# Ecohydrological Restoration Assessment of the Aldinga Washpool

Report to the Green Adelaide Board

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**Cover photo**

Oblique aerial image of the Washpool taken by drone, 21st July 2021 (photo: Mark Bachmann)

**Disclaimer**

## Acknowledgements

Nature Glenelg Trust acknowledges the Traditional Custodians of the Washpool, the Kaurna. We recognise and respect their cultural heritage, beliefs, and relationships with Country. We acknowledge that the habitat, wildlife, and ecosystems within the reserve are of continuing importance to Traditional Custodians today.

A large number of people have contributed their time, knowledge and resources to inform this report – we thank you all for your generosity. Section 2 describes the involvement of key people in detail.

*This project was funded by Green Adelaide.*

## Executive Summary

The Washpool, Blue Lagoon and general vicinity has high cultural significance to Kaurna traditional custodians, with a high density of archaeological material and significance to Tjilbruke dreaming. A passionate and well-informed local community, comprising both Kaurna and non-Indigenous people, won the battle against a proposed marina development in the 1980s and have continued to advocate for the conservation and improved management of the Washpool and Blue Lagoon since then. Most of the area comprising the Washpool was proclaimed as part of Aldinga Conservation Park by the South Australian Government in January 2022. However, despite this form of legal protection, the Washpool and Blue Lagoon are in a relatively degraded state - in terms of their ecological function - as a result of changes to catchment and site hydrology since colonisation.

In January 2021 Nature Glenelg Trust received a Green Adelaide Grassroots Grant for a project entitled *Overcoming Obstacles to Hydrological Restoration at the Washpool and Blue Lagoon* aimed at developing hydrological restoration options for the area. A primary focus during the development and exploration of options is that they are informed by Kaurna knowledge, ecological science and historical evidence and they are agreed to by key parties (Kaurna representatives, DEW, City of Onkaparinga, adjoining landholders and others). In addition, options need to be achievable and articulated in a suitable format for grant funding opportunities capable of leading to future on-ground implementation.

Historical evidence, in the form of early surveyor maps and descriptions suggest that the historical, pre-colonial state of the Washpool was a brackish, open water lagoon surrounded by reeds, rushes and sedges. The lagoon likely had two outlets to the sea and occupied an extent of 26 ha. Inflows were diffuse and the lagoon dried down seasonally with some water retention in the deepest points during all but the driest of years, likely due to the surface expression of groundwater. Colonial settlement and subsequent development of the catchment involved clearance of native vegetation, the introduction of sheep and cattle grazing and channelisation of watercourses (both deliberate and uncontrolled) leading to erosion. This acted to increase delivery of sediment to both the Blue Lagoon and Washpool, reducing their overall volume, and combined with drainage, meant the system held less water and dried down earlier despite experiencing flashier filling events.

A concrete weir was constructed in the late 1980's and raised in the early 2000's to increase water holding capacity in the Washpool, albeit at a much reduced extent compared to its former state. The depth and extent of inundation has implications for both the ecology of the wetland and also its cultural affinity. In pre-colonial times, when summer water levels in the Washpool dropped, mudflats were exposed on the southern edge of the Washpool and these mudflats were important for curing animal skins. These mudflats have now been displaced by the downslope migration of samphire vegetation in response to reduced depth and duration of inundation. Consideration of digital elevation modelling and the historic presence of seasonal brackish aquatic bed (a surrogate vegetation indicator for these mudflats) suggest a pre-colonial water full supply level which was 0.26 – 0.46 m above the crest of the existing concrete weir.

Blue Lagoon is thought to have previously been much deeper than it currently is and was a deep, permanent water body. Similar to the Washpool, it has experienced volume reduction as a result of increased sediment deposition and increased water loss through drainage, resulting in a waterbody that is now shallower.

In lieu of more substantive evidence regarding the historical state of Blue Lagoon, and a requirement for greater consultation on potential restoration options, the Washpool is the primary focus of restorative actions.

After consideration of several potential restoration options for the Washpool (see table below), it is suggested Option 1 will best match pre-colonial conditions in terms of water depth and duration of inundation. Outcomes under this scenario would be augmented by sediment removal works (Option 3) and a combined approach is considered the highest priority for future investigation and implementation to maximise potential environmental benefit. An additional option to improve fish passage (Option 6) is also considered a desirable addition and, for efficiency, could be incorporated into the detailed design of Option 1. Implementation of Options 1 and 3 will necessitate Option 4 (removal of Button Rd). Additional Options (5 and 8) are of medium priority and could be undertaken independently of other Options.

| Priority | Option | Consistent with or builds upon previous studies | High Priority Next Steps |
|---|---|---|---|
| High | Option 1 - levee and spillway | Stokes and Harris (1976)<br>Ecological Associates (2003)<br>QED (2007)<br>SKM (2008) | Washpool catchment modelling to ensure sufficient water availability to justify increased Washpool volume |
| | | | Assessment of the suitability of accumulated sediment within the Washpool as levee construction material (if Options 2 and 3 are also implemented) |
| High | Option 3 (a, b) – remove accumulated sediment, backfill Norman drain | Stokes and Harris (1976)<br>Ecological Associates (2003)<br>QED (2007)<br>SKM (2008) | Accurate, fine scale determination of the depth of sediments deposited post-colonisation within the proposed excavation footprint |
| | | | Acid sulphate soil risk assessment of proposed excavation footprint |
| High<br>(if Options 1 and 3 undertaken) | Option 4 – remove Button Rd | QED (2007)<br>SKM (2008)<br>Draper and Maland (2021) | Determine community perspectives and make decision (City of Onkaparinga) |
| High<br>(if Option 1 undertaken) | Option 6 – improve fish passage | | |
| Medium | Option 5 – convert dam to temporary sedimentation pond | SKM (2008) | |
| Medium | Option 8 – backfill drain near Blue Lagoon | | |

| Priority | Option | Consistent with or builds upon previous studies | High Priority Next Steps |
|---|---|---|---|
| n/a | Option 2 – remove central bund (merged with Option 3) | | |
| n/a | Option 7 – reactivate southern outlet (not recommended) | | |

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## Acronyms

| | |
|---|---|
| CoO | City of Onkaparinga |
| CTF | cease-to-flow (the water level in a wetland when it is full, but not overflowing, assuming a flat water surface throughout) |
| DEM | digital elevation model (a digital topographic map) |
| DEW | SA Government Department for Environment and Water |
| FoAS | Friends of Aldinga Scrub |
| mAHD | metres Australian Height Datum (elevation relative to mean sea level) |
| NGT | Nature Glenelg Trust |
| WHFLG | Willunga Hills Face Landcare Group |
| WSEL | water surface elevation (usually expressed in mAHD) |

# 1. Introduction

## 1.1. Background

The Washpool is a brackish, seasonal lagoon located behind coastal foredunes at Aldinga Beach near the southern extent of metropolitan Adelaide. Blue Lagoon is an associated wetland located approximately 0.5 km to the north. The Washpool is listed as a wetland of national importance (DAWE 2022) and is generally regarded as the last remaining coastal lagoon of its type in the Adelaide region, which historically supported extensive areas of similar habitat along the coast. The Washpool, Blue Lagoon and general vicinity has high cultural significance to Kaurna traditional custodians, with a high density of archaeological material and significance to Tjilbruke dreaming (Draper and Maland 2021). Wangkondananko, meaning "possum place", is a name associated with the Washpool (Draper and Maland 2021). A passionate and well-informed local community, comprising both Kaurna and non-Indigenous people, won the battle against a proposed marina development in the 1980s and have continued to advocate for the conservation and improved management of the Washpool and Blue Lagoon since then. On-ground works, such as weed management and revegetation, have been undertaken by the local community, in recent years with support from the (former) Adelaide and Mt Lofty Range Natural Resources Management Board, Green Adelaide and City of Onkaparinga. Decades of lobbying has recently achieved a major success, with the majority of the land in question (69 of 90.6 ha, Figure 1) proclaimed as part of Aldinga Conservation Park by the South Australian Government in January 2022.


Figure 1. Aldinga Conservation Park as at January 2022 (source: NPWS 2022).

Reservation is sometimes mistakenly viewed as the end of the conservation journey, because it is a change in legal status which ensures the protection of ecological values in perpetuity. However, for many wetland reserves, including the Washpool, reservation generally does not include investment in proactive remedial or restorative action. Dramatic changes to pre-colonial hydrology, through actions such as the excavation of drains and processes such as sedimentation, often mean that wetlands are in a relatively degraded and partially modified state despite the persistence of important ecological values. Considerable scope exists for the recovery and improvement of ecological values via on-ground works and, in the case of the Washpool, now is an apt time to be considering such works, particularly given we have entered the United Nations Decade on Ecosystem Restoration (2021 - 2030, UN Environment Program 2022). The Washpool presents an exciting opportunity for ecohydrological restoration that would, if planned and implemented in collaboration with Kaurna community, also help enliven Kaurna culture. To that end, NGT has endeavoured to work closely with Kaurna representatives, as far as opportunity has permitted, in undertaking what is considered the next phase of action necessary for this important cultural site via this ecohydrological assessment.

## 1.2. What is an Ecohydrological Assessment?

Hydrology is concerned with how water moves through and is held within the landscape and ecohydrology is concerned with how hydrological patterns influence ecosystems and ecological values, noting that hydrology is the key driver of wetland ecology. The presence of surface water has a profound influence upon ecosystems. For example, plant species tolerant of flooding generally do not occur in areas that are never subject to inundation, and vice versa , noting that some semi-aquatic or fringing plants are equipped to take advantage of conditions in a gradient of hydrological conditions between these two extremes. The same applies to fauna adapted to the aquatic environment and its margins. Therefore, when hydrology is altered, ecological changes occur, as species are forced to move up or down this elevation / inundation gradient, in some cases dropping out of a site altogether. Understanding the hydrology of an area in its original unmodified state can therefore provide insights capable of informing the vision for what could be achieved through remedial works. Nature Glenelg Trust has, since our inception in 2012, restored over 50 wetlands in south-eastern Australia and have brought this breadth of experience to bear in this assessment of the Washpool, Blue Lagoon and surrounds.

## 1.3. Grassroots Grant Objectives

In January 2021, NGT received a Green Adelaide Grassroots Grant for a project entitled *Overcoming Obstacles to Hydrological Restoration at the Washpool and Blue Lagoon*. The initial project objectives were to develop hydrological restoration options for the area that are:

- informed by Kaurna knowledge;
- informed by ecological science and historical evidence;
- agreed by key parties (Kaurna representatives, DEW, City of Onkaparinga, adjoining landholders and others);
- achievable; and
- readily convertible to funding applications for future on-ground implementation.

As work progressed it became apparent that governance arrangements for Aldinga Conservation Park were still being finalised. Management of the newly expanded reserve is to be overseen by a Co-Management Advisory Committee, comprising representatives from Kaurna Yerta Aboriginal Corporation and the Department for Environment and Water. Given the Advisory Committee was only established in August 2022, there was no opportunity for the restoration options presented in this assessment to be considered by the Committee. Restoration options have therefore been developed as concepts for consideration, rather than detailed designs for implementation. This approach has allowed a greater emphasis on historical evidence and scientific information, to improve confidence around determinations of the pre-colonial status of the Washpool and surrounds, and the subsequent trajectory of change. This in turn provides an improved foundation for decisions regarding the future of the area.

## 2. Methodology

This assessment has involved:

- Engagement with members of the Kaurna community:
    - Drew Kilner employed by NGT as a Cultural Liaison Officer from May to September 2021, including several site visits;
    - Site visit with Buster Turner (who sadly passed during the preparation of this report), Ben Stokes and Drew Kilner;
    - Four presentations to, and feedback from, Warpulai Kumangka, the Green Adelaide Kaurna Advisory group attended by Merle Simpson (×4), Drew Kilner, Quahli Newchurch (×4), Lynette Crocker (×3), Allan Sumner (×2), Clem Newchurch (×2), Corey Turner (×2), Jardi Welch and Rebecca Simpson (×2);
    - Involvement with cultural heritage survey of the land parcels recently added to the Conservation Park led by Neale Draper; and
    - Discussions with Karl Winda Telfer.
- Engagement with a range of non-Indigenous stakeholders (individuals and groups) including:
    - Presentations to, and feedback from, the Washpool Working Group, convened by Green Adelaide and National Parks and Wildlife Service (NPWS), on 8$^{th}$ April 2021 and 4$^{th}$ November 2021;
    - Presentations to, and feedback from, the City of Onkaparinga (CoO) staff on 3$^{rd}$ June 2021 and 22$^{nd}$ August 2022;
    - Presentations to, and feedback from, Friends of Aldinga Scrub (FoAS) on 10$^{th}$ June 2021 and 11$^{th}$ August 2022;
    - Presentations to, and feedback and data from, Willunga Hills Face Landcare Group (WHFLG) in August 2021 and 15$^{th}$ September 2022;
    - Presentation to, and feedback from, the Washpool Coalition on 31$^{st}$ August 2021 and 15$^{th}$ September 2022;
    - Presentation to, and feedback from, Department of Environment and Water staff on 31st August 2022.

  - Information collated by Chas Martin provided by Willunga Environment Centre;
  - Discussions, including on site, and in some cases resources provided by, a range of individuals including Damian Moroney (DEW), Tony Flaherty (Green Adelaide), Michael Lawton (FoAS), Richard Dekker (CoO), Kerri Bartley (CoO), Paul Rosser, John Edmeades (FoAS), Julie Burgher (FoAS), Matt Endacott (City of Holdfast Bay), Gavin Malone, Chester Schultz, Maarten Ryder (WHFLG), Neale Draper and Tom Gara.
  - An earlier draft of this report was reviewed by:
    - Friends of Aldinga Scrub;
    - Willunga Hills Face Landcare Group;
    - Friends of Willunga Basin;
    - City of Onkaparinga; and
    - Department for Environment and Water.

    Comments providing specific support for, or objections to, the restoration options from the reviewing organisations are provided in Appendix A.

  (A more detailed record of engagement undertaken for the project was made but is not included in this report).

- A review of historical sources including early colonial accounts and maps, newspaper articles and government records pertaining to relevant land parcels;
- A review of contemporary literature, cited herein, across a range of themes including planning, hydrology, archaeology, flora, fauna and climate change.
- The review and interpretation of existing data, in particular:
  - a $1m^2$ (pixel size) digital elevation model (DEM) of the area obtained from the Elvis - Elevation and Depth Foundation Spatial Data website (Geoscience Australia 2022a);
  - elevation survey point data obtained from CoO;
  - aerial imagery from 1949 to the present obtained from DEW;
  - Washpool outflow data obtained from Water Data Services;
  - tidal data obtained from the Bureau of Meteorology (BOM), assistance with interpretation provided by Mike Davis (BOM Tide Unit);
  - water quality data provided by WHFLG.
- Obtaining and interpreting new data to fill knowledge gaps, specifically:
  - water surface elevation (WSEL) data for the Washpool via a logger installed in June 2021;
  - salinity data for the Washpool via spot measurements taken in August 2022; and
  - a fish survey of the Washpool undertaken in October 2022.

# 3. Pre-colonial Hydrology of the Washpool and Blue Lagoon

## 3.1. Kaurna use of the Washpool and Surrounds

The cultural significance of the Washpool area to Kaurna and knowledge of how the area was utilised in pre-colonial times sheds light on its original hydrology. The Tjilbruke spring, located along the inland edge of the coastal dunes south of modern day Button Rd, indicates the historic presence of groundwater fresh enough for human consumption. This spring was one of a number of "native wells" in the Aldinga Scrub and Washpool area (Draper and Maland 2021). The natural bed of the Washpool is lower lying than these spring locations, suggesting a groundwater contribution to the pre-colonial hydrology of the Washpool.

Wangkondanungko, meaning "possum place", is a name associated with the Washpool (Draper and Maland 2021). The name Wangkondanungko is believed to derive from the practice of curing possum skins by pegging them flat, fur side uppermost, onto the unvegetated claypans of the lagoon (Draper and Maland 2021). There are unvegetated claypans persisting today within the Washpool immediately south of Button Rd and approximately 400 m east of the eastern shoreline of the Washpool, on land recently added to the expanded Aldinga Conservation Park. Nobbs (1973) stated:

> *"Originally the whole Willunga Plain was … drained by small intermittent creeks which flowed into the large lagoon south of the present scrub. The lagoon was considerably reduced in size during the summer months and the mud on the southern edge of the lagoon was known by the Aborigines to possess qualities eminently suitable for the preparing and curing of skins. This mud probably owed its curing property to the fact that the southern edge of the lagoon received water which had flowed over the calcium and magnesium rich Cambrian limestones which outcrop on the Willunga Range … Animal skins of for example possum and Kangaroo were collected, brought to the site and pegged out with little wooden pegs fur side uppermost."*

Nobbs is clearly referring to the Washpool, as has been confirmed by Tom Gara (pers. comm., 8/7/22) who worked with her at the Washpool in the 1980s. This use of exposed wetland sediments by Kaurna suggests relatively unvegetated mudflats. In the brackish conditions of the Washpool (see Section 3.2) such mudflats likely correspond with "seasonal brackish aquatic bed" wetland vegetation described by Ecological Associates (2009), characterised by salt tolerant submerged aquatic plant species when inundated (e.g. *Ruppia* sp.) and sparsely vegetated/unvegetated mudflats when exposed (dry). The ideal water regime to maintain seasonal brackish aquatic bed is inundation for 6-8 months to a maximum depth of 0.7-0.9 m (Ecological Associates 2010). This may describe the pre-colonial water regime of the lowest elevations within the Washpool.

The cultural and heritage values of the Washpool and surrounds are addressed more comprehensively in several other reports (e.g. ACHM 2000, Draper and Knight 1998 , Draper and Maland 2021, Lucas 1989).

## 3.2. Early Colonial Maps and Accounts of the Washpool

Detailed accounts of the Washpool during the early years of colonisation, that would shed light on the ecohydrology of the wetland prior to colonisation, are few, but the wetland appears on several early colonial maps. The Washpool was generally labelled "Salt Lake" or "Salt Water Lagoon" and often sketched showing a swampy margin, with two possible outlets to the sea. The earliest map that shows the Washpool comes from Colonel William Light, Surveyor-General. His survey of the coast (Figure 2) is probably based on his landing at the Washpool in September 1836. Light's description of the "Salt Lake" was brief when he visited what he dubbed 'Deception Bay' (now Aldinga Bay) on 23rd September 1836:

> *"The whole country ... presenting a most beautiful appearance... went on shore. Felt some disappointment at the appearance of the land, as it looked so luxuriant from the ship; we could find no fresh water; a lake of some extent on the high ground above the beach proved, on reaching it, to be salt."* (Schultz 2018)

Light's disappointment may be the reason he named the anchorage Deception Bay.

John Morphett, who arrived on the Cygnet in 1836 and was a prominent figure during early European colonisation of Adelaide, describes the Washpool in a letter dated 1837 (Schultz 2018). According to Schultz (2018), Morphett's description is based on a visit to the Washpool area made "a couple of weeks" after Light's, i.e. in early to mid-October 1836. He mentions the brackish and seasonal nature of the lagoon, and alludes to the seasonal inflow of seawater during high spring tides. Morphett states:

> *"the lower part* [of the Aldinghi Plains] *is impregnated with salt, being beneath the level of the sea at spring-tides, and this imparts a brackish taste to the rains, which collect there during the winter months and form a small lake. This place has a very singular and interesting aspect from the sea. The sloping grassland in front, without a single tree for three or four miles square, of a beautifully bright green in winter and spring, and a golden colour during the hotter months, is surrounded by finely wooded eminences, and a bold range of hills beyond."* (cited by Schultz 2018)

John McLaren arrived in South Australia in 1838 and became a member of the team, working under then Surveyor-General G. S. Kingston, responsible for surveying Sections B, C and D to the south of Adelaide, including the Washpool area. Richard Counsell was a member of McLaren's team and prepared survey maps in a Fieldbook that has been preserved and is held by the State Records of South Australia. These maps show both natural features and allotment boundaries. In 1839 Counsell prepared a map on page 41 of his Fieldbook (Counsell 1839) that included the Washpool, an extract of which shown in Figure 3. Schultz (2018) has estimated, based on dates throughout Counsell's and other Fieldbooks, that the field work was done in the Washpool locality in mid-October 1839. Just three years after the establishment of the colony of South Australia, this map provides one of the earliest records of the pre-colonial state of the Washpool, under Kaurna management. The central part of the Washpool is clearly labelled "Salt Water Lagoon" while a peripheral area, which includes an arm extending to the southern outlet, is labelled "Swampy". A northern arm, north of modern-day Button Rd, appears to end blindly. The country immediately east of the Washpool is labelled "open plains".

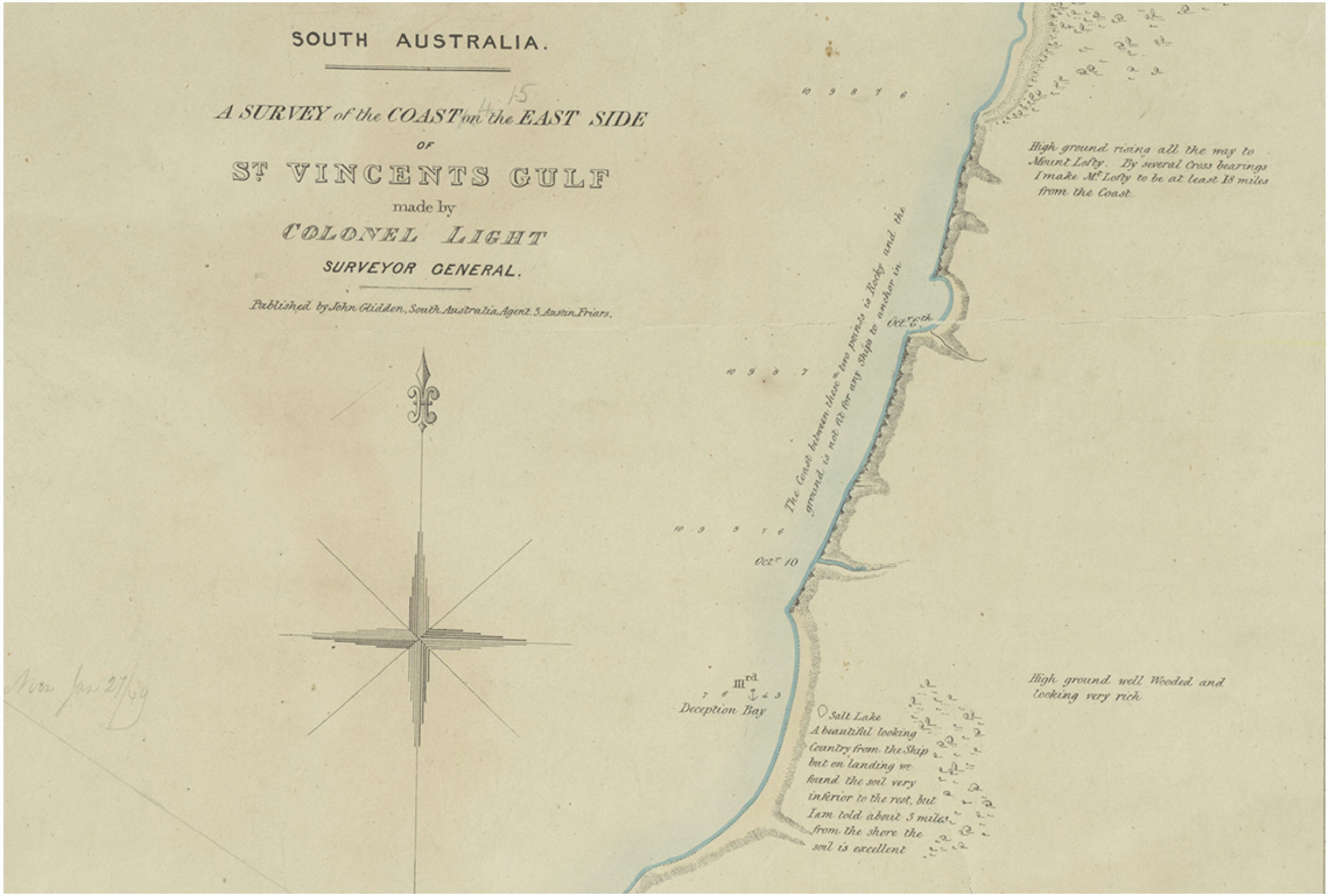



Figure 2. Excerpt of the map '*South Australia: A survey of the coast on the east side of St. Vincent's Gulf*' made by Colonel Light in 1836 (State Library of South Australia).

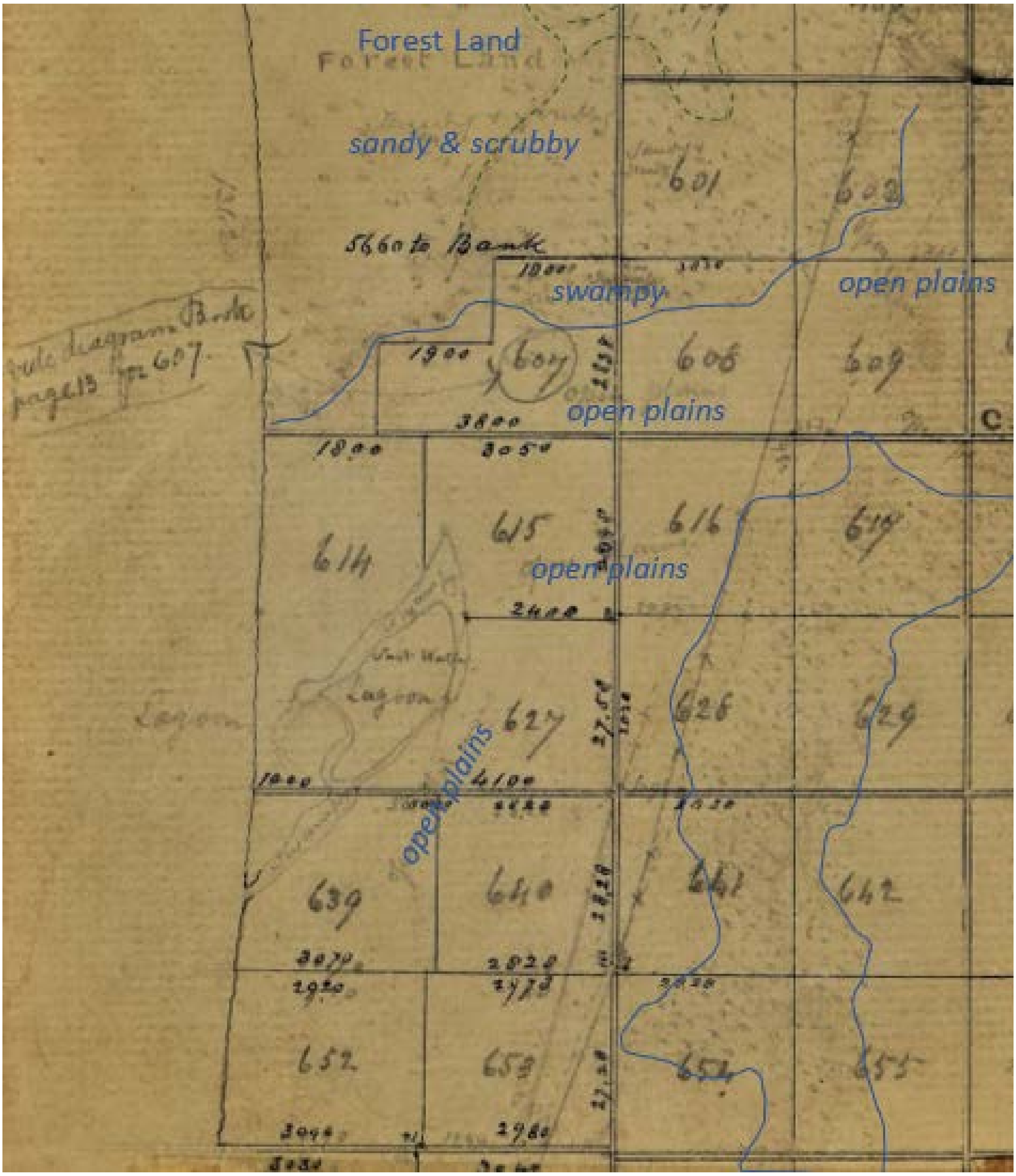



Figure 3. Map of the Washpool and surrounds from pg. 41 of Richard Counsell's Fieldbook 102 (Counsell 1839), likely produced in October 1839. We have enhanced some mapped boundaries and labels in blue. Map obtained by Chester Schultz from the State Library of South Australia and generously provided.

On page 61 of Counsell's Fieldbook is another map of the Washpool (Figure 4) showing what appears to be a second outlet just north of modern-day Button Rd, i.e. the location of the contemporary active outlet. Schultz (2018) suggested this second sketch was made "some weeks later". Either this more northern outlet was missed during Counsell's first visit or it formed during the intervening period of several weeks in spring 1839. We cannot be certain, but the first option seems more likely. However, it is possible that high rainfall in spring 1839 may have led to high outflows and the establishment of a new outlet, or more likely the re-activation of an existing but temporarily closed outlet, in that location. The creation of this northern outlet artificially, by excavation, in Spring 1839 seems highly unlikely given the undeveloped nature of the district at that time.

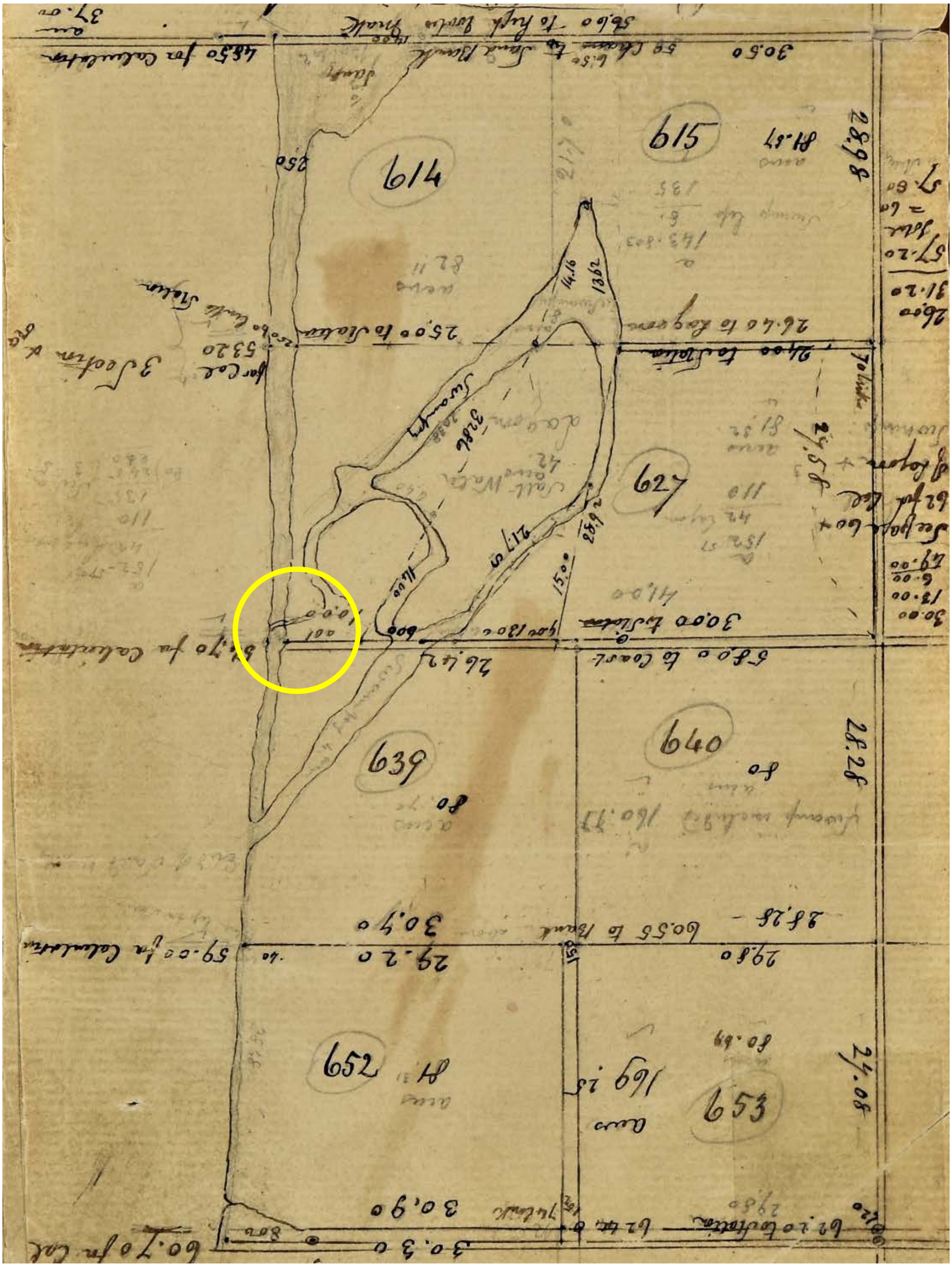



Figure 4. Map of the Washpool and surrounds from pg. 61 of Richard Counsell's Fieldbook 102 (Counsell 1839) showing a second outlet to sea (circled yellow). Map likely produced in late 1839 (Schultz 2018). Map obtained by Chester Schultz from the State Library of South Australia and generously provided.

