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INFRASTRUCTURE,
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The geology and groundwater resources of Nine Mile Beach, eastern Tasmania

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The geology and groundwater resources of Nine Mile Beach, eastern Tasmania

by William. C. Cromer*, B.Sc. (Hons)

*(*William C. Cromer Pty Ltd;
from 1972–1981 Engineering and Groundwater Geologist, Tasmania Department of Mines)*

Cover photograph: *Aerial view of the Nine Mile Beach spit in November 1979, looking east from the western end of the beach ridge and swale system, past the 24-spear bore array (centre) towards the Swan River estuary and backbarrier deposits (left) and Great Oyster Bay (right). The sandy track on the left is a farm access track. The Dolphin Sands Road crosses the middle of the photo from west to east past the spear array. In the distance are extensive areas of blow-out dunes, which, a quarter of a century later, and now largely stabilised. [Photo: E. L. Martin; MRT 2289]*

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In 1979, the Tasmania Department of Mines (now Mineral Resources Tasmania) conducted detailed hydrogeological investigations at Nine Mile Beach, near Swansea, on Tasmania's east coast. Previous departmental investigations into the groundwater resources of the spit had been undertaken on a piecemeal basis from the early 1970's, largely in response to individual inquiries from land owners. The work in 1979 was aimed at assessing whether the aquifer could supplement Swansea's town water supply, which was under stress in a below-average rainfall year.

The investigations focussed on the western end of the 15 km long spit, closest to Swansea. The work undertaken included geological mapping, the drilling and logging of 40 investigation boreholes to depths of about 8–10 m (with one bore extended to 40 m), sand sampling and grain size analyses, radio-carbon dating of shell fragments from various holes, and the casing, screening and pump testing of selected bores to investigate flow rates and groundwater quality. In June 1980, additional investigation holes were drilled inland north of the spit to assist in geological mapping of the area.

The hydrogeological results were sufficiently encouraging to proceed with the installation and pump testing of a circular array of 24 spear bores in October–November 1979. Over a 21-day period, the array produced 34 000 litres of water per hour for a total pumped volume of 17 megalitres. Water quality remained good and constant. Drawdowns were measured in eleven observation bores located at various distances from the array.

The array was never used for its intended purpose. It remains largely intact and still able to supplement the town supply.

The main findings of the 1979/1980 investigations were:

- The unconfined aquifer at Nine Mile Beach is composed entirely of unconsolidated Holocene-age beach and near-shore marine sand extending the full length and width of the spit (i.e. covering about 15 km^2), and with a saturated thickness varying from about three to four metres along its landward edge, to about 10 m along the seaward edge. The volume of saturated sand is therefore about 0.1 km^3, or 100 million m^3.

- The base of the aquifer is a sharply defined, relatively impermeable clay at depths of between four and ten metres below sea level in the western parts, to more than 12 m in the east.

- The aquifer contains only 'fresh' groundwater with salinities in the approximate range of 250 to 600 mg/L of total dissolved solids. The aquifer is bounded to the south by sea water along the beach, and on the inland side by the Swan River estuary, and high salinity groundwater in backbarrier sediments.

- Based on an average porosity of 0.25, the aquifer contains about 25 000 ML of groundwater, which has originated only from infiltrating rain. There are no other sources.

- The sustainable yield of the aquifer is approximately equal to the long-term average annual recharge (rainfall less evapotranspiration), which varies monthly and annually. In normal years it may be 600 ML/year, equivalent to 400 000 L/year/hectare, or about 1000 L/day/hectare. In some years no effective recharge occurs, and in others, greater than average recharge occurs. Sustainability is a long-term concept with a time scale longer than these fluctuations.

- The aquifer has permeabilities in the range of 5 to 30 m/day and a specific yield in the range 0.17 to 0.2, and is able to produce yields in individual spear bores of up to 3000 L/hour, depending on bore construction and installed depth.

- Current groundwater use is restricted to relatively small-scale domestic pumping from shallow spear bores or wells. The total groundwater extracted from the several hundred rural residential allotments is not known, but might amount to about 0.15 ML/day, or 50 ML/year. This is less than 10% of the estimated sustainable yield of the aquifer. At least some of the current groundwater is recycled when applied to garden watering and toilet use, so the *effective* total extracted is probably less than these estimates.

- The aquifer is also able to supply larger-than-residential quantities of water on a short-term basis, and in this regard the 24-spear bore array remains available to supplement Swansea's town water supply.

- Aquifer quality is locally affected by domestic wastewater disposal in the vicinity of on-site wastewater disposal systems, but is probably generally uncontaminated by other current activities.

Under present conditions, in 2003, there are no critical management issues to be addressed. The aquifer is being used sustainably, with apparently minimal impact on beneficial uses. Long-term sustainability can best be maintained by a monitoring program which includes collecting basic hydrogeological data (rainfall, water table depth, groundwater quality, etc.) and setting up a database of existing and future bores, and on-site domestic wastewater disposal systems. Such activities are already underway and are being co-ordinated by the Glamorgan-Spring Bay Landcare Committee, assisted by local residents. Any need to revise this approach will be apparent when the collected data are reviewed.

Acknowledgements

Introduction

Background and purpose of report

This report describes the geology and groundwater resources of Nine Mile Beach (including the Dolphin Sands subdivision) near Swansea on Tasmania's east coast (fig. 1). It is based mainly on investigations carried out in the late 1970's by the Tasmania Department of Mines (now Mineral Resources Tasmania), and is supplemented with more recent information from researchers and concerned interest groups such as the Glamorgan-Spring Bay Landcare Committee.

Commencing in the late 1960's and extending through the 1970's, the Department of Mines conducted statewide investigations into the occurrence of groundwater in coastal sands (Cromer, 1975*a*). Some of the localities included Ocean Beach (Cromer, 1975*b*) near Strahan, Seven Mile Beach (Cromer and Sloane, 1976) near Hobart, Greens Beach (Cromer, 1979) at the
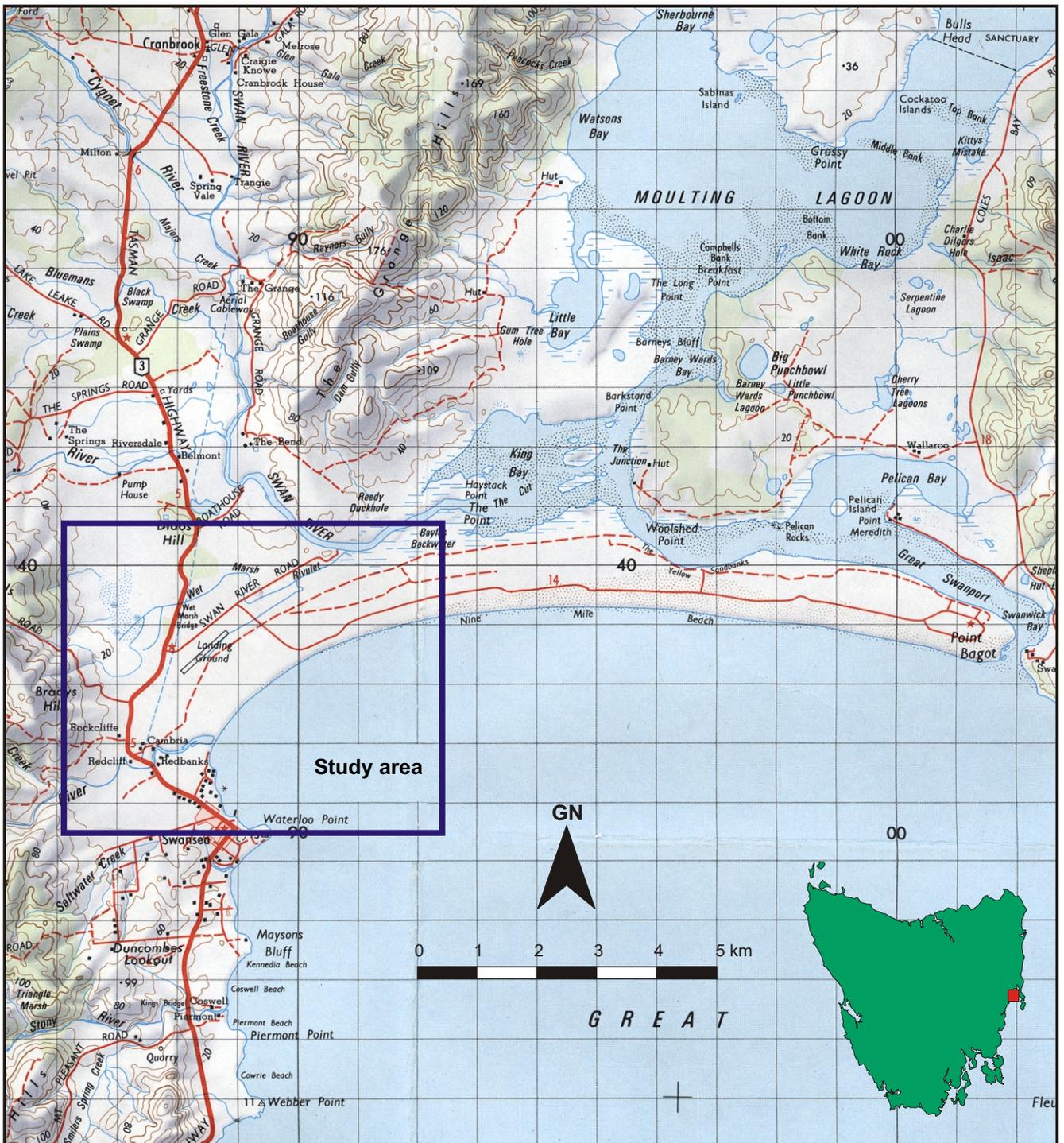
Figure 1

Location of the Nine Mile Beach area.

mouth of the River Tamar, at Currie on King Island (Matthews and Cromer, 1975) and Lady Barron on Flinders Island.

As part of this program, groundwater investigations of Nine Mile Beach started as early as 1969 (Stevenson, 1969). A more detailed study, which forms the basis of the present report, commenced in 1979 as a result of a request from the Glamorgan Council. At the time, the district was experiencing low rainfall (335 mm in 1979) and water shortages, and Council hoped to supplement town surface water supplies with groundwater. Investigations were largely completed the same year, culminating in the installation and 21-day pump testing, in October–November 1979, of an array of 24 shallow spear bores which collectively yielded 34 000 litres of water per hour.

For a combination of reasons[1], Council did not proceed with groundwater use, and the spear bore array remains unused to this day.

A start was made in 1980 to report on the hydrogeological investigations, but the writer resigned from the Department of Mines that year and the project lapsed. The impetus to publish the results of the investigations now, 23 years later, came from a May 2001 public forum at Swansea, instigated by Melanie Kelly, the Waterwatch Facilitator of the Glamorgan-Spring Bay Landcare Committee. The forum was attended by local residents of the Dolphin Sands subdivision, and representatives from industry, the Glamorgan/Spring Bay Council and the Landcare Committee. It was addressed by the writer, and geologist M. Latinovich of Mineral Resources Tasmania. The main question at the forum was:

☐ how can we sustainably manage the Dolphin Sands groundwater system for current and future generations?

The forum's aims were to:

☐ provide the community with existing information about the Dolphin Sands aquifer and encourage discussion about current and future management issues; and

☐ determine the direction for future co-operative management involving the community, industry,

Tasmanian Government and the Glamorgan/ Spring Bay Council.

Subsequently, in late 2002, the writer was formally engaged by Mineral Resources Tasmania to compile existing information and report on the hydrogeology of Nine Mile Beach. Because the report is likely to be of interest to readers with little or no knowledge of hydrogeology, technical terms and concepts are kept to a minimum, or are explained in the text or footnotes where their use is unavoidable.

Previous investigations at Nine Mile Beach

Augering, 1969

The earliest known hydrogeological investigations at Nine Mile Beach were conducted by the Department of Mines in January 1969 (Stevenson, 1969). Twenty-seven holes were drilled by mechanical auger to depths of up to 3.6 m, at approximately 800 m intervals in two parallel lines. One line was parallel to the southern foreshore, and between about 50 and 100 m inland from the beach; the other was parallel to the northern shoreline and about 200 m inland from it. A further four holes were drilled along the east-west centreline of the spit, with a further eight, closely spaced holes, being located at 1.5 m intervals in a line extending inland from high water mark. The survey recorded the depth to the water table[2], and the electrical conductivity[3] of the groundwater.

