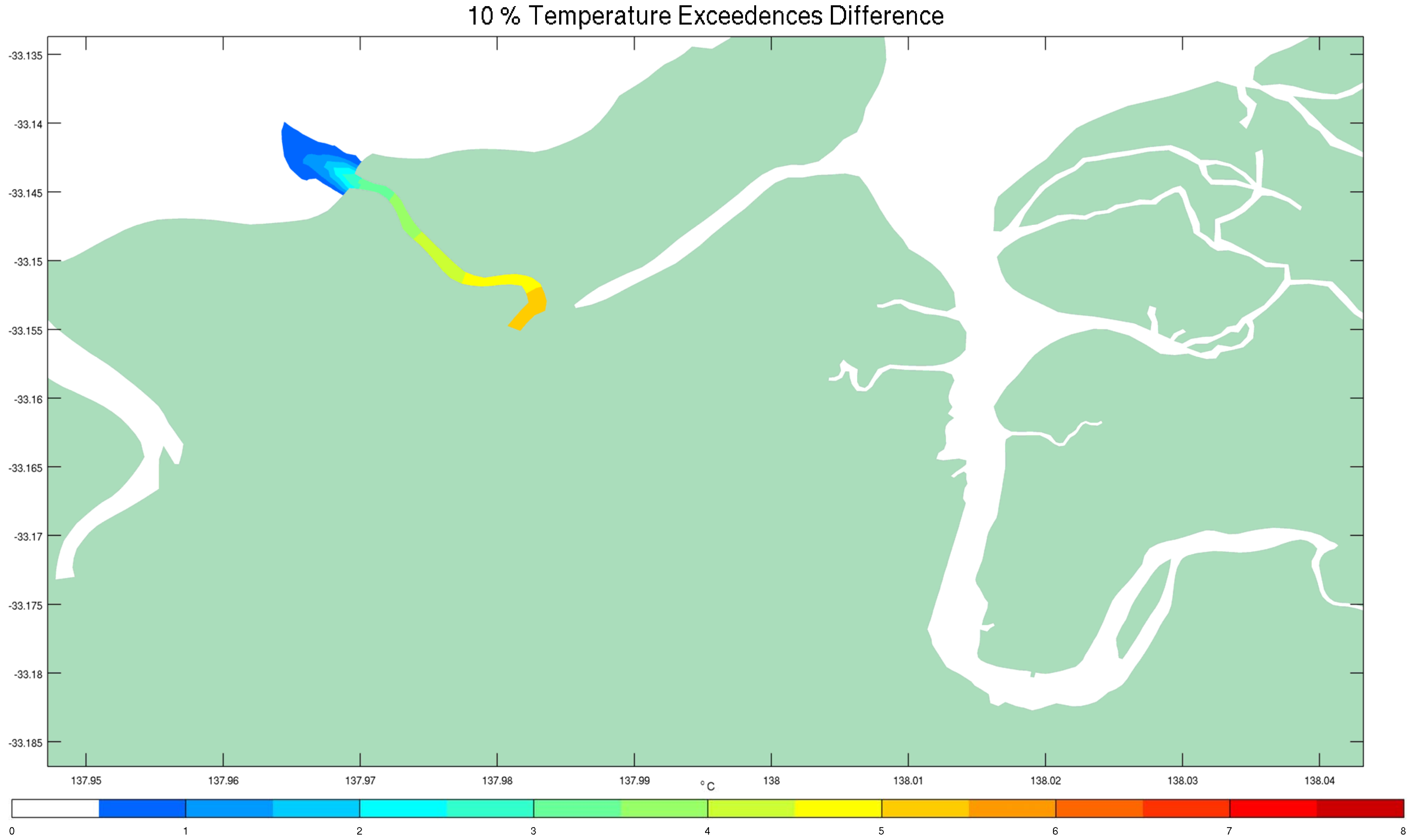

Figure 4-57 10th Percentile Temperature Exceedences Differences – Scenario 3 Discharge and Natural Baseline

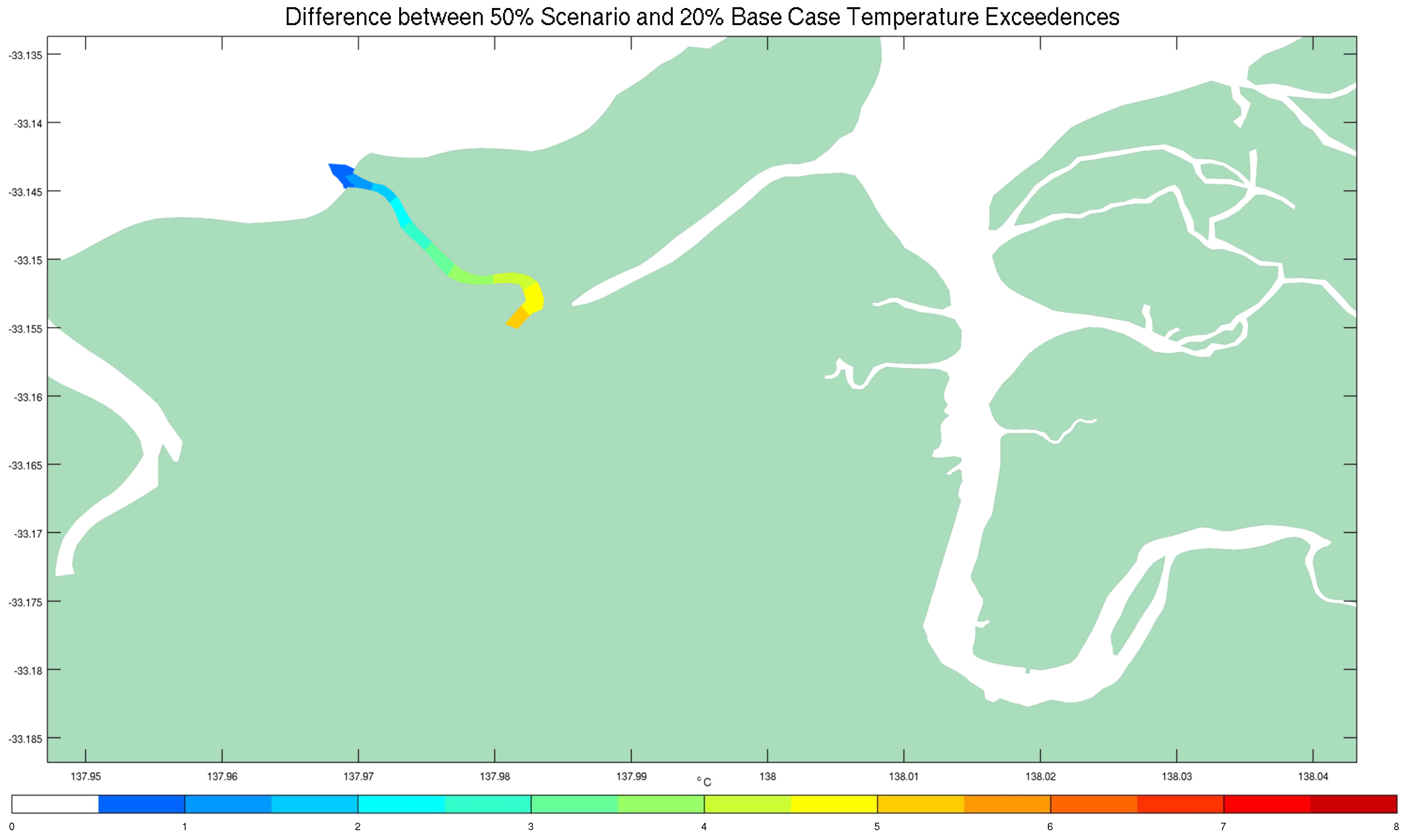

Figure 4-58 Differences between Scenario 3 50th Percentile Temperature Exceedences and Natural Baseline 20th Percentile Temperature Exceedences

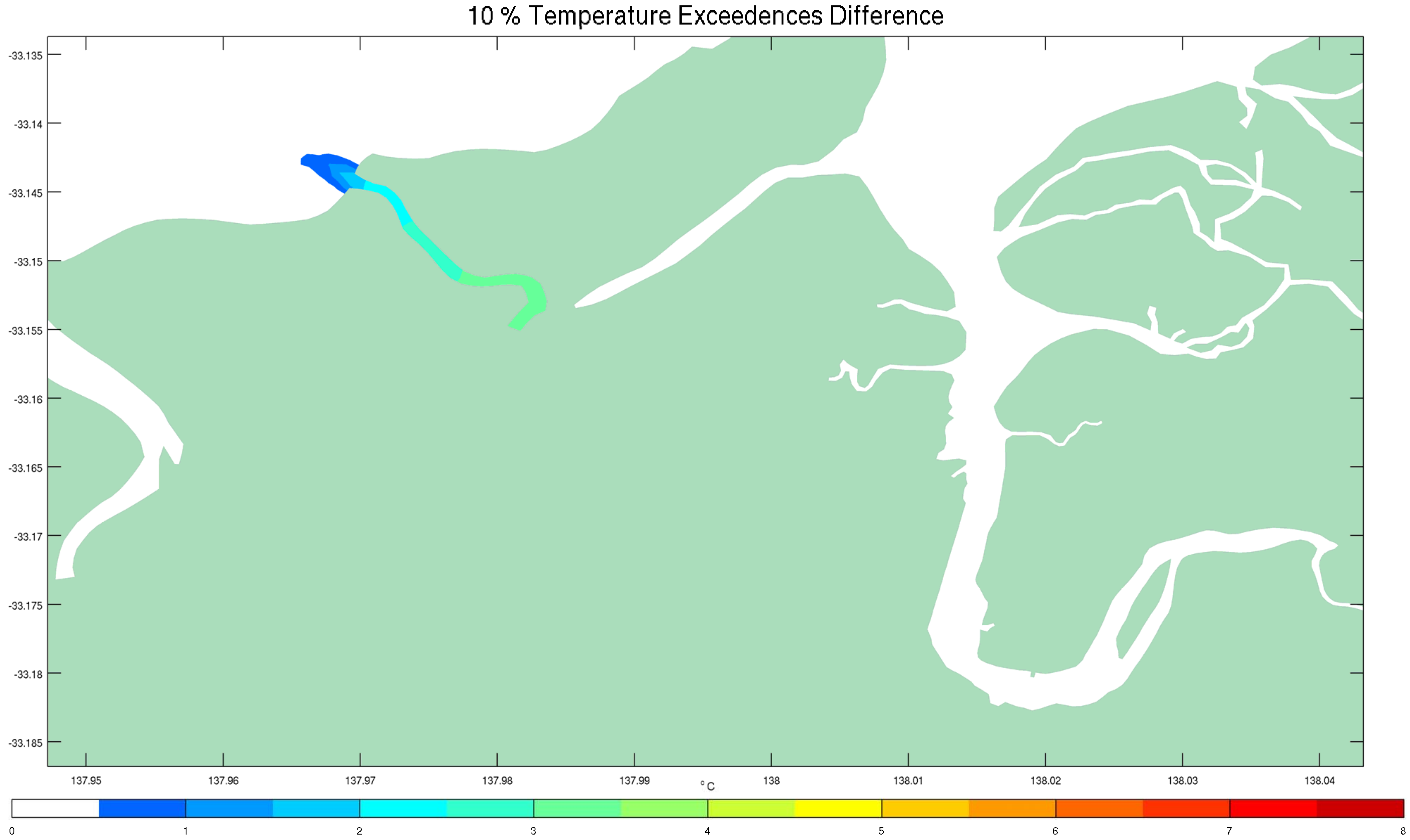

Figure 4-59 10th Percentile Temperature Exceedences Differences – Scenario 4 Discharge and Natural Baseline

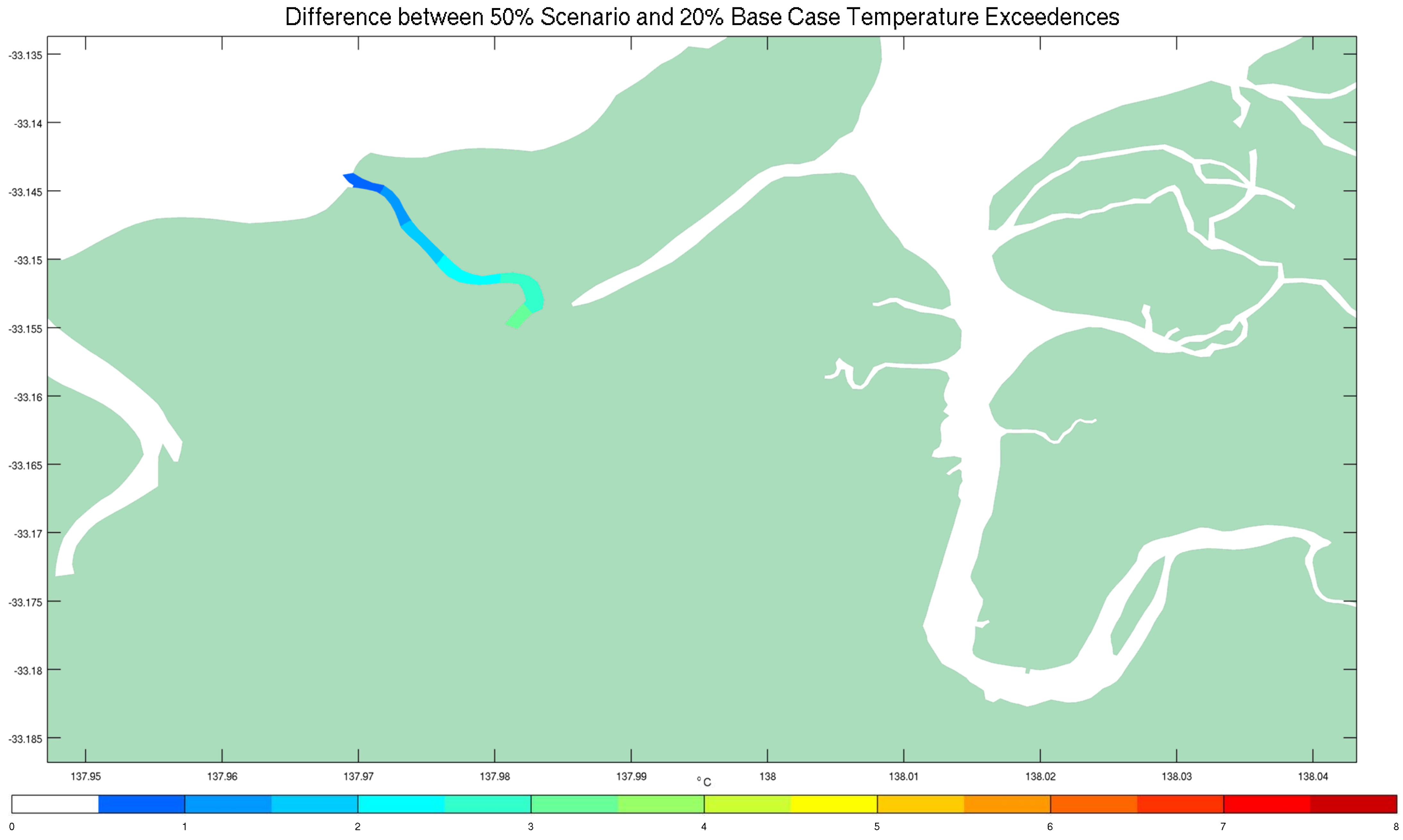

Figure 4-60 Differences between Scenario 4 50th Percentile Temperature Exceedences and Natural Baseline 20th Percentile Temperature Exceedences

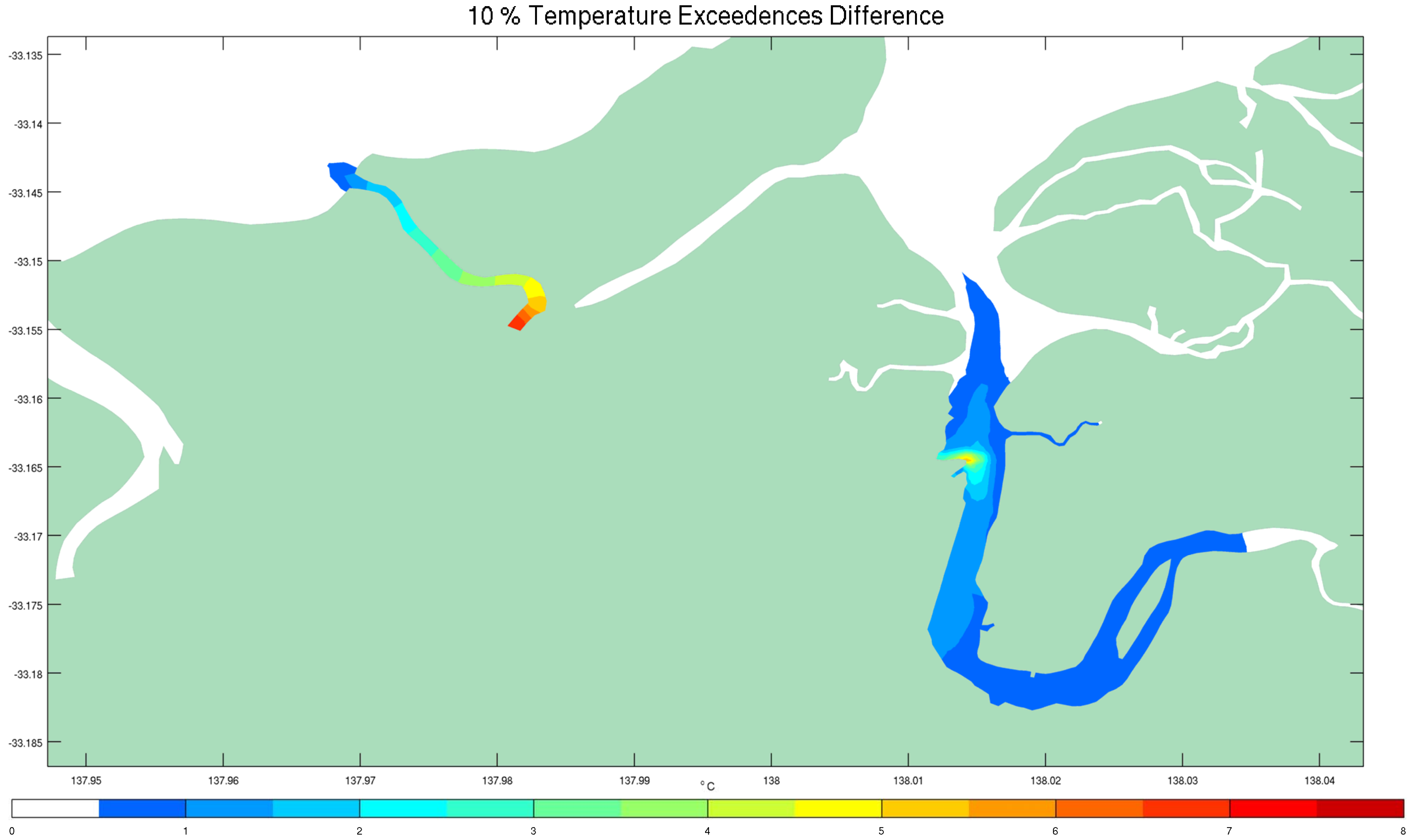

Figure 4-61 10th Percentile Temperature Exceedences Differences – Scenario 13 Discharge and Natural Baseline