Counsell's maps are the primary source for a map published in 1840, which has become known as the "McLaren Map" (Figure 5). In addition to the Washpool, the McLaren Map defines land parcels and road reserves.

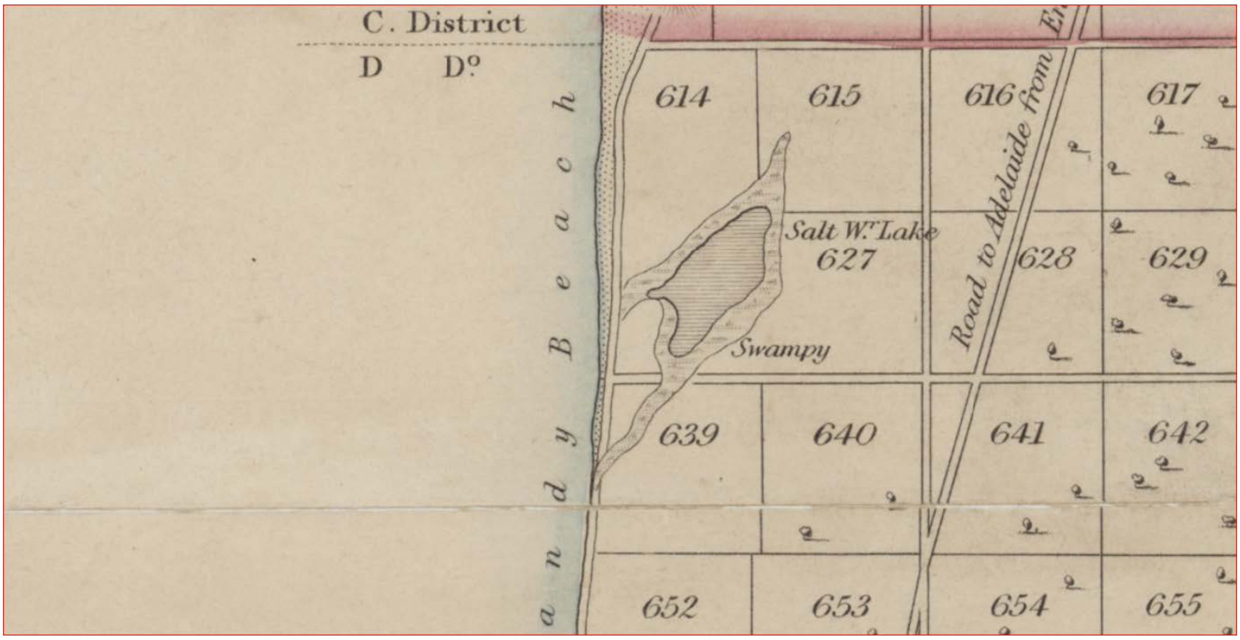



Figure 5. From Map 'Country south of Adelaide from O'Halloran Hill to Mt. Terrible including District C and portions of Districts B and D', Surveyed by J. McLaren esqr., John Arrowsmith September 1st 1840.

Other early accounts echo the descriptions of a salty and seasonally inundated lagoon. An article in The Adelaide Observer, 13th April 1844 provides "… a brief description of the Onkaparinga and Willunga districts …", being the greater portion of an administrative area known as "Preliminary district "C"". The southern boundary of Preliminary District C is described as:

> *"a line … drawn from the Gulf, near the Lagoon at Aldinga, due East …"*

Further on, the author again mentions this lagoon, which is presumably the Washpool:

> *"Returning, and keeping more to the coast, we cross the plain called Aldinga (properly Ngaltingga). Close by is the lagoon which dries up in the summer, and the water of which is salt in the winter."* (Piesse 1844)

An article in the South Australian Register from March 1851 includes an account of an ascent of "Loud's Hill" near Willunga on 18th November (presumably 1850) and describes the view from the top:

> *"Before us lay all the Aldinga Plains, and the whole country north and west, with the Gulf and coast to Holdfast Bay – Mount Lofty and his subordinates bounding our landward view on the right, the glitter of a lagoon below contrasting curiously with the calm shine of the Gulf waters."* (South Australian Register 1851)

According to the contemporary gazetteer, Loud's Hill is located 5.5 km east of the Washpool with an uninterrupted view to the coast, suggesting the glittering lagoon referred to is the Washpool, clearly inundated in late spring of that year.

In 1858, The Adelaide Observer features an account of a meeting of the "Central Road Board" held on 21st October (Adelaide Observer 1858) at which the construction of a stone bridge on Sellick's Hill is discussed. Concern is raised by a Mr J. D. Manton about the quality of the workmanship, including that:

> *"the mortor* [has been] *made with salt water not fresh".*

In response, a Mr Norman states that:

> *"The lime he had heard Mr Manton pronounce to be good, the stone was of the hardest and most durable character, and the water was fetched two miles from the lagoon. It was the best that could be procured in that neighbourhood, and was not salt, though certainly a little brackish."*

The article goes on to say:

> *"The lagoon water was ordered to be used when no other could be procured."*

The lagoon in question is likely the Washpool and the account confirms its brackish water quality at this time.

We have not found historical accounts that provide a confident measurement of the depth of the Washpool in its pristine state. However, several contemporary reports have speculated on this question. Ashton (2001) suggested an original depth of "several metres". Ecological Associates (2003) and KBR (2011b) both suggest a maximum depth of 1.5 m originally. According to Gardiner (1989), in the 1930s (hydrological degradation was likely well advanced by this time) the Washpool was about 1.4 m deep. This issue is further explored in Section 7.

## 3.3. The Washpool Catchment Pre-colonisation

The Washpool catchment, as mapped by KBR (2011a) is 4,174 ha in size. Figure 6 is an extract of a map entitled "*Plan of the country south of Adelaide from O'Halloran Hill to Mt. Terrible including District C and portions of Districts B and D [cartographic material] /as surveyed by J. McLaren esqr [C 236/SE]*" obtained by Chester Schultz from the State Library of South Australia and generously provided. Written on lower right corner of the original is "*copied from Mr. McLaren... 24th D... 1839*". Thus, the map shows the Aldinga Plains in 1839 or earlier, i.e. likely prior to significant development. We have overlain the Washpool catchment boundary as mapped by KBR (2011a). The map features several watercourses extending from the Willunga escarpment towards the Aldinga Plains, however it is noteworthy that there are none extending all the way to the Washpool. The area surrounding the Washpool is mapped as unwooded, similar to Counsell's maps, but much of catchment, including the Willunga hiils face, is wooded.

The topography of the Washpool catchment, represented by the contemporary DEM, is shown in Figure 7. This shows the Washpool located at the south-western end of a low-lying, relatively flat area extending to the north and north-east.

These maps suggest that historic surface flows to the Washpool, when they occurred, would have been broad, sheet flows through swampy, flat country to the north and north-east, rather than via distinct, incised watercourses. This is consistent with descriptions provided by Kaurna representatives (Buster Turner, Drew Kilner). It is also consistent with past reports. Gardiner (1989) stated that "to the east of the [Aldinga] scrub the land was boggy most of the year and formed a swamp that was continuous with Blue Lagoon to the south of the Scrub". This flat area must have been in the order of 0.8 km wide because “properties along the main South Road between Aldinga and Sellicks suffered flooding each year” in the early days of colonisation (Gardiner 1989). Ecological Associates (2012) stated “the lack of a flowpath [out of Aldinga Scrub] suggests that outflows were sufficient to create waterlogging and local inundation outside the Scrub, but not enough to form a flowpath or channel.” ACHM (2000) describe how water would “accumulate south of the Aldinga Scrub and into the deep, fresh water of Blue Lagoon”, which, when full, would overflow into the “more extensive but shallower Washpool”.

Gardiner (1989) describes how some surface water flows would enter the Washpool from the south-east by “flowing out onto the Church of England property where it fanned out and formed large screes before finally emptying into the Washpool”. According to Kinhill (1996) the parcels held by the Church included Section 639, which contains the Washpool’s southern outlet, and Section 652, immediately south of 639 (Figure 5). Gardiner’s (1989) description of inflows from the south-east concurs with Nobbs’ (1973) statement (see Section 3.1) which suggests the southern edge of the Washpool received flows from a separate source to the larger body of the wetland.

Figure 7 also illustrates the proximity between the high ground of the Willunga escarpment and the very low ground of the Washpool. This proximity, combined with the lack of a distinct watercourse between the two, further supports groundwater as being a significant contributor to the natural hydrology of the Washpool.

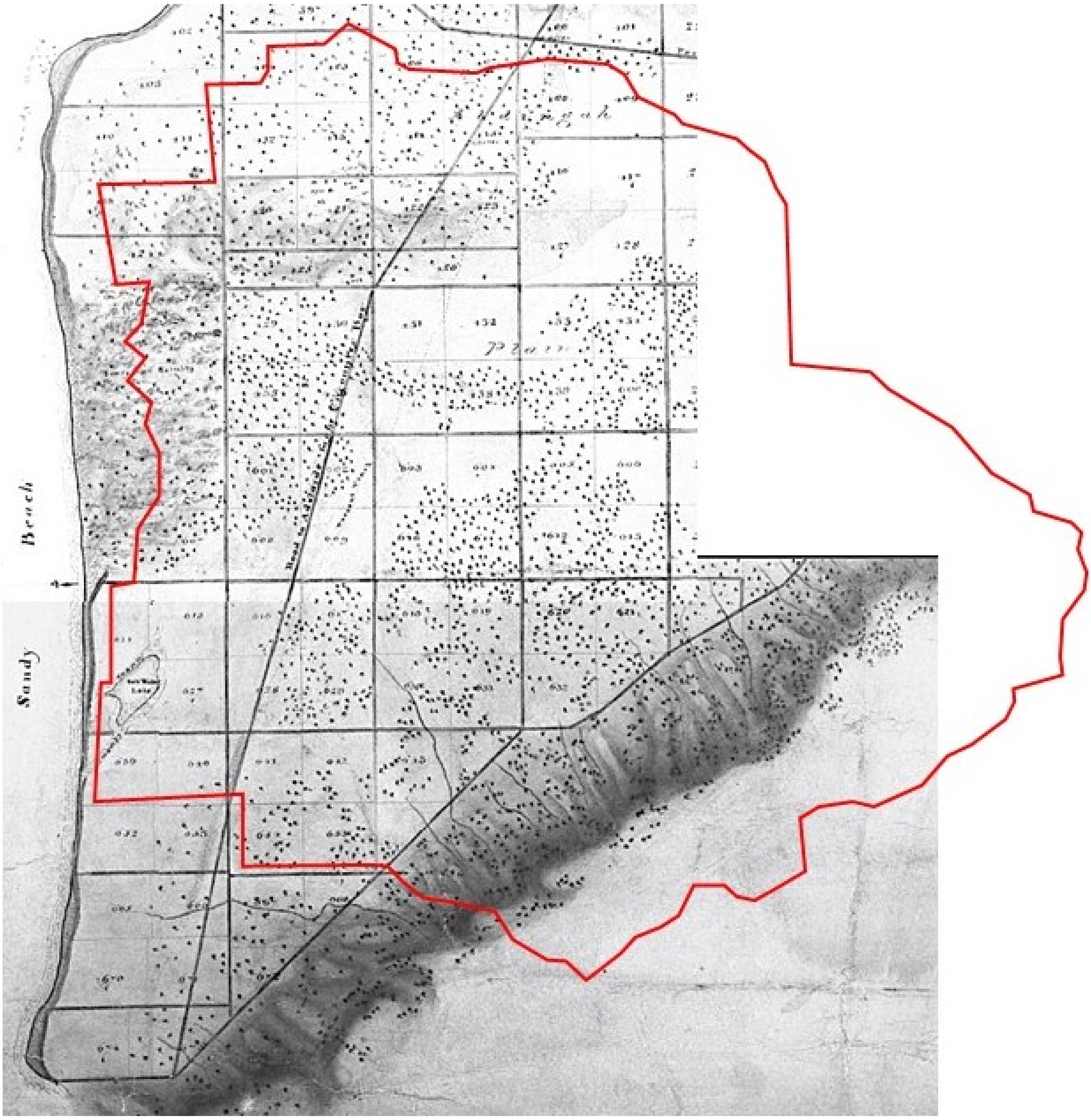



Figure 6. Map of the Washpool catchment as surveyed by John McLaren in 1839. Catchment boundary (red polygon) based on KBR (2011a).

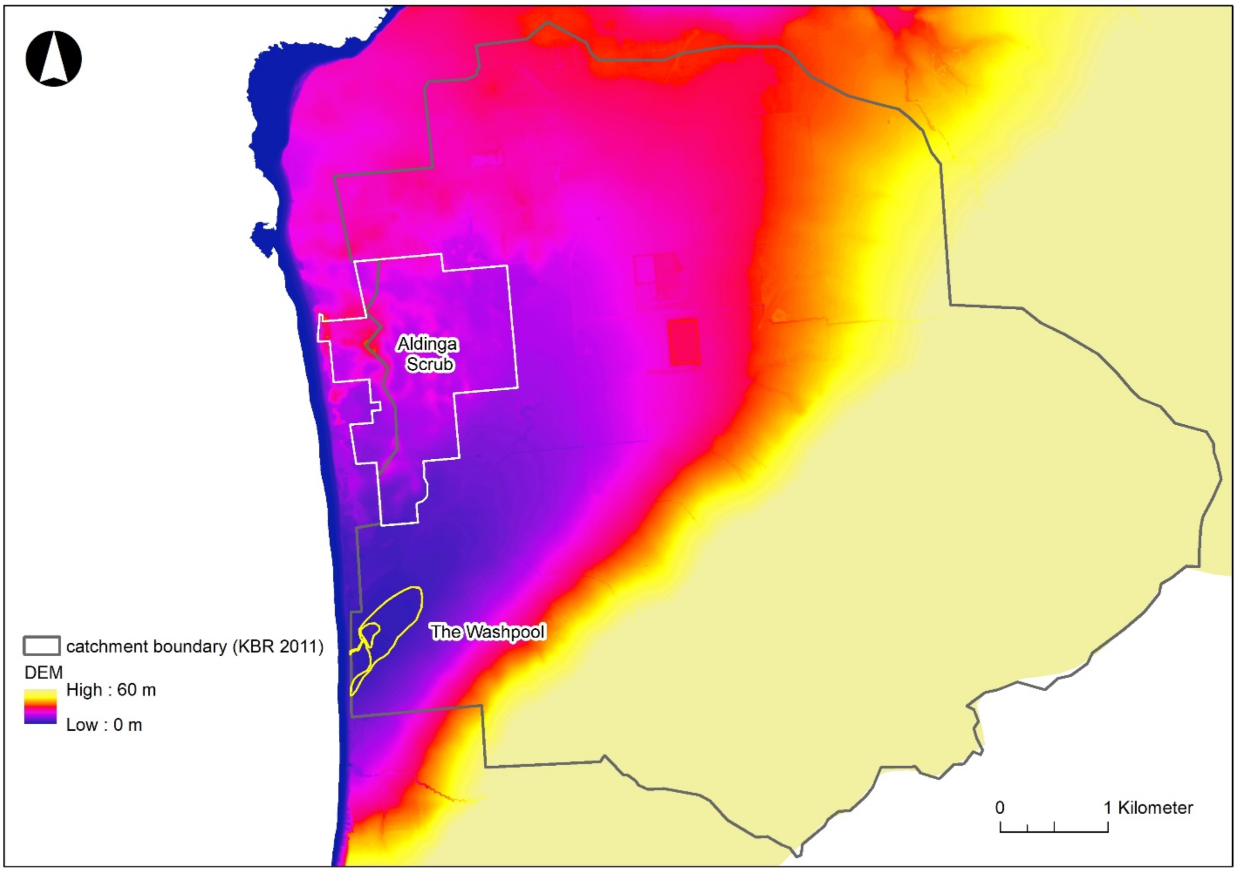



Figure 7. Contemporary DEM of the Washpool catchment. Aldinga Scrub is shown (white polygon).

## 3.4. Blue Lagoon Pre-Colonisation

Early colonial accounts and maps of the Washpool area generally do not include the Blue Lagoon. The feature may have been too small to warrant inclusion in the early survey maps prepared by Counsell, or it may have remained undiscovered by the colonists for several years. We have obtained no first hand accounts of the Blue Lagoon in its pre-colonial condition.

Surface inflows to the Blue Lagoon entered from the north east, flowing around the eastern and southern edges of the Aldinga Scrub (Gardiner 1989, Stokes and Harris 1976). Groundwater interactions with the Blue Lagoon are discussed in Sections 3.5 and 5.3. Although we have no definitive records of the pre-colonial condition of the Blue Lagoon, several authors have provided their best guess based on their own research. According to Stokes and Harris (1976) and (Wollaston 1973) the depth of the Blue Lagoon was originally 1.8 m "according to early reports". Ecological Associates (2003) stated that the Blue Lagoon "originally supported duck populations of 400 to 500 birds and was 2 m deep. Receiving discharge from the flooded area near Main South Road and Aldinga Scrub, Blue Lagoon would have been permanently flooded." Ross (1984) stated "Blue Lagoon was originally three to five metres deep".

The ecosystem of the Blue Lagoon is not well described in available historical records but likely featured submerged aquatic plants in the deeper areas, a peripheral zone of emergent rushes and reeds and was likely a drought refuge for aquatic fauna (Ecological Associates 2003).

The use of the Blue Lagoon and surrounds by Kaurna in pre-colonial times is documented by Draper and Maland (2021). The site has important ongoing cultural significance to Kaurna.

## 3.5. Pre-Colonial Ecohydrology of the Washpool and Surrounds – An Interpretation of Historical Evidence

In this section, based on the evidence presented in the preceding sections, we attempt to describe the ecohydrology of the Washpool and surrounds in pre-colonial times under Kaurna custodianship. This interpretation is provided from our perspective as, first and foremost, ecologists. It is not an attempt to paint a picture of Kaurna culture and use of the Washpool area although our understanding has been informed by our engagement with Kaurna representatives, through early-colonial accounts and maps and from archaeological research.

Beginning in the driest time of the year in mid-autumn, the Washpool lagoon would have been dry or reduced to a small, shallow pool a few centimetres deep. If present, the salinity of surface water would have been at its annual maximum but likely considerably lower than sea water. The absence of outflows for several months would have closed both mouths through the action of ocean waves and wind upon the beach sand and pebble embankment of the foredune. Water levels in the Blue Lagoon would be at their seasonal low but probably still over 1 m deep and this pool was likely permanently fresh due to connection with freshwater lenses beneath the coastal dunes. Similarly, the discharge from the Tjilbruke spring to the south would be at its seasonal low but freshwater would have been accessible by shallow digging.

As autumn progressed, mean sea level rose and atmospheric pressure decreased, with groundwater rises independent of rainfall. In response, water levels in the Washpool and Blue Lagoon would also begin to rise and Tjilbruke spring discharge would have increased.

As winter rains progressed, the flat, low-lying country to the north-east of the Washpool, east of Aldinga Scrub, would have begun to inundate. In typical years, by late winter / early spring inundation would have reached a level that resulted in broad, shallow sheet-flow in a south-westerly direction towards the Blue Lagoon and Washpool. Based on the DEM and past reports (e.g. Wollaston 1973), in wetter years there was a continuous area of inundated country, albeit with gradually descending surface water elevation, from around half a kilometre north of the north-east corner of Aldinga Scrub (west of the modern-day intersection of Main South Rd and Hart Rd / Colville Rd), all the way to the Washpool, including Blue Lagoon. This low-lying country was “damp and boggy most of the year” (Wollaston 1973) and made the Scrub largely inaccessible for nearly six months of the year (Stokes and Harris 1976). Elevated groundwater levels in winter would also cause groundwater seepage at the surface from the claypans to the east (within approximately 400 m) of the Washpool lagoon. Towards the end of winter, or in early spring, water depth in the Blue Lagoon would attain its seasonal maximum of around 1.8 m and inflows thereafter would spill towards the Washpool. Water levels in the Washpool would rise through the winter, first covering the extent of the open water lagoon, then extending out into the surrounding swampy, more vegetated ground. In drier winters, outflows from the Washpool would have been insufficient to overtop the sand and pebble barriers formed at the mouth(s) and during the following summer and autumn the lagoon would have remained disconnected from the sea for a period of over 12 months. In more average or wet winters, water levels would rise until sand and pebble barriers at the mouth(s) were breached. At its maximum inundated size the Washpool waterbody occupied a combined area of 26 Ha, consistent with the area mapped by Counsell as “Salt Water Lagoon” and “Swampy”. Maximum depth under these conditions was c.0.9 m (see Section 7). Given the dynamic nature of the mouths of the Washpool, in some years this may not have been achieved, with outflows breaching the seasonally blocked mouth(s) under a lower water level. Salinity would have been at its lowest when the Washpool was fullest, less than half the salinity of seawater and quite possibly fresher. Once outflows commenced, via one or both mouths, the sand and pebble embankment would begin to erode down, reducing the extent and depth of inundation of the Washpool. It is also likely that spring tides combined with storms in late winter / early spring contributed to this mouth opening process and provided temporary connectivity for fish to migrate into the Washpool from the marine environment. The active mouth of the Washpool probably alternated between the northern and southern outlets and there may have been periods when both were simultaneously active. Leakage of flows i.e. through the pebble bank but without overtopping it, would have occurred at both mouths as happens today at the northern outlet (see Section 5.1).

In late spring / early summer water levels in the Washpool would begin to recede due to the lowered outflow sill elevation (eroded mouth(s)), reduced surface water inflows, increased evaporation and a seasonally declining water table due to increased evapotranspiration of vegetation in the catchment. Salinity in the Washpool would increase via evapo-concentration. However, while sufficient depth persisted, the increased temperature and day-length would have made this a highly productive time, with high growth rates of emergent vegetation around the lagoon margins and submerged aquatic vegetation within the open water lagoon. As water levels dropped below the vegetated swampy margin, the sparsely vegetated mudflats of the lagoon became shallowly inundated / exposed and therefore available as foraging habitat for waders, including migratory shorebirds arriving from the Arctic. The diversity and abundance of waterbirds likely peaked when the depth of the Washpool remained sufficient to support ducks and swans but shallower areas became available for waders. The Washpool's mouth(s) would close during the summer as flows reduced and/or erosion from outflows became insufficient to offset deposition of beach sand and pebbles, although seepage through the coastal dunes could still persist while surface water remained in the lagoon. Following mouth closure fish would become trapped within the lagoon, providing food for piscivorous waterbirds and for Kaurna.

As summer progressed into autumn, water levels in the Washpool and Blue Lagoon would continue to decline, further exposing the mudflats, continuing to provide wader habitat (albeit shrinking in total extent) and providing the conditions necessary for animal skin curing described by Nobbs (1973), noting there were also open pan areas to the immediate east of the wetland, on higher ground not subject to inundation, that were also likely utilised for this purpose (Draper and Maland 2021). The total period of wetland inundation would have varied annually but was likely in the range of 6-9 months typically, although it is possible that groundwater inputs maintained a degree of shallow inundation in the deepest areas throughout summer and autumn of some, possibly most, years.

Based on the historical water regime and salinity described above and the remnant native vegetation persisting today (T&M Ecologists 2016), the following zones of vegetation are most compatible with the historical hydrology of the Washpool:

- Within the area mapped as "Salt Water Lagoon" by Counsell (approx. 13 ha), i.e. the area of open water (when inundated):
    - the lowest lying (deepest) elevations of the Washpool were open mudflats when exposed, sparsely vegetated with *Wilsonia* spp. and/or *Tecticornia* spp., or completely bare, and supported submerged aquatic vegetation when inundated. The brackish water quality and seasonal nature of inundation would have favoured species such as *Ruppia* sp. (probably *R. tuberosa*) during inundation. This vegetation zone would have occupied the majority of the "Salt Water Lagoon" area. *Ruppia* persists today and is most readily detected in the dam just north of Button Rd in late winter/spring.
    - a band of samphire, dominated by *Salicornia quinqueflora* ssp. *quinqueflora*, giving rise to *Tecticornia* spp. dominance slightly further upslope, was present around the margins

of the "Salt Water Lagoon" area, on sediments slightly more elevated than the open mudflats/*Ruppia* but lower than the emergent zone. This vegetation dominates the lowest lying areas of the Washpool today, however its extent has increased due to altered hydrology (reduced depth and duration of inundation), allowing it to migrate downslope and displace open mudflats. This change is detectable by comparing the 1949 and 2020 aerial imagery (Figure 8).

- Within the area mapped as "Swampy" by Counsell (also approx. 13 ha), i.e. the emergent zone, occupying the more elevated margins of the wetland but still subject to regular inundation and supporting vegetation that protrudes above the highest water levels:
    - a band dominated by emergent sedges such as *Bolboschoenus caldwellii*
    - areas dominated by more drought-tolerant sedges such as *Baumea juncea* and *Ficinia nodosa*;
    - a band of *Gahnia filum* tussock sedgeland and possibly scattered *Melaleuca halmaturorum* and *Duma florulenta* occupying the most elevated areas subject to shallow regular or occasional inundation and/or waterlogging.
- Surrounding the Washpool, in areas not subject to inundation, would have been:
    - Coastal shrublands occupying the coastal dunes between the Washpool and the beach, dominated by species including *Leucopogon parviflorus* and *Olearia axillaris*.
    - Grasslands extending to the margins of the Washpool, interspersed with areas of unvegetated claypan on the inland side where seepage of shallow groundwater likely occurred.


Figure 8. The Washpool in the vicinity of Button Rd in 1949 (left) and 2020 (right), showing displacement of open mudflats (white areas) by samphire (dark areas) in the intervening period.

# 4. History of Hydrological Change

## 4.1. Hydrological Change in the Catchment

Development of the Willunga area started around the year 1840, with stock grazing among the first industries, with twelve initial settlers in McLaren Vale possessing over 2000 sheep and 200 cattle (The Country 1840). Soon after, wheat and barley crops were being grown around the town and slate mines opened in the hills west of the town (Gardiner 1989). Development in the Sellicks Hill area did not commence until late 1850 (Gardiner 1989). Much of the vegetation clearance within the Washpool catchment occurred in the 1860s (Newman 1994). By 1866, 30 years had passed since the beginning of European colonisation, and the area around the Washpool had changed a great deal. At the time of colonisation, Morphett (1836) had mentioned the upper part of the 'Aldinghi plains' had a 'very nice herbage' and 'would do admirably for sheep runs in the winter'. A geological study of nearby Sellicks Creek (the mouth just a few hundred metres south of the Washpool's southern outflow point) described a process of gully erosion, occurring following vegetation clearance, grazing and channel disturbance (Bourman and James 1995). Significant erosion occurred in 1915, when heavy downpours followed a severe drought in 1914 (Bourman and James 1995).

An 1866 Gazetteer of South Australian places (Whitworth 1866) entry for Sellick's Hill mentions the gullies in the catchment:

> *"there is no river or creek near his place, but there are deep gullies down which the water runs after heavy rains on the hills".*

Around 1900, ploughing in the Sellicks Hill area, near the modern day Victory Hotel, caused the development of an erosion gully within two years (Gardiner 1989), and which to this day runs parallel to Sellicks Beach Rd and discharges to sea (Figure 9). Surface flows intercepted by this gully historically entered the Washpool from the south-east (Gardiner 1989). There are similar erosion gullies in the Washpool catchment (Figure 10, Figure 11) that are likely to have been the sources of sediments that have deposited in the Blue Lagoon and Washpool and changed the bathymetry of both features, making them shallower and smaller than their pre-colonisation condition.

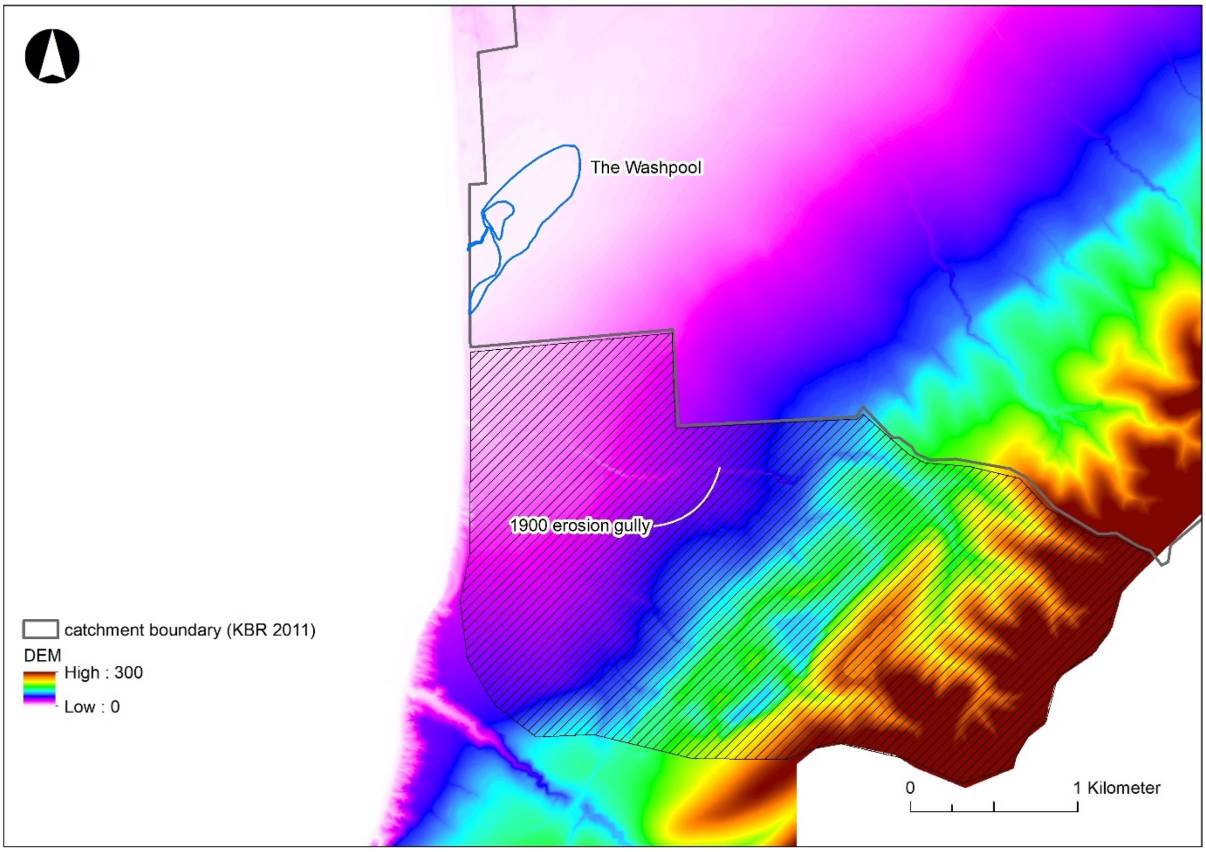



Figure 9. Contemporary DEM showing the erosion gully formed around 1900 and approximate extent of the original Washpool catchment that was subsequently lost (black hatching).