Groundwater was found at depths of between 0.6 and 3.6 m in sand, although some holes were dry. The range in depth to water was due to differences in elevation. Water salinity at the water table ranged from 200 mg/L TDS on the centreline of the spit, to 2000 mg/L TDS near the eastern end. Most salinities were less than 800 mg/L TDS, and the water was considered to be suitable for domestic uses.

Drilling, date uncertain

Five shallow auger holes were drilled along the Nine Mile Beach spit by the Department of Mines, but the hand-written unsigned summary notes are not dated. Depths to water ranged from 0.9 to 2.2 m, and reported salinities at the water table ranged from 20 mg/L (which seems very low) to 560 mg/L.

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1. Mainly related to the legal difficulty of ensuring a reliable groundwater supply if, for example, neighbouring landowners installed their own spear bore systems which interfered with Council's array.

2. The water table in a porous, permeable material like coastal sand is the surface below which all the open spaces between the sand grains are saturated with water.

3. Electrical conductivity describes how readily the water conducts an electric current. The current is conducted by dissolved chemicals (ions) in the water. The higher the concentration of dissolved chemicals, the higher the conductivity and the more 'saline' the water. Pure water, with no dissolved constituents, does not conduct electricity. Electrical conductivity is commonly measured in milliSiemens/centimetre (mS/cm) or microSiemens/centimetre (µS/cm). As a rough guide, to convert from µS/cm to Total Dissolved Solids (TDS or 'salinity') measured in milligrams/litre (mg/L), multiply by 0.65. Example: an electrical conductivity of 1000 µS/cm is a salinity of about 650 mg/L TDS. The preferred upper salinity limit for drinking water is a TDS of between 500 and 1000 mg/L, corresponding to an electrical conductivity of between about 800 and 1600 µS/cm. One mg/L is equivalent to one part per million (ppm).

Drilling and sampling, Lot 209 Dolphin Sands Subdivision, 1972

A caravan park was proposed on Lot 209, and it was intended to use groundwater to supply washing and toilet facilities. Hydrogeological investigations (Cromer, 1972) by the Department of Mines included a seismic traverse (which indicated a depth to groundwater of about two metres) followed by drilling. A 15 m deep borehole, collared at an elevation of about four metres above sea level, was drilled entirely in sand and established the presence of good quality groundwater (salinity in the range 350 to 525 mg/L TDS) extending from a depth of three metres, to a final depth about 11 m below sea level. Two groundwater samples were analysed (Table 3). In commenting on the analyses, the Chief Chemist of the Department of Mines noted that the high bicarbonate content (350–500 mg/L) might cause scaling in hot water services, and the chloride concentration (75–90 mg/L) may promote corrosion of copper pipes.

Drilling for geological mapping and geomorphological studies, 1980

An augering program in the vicinity of the Tasman Highway north and northwest of Nine Mile Beach was conducted by Neil Chick (lecturer in Geography at the University of Tasmania) and the writer in June 1980 to investigate the Tertiary and Quaternary sedimentary rocks of the district. The work was not reported.

Palfreyman's hydrogeological investigations, 2002

Hydrogeological studies of the Nine Mile Beach area were conducted by Palfreyman (2002) as part of a geology Honours project at the University of Tasmania. The scope of investigations included water table monitoring, groundwater sampling, electrical geophysical techniques to assess sea water–freshwater interfaces, and potential contamination from on-site, in-ground domestic wastewater disposal, and groundwater and water balance modelling.

Swansea water supply and residential development

The township of Swansea obtains its reticulated water supply from the Swan River. The Dolphin Sands subdivision, including the more recent Cambria Drive development, is not served by reticulated water. Instead, residents of these large (e.g. one to two hectare) allotments rely on tank water from roof runoff, and from groundwater obtained from spear bores.

There are currently no reliable monitoring data on groundwater usage at Nine Mile Beach. As an order-of-magnitude estimate, assuming no seasonal variation in household occupancy and use, it is possible that of the several hundred houses spread along the full length of the aquifer, half of them extract up to 1000 L/day of groundwater. Some would use more, and some less. This amounts to an overall groundwater use of about 0.15 ML/day, or perhaps 50 ML/year.

The study area at Nine Mile Beach

Most of the detailed investigations conducted in 1979 were focussed on the western five kilometres or so of the spit (Plate 1 and Figure 2), where the groundwater resource is closest to Swansea and from where it could be most economically pumped via the existing Swan River main to a town storage. However, the hydrogeological findings and recommendations from this area are relevant to the full length of the kilometre-wide spit, which extends east for about 15 km from the mouth of the Meredith River at Swansea, and almost encloses Moulting Lagoon, except for a tidal channel.

Scope of investigations at Nine Mile Beach

The 1979 hydrogeological work at Nine Mile Beach was conducted by groundwater geologists W. C. Cromer and D. J. Sloane, and included:

☐ geological and hydrological mapping, including measuring water quality in many surface dams in the area;

☐ drilling, logging and sampling of twenty-six 100 mm diameter auger holes to depths of up to 10 metres;

☐ the drilling of one deeper exploratory bore to 33.9 m below sea level;

☐ grain size analysis of 67 sand samples from ten selected bores;

☐ surveying three cross sections (A, B and C) through the spit;

☐ collecting groundwater samples for chemical analysis,

☐ installing and pump testing a circular array of 24 spear bores;

☐ installing eleven observation bores to monitor the effects of the pump test of the array;

☐ installing an automatic water level recorder in one of the monitoring bores;

☐ sampling and radiocarbon dating (by others) of shells from auger holes sited in the spit; and

☐ computer analysis of the pump test data.

Subsequently, in June 1980, a further seven auger holes were drilled in the vicinity of the spear bore array, and eight holes were located along the course of Wet Marsh Rivulet as part of geomorphological investigations with the Geography Department at the University of Tasmania.

The locations of the drill holes in relation to topographic features are shown in Figure 3, together with measured salinities of surface water bodies, the three surveyed transects (cross sections) A, B and C, and the 24-spear bore array.

Plate 1

Aerial view of the western end of the Nine Mile Beach spit, with the 24-spear bore array in the centre of the photo, and the township of Swansea in the background. The grassed strip in the right foreground comprises low-lying, backbarrier deposits containing saline groundwater. Fresh groundwater in the sandy aquifer is wholly within the timbered area between the backbarrier materials and the coast.
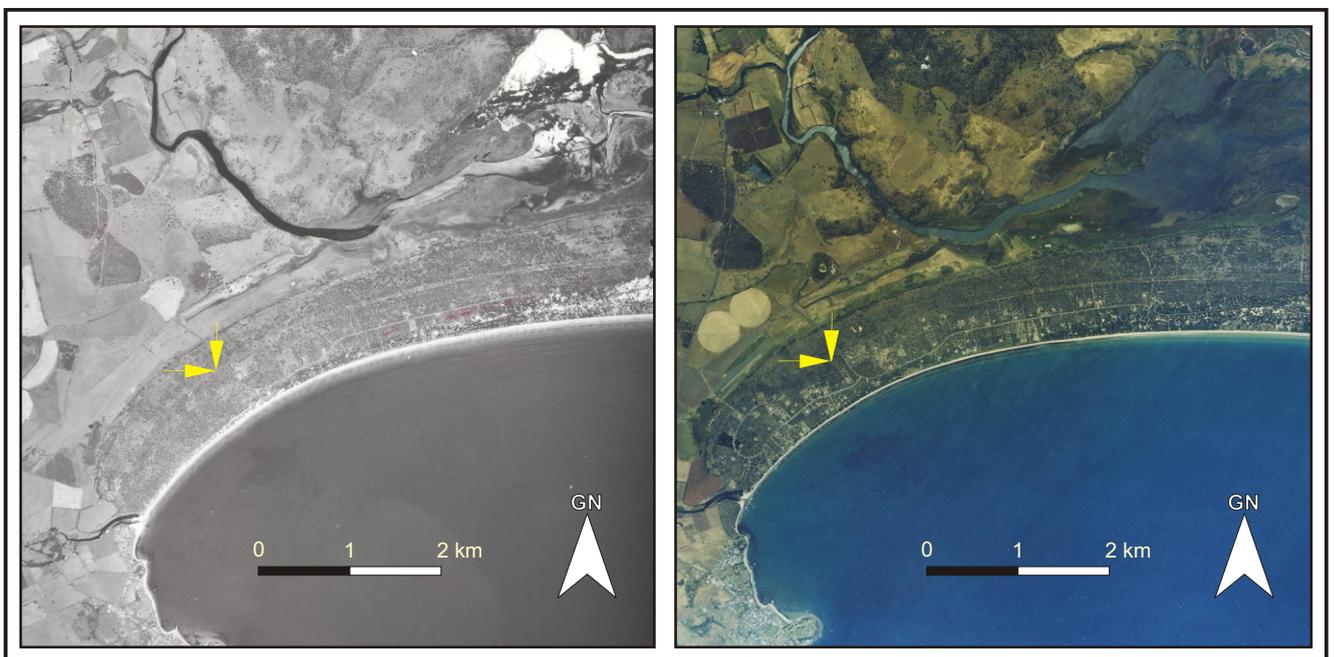
Figure 2

Aerial views of the western end of Nile Mile Beach. The field of view in each photo is about eight square kilometres. The left photograph was taken in January 1985, and the right one in February 2002. The location of the 24-spear bore array is arrowed. Most evident is the residential development along Dolphin Sands Road (right of centre), and the more recent Cambria subdivision (lower left of centre) near the mouth of the Meredith River. The township of Swansea is at the lower left of the photos. The Swan River enters Moulting Lagoon from the upper left.
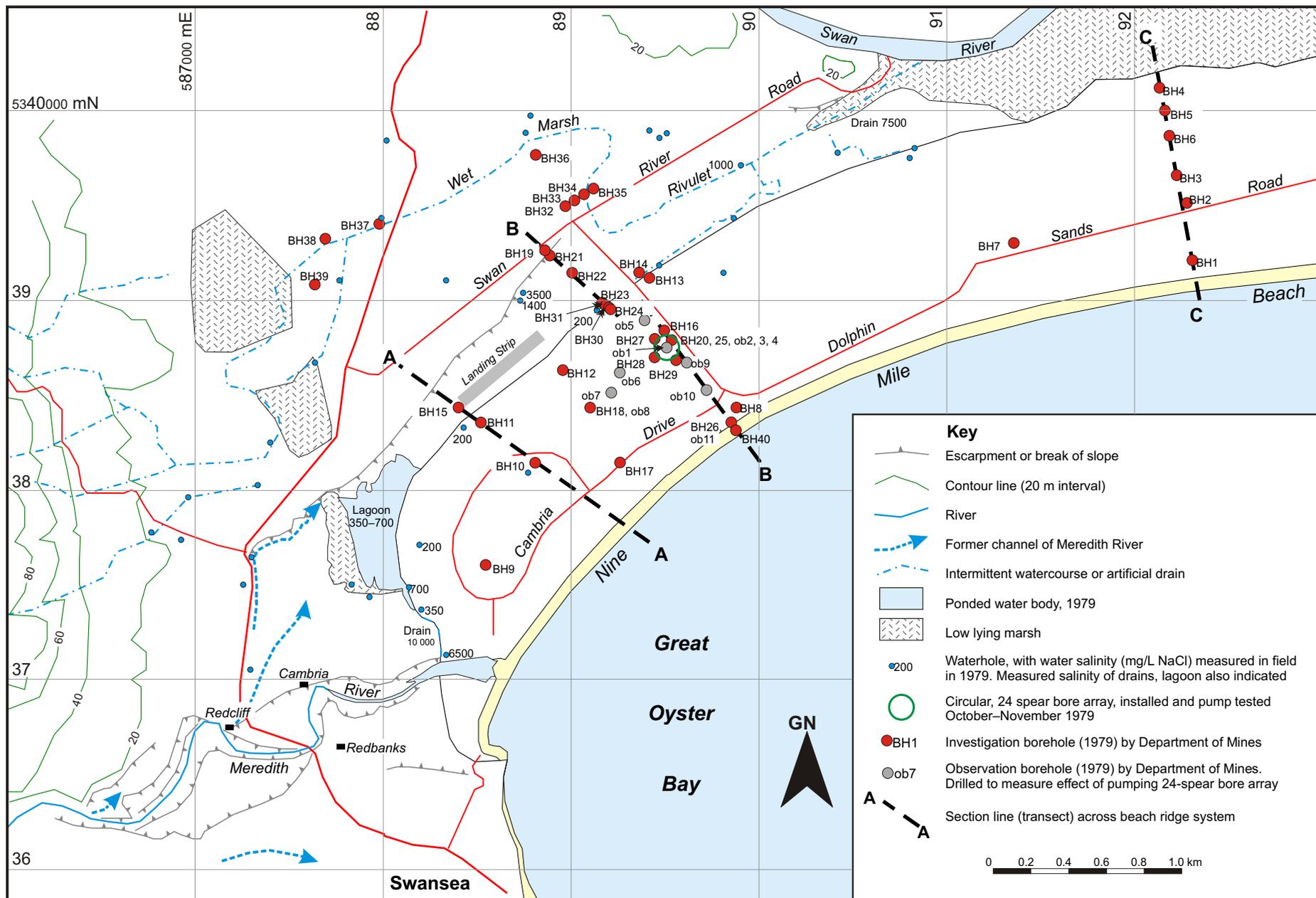
Figure 3. *The study area at Nine Mile Beach in 1979–1980, showing the locations of drill holes, the transects A, B and C, and the 24-spear bore array.*

Geomorphology, rainfall and evapotranspiration

Geomorphology

The main coastal geomorphological features of the study area include the Nine Mile Beach spit, the low-lying land immediately to the rear of the spit, and slightly-elevated land backing these units in the vicinity of Swan River Road. At the western end of the study area, the spit ends abruptly against a series of river terraces and abandoned river channels formed by the ancestral and present-day Meredith River.