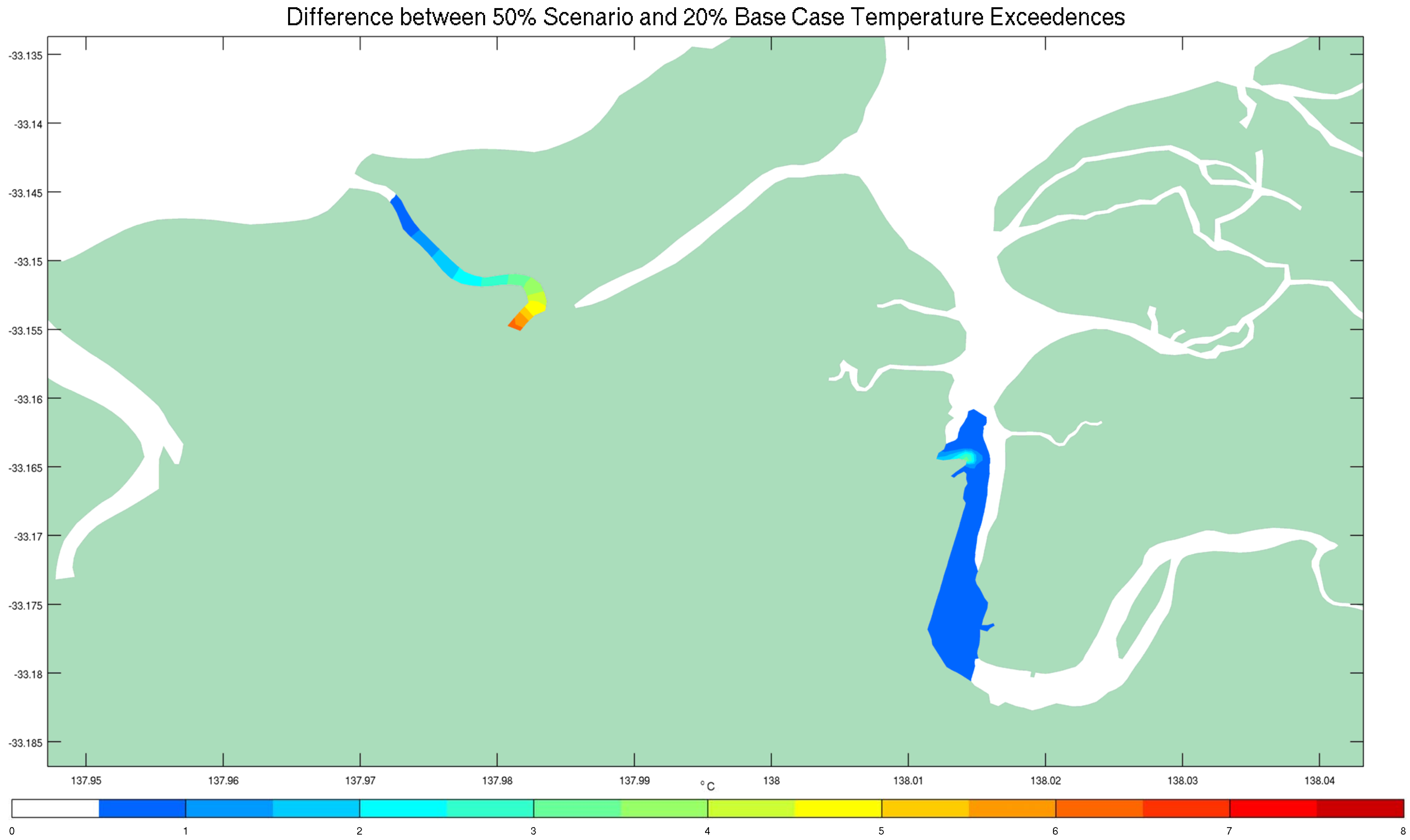

Figure 4-62 Differences between Scenario 13 50th Percentile Temperature Exceedences and Natural Baseline 20th Percentile Temperature Exceedences

4.4.6.9 Comparisons of Discharge Alternatives with the Existing Baseline

Results of the temperature exceedence differences between the alternative discharge scenarios and the existing baseline are presented below. These include the maps for the differences between the 10th percentile temperature exceedences resulting from the discharge scenarios and the corresponding existing baseline temperature exceedence percentile.

Similarly to the comparisons with the natural baseline, these results were sufficient to illustrate the total extent of the area of influence of the different discharge alternatives (including the existing discharge) in comparison to the existing conditions.

The reader is referred to the Appendices E to H for all temperature exceedence difference maps:

- Appendix E: Temperature exceedence differences between Scenario 1 and existing baseline;
- Appendix F: Temperature exceedence differences between Scenario 3 and existing baseline;
- Appendix G: Temperature exceedence differences between Scenario 4 and existing baseline; and

Appendix H: Temperature exceedence differences between Scenario 13 and existing baseline.

Although the same metric of comparisons with the natural baseline were adopted, these comparisons were not undertaken with the intent of showing compliance with guidelines, but to quantify the temperature effects resulting from the proposed discharge alternatives in comparison with existing (impacted) conditions. In this sense, the guidelines are not applicable for these comparisons.

Scenario 1 – Comparison with Existing Baseline

The differences between Scenario 1 and the existing baseline 10th percentile temperature exceedences are presented in Figure 4-63 (also Appendix E). For this scenario comparison with existing conditions, a temperature increase between 3°C and 4°C extended throughout most of First Creek length. These results indicated that the increased heat load associated with Scenario 1 would considerably increase temperature within First Creek in comparison to existing conditions.

The modeled temperature increases in comparison to existing conditions were not confined only to First Creek and extended beyond its mouth. Temperature percentile exceedences above 2°C within the plume extended approximately 100 m to 450 m beyond the mouth. Temperature percentile exceedence differences above 0.5°C extended offshore up to approximately 700 m from the mouth. The maximum plume widths for percentile exceedence differences above 0.5°C were up to 400 m.

It is again noted that the extensions of the plume offshore were largely influenced by the local bathymetry.

Scenario 3 – Comparison with Existing Baseline

The differences between Scenario 1 and the baseline 10th percentile temperature exceedences are presented in Figure 4-64 (also Appendix F). Note the temperature difference scale for this scenario was modified in relation to Scenario 1, so as encompass the a negative range. Note however, that the range amplitude in the colour scale was preserved.

For this scenario an increase smaller than $2^{o}C$ in relation to existing conditions was obtained for all exceedence percentiles differences. Near the point of discharge these exceedence percentile differences were negative, indicating an improvement from existing conditions.

Conditions in downstream portions of First Creek would deteriorate in comparison to existing conditions. Such results were a reflection of the increased heat load with the proposed discharge in a creek where the hydrodynamics are largely influenced by the tidal motion. For Scenario 4, temperature exceedence differences larger than 0.5 ^{o}C extended offshore of the mouth of First Creek for approximately 500 m, with a width near the mouth of approximately 250 m.

Scenario 4 – Comparison with Existing Baseline

The differences between Scenario 4 and baseline 10^{th} percentile temperature exceedences are presented in Figure 4-65 (also Appendix G). Also, for this scenario, a temperature increase smaller than $2^{o}C$ in relation to existing conditions was obtained for all percentiles. Moreover, temperature decreases in comparison to the baseline resulted. Given the reduced heat load, these temperature differences were more appreciable than Scenario 3. This result shows that this discharge would be compliant with the present guidelines, in comparison to existing conditions.

For this scenario an increase smaller than $1^{o}C$ in relation to existing conditions was obtained for all exceedence percentiles differences. Contrasting to Scenario 3, negative exceedence percentile differences occurred throughout most of First Creek extension. Given the reduced heat load in relation to the other First Creek discharge scenarios, the resulting improvement in comparison to the existing conditions were more appreciable. However temperatures near the mouth of the creek would still be generally up to $1^{o}C$ higher than the existing conditions (see e.g. the 50^{th} percentile). Under this scenario, temperatures offshore of the mouth of the creek would remain essentially the same as the existing conditions. The 10^{th} percentile exceedence difference showed that temperatures in comparison to the existing conditions would extend up to approximately 140 m offshore.

Scenario 13 – Comparison with Existing Baseline

The differences between Scenario 1 and baseline 10^{th} percentile temperature exceedences are presented in Figure 4-66 (also Appendix H). As expected, this scenario showed no differences in terms of increased (or reduced) temperatures within First Creek. These results reinforce the statement that discharges to Port Pirie River would have negligible influence at First Creek.

The effects in the Port Pirie River were (essentially) the same as the ones described in the comparisons with the natural baseline, as expected.

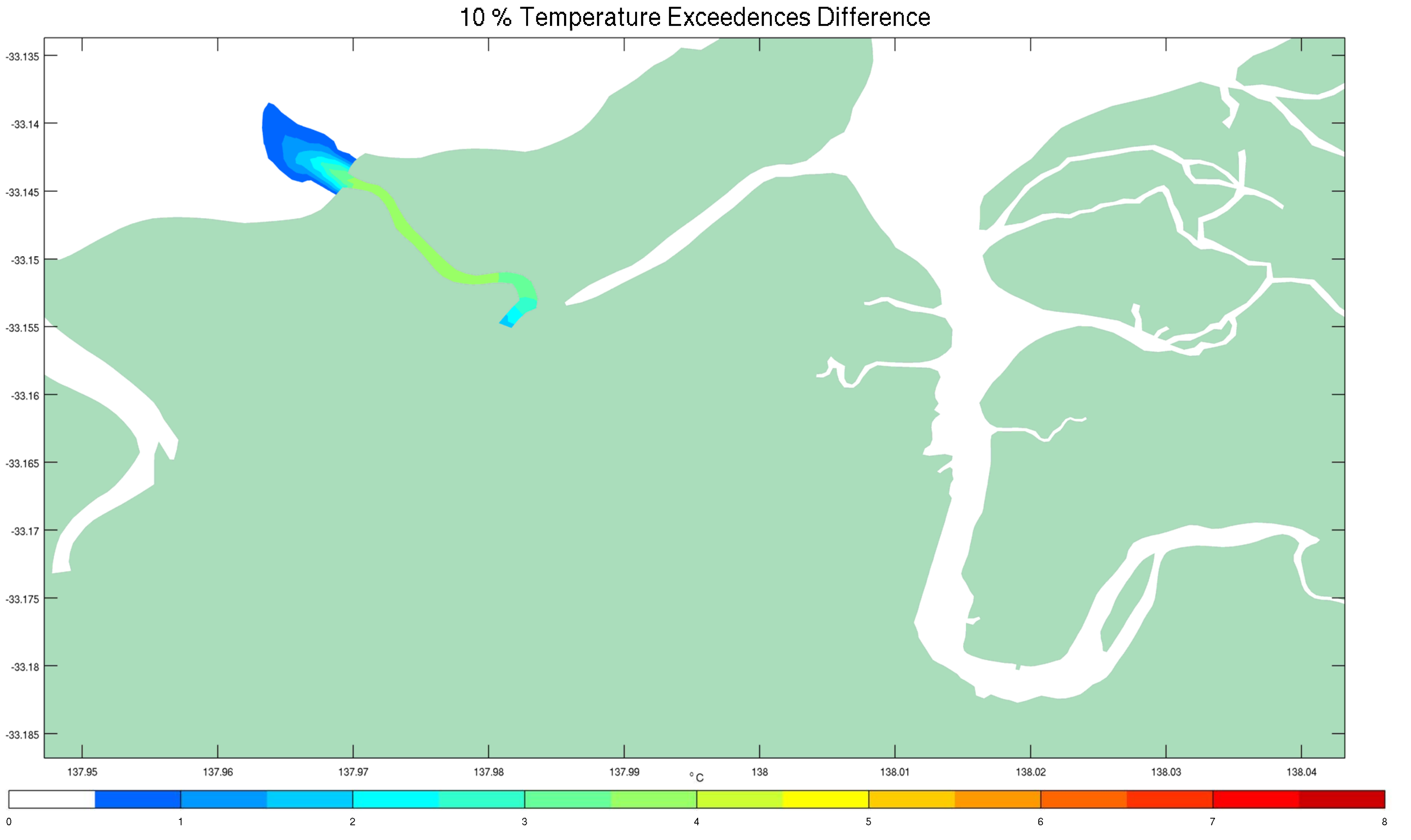

Figure 4-63 10th Percentile Temperature Exceedences Differences – Scenario 1 Discharge and Existing Baseline

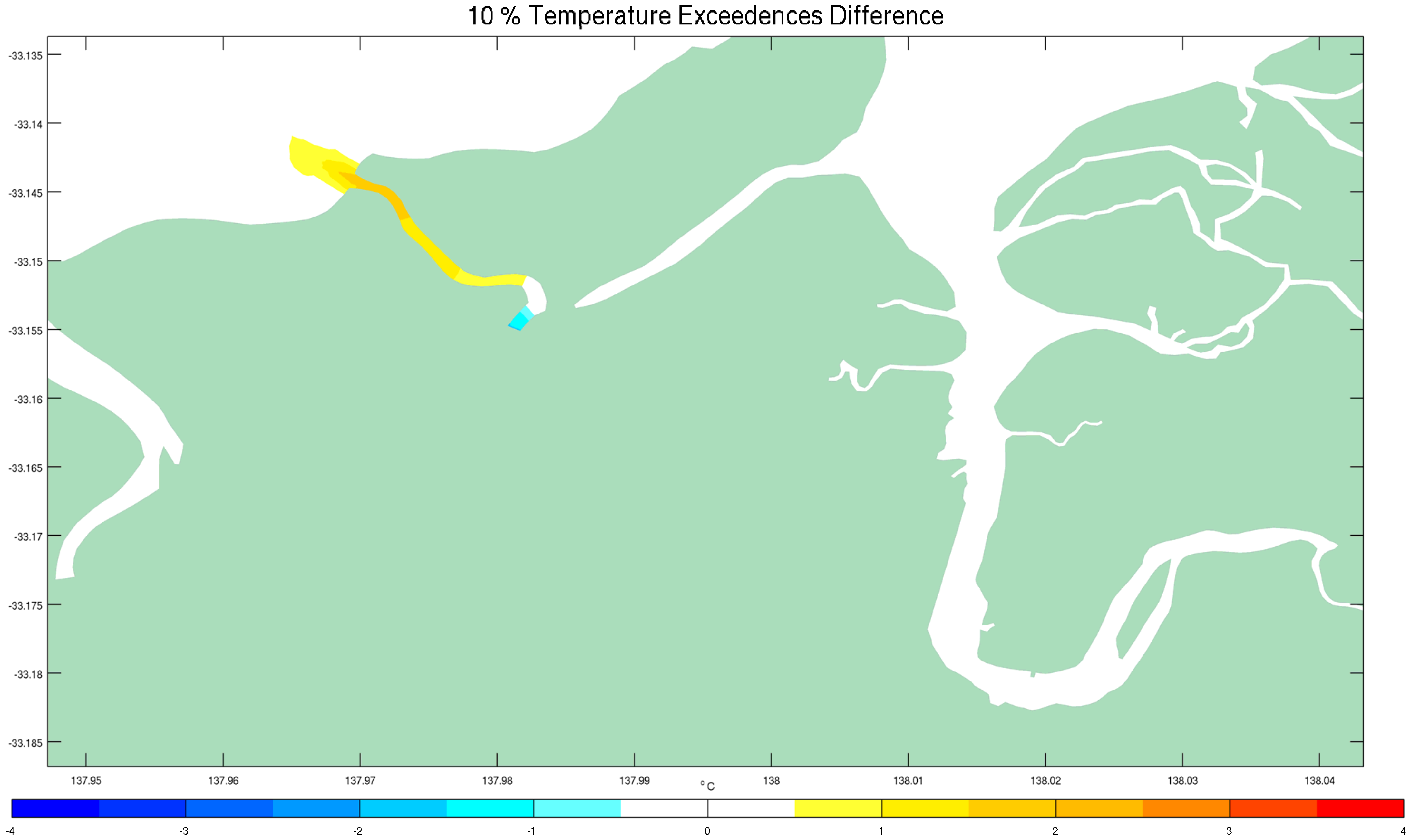

Figure 4-64 10th Percentile Temperature Exceedences Differences – Scenario 3 Discharge and Existing Baseline

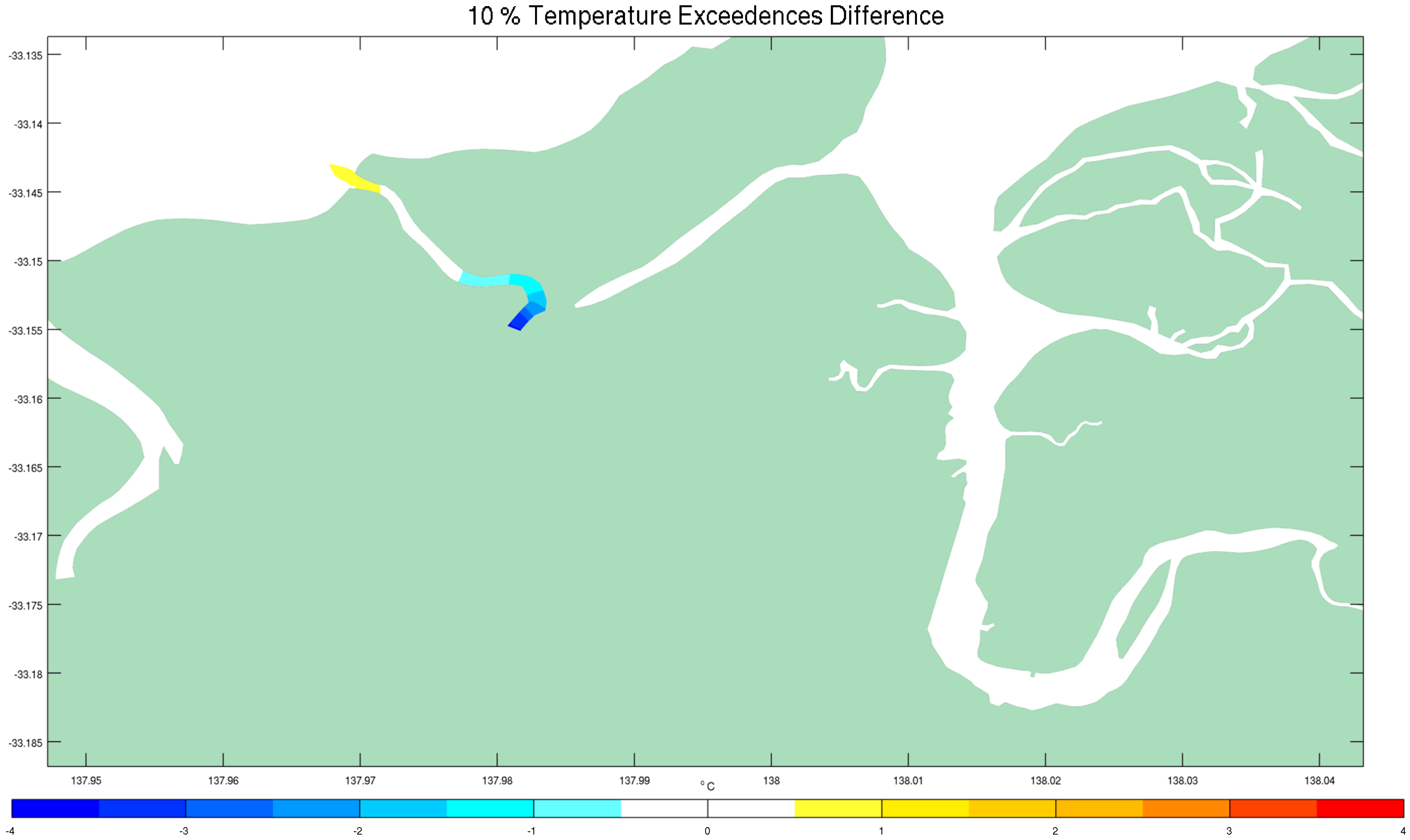

Figure 4-65 10th Percentile Temperature Exceedences Differences – Scenario 4 Discharge and Existing Baseline