Figure 10. Erosion gully in the Washpool catchment (source: Wegener 1995).

Figure 11. Erosion gully in the Washpool catchment near Louds Hill, July 2019 (photo Maarten Ryder, WHFLG).

Research and mapping undertaken by Newman (1994) shows how the total length of distinct watercourses, formed either by erosion or direct excavation (drains) has greatly increased since the 1840s (Figure 12). A number of other reports refer to this process, by which inflows to the Washpool have gradually become less diffuse and more channelised. T. J. Fatchen and Associates (1986) stated that “active drainage of surrounding wetlands apparently started about 1900, in the Washpool area. By the 1930s, the Blue Lagoon was some 4 ft 6 in deep (rather than [it’s original] 6 ft), drying out in late summer. Post-war drainage channels eliminated the remainder of the Blue Lagoon”.

Kinhill (1987) stated that“Inspection of the [Washpool catchment] creeks show that their paths have been considerably influenced by property boundaries (farmers have diverted creeks around properties, and alongside roads).”

Friends of the Earth (1990) documented recollections of active drainage in the Washpool catchment around the inland side of Aldinga Scrub, e.g.: “Mrs. Stevens' mother had often talked about the changing face of the [Aldinga] plains. She spoke of how the area was once thick with Red and Box Gums, and that the area was so wet that often it was impassable by horse and cart. Growing rice in the area was considered by some, however the water level was unreliable and parallel drainage ditches were dug to drain the area. These still exist today." The authors stated that “The northern and north-eastern portions of the reserve [Aldinga Scrub] were, at one time, seasonally flooded to a depth of approximately one metre, until a series of drains outside the reserve were constructed, beginning around the turn of the [20th] century. These drains have progressively reduced the amount of surface and groundwater available to the Scrub."

Ecological Associates (2012) stated that "The plain [surrounding Aldinga Scrub] has been drained extensively over the past 100 years to reclaim flooded land and to facilitate agricultural development" and that these works included "excavating drains east of South Road and south of Aldinga Scrub."

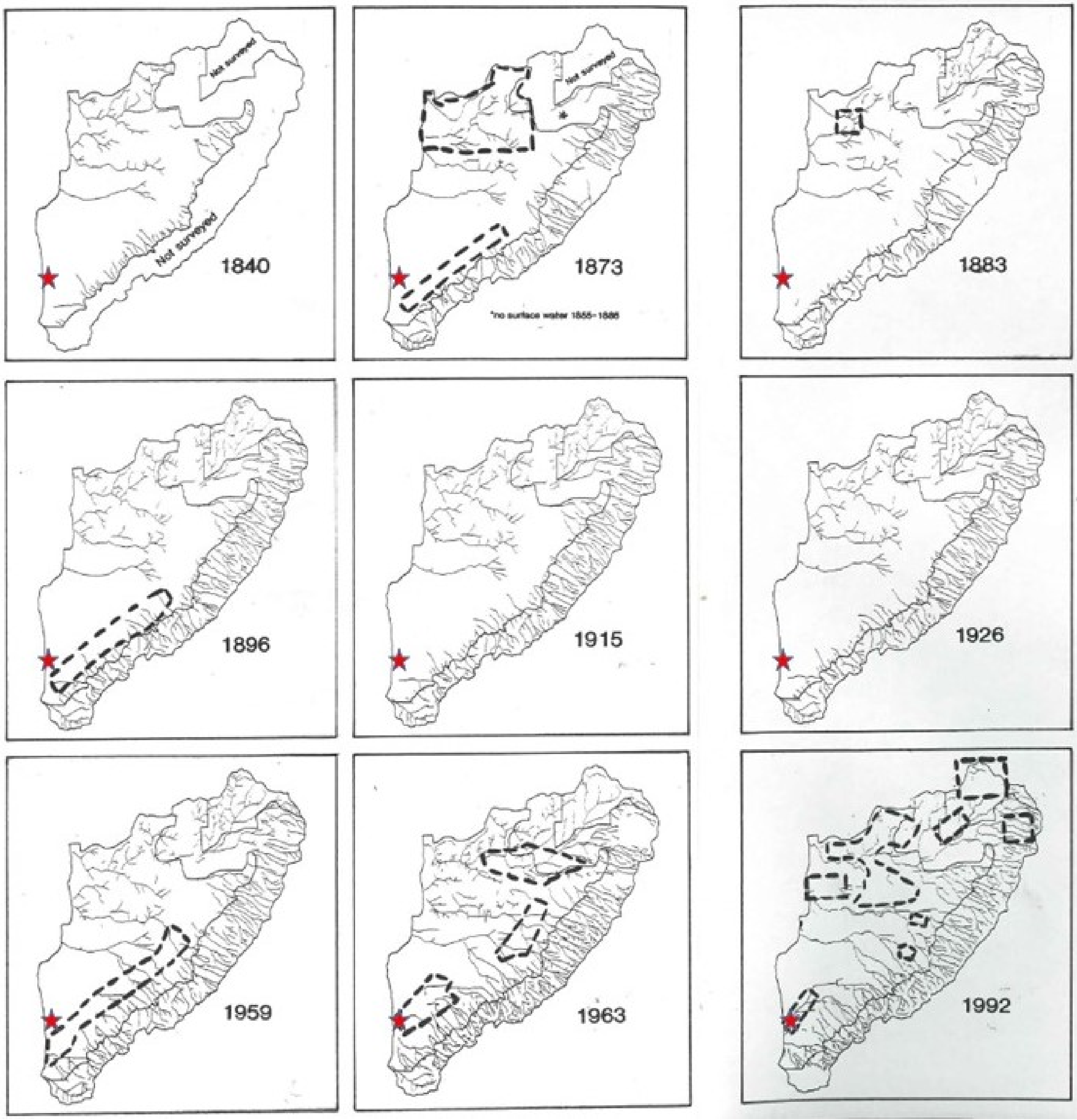



Figure 12. Map of surface drainage in the Willunga Basin, 1840 – 1992 (source: Newman 1994). The location of the Washpool is indicated (red star). Dashed lines indicate areas of major change since previous date.

From the latter half of the 20th century, urbanisation has occurred within the Washpool catchment north of Aldinga Scrub and at Sellicks Beach. Approximately 310 ha (7.4%) of the Washpool catchment is currently urbanised but this figure is likely to increase (Southfront 2020). The impermeable surfaces of urban areas have the general effect of increasing the rate and total volume of surface runoff and decreasing the duration of runoff events.

The combined effects of vegetation clearance, channelisation of flows (both planned and unplanned via erosion) and urbanisation have likely shortened the duration and increased the peak flow rate of inflows compared to pre- colonisation conditions. The duration of inflows following rainfall events has likely been truncated and this may have reduced the duration of wetland inundation (Ecological Associates 2003). High velocity inflows within engineered channels carry more suspended material and sedimentation of the Washpool has occurred as a result (Dyson 2000) (see Section 5.3). Water quality has likely declined, although the seasonal drying of the Washpool, and the high rates of turnover (total annual inflow volume much greater than storage volume within the wetland) likely help maintain an aquatic ecosystem free of the poor water quality issues that can beset permanent waterbodies (e.g. algal dominance, loss of submerged aquatic vegetation, odours).

## 4.2. Hydrological Change at the Washpool and Blue Lagoon

The excavation of drains in and around the Washpool and Blue Lagoon may have started as early as 1859. An article in the South Australian Register from 7th May 1859, reporting on a special meeting of the Aldinga Council, stated that:

> *"The Chairman was authorised to have a necessary drain made by the lagoon … " (South Australian Register 1859).*

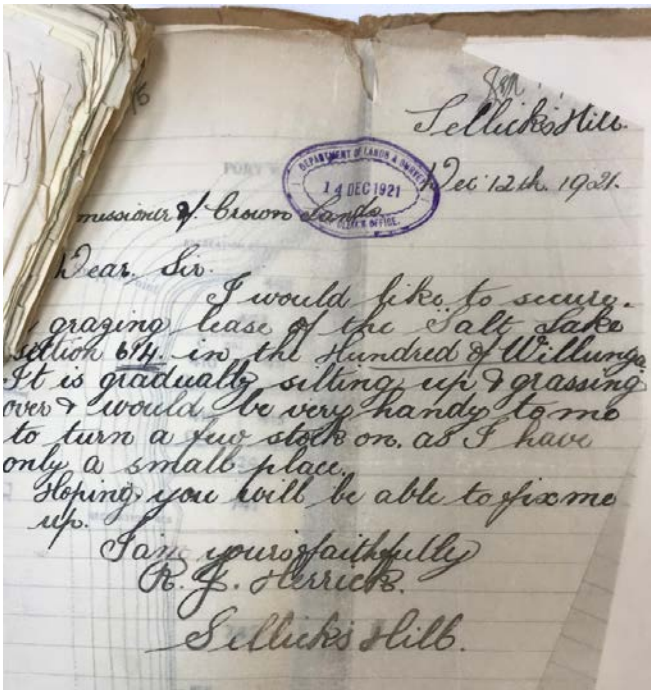
An article in the Adelaide Observer on 2nd February 1889 describes the Washpool as follows:

> *"As we pass across the* [Aldinga] *plain we notice a patch of country covered with salt flakes, and on reaching the little township of Sellick's Hill, almost upon the seacoast, we can see a lagoon close to the seashore. This lagoon is exceedingly interesting and suggestive of reflection. " (Adelaide Observer 1889).*

The date of this observation is not clear but was likely close to the date of publication, i.e. in mid to late summer. The presence of water is not clearly stated but seems likely given the description. Another interesting account, which gives us some insight into the condition of the Washpool in winter (July), is the following article from the Adelaide Observer in 1895, describing a sad event:

> *"On Saturday evening, between here and Sellick's Hill, at the Lagoon, Mr. Richard John Shepherd, father of the Sellick's Hill State School teacher, walked along the beach, as was his custom, and it is supposed that be must have got farther than he intended, and getting benighted on his return, lost the road, and got into the Lagoon. He had waded into the middle when he seems to have become exhausted, and falling down was unable to rise again. M.C. Tuohy, of Willunga, was communicated with, and search was made, but the body was not found until after midday on Sunday. This morning his remains were taken to Adelaide for interment. He was 63 years of age, and very feeble. Recently he came here with his daughters from Bull's Creek, and formerly he resided at Sellick's Hill. Much sympathy is felt with the bereaved family." (Adelaide Observer 1895)*

The Washpool was clearly holding water in the winter of 1895. But just 26 years later, in 1921, the lagoon had silted up and grassed over to such a degree that local grazier Mr Robert J. Herrick wrote to the Commissioner of Crown Lands to request a grazing lease over the area (Figure 13).



Sellicks Hill.
Dec 12th 1921.
14 DEC 1921
missioner of Crown Lands
Dear Sir.
I would like to secure
grazing lease of the Salt Lake
section 614. in the Hundred of Willunga
It is gradually silting up & grassing
over & would be very handy to me
to turn a few stock on. as I have
only a small place.
Hoping you will be able to fix me
up.
I am yours faithfully
R. J. Herrick.
Sellicks Hill.

Figure 13. The original letter to the Commissioner of Crown Lands from Mr Herrick requesting a grazing lease over the 'Salt Lake' Section 614, in 1921 (Herrick 1921).

Herrick (1921) wrote:

> *"I would like to secure a grazing lease of the Salt Lake section 614.... It is gradually silting up and grassing over and would be very handy to me to turn a few stock on, as I have only a small place. … R. J Herrick. Sellick's Hill"*

Early survey maps exclude the "Salt Lake" from the surrounding parcels, as shown in Figure 14(a). From later maps (Figure 14(b)) and correspondence (see below) it is apparent that in 1921 Mr Herrick was requesting the grazing lease over what would later be defined as Section 296, the parcel containing the Washpool. Hereafter we refer to the parcel as Section 296, although it was not numbered as such until c.1940. Section 614 was the higher ground north-west and south-west of Section 296, and was held by Herrick's neighbour Mr Norman. Mr Herrick also held sections 653 and 665, south of the Washpool (Figure 14(a)), the latter of which he went on to subdivide into "glorious large coastal bungalow sites" of the Sellicks Beach Estate, together with George A. Herrick in 1925 (Manning 1990).

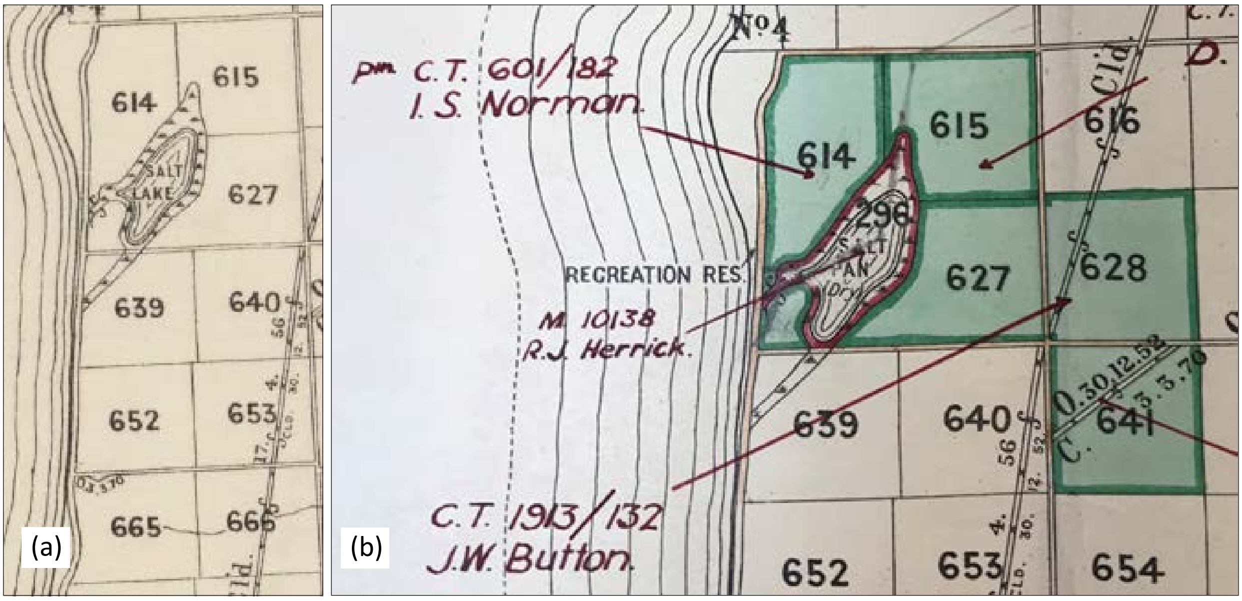



Figure 14.(a) Excerpt of the Hundred of Willunga map 1896, Surveyor-General's Office Adelaide, A. Vaughan photo-lithographer. Note the exclusion of the "Salt Lake" from adjoining parcels. (b) Excerpt of a Hundred of Willunga map from 1956 showing lessees/ownership of parcels in and around the Washpool. The Washpool is labelled Section 296, Salt Pan, (Dry) (source: J. M. K. 1956).

Upon receiving the lease request, the Surveyor-General wrote to the Secretary for Lands, and approved the grazing lease on Section 296 on the special condition that "no drain must be cut so as to allow storm waters to get away" (Surveyor General 1922). He agreed that the lake was gradually being filled by "soil and debris washing down from the adjoining highlands**"** and granted permission for a grazing licence over the area. This original prohibition of drain cutting is of interest from a hydrological perspective. It seems the reason for no drain was not to maintain the original state of the Washpool, but conversely to allow the silt to continue filling the Washpool, naturally converting it from wetland to pasture without intervention, a clever foresight (from an agricultural perspective) of the Surveyor-General.

By 1933 it appears the sedimentation of the Washpool was well advanced. An excerpt from *The Adelaide Chronicle* on 1st June 1933 states:

> *"I have in front of me an old record, dated 1866, which describes "Aldinga big lagoon" as a swampy lagoon lying a mile and a half north-west by west of Sellick's Hill. That lagoon, which was large enough to have a special description allotted to it in an Australian "Gazetteer," no longer exists. The old people remember it, but to the present generation it is either a legend, of they know nothing about it. In the days when the lagoon was there, there were no creeks. Now there are creeks which have washed the soil from the high ground into the swamp and filled it up." (The Adelaide Chronicle 1933)*

This may be an example of journalistic exaggeration, given other accounts, albeit written decades later, of the Washpool being regularly inundated to around 1.4 m in the early 1930s (e.g. Gardiner 1989). However, it is consistent with the evidence of sedimentation and consequent drying.

Sedimentation was also affecting the Blue Lagoon. According to Stokes and Harris (1976), roadside drains were cut that directed flows into Blue Lagoon and, with increased agricultural activity in the catchment, these drains deposited silt such that by the 1930s the Blue Lagoon had been reduced to a maximum depth of·1.4 metres, compared to its original depth of 1.8 m. Ecological Associates (2003) also stated that the Blue Lagoon has been infilled via active land reclamation.

In late 1936 Mr Herrick again contacted the Department of Lands by telephone and asked if cultivation of part of Section 296, to “improve the grazing”, was permissible under his licence conditions and was informed by the Superintendent of the Lands Branch that it was (Superintendent of Lands 1936). This may have led to direct disturbance of the Washpool, which was no doubt already significantly drier from sedimentation and had been grazed for at least 14 years.

Gardiner (1989) described changes to hydrology around Aldinga Scrub and the Washpool from the 1930s onwards, including:

- “In the 1930s the lagoon was about 4 ft 6 ins (1.37 m) deep and gradually dried out in the late summer, although permanent water always remained in the deep channel in the Washpool.”
- “… during winter months, heavy seas assisted by high winds sometimes broke over the sandbar at the outlet of the Washpool carrying salt water possibly 200 – 300 yards inland and making the pool quite brackish.”
- “After WW2 Mr Norman had a drainage channel dug across his property passing under Norman’s Rd and emptying into the Washpool; this was the end of the Blue Lagoon.” The channel referred to is clearly the main inflow drain, also referred to as the “community channel” (see below), present today, which is visible in the 1949 aerial image (Figure 15).


Figure 15. Aerial image of the Washpool and surrounds in 1949.

In 1949, 27 years after the original lease was granted on condition that no drain was to be cut to remove stormwater from the land, Herrick and his neighbour from Section 614, Mr Norman, applied for permission to cut a drain through the Washpool (Section 296) and part of Norman's land (Section 614) between the Washpool and the sea (Director of Lands 1949a). A handwritten note in the file, presumably from a meeting or phone conversation between an officer in the Department of Lands and Mr Herrick, states the purpose of the drain is to "get ready for next years flood" and also notes "silt collected northern end of lake causing flooding of adjacent country" (Director of Lands 1949b).

A 1949 inspection report by the Surveyor-General (Surveyor General 1949) confirms the original intention of the prohibition of a drain in 1922 was to allow the lake to infill with sediment. In 1949 silt was still filling the lagoon, the northern end was not holding any water at all and the "swampy" margin drawn on the original maps was now dry land. The Surveyor-General stated:

> *"… the* [1922] *Surveyor-General pointed out that the swamp was gradually being reclaimed by soil and debris … and he made it a condition of the lease that no drain must be cut … no doubt having in mind that whilst storm-waters flooded out over the lake, soil would continue to be deposited and thus reclaim the whole area. This has been the case and at present* [late October 1949]*, the only water is situated on the south end of the lake and into section 639* [south of Button Rd]*, the latter apparently only being swamp at the time of the original survey. This silting up has reduced the quantity of water that can be held in the lake, and although in wet seasons a channel is opened to the sea near the south-western corner of section 614* [this is the location of the contemporary outlet just north of Button Rd]*, the speed of the water is so reduced that large quantities of silt are deposited at the northern end of the lake. This is clearly indicated by the fact that a fence erected a few years ago is now nearly buried."*

Satisfied that the Washpool had naturally infilled enough as per the original intention of the lease conditions in 1922, on 10th of November 1949 the Director of Lands granted the two farmers permission to construct the drain (Director of Lands 1949a):

> *"… Mr. Herrick and Mr I. S. Norman of Aldinga asked for permission to construct a channel across the swamp so that water could flow more easily and thus save the flooding of valuable land. An inspection has been made and the Minister of Lands has approved of Messrs. Herrick and Norman being permitted to construct a drain to deal with storm water in the area.*"

Herrick and his neighbour Norman excavated the drain through the Washpool themselves (Section 296; Herrick's) and Section 614 (Norman's), around early 1950. We can reasonably assume that the drain connected in to the existing outlet channel, and later evidence suggests the outlet channel was also deepened and widened as part of the exercise (Department of Lands 1956, see below). We learn a little more about the hydrology of the site when a dispute arises over the drain in 1956.

In April 1956 Mr Norman, the lease holder of Section 614, complained in a letter to the Director of Lands (Norman 1956) that the section of drain running through Section 296, excavated by Herrick with the spoil bank placed on its southern side only, was causing inflows to be pushed northwards into Section 614, which Norman described as "up to now is good arable land". The linear edge of Herrick's spoil mound is still clearly visible in the Washpool today (Figure 16), having the appearance of a bund aligned north-east to south-west. Norman's letter also tells us that the drain is connected to the sea at this point in time. He explains that "Herrick and I agreed to do the part crossing the lake to the boundary through section 614 which goes to the sea. I did my part by putting a bank on both sides of the drain to ensure flood water not escaping from drain".

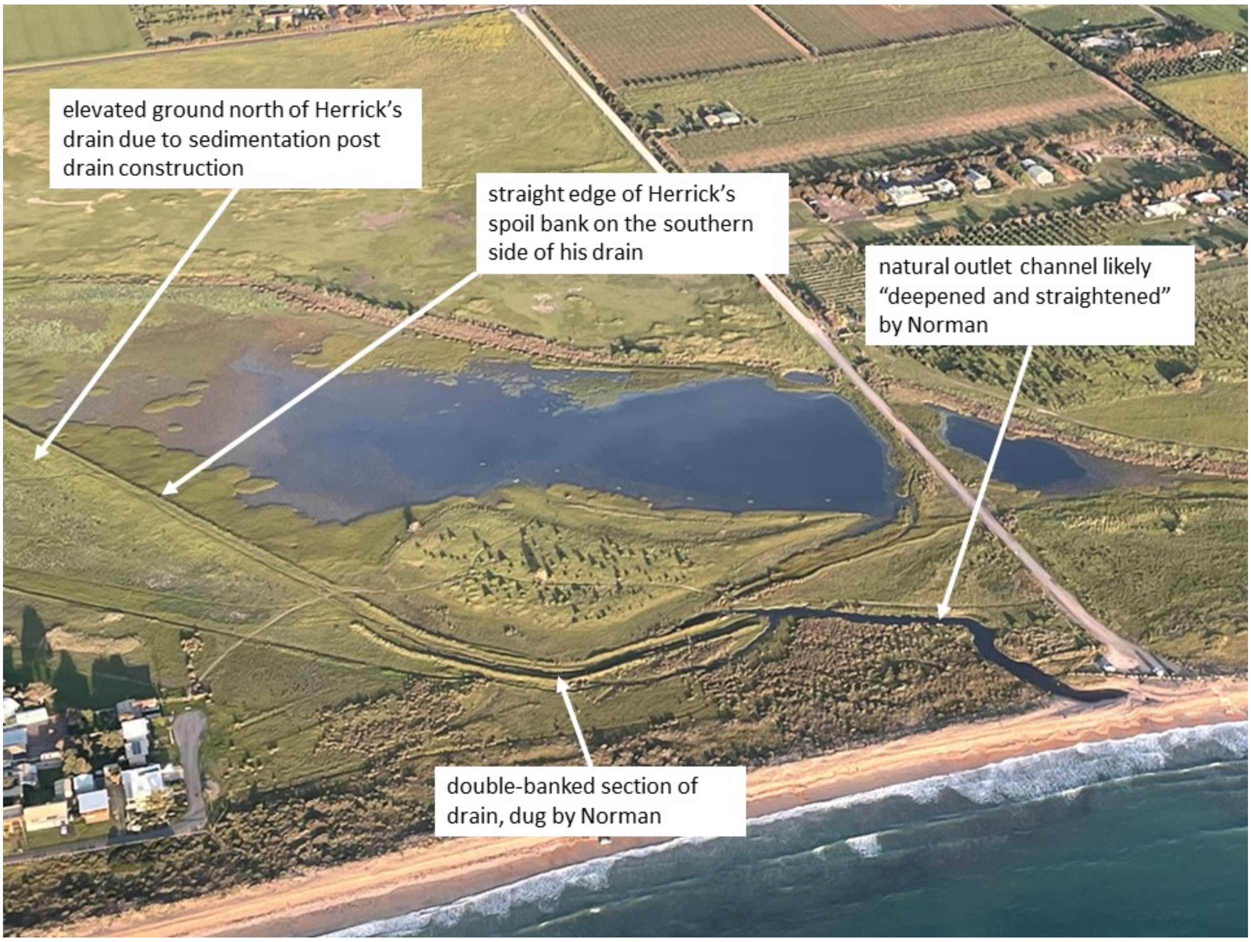



Figure 16. Oblique aerial image of the Washpool, 8th October 2021, with legacy effects of Herrick and Norman's c.1950 drain highlighted (photo: Coast Protection Board / Coast and Marine Branch, DEW).

The dispute led to an aerial photo and mapping of the drainage of the area (Figure 17). This map provides an important insight into the drainage and condition at the time. The red lines indicate a drain bypassing the Washpool on the north side through Section 614, possibly the one referred to 100 years prior (South Australian Register 1859), and also the one cut in 1950 aligned north-east to south-west through Section 296 and to the northern outlet to the sea excavated by Messers Norman and Herrick. The map clearly shows areas of higher ground where cultivation is occurring in Section 614. Cultivation is not mapped within Section 296 (The Washpool) even though the lessee Mr Herrick had been advised that cultivation was permissible under his lease 20 years earlier (Superintendent of Lands 1936). Similarly, the 1949 aerial image (Figure 15) shows no obvious signs of cultivation within the Washpool itself. It is possible that Mr Herrick never cultivated the bed of the Washpool during the 40 years (1922 – 1962) he held the grazing lease.


Figure 17. Map of the Washpool and surrounds digitally traced from an original hand traced map, showing drains, fences and cultivated (elevated) ground derived from aerial photographs in 1949 and 1956 (Author Unknown 1956). Insert: a photograph of the original hand traced map on degraded brittle plastic sheeting.

The dispute between Mr Norman and Mr Herrick also initiated a comprehensive report several months later, which provides some more detail about the drainage, as well as some insight into the outlet to the sea, which has been barely mentioned up until now. The report (Department of Lands 1956) describes Herrick's drain through Section 296 as having a bund 122 - 152cm on only the southern side, which is causing water to build up on the north side and flow into a natural channel around the western corner of Section 614 (Figure 17). The report states:

> *"When I made my inspection it was raining very heavily, although not sufficiently so to overflow at the above point, the conditions were very favourable for assessing the effect of heavy and sustained rain on flooding of Sections 296 and 614, The drain excavated by Messrs Herricks and Norman is reasonably effective but would be more so if Herrick's portion (S 296) were deeper, it is apparently only approximately 1/2 as deep as Norman's portion….*
>
> *…The portion* [of the drain] *south and west of the fences marked green* [note – this plan was not found, refer Figure 17 for closest analogue] *was excavated by Mr. Norman it has a 4 to 5 foot high bank on each side, the portion done by Mr. Herrick has a bank the same height on the south side only, this section is apparently not capable of dealing with the same quantity of water as Norman's and it banks up to the north of the drain and flows out into the main natural channel around the western corner of Norman's portion. I was unable to get to the eastern end of Herrick's portion, but it appears that with a large volume of water coming down the community channel some of it spills over southwards at the junction, this drains off naturally through a shallow depression as indicated by the irregular red bowed line at the bottom portion of Section 614,* [this may be the unexplained line now drawn in purple on Figure 17] *I anticipate practically all water would drain off the whole area, within a day or so."*
>
> *It is apparent that years ago a storm blocked up the old outlet to the sea with shingle and sand, thus diverting the waters to a new outlet, Norman's portion of the excavation appears to be mainly a deepening and straightening of this new natural channel as far as what is locally known as the Wash-pool, this is apparently quite deep and when inspected had swirling water in it, no doubt caused by the sea and fresh water meeting as the tide was then in."*

According to Schultz (2018) it is unclear when the term "Washpool" was first used by European colonists as a name for the wetland. It's use in the Department of Lands (1956) report is the earliest use of the term that has been uncovered in the scope of historic research undertaken for this report.

The "community channel" referred to is clearly the main inflow drain that exists today, incorporating the confluence of the drains that pass under Norman Rd and Justs Rd. It is noteworthy that, in 1956, where this drain enters the Washpool (Section 296), water in excess of the drain's capacity spilled out to the north, with only some spilling to the south in high flow events. Today the situation is reversed; Herrick's spoil bank has been breached and almost all inflow is directed to the south of Herrick's drain, the area we recognise today as the Washpool and which is inundated each winter.

The Department of Lands (1956) description of the northern outlet of the Washpool, through Section 614, as "new" in 1956 is likely incorrect given this outlet was mapped 117 years earlier by Richard Counsell in 1839 (Figure 4). However, the observation that Norman appeared to have deepened and straightened this natural outlet channel is telling. It strongly suggests that the original sill elevation of the Washpool was lowered and therefore, from at least that time onwards, peak water levels in the Washpool would have been lower than they were historically. While several contemporary reports allude to the deliberate excavation of the outlet channel (Ashton 2001, Draper and Maland 2021, Ecological Associates 2012, Gardiner 1989, KBR 2011b), this statement in the Department of Lands (1956) report is the strongest piece of evidence we have obtained to indicate it occurred.

The statement "I anticipate practically all water would drain off the whole area, within a day or so" is also telling. It suggests that by 1956, through a combination of sedimentation and drain construction, the Washpool had completely lost its capacity to store water, only inundating briefly during inflow events. Despite its greatly reduced duration of flooding, the desire to even more effectively drain the Washpool remained. The below excerpt from the same report further discusses the outlet channel to the sea, confirming its variability and the occasional intrusion of seawater into the Washpool, as described in some of the earliest accounts (e.g. Morphett 1836). Various solutions to the flooding in and around the Washpool are discussed, but the result is that the complex interactions with the tides, drain, community channel and natural depression leaves no easy solution and the neighbours are advised to accept the status quo (Department of Lands 1956):

> *"As regards Mr. Norman's complaint that his land is or would be flooded, it appears the change in the natural outlet to the seas has confused him as to the position of the mutual boundary, and without taking measurements and compass readings, it appears the flooded area is mainly on the lagoon, the new channel has taken some of his freehold land but he has some of the lagoon area fenced in with his land.*
>
> *After inspecting the locality with Mr. Norman I contacted Mr. Herrick at his home, he stated he considered the position would be more satisfactory if portion of the water was diverted to the south of the lagoon by opening his channel at the western end at the junction with the community channel, then deepening the natural shallow depression across Norman's land (S 614) from the Washpool to the south of the lagoon, at the Washpool end it is already 3 to 4 feet deep for a short distance, this has seaweed along the sides near the top, Mr. Norman pointed this out to me, it is his opinion that if the channel was deepened right through to the lagoon it would let the seawater in at high tide. I agree that would probably be the case, and told Mr. Herrick so when discussing the matter with him.*
>
> *After discussing the matter from all angles with both parties, and advising them that the Department would not make a survey to fix the boundary between the two sections, and they realized it would probably cost up to 60 pounds for the services of a private Surveyor and bearing in mind the fact that I told them I considered, in view of the setup neither had reasonable grounds for complaint. Each party to the dispute was interviewed separately, and I advised that when next they met to shake hands then forget the whole matter I anticipate this will be done."*

The next five years (1956 – 61) appear to progress as normal, with no further alterations to the drains and neighbourly disputes on the backburner. Herrick was presumably aware that his lease would expire soon. Herrick's 21 year lease was granted after 19 years of annually renewed leases, and expired on the 2$^{nd}$ of February 1962, after a total of 40 years grazing the Washpool. The District Council of Willunga must have noted the importance of the area as a wetland, probably for reasons more practical than environmental, being a collection point for so much storm water in the catchment. In an application to the Minister of Lands to obtain "care, control and management" of Section 296 after the expiration of Mr Herrick's lease, DC Willunga (1961) describes the importance of the Washpool area "in the control or the drainage of the south western portion of Aldinga and Sellicks Beach wards" and notes it as the point where "the drainage of the district converges and passes to the sea".