Nine Mile Beach bayhead spit

Nine Mile Beach is the dominant landform in the study area. It is a large bayhead spit (fig. 4) formed by the accumulation of sand moving both onshore, and in a west to east direction, under conditions of varying sea level during about the last 6,000-10,000 years.

In a landward direction from its southern boundary along Great Oyster Bay, the spit's western part comprises (fig. 5):

☐ a modern beach at or near mean sea level (MSL);

☐ a foredune system comprising one to five partly vegetated dunes ranging in height from about three metres above MSL, to nine metres above MSL, and in width from 75 m to 150 m inland from high water mark; and

☐ a series of up to 26 subparallel beach ridges and swales, the former averaging about 2.5 m above MSL in the west but rising to about 4 m above MSL towards the east, and the intervening swales lower than adjacent ridges by about 0.5 m (in the west) to 1.5 m (towards the east).
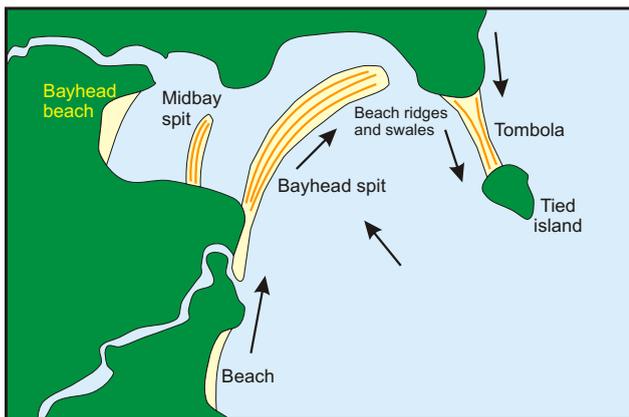
Figure 4

Types of coastal sand bodies. Nine Mile Beach is a typical bayhead spit. Other examples include Seven Mile Beach near Hobart, and Ocean Beach at Strahan. The isthmus at Wineglass Bay, and the necks on Maria and Bruny islands, are tombolos, and Mt Freycinet, north and south Maria Island, north and south Bruny Island, and South Arm are examples of tied islands.

The number of ridges and swales decreases eastwards towards the Swan River estuary, where the river has eroded the inner side of the spit. Here the ridge and swale system has also been disrupted by relatively recent wind erosion, which has created a very irregular topography of steep-sided hillocks and intervening depressions (blowouts), now partly stabilised by vegetation.

Low-lying backbarrier swamp and estuary

Low-lying swampy ground, and the Swan River estuary and Moulting Lagoon, extend the full inner length of the Nine Mile Beach spit. In the study area, this 300–500 m wide strip of poorly-drained swampy ground slopes gently seaward (towards the spit) from about 1–2 m above MSL, to less than one metre above MSL where it joins the spit. Dolphin Sands Road crosses this poorly drained area at a low-level watershed, so that the area to the southwest of the road drains towards the Meredith River, and that to the northeast drains east via Wet Marsh Rivulet to the Swan River.

Elevated land behind the backbarrier swamp

A fairly prominent gentle escarpment between about five and eight metres high separates the low-lying spit and backbarrier swamp from gently undulating ground extending north and northwest for one to two kilometres past the Tasman Highway. This area is underlain by older sedimentary materials (clay and sandy clay) on which are locally superimposed younger deposits like the prominent clay lunette near the Swan River Road junction with the Tasman Highway. Extending above this general level to heights around 20 m above MSL are isolated low hills and outcrops of basement rocks (Jurassic-age dolerite).

Rainfall and evapotranspiration

Rainfall is recorded at several locations in the Swansea district. The mean monthly figures are summarised in Table 1 and Figure 6. Evapotranspiration has been estimated using a Forestry Tasmania technique based on mean maximum daily temperature. On this basis, evapotranspiration exceeds average mean rainfall most months of the year, although the records point to a possible rain excess in May and June, in an average rainfall year amounting to 23 mm (say, 25 mm). This is equivalent to 250 000 litres of water for every hectare.

There is effectively no runoff in coastal sands, so that any excess rain is available for infiltration below the root zone of plants to contribute to soil moisture and to recharge groundwater. In abnormally dry years there is no rainfall excess. Conversely, abnormally wet years result in additional groundwater recharge.
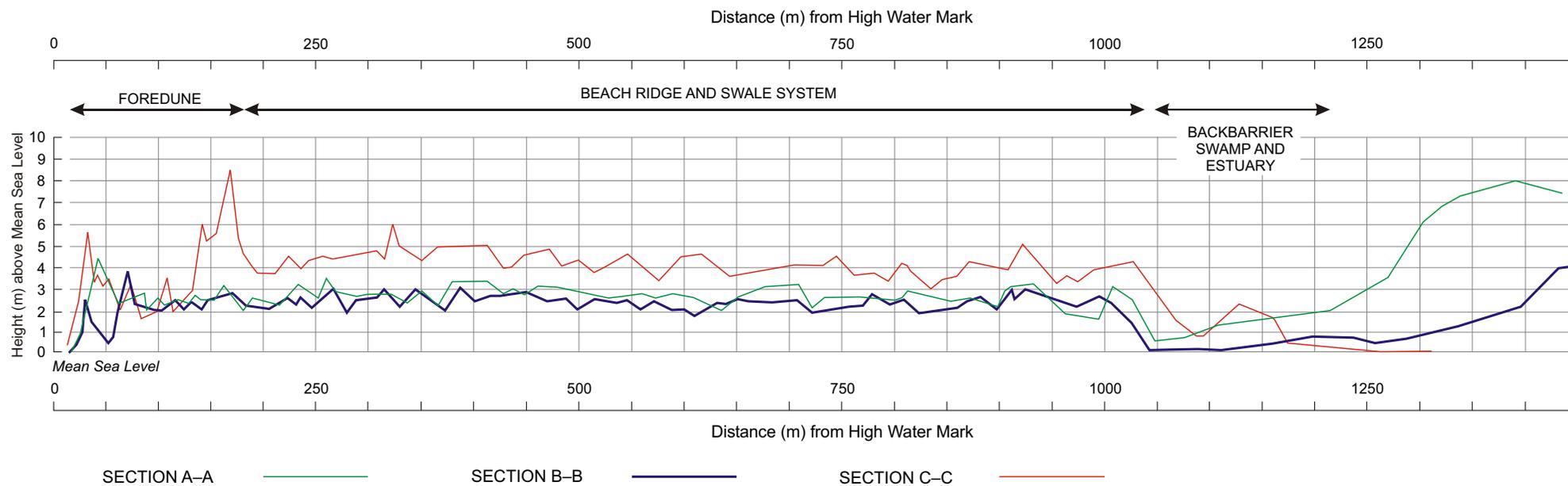
Figure 5
Surveyed transects A, B and C showing the morphology of the western end of the Nine Mile Beach spit.

Mean monthly rainfall for five stations near Nine Mile Beach

Rainfall (mm)	From	To	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Belmont	1962	1998	39	37	66	49	68	59	34	54	37	45	58	67	**613**
Kelvedon	1876	1998	51	49	54	53	50	58	49	45	43	57	57	64	**629**
The Grange	1921	1993	43	54	54	58	61	58	48	43	37	52	53	65	**625**
Swansea PO	1884	1998	49	43	51	51	48	59	49	44	41	53	51	62	**602**
Swanwick	1932	1953	45	57	48	63	64	64	49	49	34	59	55	62	**649**
Mean rain			**45**	**48**	**54**	**55**	**58**	**59**	**46**	**47**	**38**	**53**	**55**	**64**	**624**
Maximum mean daily temperature (°C)			22	22	21	19	16	14	13	14	16	18	19	20	
Estimated evapotranspiration (mm)			83	69	65	55	46	49	49	52	57	66	68	76	735
Rain excess (mm)							12	10							23

Note: Evapotranspiration (ET) is estimated using a Forestry Tasmania method based on maximum mean daily temperature (T).

For the months June–January, the relationship is ET = 0.12T mm/day.

For the months February–May, the relationship is ET = 0.13T - 0.4 mm/day
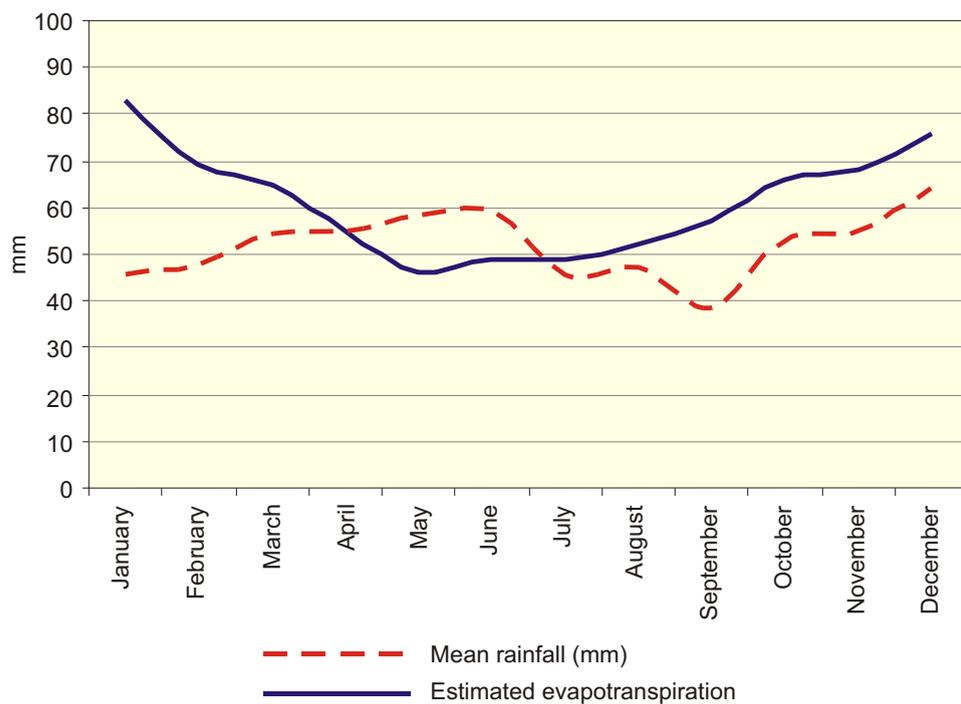
Figure 6

Mean monthly rainfall and evapotranspiration for Nine Mile Beach.

Regional setting

Great Oyster Bay is a down-faulted basin (graben) bordered by uplifted basement rocks and filled with unconsolidated sediments deposited since Tertiary times. It extends from near Bicheno in the north, south towards Maria Island, and is up to about 20 km wide. Several hundred metres of Tertiary materials may be present (Leaman and Richardson, 1981). The Nine Mile Beach spit commences at the western edge of the graben, and extends eastwards almost the full width of it. Within a very short distance of outcropping dolerite basement rocks near the mouth of the Meredith River, the thickness of Tertiary sediments in the graben is estimated at about 100 metres.

Jurassic dolerite

West of the study area, dolerite crops out in the floor of the Meredith River, and forms much of the uplands extending north and south from Swansea (fig. 7). Within the study area, dolerite occurs at Didos Hill on the Tasman Highway, near the mouth of the Meredith River, and as isolated knolls near the mouth of Wet Marsh Rivulet.

Tertiary sedimentary rocks

Unconsolidated sedimentary rocks, inferred to be Tertiary in age, include clay, sandy clay and clayey sand on gently-undulating ground behind the low escarpment at the rear of the beach ridge system, and on the southern side of the Meredith River mouth. A scatter of limonite and pisolitic ironstone lag is sometimes present on the surface. In drill holes (e.g. BH19, BH21) the Tertiary materials are often brightly coloured, and sometimes contain ironstone horizons and concretionary calcareous patches.