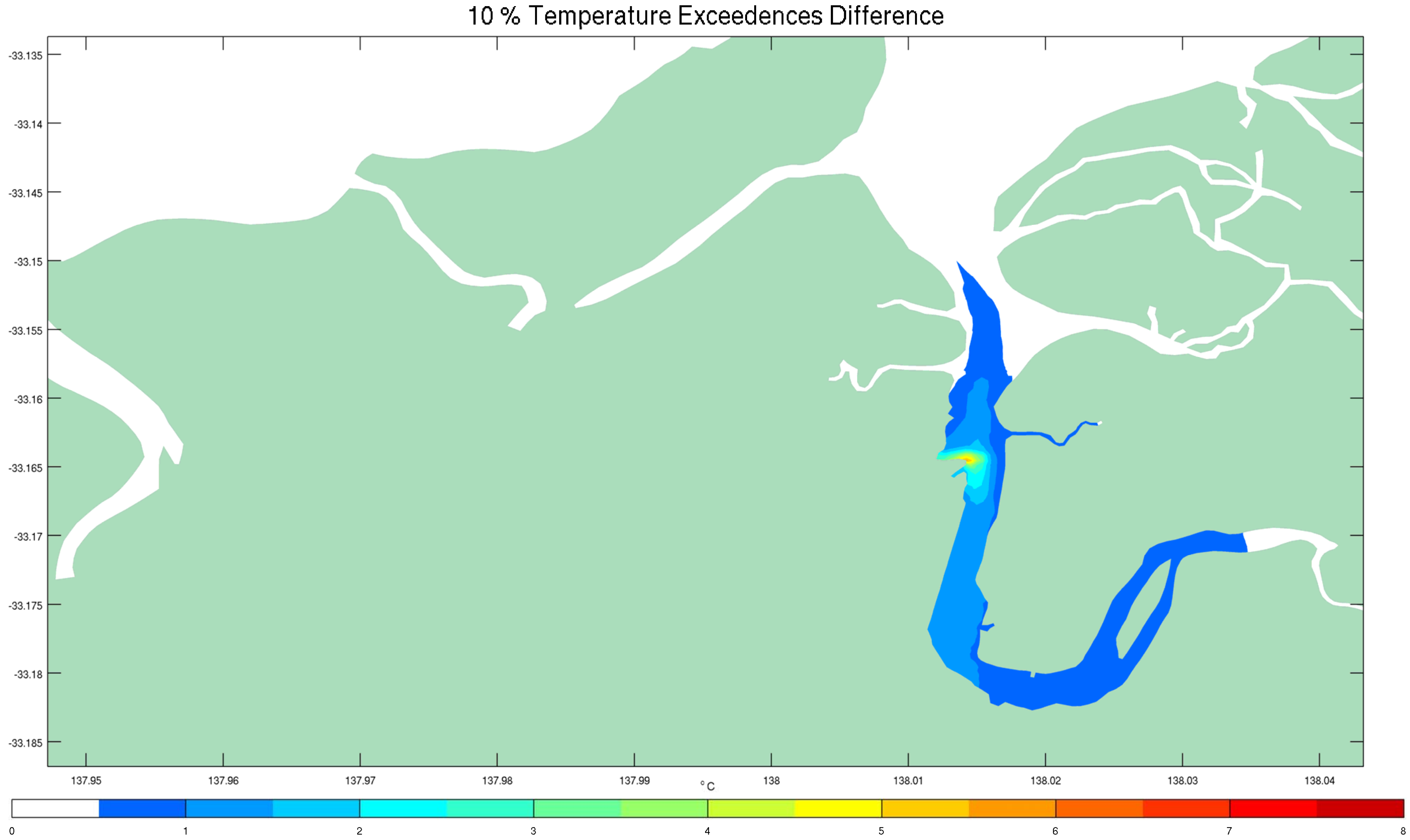

Figure 4-66 10th Percentile Temperature Exceedences Differences – Scenario 13 Discharge and Existing Baseline

5 DISCUSSION

This report describes near and far field assessments for alternative configurations of a cooling water discharge in Port Pirie, South Australia. This cooling water discharge will form part of the infrastructure required to transform the existing Nyrstar multi metals recovery plant into a state-of-the-art poly-metallic processing and recovery facility. The findings of the present assessments will be used to support pre-feasibility and bankable studies, including a Public Environmental Review.

5.1 Nearfield Assessment

Results of the nearfield models considering a limited number of outfall configurations and the ambient conditions encountered in the Port Pirie River showed that it is possible to have an outfall designed to meet present SA EPA water quality guidelines. For a discharge temperature increase above background of 10 ^{o}C, these guidelines require a dilution factor of five, which was shown to be achieved under most of the options investigated.

From the results presented, it was observed that plume temperatures at 20 m from the diffuser would be higher for increased ambient velocities and a greater number of ports, considering the same port diameter. These results occurred because:

1. The flows above 5 cm/s would deflect the plume from each nozzle into the downstream nozzle plume, limiting their mixing with ambient water and therefore reaching 20 m from the diffuser less diluted; and
2. The larger number of ports would produce plumes with less momentum, therefore more prone to deflection by the ambient flow.

Nevertheless, only the 18-port diffuser 10m from the bank modelled in CORMIX showed temperatures at 20 m from the diffuser exceeding the present SA EPA guidelines. These exceedences only occurred at ambient velocities above 5 cm/s.

The modelling assumptions however were generally conservative, in particular:

1. The discharge temperature was assumed to be the maximum proposed increase of 10 ^{o}C above background temperature; and
2. The modelling neglected surface heat exchange.

Notwithstanding these results, it was shown that a 12-port outfall would meet the present and new draft SA EPA proposed water quality criterion at all ambient conditions. For the 18-port diffuser, most of the modelling configurations showed the temperatures would meet the water quality criterion.

Taking into consideration the limited number of tests, the outfall design can be further optimised to achieve even more favourable conditions for the thermal effluent dilution. For example, by reducing the port diameter of the 18-port outfall, it may be possible to achieve conditions that meet both guidelines. If Nyrstar wishes to progress consideration of this option then we suggest that more detailed modelling (CFD) analyses be undertaken in conjunction with more detailed far field modelling studies.

5.2 Far Field Model Performance

A three dimensional hydrodynamic and transport model was set-up and executed for far field assessments of a subset of the alternative proposed discharges. The model was shown to reproduce the tidal features throughout the Gulf and performed particularly well in terms of reproducing current velocities offshore of First Creek. Due to inaccuracies of the bathymetry in the intertidal areas, the model did not perform as well in the Port Pirie River area. The model, nevertheless, did reproduce the essential features of the hydrodynamics and was considered fit for the purpose of this conceptual study. Temperatures in the water column were particularly well reproduced. It is recommended that a bathymetric survey in the intertidal areas of the study area be conducted. These were not possible within the scope of this preliminary study.

5.3 Proposed Discharges to First Creek

Results of the proposed alternative discharges were contrasted with natural and existing conditions. The comparisons with natural conditions showed that the discharges into First Creek, both existing and the existing in combination with any of the proposed alternatives, were not compliant with either present or draft proposed guidelines. In these cases, model results indicated most of First Creek would be non-compliant. The only small exception was the case of a 2°C temperature increase between intake and the point of discharge. However, even in this case, only about 150 m from the mouth into the creek would comply with present guidelines, noting it would not comply with the proposed draft guidelines.

In addition to First Creek, the intertidal area immediately offshore of the creek would be non-compliant with any of the guidelines. As expected, the extent of the non-compliant area would be reduced for smaller temperature increases between intake and discharge.

5.4 Proposed Discharge to the Port Pirie River

For the proposed discharge to the Port Pirie River, only a temperature increase of 10 °C in relation to the water intake temperatures was considered. Model results indicated an asymmetric plume, with tendency of movement during flood tides into the River. This is consistent with the ADCP measurements at Site 1 and implied the Port Pirie River is poorly flushed.

The discharge input into the model did not consider the effects of mixing in the nearfield. Consistent with other discharge modelling studies, neglecting these effects produce very conservative dilutions (therefore, also temperature increase) in the vicinity of the diffuser (see e.g. Botelho et al., 2013). Consequently, the far field assessment showed the discharge to the Port Pirie River would not be compliant over a significant area with either of the water quality guidelines. This result was unrealistic in the sense that the near field model showed temperature increases below 2°C can be achieved within 20 m from the diffuser. Also, smaller temperature increases between the intake and the discharge would create a smaller area of influence.

Given the flushing characteristics of the Port Pirie River, the other outfalls located further South in the Port Pirie River (i.e. PP03 and PP04) would not perform as well as an outfall at PP05.

It is noted that the effects of tidal reversals were not considered in the nearfield analysis. If this option is to be advanced, it is recommended that these unsteady effects be considered for diffuser optimisation, particularly in view of the poor flushing of the Port Pirie River. Computational Fluid Dynamics (CFD) is the recommended tool for such an analysis, given the models adopted can only reliably consider steady-state conditions. Adoption of such an approach would also allow proper nearfield "seeding" of the far field model and consequently more realistic estimates of temperature increase within the Port Pirie River.

In addition to the temperature increase in the Port Pirie River, no abatement of the existing discharge conditions would occur in First Creek.

5.5 Comparisons with Existing Conditions

Proposed discharges to First Creek with temperature increases smaller than 10 ^{o}C in relation to the intake temperatures would result in reduction of temperatures over significant lengths of First Creek. Despite the lower temperature increases assumed in these proposed discharges to First Creek, they would still represent an additional heat load to the marine environment. As advection and dispersion mechanisms in the creek are controlled by the tides, portions of the creek and the intertidal area immediately offshore still presented a temperature increases in comparison to existing conditions. In particular, the areas near the mouth of the creek tended to present temperature increases, whilst a reduction was simulated near the discharge location.

For a discharge above 10 ^{o}C, the discharges into First Creek would result in temperature increases, both along the entire First Creek stretch as well as in the intertidal area immediately offshore of First Creek. Such a temperature increase would therefore exacerbate impacts of the existing discharge.

In view of these results, it may be possible to combine a mixed approach in which part of the effluent is discharged to the Port Pirie River and the remaining pre-mixed with the existing discharge before discharging into First Creek. Any improvement in terms of temperature to First Creek would require a temperature increase in relation to intake temperatures significantly lower than the 9^{o}C increase assumed in the existing discharge. It should be noted that this suggestion did not consider any costs, design, or operational matters involved in this mixed approach.

5.6 Choice of Discharge Alternative

It is difficult to recommend the most viable discharge alternative option solely on the grounds of temperature effect on the marine environment, given either alternatives of the thermal discharge to Port Pirie River or First Creek have their own advantages and disadvantages. These advantages need to be weighed in conjunction with other factors not necessarily related to the discharge itself (e.g. benefit to air quality, groundwater pollution control). Once a decision is made on the way forward, more detailed investigations have to be undertaken to progress the chosen alternative. The advantages and associated studies required for each of the options are discussed below.

5.6.1 Discharge to the Port Pirie River

It was shown that it is possible to design an outfall capable of meeting existing water quality guidelines in the Port Pirie River. However, this option would not provide any abatement of the effects of the existing discharge conditions in First Creek. As a result, the impact of the Nyrstar operations in the marine environment near Port Pirie would consist of two isolated zones.

A possible solution to this outcome is to pre-mix both existing and proposed cooling water discharges for disposal through the outfall in the Port Pirie River. It should be noted that this suggestion did not consider any costs, design, or operational matters involved in this mixed approach.

If Nyrstar wishes to progress consideration of discharging to the Port Pirie River, the following is suggest:

1. A bathymetric field survey be undertaken in the intertidal areas within the Port Pirie River. Such a survey will allow further refinement of the hydrodynamic model in such a way as to improve predictive capability of the observed tidal asymmetry. This asymmetry is an important feature that relates to mixing processes so it is relevant to capture it well.

2. A pre-mixed approach with results from a nearfield model be adopted to "seed" the discharge into the far field model. Such an approach will allow the simulation of less conservative far field plume characteristics within the Port Pirie River.

3. The nearfield analysis be upgraded with more detailed Computational Fluid Dynamics (CFD) modelling. Such an approach will allow improved understanding of the effects of tides in the nearfield dilution as well as to provide reliable dilutions for the discharge "seeding" referred above.

Additionally, if both existing and proposed discharges are to be combined into a single disposal location, the nearfield study needs to be upgraded to reflect the increased heat load. This exercise should be taken in conjunction with a formal diffuser optimization study.

5.6.2 Discharge to First Creek

Considering the combination of existing and proposed discharges to First Creek will result in non-compliant condition with SA EPA water quality guidelines.

In this case, any improvement in terms of temperature to First Creek would require a temperature increase in relation to intake temperatures significantly lower than the 9^{o}C increase assumed in the existing discharge. In particular, a 2^{o}C increase in the proposed discharge resulted in significant improvement of overall conditions within some reaches of First Creek, with only relatively small deterioration in other locations.

If Nyrstar wishes to progress consideration of discharging to First Creek we suggest that:

1. A bathymetric field survey be undertaken in the intertidal areas within Germein Bay offshore of First Creek. Such a survey would allow further refinement of the hydrodynamic model in such a way as to improve predictive capability in the intertidal areas beyond the mouth of First Creek.

2. Collection of temperature and meteorological data be undertaken in First Creek and the adjacent intertidal areas. This data collection would allow increased understanding of the

effects of the tidal dynamics on temperature within First Creek and allow improved model validation and predictive capability within the area.

3. The far field model be upgraded with increased resolution in the First Creek and immediately adjacent area. While sufficient resolution was adopted for this conceptual study, a more detailed investigation would benefit from increased resolution in the area.

5.7 Further Studies

Finally, this conceptual study did not address seasonal conditions other than autumn. It is recommended that simulations be undertaken for other periods of the year that present different thermal characteristics, i.e. summer (January) and winter (July). Undertaking of these seasonal simulations should be progressed once a decision on the discharge alternative is made, concurrent with the modelling upgrades discussed above.

6 CONCLUSIONS

From the assessment conducted in this report the following could be concluded:

1. An outfall consisting of multiport diffusers can be successfully designed to discharge cooling water effluent in the Port Pirie River in such a way to meet SA EPA present and draft proposed water quality guidelines.

2. The Port Pirie River is relatively poorly flushed, with tidal asymmetry presenting increased fluxes into the river. Of the proposed outfall alternatives in the Port Pirie River, PP05 is the recommended locations as it is the nearest to the River mouth and thus, better flushed.

3. Discharges to First Creek (both existing and any of the proposed alternatives) would not be compliant with any of the water quality guidelines.

4. Discharges to First Creek require that the cooling water process deliver a temperature increase in relation to the intake temperatures substantially lower (i.e. 5^{o}C or less) than the increase in the current discharge (i.e. 9^{o}C).

5. Even under these conditions the increased heat load would exacerbate the temperature increases within and in the intertidal areas immediately adjacent to First Creek.

6. A decision on the best alternative discharge option will not depend on the thermal effects on the marine environment alone, given both sites have their strengths and weaknesses. A decision on the way forward needs to consider aspects other than the discharge location alone (i.e. benefit to air quality, groundwater pollution control).

It is recommended that once a decision on location of the discharge is made:

1. A bathymetric survey be undertaken in the intertidal areas within the area of the study. Such bathymetric information will allow improved model performance in the Port Pirie River area.

2. Further data collection (particularly temperature and local meteorological data) be undertaken to test and improve some of the assumptions underlying the existing discharges adopted in this model.

3. A design optimisation study be undertaken if the alternative of an outfall in the Port Pirie River is advanced. This design should consider the unsteady effects of tidal reversals in the Port Pirie River. Computational Fluid Dynamics should be adopted as the tool for such a study.

4. Investigation of the discharge influences on temperature under different seasons need to be undertaken to verify the temperature effects of the proposed discharge throughout other periods of the year.

7 REFERENCES

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APPENDIX A: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 1 AND NATURAL BASELINE

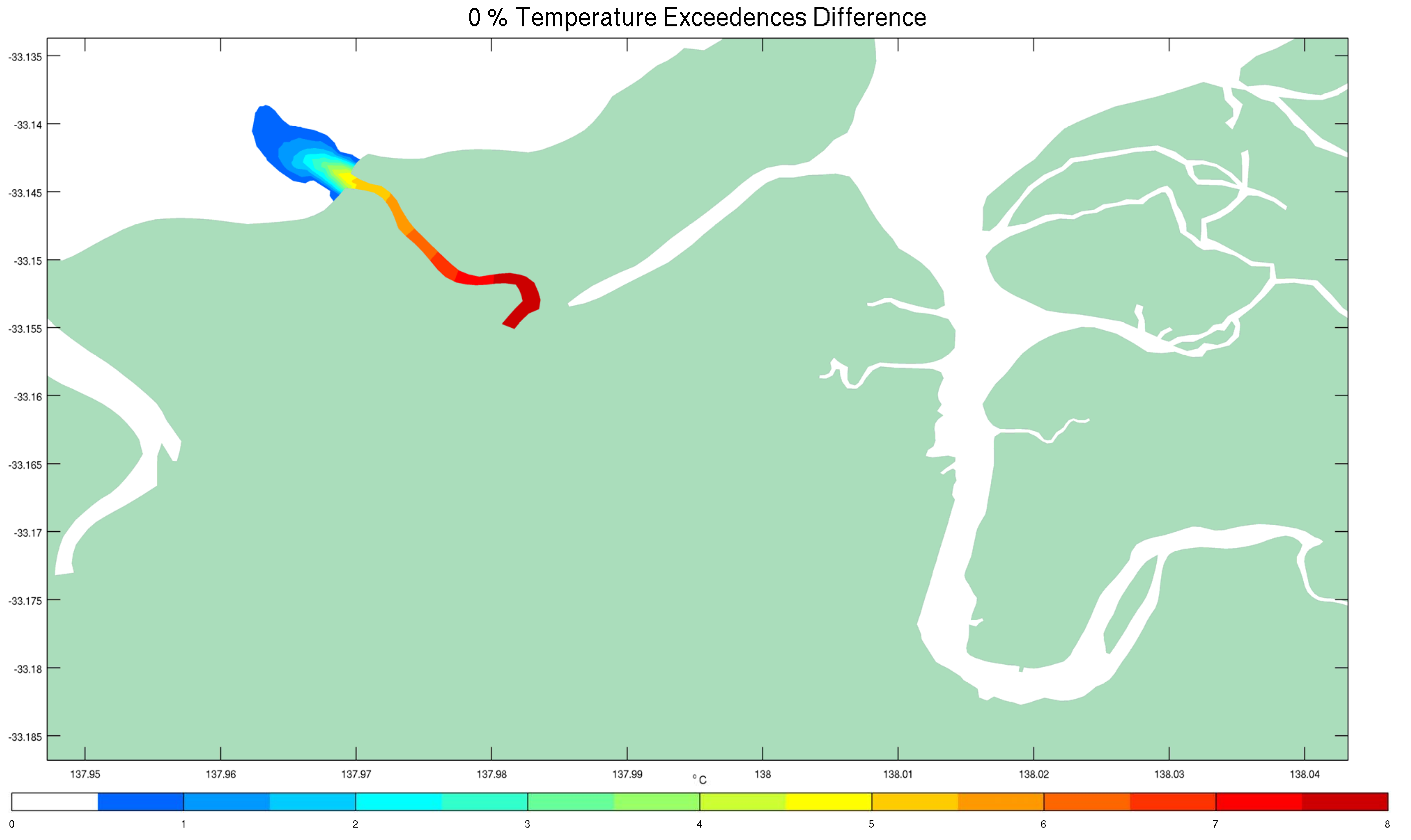

Figure A- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 1 and from Natural Baseline