The Surveyor-General (1961) approved transfer to DC Willunga, highlighting that area serves as a "kind of ponding basin for drainage for a considerable area to the east". This arrangement is fortunate for the future of the Washpool, as had the neighbourly dispute led to deepening of drains, or a permanent lease over the land, it may have been further degraded today.

A record of an interview between an Inspector from the Department of Lands and Mr Herrick conducted on 23rd January 1962 (Department of Lands 1962) explains that Mr Herrick does not claim any costs for construction of the drain, saying that any costs were recouped due to the drain's effectiveness at increasing stock capacity, and that the "lake bed is now quite dry and well grassed".

The drain excavated by Herrick and Norman in early 1950 set in place a pattern of water movement and sedimentation that created the bathymetry observable today. The effect of the Herrick and Norman drain on contemporary bathymetry is discussed further in Section 5.3. The historical evidence suggests that after about 1950 the Washpool held water only briefly, during inflow events, and had effectively lost its storage capacity. This situation appears to have persisted until the construction of the concrete weir that remains in place today. The concrete weir was constructed by local residents Bob Golding and Paul Rosser in the late 1980's (Paul Rosser, pers. com., 9/12/2021) and had the immediate effect of holding water in the Washpool during winter. In the early 2000s the weir crest was raised by approximately 20 cm to its current elevation of 2.64 mAHD and a low (c.0.3 m) levee was built between the weir and Button Rd to help contain outflows to the weir location. According to Paul Rosser, Bob Golding had the support of Kaurna Meyunna Senior Woman the late Georgina Williams to install the weir as she felt it a better option than dredging the basin. Georgina had some concerns regarding burials in the basin that could be exposed during any excavations. Bob had her support to raise the level, retaining water levels until after the birds had fledged as it was a fail-safe option.

# 5. Contemporary Ecohydrology of the Washpool and Blue Lagoon

## 5.1. Inflows and Outflows

Drains from the wider catchment carry water through culverts under Norman Rd and Justs Rd, converging on the eastern side of the Washpool (Figure 18, red lines) and providing surface inflows. Stormwater from Sellicks Beach also enters the southern end of the Washpool via an outlet pipe (Figure 18, yellow triangle), although the majority of Sellicks Beach stormwater flows directly to sea via Sellicks Creek further south. Swales along either side of Button Rd also carry (sometimes highly turbid) inflows to the Washpool from the east (Ecological Associates 2003). The concrete Washpool outlet weir holds inflows within the Washpool lagoon until the WSEL exceeds the crest of the weir, an elevation of 2.64 mAHD according to survey data provided by City of Onkaparinga and also stated by SKM (2008). Water spilling over the outlet weir enters the outlet channel (Figure 18, green line). Survey data also indicates that the lowest lying area of the Washpool, situated within samphire vegetation just north of Button Rd, has an elevation of 2.20 mAHD. Thus the maximum depth of the Washpool at CTF is 0.44 m. All wetlands temporarily surcharge above their sill elevation under high inflows when full. Water level data collected by NGT in 2021 and 2022 shows a maximum WSEL of 2.83 mAHD at the logger location (see Section 5.2).

Stormwater from the Silver Sands residential area does not enter the Washpool (except possibly in extremely intense rainfall events) but flows into a separate drain along the south-eastern edge of the estate (Figure 18, yellow lines), converging with outflows from the Washpool 35 m downstream of the Washpool outlet weir. The combined outlet channel discharges to sea across Silver Sands beach. Between the outlet weir and the beach the invert (bed elevation) of the outlet channel is deeply incised to approximately 0.80 mAHD (survey data provided by City of Onkaparinga) and contains a semi-permanent pool. Closer to the beach, the invert rises and surface flows must breach an embankment of sand and pebbles that is part of the coastal foredune. This is what remains of the original, dynamic northern mouth of the Washpool. When overtopped and eroded by high outflows and/or high seas this embankment can be temporarily lowered or removed (Figure 19), lowering the water level in the outlet channel upstream (but not the Washpool itself). Under these conditions, hydrological connectivity between the sea and the outlet channel exists, potentially enabling fish movement between the two. However, fish movement from the sea into the Washpool lagoon itself is likely prevented by the concrete outlet weir, which is not designed to accommodate fish passage.

Following a period of mouth openness, the pebble embankment can be reformed relatively quickly via wave action when outflows reduce, likely a matter of weeks according to local reports and photographic evidence (FoAS 2022). It may then persist for one or several years, depending upon rainfall in the Washpool catchment, presenting a barrier between the sea and the outlet channel (Figure 20). The dynamic nature of this outlet means the crest elevation of the embankment is not constant. The DEM suggests an elevation of 2.15 mAHD, i.e. approximately 0.5 m lower than the crest of the concrete outlet weir. Interestingly, in the mid-1970s an elevation of 2.1 mAHD was measured for the same feature (B. C. Tonkin and Associates 1977). Western et al. (2020) measured an elevation of 2.0 mAHD for the feature. Based on our observations and photographic evidence (FoAS 2022), the crest elevation of the pebble embankment likely fluctuates between approximately 1.0 and 2.5 mAHD. The pebble embankment has the potential to influence the effectiveness of stormwater drainage from Silver Sands estate, however management intervention to open the mouth, e.g. using an excavator, is not undertaken to our knowledge. Natural processes keep the mouth of the Washpool sufficiently open to provide stormwater drainage and prevent flooding of Silver Sands estate.


Figure 18. The contemporary Washpool and Blue Lagoon showing outlet weir location, drains and extent of inundation at CTF (2.64 mAHD) interpreted from DEM and on-ground observations. The primary outflow path from the Washpool is shown (white dashed arrow).

Figure 19. The Washpool outlet channel showing the pebble embankment lowered by a period of high outflows, 17th July 2017 (photo: Chas Martin (FoAS 2022)).

Figure 20. The Washpool outlet channel showing the raised pebble embankment in place, July 2018 (photo: Julie Burgher (FoAS 2022)).

Figure 21. The Washpool outlet showing reverse flow of seawater into the outlet channel, 9th May 2016 (photo: Julie Burgher (FoAS 2022)).

Photographic evidence (FoAS 2022) and tidal data suggests that reverse flow events, when seawater pushes into the outlet channel (Figure 21), also occur in most years that the mouth is open. However, seawater intrusion into the Washpool lagoon itself, requiring a tide higher than the crest of the concrete weir (2.64 mAHD) is a far less frequent phenomenon. We calculated daily maximum tide heights in cmAHD for Port Stanvac, a surrogate for heights at Aldinga Beach, for the eight year period 2013 to 2020 inclusive. Daily tide data were obtained from the nearest active gauge at Outer Harbour and converted to levels at Port Stanvac (historically gauged) using the equation (Mike David, Bureau of Meteorology, pers. com.):

Outer Harbor observed × 0.8687 – 0.0114 = Port Stanvac

Data are displayed in Figure 22 and compared to the approximate elevation of the crest of the pebble embankment across the outlet channel when it is eroded down by outflows (1.0 mAHD). This potential occurs numerous times each year, although actual inflow events are much less frequent as the mouth is often closed, i.e. the pebble embankment is in place with a crest elevation of c.2.20 mAHD. The elevation of the concrete weir further upstream is also shown. These data suggest that sea levels remained well below the 2.64 mAHD elevation of the weir crest for the entire period 2013 – 2020, rarely exceeding 1.5 mAHD. Modelling undertaken for the City of Onkaparinga's Coastal Adaptation Study (Western et al. 2020) showed that high seas resulting from a 1 in 100 year storm event would attain a level of 2.60 mAHD by 2020, which would contain seawater inflows to the outlet channel and would not overtop the concrete weir. However, under sea level rise predicted for 2050, 2070 and 2100, seawater would overtop the concrete weir (see Section 10).

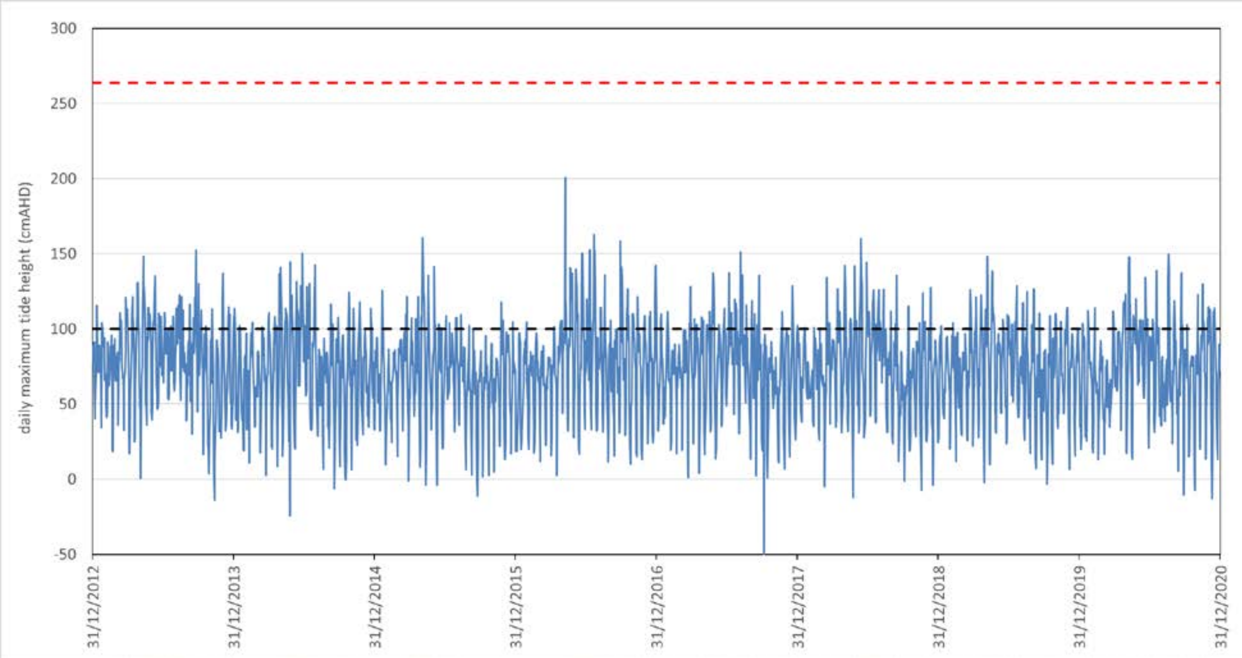



Figure 22. Daily maximum tide heights at Port Stanvac 2013 – 2020 (blue line), approximate elevation of pebble embankment when eroded by outflows (black dashed line) and elevation of crest of concrete weir (red dashed line).

An interesting feature of the pebble embankment that forms across the mouth of the Washpool is that it is very leaky. Even when the water level in the outlet channel is below the crest of the embankment, water can pass rapidly through the embankment and re-emerge at the surface on it's beach-facing side, forming a flowing channel, or series of channels, carrying surface flows across the beach to the sea (Figure 23). This is presumably how the outflow from the Washpool makes its way to sea in drier years when the mouth remains "closed".

Figure 23. The Washpool outlet on 17th July 2021, looking upstream, showing the pebble embankment in place but leaking, with water re-emerging on its beach-facing side to form a fast flowing stream. Onlooker is Drew Kilner (photo: Ben Taylor).

The crest of the concrete outlet weir forms the contemporary sill of the Washpool. Survey data provided by the City of Onkaparinga shows that the crest of the concrete weir has an elevation of 2.64 mAHD. Thus, at cease-to-flow (CTF) the water surface elevation (WSEL) of the Washpool is 2.64 mAHD. The extent of inundation at CTF, as interpreted from the DEM and on-ground observations, is 9.55 ha and is shown in Figure 18. An oblique aerial photograph taken on 3rd October 2021 (Figure 24) shows good alignment with the DEM interpreted extent at 2.64 mAHD. Logger data for this date (see Section 5.2) confirms a WSEL of 2.64 mAHD when the photograph was taken. A contemporary extent of 9.55 ha at CTF represents a 63% reduction in size since 1839 based on Richard Counsell's map, which suggests the Washpool at that time had an area of approximately 26 ha (using the outer margin of the ground labelled "Swampy" as the outer extent of the Washpool at CTF).

Figure 24. The Washpool 3rd October 2021, showing extent of inundation at CTF, i.e. with a water level equal to the crest of the concrete outlet weir (2.64 mAHD) (photo courtesy of Damian Moroney, DEW).

Button Road has been constructed across the natural bed of the Washpool, is not culverted and divides the wetland into northern and southern sections. The DEM indicates that the elevation of Button Rd is approximately 2.90 mAHD where it passes through the Washpool. Thus the northern and southern sections of the Washpool become hydrologically connected only temporarily under very high inflows that push water levels to approximately 25 cm above the crest of the concrete outlet weir. The surface of Button Rd occupies 0.13 ha of former wetland habitat and the elevated verge of Button Rd has altered the vegetation of an additional 0.53 ha, facilitating the development of emergent sedgeland (mostly *Bolboschoenus caldwellii*) where the natural surface would likely support saltmarsh and open water habitat.

## 5.2. Water Regime and Water Quality

### 5.2.1. Depth and Duration of Inundation

The contemporary depth and duration of inundation at the Washpool is described in several reports (Carpenter 2001, Ecological Associates 2003, KBR 2011b, Kinhill 1996, QED 2007, SKM 2008, T&M Ecologists 2016), with general agreement that the Washpool in its contemporary form is typically inundated between June and November and has a maximum depth of approximately 40 cm.

The Water Observations from Space (WOfS) tool in the National Map application (Geoscience Australia 2022b) summarises surface water information as detected by remote sensing satellites from 1986 to the present. A summary of all water observations combined for the Washpool is shown in Figure 25. The total extent of inundation aligns well with that estimated from the DEM (Figure 18) and the aerial photograph taken on 3rd October 2021 (Figure 24). The WOfS tool indicates water was present within this area for 20-30% of observations. This suggests that inundation for a duration of 3-4 months is typical for the Washpool. This may be an underestimate according to data from other sources (see below).

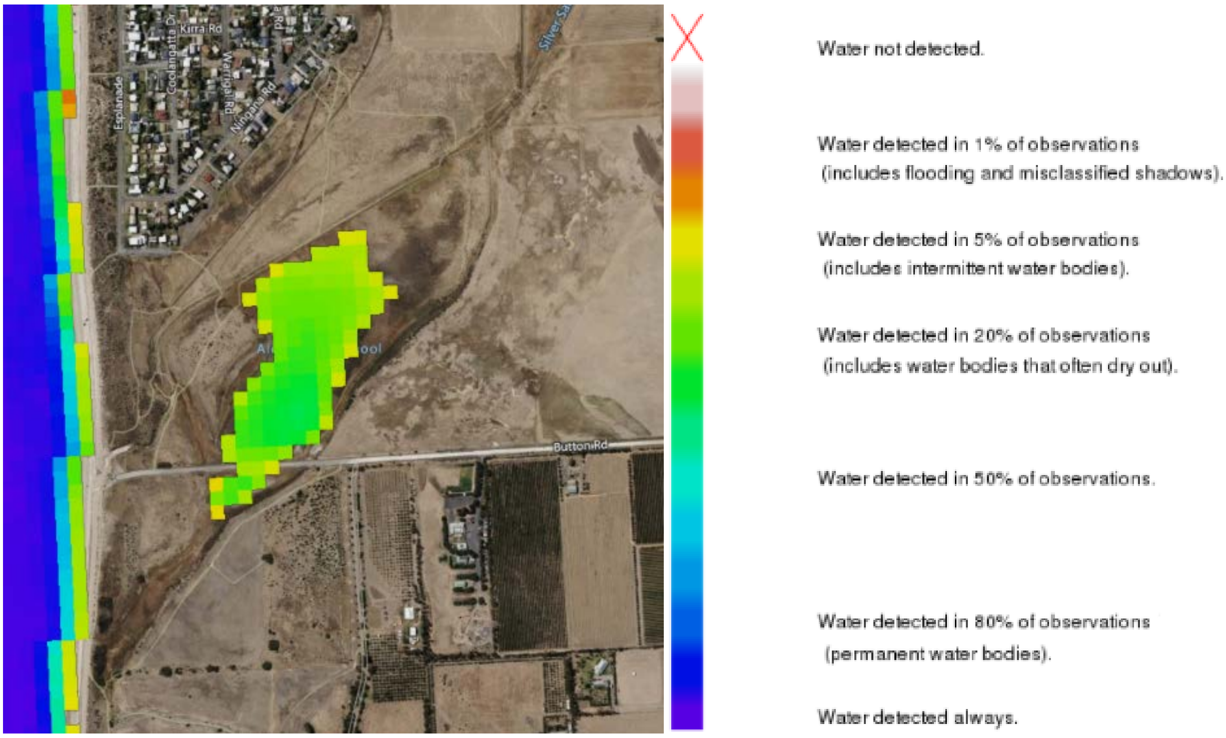



Figure 25. Water Observation from Space summary for the Washpool (source: Geoscience Australia 2022b).

The Global Surface Water Explorer (https://global-surface-water.appspot.com/) (Pekel et al. 2016) summarises global surface water as detected by Landsat satellites from 1984 to the present. Monthly water recurrence for the Washpool, i.e. the percentage of valid satellite observations that have detected surface water in the Washpool for each calendar month since 1984, is shown in Figure 26. These data suggest that inundation for four to five months is typical, but inundation for up to seven months occurs in approximately one in four years. Given the coarse nature of Landsat data, and the potential for false negatives (i.e. water present but not detected due to interference from vegetation), these data are only indicative. More confidence can be obtained by direct measurement of water levels *in situ*.

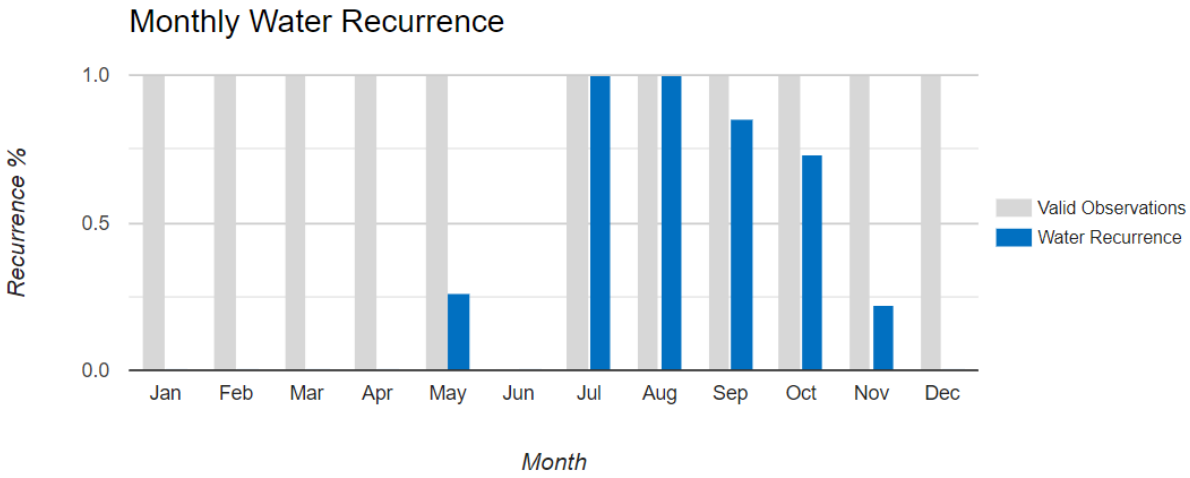



Figure 26. Monthly water recurrence at the Washpool (source: Pekel et al. 2016).

### 5.2.2. NGT Water Level and Salinity Monitoring

To improve confidence of water regime at the Washpool we installed a logger in the lowest lying area of the wetland. We installed a Hobo® U20L-04 water level logger in the Washpool and a corresponding logger for barometric compensation at Treasure St Aldinga Beach on 11th June 2021. These loggers were set to take four measurements per day. On the installation date there was already shallow water in the Washpool. We also installed an Odyssey conductivity logger to measure salinity however this logger failed. The water level logger location (location 1) is shown in Figure 27. Data was downloaded on 13th December 2021. In early May 2022 it was discovered that the water level logger had been stolen. On 23rd May 2022 a new water level logger was installed in a new location (location 2) to reduce the likelihood of theft (Figure 27). The Washpool was dry at the logger location when this logger was installed. Water level data for the period 11th June to 13th December 2021 are shown in Figure 28. At the time of writing this logger has not been relocated and is assumed stolen, with loss of the 2022 water level data.

Although the commencement of inundation in 2021 was missed, WSEL was low (2.24 mAHD, i.e. 0.04 m max. depth) in mid-June. By late June 2021 the Washpool had filled to the weir crest (2.64 mAHD, i.e. 0.44 m max. depth). Several high inflow events, visible as peaks in the WSEL plot, occurred during July and early August and again in mid-October. The maximum WSEL measured in 2021 was 2.83 mAHD on 26th July, a level 0.19 m above the sill elevation (weir crest). At this time maximum WSEL may have been even higher closer to where the inflow drains enter the wetland, i.e. there was likely a temporary slope on the water surface from inflow location down to outlet weir. The water level dropped below the weir crest on about 24th October and declined thereafter. By 13th December (last available data) the WSEL had dropped to 2.32 mAHD (0.12 m max. depth). At the rate of decline observed, the wetland was likely completely dry by 22nd December.


Figure 27. Water surface elevation (WSEL) and conductivity (EC) logger locations established by NGT in the Washpool.

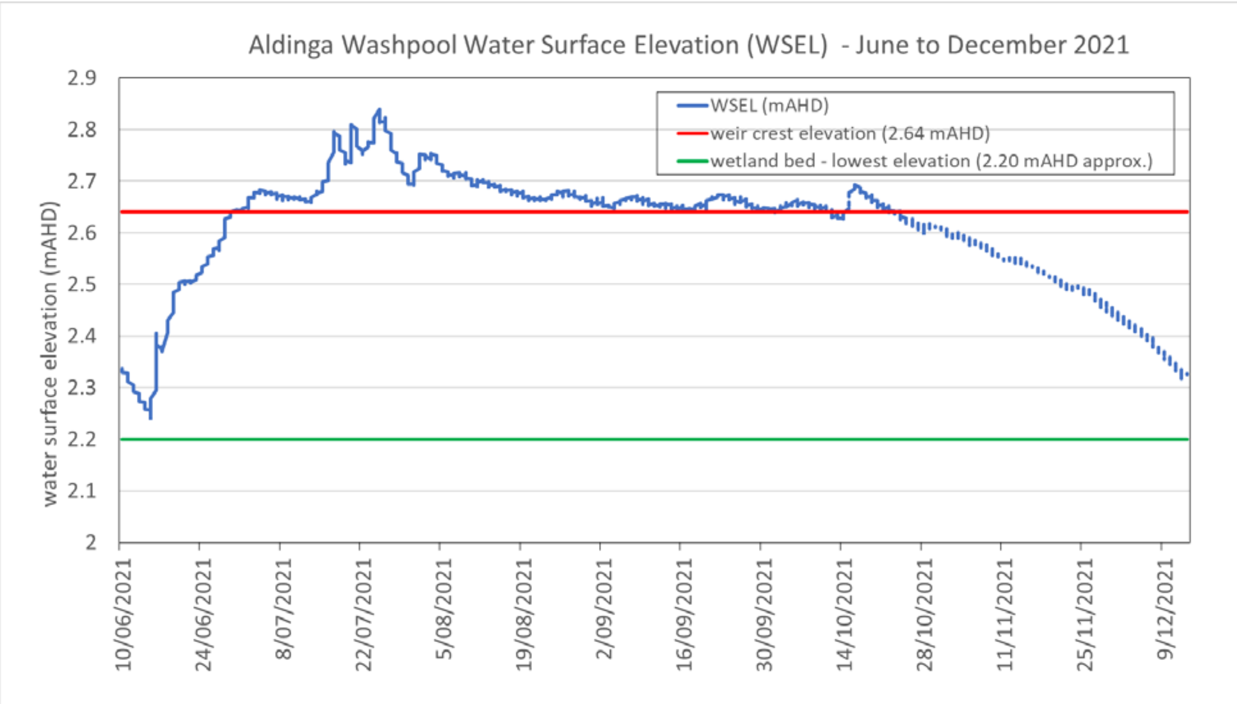



Figure 28. Water surface elevation (blue line) for the Washpool for 2021. The elevation of the

To improve understanding of the spatial variation of salinity within and around the Washpool we took spot measurements of electrical conductivity of surface water using a YSI probe on 4th August 2022. Results are shown in Table 1 and Figure 29.

Table 1. Spot measurements of salinity taken in and around the Washpool on 4/8/22.

| location | flow status | salinity (mS/cm) |
|---|---|---:|
| Drain south of Norman Rd | Standing water | 1.039 |
| Main inflow drain under Norman Rd | Low flow | 0.831 |
| Silver Sands stormwater drain | Standing water | 7.660 |
| Channel immediately upstream concrete weir | | 3.135 |
| Outlet channel downstream concrete weir | Low flow over weir, mouth closed | 3.716 |
| Outlet channel upstream pebble embankment | Low flow over weir, mouth closed | 3.650 |
| Washpool just north of Button Rd | Washpool at CTF, low inflow | 2.926 |
| Washpool just south of Button Rd | Washpool at CTF, low inflow | 1.634 |
| Dam | Almost full, no connection to Washpool | 48.035 |
| Possible Tjilbruke spring historic location | Standing, isolated water | 10.040 |
| Shallow channel near historic southern outlet | Standing water | 1.305 |
| Inundated vegetation near historic southern outlet | Standing water | 0.950 |


Figure 29. Spot measurements of salinity (electrical conductivity, µS/cm) within and around the Washpool 4/8/22.

The salinities we measured in the Washpool were within the range measured by Coleman (2019) in 2017 and 2019, which ranged from 1.63 to 5 mS/cm. Ashton (2001), based on 630 visits to the Washpool between 1978 and 2000, mostly when inundated, considered the salinity "always … potable" (fresh), although data were not provided.

The salinity spot measurements indicate:

- Surface inflows to the Washpool may be quite fresh but water within the Washpool, when full, is mildly brackish, likely due to residual salt within the basin and the groundwater salt input from the Semaphore Sand perched water table aquifer (see Ecological Associates 2003);
- The hydrological separation caused by Button Rd can cause salinity to differ on either side;
- If our understanding of the Tjilbruke spring location is correct it no longer appears to be discharging fresh water at the surface;
- The old farm dam just north of Button Rd had a salinity close to that of seawater and over 10 times the salinity in the Washpool. There is clearly no hydrological connection between the two waterbodies. High salinity in the dam may be due to a lack of flushing combined with salt inputs from groundwater and/or sea spray.

### 5.2.3. Turbidity

The discharge of turbid water into the marine environment may contribute to degradation of the marine ecosystem and certainly detracts from the recreational and aesthetic values of suburban beaches (Fox et al. 2007). The Washpool likely plays a role in trapping sediment and reducing sediment discharge into the marine environment (Southfront 2020, Wegener 1995) and this role could potentially be enhanced if the volume of the Washpool was increased through hydrological restoration works that include site remediation. As has been discussed previously in Section 4, and below in Section 5.3, sediments eroded from the catchment have been deposited in the Washpool in the past and have raised the bed, and reduced the volume of the wetland. At face value, based on aerial imagery and the general literature on the Washpool, the process of sedimentation appears to have ceased or at least slowed in recent decades, however turbid inflows remain an ongoing concern. Turbid inflows, if not depositing sediments on the bed of the wetland, may be affecting the quality of aquatic habitat in other ways such as through reduced penetration of light through the water column.

Willunga Hills Face Landcare Group (WHFLG) have obtained turbidity data throughout the Washpool catchment during intense rainfall events in order to identify locations where erosion is occurring and suspended sediment is being added to Washpool inflows. Figure 30 shows highly turbid inflows displacing clear water within the Washpool during an extreme inflow event on 21st June 2020. Data obtained by WHFLG is directing on-ground efforts to reduce erosion, reduce the volume and rate of surface runoff and increase infiltration across the catchment. In addition, to improve water quality of inflows, these actions have the potential to increase the duration of inflows and extend the duration of seasonal inundation of the Washpool, a recommendation of Ecological Associates (2003). City of Onkaparinga have constructed the Cox Road Detention Sedimentation Basins on Cox Rd Aldinga with aligned objectives, although the effectiveness of these basins at preventing sediment transport into the Washpool may be limited during extreme events.

Figure 30. Highly turbid inflows to the Washpool displacing clear water, early afternoon 21st June 2020 (photo: Stewart Bond for Willunga Hillsface Landcare Group).

### 5.2.4. Other Water Quality Parameters

In association with our spot measurements of salinity, in August 2022 we measured the pH and dissolved oxygen concentration of surface waters at the same locations in and around the Washpool. Both parameters were within the typical range, indicating a relatively healthy aquatic environment at that time. Dissolved oxygen ranged from 30 – 123 % saturation while pH ranged from 7.55 - 8.91.

We did not examine any other water quality parameters for this study. Understanding the role that the Washpool could play in reducing nitrogen discharge to the marine environment could add weight to the case for hydrological restoration. Nitrogen is implicated in seagrass decline in Adelaide's coastal waters (Fox et al. 2007) and seagrass beds occur near the Washpool outlet (DEH 2008). Restoring the volume of the Washpool would reduce the volume of discharge to sea and increase the residence time of water within the wetland, likely reducing nitrogen concentration of discharge.

Coleman (2018b) surveyed the diatom community of the Washpool and applied "pollution and disturbance" indices to the diatom data to provide commentary on water quality. The diatom community of the Washpool suggested the following about Washpool water quality:

- a middle range of catchment disturbance;
- indicators of good water quality including:
    - a relatively low organic loading;
    - a relatively low nutrient (phosphorus, nitrogen, inorganic carbon and silica) loading;
    - a relatively low bound nitrogen loading; and

- o relatively high dissolved oxygen levels.

In contrast, opportunistic observations made during the course of the current study suggest moderate nutrient loading, as indicated by dense coverage of filamentous green algae in the shallow margins of the Washpool and dense coverage of epiphytic algae on submerged aquatic vegetation (Figure 31).

Figure 31. Dense coverage of filamentous green algae along the shoreline (left) and epiphytic algae on submerged aquatic vegetation (right) within the Washpool, 20th October 2022 (photo: Ben Taylor).

Eutrophication, i.e. the degradation of aquatic ecosystems due to excessive nutrient loading, is typically a lower risk in wetlands with a regular dry phase than permanent waterbodies. However, the condition of the Washpool would be best served by minimising nutrient loading through catchment-wide measures such as those mentioned in Section 8.13.

## 5.3. Groundwater

The groundwater environment in and around the Washpool and its catchment has been examined in some detail by Ecological Associates (2003) and AGT (2015).