It is inferred that Tertiary sediments underlie the beach ridge system, thickening in a generally eastward direction towards the deeper parts of the Oyster Bay Graben. Some of the materials intersected in BH25, for example, may be Tertiary in age.

Quaternary sedimentary rocks

Quaternary-age[4] sedimentary rocks are widespread in the study area. Of most interest to the present study are the beach, near-shore (shallow) marine, fluvial, estuarine and backbarrier swamp deposits laid down in the Late Pleistocene and Holocene epochs, and which now form or border the Nine Mile Beach spit.

Figure 8 is a schematic time scale showing the relationships between the Pleistocene and Holocene epochs in the Quaternary Period in Tasmania, and the inferred rises and falls of sea level occasioned by waning and waxing glaciations. By inference with dated coastal sand bodies elsewhere in southeastern Australia (including Tasmania), the Nine Mile Beach spit is thought to have been formed during the Holocene Epoch (Thom *et al.*, 1981).

Late Pleistocene? higher terraces

Materials inferred to be Late Pleistocene in age (possible Last Interglacial or Interstadial) include the higher terrace fluvial deposits laid down by and bordering the Meredith River (fig. 7). These deposits fan out from the break of slope where the river emerges at the foot of the nearby hills, and generally comprise unconsolidated or poorly consolidated red-brown conglomerate and friable silty sandstone. These deposits are currently being locally eroded by the river. Abandoned former river channels are clearly evident in places.

The higher terraces pre-date the Holocene beach ridge system, and post-date the inferred Tertiary deposits. They were probably formed at a time of higher sea level, and their degree of consolidation may indicate a Last Interglacial age rather than the Interstadial of the Last Glacial.

Last Glacial lunettes

A prominent lunette lies a few hundred metres west of the Tasman Highway near the junction with Dolphin Sands Road. The arcuate feature is approximately 10–15 m high and about 500 m long. The drilling of hole BH39 in June 1980 (fig. 3 and Appendix 1) showed that the lunette consists mainly of clay and sandy clay. A second smaller lunette lies immediately to the northwest.

Like many other similar features in Tasmania, the lunettes are inferred to date from the Last Glacial, when cool winter conditions and a local lack of vegetation cover caused the drying out and deflation of lagoons and river beds. Desiccation of hypersaline clays on these exposed surfaces produced flocculated sand-sized clay, and the dunes formed as this material was blown and deposited nearby to windward.

Nine Mile Beach stratigraphy

Materials exposed at the surface, and inferred to be Holocene in age, include beach sand on the modern beach, aeolian sand in the foredunes, aeolian sand and beach sand in the ridge and swale system behind the foredunes, and backbarrier clay and mud, and some river cobbles, along the landward edge of the spit.

The subsurface distribution of materials has been reasonably established near the western end of the spit, along transect B (Appendix 1, fig. 7 and Table 2). This cross section extends in a northwesterly direction from near high water mark, over the foredunes, the beach ridge system, the 24-spear bore array, the

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4   The Quaternary Period of geological time is the last two million years. Of this, the first 99.5% is called the Pleistocene Epoch, and the rest (0.5%, or the last 10,000 years) is the Holocene Epoch.

GEOLOGY OF THE NINE MILE BEACH AREA
Mapping by Willam C. Cromer

QUATERNARY	HOLOCENE	Marsh deposits — mud, sand, clay
		Beach sand
		Estuarine deposits – clay, sandy clay, clayey sand, with interbedded shelly marine mud
		Fluvial deposits — minor pebbles, cobbles, muds
		Aeolian sand — beach ridges (overlying nearshore marine sand)
		Cobble beds (in nearshore marine sand beneath aeolian sand)
		Fluvial deposits (Lower river terrace) – dark brown cobbly silt, boulders and gravel
	Last Glacial	Lunette — clay (and sand)
	Pleistocene?	Fluvial deposits (Upper river terrace) — poorly consolidated red-brown conglomerate, friable silty sandstone
		Scree — dolerite cobbles and boulders
TERTIARY?		Clay — with minor interbedded sand and limonite horizons
JURASSIC		Dolerite

Figure 7

Figure 8

Tasmanian glaciations and sea level changes in the Quaternary Period, adapted from Colhoun (1975). The heavy black line represents inferred approximate sea level temperature. Low temperatures correspond to times of maximum glacial activity and lower sea level; higher temperatures correspond to times of minimum glacial activity and higher sea level. In between, sea level is either rising (transgressing) or falling (regressing). The Last Interglacial sea level may have been 10 to 20 m higher than at present. The Late Last Glacial sea level may have been 70 m lower than at present. Tasmania was then connected to mainland Australia by a dry Bass Strait, and the Tasmanian coastline was about halfway across the continental shelf. From about 15,000 to 12,000 years BP (Before Present), ice caps started to melt and sea level rose. It reached its highest point (about one metre above present mean sea level) about 6,000 years BP, during the Holocene Epoch, when the Nine Mile Beach spit (and other similar coastal deposits) was forming. After a brief period of falling level, sea level has remained fairly constant over the past few thousand years.

low-lying backbarrier deposits at the rear of the spit, and up onto the low escarpment underlain by inferred Tertiary sedimentary rocks. The stratigraphy along this line is generally supported by transects A and C to the west and east respectively, although both of these are based on fewer, more shallow drill holes.

Figure 9 shows the inferred stratigraphy across transects A, B and C at Nine Mile Beach, based on the detailed bore logs of investigation holes presented in Appendix 1. Figure 10 is a schematic section through transect B, summarising the four stratigraphic units (1, 2, 3 and 4) identified.

UNIT 1

The lowest unit (Unit 1) in the sequence is a stiff, dark coloured (olive-green, grey-green, olive-grey, grey-blue, brownish-black or olive-brown) high plasticity clay which was intersected in two drill holes in transect A, seven in transect B, and one in transect C. The unit is shell-free, sometimes includes clayey sand or sandy clay horizons in its upper levels, and contains ironstone fragments (to 20 mm) probably reworked from the nearby Tertiary sedimentary rocks, and charcoal. At its extreme landward limit, the colour of the Unit lightens to yellow-brown, suggestive of former oxidising conditions.

The thickness of Unit 1 is uncertain. Drill hole B25 on transect B passed through 27 m of clay, but not all of this is necessarily Unit 1. It is possible that deeper sections of the hole intersected Tertiary clay. Unlike most others in the program, holes B25 and B26 were drilled with a rotary rig, which results in highly disturbed samples with limited depth control.

The upper surface of Unit 1 shows a relief of several metres along the spit, and at transect B it slopes seawards from about -4 m beneath the backbarrier at the rear of the spit, to about -9 m beneath the modern beach. The resulting fall of about 5 m in 1250 m is a gradient of 1:250, or a slope of a mere 0.23°. The upper surface of Unit 1 is therefore essentially horizontal.

Unit 1 controls the hydrogeology of Nine Mile Beach in a significant way:

☐ the inferred very low permeability means Unit 1 acts as an aquiclude (i.e. it effectively prevents the vertically downward movement of groundwater from the overlying sand, and the vertically upward movement of any groundwater which may be present in sandier materials within it; and

☐ its presence at relatively shallow depth means that, from an hydrostatic viewpoint, the overlying Nine Mile Beach aquifer above it is entirely full of relatively fresh groundwater.

Table 2. *Summary of hydrogeological investigation bores drilled July 1979 to June 1980 at Nine Mile Beach*

Hole (BH)	Easting (m)	Northing (m)	Collar elevation (mAMSL)	Date drilled	Logged by	Total depth (m)	Depth (mBMSL)	Depth (m) to water	Casing diameter (mm)	Slotted interval (m)	Pump rate (L/min)	Pumped level (m)	TDS (mg/L)	EC (µS/cm)	Odour	Colour	pH
1	592311	5339254	3.5	19/06/1979	WC, DJS	8.1	-4.6	2.4									
2	592276	5339503	3.8	20/06/1979	WC, DJS	8.2	-4.4	3.4									
3	592241	5339719	3.5	21/06/1979	WC, DJS	7.9	-4.4	3.2									
4	592158	5340123	0.9	21/06/1979	WC, DJS	3.7	-2.8	0.0									
5	592205	5340018	3.3	21/06/1979	WC, DJS	4.9	-1.6	3.0									
6	592219	5339901	3.5	21/06/1979	WC, DJS	7.9	-4.4	2.4									
7	591339	5339350	3.5	16/07/1979	WC	11.3	-7.8	2.4	50	2.2-5.3	60	4.0	360	600	None	None	7.3
8	589847	5338395	2.0	17/07/1979	WC, DJS	9.8	-7.8	1.8	50	2-4.7	53	4.6	370	615	None	None	7.8
9	588514	5337595	2.6	17/07/1979	WC	3.4	-0.8	1.8	50	1.7-3	4	3.0	250	390	None	None	7.6
10	588802	5338161	2.1	17/07/1979	WC, DJS	6.1	-4.0	1.2	50	1.2-3.3	53	1.7	300	430	None	None	7.4
11	588524	5338338	1.9	18/07/1979	WC	4.3	-2.4	1.4									
12	588959	5338692	2.9	18/07/1979	WC	6.1	-3.2	2.1	50	2.2-5.5	53	3.5	370	625	None	None	7.6
13	589393	5339133	2.0	18/07/1979	WC	2.4	-0.4	1.9						1,500			
14	589361	5339149	2.0	19/07/1979	WC, DJS	1.5	0.5	Dry									
15	588414	5338422	1.5	19/07/1979	WC, DJS	5.1	-3.6	1.6	50	1.6-4.5	16		12,180	12,000	Salty	Slight	7.5
16	589515	5338855	2.2	08/08/1979	DJS	4.7	-2.5	1.7	50	1.7-5.0	68	4.4	360	570	None	None	7.5
17	589280	5338180	2.1	08/08/1979	WC	5.0	-2.9	1.6	50	2-5	53		320	500	None	None	7.6
18	589089	5338410	2.1	08/08/1979	WC	3.5	-1.4	1.3	50	1.3-3	68	1.3	410	620	None	None	7.6
19	588899	5339260	4.3	28/08/1979	DJS	2.4	1.9	Dry									
20	589551	5338790	2.8	29/08/1979	DJS	5.7	-2.9	2.1									
21	588918	5339239	2.8	29/08/1979	DJS	6.1	-3.3	2.5									
22	588997	5339152	1.2	29/08/1979	DJS	5.5	-4.3	1.0					7,400				
23	589139	5338996	0.7	29/08/1979	DJS	4.9	-4.2	0.5					620				
24	588173	5338955	2.7	29/08/1979	DJS	7.7	-5.0	1.4									
25	589548	5338789	2.7	28/08/1979	WC, DJS	36.6	-33.9	2.0									
26	589877	5338340	2.0	02/09/1979	KR	13.7	-11.7	2.0									
27	589469	5338805	2.9	26/06/1980	WC	9.6	-6.7	2.6									
28	589430	5338711	2.3	26/06/1980	WC	6.0	-3.7										
29	589536	5338684	2.4	26/06/1980	WC	6.1	-3.7	2.0									
30	589145	5338968	1.0	25/06/1980	WC	6.9	-5.9	0.4									
31	589150	5338980	0.6	25/06/1980	WC, NC	6.9	-6.3										
32	588984	5339422	4.0	25/06/1980	WC, NC	3.3	0.7										
33	589010	5339453	3.1	24/06/1980	WC, NC	3.4	-0.3										
34	588039	5339484	2.2	24/06/1980	WC, NC	6.1	-3.9										
35	589141	5339531	2.7	25/06/1980	WC, NC	6.0	-3.3										
36	588813	5339742		24/06/1980	WC, NC	6.2											
37	587984	5339359		23/06/1980	WC, NC	5.1											
38	587656	5339389		23/06/1980	WC, NC	4.2											
39	587628	5339109		24/06/1980	WC, NC	7.8											
40	589850	5338350	0.8	June 80	WC	9.4	-8.6	0.4									