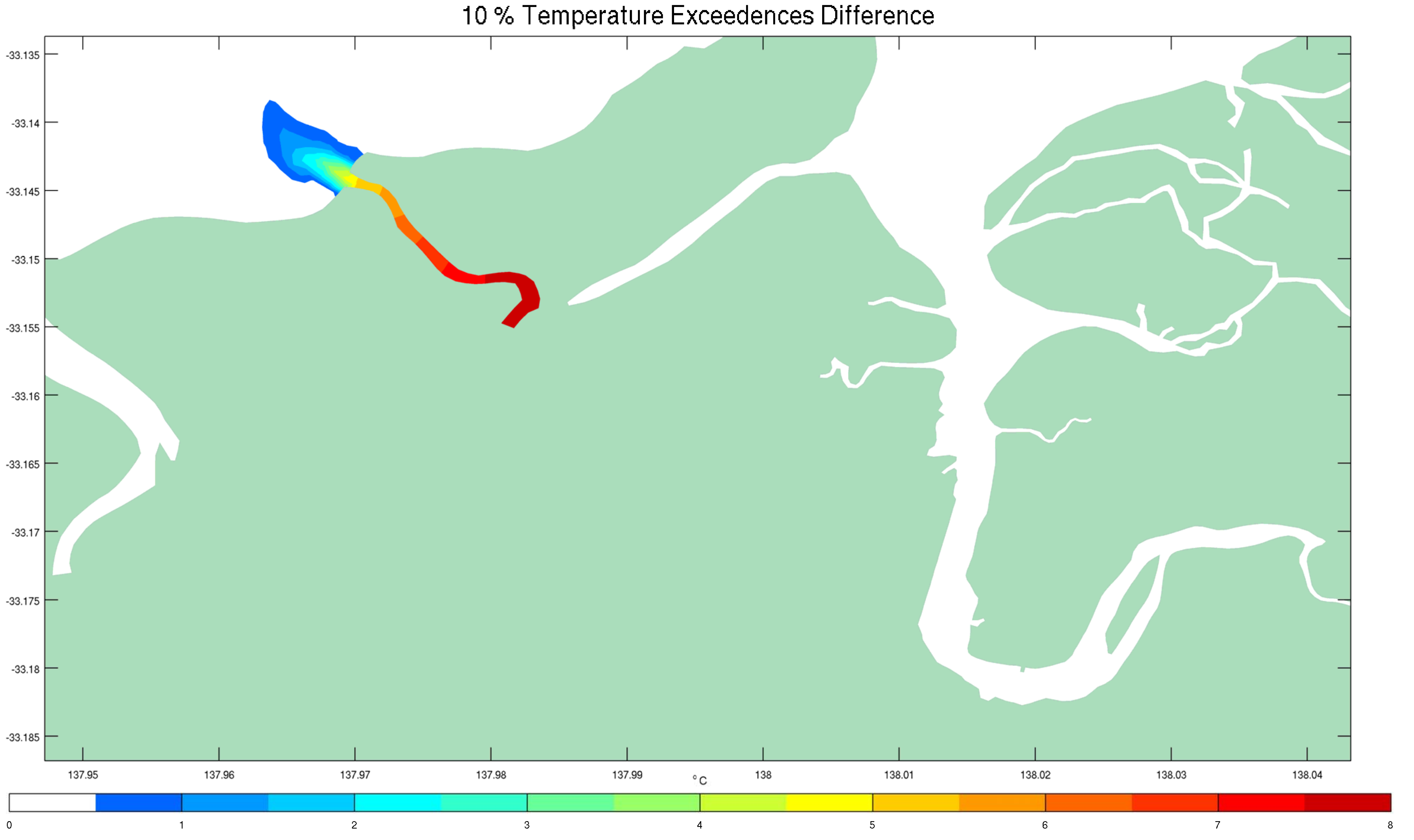

Figure A- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 1 and from Natural Baseline

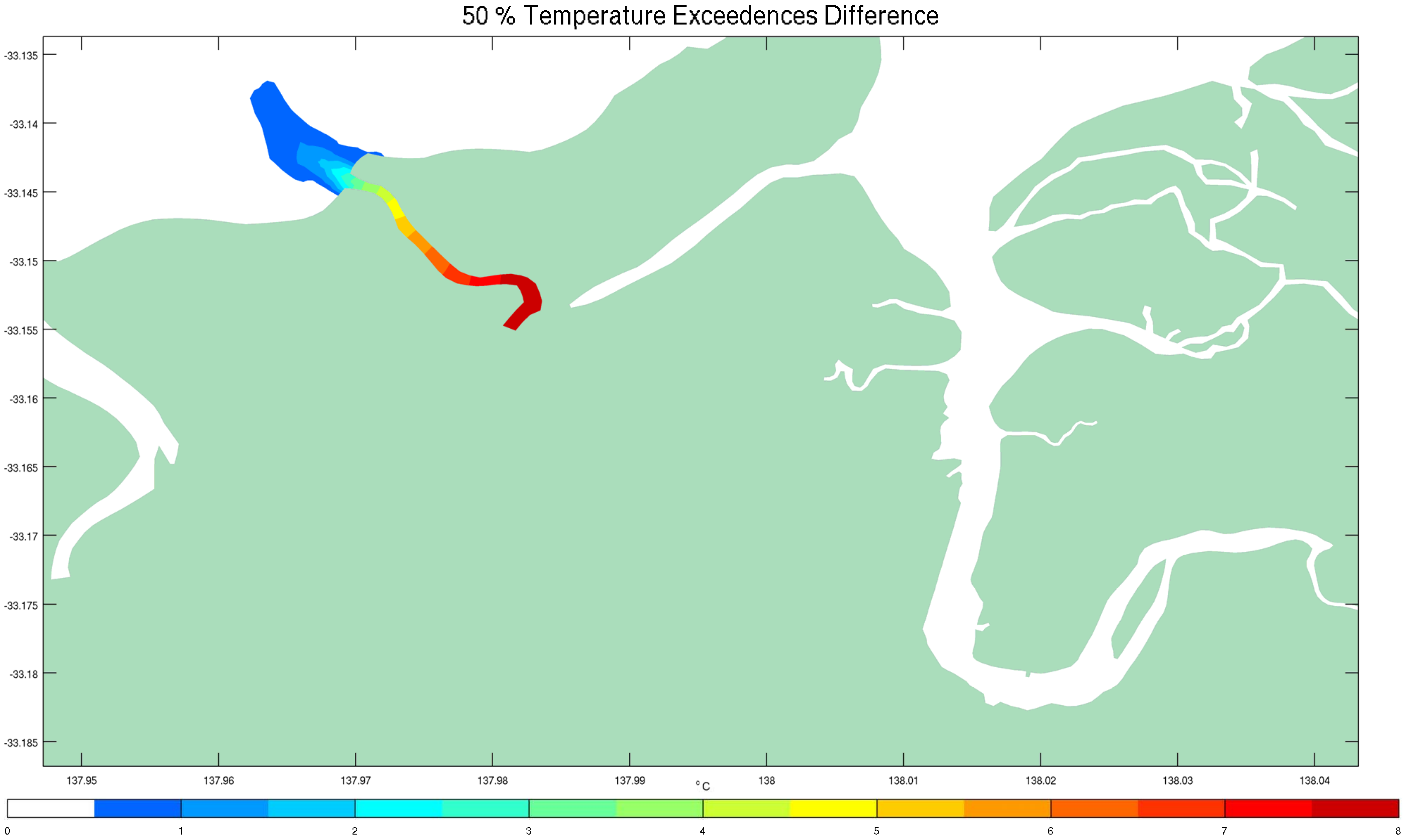

Figure A- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 1 and from Natural Baseline

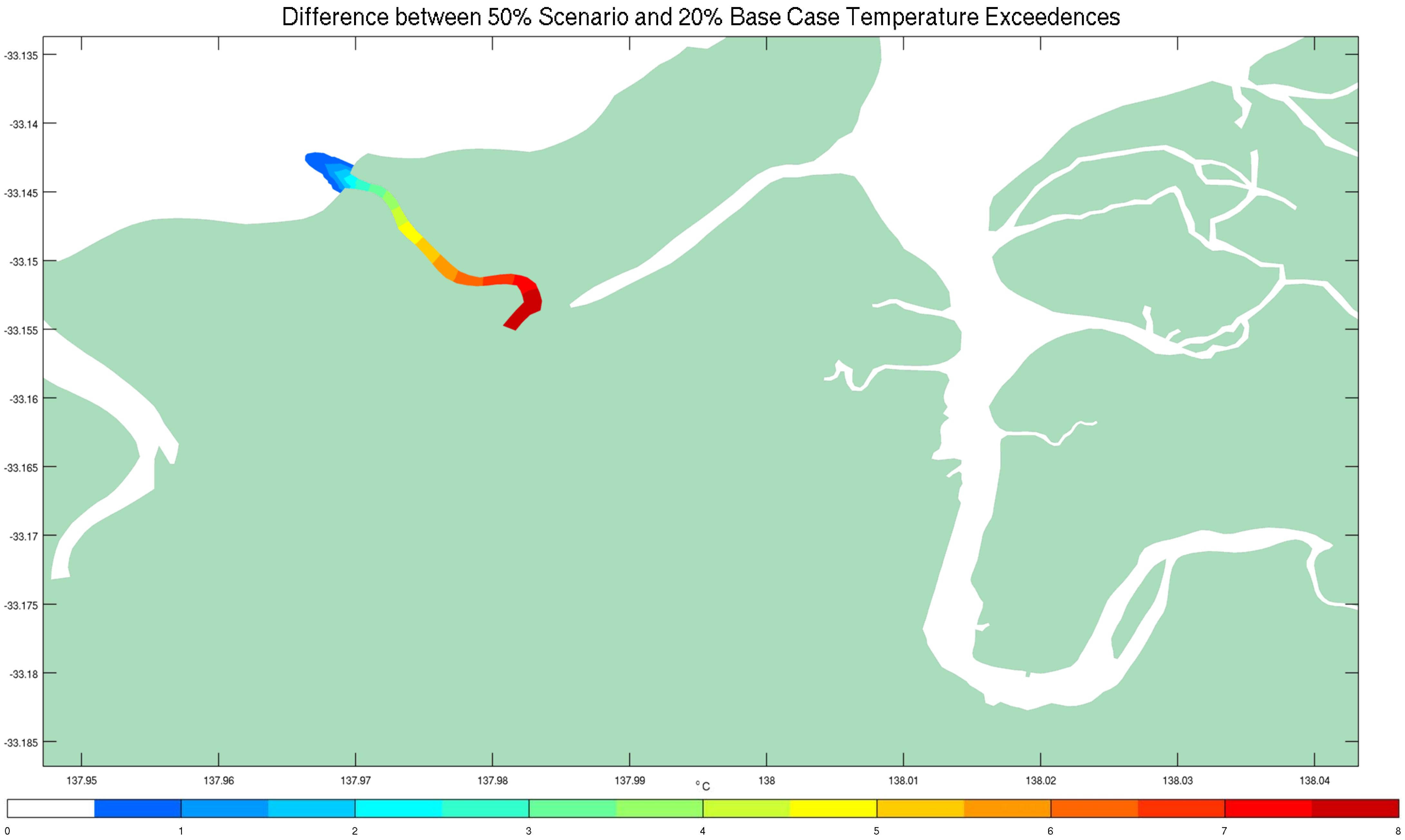

Figure A- 4 Differences between Scenario 1 50th Percentile Temperature Exceedences and the Natural Baseline 20th Percentile Temperature Exceedences

APPENDIX B: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 3 AND NATURAL BASELINE

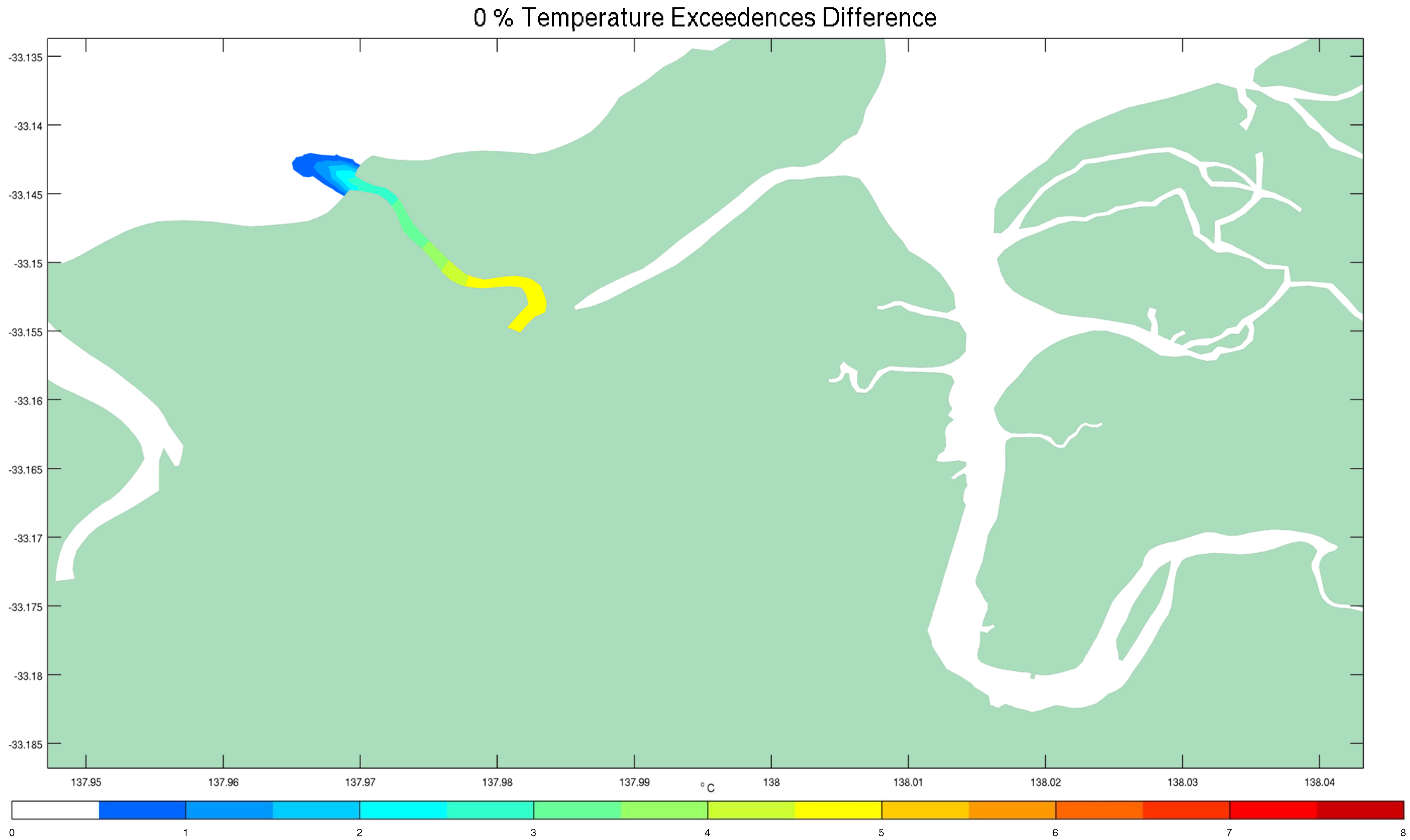

Figure B- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 3 and from Natural Baseline

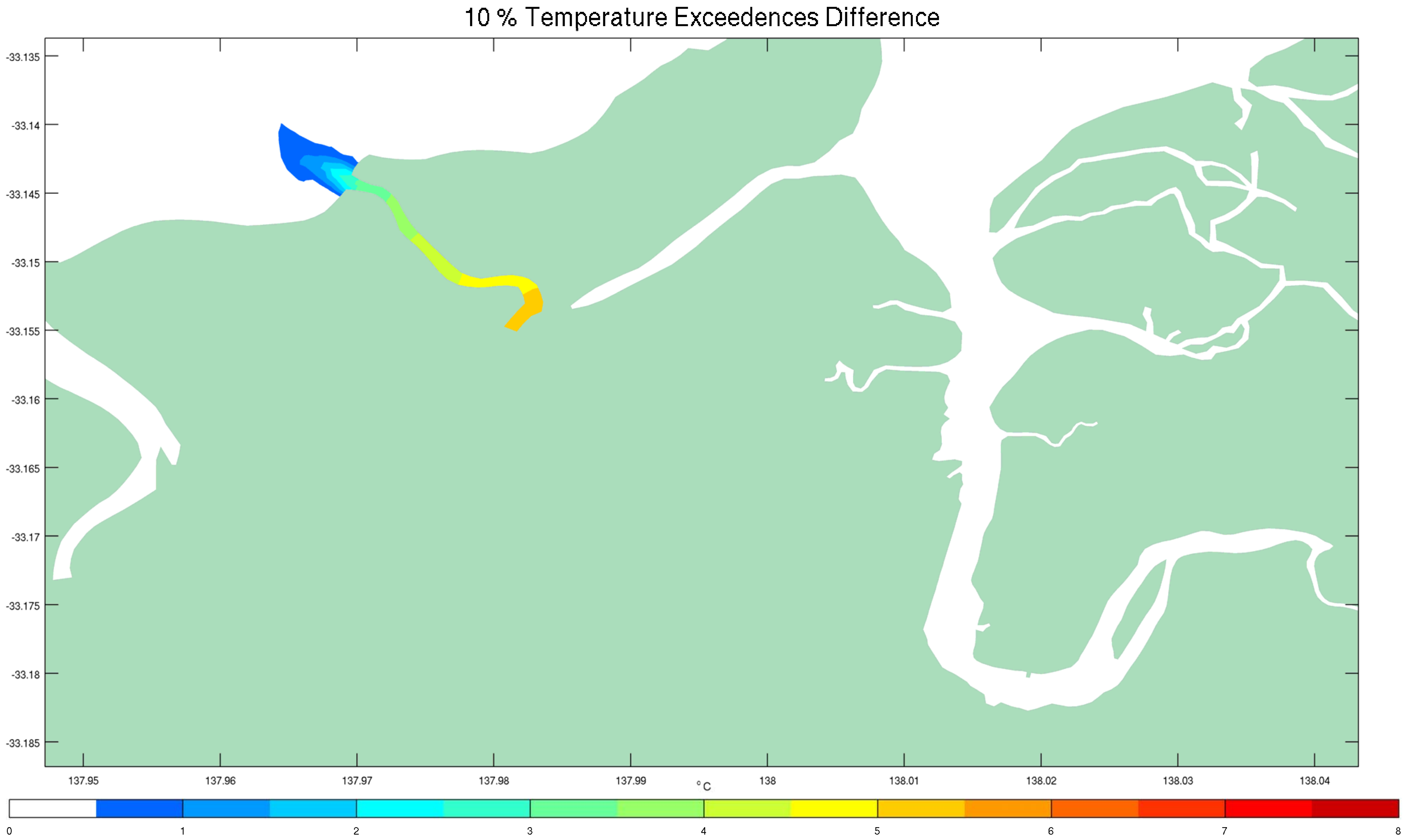

Figure B- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 3 and from Natural Baseline