Historic information on groundwater in the Washpool area and its catchment is limited (Ecological Associates 2003) but, as is the case for surface water, has likely been significantly altered. Drains in the catchment upstream of the Washpool, along the east edge of Aldinga Scrub, apparently flowed continuously for several years after they were first constructed in the 1940s and 50s (Nurton 1995), likely dewatering a local perched aquifer (Ecological Associates 2003). Prior to drain construction, the Semaphore Sand perched water table aquifer beneath Aldinga Scrub likely flowed laterally towards the Washpool and from the north and east and likely maintained inundation or waterlogging within the wetland through much of summer and autumn (Ecological Associates 2003). It appears that drains now intercept this groundwater when it rises in the winter and direct it to the Washpool more rapidly, and for a shorter duration, than would have occurred naturally (Ecological Associates 2003).

North of the Washpool, in the vicinity of Blue Lagoon, water levels in the perched water table aquifer fluctuate seasonally between approximately 1.0 and 5.0 mAHD (AGT 2015). The salinity of this aquifer ranges between approximately 6,000 mg/L and 14,000 mg/L Total Dissolved Solids (TDS) (AGT 2015). Given the lowest elevations within the Washpool are 2.20 mAHD, it is likely that a small, direct (non-drain) contribution of groundwater to the surface hydrology of the Washpool occurs seasonally, as suggested by Ecological Associates (2003). The presence of the Tjilbruke spring south of Button Rd, historically a source of fresh water for human consumption, highlights the complex hydrogeology of the area. This spring may have been maintained by a highly localised perched aquifer within the coastal dunes that was fresher than the broader Semaphore Sand perched water table aquifer.

There is nothing in the current understanding of groundwater to suggest that hydrological restoration of the Washpool presents risks to, or is limited by, the surrounding groundwater environment. Retaining a higher WSEL within the Washpool (see Sections 8.1 and 8.5) could result in a localised increase to groundwater recharge, but the possible changes to groundwater level that might arise would likely be within the currently existing range. The existing Silver Sands stormwater drain, which would be retained, would intercept seepage towards Silver Sands and would likely maintain similar groundwater levels along the north-western margins of the Washpool.

## 5.4. Bathymetry

The bathymetry of the Washpool and Blue Lagoon has changed since pre-colonial times as a consequence of both active interventions (e.g. drain excavation, land reclamation, rubbish dumping, Button Rd construction, possible sand mining) and passive processes (e.g. sedimentation, possible erosion). Figure 32 shows the contemporary bathymetry of the Washpool, derived from the DEM, with Richard Counsell's 1839 outline of the wetland (Counsell 1839) overlain. The current extent of inundation when full (i.e. a water level equal to the crest of the concrete outlet weir) is also shown. Clearly, the size and shape of the contemporary Washpool has changed since 1839, however the changes are not consistent spatially and suggest different processes have affected different areas of the wetland bed. The south-eastern edge of the Washpool shows reasonable agreement with the Counsell map, however there is no particular elevation, or contour line, that shows good agreement with the Counsell map around the complete perimeter of the wetland.

The northern extent of the Washpool as mapped by Counsell now features ground elevated well above the bed of the wetland. Some of this bathymetric change can be attributed the sedimentation of material eroded from the catchment. Dyson (2000) took sediment cores (costeans) throughout the Washpool and examined the qualities of sediments down the soil profile to determine the depth of sediment that had accumulated since colonisation at each location. These locations are shown in Figure 32, with labels referring to the depth of post-colonisation sediment at each (in metres). Recent sediment deposition has been greatest (0.5-0.9 m) in close proximity to where the inflow drain meets the Washpool lagoon. This is where high velocity inflows carrying a high sediment load would meet the still water of the Washpool, causing sediment to drop out of suspension. Sedimentation has occurred throughout the Washpool but appears to have been relatively minimal (0-0.3 m) in the (currently) most low lying ground immediately north of Button Rd (Figure 32).

The nature of bathymetric changes in the very north of Counsell's mapped Washpool extent suggests deliberate land reclamation, as has been suggested previously by some authors (e.g. Carpenter 2001, Dyson 2000). This is supported by a closer examination of the DEM in this area, which shows a linear edge to elevated ground along the western edge of land parcel D7917 A1 just east of Silver Sands estate (Figure 33). The linear step-up to higher ground is strongly suggestive of deliberate land reclamation via the importation and shaping of spoil, rather than a fluvial process of deposition.

The bathymetry of the Washpool may also have been altered by the deliberate dumping of rubbish. In June 1989, the Friends of Aldinga Scrub sent a letter to District Council of Willunga expressing "surprise and outrage at the continued action of Council in dumping rubbish in the Washpool area" (Lumb 1989). The precise location of rubbish dumping is unclear.

A linear section of high ground, having the appearance of a bund, is aligned in a north-east to south-west direction through Counsell's inner "Salt Water Lagoon"(Figure 32). The ruler-straight edge of this "bund", over approximately 450 m in length, is clearly the southern side of the single spoil mound created by Herrick when he excavated a drain through the Washpool in c.1950 (see Section 4.2). It appears that subsequently, inflows to the Washpool were directed through the drain, with any flow exceeding the capacity of the drain overflowing to the north. This concurs with Norman's complaint about inundation of land in Section 614, north of the drain, following drain construction (see Section 4.2). During the period of this arrangement, the part of the Washpool south of Herrick's drain would have received little surface inflow (the opposite of what occurs today, now that Herrick's spoil mound has been breached near the eastern edge of the Washpool). It appears that, as inflows carrying sediment slowed, sediment was deposited in this drain. Gradually the drain's capacity was reduced, forcing a greater proportion of inflows to overflow to the north, broadening the zone of deposition. Eventually the drain filled completely with sediment but the spoil mound along its southern edge, elevated well above natural surface, continued to force water to the north and allowed sediment to accumulate well above natural surface. This explains the shape of this feature today; a linear southern edge, a less clearly defined northern edge, widest near the point of inflow and gradually narrowing further to the south-west.

The areas immediately north and south of Button Rd, west of Counsell's mapped Washpool extent, are so low lying (Figure 32) they would be inundated should water levels in the Washpool be raised only slightly higher than the current sill elevation. This lack of consistency between the Counsell 1839 map and the contemporary topography may be due to the historic mining of sand from the area. According to Gardiner (1989) "Many native middens used to occur in this area but when the Myponga Reservoir was built the E. & W.S. Department established a water reserve in this region and huge quantities of sand were removed from it; the middens went with the sand". Ecological Associates (2003) suggested sand mining took place in the 1930s and 40s and that it may have lowered the sill of the Washpool. Draper and Maland (2019) stated that the area "was heavily disturbed by sand mining for the Myponga pipeline in the 1950s". Draper and Maland (2019) also refer to a significant archeological site located around 50 m south-east of Blue Lagoon that was destroyed by the removal of sand for construction of the Myponga pipeline and subdivision for housing development. A souvenir booklet provided to attendees of the official opening of Myponga Reservoir on 8$^{th}$ November 1962 stated that sand used in the construction of the reservoir dam and outlet was obtained from Normanville and Noarlunga. The question of the precise location on sand mining at the Washpool remains unresolved, however if sand mining did occur near the Washpool, Button Rd would have provided good access to the coastal dunes and therefore the dunes closest to the road may have been targeted. This may explain why the elevation of the land surface in this area today appears lower than is suggested by Richard Counsell's map from 1839.

Along the north-western edge of the Washpool there is a poor alignment between Counsell's mapped extent and the contemporary DEM, with low lying ground extending beyond Counsell's edge towards properties within Silver Sands estate (Figure 32). It may be that Counsell's boundary is not correct in this area and should have been drawn approximately 60 m closer to modern day Silver Sands. An alternative explanation is that sand mining, or excavation for some other purpose, has occurred in this area. Material may have been excavated and placed onto the adjoining land parcels within Silver Sands prior to building to provide improved flood protection, but we have uncovered no direct evidence of this.

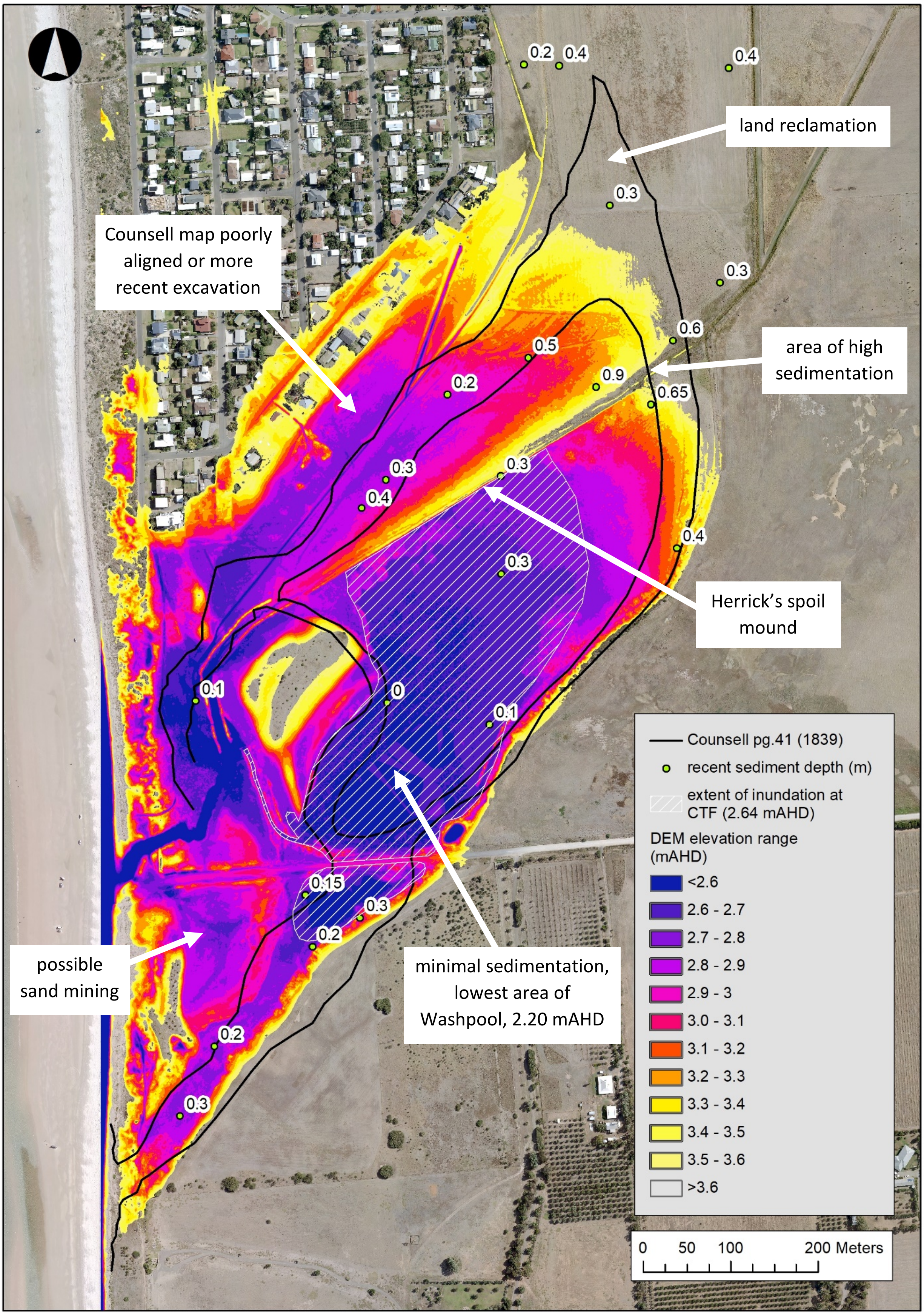



Figure 32. Contemporary bathymetry of the Washpool with Counsell's 1839 map, current extent of inundation at CTF and Dyson's core locations (depth of recent sediment accumulation labelled) overlain.

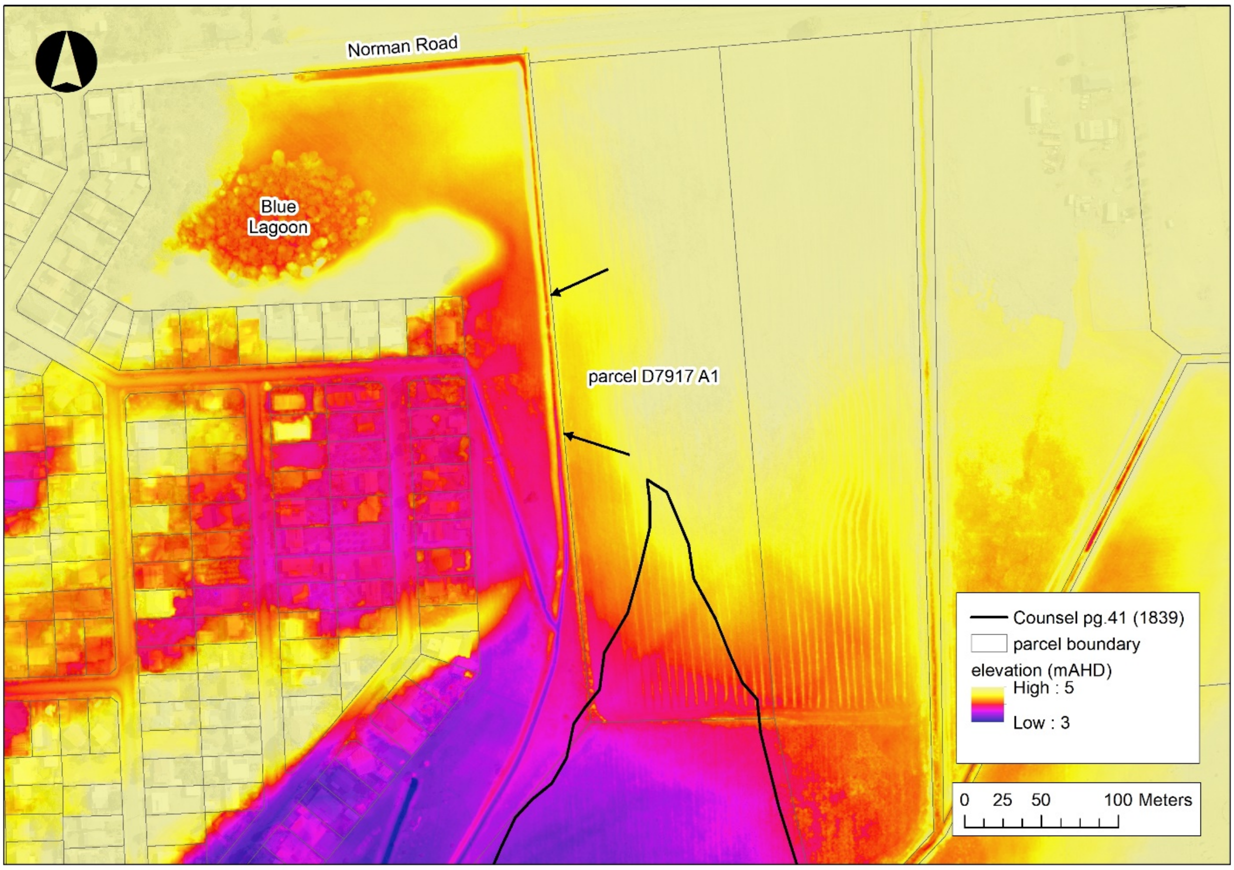



Figure 33. Topography suggestive of land reclamation within parcel D7917 A1 (indicated by black arrows). The area in question includes the northern arm of the Washpool as mapped in 1839.

## 5.5. Vegetation

The vegetation of the Washpool and Blue Lagoon was comprehensively described and mapped in 2016 by T&M Ecologists (T&M Ecologists 2016) who in turn referred to previous mapping undertaken in 2008 (Durant 2008). T&M Ecologists (2016) mapped and described 12 vegetation associations and also mapped the condition of the vegetation. Vegetation subject to regular inundation is generally in the best condition (T&M Ecologists 2016), probably because most weed species of the district do not tolerate inundation and as a result of increased inundation over recent decades stimulating a positive response of the residual seedbank of native wetland plants. The Washpool and its immediate surrounds supports at least twenty plant species listed as regionally rare or threatened, most occurring in association with wetland or saltmarsh habitats (T&M Ecologists 2016).

A relevant issue in relation to the restoration of the Washpool is the conservation status of the samphire vegetation that dominates the lowest lying areas of the wetland, i.e. the +/- *Tecticornia* spp. +/- *Sarcocornia* [syn. *Salicornia*] spp. Low Shrublands mapped T&M Ecologists (2016). There is debate as to whether this is an example of the "Subtropical and Temperate Coastal Saltmarsh" ecological community listed as nationally vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*. The Conservation Advice for this ecological community (DSEWPC 2013) states that it occurs in "areas within the astronomical tidal limit, often between the elevation of the mean high tide and the mean spring tide" or areas that "retain a regular or intermittent tidal connection", such as estuarine lagoons that are only tidally influenced when the mouth of the lagoon is open. The samphire vegetation of the Washpool lagoon proper (excluding the outlet channel) occupies elevations of 2.20 mAHD and above. Tidal data obtained for this report (see Section 5.1) indicate sea levels do not reach the height necessary to inundate the bed of the Washpool, even if the concrete weir was removed. This is supported by the astronomical tidal range suggested in other reports (KBR 2011a, Southfront 2020, Western et al. 2020). We conclude that the samphire vegetation occupying the lowest elevations of the bed of the Washpool lagoon is not an example of the "Subtropical and Temperate Coastal Saltmarsh" ecological community. However, samphire occurring downstream of the outlet weir, along the margins of the outlet channel, may meet the criteria for the *EPBC Act* listed community.

The vegetation of the Washpool is discussed in more detail in Section 7.2, where we deduce the pre-colonial vegetation of the Washpool and use it to describe the likely water surface elevation of the wetland when full prior to development.

## 5.6. Birds

Prior to colonisation the Washpool likely supported a number of bird species now locally extinct, including orange-bellied parrots and possibly eastern ground parrots, which were documented in similar habitats of the Greater Reedbeds of the Adelaide Plains (Paton 2021). Contemporary bird observations at the Washpool are documented in several other reports (e.g. Ashton 2001, Carpenter 2001, Coleman 2018a) and websites (e.g. BirdsSA 2022, FoAS 2022) and are not repeated here. The Washpool has been subject to a high survey effort for birds. Ashton (2001) conducted a remarkable 630 surveys between 1978 and 2000, mostly when water was present. In the 15 years to 2017 a total of 145 surveys were conducted (Chris Purnell, BirdLife Australia, 2017 Community Forum, https://aldingawashpool.net/2017). In summary, 115 bird species have been recorded in the Washpool area of which 52 are waterbirds, 6 are Palearctic migrants (migratory shorebirds), 11 are regionally threatened and 3 are nationally threatened. Species richness is high for such a small area, a reflection of the diverse range of habitats available through space and time. The wetland habitats at Washpool broadly include:

- open water/saltmarsh/mudflat (depending upon water level), which:
    - when deeply inundated provides habitat for species including dabbling and diving ducks, black swan, grebes, stilt, herons, egrets, spoonbills and terns;
    - when shallowly inundated provides habitat for species including migratory shorebirds, plovers, Australian painted snipe (nationally endangered), ibis, Cape Barren goose and *Neophemas*;
- Dense emergent vegetation of the wetland margins (*Gahnia filum* sedgeland*, Bolboscheonus caldwellii* sedgeland), which;
    - provides habitat for species including Australian reed-warbler, little grassbird, golden-headed cisticola, crakes, black-tailed native hen and Australasian bittern (nationally endangered).

Waterbird use of the Washpool is limited by the water regime of the wetland. Washpool in its current state is a relatively shallow wetland (maximum depth at CTF 44 cm) with a duration of inundation of approximately 5 - 7 months, with the wetland typically dry by early January (see Section 5.2). This water regime is sub-optimal for migratory shorebirds, that require shallowly inundated mudflats from October to March (Ferenczi et al. 2020). The relatively shallow maximum depth may be limiting for some diving duck species, e.g. musk duck, which has not been recorded (BirdsSA 2022).

NGT's proposed hydrological restoration objectives for birds:

- firstly, do no harm: maintain the diversity, extent and quality of habitat;
- increase the total extent and quality of existing habitat, in particular:
    - increase the extent of open mudflat (WVC 1.2 Seasonal brackish aquatic bed, see Section 5.5) to better support migratory shorebirds and other waders;
- increase the maximum depth of inundation to improve habitat for diving birds; and
- extend the duration of inundation further into summer to better support migratory shorebirds and other waders

A larger, deeper Washpool, with a longer duration of inundation and increased habitat diversity is likely to drive:

- increased total abundance (carrying capacity) of birds;
- increase breeding opportunities for some bird species; and
- greater overlap between the presence of water and the seasonal presence of migratory shorebirds in south-eastern Australia; October to March inclusive (Weller and Lee 2017).

## 5.7. Fish

Prior to this study there have been no formal fish surveys of the Washpool and there are no records or anecdotal accounts of fish in the Washpool in recent times to our knowledge. The Washpool contains aquatic invertebrates that are indicative of the absence of fish (Peri Coleman, pers. comm., Washpool Community Forum, 5th February 2017). However, Kaurna representatives have informed us that fish were historically present within the wetland (Buster Turner, pers. com., 16/8/22). This has also been suggested by previous authors (e.g. Ecological Associates 2003). Fish in the Washpool would provide a food resource for a range of waterbirds that utilise the wetland (Coleman 2018a). The dynamic nature of the mouth, with extended periods of closure and brief periods of openness (see Section 5.1) means that fish passage between the sea and the Washpool has likely always been seasonally limited and is likely to remain so. However, the concrete outlet weir at the Washpool presents an obvious barrier to upstream fish movement.

Fish identified as juvenile common galaxias, *Galaxias maculatus*, were photographed in the Washpool outlet channel, downstream of the outlet weir, in August 2011 (Figure 34). Although landlocked populations of common galaxias are known to exist (Gomon and Bray 2021), populations are more typically diadromous, i.e. having both a marine and freshwater phase to their life cycle. Common galaxias adults live in freshwater habitats but migrate to estuaries to spawn in winter, with larvae migrating to sea where they spend several months before migrating into freshwater habitats as juvenile "whitebait" in spring (Native Fish Australia 2022). A study of fish movement in the Drain L system near Robe in the South East region of SA (Hammer et al. 2012) detected common galaxias whitebait migration from the sea into freshwater from late winter to early summer, peaking in spring. It is likely that the common galaxias observed in the Washpool outlet channel in August 2011 had recently migrated from the sea.

Waterbird observations at the Washpool suggest fish may at times be present within the lagoon. For example, observations of Caspian terns, *Hydroprogne caspia*, hovering above and plunging into open water habitat within the Washpool (Figure 35) suggests the presence of fish as this species is almost exclusively piscivorous (Birdlife Australia 2022, Thompson et al. 2002). Conversely, terns are known to use the same swoop and dive technique they use to capture small fish to capture flying insects (Coleman 2018a), which may also explain this behaviour.

In winter 2021 fish surveys were conducted in two permanent, constructed waterbodies within the Washpool catchment upstream of the Washpool; Cox Rd sedimentation basin and Hart Rd wetlands (Zukowski and Whiterod 2021). These surveys recorded populations of common galaxias at both sites, suggesting that, despite the physical barriers involved, migration of this species from the sea to these locations, is occurring. Unfortunately, two introduced pest fish species were also recorded; redfin perch, *Perca fluviatilis*, at Hart Rd wetlands and eastern gambusia, *Gambusia holbrooki*, at Cox Rd. Neither of these species are diadromous.

Figure 34. Juvenile (whitebait) common galaxias in the Washpool outlet channel, 12th August 2011 (photo: Julie Burgher (FoAS 2022)).

Figure 35. Caspian tern hovering over (left) and plunging into (right) the Washpool lagoon, 19th July 2012 (photo: Julie Burgher (FoAS 2022)).

To better understand the fish community of the Washpool, Aquasave-NGT undertook baseline fish monitoring on 7-8th October 2022. Four sites were sampled across the wetland (Figure 36, Table 2). All sites were sampled using 4 x single-winged fyke nets set overnight. All sampled fish were identified to species level (Allen et al. 2002), counted and observed to obtain general biological information (reproductive condition and external disease or parasites). Total length (TL, mm) was recorded for all individuals for each species per net. Records of other fauna opportunistically sampled were noted. At each site, environmental descriptors such as pool condition, flow and water quality were recorded. All monitoring was conducted in accordance with relevant permits (PIRSA Ministerial Exemption: ME9903173).


Figure 36. Sites sampled in October 2022 across the Washpool.

Table 2. Location data for fish sampling sites in October 2022 across the Washpool.

| Site Number | Description | Easting | Northing |
|---|---|---|---|
| Site 1 | Deepest area of the Washpool, north of Button Rd | 268333 | 6088634 |
| Site 2 | Open water south of Button Rd | 268276 | 6088546 |
| Site 3 | Channel upstream of weir | 268188 | 6088661 |
| Site 4 | Outlet channel downstream of weir | 268131 | 6088670 |

Twelve Common Galaxias (*Galaxias maculatus*), a small bodied native diadromous species (Figure 37), were sampled. Fish were only recorded at site 4, in the outlet channel downstream of the weir, with no fish found at sites 1–3 in the Washpool lagoon proper. Common Galaxias sizes ranged from 41 mm OCL to 149 mm OCL, with the majority (10) of fish sampled under 50 mm OCL. Other opportunistic catch included tadpoles (Banjo Frog, *Limnodynastes dumerilii* and Spotted Marsh Frog, *Limnodynastes tasmaniensis*) and freshwater shrimp.

Figure 37. Common Galaxias caught in the Washpool outlet channel, downstream of the weir (photo: Sylvia Zukowski).

At the time of sampling, the Washpool was full with moderate flows over the weir. The mouth was closed (pebble embankment in place) and water levels in the outlet channel were high (c.2.4 mAHD). A strong presence of filamentous green algae was present in sites 1 and 2.

Water quality (WQ) parameters showed some variability between sites. At Site 1, electrical conductivity (EC: 1737 µScm$^{-1}$), dissolved oxygen concentration (DO: 5.5 mgL$^{-1}$), and water temperature (14.9°C) were higher than that found at Site 2 (EC: 1316 µScm$^{-1}$, DO: 2.1 mgL$^{-1}$, temp: 13.7°C) whilst pH was lower at Site 1 (pH: 6.7) compared to pH at Site 2 (7.04). No WQ data were collected at Site 4, however see Section 5.2.2 for EC data for the outlet channel downstream of the weir obtained two months prior.

Table 3. Water quality parameters at Washpool in October 2022.

| Site Code | EC (µS.$cm^{-1}$) | DO (mg.$L^{-1}$) | Temp (°C) | pH |
|---|---|---|---|---|
| Site 1 | 1737 | 5.5 | 14.9 | 6.7 |
| Site 2 | 1316 | 2.1 | 13.7 | 7.04 |
| Site 3 | 1823 | 5.7 | 14.1 | 6.8 |
| Site 4 | no data | | | |

## 6. Summary of Previously Recommended Actions

The idea of restoring the Washpool and surrounds is not new and one of the most ecologically and hydrologically informed proposals is also one of the oldest (Stokes and Harris 1976). Proposals predating this current assessment date back to at least the early 1970s and are summarised below.

**NCSSA 1970**

- In 1970 the Nature Conservation Society of South Australia (NCSSA) proposed that Section 296 be purchased by the State Planning Authority and that restoration of the Blue Lagoon and Washpool be undertaken “by diversion of water from the agricultural drainage channel” and that “a spillway could be constructed to the sea” (Stokes and Harris 1976). Note that Section 296 is approximately the original outline of the Washpool. The Blue Lagoon is located within historic Section 614.

**Stokes and Harris 1976**

- In response to the NCSSA, the SA Department for the Environment undertook an assessment of the merits of the purchase of Section 296 by the State Planning Authority and restoration of the Blue Lagoon and Washpool (Stokes and Harris 1976). This assessment found that the NCSSA proposal was “basically sound as the likely return of waterbirds to the lagoon would enhance the beauty of the [Aldinga] scrub and add to the educational value of this area”. The authors noted:
    - “… the present drainage scheme must be maintained in a form which does not restrict the reasonable flow of water from the adjacent rural areas.”;
    - “Extensive earthworks would … be required to remove the silt from this area (up to 1.8 metres) should the lagoon and Washpool be reinstated to their original condition.”;
    - “Although under normal conditions the waterspread would probably not interfere with housing in the Silver Sands area, flooding may occur under extreme conditions. This problem could be readily overcome by the construction of a levee bank around the western boundary of the [Washpool] lagoon adjacent to the subdivision. It may be feasible for such a levee to be constructed by using the silt which would be excavated from the main body of the Blue Lagoon and Washpool areas.”;
    - To prevent an undesirable backwater effect upstream of the Washpool “A spillway would … be required at the outlet of the [Washpool] lagoon to regulate the level of water held during winter months.”

**B.C. Tonkin and Associates 1977**

- B. C. Tonkin and Associates subsequently undertook a feasibility study for the then State Planning Authority (B. C. Tonkin and Associates 1977). The engineers at B. C. Tonkin and Associates interpreted their task as the conversion of the Washpool into a permanent waterbody. They recommended a constructed lagoon with a depth of 2.5 m, area 20 ha and WSEL 4.0 mAHD when full. Little to no consideration was given to existing ecological values or cultural values. Mercifully, this vision for the future of the Washpool failed to gain any momentum.

**Lucas 1989**

- The proposal to develop the Washpool as a marina with residential and commercial precinct in the 1980s initiated a number studies including an anthropological study of the significance of the area for Kaurna (Lucas 1989). Draper and Maland (2021) stated "Lucas' informants expressed … views on the need to preserve and rehabilitate the Washpool in a naturally functioning wetland context, which would support native plants and wildlife, as well as retaining the essence of the cultural landscape made by the Kaurna creation Ancestors. This was seen as having some interpretative and educational potential for tourism and schools - but more importantly, for the cultural survival of the younger generations of Kaurna people."

**Friend of the Earth 1989**

- FoE (Willunga) and representatives of the Field Naturalists Society, Friends of the Aldinga Scrub, Ngurlonga Nunga Centre, as well as Mr Jim Fletcher, Councillor for McLaren Vale Ward, presented a map and concept plan to state Environment and Planning Minister Susan Lenehan on 4th October 1989 (Friends of the Earth 1990), which attempted to address Environmental and Aboriginal Heritage problems with the Park, and provide protection for Aldinga Scrub, the Washpool and Blue Lagoon.

**Kinhill 1996**

- In 1996 Kinhill Engineers were engaged by the District Council of Willunga to investigate options for the reestablishment of the Washpool Lagoon (Kinhill 1996). The objectives of the project were to:
    - restore and enhance the habitat and environmental values of the wetland;
    - improve in the quality of water being discharged into the sea from the Washpool catchment;
    - provide 100 year ARI flood protection for the adjoining subdivision; and
    - conserve plant species of conservation significance on the site.
- Kinhill subsequently produced a report identifying three possible design concepts for the rehabilitation of the site. Option two was selected by the Committee and following community consultation, was endorsed by the former District Council of Willunga in 1997.
- The design concept incorporated two large mainly shallow wetland ponds. The main wetland received inflow from the greater Washpool catchment while the smaller received runoff from the adjacent residential catchment of Silver Sands. The static water level of both was to be provided by a single outlet weir.

**ACHM 2000**

- ACHM (2000), giving consideration to restoration proposals under consideration at the time, and based on consultation with a large number of Kaurna participants, considered to be a consensus view at the time, stated that participants "believe that any wetland rehabilitation and management process must recognise the great cultural heritage significance of this locality for Indigenous people, particularly the Kaurna Traditional Owners. Involving Kaurna fully, on the management of the rehabilitation and the future management of this area, is essential to recognise and support their traditional cultural status and responsibilities with respect to the area. This is most important to them – ongoing recognition and involvement in looking after this area and the Washpool, not just a consultation with them about a process that is otherwise external to them." Quoted in Draper and Maland (2021).

**Ecological Associates 2003:**

- In a report addressing the environmental water requirements of Aldinga Scrub, the Blue Lagoon and the Washpool, Ecological Associates (2003) proposed:
    - "The level of the outlet sill [of the Washpool] could be raised to increase the depth, extent and duration of flooding. A higher sill would also reduce the inflow of sea water [to] the wetland"; and
    - "The area of the Washpool subject to regular inundation is believed to have declined through sedimentation, the dumping of fill, land reclamation and water regime manipulation … These recent materials could be excavated to increase the extent of shallow flooding and available wetland habitat."