Notes:
1. AMSL and BMSL = 'above mean sea level' and 'below mean sea level' respectively.
2. WC = William Cromer; DJS = D. John Sloane; NC = Neil Chick; KR = Kerry Richardson.
3. All holes except BH25 and BH26 drilled by B. Cox using a Triefus mechanical auger rig and 100 mm diameter solid augers. Samples collected by auger pull method at approximate one metre intervals.
4. BH25 and BH26 drilled by Kerry Richardson using a Failing rotary rig.
5. TDS = Total Dissolved Solids ('salinity') in milligrams per litre (mg/L).
6. EC = Electrical Conductivity in microSiemens per cm (µS/cm), measured in the field.
7. TDS, pH measured in laboratory.
8. Colour and odour are subjective field estimates.
9. Blank boxes indicate no information.
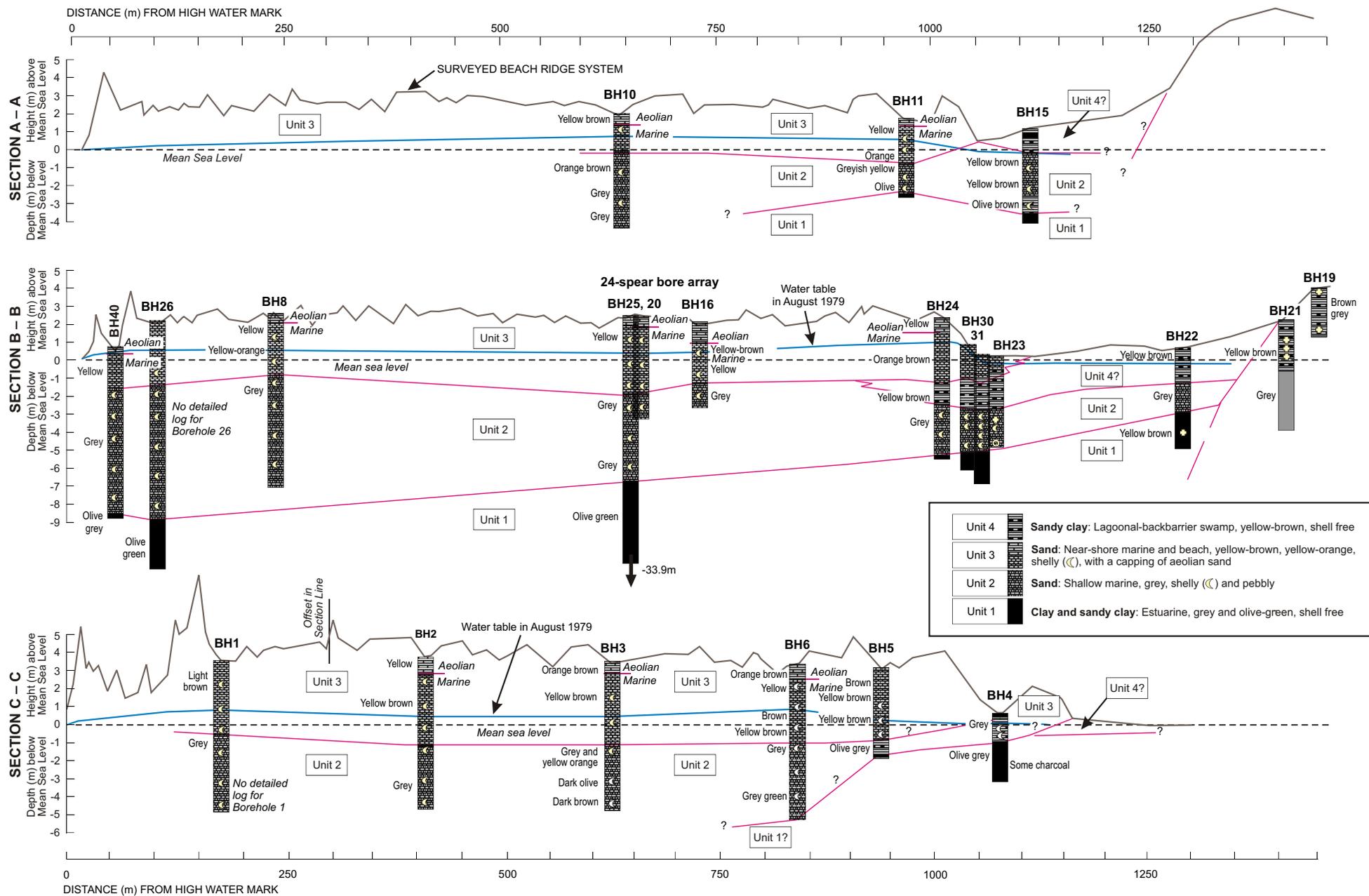
Figure 9. *Interpreted stratigraphy of the Nine Mile Beach spit at transects A, B and C.*
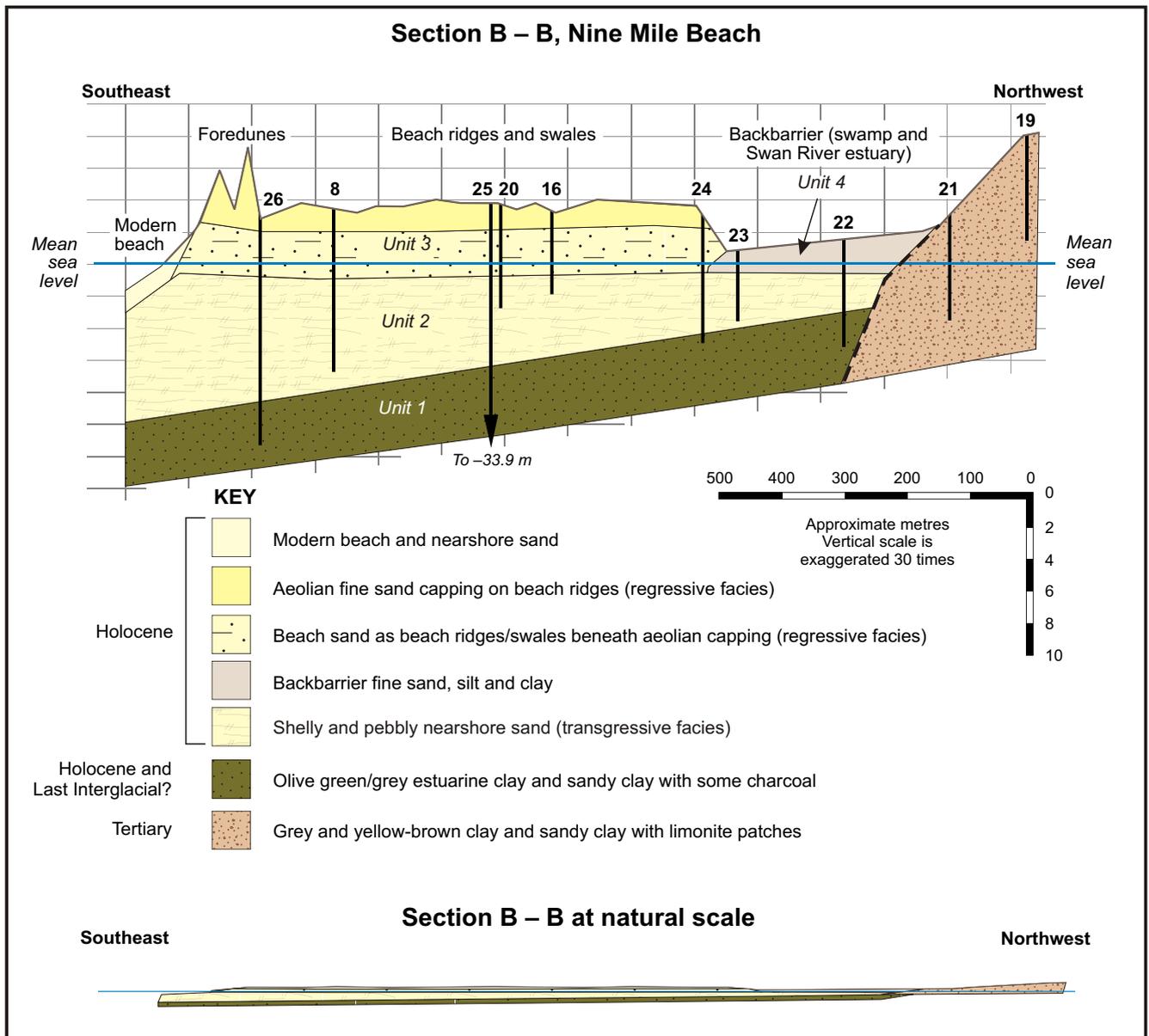
Figure 10. *Schematic stratigraphy of the Nine Mile Beach spit at transect B*

UNIT 2

Unit 2 comprises the lowermost sandy deposit beneath Nine Mile Beach, and rests with sharp contact on Unit 1. Unit 2 was intersected in most of the drill holes in the investigation program, which shows that it extends the full width of the spit and also underlies the low-lying backbarrier at the spit's rear. The top of Unit 2, as inferred from drill hole logs (Appendix 1) shows a relief of perhaps one to two metres, but is essentially horizontal at about -1 m and -2 m below MSL (fig. 9). Because its base dips very slightly seawards, the Unit

thickens in this direction, from about 2–3 m along the landward edge of the backbarrier, to about 7–8 m beneath the modern beach.

Unit 2 materials include both shell-free sand and shelly sand, which are yellowish grey, dark grey, dark olive or olive-brown in colour. Texturally, the sand is mainly very fine grained (with a tendency to become finer grained with depth). The median grain size (D_{50})[5] is usually in the range 0.12 to 0.15 mm, but sorting is usually fairly poor because of the very common occurrence of fragmented and whole shells, which

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5   Selected engineering logs of drill holes in Appendix 1 show the results of grain size analysis of sand samples collected during drilling, expressed as the D_{50} value (which measures grain size), and the S_o value (which measures the range of grain sizes in the sample). In grain size analysis, a dried sample of sand is passed through a series of standard sieves, and the proportion of each sample retained on each sieve is recorded. D_{50} (the 50% size) is the grain size at which half the sample is retained, and the other half passes. The sorting coefficient (S_o) is defined as the square root of the ratio of the 25% size to the 75% size, and is an indication of the slope of the grain size distribution curve. Values of S_o less than 0.5 indicate the sample is well sorted (most of the sand grains are all about the same size); between 0.5 and 1 indicates the sample is moderately sorted, between 1 and 2 indicates the sample is poorly sorted, and an S_o more than 2 indicates the sample is very poorly sorted (there is a wide range of grain sizes in the sample). Another, similar measure of sorting is the uniformity coefficient, the ratio of the 40% to the 90% sizes, as shown in Figure 11.
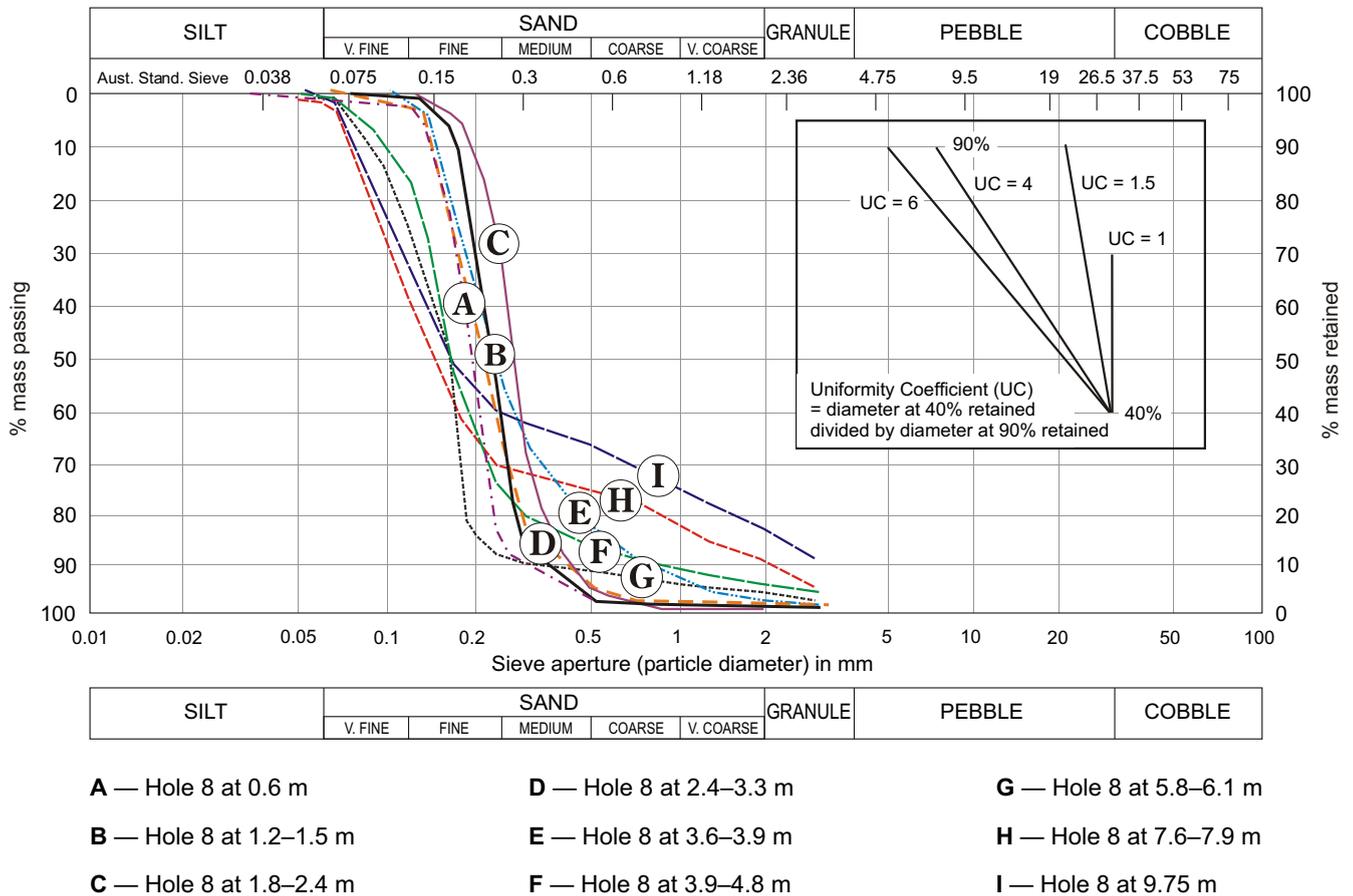
Figure 11