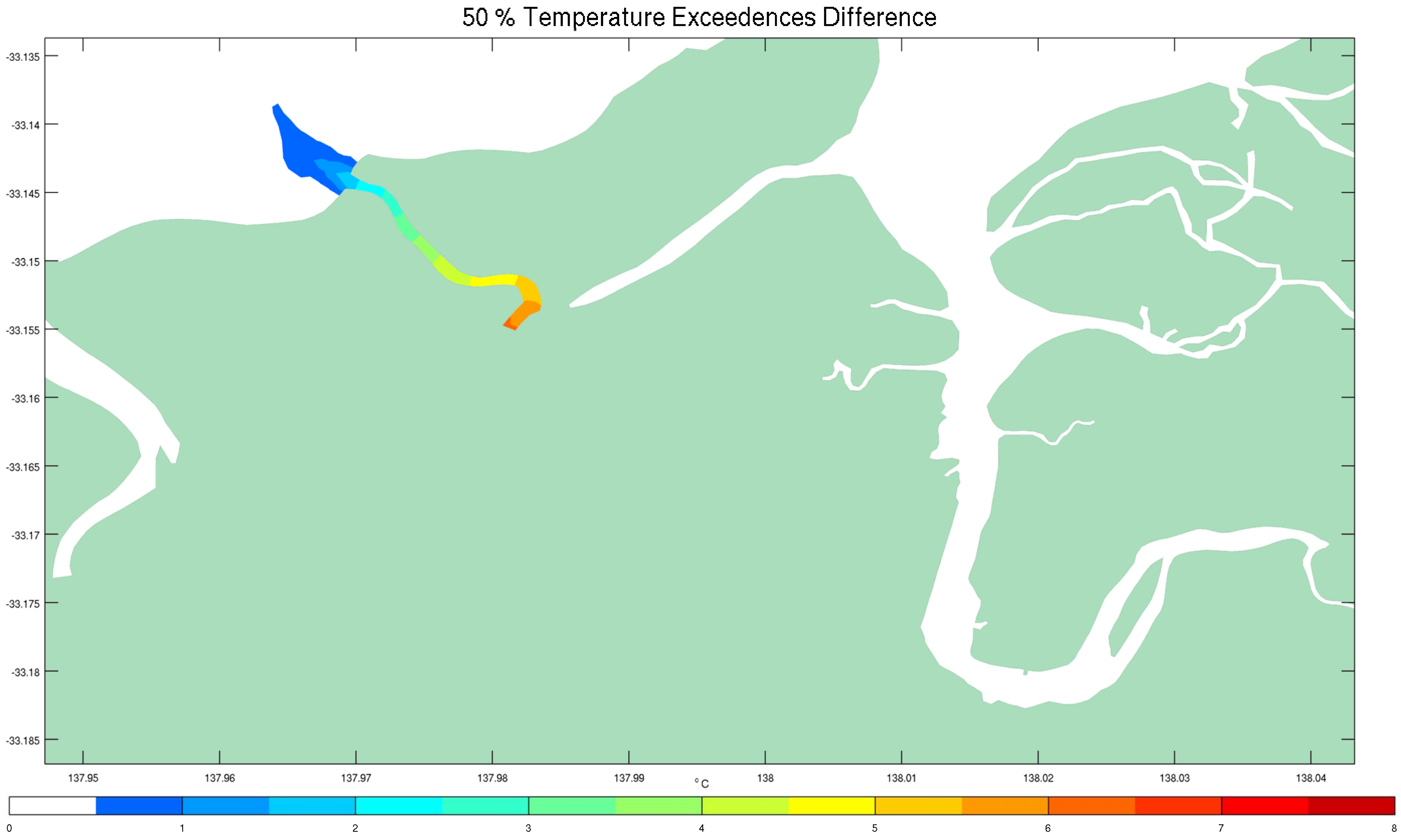

Figure B- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 3 and from Natural Baseline

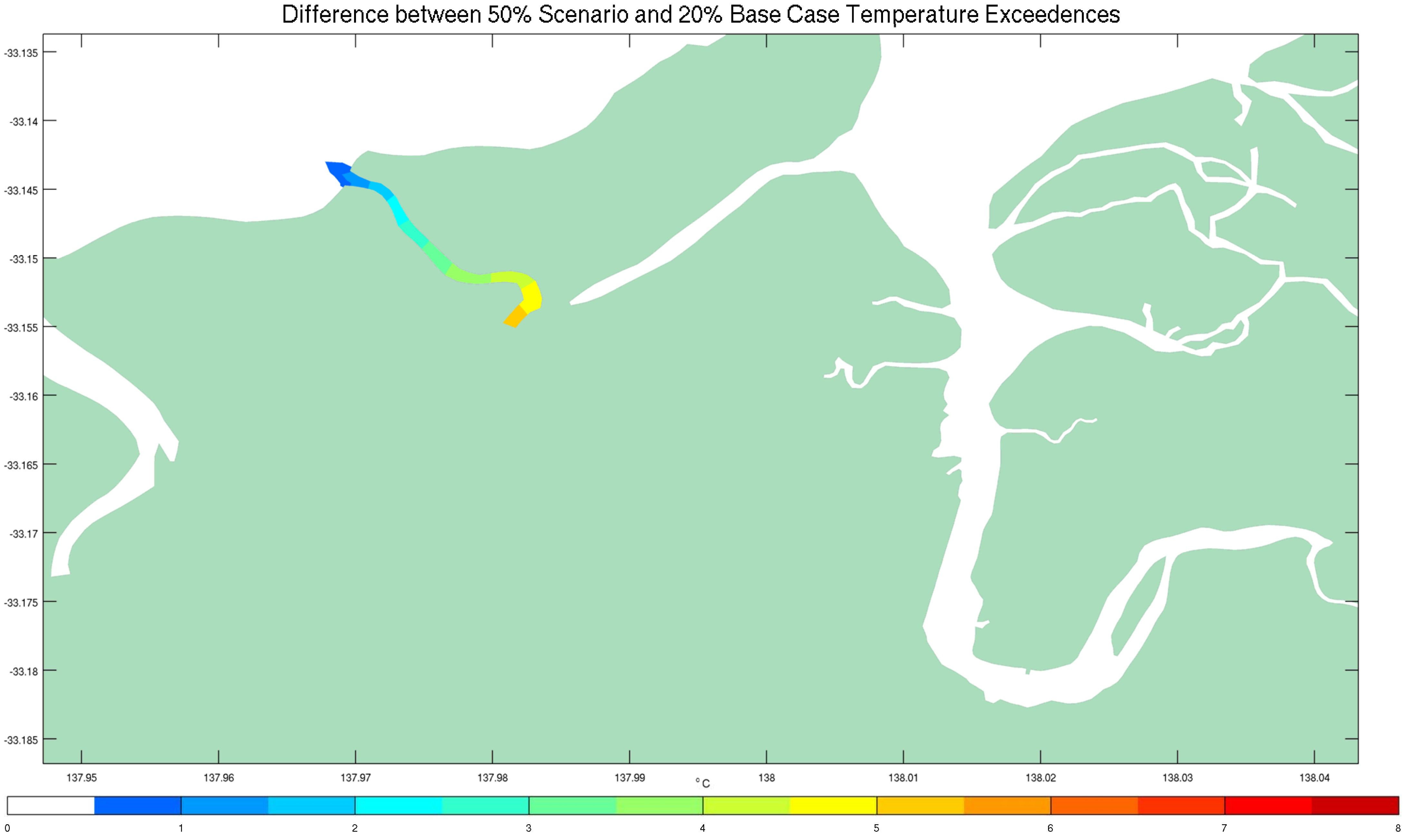

Figure B- 4 Differences between Scenario 3 50th Percentile Temperature Exceedences and the Natural Baseline 20th Percentile Temperature Exceedences

APPENDIX C: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 4 AND NATURAL BASELINE

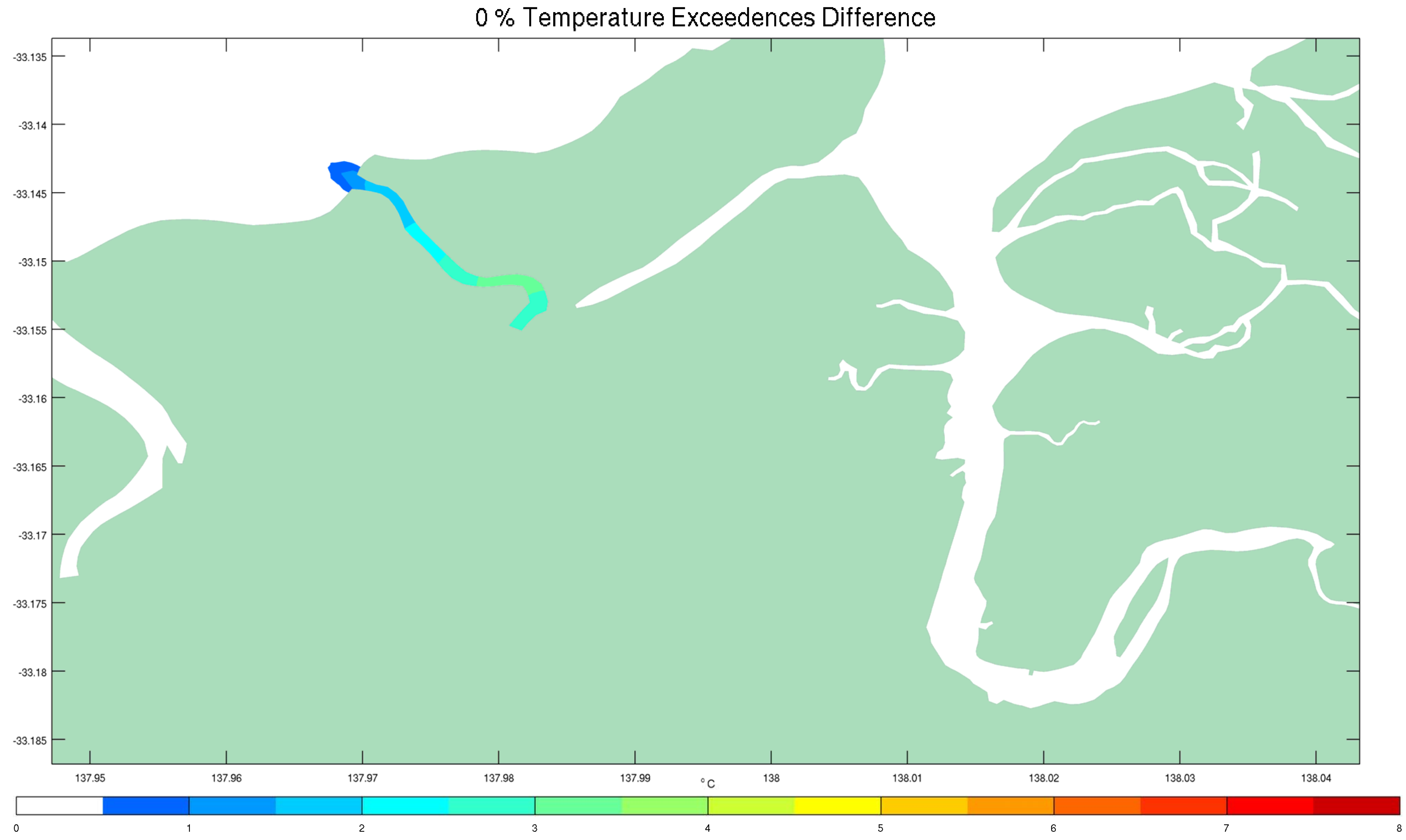

Figure C- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 4 and from Natural Baseline

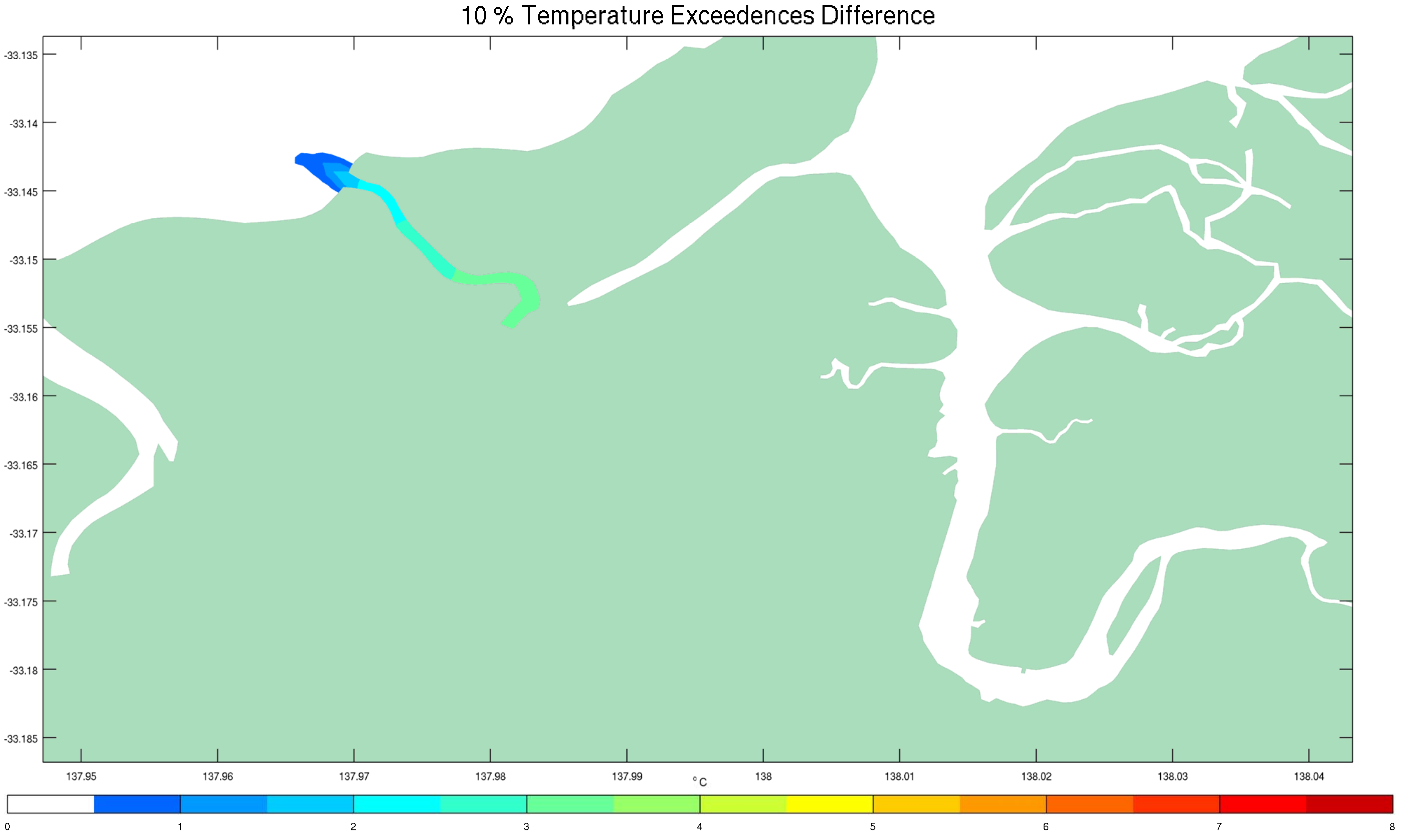

Figure C- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 4 and from Natural Baseline

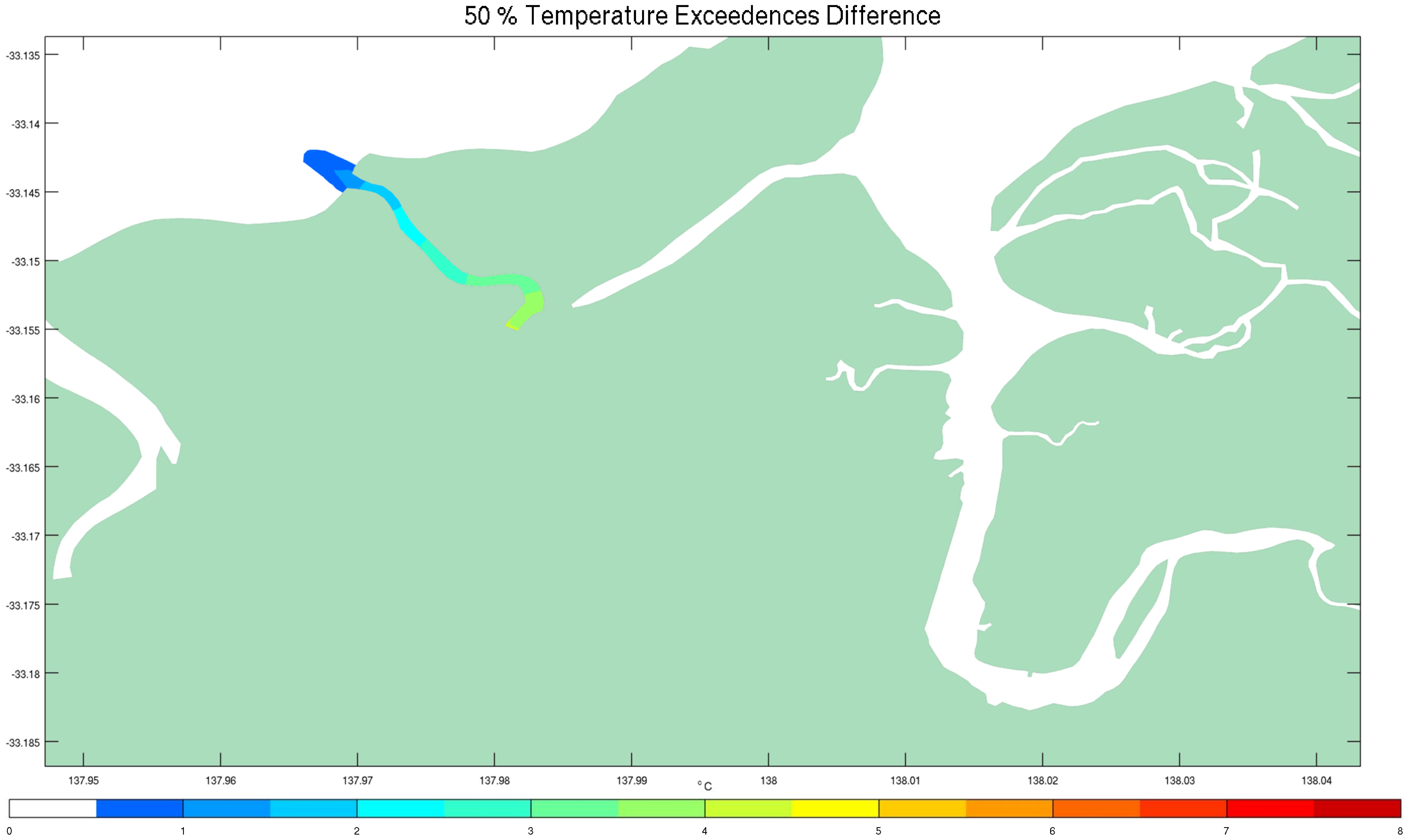

Figure C- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 4 and from Natural Baseline