**QED 2007:**

- In 2007, City of Onkaparinga and Planning SA commissioned consultants QED Pty Ltd to prepare the Washpool Lagoon and Environs Management Plan (QED 2007) to provide a "comprehensive and coordinated approach, to protect and conserve the Washpool Lagoon and surrounding environs' environmental values, Kaurna Cultural Heritage whilst enhancing the social and recreational opportunities of the area". The plan included proposals to:
    - increase the area of submerged habitat (samphire areas) in the Washpool and increase the duration of ponding later into the summer period, to provide an environment suitable for waterbird breeding and improved habitat conditions;
    - remove Button Rd and reshape the wetland bed;
    - remove the small dam near Button Rd and reshape to natural surface;
    - excavate/reshape to create additional samphire habitat north and west of existing;
    - using material gained from above, create levee to 3.0 mAHD between samphire and Silver Sands stormwater outlet;
        - This levee appears to have been constructed between the outlet weir and Button Rd, as indicated by the topography. Western et al. (2020) stated the levee "has been installed and random checks along the top of the levee in the digital elevation model confirm that the installation height is 3.0m AHD or above".
    - backfill inflow channels to some extent;

  - maintain the current weir height to ensure that there is no actual or perceived increase to the risk of flooding of the adjacent Silver Sands residential area;
  - contain urban runoff from Silver Sands away from the Washpool Lagoon in a constructed detention and treatment system including linear ponds that would discharge to sea via the existing outlet channel.
- The Plan did not propose to alter the existing water regime of the Blue Lagoon, stating "the objectives of the project are to maintain existing ecosystems on the site rather than try to restore historical ecosystems."

**SKM 2008:**

- In 2008 the City of Onkaparinga commissioned consultants SKM to prepare a Restoration Action Plan for Washpool Lagoon (SKM 2008) based on the Washpool Lagoon and Environs Management Plan prepared by QED (2007). Recommendations of the Action Plan included:
  - improved ecological monitoring;
  - a program of revegetation;
  - upgrading the outlet weir to prevent leakage (but not raising the height of the weir);
  - partial excavation of accumulated sediment and the creation of an island in the north-eastern area of the Washpool;
  - relocation of "the embankment", i.e. the spoil mound of the drain cut by Mr Herrick in 1950 (see Section 4.2), closer to Silver Sands to increase the area of the Washpool subject to regular inundation;
  - the creation of sedimentation pond where the main inflow drain first enters the Washpool;
  - remove the section of Button Rd passing through the Washpool;
  - creation of walking trails and interpretive signage;

**KBR 2011**

- KBR (2011a) was commissioned by City of Onkaparinga to assess flood risk to Silver Sands. The report is not focussed specifically on the restoration of the Washpool but does provide some valuable insights. Modelling examined the impact of raising the outlet sill of the Washpool and building a levee along the eastern and southern boundary of the Silver Sands estate upon peak water levels in the Washpool in a 1 in 100 year flood. For simplicity, the model raised the Washpool outlet sill at the mouth of the outlet channel, not at the location of the existing concrete weir, i.e. the model did not account for storm water drainage from Silver Sands to sea. Sill elevations of 2.5, 2.8 and 3.0 mAHD were modelled and the peak WSEL along the Silver Sands levee reported. Under the highest sill elevation (3.0 mAHD) peak WSEL ranged from 3.76 mAHD at the south-western edge of Silver Sands to 4.83 mAHD near the north-eastern edge. Notably, no properties upstream of the Washpool experienced increased flood levels as a result of the placement of the flood levee or raising the outlet weir of the Washpool.

**Southfront 2020**

- Southfront (2020) prepared the Silver Sands Catchment Stormwater Management Plan for the City of Onkaparinga. It includes the following goals:
    - protect development from above floor inundation from all events up to and including the 100 year ARI event;
    - manage flows to provide a flow regime that supports restoration / protection of the Washpool and Aldinga Scrub Recreation Park;
    - restore and protect natural riparian values within the Washpool and Aldinga Scrub Recreation Park; and
    - maintain environmental flows to support water dependent ecosystems.

# 7. Estimating the Pre-Colonial WSEL at CTF

## 7.1. Using Early Colonial Maps and Contemporary DEM

Determining the water surface elevation (WSEL) when the wetland was full (i.e. at cease-to-flow (CTF)) in its pristine state is central to the hydrological restoration of any wetland. Ideally, early colonial maps of the wetland can be compared to the contemporary bathymetry (DEM) and the contour line (elevation) that best coincides with the original wetland extent determined. In the case of the Washpool we have early colonial maps (See Section 3.2) and high resolution contemporary DEM to enable this approach. However, the bathymetry of the Washpool has changed considerably due to sedimentation, possible mining, land reclamation and related activities (see Section 5.4), meaning there is no neat alignment between contemporary bathymetry and historic mapped extent. Despite this, there is some value in examining the extent of inundation that would be achieved under different water surface elevations. There are parts of the wetland where, as indicated by the available sediment core data and interpretation (Dyson 2000), the bathymetry appears little changed from its pre-colonial condition.

Figure 38 compares Richard Counsell's 1839 mapped extent of the Washpool with the extent of inundation indicated by the contemporary DEM for a range of water surface elevations. Note this mapping is theoretical only. Any raising of the Washpool water level would require protection of the Silver Sands estate using a levee. The maps show that re-engagement of the southern arm of the Washpool (south of Button Rd) is best achieved when the WSEL is 2.9 mAHD or higher. An area south of Button Rd but west of the original mapped wetland becomes inundated even at 2.8 mAHD. This area may have been mined for sand (see Section 5.4). An area of low ground along the north-western edge of the Washpool, between Counsell's extent and the Silver Sands estate, becomes inundated at or above 2.8 mAHD. It is unclear if this is due to an inaccuracy in Counsell's mapping or more recent mining or excavation. Above 3.2 mAHD inundation extends beyond even this edge and is therefore likely higher than pre-colonial. For the range presented, the legacy of Herrick's drain, subsequent sedimentation (see Section 4.2) and land reclamation in the far north of the original Washpool (see Section 5.4) are apparent. The south-eastern shoreline of the Washpool shows good alignment with Counsell's map across the full range of WSELs examined, reflecting the steep gradient of the ground to the immediate south-east of the wetland.

It is difficult to discern the pre-colonial WSEL at CTF by comparing Counsell's map with the contemporary DEM, however a WSEL of 2.9 mAHD or higher best extends inundation though the southern arm of the Washpool while a WSEL of 3.2 mAHD or higher appears to extend inundation to the north-west well beyond Counsell's mapped extent even accounting for some mapping inaccuracy.

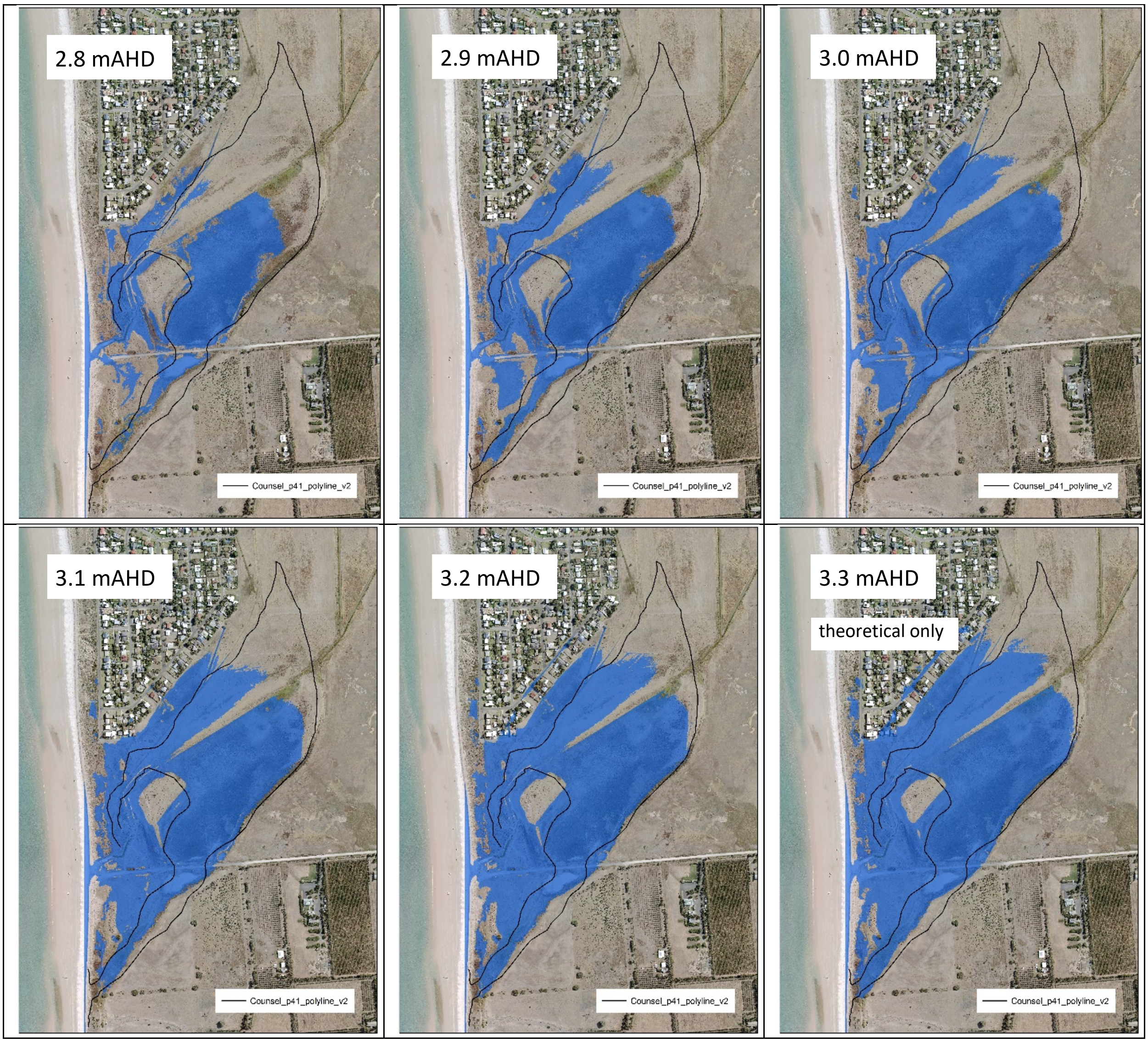



Figure 38. Comparison of Richard Counsell's 1839 mapped extent of the Washpool and the theoretical extent of inundation indicated by contemporary DEM (blue shading) for a range of water surface elevations.

## 7.2. Using Wetland Vegetation Water Regime

As discussed in Section 3.1, dropping water levels in the Washpool exposed mudflats on the southern edge of the Washpool and animal skins were cured by the Kaurna by pegging them, fur side uppermost, onto the exposed mud (Nobbs 1973). Presumably the curing process required maximum contact between skin and mud. This would not be achievable if the bed of the Washpool supported perennial vegetation, such as the *Salicornia quinqueflora* ssp. *quinqueflora* saltmarsh that dominates today. The lowest elevations of the Washpool must therefore have been largely free of perennial vegetation. A small (0.37 ha) area of this open mudflat persists today immediately south of Button Rd. However, as discussed in Section 3.5, comparison of the 1949 and 2020 aerial images reveals it was formerly more extensive, occupying approximately 2.15 ha in 1949. Given that hydrological changes to the Washpool were well advanced by 1949 (see Section 4.2), it is likely this open mudflat area was even more extensive prior to colonisation.

A useful way of describing the zonation of wetland vegetation, and how water regime creates and maintains this zonation, is the "Wetland Vegetation Component" (WVC) models developed for the (then)

SA Government Department of Water, Land and Biodiversity Conservation (Ecological Associates 2009, 2010). The WVC models were developed for wetlands in the South East region of SA but are equally applicable to the Willunga Basin with its similar climate. The models describe the water regime and salinity required to maintain different wetland plant communities and have been used in the calculation of environmental water requirements for wetlands. The WVCs present at the Washpool are:

- WVC 1.8 *Gahnia filum* tussock sedgeland
    - Occupying the highest elevations that are subject to brief, shallow seasonal inundation or waterlogging with brackish water. The target salinity is 6 – 10 mS/cm and the target maximum depth is 10 – 30 cm, although this WVC can occur in areas not subject to inundation but waterlogging only (Ecological Associates 2010). This WVC corresponds with "*Gahnia filum* Sedgelands" mapped at the Washpool by T&M Ecologists (2016).
- WVC 1.11 Seasonal freshwater emergent sedgeland
    - Occupying intermediate elevations subject to longer, deeper inundation with fresh to brackish water (note the word "freshwater" in the name of this WVC is somewhat misleading as it actually has a broad salinity tolerance). The target salinity is 1 – 9 mS/cm and the target maximum depth is 40 – 60 cm (Ecological Associates 2010). This WVC corresponds with "*Bolboschoenus caldwellii* +/- *Typha domingensis* Sedgelands" mapped at the Washpool by T&M Ecologists (2016).
- WVC 1.12 Samphire low herbland
    - Occupying a similar elevation band to WVC 1.11 and subject to the same degree of inundation but with a higher salinity tolerance. The target salinity is 4 – 20 mS/cm and the target maximum depth is 40 – 60 cm (Ecological Associates 2010). At the Washpool this WVC extends to lower elevations than WVC 1.11 but has a similar upper elevation. It corresponds with "+/- *Tecticornia* spp. +/- *Sarcocornia* [syn. *Salicornia*] spp. Low Shrublands" mapped at the Washpool by T&M Ecologists (2016).
- WVC 1.2 Seasonal brackish aquatic bed
    - Occupying the lowest elevations subject to the longest, deepest inundation with brackish water. Target salinity is 3 – 16 mS/cm and target maximum depth is 70 – 90 cm (Ecological Associates 2010). This WVC corresponds with the unvegetated (when dry) mudflat immediately south of Button Rd. It is the open mudflat that is observable north of Button Rd in the 1949 aerial image (see Section 3.5, Figure 8). T&M Ecologists (2016) did not describe or map the vegetation of this area. Typical vegetation of this WVC includes *Ruppia* spp. aquatic beds when inundated and very sparse, low herbs such as *Wilsonia* spp. and *Salicornia* spp. when dry (Ecological Associates 2010).

The typical zonation of WVCs across the elevation gradient of a wetland and the target hydrograph (water regime) required to maintain that zonation are shown in Figure 39. Two target hydrographs are presented. The 1:1 target hydrograph should ideally be achieved every year while the 1:3 target hydrograph should ideally be achieved 1 year in 3 (i.e. it represents a wetter than average year).

Some points highlighted by the WVC models that are relevant to the Washpool and its potential hydrological restoration include:

- The deepest area of the Washpool that was mapped by Counsell in 1839 as "Salt Water Lagoon" was likely dominated by WVC 1.2 Seasonal brackish aquatic bed. The water regime to maintain this WVC is inundation to a maximum depth of 70 – 90 cm.
- With maximum depth of 44 cm at CTF, the contemporary Washpool water regime today favours WVC 1.11 Seasonal freshwater emergent sedgeland and WVC 1.12 Samphire low herbland throughout the lowest lying elevations, i.e. within the area historically occupied by WVC 1.2 Seasonal brackish aquatic bed. This is likely why samphire has expanded downslope, displacing seasonal brackish aquatic bed.
- The above points suggest that restoration of the pre-colonial wetland vegetation of the Washpool could be achieved by increasing the maximum depth from 44 cm to 70 - 90 cm (i.e. raising the WSEL at CTF from 2.64 mAHD to 2.90 - 3.10 mAHD). This would, over the course of several years, lead to the upslope migration of all existing WVCs and the expansion of WVC 1.2 Seasonal brackish aquatic bed to cover much of the lowest lying area currently occupied by WVC 1.12 Samphire low herbland and, to a lesser extent, WVC 1.11 Seasonal freshwater emergent sedgeland.

In summary, the pre-colonial WSEL of the Washpool at CTF was likely within the range of 2.90 – 3.10 mAHD, as determined by the following lines of evidence:

- Comparison of contemporary bathymetry with the earliest colonial maps of wetland extent;
- Pre-colonial use of the wetland bed by Kaurna and what this reveals about the original vegetation;
- Historic aerial imagery and what it reveals about changes to the original vegetation;
- Scientific understanding of the water regime, including maximum depth, required to restore/maintain the original vegetation.

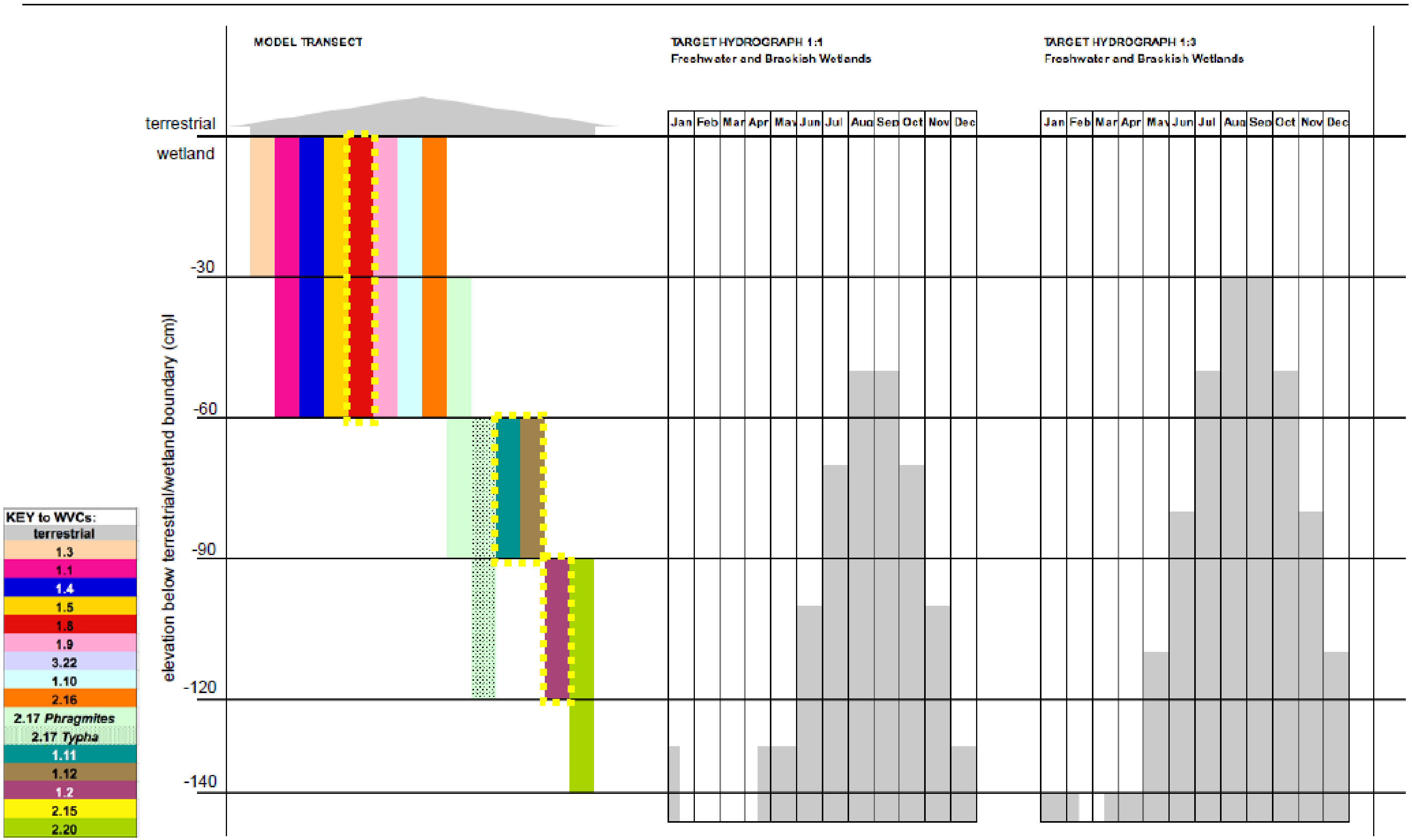



Figure 39. Typical zonation of WVCs across the elevation of a wetland and target hydrograph required to maintain that zonation (source: Ecological Associates 2010). WVCs present at the Washpool are highlighted (yellow dashed boxes).

# 8. Restoration Options

The information and lines of evidence presented in preceding sections of this report provide the foundation for determining a baseline or "natural" state against which restoration can be compared. The following section outlines interventions which offer potential for setting the Washpool back on a trajectory toward its pre-colonial state.

## 8.1. Option 1: Construct Levee with Spillway

This Option, or variations of it, has been proposed previously by Stokes and Harris (1976), Ecological Associates (2003), QED (2007) and SKM (2008).

The current extent of inundation within the Washpool when full (i.e. with a WSEL of 2.64 mAHD, the elevation of the crest of the existing concrete outlet weir) is 9.55 ha, much smaller than the 26 ha historical extent as mapped by Counsell in 1839. Evidence suggests there are two broad reasons for this:

- the sill elevation has been lowered by the excavation of a (deeper than natural) outlet channel through the coastal dunes to the sea; and
- accumulated sediment has raised the bed of the Washpool.

Hydrological restoration requires both of these issues to be addressed. Option 1 relates to the first. Ideally, the natural sill elevation would be reinstated in its original location; the original outlet. This might involve re-establishing the sand dunes and pebble bank across the existing outlet at a higher elevation, thereby forcing the Washpool to fill to a higher level before spilling to sea. However, the Washpool outlet channel receives flows, not just from the Washpool itself (via the concrete weir), but also from drains running along the south-eastern edge of the Silver Sands estate carrying stormwater (see Section 5.1). Raising the sill of the outlet channel would therefore prevent storm water generated within Silver Sands from flowing freely to sea as currently occurs.

The construction of a levee between the Washpool and the Silver Sands estate is proposed so that water levels in the Washpool can be restored to their original elevation without affecting the stormwater drainage service to Silver Sands. To estimate the crest elevation of the levee we have assumed:

- that the Washpool historically reached a WSEL of 3.1 mAHD when full (the upper limit of the 2.9 – 3.1 mAHD range estimated in Section 7);
- the Washpool would surcharge up to 0.4 m above CTF during brief high inflow periods. Water level monitoring obtained for this project (see Section 5.2.2) shows a maximum WSEL of 2.83 mAHD in the Washpool, i.e. a 0.19 m surcharge above the weir crest of 2.64 mAHD. A predicted maximum surcharge of 0.4 m for a restored Washpool with a larger surface area and a broad spillway is therefore conservative;
- to protect the integrity of the levee it would require 0.5 m of freeboard above maximum WSEL in the Washpool.

Based on the above assumptions the crest of the proposed levee should have an elevation of 4.0 mAHD. The levee therefore needs to extend across ground where the existing surface is below 4.0 mAHD. The levee alignment is shown in Figure 40. Its total length is 1,100 m and the structure grades into an existing surface of 4.0 mAHD at either end. A spillway is located at the location of the existing concrete weir. Factors to consider in the design of the spillway include:

- *choice of the correct sill elevation*. We have assumed 3.1 mAHD but a trial phase, with an adjustable spillway height, is recommended initially. A spillway initially constructed of geofabric sandbags has been used by NGT during trial phases at many wetland restoration sites. This allows fine scale adjustments to be made quickly and cheaply until the ideal sill elevation is achieved. Subsequently, the spillway can be permanently set in place.
- *minimisation of surcharge*. Wider spillways can accommodate high flows with less effect on upstream water levels than narrower ones.
- *erosion protection*. A headloss of up to 1.5 m from the Washpool into the outlet channel could occur at times. This has potential to cause erosion on the downstream side of the spillway and necessitates a degree of armouring. Additionally, high sea levels and wave action have the potential to erode the seaward side of the levee in the vicinity of the mouth of the outlet channel, particularly under sea level rise predicted in the latter half of this century (City of Onkaparinga 2022).

A distance of c.80 m can be maintained between the levee and Silver Sands property boundaries, incorporating a natural swale and the existing Silver Sands stormwater drain. This will ensure any seepage through the levee is directed to sea.

Note that previous modelling by KBR (2011a), while not perfectly analogous with Option 1, strongly suggests that the Option 1 levee and spillway as proposed would not cause increased flood risk to properties upstream of the Washpool.

If Options 2 and 3 (below) are also implemented, the excavated material may be suitable for levee construction. This would reduce the cost of both levee construction and sediment removal. Our preliminary estimate of the volume of material requiring excavation under Options 2 and 3 is approximately 57,520 $m^3$. We have not estimated the volume of material required to construct the levee as the question of width and trafficability (vehicular (for maintenance) or pedestrian only) still need to be resolved.

The existing rain-induced flood risk to Silver Sands has been investigated (KBR 2011a, b, Southfront 2020) and the construction of a flood mitigation levee has been proposed as a potential measure (KBR 2011a). Sea level rise also poses a flood risk to Silver Sands but impacts to housing do not become apparent until 2100 (Western et al. 2020). The levee we propose under Option 1 has the objective of restoring the natural hydrology of the Washpool for ecological enhancement. It may be possible to marry the objective of Silver Sands flood mitigation and Washpool restoration within a single levee structure. This would require further detailed investigation and close collaboration between key parties, particularly City of Onkaparinga, National Parks and Wildlife Service and Kaurna Yerta Aboriginal Corporation.


Figure 40. Proposed levee alignment.

Pre-requisites to the implementation of Option 1:

- Washpool catchment modelling to ensure sufficient water availability to justify increased Washpool volume (see Section 9);
- Assessment of the suitability of accumulated sediment within the Washpool as levee construction material (if Options 2 and 3 are also implemented);
- Confidence (modelling may be required) that the levee will not exacerbate flood risk to Silver Sands during periods of high stormwater runoff and/or high seas;
- Detailed design including:
    - Determine the required width of the levee, a question of the required trafficability (vehicular (for maintenance) or pedestrian only);
    - Determine spillway design that minimises Washpool surcharge level during high inflows (hydraulic modelling may be required);
- Cultural heritage assessment of the levee footprint;
- Flora and fauna assessment of the levee footprint and implications of restored hydrology within the Washpool.

## 8.2. Option 2: Remove Central Bund

Option 2 was proposed in Project Update 2, 21st December 2021. For simplicity we have combined removal of the central bund with Option 3 below, as the central bund is actually just one part of a larger area of accumulated sediment and its removal in isolation would have limited effect.

## 8.3. Option 3a: Remove Accumulated Sediment

Note this is a combination of Options 2 and 3 as described in Project Update 2, 21st December 2021.

This Option has been proposed previously in various forms by Stokes and Harris (1976), ACHM (2000), Ecological Associates (2003), QED (2007) and SKM (2008).

The objective of removing accumulated sediments as proposed here is to reveal and restore the natural bathymetry of the Washpool, thereby restoring the full extent of wetland habitat. It is not, as was the case with some previous proposals, to create deep areas that did not naturally occur in the Washpool.

The removal of accumulated material comes with risks that would need to be carefully managed, specifically:

- damage to Kaurna cultural heritage;
- risk of exposing acid sulphate soils; and
- damage to threatened species and/or ecological communities.

These risks are discussed further below.

The extent and depth of excavation proposed here is informed by a comparison of current topography (DEM and survey data provided by City of Onkaparinga) with the original extent of the Washpool as mapped by Counsell in 1839 and also by the sediment core analysis undertaken by Dyson (2000). However, our proposal is preliminary and considerably more confidence regarding the extent and depth of excavation is required before proceeding. Options for more accurately determining the extent and depth of excavation required include:

- an interpretation of sediments as per the approach of Dyson (2000);
- pine pollen analysis, which uses the presence in sediment of pollen from introduced pine species to determine the boundary between pre- and post-colonisation sediments and is a relatively cheap method (John Tibby, pers. com., 2/6/2022);
- electrical resistivity tomography (ERT) data, collected via lines of metal pegs connected by electrical cables (Figure 41) and providing a high resolution profile of the subsurface in the area surveyed. At the Washpool, where the depth of sediments deposited post-colonisation is less than 1 m (Dyson 2000), ERT should enable the depth of the original bed to be accurately determined ERT, ideally undertaken during the dry phase. A preliminary estimate for the use of ERT to map the relevant 9 ha area of the Washpool is 4 days for a cost in the order of $35,000 (Dr Ian Moffat, Flinders University, pers. com., 5/2022).

Figure 41. Electrical resistivity tomography in progress (photo courtesy of Dr Ian Moffat, Flinders University).

A much improved coverage of points for which the depth of post-colonisation sedimentation is required before proceeding. Ideally, a simple and cost effective approach, such as hand auguring and visual assessment, would be compared to more sophisticated techniques over a small area and, if a good correlation was found, the simpler approach applied more broadly.

The proposed extent of excavation, and the target elevation (in mAHD) of the bed of the wetland following excavation, is shown in Figure 42. The Washpool as mapped by Counsell in 1839, including both the inner "Salt Water Lagoon" and peripheral "Swampy" outlines, are also shown for reference. The total area proposed for excavation is 9.04 ha. The area recommended for excavation down to 2.4 mAHD corresponds with Counsell's "Salt Water Lagoon" area, i.e. historically the deepest area of the Washpool. Areas recommended for excavation down to 2.7 and 3.0 mAHD lie within the area mapped as "Swampy" by Counsell. In reality, if excavation was undertaken, a gradually sloping bed would be contoured from 2.4 to 3.0 mAHD, not the stepped approach presented here for simplicity.

We have used the available DEM and ArcGIS tools to estimate the volume of material requiring excavation as 57,520 $m^3$. This should be considered a preliminary estimate. As stated in Section 8.1, ideally the excavated material would be used to construct the levee proposed under Option 1. The degree of similarity between the volume to be excavated and the volume required for levee construction will determine the requirement for the dumping of excavated material offsite or the importation of material for levee construction, both of which will add to costs and should therefore be minimised.

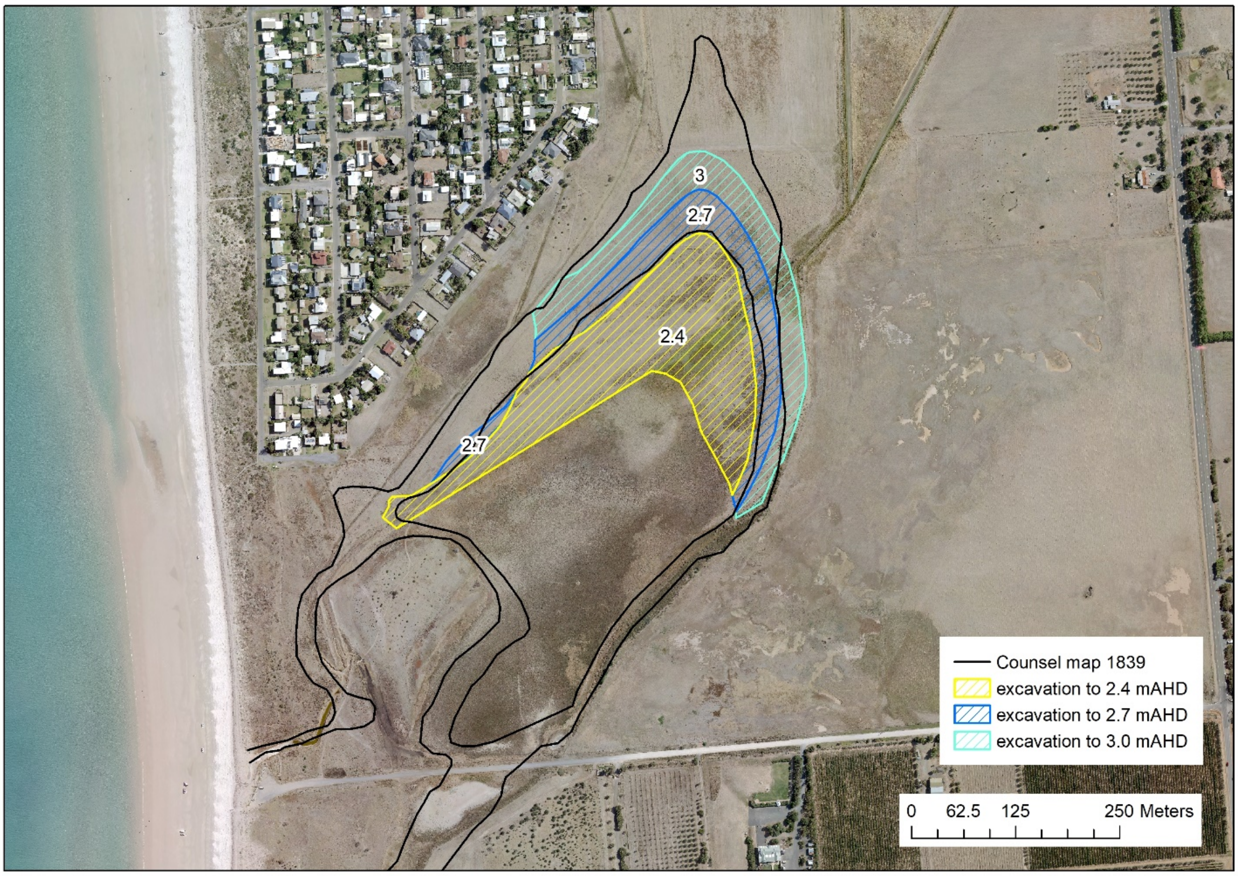



Figure 42. Proposed extent and target surface elevation of excavation within the Washpool. Counsell's 1839 map is shown for comparison.