Grain size analysis of sand samples from drill hole 8 at Nine Mile Beach. It is possible to distinguish the various stratigraphic units on the basis of sand size and sorting (i.e. the shape and position of the grain size distribution curve). Curves A, B, C and D are all poorly-graded (well-sorted) sands mostly in the fine-medium grain size range, and represent Unit 3 (beach sand) material. Curves E to I are more poorly sorted, with a wider range of grain sizes ranging from granule to very fine sand, and are inferred to be nearshore marine (Unit 2) material.

constitute the bulk of the coarser fragments at all depths in all holes tested. Contributing to the poorer sorting are lenses and thin horizons of fine quartzite gravel, fragments of sandstone to 10 mm, rare dolerite clasts, and patches of carbonate-cemented sand. Heavy dark minerals commonly form part of the finer fraction.

Shell species identified in Unit 2 sands in drill hole 8 between 3.4 m and 4.3 m (1.4 m to 2.3 m below MSL) include *Donacilla nitida, Fulvia, Glycimeris striatularis, Clanculus, Austroginella muscaria, Polymices, Scaeoleda crasea* and *Bankivia fusciata*. Species in the interval 4.3 m to 7.7 m (2.3 m to 5.7 m below MSL) include all of the above, as well as *Zeacumantuo diemeinsio, Nassarius pauperatus, Guratens pictus, Subminella undulata, Tawera gallinule*, and echinoderm spines. Species in the interval 7.7 m to the base of the hole at 9.75 m (5.7 m to 7.75 m below MSL) include all of the above, as well as *Mactra rufencens, Pullastra fabayella, Nastid* spp., *Placenen flaccida, Fulvia tennicostata* and *Mytilus flamulatus*.

UNIT 3

Unit 3 at Nine Mile Beach is a fine to medium-grained, poorly-graded (well sorted) sand and shelly sand, usually light in colour (yellow, bright yellowish brown, orange-brown, dull yellow-orange) and contrasting markedly with the darker, underlying Unit 2 sand. The surface 0.5 m or so of the unit is finer grained and usually free of shell and fragmented shell. It forms a thin capping over the underlying sand, which has a median grain size in the range 0.2 to 0.25 mm.

Unit 3 sand also contains traces of charcoal and cemented calcareous patches. Along the rear of the spit the sand is locally mixed with well-rounded dolerite cobbles and boulders, which probably represent reworked river deposits associated with former channels of the ancestral Meredith River.

UNIT 4

From the surface down, Unit 4 generally comprises the shell-free clay, sandy clay, and clayey sand on and beneath the backbarrier at the rear of the spit. Colours tend to be dark (dark grey, brown-grey, grey, olive-brown, dark greenish grey), and the materials stiff to very stiff. The clays are of high plasticity. Traces of ironstone, calcareous material and pebbles are common.

Unit 4 tends to thin in a longshore direction, from a lensoid cross section about five metres thick on transect A, to a tabular cross section one or two metres thick at transect C. The unit's almost horizontal upper surface extends from the base of the Tertiary escarpment and either abuts, or dips beneath, the landward edge of the spit. On transect B, and probably elsewhere, the seaward edge of the material interfingers with the Unit 2 sand, indicating that the two types of materials probably formed at the same time.

Radiocarbon dating of Holocene materials at Nine Mile Beach

In June 1979, six samples of shell hash (fragmented shells) were collected from BH1 (1 sample), BH2 (2 samples), BH5 (1 sample) and BH6 (2 samples) on transect C at Nine Mile Beach. The sampling was part of a program of radiocarbon dating of Holocene coastal landforms in southeastern Australia, conducted by the Department of Geography at the University of New South Wales (Thom *et al.*, 1981). Other Tasmanian sites included Rheban, Greens Beach, Seven Mile Beach and Anthonys Beach near Smithton.

Five dates were obtained from the Nine Mile Beach samples, and all were in excess of 8,500 ^{14}C years BP. These were considered 'anomalously old', resulting from the mixing (by beach and near-shore marine processes) of shell fragments of different ages from early to late Holocene, perhaps with some Pleistocene detritus. Similar problems were encountered with shell hash dates from the other Tasmanian sites, although a young age of 3,650 ±270 years BP was obtained from one of the Greens Beach samples.

Quaternary history of the Nine Mile Beach area

At the height of the Late Last Glacial, about 18,000 to 20,000 years BP, sea level is thought to have been about 70 m lower than at present. Everywhere, coastlines stood out on continental shelves. In the Tasmanian region, Bass Strait was dry land, and northern Tasmanian rivers like the Tamar, Mersey and Leven meandered across an almost flat grassland to join the ancestral Yarra River and flow westward north of the present day King Island. In eastern Tasmania, Schouten and Maria Islands were isolated uplands on a coastal plain which stretched east for 10 km or so across the continental shelf. The Meredith River was then a tributary of the Swan, which flowed across what is now Great Oyster Bay. Nine Mile Beach and Moulting Lagoon did not exist.

Colhoun (1975) has attempted a reconstruction of landform types, geomorphic processes, climate and vegetation for Tasmania during the Last Glacial. In eastern Tasmania the probable vegetation was grassland, coastal scrub and light eucalypt savannah. Winters were probably cool, with snow on high ground. Deposits included valley fills and slope deposits, and the accumulation, from adjacent dry river beds or swamps, of windblown sand and clay to form lunettes.

Possibly from as early as 15,000 years BP, but at a quickening pace from about 10,000–12,000 years BP, global sea levels started to rise as ice caps and glaciers melted. As the Tasmanian shoreline moved inland, available sand supplies were worked into near-shore barriers. Inland from these barriers, estuarine conditions started to develop in what is now Great Oyster Bay, and Unit 1 started to form. The Swan and Meredith rivers were separated by rising (transgressing) waters, and each flowed into a broad wet depression similar to the present day Moulting Lagoon. As transgression continued, and sea level rose to about a metre above present day levels by about 6,000–6,500 years BP[6], the estuarine conditions were pushed inland, or disappeared, and the near-shore deposition of grey shelly sand (Unit 2) extended to the present day escarpment near Dolphin Sands Road.

The sea level receded slightly to present day levels during the mid-Holocene and parts of Unit 2 were eroded (so that, at the rear of the present day backbarrier materials, Unit 1 was briefly exposed and oxidised), and seaward growth (progradation) of the beach and swale system (Unit 3) occurred. As the beach ridges accumulated under the slight fall of sea level, backbarrier clay, clayey sand and sandy clay were deposited in the low-lying zone behind the innermost beach ridge at the western end of the spit.

Most recently, the present outlets of the Swan and Meredith rivers were established, a system of aeolian foredunes has developed, and some of this material has been blown inland to form a thin aeolian capping on the underlying beach materials.

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6   A rise of (say) 100 m in sea level in 5,000 years is an average rate of one metre in 50 years, or 20 mm a year. On a coastal plain sloping seawards at (say) 1°, this rate of sea level rise would cause the coastline to move landwards at the rate of one metre a year — rapid enough to be readily apparent to indigenous communities.

Groundwater

General principles

The following comments are drawn largely from Cromer (1993) to provide a basic background to hydrogeological principles and to assist landowners, regulators and others in groundwater management.

Origin of groundwater

With the exception of 'new' water formed underground from magmatic and other volcanic processes, all groundwater is derived from that part of precipitation which, after surface runoff and evaporation, infiltrates the soil. Some of the infiltrating water is transpired by plants, some is drawn upward by capillary action and evaporated, and some remains indefinitely in microscopic voids in the soil profile. During and after continuous and wetting rain, the remainder infiltrates downwards, intermittently and successively saturating the material through which it passes, until the water reaches the *zone of saturation*. Here, the soil or rock *voids* (openings) are completely filled with water. The water is then called *groundwater*, and the upper surface of the zone of saturation is known as the *water table*. The water table is usually a subdued replica of the land surface, being almost flat under gently undulating ground (like Nine Mile Beach), and deeper and sloping under hills.

The proportion of rain infiltrating into the soil is very variable, ranging from a few percent on steep, rocky slopes, to perhaps 50% or more in sandy or gravelly areas with little runoff. The proportion also changes seasonally, and infiltration into sand like that at Nine Mile Beach, for example, would be expected to be at a maximum when evaporation is least — at night in winter. Only a fraction of the water which enters the soil avoids transpiration or retention in soil voids, and infiltrates to the water table.

Groundwater is therefore a part of the general hydrological cycle, and is directly related to the surface movement of water.

Unconfined and confined aquifers

An *aquifer* is a body of rock, or unconsolidated material such as sand, capable of supplying useful amounts of groundwater. An aquifer has two purposes: it *stores*, and *transmits*, groundwater. The relative importance of each function is determined by the nature of each aquifer. Some aquifers (e.g. hard sandstone) may store only a small amount of water in a network of thin fractures, but might transmit it freely, and remain reliable suppliers, if the fractures are sufficiently interconnected. Other materials, like fine-grained and porous clays, may contain larger amounts of water, but yield only small amounts because the water is not transmitted easily through their microscopic voids.

Aquifers may be *unconfined* (like Nine Mile Beach) or *confined*. An unconfined or water table aquifer exists in unconsolidated sediments or other materials whenever the water table is in contact with air at atmospheric pressure. Unconfined aquifers therefore receive recharge from infiltrating rain over their full areal extent. Groundwater in a bore tapping an unconfined aquifer remains at the level of the water table. By contrast, a confined aquifer is a saturated, permeable zone bounded above and below by relatively impermeable materials. The aquifer cannot receive recharge by directly infiltrating rain, but must get it from a more elevated recharge area elsewhere, where the permeable zone is exposed at the land surface, and where at least local unconfined conditions exist. The infiltrating groundwater in the zone of recharge moves downslope beneath the confining impermeable layer. The water in confined aquifers is therefore not in contact with the atmosphere, and is at a pressure greater than atmospheric. Water in bores tapping confined aquifers rises up the bore under pressure, and may overflow at the land surface.

Storage capabilities of unconfined coastal sands

Unconsolidated sands, like those at Nine Mile Beach, are reliable aquifers. They have good storage capabilities, and are also relatively good transmitters. The water is stored in voids between the sand grains, and the voids are interconnected (i.e. the aquifer is intergranular). The voids may constitute from 25% to 35% of the volume of sand (i.e. the *porosity*, θ, of the sand is 25% to 35%, or 0.25 to 0.35 expressed as a fraction). Each cubic metre of saturated sand below the water table therefore contains 250 to 350 litres of groundwater. A proportion of this is held tightly around the sand grains, and cannot easily be removed. A measure of the extractable volume of water in an unconfined aquifer is its *specific yield* (S), defined as the ratio of (a) the volume of groundwater which the saturated aquifer will yield on gravity drainage to (b) the volume of the aquifer. It is equivalent to the porosity minus the firmly-held water (*specific retention*), or

$$\text{Porosity} = \text{specific yield} + \text{specific retention}$$

Primary and secondary porosity

The voids between sand grains in a coastal sand body like Nine Mile Beach constitute primary porosity, because they were formed at the same time as the sand was deposited. As the sand becomes progressively cemented and consolidated in the process of becoming hard rock, the primary porosity is reduced. Most hard rocks have very little remaining primary porosity. If the hard rock becomes fractured and otherwise jointed, the fractures constitute *secondary porosity*.