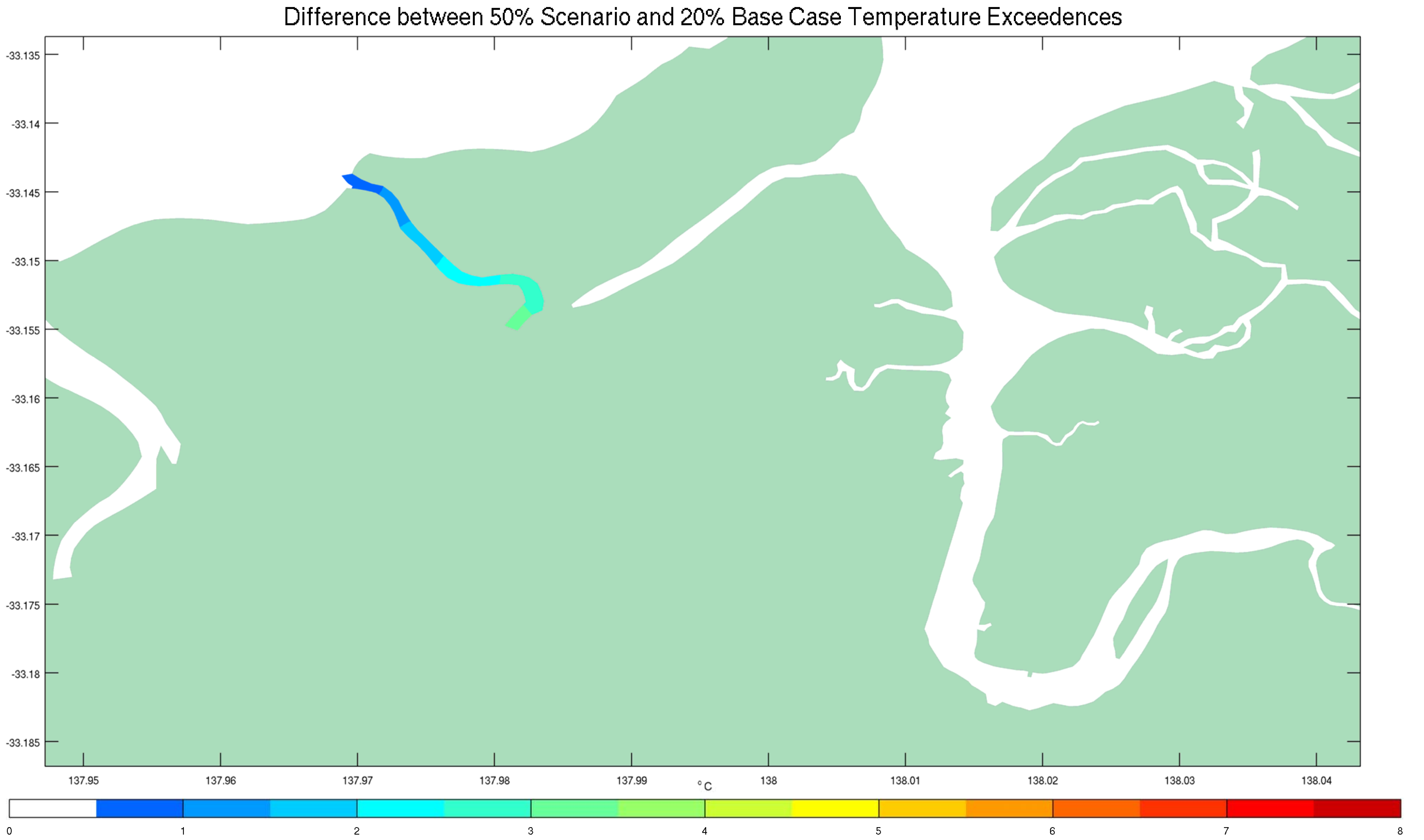

Figure C- 4 Differences between Scenario 4 50th Percentile Temperature Exceedences and the Natural Baseline 20th Percentile Temperature Exceedences

APPENDIX D: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 13 AND NATURAL BASELINE

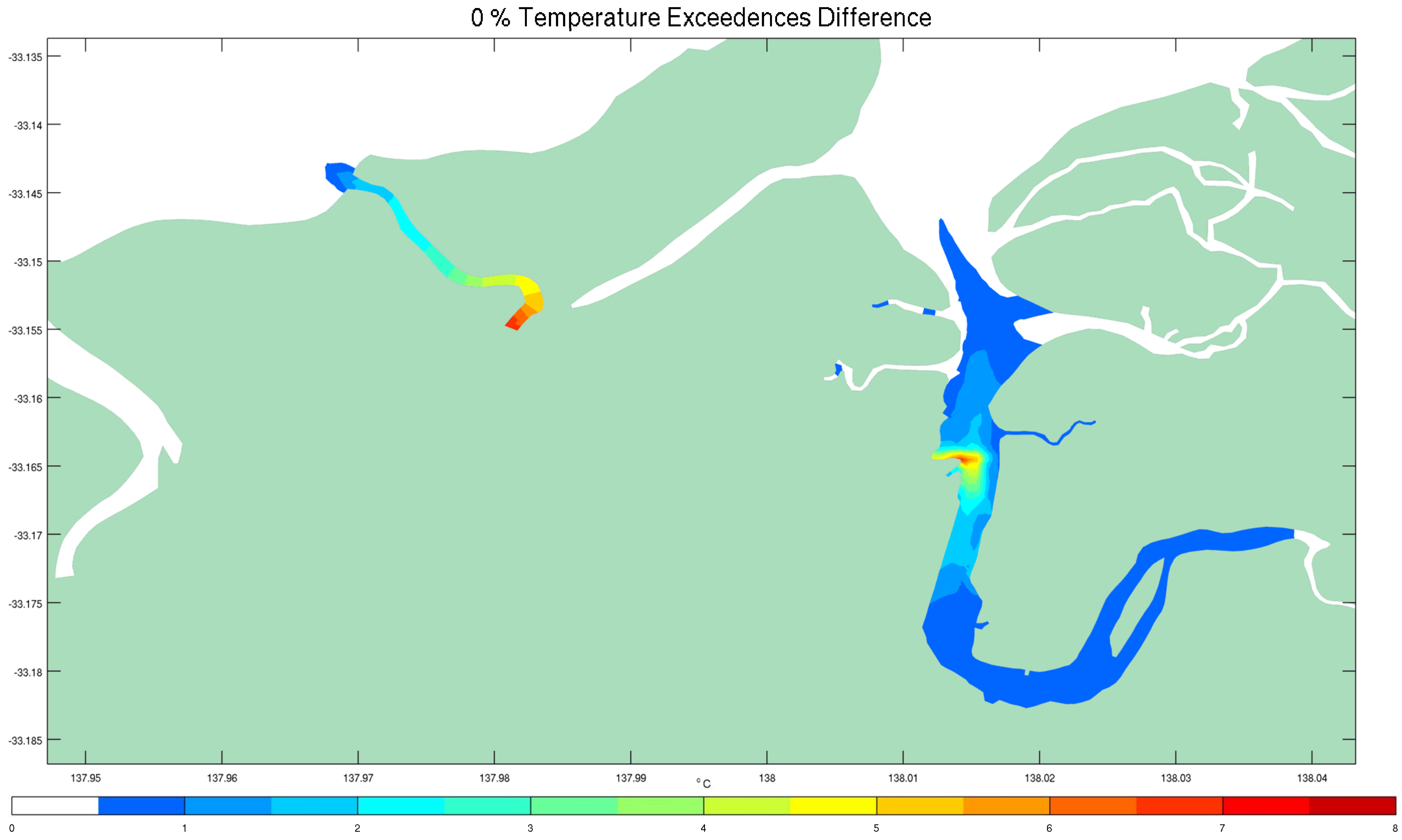

Figure D- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 13 and from Natural Baseline

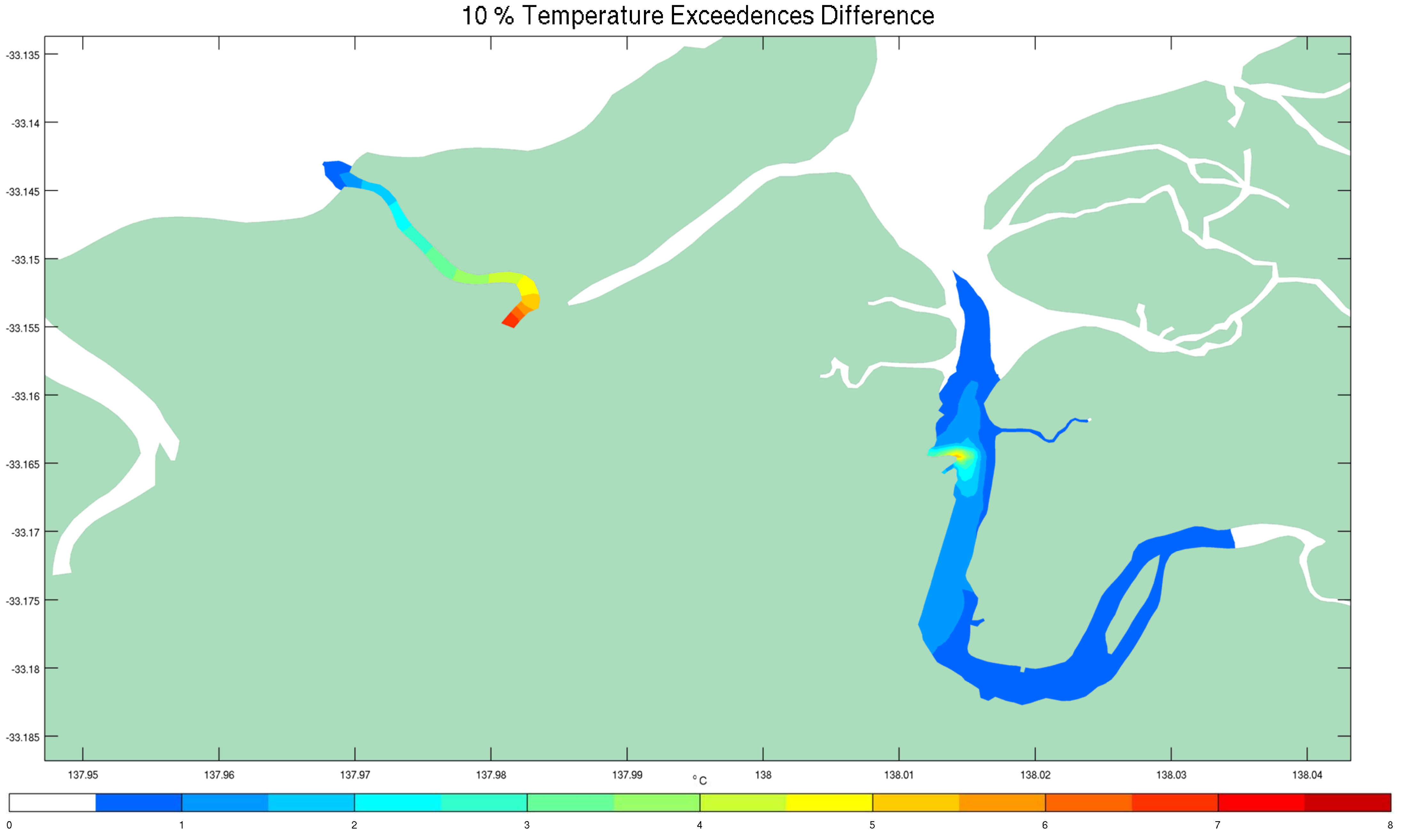

Figure D- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 13 and from Natural Baseline

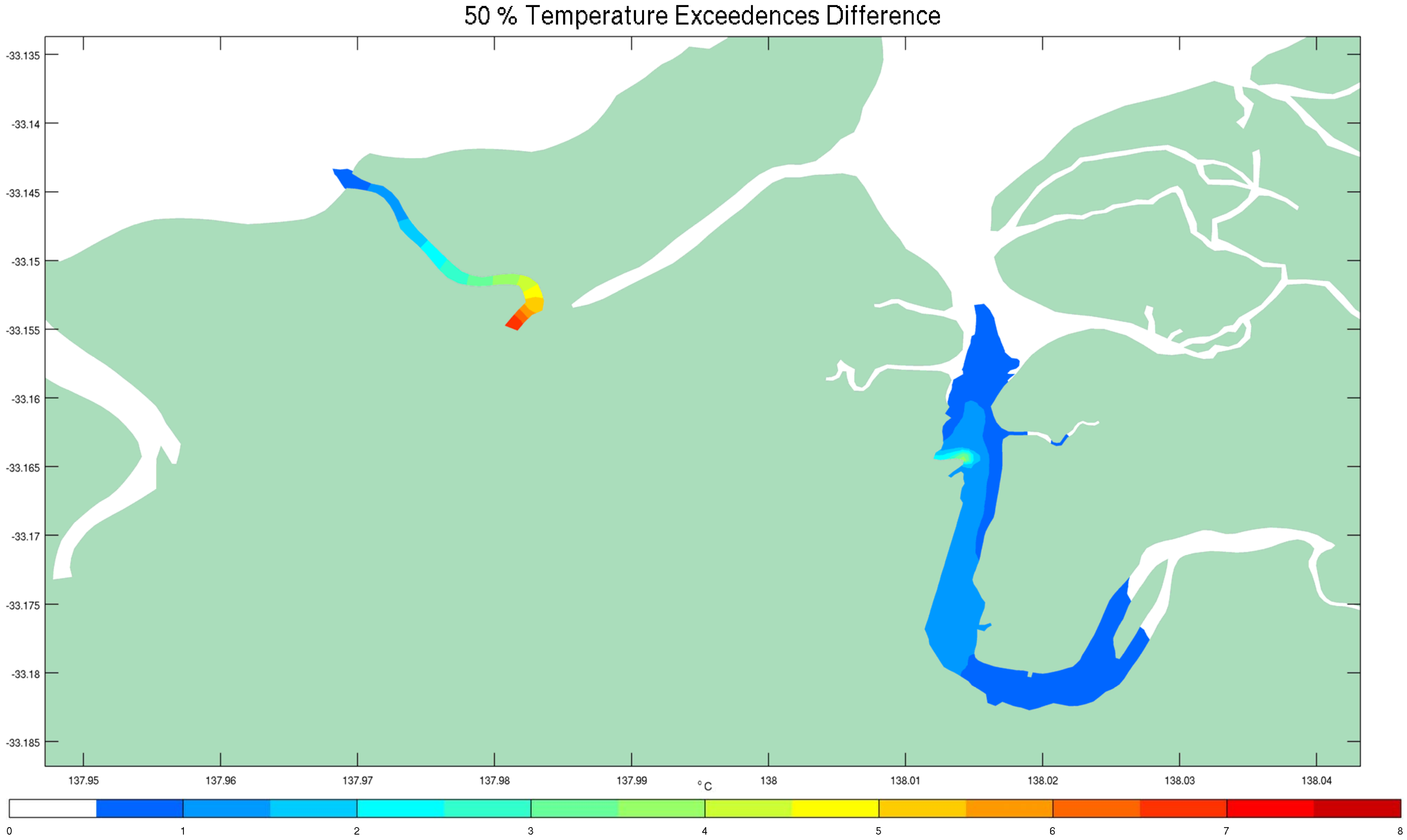

Figure D- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 13 and from Natural Baseline

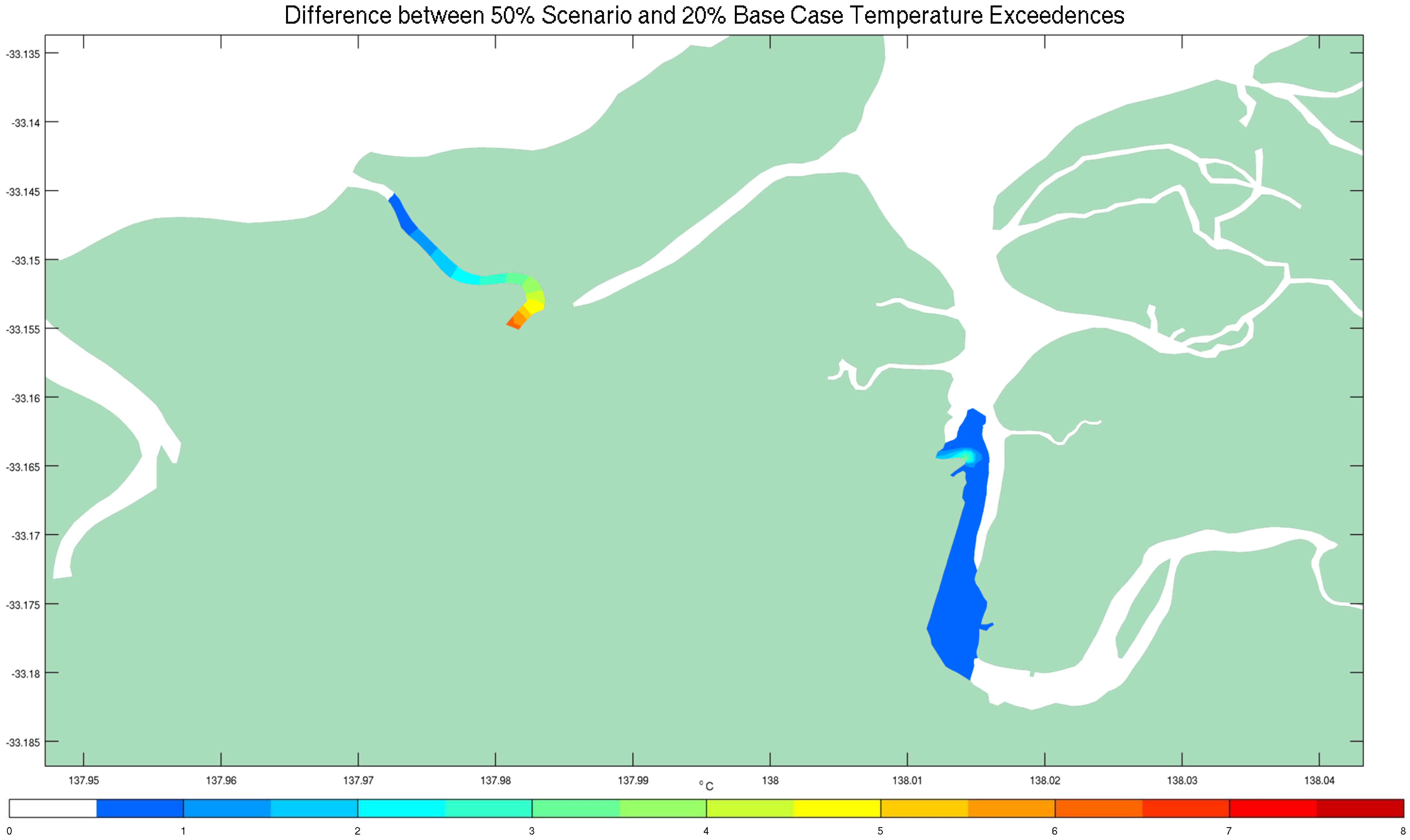

Figure D- 4 Differences between Scenario 13 50th Percentile Temperature Exceedences and the Natural Baseline 20th Percentile Temperature Exceedences

APPENDIX E: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 1 AND EXISTING BASELINE

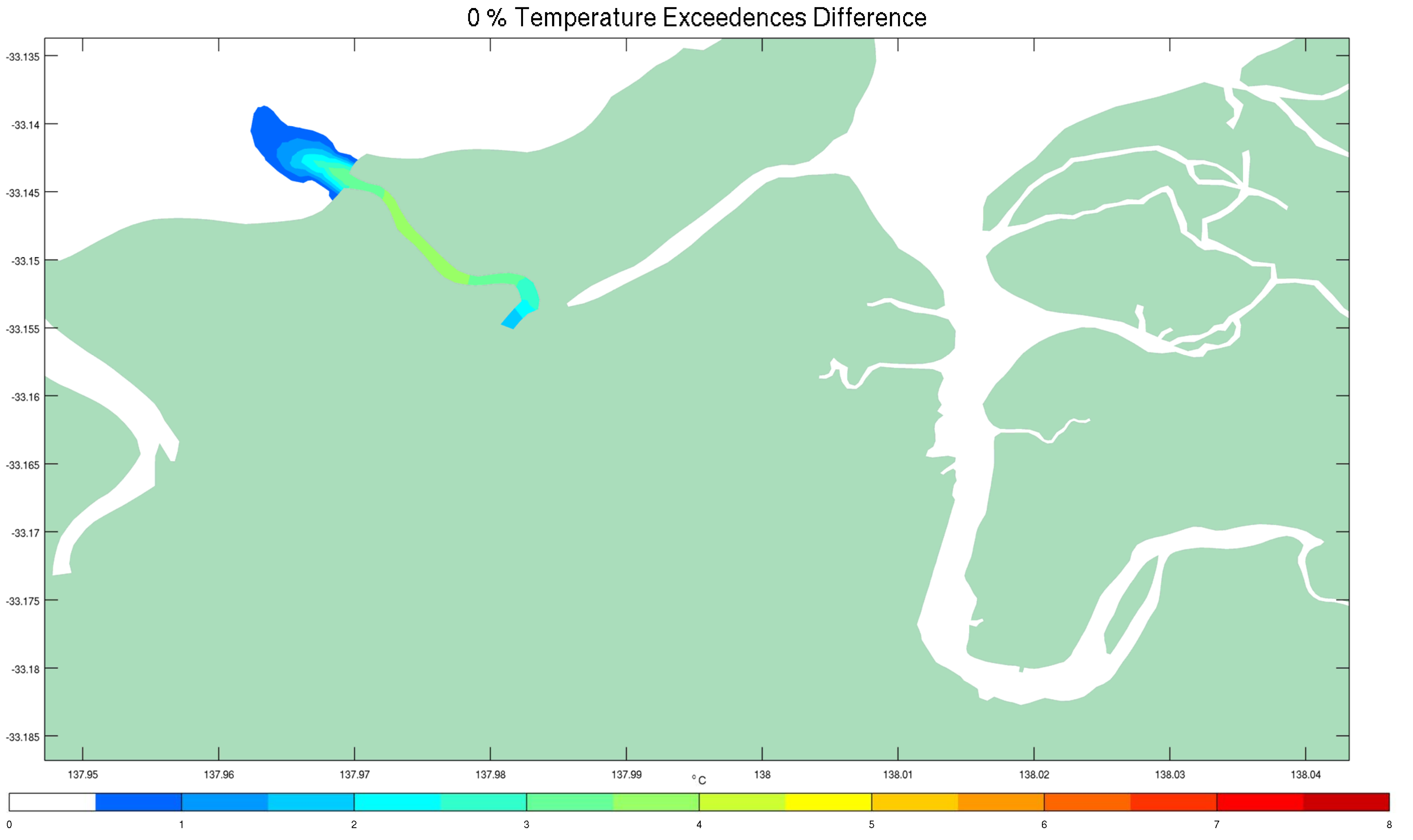

Figure E- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 1 and from Existing Baseline