In Figure 43 the proposed excavation is overlain on the DEM, illustrating that the excavation footprint includes the central bund, along with elevated ground on its northern side. Note we have not recommended excavation extend to the northern extremity of Counsell's Washpool outline because, in addition to sediment accumulation, deliberate land reclamation appears to have occurred in this area (see Section 5.3). The land surface is now up to 4.6 mAHD in this area, meaning a large volume of material would need to be excavated to achieve a wetland bed elevation of 3.0 mAHD, yet the area of wetland gained would be relatively small i.e. less than one hectare.

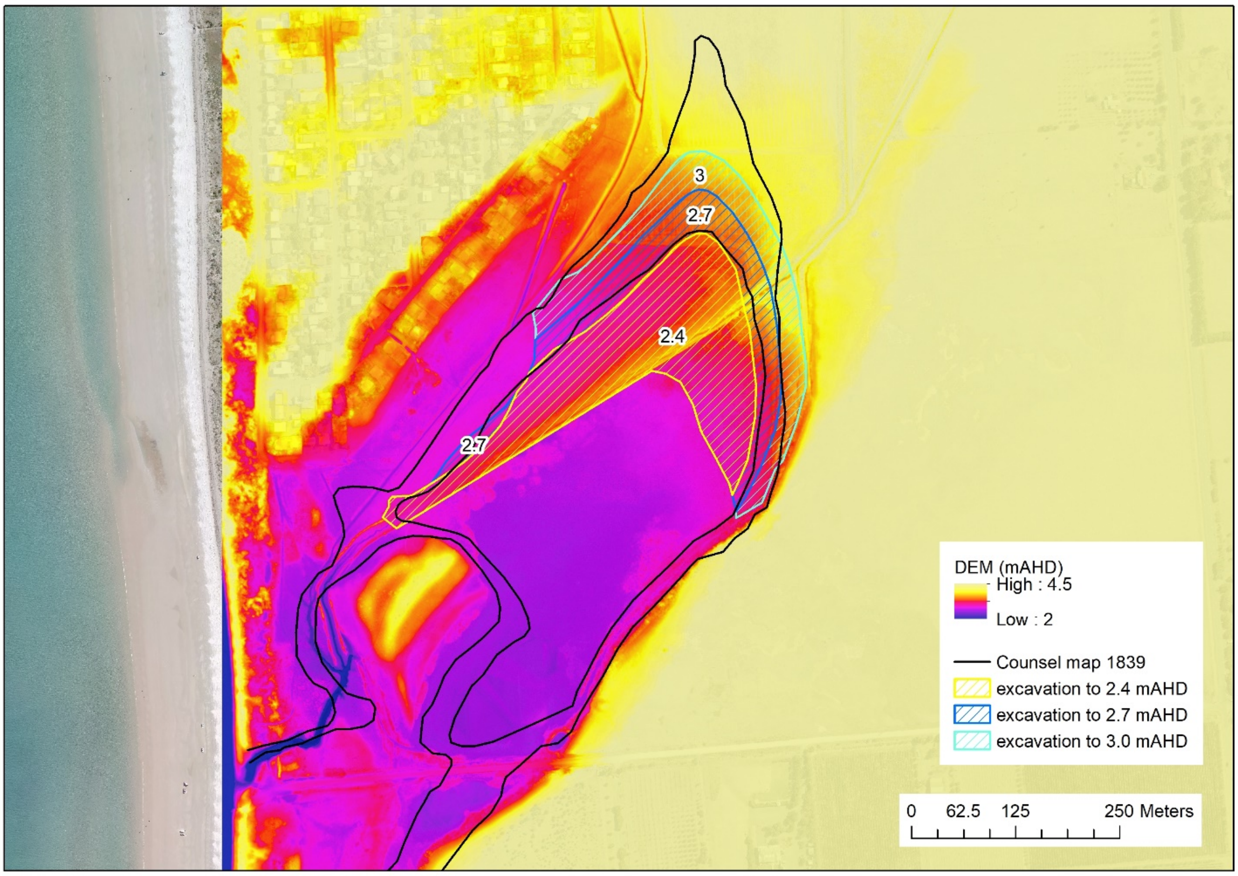



Figure 43. Proposed extent and target surface elevation of excavation within the Washpool overlain on the DEM. Counsell's 1839 map is shown for comparison.

The proposed extent of excavation avoids areas of native wetland vegetation in good and moderate condition (Figure 44) as mapped by T&M Ecologists (2016). Thus almost all of the samphire vegetation within the Washpool is avoided. *Gahnia filum* dominated areas are also avoided. Only poor or highly degraded vegetation lies within the excavation footprint, as do some areas where revegetation has been undertaken in recent years. This is an unfortunate but unavoidable side effect when hydrological restoration is not undertaken as the first step in wetland restoration. It is noted that revegetation at the Washpool has adopted a "no regrets" philosophy, acknowledging that ongoing restoration has the potential to disrupt revegetated areas, particularly given that excavation has been discussed since at least the early 1970s (see Section 6).

The proposed excavation footprint also avoids Kaurna cultural artefact locations identified in the South Australian Government's Register of Aboriginal Sites and Objects, informed by the most up to date mapping of cultural artefact locations at the Washpool and surrounds, field surveys conducted in August/September 2021 (Draper and Maland 2021). There are no known cultural artefact locations within the proposed excavation footprint and most are at least 30 m away, although the "6527-1872 Washpool Campsite" and a nearby artefact (Draper and Maland 2021) partly overlap the footprint. Some minor adjustment may be required to avoid these locations. It should also be noted that field surveys are unlikely to find artefacts buried beneath sediment. It is possible that the area of the Washpool that has been affected by sediment accumulation since colonisation contains buried artefacts. Careful management of potential cultural heritage material within the proposed excavation footprint would be required in the planning and implementation of this Option.

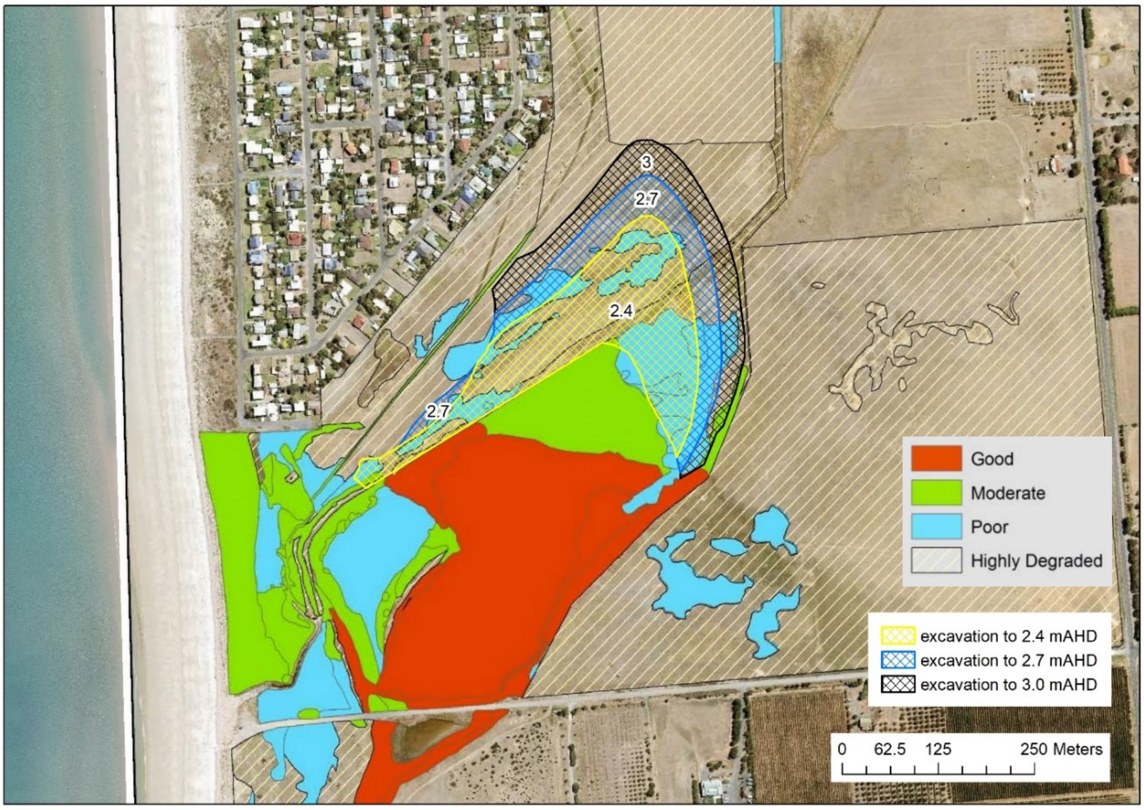



Figure 44. Proposed extent and target surface elevation of excavation within the Washpool overlain on vegetation condition mapping (source: T&M Ecologists 2016).

As noted in Section 5.2.3, the sedimentation of the bed of the Washpool appears to have slowed or ceased in recent decades, despite occasional inflows of highly turbid water during intense rainfall events. It may be the case that particles deposited during such events are of such a fine grade that they are readily removed via the natural process of deflation, i.e. the erosion by wind of uncemented lakebed sediments, during the annual dry phase. That some areas of the Washpool are free of recently deposited sediments (Dyson 2000) despite regular inundation with turbid water in recent decades suggests it is unlikely there will be a requirement for ongoing, regular removal of sediment; Option 3a is proposed as a once-only action.

The NatureMaps tool (DEW 2022) identifies the Washpool as a location susceptible to the development of acid sulphate soils. An assessment of the acid sulphate soil risk is therefore an essential pre-requisite of any proposed works involving soil disturbance.

In summary, pre-requisites to the implementation of Option 3a include:

- Accurate, fine scale determination of the depth (and thereby total volume) of sediments deposited post-colonisation within the proposed excavation footprint;
- Cultural heritage assessment of the excavation footprint (and cultural heritage monitoring during excavation);
- Assessment of the suitability of excavated sediments as material to construct the levee under Option 1;
- Acid sulphate soils risk assessment of proposed excavation footprint;

- Flora and fauna assessment of the excavation footprint.

## 8.4. Option 3b: Backfill Norman Drain

This Option is linked to Option 3a as it is a relatively minor piece of earthworks that, for cost effectiveness, would best be undertaken in conjunction with the more significant earthworks of Options 1 and 3a. However, it could potentially be undertaken as a stand-alone Option independent of other Options.

As explained in Section 4.2, neighbouring landholders Herrick and Norman collaborated to excavate a drain across the Washpool and into the outlet channel in c.1950. Much of this drain has subsequently filled with sediment and no longer functions as a drain. However, the most downstream 200 m section, the section excavated by Norman with a spoil bank on both sides (Figure 45), remains active. The drain is drawing water out of the Washpool and should be decommissioned.

Figure 45. Oblique aerial image of the Washpool, 8th October 2021, with Norman's double-banked drain highlighted (yellow dashed line) (photo courtesy of Damian Moroney, DEW).

Option 3b would involve the use of a small excavator to backfill this drain by moving the spoil heap material back into the drain. Due to sedimentation within the drain since construction, there may be insufficient volume within the drain void to accept all of the spoil bank material. The eastern (inland) spoil bank should be prioritised. If Option 1 (levee and spillway) is implemented, the western (seaward) spoil bank should be left *in situ* and incorporated into the levee as its location aligns almost perfectly with the proposed levee alignment.

Pre-requisites to the implementation of Option 3b:

- Cultural heritage assessment of the works footprint (and cultural heritage monitoring during excavation);

- Flora and fauna assessment of the works footprint.

## 8.5. Restored Washpool Volume, Area, Depth and Duration Comparison

Option 3 (remove accumulated sediment) would increase the area of wetland habitat, the maximum depth and the volume of water held within the Washpool, but the degree of increase would depend upon whether or not Option 1 (levee) was also implemented. Figure 46 shows the extent of inundation if Option 3 was implemented without any other actions and Figure 47 shows the extent of inundation if Options 1 and 3 were both implemented. The original extent of the Washpool as mapped by Counsell is shown for comparison. Options 1 and 3 combined show a reasonable alignment with the Counsell outline, although there would be inundation towards the western end of Button Rd that was not mapped as wetland in 1839. This could be related to historic sand mining from this area (see Section 5.3).


Figure 46. Extent of inundation in the Washpool at CTF if accumulated sediment were removed (Option 3) but existing concrete weir was maintained as sill.

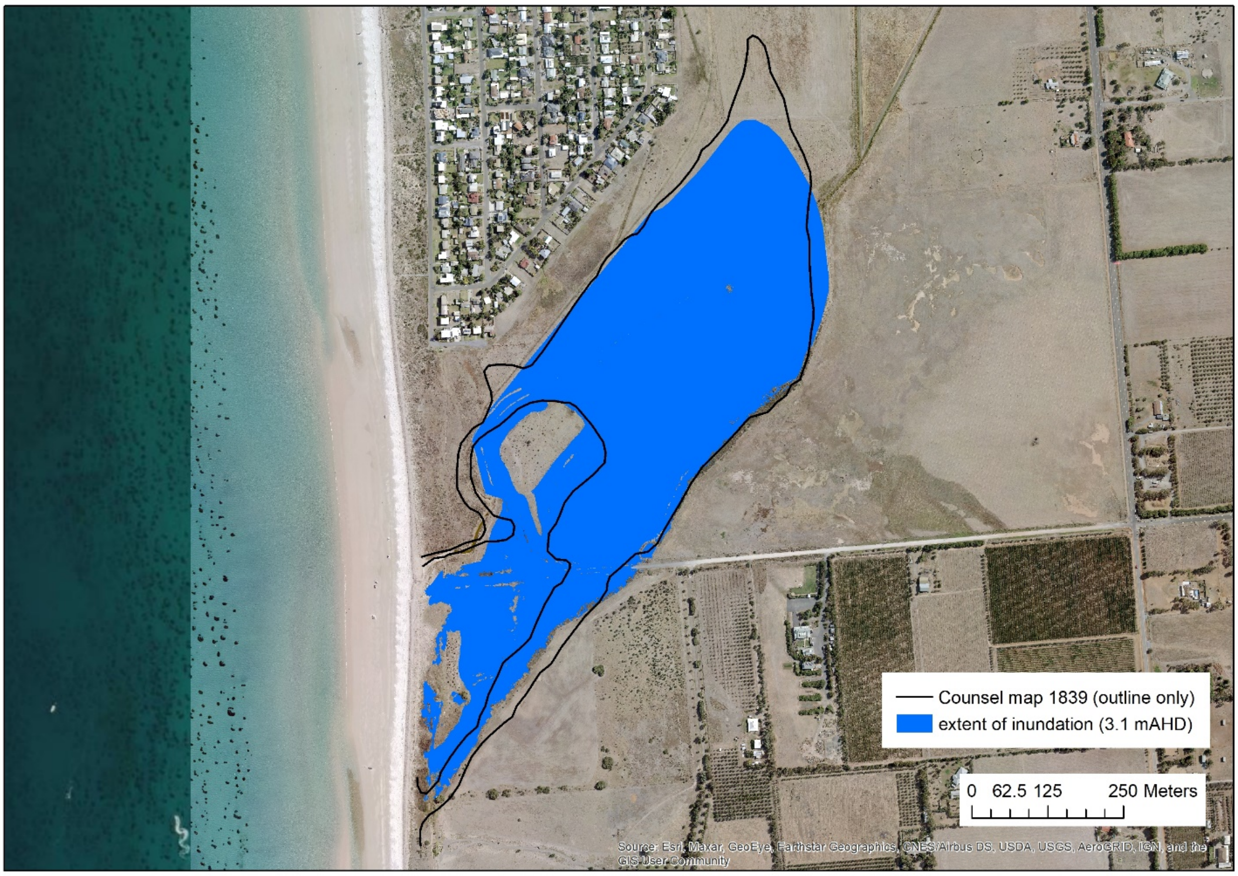



Figure 47. Extent of inundation in the Washpool at CTF if accumulated sediment were removed (Option 3) AND the sill was raised to 3.10 mAHD via construction of a levee with spillway (Option 1).

Table 4 provides a comparison of the area, maximum depth and volume of the Washpool under different combinations of restoration Options. For reference, the implications of removal of the existing concrete weir, an action pondered by some in the community, is included. In summary:

- if the existing concrete weir were removed and no other action was taken, the Washpool would effectively cease to hold water, as was the case prior to the weir's construction;
- implementation of Option 1 (levee) only would result in a 4-fold increase in area, a doubling of maximum depth and a 25-fold increase in volume;
- implementation of Option 3 (remove accumulated sediment) only would result in a doubling of area, no change to maximum depth and a 13.5-fold increase in volume;
- implementation of Options 1 and 3 in combination would result in a 5-fold increase in area, a doubling of maximum depth and a 45-fold increase in volume. This combination of Options most closely restores the original shape of the Washpool.

In spring and early summer 2021 water level in the Washpool declined at an average rate of 0.643 cm/day. Applying this same rate of decline, if the maximum depth of the Washpool was increased from its current 44 cm to 90 cm (Option 1), the period of inundation would be extended by approximately 70 days. This is likely to be an overestimate as the rate of decline would likely increase as summer progressed. An extension of approximately 6-8 weeks is likely under Option 1, meaning the Washpool may retain water until early to mid-February in years when it filled.

Table 4. Comparison of the area, maximum depth and volume of the Washpool at CTF under various combinations of restoration Options.

| WSEL (mAHD) | Action | Current Bathymetry | | | With Sediment Removed (Options 2 and 3) | | |
|---|---|---|---|---|---|---|---|
| | | **Area (ha)** | **Max. depth* (m)** | **Volume (ML)** | **Area (ha)** | **Max. depth* (m)** | **Volume (ML)** |
| 2.20 (approx.) | Remove concrete weir. Crest of pebble bank in outflow channel becomes Washpool sill – noting this varies markedly. | 0.03 | dry | 0.053 | 0.03 | dry | 0.053 |
| 2.64 | No action - retain concrete weir as sill | 9.55 | 0.44 | 2.79 | 14.2 | 0.44 | 37.71 |
| 3.10 | Construct levee with spillway (Option 1) | 21.8 | 0.90 | 69.24 | 27.54 | 0.90 | 126.46 |

*based on survey point data provided by City of Onkaparinga.

## 8.6. Option 4: Remove Western End of Button Rd

This idea has been proposed previously by Kinhill (1996), QED (2007), SKM (2008) and Draper and Maland (2021).

Option 4 involves the removal of the western-most 380 m of Button Rd, including the terminal car parking area at the mouth of the Washpool (Figure 48). Approximately 3,450 $m^2$ of road base would be removed to reveal the underlying natural surface, thereby restoring wetland and coastal dune habitat. Road removal would restore the integrity of the Washpool as a single, intact wetland feature. It would also likely provide Kaurna cultural heritage in the vicinity of the Washpool mouth improved protection from vehicle disturbance and rubbish dumping (Draper and Maland 2021). Related actions could include:

- establishment of an alternative walking trail to the beach along the eastern edge of the Washpool south of Button Rd (Figure 48);
- removal of the remains of the concrete boat ramp at the terminus of Button Rd.

Option 4 would provide relatively minor inconvenience for beach users as Button Rd currently provides pedestrian-only beach access, which is also provided 380 m north from Loongana Rd and 560 m south.

If Option 1 was implemented, the inundation of Button Rd would become a near annual event, much more frequent than is currently the case. This would likely create an annual public safety issue requiring management and increase the costs of maintaining Button Rd, making the case for its closure more compelling. If closure was not possible due to community opposition, alternative measures such as road raising and the installation of culverts would likely be required. Irrespective of the implementation of Option 1, the future of Button Rd should be carefully considered as, based on the engagement conducted by NGT for this report, there is widespread support, including from Kaurna representatives, for its closure.

Button Rd, in its current form and configuration, is likely to be required to facilitate access for implementing Options 1 and possibly Option 6. Therefore, implementation of Option 4 should not be undertaken until these options have been completed or ruled out.

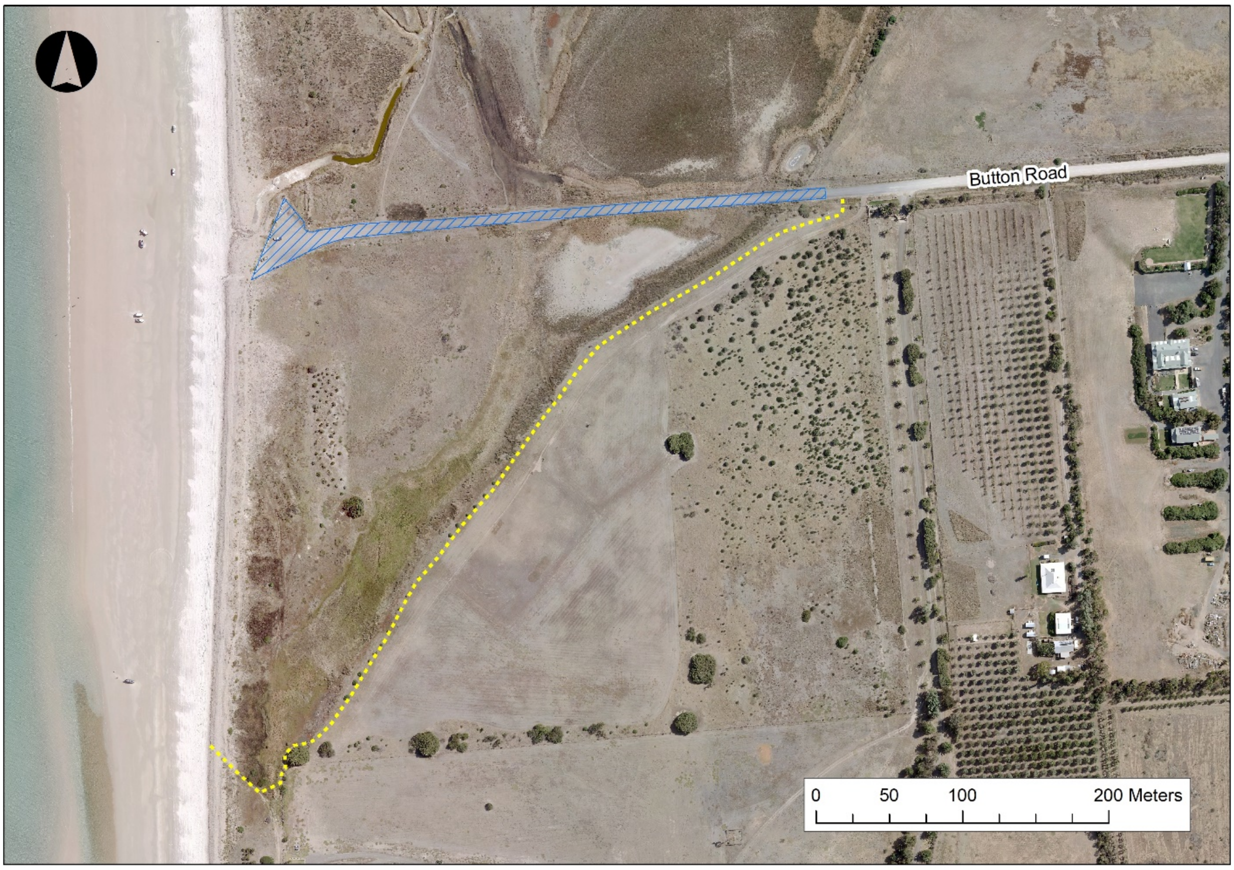



Figure 48. The western end of Button Rd with the area suggested for removal (blue hatching) and alternative pedestrian beach access route (yellow dashed line) indicated.

Preconditions for Option 4 include:

- Consultation during the consultation period for the Aldinga Conservation Park Management Plan to determine:
    - Kaurna support
        - Kaurna community members have verbally expressed their support for Option 4 through the Warpulai Kumangka forum of Green Adelaide. Support for Option 4 from Kaurna representatives was also documented by Draper and Maland (2021).
    - Broader general community support;
    - The support of the City of Onkaparinga, the authority currently responsible for road maintenance;
- Options 1 and 6 completed or ruled out;
- Cultural heritage assessment.

## 8.7. Option 5: Convert Dam to Temporary Sedimentation Pond

This Option was recommended by SKM (2008).

The old farm dam located on the eastern edge of the Washpool just north of Button Rd (Figure 49) serves no ecological role and detracts from the natural aesthetics of the Washpool. In August 2022 salinity in the dam was 48,035 µS.cm$^{-1}$, while salinity in the Washpool nearby was 2,926 µS.cm$^{-1}$. The lack of flushing of the dam may be contributing to the accumulation of salt.

Turbid runoff flows downslope in a westerly direction within roadside swales along the edges of Button Rd and into the Washpool during intense rain events (Matt Endacott, pers. com., 17/12/2021) impacting water quality. Ecological Associates (2003) described the Button Rd swale as a minor drain. These flows could be diverted into the dam to capture the sediment load they carry and prevent it entering the Washpool. Flows down both sides of Button Rd could be diverted, with flows on the southern side directed across the road via a gutter. Ultimately the dam would fill with sediment and an alternative solution would be required.

Over the longer term the amount of sediment entering the Washpool from this source could be reduced by improved management of the roadside swales or the sealing of Button Rd upslope of this location. This would allow the dam to be removed and the area reshaped back to the natural topography of the wetland margin. There would be minimal impact to vegetation, however regionally vulnerable plants *Wilsonia humilis* and *W. rotundifolia* may occur on the dam wall (John Edmeades, Friends of Aldinga Scrub, pers. com., 11/8/22) and translocation of these individuals may be required to minimise impacts.

A cultural heritage assessment would be required prior to any earthworks associated with this Option.

Figure 49. The old farm dam on the eastern edge of the Washpool just north of Button Rd, 10th June 2021.

## 8.8. Option 6: Improve Fish Passage

Improving fish passage between the sea and the Washpool has the potential to increase the diversity and abundance of fish within the lagoon. This in turn has the potential to invigorate the broader ecosystem of the wetland, with obvious direct benefits for piscivorous waterbirds, and likely benefits throughout the wider food web. It would also be in keeping with the cultural understanding of Kaurna representatives with whom we have spoken. Options to improve fish passage between the sea and the Washpool lagoon vary depending upon which other restoration options are implemented. If pursued, the incorporation of a fishway should form part of the detailed design process for Option 1. Cultural heritage assessment would be required prior to construction.

### 8.8.1. Under the Current CTF Elevation of 2.64 mAHD

If Option 1 was not pursued, and the current WSEL of 2.64 mAHD at CTF was maintained for the Washpool, the existing concrete outlet weir could be replaced by a rock ramp fishway. The fishway could be constructed within the channel that exists upstream of the outlet weir (Figure 50). Rock ramp fishways consist of a series of resting pools, of descending WSEL, separated by riffles, i.e. sections of higher velocity, turbulent flow where the WSEL drops between pools (Figure 51).

The existing channel is approximately 140 m in length and would need to accommodate a drop in WSEL of approximately 1.5 m between the upstream (lagoon) and downstream (outlet channel) waterbodies. This represents an overall gradient of approximately 1:90, which is a relatively low gradient for a rock ramp fishway and improved fish passage is therefore readily achievable. For example, a rock ramp fishway constructed within the outlet channel of Piccaninnie Ponds, South East SA, in 2006 had an overall gradient of 1:25 (Taylor 2006). Subsequent assessment found this fishway was successfully passing the full suite of target species (Hammer 2008).

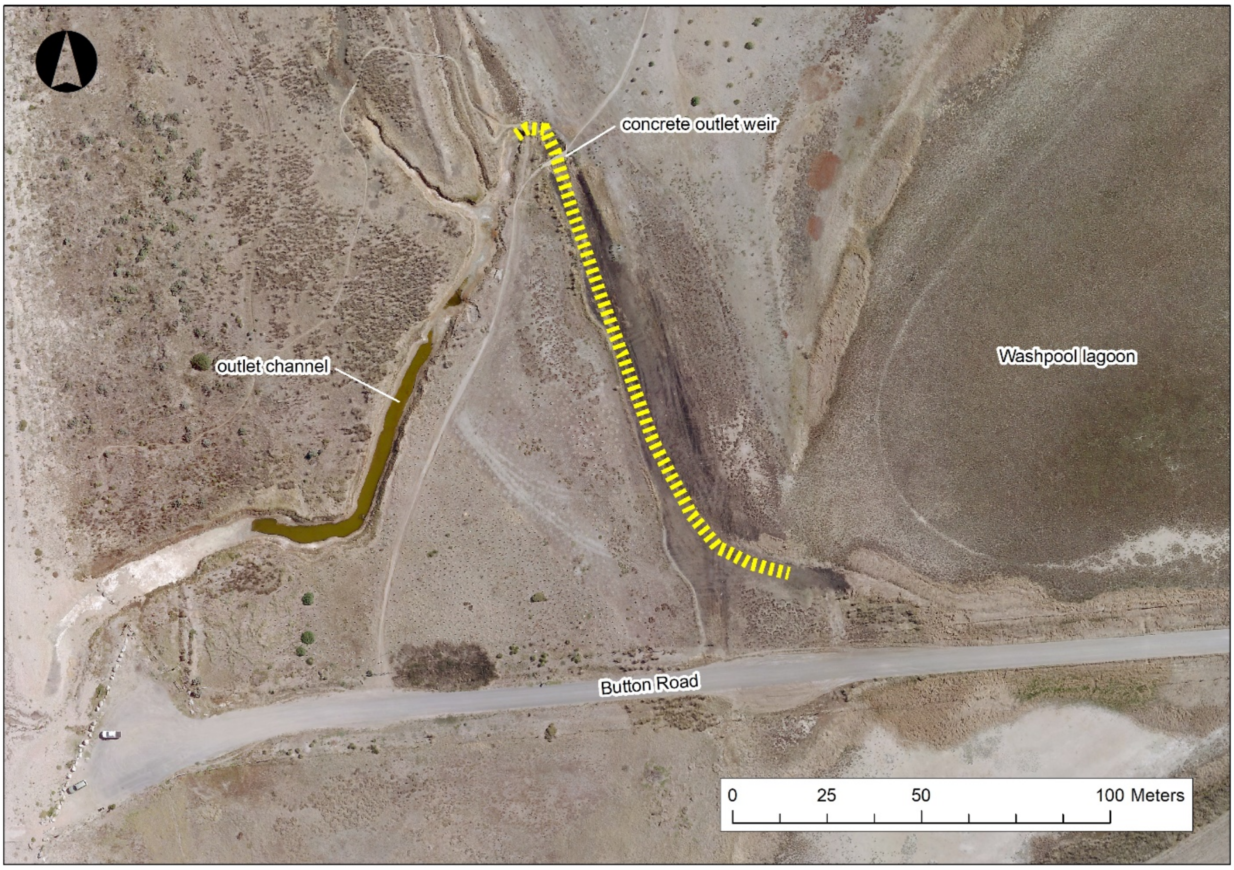



Figure 50. Existing channel (yellow dashed line) that could accommodate a rock ramp fishway at the Washpool.