Groundwater gradient

Groundwater is rarely stationary. It moves in response to gravity, and hydrostatic and lithostatic pressures, from recharge areas to discharge zones. Discharge occurs wherever the water table intersects the land

surface in springs, swamps, rivers and the sea, provided the water table slopes towards the feature. If the water table is lower than the feature, water may flow from the spring or river to the groundwater body. The slope of the water table is called the water table *gradient*[7], which determines the direction and rate at which groundwater moves. The greater the gradient, the more rapid the flow. Groundwater usually flows in the direction of steepest gradient. In coastal sand bodies, the gradient is usually very low (often less than 1:100) so that the groundwater is slow moving.

Aquifer permeability and transmissivity

Permeability (symbol K) is a measure of how readily an aquifer transmits water, and is defined as the rate at which groundwater will flow from a unit area (e.g. one square metre) of aquifer under a unit gradient (i.e. the gradient is 1). It is expressed as cubic metres per day per square metre ($m^3/day/m^2$, which reduces to m/day). Typical coastal sands have permeabilities in an approximate range of 2 to 20 m/day, depending on the size and interconnectedness of the voids between the sand grains, and whether the sand is poorly sorted or well sorted. Permeability usually varies horizontally and vertically in an aquifer. *Transmissivity* (T) is defined as the product of permeability and saturated aquifer thickness, and is therefore the rate at which groundwater will flow from a vertical, one-metre wide strip of the aquifer under a unit hydraulic gradient.

Groundwater flow

The groundwater flow through a unit area (e.g. one square metre) of an aquifer is determined by the aquifer permeability and the water table gradient, and is calculated from Darcy's Law:

Flow = permeability × gradient[8]

Rate of groundwater travel

The rate at which groundwater moves through an aquifer is determined by the aquifer permeability, the water table gradient, and the aquifer porosity (expressed as a fraction):

Rate of flow =
permeability × gradient/effective porosity[9]

In coastal sand bodies, where gradients are low, the rate of groundwater movement is also usually low. Water falling as rain and entering the water table in the centre of a large sand spit like Nine Mile Beach may take 10 to 20 years to travel the 500 metres or so to the coast.

Groundwater in Jurassic dolerite near Swansea

The groundwater resources in dolerite in the Swansea area are outside the scope of this report, but some general comments are possible.

Jurassic dolerite throughout Tasmania is a fractured-rock, usually unconfined, aquifer. Groundwater below the water table is contained within fractures (secondary porosity), so that the yield (flow rate) from a bore drilled into this rock depends on whether the bore intersects water-bearing fractures, and to what extent the fractures are interconnected. The sustainability of the yield depends on the storage capability of the aquifer, the annual rainfall and the proportion which recharges the aquifer.

Mineral Resource Tasmania holds records of bores drilled into dolerite in the Swansea area. Little information is available on water quality, but by inference with other low-rainfall parts of Tasmania, it is expected to generally be poor.

Groundwater in Tertiary sedimentary rocks near Swansea

Tertiary sedimentary rocks in Tasmania are mainly intergranular aquifers with both unconfined and confined examples. Little information is available on water quality, but by inference with other low-rainfall parts of Tasmania, it is expected to generally be poor.

Groundwater in coastal sands at Nine Mile Beach

Occurrence

All the Holocene materials (Units 1 to 4 in Figures 7 and 9) in the Nine Mile Beach spit contain groundwater, although collectively, only Units 2 and 3 constitute an aquifer. These sands have the capability to supply useful quantities of groundwater because they have relatively good storage capacities and permeabilities. Unit 1 (the estuarine clay beneath the near-shore and beach sand) is saturated with water, but the material appears, from drilling evidence, to be too impermeable to supply water at useful rates. Unit 4 also contains groundwater, but these backbarrier clays, sandy clays and clayey sands along the rear of the spit are generally too impermeable. Some higher permeability horizons probably exist within Unit 4, but the salinity of water in waterholes which intersect

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7   The gradient is usually expressed as the difference in elevation of the water table between two points, divided by the distance between them. For example, a fall of one metre in water table elevation over a horizontal distance of 50 metres is a gradient of 1:50 (i.e. 0.02 expressed as a fraction).

8   For example, assuming a permeability of 10 $m^3/day/m^2$ and a gradient of 1:100 (i.e. 0.01), the flow through a single square metre of sand is $10 × 0.01 = 0.1 \ m^3/day$ (100 L/day). If the sand permeability is 2 $m^3/day/m^2$, and the gradient remained at 0.01, the flow would be $2 × 0.01 = 0.02 \ m^3/day$ (20 L/day). On a one hectare property, with a 100 m boundary parallel to a beach, the groundwater flow across the boundary would be $100 \ m × 0.02 \ m^3/day$ (i.e. 2 m^3/day, for each one metre depth of saturated sand).

9   For example, if the sand permeability is 2 $m^3/day/m^2$, the gradient is 0.01 and the effective porosity is 0.25, the rate of flow would be $2 × 0.01/0.25 = 0.08 \ m/day$ (i.e. 80 mm/day).

the water table (fig. 3) show that the groundwater is generally of poor quality.

Size of the aquifer at Nine Mile Beach

The intergranular and unconfined aquifer (Units 2 and 3) at Nine Mile Beach extends the full length (about 15 km) and width (about 1 km) of the sand body, and therefore covers an area of some 15 km^2. The western limit of the aquifer is marked by the edge of the beach ridge and swale system at the drainage line leading from the airstrip on *Cambria*, south to the mouth of the Meredith River. The northern limit is the inner edge of the beach ridge and swale system, and the Swan River estuary. The southern limit is the beach at high water mark, and high water mark at the tidal outlet near Swanwick is the eastern limit.

Figure 9 shows that at its western end the aquifer extends vertically from the water table in Unit 3, to the top of the low-permeability Unit 1. The thickness therefore varies from about 3–4 m along the landward edge of the spit, to about ten metres along the seaward edge. Based on transect B, the average depth is approximately seven metres.

The volume of the aquifer is therefore about 0.1 km^3, or 100 million cubic metres.

Volume of stored groundwater in the Nine Mile Beach aquifer

Apart from a narrow mixing zone near the coast where fresh groundwater and sea water mix (the fresh water – sea water interface), relatively fresh groundwater exists throughout the full lateral extent and thickness of the aquifer.

The volume of fresh groundwater stored in the Nine Mile Beach aquifer is readily estimated from:

$$\text{Groundwater volume} = \text{aquifer volume} \times \text{aquifer porosity}$$

Assuming aquifer porosity is about 25% (i.e. 0.25):

$$\text{Groundwater volume} = 100 \text{ million m}^3 \times 0.25$$
$$= 25 \text{ million m}^3 = 25\,000 \text{ ML}$$

It would be practically impossible to remove all this water from the aquifer. This would require a grid of bores, at say 20 m centres, to completely cover the aquifer, with at least 30,000 bores being needed. If each bore was pumped at 1000 L/hour, it would take a month to completely remove the freshwater resource — providing it did not rain.

Origin and age of the groundwater

The groundwater in the Nine Mile Beach aquifer is derived wholly from infiltrating rain. There is no other source, because:

(a) the aquifer is underlain by relatively impermeable clay (Unit 1) and is bounded to the west by similarly impermeable Tertiary sedimentary rocks; and

(b) the water table within the aquifer is higher than anywhere around its immediate perimeter.

This latter observation is fundamental — it means that under normal, non-pumping conditions, groundwater flows laterally away from the aquifer in all directions, and not towards it.

Some of the groundwater may be relatively old. Rain water displaced sea water, and started accumulating in the sand, as soon as the spit started to grow and stabilise above mean sea level. This commenced during the progradation (seawards-growing) stage when sea levels fell from about one metre above present levels, in mid-Holocene times approximately 6,000 years BP. Since then, rain has constantly recharged the aquifer from above, and has discharged on all sides, so that some of the groundwater is continually being replenished. This flushing is more effective at and near the water table, where the water is youngest and as a result groundwater salinity is the lowest. There is no clear evidence from Nine Mile Beach that water in the deeper parts of the aquifer is of higher salinity, but this situation exists in several other coastal sand aquifers in Tasmania, and results from slower flushing and longer contact with the sediments.

Depth to groundwater and the shape of the water table

Groundwater is found at Nine Mile Beach at depths slightly above mean sea level, except at the coast and along the Swan River estuary, where the depth to water fluctuates in response to tides. Elsewhere, the groundwater is deepest under the foredunes, and shallowest in swales.

Figure 9 shows the approximate water table position in transects A, B and C across the spit between June and August 1979, based on the drill hole logs in Appendix 1. In transect A, the water table displayed a convex shape, reaching a maximum elevation of about 0.8 m above MSL in drill hole BH8, and falling to mean sea level at the coast and the backbarrier swamp. The average gradient in both directions was between about 0.001 and 0.0015. Steeper gradients can be expected close to the coast and along the Swan River estuary.

The shape of the water table was slightly more irregular in transects B and C, but the irregularities are probably explained by:

(a) uncertainties in measurement, especially in uncased drill holes; and

(b) the fact that the measurements span two months rather than being done simultaneously.

The water table was highest near the rear of the beach ridge system in both transects, at elevations of about one metre above MSL. The overall water table gradient was 0.001 along transect B, and 0.0011 along transect C.

Groundwater flow directions and rate of flow

As discussed in the *General Principles* section (p. 23), groundwater moves in the direction of maximum gradient. At Nine Mile Beach, movement is mainly towards the coast and towards the Swan River estuary.

At the western end of the spit, groundwater flows to the low lying swampy ground at the rear of the spit, and westwards to the Meredith River. The speed at which the groundwater moves is governed by aquifer permeability and porosity, and the water table gradient.

Palfreyman (2002) conducted falling head tests at three sites at Nine Mile Beach and found sand permeabilities in the range of 2 to 8 m/day. Permeability usually varies horizontally and vertically within an aquifer, and this range, while perhaps representative of vertical permeability in finer-grained aeolian sand, is towards the low end of typical permeabilities in coarser-grained beach sand, where values of 20 m/day or more are not unusual. High rather than low permeabilities are also indicated from the yields of individual spears pump tested at selected investigation bore holes, where relatively high pump rates of 53–68 L/min from screen lengths of 2.5–3 m were typical. Permeabilities of at least 30 m/day are indicated from the results of the 21 day pump test on the 24-spear bore array at Nine Mile Beach.

Assuming an average permeability of 30 m/day, a gradient of 0.001, and porosity of 25% (0.25) for the Nine Mile Beach aquifer:

$$\text{Rate of flow} = 30 \text{ m/day} \times 0.001 / 0.25 = 0.12 \text{ m/day}$$
$$= 12 \text{ cm/day} = 45 \text{ m/year}$$

In practice, a range of flow rates is likely to be occurring at any time in the aquifer because of differing permeabilities, porosities and gradients.

Water table fluctuations

An automatic water level recorder was installed at observation bore 8 (BH18 in Figure 3) at Nine Mile Beach for the 161 days between 5 September 1979 and 12 February 1980. The depth to water was recorded daily to the nearest millimetre. The monitoring period included the 21 days of the pump test at the 24-spear bore array. The distance from the centre of the pumped array to observation bore 8 was 528 metres.

Figure 12 shows the fluctuations in the depth to water at observation bore 8, compared to daily rainfall figures for Swansea for the same period. This figure yields the following relevant information:

☐ On 5 September 1979, when monitoring started, the depth to water in the bore was 1.440 metres. At the end of monitoring, the water level was at 1.546 m, a fall of 0.106 m (or 106 mm) over 161 days. The total rainfall for the recording period was 135 mm, less than half the mean rainfall for the same period (fig. 6).

☐ In the absence of rain, the water table declined, but at a decreasing rate as the dry period lengthened. This is best seen after about 16 January 1980, where the rate of decrease was flattening out, but the decline totalled about 3 mm for the 28 days to the end of monitoring. This is an average of about 0.1 mm/day.

☐ The effect of infiltrating rain in recharging the aquifer is clear. Individual rain events of less than about 2 mm spaced more than a few days apart had no measurable effect, but many combinations of light or heavy rain did affect the water table. For example, the single 17 mm event on 12 September 1979, while not raising the water table, prevented its further decline. During the 11-day period from 16 to 26 September 1979, 3 mm of rain in three separate events did not prevent a water table decline of 10 mm, or about 1 mm/day. Between 26 and 30 September 1979, 35 mm of rain not only arrested the decline, but raised the water table by at least ten millimetres. These events, and the succeeding set totalling 18 mm between 6 and 15 October 1979, collectively raised the water table by at least twenty millimetres.