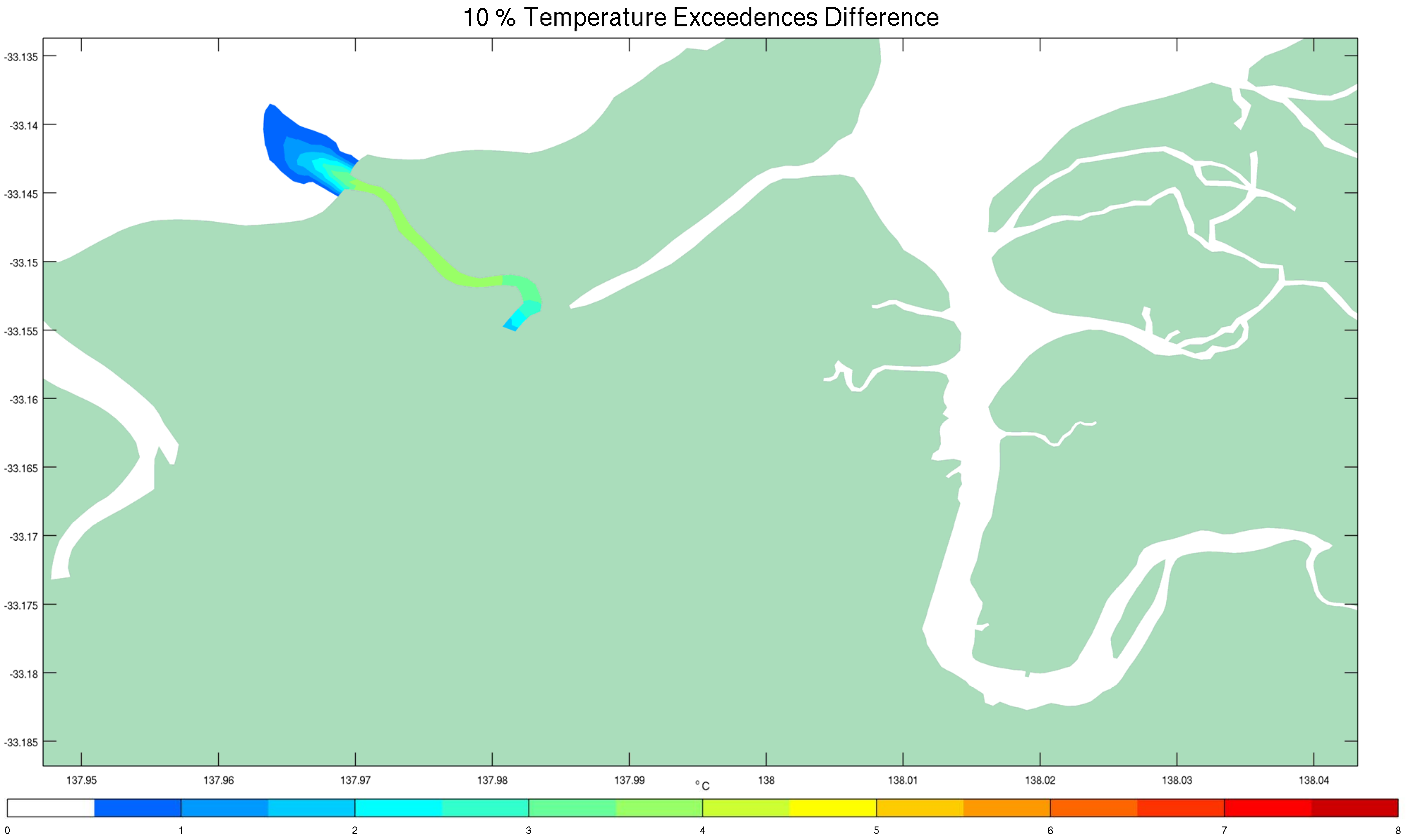

Figure E- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 1 and from Existing Baseline

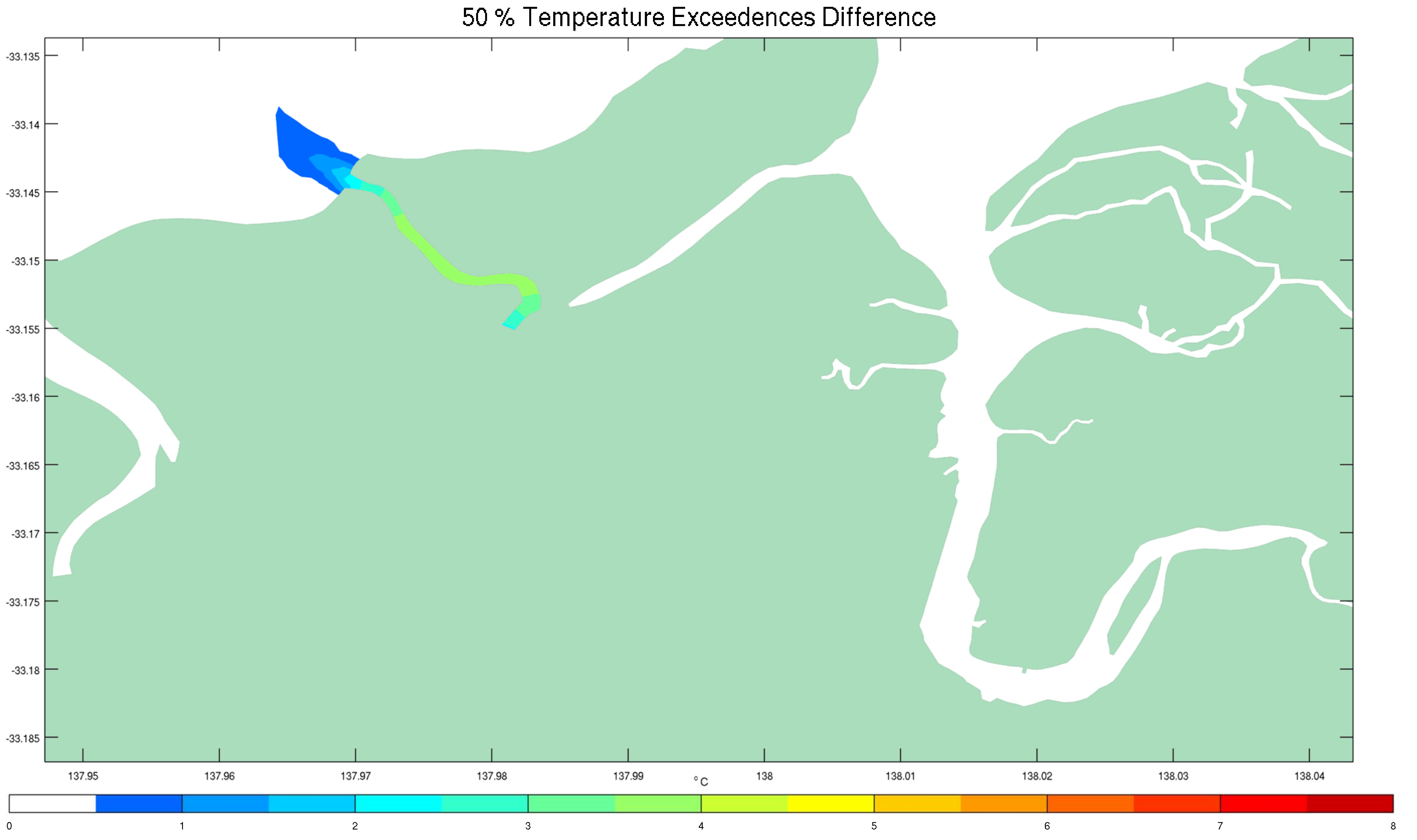

Figure E- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 1 and from Existing Baseline

APPENDIX F: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 3 AND BASELINE

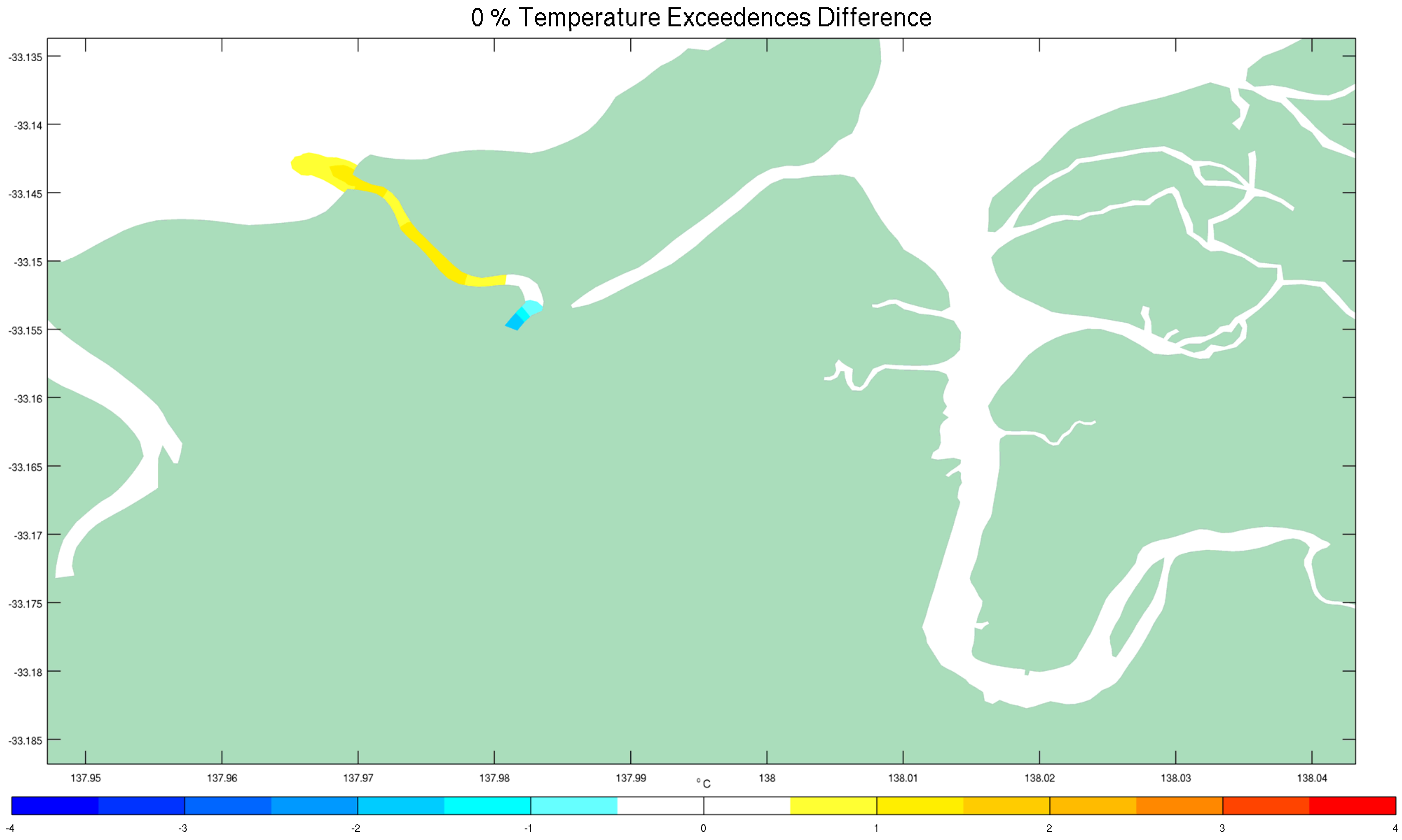

Figure F- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 3 and from Existing Baseline

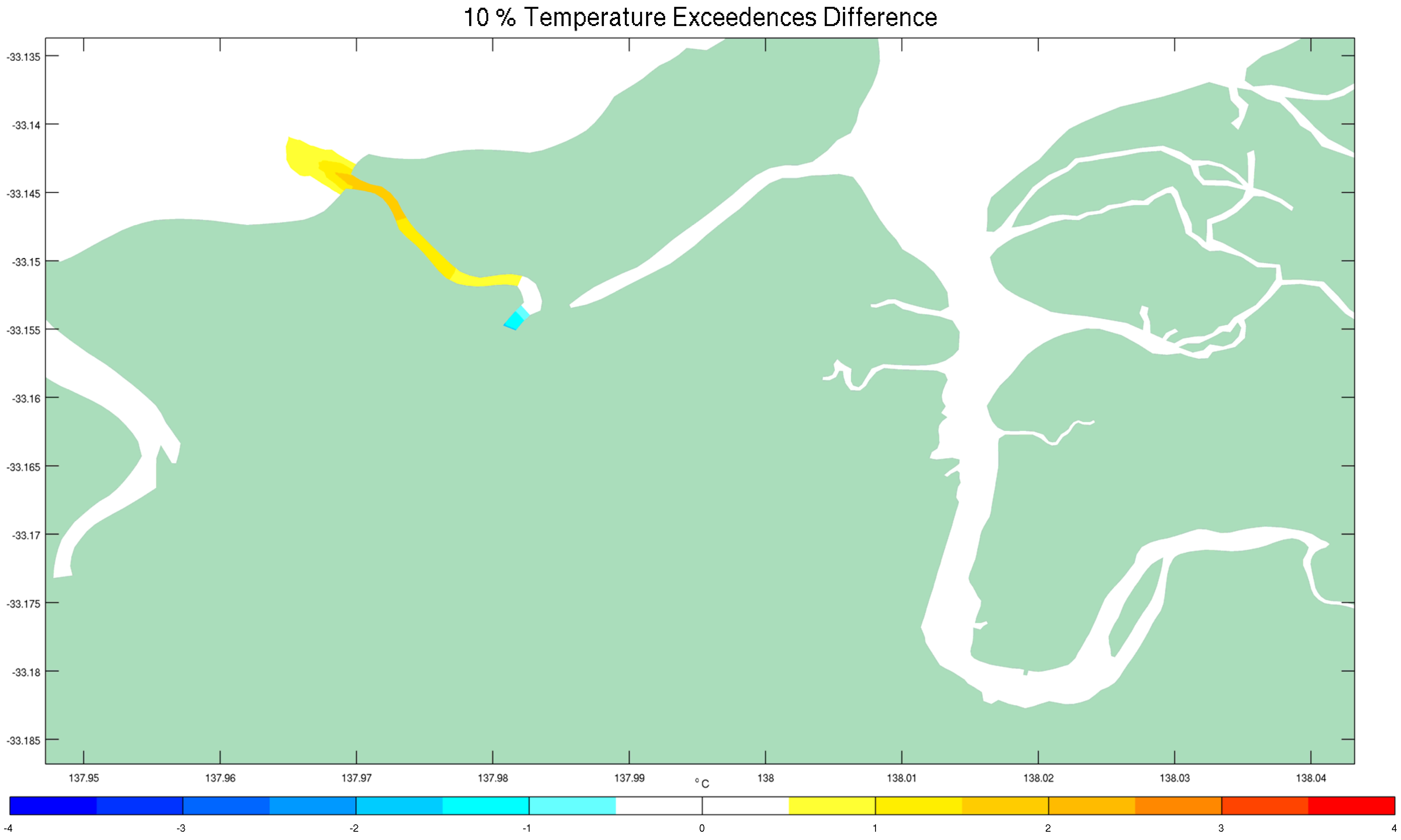

Figure F- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 3 and from Existing Baseline

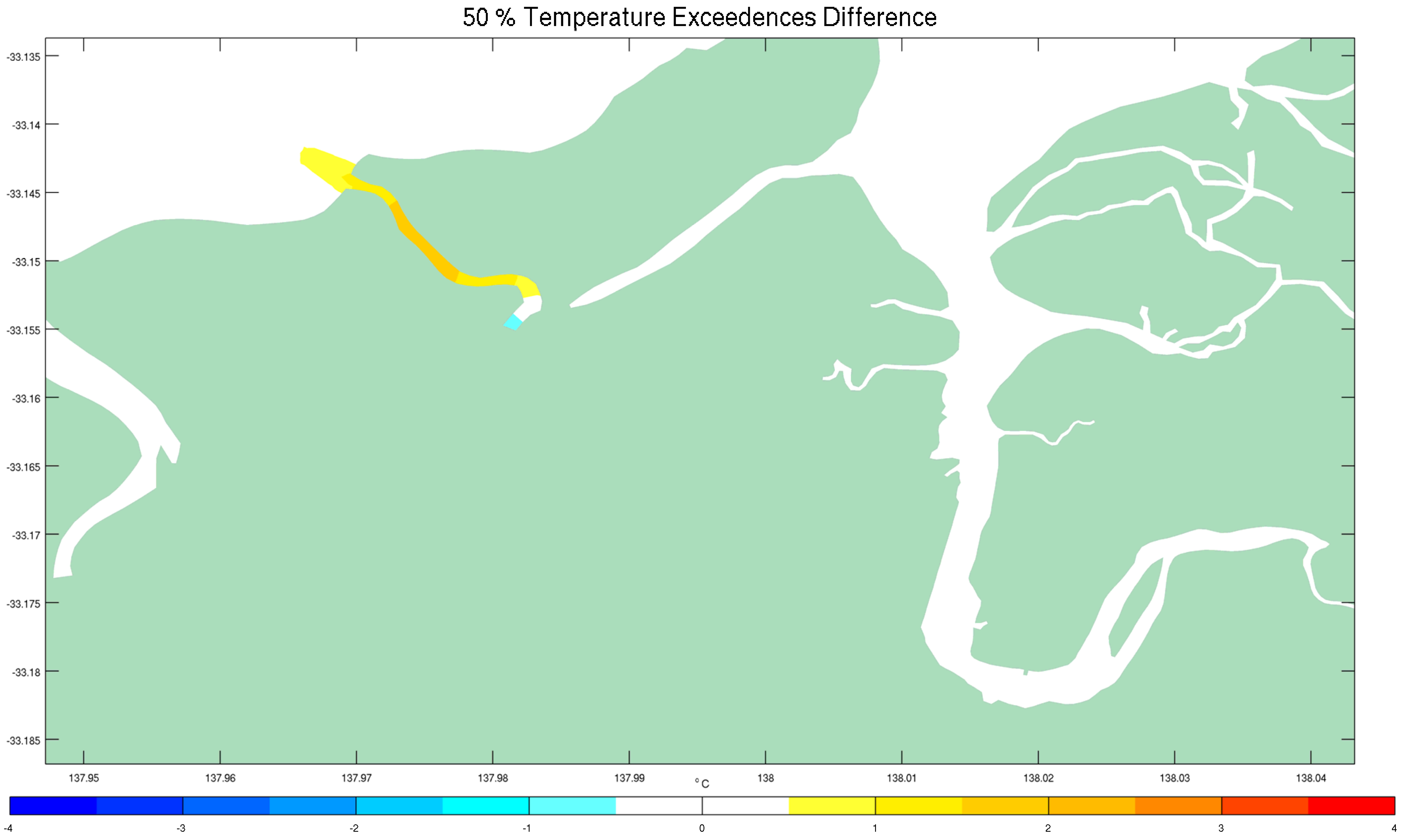

Figure F- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 3 and from Existing Baseline