Figure 51. Example of a rock ramp fishway in Mackay, Queensland (photo: Catchment Solutions (2022)).

To contain all low to moderate outflows from the Washpool within the fishway some minor earthworks may be required in and around the structure. Under high water levels and high outflows from the Washpool, alternative flowpaths would be activated as occurs currently, e.g. the Norman Drain (see Section 8.4). The fishway would require the structural integrity to accommodate high flows as it would continue to provide the primary flowpath and all conditions. The upstream passage of fish would only be anticipated under low to moderate outflows and with the mouth of the outlet channel open.

### 8.8.2. Under a Restored CTF Elevation of 3.1 mAHD and Levee

If Option 1 were pursued (see Section 8.1), with a levee constructed and the sill elevation of the Washpool raised to 3.1 mAHD, the existing Silver Sands stormwater drain could be utilised as a fishway. At a location where the natural bed of the Washpool has an elevation of 3.1 mAHD a gap in the levee bank could be created with a box culvert (grated above to allow light in), taking outflows from the Washpool through the levee and into the stormwater drain and from there into the outlet channel and to sea (Figure 52). The stormwater drain has a gentle gradient of approximately 1:300 as it falls to the outlet channel, thus high flow velocities, detrimental to fish passage, are unlikely to occur. Some reworking of the stormwater drain may be required to ensure sufficient depth is maintained along this route and barriers such as erosion heads are removed.

If all outflows from the Washpool, including high flows, were directed through the stormwater drain / fishway at this location there are risks that:

- a backwater effect within the stormwater drain may negatively affect stormwater drainage from the Silver Sands estate; and
- high velocity flows may cause erosion or other damage within the stormwater drain.

To avoid these risks, the following could be incorporated into the overall design to prevent high flows through the stormwater drain / fishway:

- a narrow width of the culvert through the levee connecting the Washpool with the stormwater drain / fishway;
- a spillway for high outflows from the Washpool with a crest elevation slightly (c.10 cm) higher than the fishway's, but a much greater width and therefore the ability to accommodate a high proportion of outflows when activated. The spillway would require sufficient capacity to minimise surcharging of the Washpool during high inflow events. If this spillway was located in the location of the existing concrete outlet weir and directed flows into the outlet channel it would serve the necessary function of providing attractant flows to the entrance of the fishway; the confluence of the Silver Sands stormwater channel and Washpool outflows is at this location.

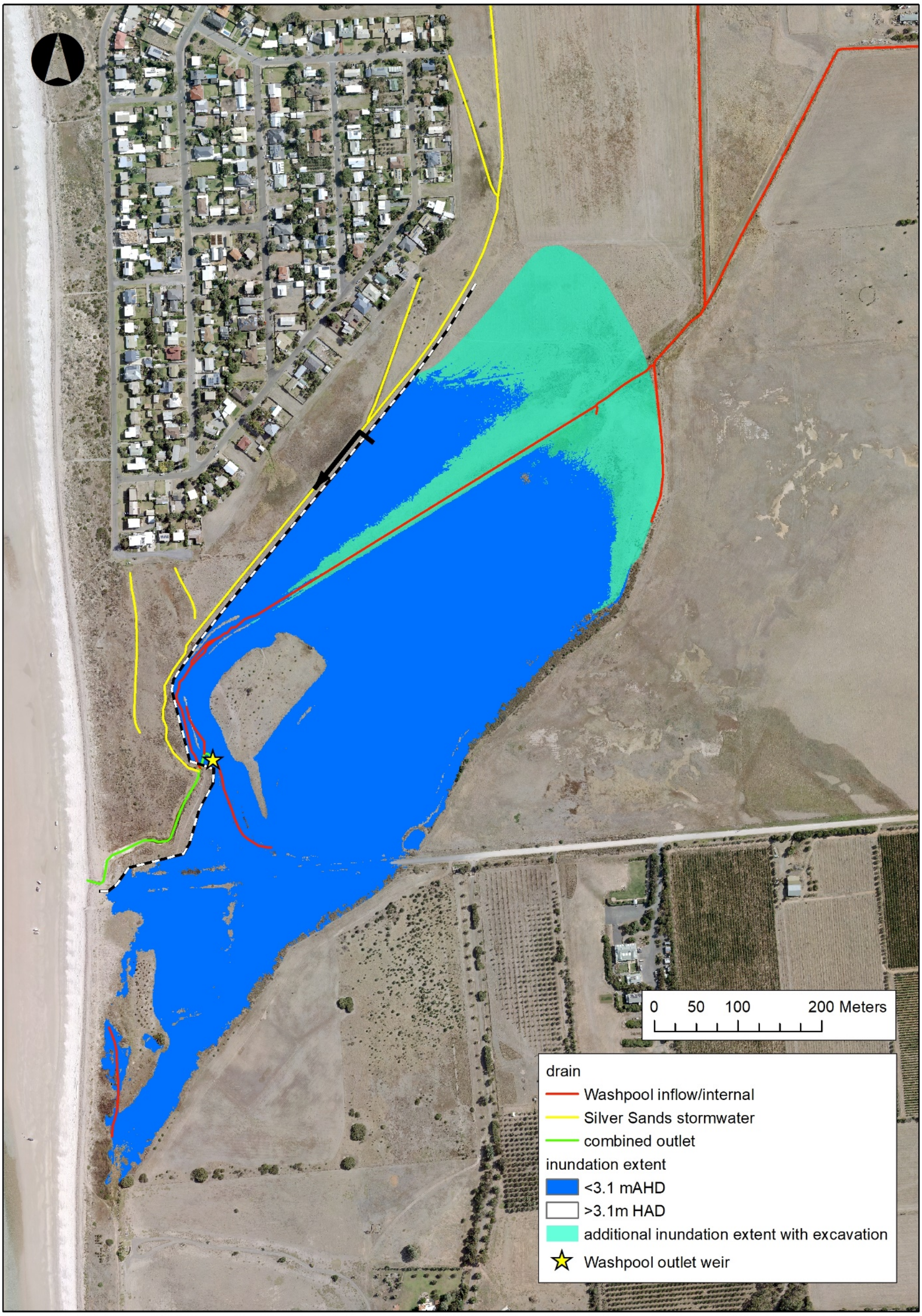



Figure 52. Approximate location of an opening through the proposed levee to allow for fish passage (black arrow).

## 8.9. Option 8: Backfill Drain Near Blue Lagoon

While the primary focus of this investigation has been on the Washpool, options for Blue Lagoon are also suggested, albeit tentatively and less developed than those presented for the Washpool.

A section of drain that runs parallel immediately south of Norman Rd then turns 90 degrees towards the south (Figure 53) carries water in an easterly, then southerly direction around Blue Lagoon. Observations made during the project period (e.g. Figure 54) indicate that the water within this section of drain is groundwater and the drain is likely having the effect of drawing water away from Blue Lagoon. The drain did not appear to be playing a role in surface stormwater management in winter 2021 nor 2022, although City of Onkaparinga have advised that it does play such a role at times.

The more comprehensive restoration of Blue Lagoon appears to require:

- Determination of the depth of sediment that has been deposited since colonisation; and
- Excavation of sediment deposited since colonisation.

Due to the cultural significance of the Blue Lagoon, this is primarily a question for the Kaurna community. If excavation penetrated the water table, an aquatic feature may reappear. The drain backfilling works proposed as Option 8 would complement such a project.


Figure 53. Section of drain near Blue Lagoon proposed for backfilling (white cross-hatching).

Figure 54. Drain near Blue Lagoon, 17th July 2021.

## 8.10. Consideration of the Tjilbruke Spring

According to Draper and Maland (2021), the Tjilbruke spring at the Washpool "originally was a soakage, constantly requiring the removal of encroaching sand to access the fresh water. In order to maintain the water supply in a useable state, it is likely that the early colonial farmers lined the soakage with stone to provide easier access to the water. The well has recently been covered with dumped land-fill …".

Spot salinity measurements of surface water in August 2022 in the area where the spring is thought to be located did not indicate freshwater discharge (see Section 5.2.2). A more thorough investigation, potentially involving digging and the measurement of salinity of subsurface water, could be undertaken to determine the current location and status of the spring – this would require Kaurna approval and cultural heritage monitoring. The current hydrogeological status of the Tjilbruke spring (extinct or still actively discharging) remains unclear.

Irrespective of its current status, there may be a case for the removal of the spoil that has been dumped in the vicinity of the spring. The location and extent of the spoil is relatively clear from the aerial imagery (Figure 55) and from the foreign material (e.g. concrete, bricks) it contains. Its careful removal could serve as an act of cultural, if not ecological, restoration. This is primarily a question for the Kaurna community to consider.


Figure 55. Approximate extent (yellow polygon) of dumped spoil in the vicinity of the Tjilbruke spring.

## 8.11. Consideration of the Southern Outlet

The original southern outlet of the Washpool, that the first colonial survey maps suggest was active in 1839 (see Section 3.2), could be reactivated by excavating through the pebble foredune in that location. With flows directed exclusively out of the northern outlet since the early days of colonisation, the foredune at the southern outlet (Figure 56) has grown through natural coastal deposition processes without the counteracting erosive effects of regular outflows. The foredune currently has a crest elevation of c.4.2 mAHD in this vicinity. The bed of the southern arm of the Washpool that extends to the southern outlet location has an elevation of approximately 2.5 mAHD. A flowpath could be re-established through the pebble foredune by excavating down to the desired sill elevation of the Washpool, i.e. the current sill elevation of 2.64 mAHD or a restored elevation of 3.1 mAHD under Restoration Option 1.

Figure 56. Pebble foredune in the vicinity of the historic southern outlet of the Washpool, 10th June 2021.

Reactivation of the southern outlet could be undertaken as a stand alone action or integrated with other restoration options. It would be possible for all outflows from the Washpool to be directed through the reactivated southern outlet, with only Silver Sands estate stormwater flowing to sea via the existing outlet channel north of Button Rd. This would require decommissioning of the existing concrete outlet weir and its replacement with a levee (as per Option 1, or a lower levee if the current sill elevation was to be maintained). However, there are some risks with this approach including:

- While a dynamic mouth would be restored, with a variable sill elevation, periods of mouth closure due to extended dry conditions could lead to the pebble foredune resetting to a higher elevation and thereby causing a higher than anticipated WSEL in the Washpool during subsequent refilling. This would not be a problem if the surrounding terrain was in its natural state, but today would present a flood risk to housing in low lying areas of the Silver Sands estate. While the sill elevation of the southern outlet could be carefully monitored and maintained to manage this risk, such an arrangement presents and ongoing management burden and liability that is best avoided.
- The additional distance water would have to travel through the Washpool to reach the southern outlet, compared to the existing outlet channel, would cause a greater surcharge of upstream water levels due to the backwater effect during high inflows, with flooding risks to adjoining land including the Silver Sands estate. While the sill elevation of the southern outlet could be set lower to counteract this, a lower sill elevation would mean a smaller and shallower Washpool at CTF compared to what could be achieved if the existing outlet channel continued to be utilised.

For these reasons, and for the disturbance to intact coastal vegetation and the pebble embankment that would be required, we do not recommend reactivation of the southern outlet. However, if a consensus was achieved to pursue this option, we recommend that it only be undertaken as an addition, rather than an alternative, to restoration options that continue to direct Washpool outflows to the sea via the existing northern outlet channel. This recommendation is consistent with the map drawn by Richard Counsell in late 1839 on page 61 of his fieldbook (Figure 4) indicating that both the northern and southern outlets were active at that time. Note that without removal of lower Button Rd, outflows via a reactivated southern outlet would be restricted when the WSEL within the Washpool was below c.2.8 mAHD, the approximate elevation of road surface through the wetland.

## 8.12. Revegetation, Regeneration and Weed Management

Areas that become regularly inundated, or more deeply inundated, following hydrological restoration typically require minimal further management. Wetland vegetation usually re-establishes, either from dormant propagules *in situ* or propagules that are naturally imported to the site (e.g. via inflows from upstream sources or via the bodies and/or droppings of waterbirds) without the need for revegetation. Weeds, many of which are only able to persist due to the lack of regular inundation, are typically drowned and greatly reduced in cover. At the Washpool there are possible exceptions to this general rule that may necessitate ongoing intervention even if hydrological restation is undertaken:

- *Gahnia filum* tussock sedgeland typically occupies elevations up to 30 cm above the high water line (Ecological Associates 2010). Revegetation may be required to re-establish this species, and co-occurring species, in areas not subject to regular inundation.
- There are some aquatic weed species at the Washpool that increased depth and duration of inundation is unlikely to eliminate completely and may therefore require ongoing management. The most notable of these is *Phalaris aquatica*, but *Suaeda baccifera* is another inundation-tolerant pest plant of concern.

## 8.13. Catchment Management

It is an important time to consider catchment management at the Washpool. The management of stormwater from the future development of land within the catchment, such as the Renewal SA land in Aldinga (bound by Main South Rd, Aldinga Beach Rd, How Rd and Quinliven Rd) is currently under consideration. The historical evidence indicates that the inflow channels directing surface water into the Washpool today are artificial. Historically, the Washpool likely received surface inflows via broad, sheet flow through a series of wetlands, including Blue Lagoon, and low ground to the north-east, but there was no defined inflow creek as such (see Section 3.3). Thus, the contemporary catchment likely delivers shorter duration, higher peak flow rate flows to the Washpool than the pre-colonial catchment (Figure 57). Watercourse restoration works within the Washpool catchment that aim to "flatten the curve" are an important part of the long term restoration and management of the Washpool. Broadly, the objectives of such works are to:

- increase water retention within the catchment upstream, thereby reducing peak flow rates and extending the duration of inflows to the Washpool, thereby extending the duration of inundation;
- reduce sediment and nutrient loads to the Washpool and marine environment;
- restore local aquatic and riparian ecosystems throughout the catchment.

An example project is Willunga Hills Face Landcare Group (WHFLG) collaborating with SA Water and Biodiversity McLaren Vale (BMV) to revegetate a watercourse near SA Water's Aldinga Wastewater Treatment plant on Plains Rd. For the protection and enhancement of the Washpool's aquatic ecosystem, future urbanisation, and development generally, within the Washpool catchment should manage runoff such that the problem of short duration, high peak flow rate inflows is improved, not exacerbated.

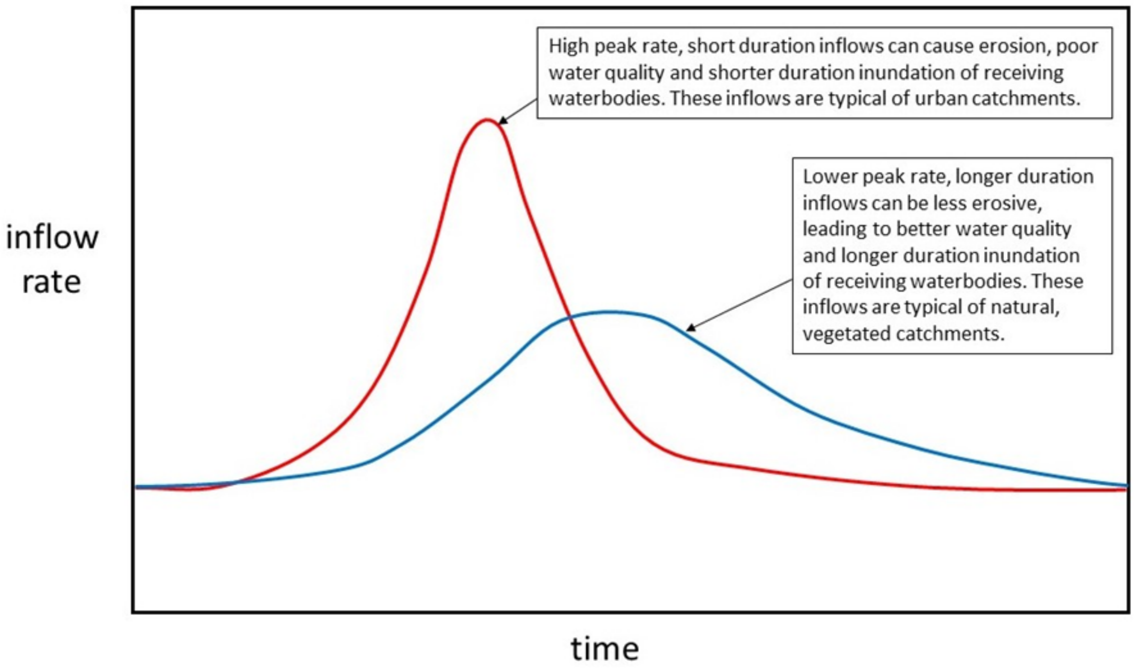



Figure 57. Theoretical stream flow from developed (urban or agricultural, red line) vs natural (blue line) catchments for a given rainfall event.

## 9. Water Availability

With a current volume of 2.8 ML at CTF, but a restored volume of up to 126.5 ML at CTF (see Section 8.5), the question of whether Washpool restoration is justified based on water availability is a valid one. Kinhill (1996) estimated average catchment inflows to the Washpool of 1,400 ML/year. A Watercress model of the Washpool catchment first developed by Ecological Associates (2006), and updated by Southfront (2020), estimated an average inflow to the Washpool of 778 ML/year, but quite variable between years (Figure 58). Southfront (2020) predicted inflows to increase from 778 ML (existing catchment conditions) to 1020 ML (future development, current measures in place) due to urbanisation of some areas of the catchment that are currently rural.

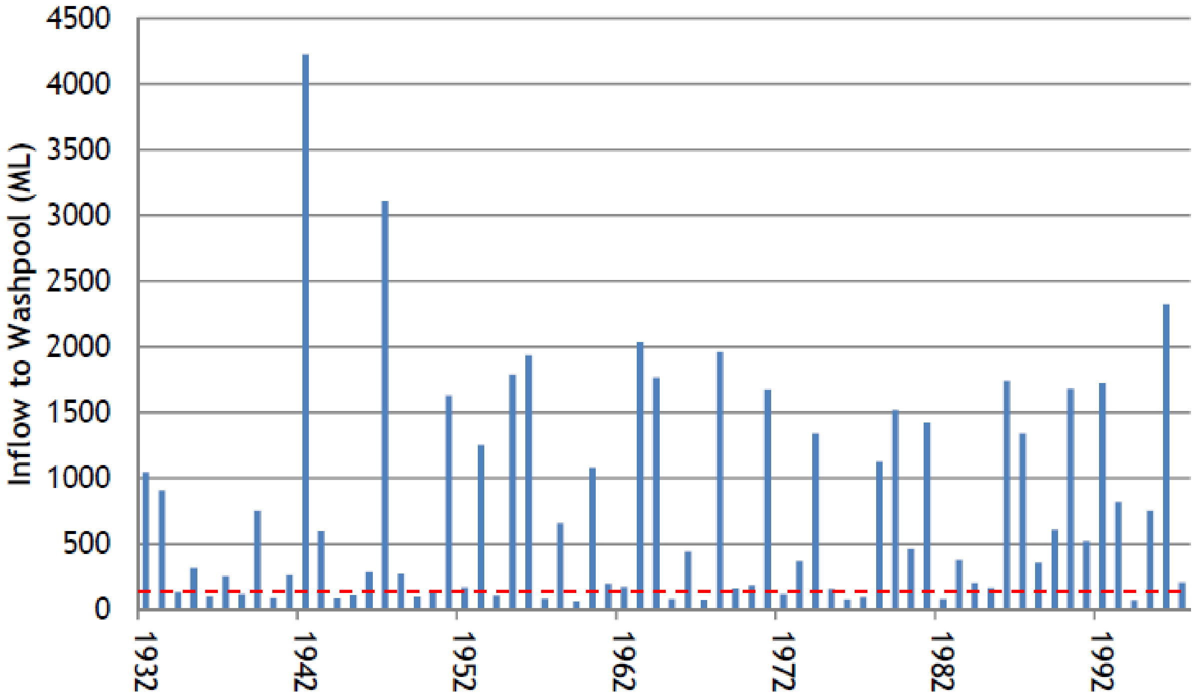



Figure 58. Modelled annual inflows the Washpool, 1932 – 1997 (source: Southfront 2020). The maximum restored volume of the Washpool (126.5 ML) is indicated (red dashed line).

Southfront's (2020) modelling suggest a fully restored Washpool (Options 1, 2 and 3 all implemented) would likely fill in 48 of 65 years. However, the modelling does not investigate the implications of climate change.

We also examined Washpool outflow data, provided by Water Data Services, collected by an instrument deployed in the outflow channel from 2014 to 2018 inclusive. The correlation between these data and rainfall data for the Washpool catchment (surrogate Bureau of Meteorology station in Noarlunga) was very poor and we therefore excluded them from consideration.

To provide improved confidence of Washpool inflows under climate change and ensure the increased volume of the Washpool under restoration is justified, revised catchment modelling is recommended.

## 10.Predicted Climate Change Impacts and Implications for Restoration

The three main impacts of climate change with implications for the Washpool are (Western et al. 2020):

- reduced overall rainfall in the catchment;
- increased intensity of rainfall events in the catchment;
- sea level rise.

Reduced overall rainfall has relevance for water availability to the Washpool, under both current and restored scenarios, potentially influencing the justification for restoration, and should be examined via catchment modelling (see Section 9).

The issue of rainfall intensity has relevance for the hydraulics of the Washpool and the protection of Silver Sands estate from flooding caused by stormwater and inflows from the wider catchment. This issue could be examined by modelling as a pre-requisite of Option 1 (levee and spillway), as proposed in Section 8.1.

The implications of sea level rise were examined in detail for the City of Onkaparinga's Coastal Adaptation Study (Western et al. 2020). The Washpool is recognised as an area at risk of sea-flood under predicted sea-level rise. Predicted storm surge levels (high tide + wave setup) under a 1 in 100 year event (Western et al. 2020) are:

- 2.60 mAHD by the year 2020;
- 2.90 mAHD by the year 2050;
- 3.10 mAHD by the year 2070; and
- 3.60 mAHD by the year 2100:

These modelled levels relate to sea levels only, not the combined effects of sea levels and catchment inflows. The modelled levels indicate that currently (2022), 1 in 100 year storms do not pose a risk to Silver Sands or lead to seawater inflows into the Washpool (except the outlet channel) because the concrete weir (crest elevation 2.64 mAHD) is not overtopped. However, by 2050, considerable seawater intrusion into the Washpool (under current arrangements without restoration) can be anticipated under such events. Seawater flooding of Silver Sands is predicted to occur under such events by 2100. Sea level rise is likely to reshape the coastline, potentially causing the pebble bank to retreat by c.26 m by 2100 or disappear completely and lead to a c.43 m retreat of the coastline in the vicinity of the Washpool (Western et al. 2020).

The ecological character of the Washpool will change as a consequence of climate change. Increased seawater intrusion will occur and will likely increase the salinity of the wetland, causing the loss of the more salt sensitive biota and favouring salt tolerant species. Hydrological restoration options proposed in this report, particularly Option 1 (levee and spillway), have the potential to limit the degree of seawater intrusion and help maintain the brackish ecology of the Washpool. The recommended spillway elevation, 2.90 – 3.10 mAHD, would prevent seawater incursion prior to 2070, provided the structural integrity of the levee and spillway was maintained and breaches through the natural pebble embankment did not occur in other locations, particularly south of Button Rd where the levee is not proposed. By 2100, peak sea levels in a 1 in 100 year storm are still 0.4 m below the crest of the proposed levee (4.0 mAHD), meaning that, while seawater inflows to the Washpool would occur via the spillway, the levee would continue to maintain the Washpool as a distinct waterbody, separate from the sea, most of the time. This would help preserve the brackish character of the Washpool.

The role a levee and spillway could play in maintaining the brackish ecological character of the Washpool out to 2100, and the implications for levee design, particularly protection from erosion from high sea levels, need to be considered.

## 11. Summary and Recommendations

The beach, adjacent wetlands and fresh water spring in the Washpool area are integral to the Tjilbruke dreaming and are identified by Kaurna as a sacred place (Draper and Maland 2021). Kaurna community perspectives are central to decision making regarding the restoration of the Washpool, Blue Lagoon, Tjilbruke spring and general vicinity, so restoration of these places should be considered as both cultural and ecological restoration. NGT has collaborated with Kaurna community representatives, primarily through the Warpulai Kumangka forum, in the development of restoration options.

Previous proposals to restore the Washpool (e.g. Stokes and Harris 1976) highlight that it is not the lack of informed, sensible restoration planning that has led to minimal on-ground hydrological restoration work at the Washpool but rather competing agendas (e.g. 1980s marina proposal), complexities around land tenure and uncertainty as to which authority is responsible for the area appear responsible for a lack of progress. With the recent inclusion of (most) of the Washpool into an expanded Aldinga Conservation Park and the establishment of a Co-Management Advisory Committee with the Kaurna Yerta Aboriginal Corporation, some of these barriers may now have been removed.

The pre-colonial hydrology of the Washpool will be best restored by undertaking Option 1 in combination with Option 3, therefore these Options are considered high priority. Option 6 is a desirable addition to Option 1 that, for efficiency, should be incorporated into the detailed design of Option 1. Implementation of Options 1 and 3 will necessitate Option 4 or some alternative management of Button Rd. Options 5 and 8 are of medium priority and could be undertaken independently of other Options. A prioritisation of Options and next steps is provided in Table 5.

Table 5. Prioritisation of Options and next steps.

| **Priority** | **Option** | **High Priority Next Steps** |
|---|---|---|
| high | Option 1 - levee and spillway | Washpool catchment modelling to ensure sufficient water availability to justify increased Washpool volume |
| | | Assessment of the suitability of accumulated sediment within the Washpool as levee construction material (if Options 2 and 3 are also implemented) |
| high | Option 3 (a, b) – remove accumulated sediment, backfill Norman drain | Accurate, fine scale determination of the depth and total volume of sediments deposited post-colonisation within the proposed excavation footprint |
| | | Acid sulphate soil risk assessment of proposed excavation footprint |
| high (if Options 1 and 3 undertaken) | Option 4 – remove Button Rd | Determine community perspectives and make decision (City of Onkaparinga) |
| high (if Option 1 undertaken) | Option 6 – improve fish passage | |
| medium | Option 5 – convert dam to temporary sedimentation pond | |
| medium | Option 8 – backfill drain near Blue Lagoon | |

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## Appendix A – Comments Received on Restoration Options

**FRIENDS OF ALDINGA SCRUB**

October 2022

***Option 1 – levee and spillway***

Support raising level to about 3.1 mAHD

a) Levee should be as close to Silver Sands suburb as possible

b) Suggest doing away with separate Silver Sands stormwater drain as Silver Sands not flooded at 3.1 mADH

c) Should be a low flow spillway lower than 3.1 that acts as fish access

d) Main spillway should be very long, perhaps most of the way from Silver Sands to the second outlet so that there is 'sheet flow' like in the designs for Port Willunga wetland by B Ormsby

e) Spillway levee on coast side needs to be 'ARMOURED' to protect from storm sea surges in future with climate change at year 2100.

***Options 2-3 - remove accumulated sediment, backfill Norman drain***

Support silt removal though agree it will be tricky and expensive. Area suggested is good compromise avoiding good vegetation and heritage areas. Accurate sediment depth measurement desirable as would sediment measure for BLUE LAGOON and potential silt removal.

Agree with not removing silt in 'Hay Paddocks' where landfill considerable depth. Note also neighbours to NE of Washpool are still landfilling.

***Option 4 - remove Button Rd***

Support removal of west end of Button Road

a) As it in a windsurfing funnel, they will be most affected but they say the will cope!

b) Walking trail to beach and provision of a bird hide also desirable for birdwatchers.

c) Ramp should have gone ages ago.

d) Untreated stormwater entering from Sellicks needs at least primary treatment (trash racks) and input from dysfunctional Sellicks sewage works.

***Option 5 – convert dam to temporary sedimentation pond***

Undesirable

a) Road silt needs to go into a swale with outflow as sheetflow.

b) Council drainage on Just Road means far less water now comes down Button Road.

c) Dam should be removed but not before

   i. rescue of *Wilsonia*

   ii. reintroduction of *Ruppia* successfully into Washpool

   iii. *Ruppia* extremely valuable keystone wetland plant for waterfowl, I and others have searched for *Ruppia* unsuccessfully elsewhere locally.

***Option 6 – improve fish passage***

Fish passage supported

a) Maybe a random rock incline?

b) One like at River Torrens (Breakout Creek) outlet works.

c) Combine with a low flow outlet, say at 3.0 mADH which could add some variation to water surface level which otherwise sits about cease to flow rather statically midseason.

d) I discussed plans to build a fish ladder with people many years ago.

***Option 8 – backfill drain near Blue Lagoon***

Yes, backfill drain from Blue Lagoon area

a) From Acacia Terrace along Norman Road and southwards.

b) Could stormwater from Acacia Terrace be encouraged towards the Blue Lagoon?

Drains north of Norman road in the Aldinga Conservation Park potentially filled in also.

***Consideration of the Tjilbruke Spring***

Tjilbruke spring should also be restored

a) Important for cultural restoration

b) Part of general sediment and landfill removal

c) Issues of groundwater contamination from the Sellicks sewage site need addressing

d) Is there enough clean freshwater infiltration into the aquifer to support a healthy spring?

e) Does the island in the middle of the Washpool contain landfill? Someone suggested to me that there was Willunga Council landfill.

***Additional comments***

**Figure 1** Private properties in north-east corner of Washpool should be acquired as become available

- not contributing to ecology of Washpool
- continuing landfill of wetland area

**Page 5** Support conclusion that the Washpool originally was primarily groundwater fed.

**Page 15** Blue Lagoon originally fed by coastal dune freshwater lenses presumably removed by sand mining nearby.

**Page 40** Urbanisation of catchment a major problem, deleterious to hydrology peak runoff. Likewise agriculture also contributes by drainage and erosion.

**Page 58** 2011 flood modelling shows Silver Sands unflooded at 3.1 mADH but repeated episodes of flooding mainly due to stormwater pipes blocked with sand and/or debris. Needs independent work. With climate change, need dyke maybe up to 4 mAHD and emergency pumping capacity. Flap valves on pipes under dyke to let water out but not in.

**WILLUNGA HILLS FACE LANDCARE GROUP INC**

October 2022

Overall comments

We are impressed with the thorough work you and your team done to outline the recent history of the Washpool and its catchment, and to develop and outline the various options for restoration.

Our comments relate to the washpool history and restoration options rather than the process(es) by which the restoration might be achieved.

We strongly support the proposed Options 1 and 6 to increase the water holding capacity of the Washpool, and to help restore the ecology of the wetland. And in conjunction with these options we also strongly support Option 3, to enable the volume of water to be increased to approx. 126 ML (if Option 1 is implemented at a height of 3.1 mAHD), as illustrated in Figure 47 and outlined in Table 4.

Since Option 4 appears to be a low cost and relatively simple change, we also support the proposal for this work to be done. This proposal, for the shortening of Button Road, would be an early winner and could be done straight away. A pedestrian path / board walk could also be constructed to maintain access to the beach.

With Options 1 and 3: consideration might be given to provision of an island ("unconnected bird refuge") to enable escape from predators (as mentioned in the 2008 SKM study for Onkaparinga Council).

In the future, with any of the restoration works, interpretive signage as well as designed access paths and boardwalks would add value to the project and encourage other supportive stakeholders (e.g. bird watchers and schools).