APPENDIX G: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 4 AND EXISTING BASELINE

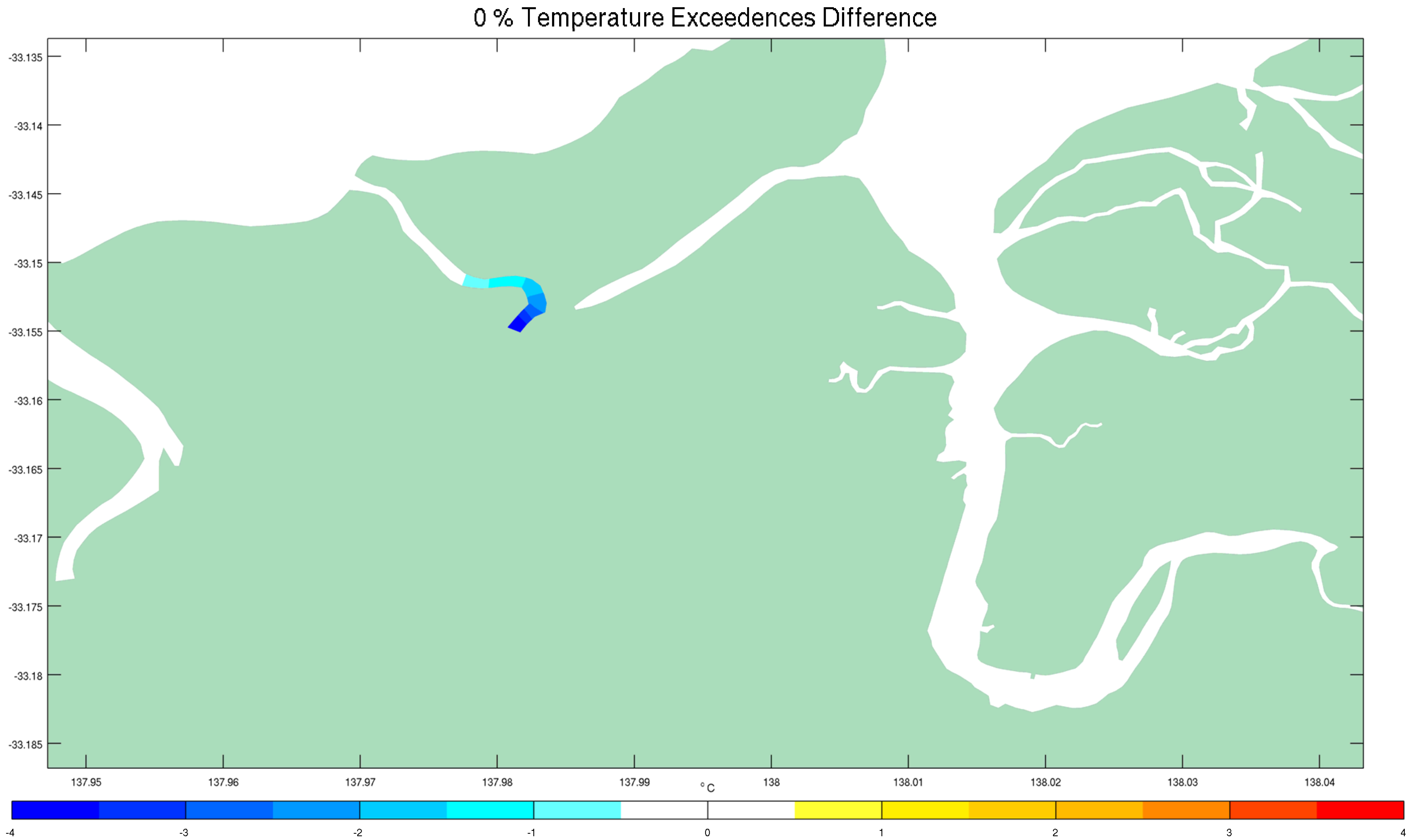

Figure G- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 4 and from Existing Baseline

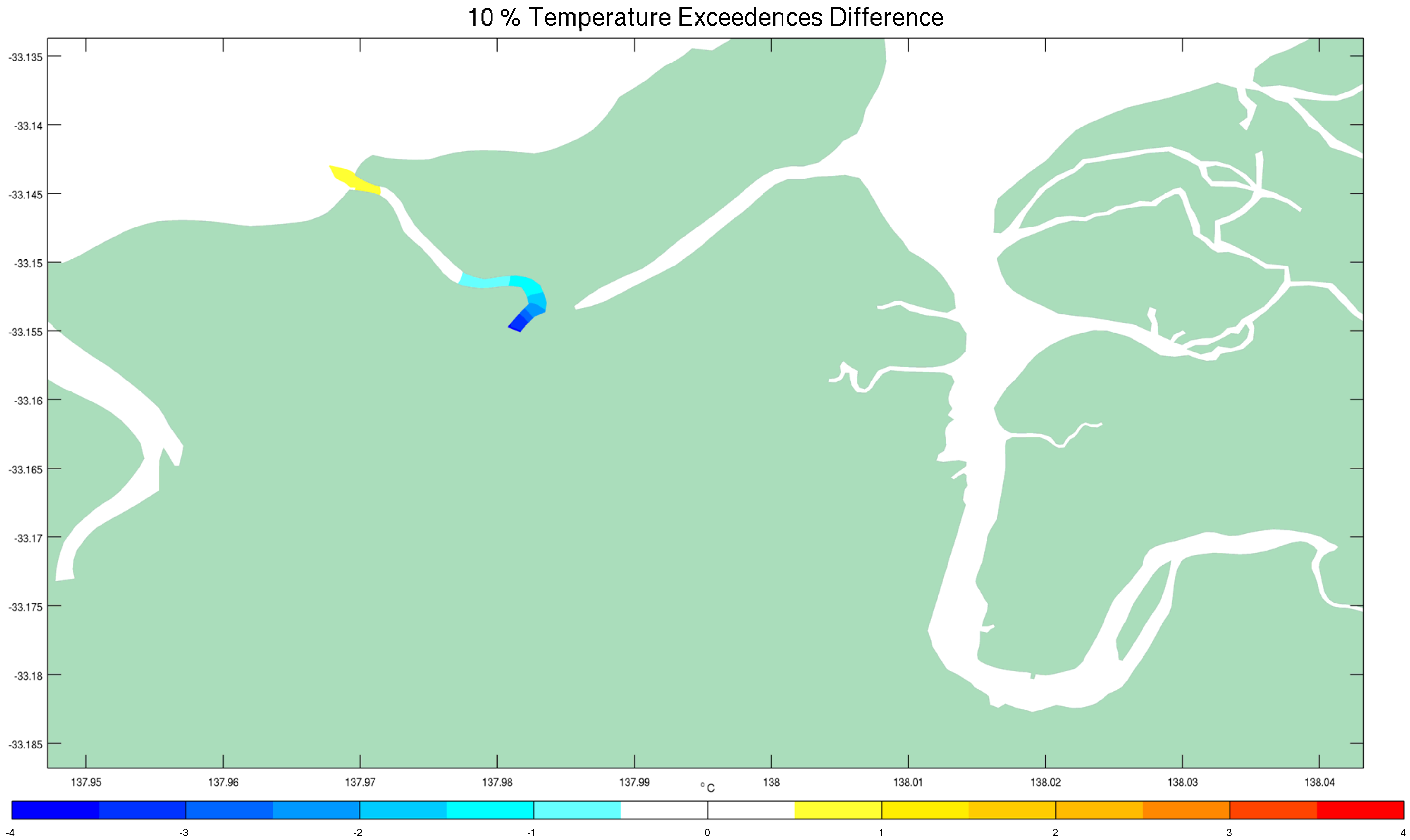

Figure G- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 4 and from Existing Baseline

APPENDIX H: TEMPERATURE EXCEEDENCES DIFFERENCES BETWEEN SCENARIO 13 AND EXISTING BASELINE

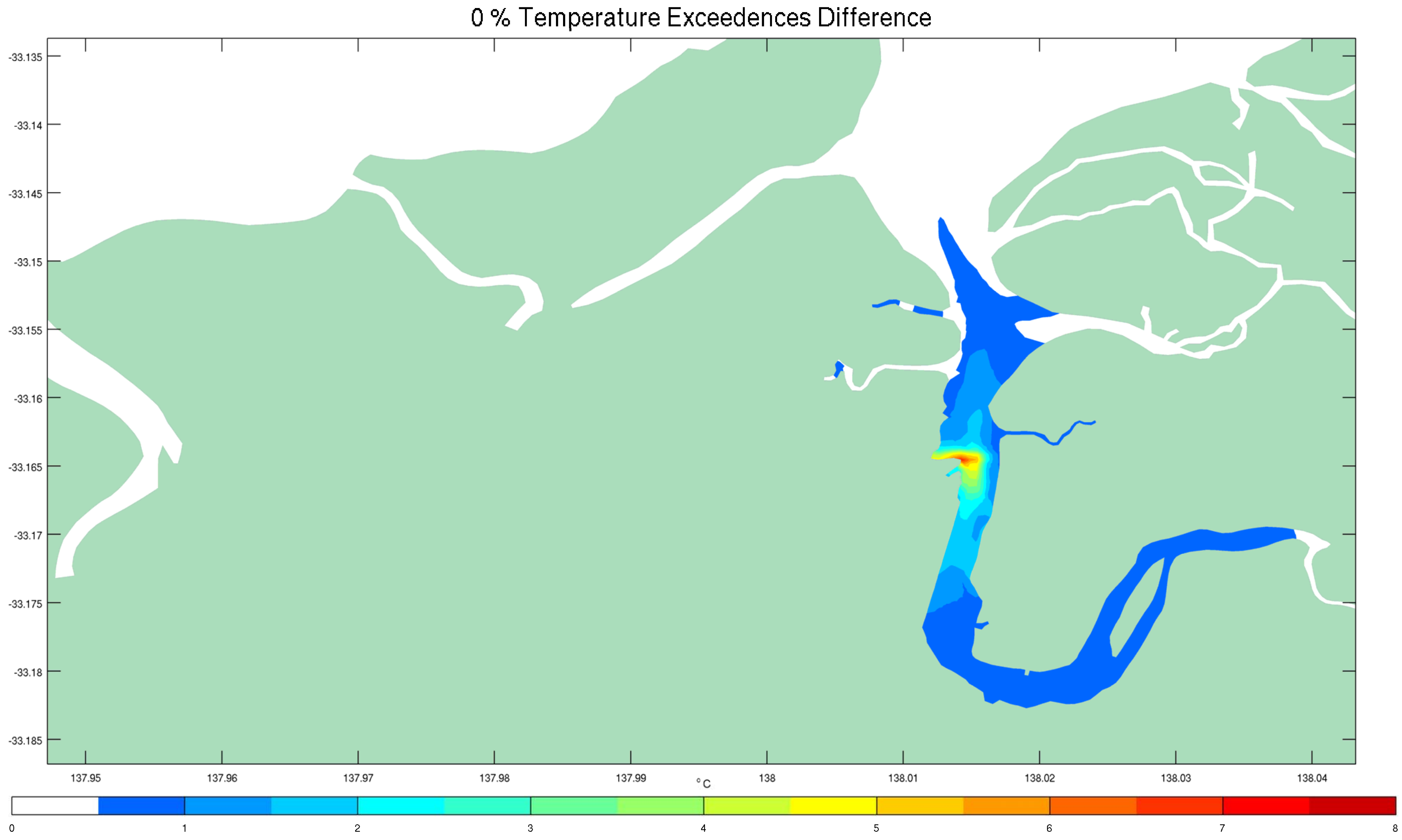

Figure H- 1 Differences between 0th Percentile Temperature Exceedences from Scenario 13 and from Existing Baseline

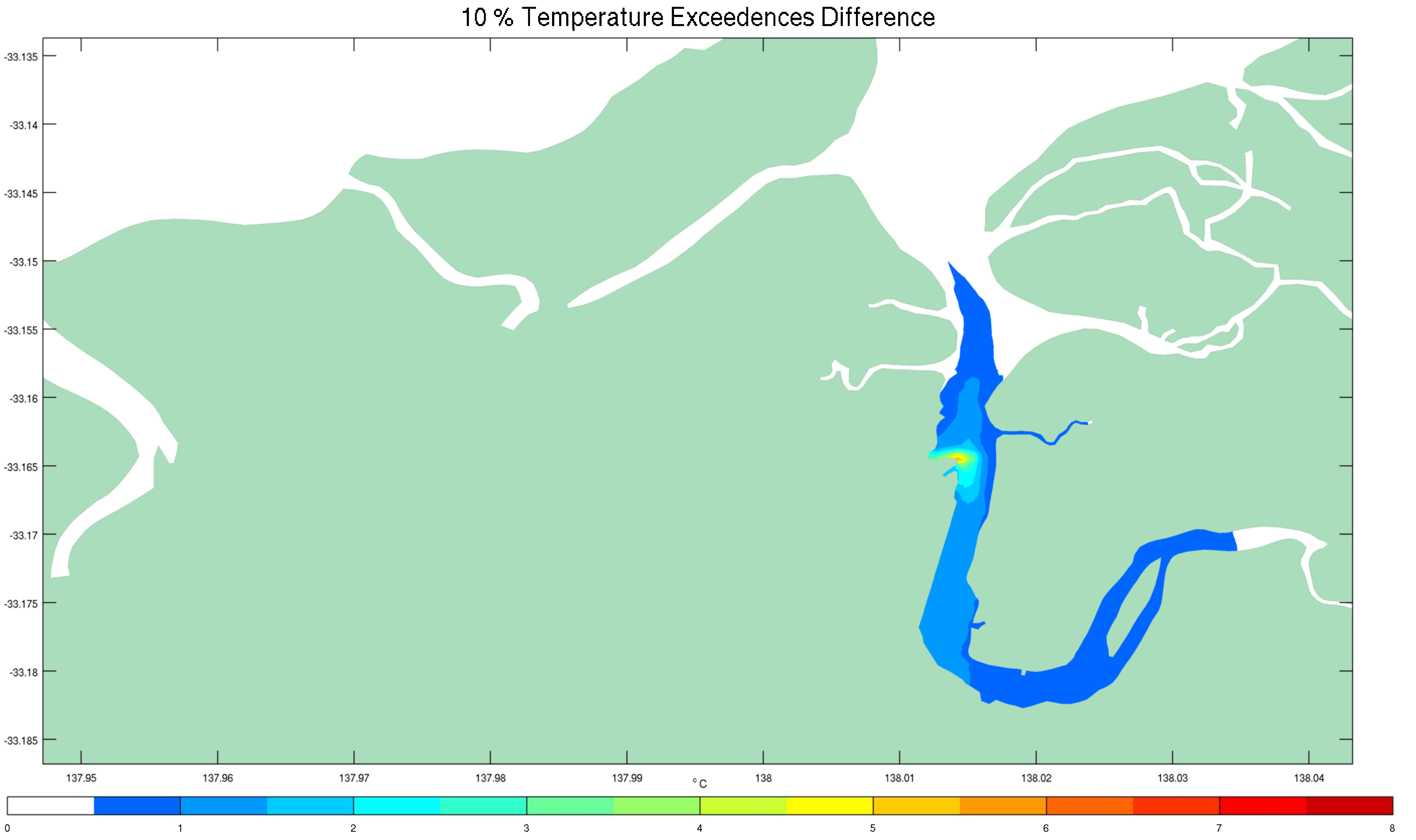

Figure H- 2 Differences between 10th Percentile Temperature Exceedences from Scenario 13 and from Existing Baseline

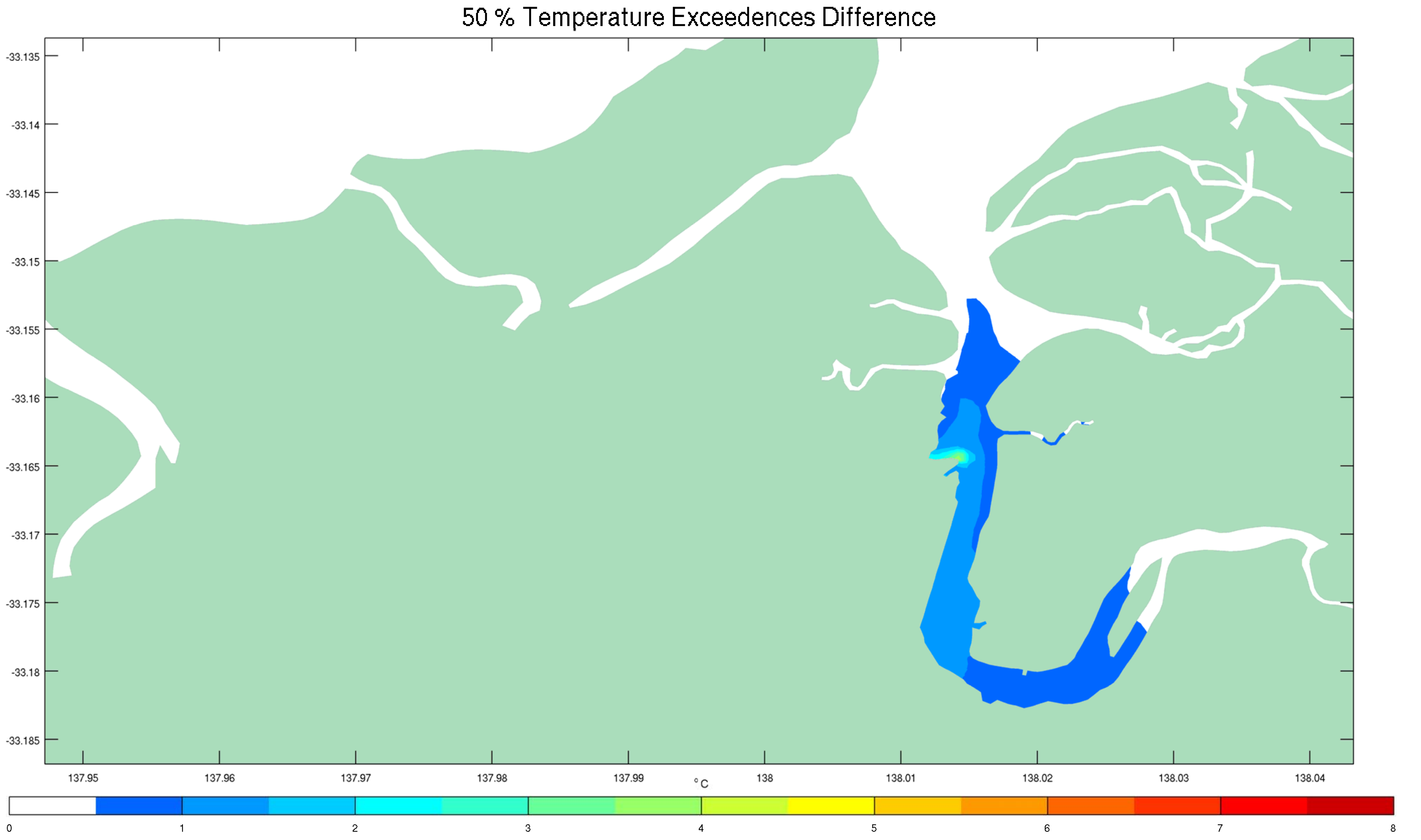

Figure H- 3 Differences between 50th Percentile Temperature Exceedences from Scenario 13 and from Existing Baseline

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