☐ The 21-day pump test had a clear but not significant effect on the water table depth at observation bore 8. The water table dropped by about 40 mm during the test, although it would have been slightly more if infiltrating rains on 24 October had not occurred.

The proportion of rain which recharges the aquifer

The results shown in Figure 12 permit estimates to be made of the proportion of recharging rain which reaches the water table, independent of other influences such as evapotranspiration. As discussed, sufficient rain must fall before any recharge effect is noticeable. At Nine Mile Beach in 1979, rain events of less than about 2 mm spaced more than a few days apart had no measurable effect, but the total of about 50 mm between 26 September and 15 October raised the water table approximately 20 mm. Assuming the porosity of the aquifer is about 25%, only about 5 mm of the 20 mm rise represents infiltrating water, which fills up the intergranular spaces between grains.

Therefore, of the 50 mm of rain which fell, perhaps 10% reached the water table in the monitored period. This estimate can be reasonably extended over a full year of normal rainfall, even though Figure 12 depicts lower-than-average rainfall. There were 45 rain days in the 161 day monitoring period, but only 13 (around 30%) were events of more than two millimetres. Nevertheless, these accounted for 95 mm, or 70%, of the rain. It can reasonably be assumed that in a normal rainfall year, with twice as much rain, the proportion of effective rain events would at least be similar (i.e. 70%) as in the drier monitoring period. Accordingly, as a first approximation, 10% of 70%, or 7%, of mean annual rain recharges the aquifer. As the mean annual rainfall for Swansea and neighbouring districts is about 600 mm (Table 1), about 40 mm may replenish the aquifer in an average year.

The estimated recharge based on average rainfall exceeds the 25 mm estimated from mean monthly rainfall less monthly evapotranspiration in Table 1. It is reasonable to assume that the higher of the two figures may be more realistic, as at least some of the rain events in any year will be of an intensity which

Daily rainfall and depth to the water table, observation bore 8, Nine Mile Beach, September 1979 to February 1980
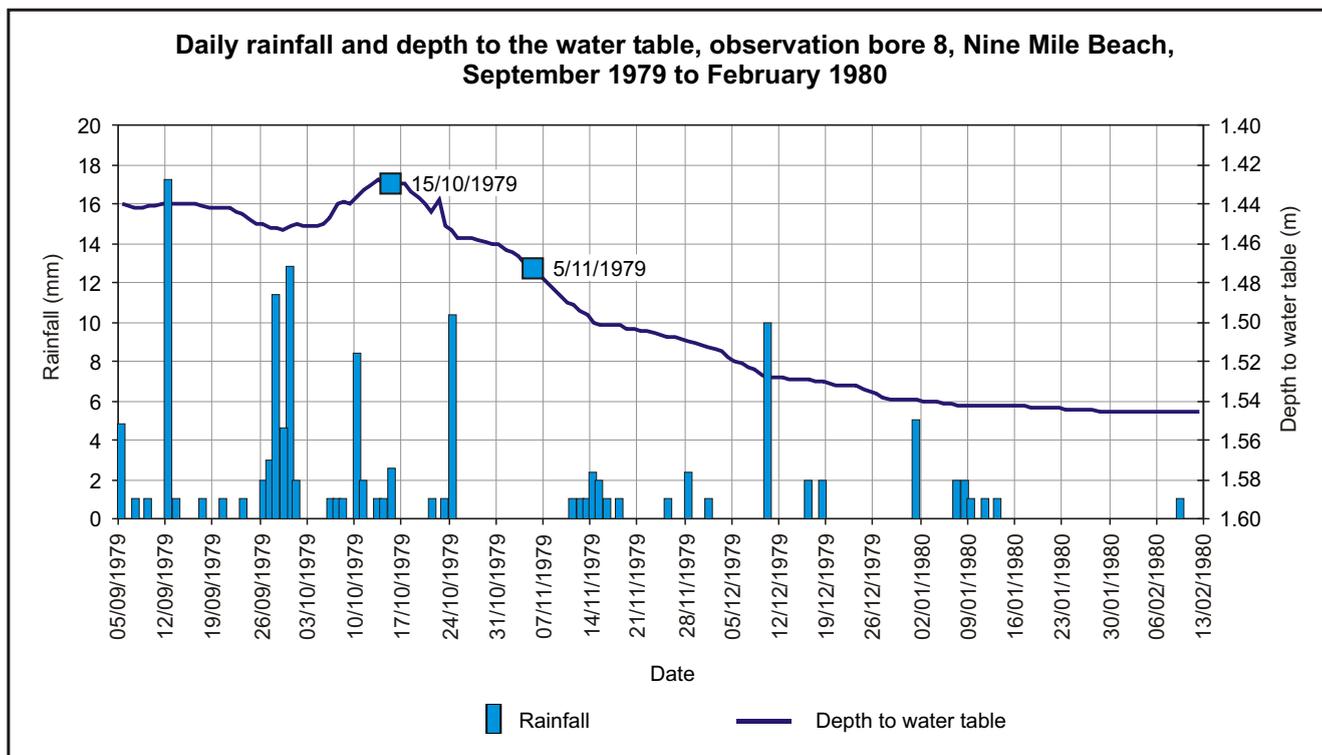
Figure 12

Daily rainfall and water table fluctuations at Nine Mile Beach, September 1979 to February 1980

exceeds the evapotranspiration rate, and because evapotranspiration estimated from maximum daily temperatures is approximate.

As a first approximation, it is assumed that about 7% of annual rain replenishes the Nine Mile Beach aquifer, and that in an average rainfall year, this represents about 40 mm, or 400 000 L/hectare. In wetter and drier years, more or less rain respectively will recharge the system.

Groundwater discharge from the aquifer

Excluding pumping, groundwater discharge from the unconfined aquifer at Nine Mile Beach occurs between high and low water level along the beach and the Swan River estuary. The fresh groundwater in both these areas is in contact with sea water in a landward-dipping, relatively narrow zone of mixing called the fresh water–sea water interface. The rate of discharge is highest when the water table and its gradient is highest, and is lowest when the water table and its gradient is lowest.

Two methods are available to estimate the discharge from the aquifer.

Using rainfall–water table relationships

Figure 12 permits estimates to be made of the volume of groundwater which discharges from the aquifer.

During the 12-day period from 16 to 27 September 1979, when only 8 mm of rain fell (over six events; five of which were of 2 mm or less), the water table at observation bore 8 dropped 12 mm, or 1 mm/day. Assuming the aquifer has a porosity of 25%, this represents a true water depth loss of 0.25 mm/day, or

2.5 kL/day/hectare (250 kL/day/km²). As the aquifer covers about 15 km², this loss spread over the full extent of the spit amounts to about 3.75 ML/day. Neglecting water uptake by deeper-rooted vegetation, and assuming the landward and seaward beaches total about 30 km in length, this discharge is about 125 kL/day/km of coastline, or 125 L/day/m of coastline. This is probably a higher than average figure. For example, in Figure 12, after 16 January 1980, the average fall in the water table was about 0.1 mm/day — an order of magnitude less. In extended dry periods, the rate would decrease further.

Figure 12 therefore suggests that, as an approximation, groundwater discharge along Nine Mile Beach is in the range of 0.01–0.1 m³/day/m of coastline, depending on the elevation of the water table.

Theoretical calculations about the fresh water–sea water interface

All coastal sand aquifers have a fresh water–sea water interface at the coast, which in practice is a narrow mixing zone of brackish water dipping inland from beach level. The shape of the interface is mathematically predictable, and depends only on the elevation of the water table, the permeability of the aquifer, and the density difference between the two water types. Because water table gradients are continually changing in response to recharge and discharge, and tidal effects near the coast, the shape and location of the interface is also continually changing.

In a static situation, one metre of fresh water above sea level will support a 40 m high column of fresh water

below sea level[10]. If the aquifer at any point is at least 40 times thicker than the elevation of the water table, then sea water will exist beneath the fresh groundwater body (fig. 13a). At Nine Mile Beach, and at all other Tasmanian coastal sand bodies which have been investigated, the aquifer is thin enough, and the elevation of the water table is sufficient, so that more than a short distance inland, the aquifer is completely filled with fresh water[11], i.e. the dipping interface is interrupted by the top of Unit 1 (fig. 13b). The best direct evidence for this is presented in Figure 9, where BH26 (about 85 m inland from high water mark) and BH40 (about 35 m inland) both penetrated the full saturated thickness of the aquifer and bottomed in relatively impermeable clay (Unit 1) at between -8 and -9 m below mean sea level. Both encountered only fresh groundwater. Accordingly, the minimum angle of dip (from the horizontal) of the freshwater–seawater interface is about 13°.

Assuming a range of reasonable gradients, the theoretical model can be used to estimate the corresponding range of groundwater flows at the beach (Q in fig. 13), and the gap between high and low water mark (x_0) through which the flow occurs. Assuming an aquifer thickness at the coast of 10 m, a density difference between fresh water and sea water of 0.025, and an average permeability of 20 m/day, the flow rate for each metre of coastline is 0.3 m³/day for a gradient of 0.0025, and 1.5 m³/day for a gradient of 0.005. The width of the gap on the beach through which the flow occurs ranges from 0.2 m (gradient 0.0025) to one metre (gradient 0.005). The distance d in Figure 13b is the inland extent of the seawater lens at the base of the freshwater aquifer. Under the above assumptions, this depth ranges from about 70 m to 100 m, which is not inconsistent with field observations at BH40 and BH26.

Using a different set of assumptions, Palfreyman (2002) estimated a flow of 0.05 m³/day/m of coastline, and a gap width of 0.5 metres.

The flow rates obtained by using the theoretical model in Figure 13 are higher than the estimated range estimated from rainfall–water table fluctuations in Figure 12. The width of the gap through which the discharge occurs seems much too narrow to be realistic. These discrepancies highlight the difficulty of estimating such flows in aquifers where basic parameters such as permeability, porosity and gradient vary unpredictably. The theoretically static groundwater system is also dynamically changing with the tides. Near the beach, the tide-induced diurnal variations in water table level are a significant proportion of the tidal range, but the fluctuations are dampened out rapidly in a landwards direction at a rate determined by the permeability of the aquifer.

Figure 13

*Flow patterns near a beach in an unconfined aquifer,
after Glover (1964) and Cromer (1979)*

Yields from shallow bores in the aquifer

Investigation bores BH7, BH8, BH9, BH10, BH12, BH15, BH16, BH17 and BH18 were cased with 50 mm

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10 This relationship arises because fresh water is slightly less dense than sea water. The difference is about 0.025, or one-fortieth. To be in hydrostatic equilibrium, the weight of adjacent columns of water in an aquifer must be equal. For example, a column of sea water 40 m high weighs the same as a column of fresh water 41 m high.

11 This statement is probably at odds with the findings of Palfreyman (2002). She used indirect electrical geophysical methods to attempt to delineate the shape of, and depth to, the freshwater–seawater interface and at a few locations interpreted it to be shallowly and irregularly dipping. Statements such as "…only a few metres below the surface, at least 60 metres inland…" seem to conflict with field evidence because 'a few metres' is undefined. If it means 7 or 8 metres, this is closer to field evidence — the aquifer is only about this thick, but it rests on the top of Unit 1 and there is no sea water lens beneath it this far inland. Indirect methods (in contrast to direct methods like drilling and water sampling) require mathematical modelling and various assumptions which generate numerous possible solutions and equivocal interpretations. Palfreyman's assumed 7 mS/cm electrical conductivity for fresh groundwater, for example, is an order of magnitude too high based on numerous analyses. Some inferred saline water may not be sea water, but simply high salinity water in the Unit 1 clay underlying the freshwater aquifer.

slotted PVC casing (Table 2) during July and August 1979. Each was then briefly pump tested to obtain a water sample for analysis and to assess the capacity of the aquifer to yield water to shallow bores.

With the exception of BH9 (which yielded 4 L/min of water from sand and dolerite pebbles) and BH15 (yielding 16 L/min from the fine-grained Unit 4 backbarrier sand) the remaining seven holes sustained groundwater pump rates in the range 53–68 L/min. These results were encouraging, and suggested that a group of shallow bores could yield enough groundwater to contribute to Swansea's town-water supply.

The 24-spear bore array at Nine Mile Beach

Layout of the array

A 24-spear bore array was installed near the Dolphin Sands Road in August and September 1979. The array was located close to the centreline of the spit, and as close as possible to the Glamorgan Council's pipeline carrying water from the Swan River to Swansea.

The array (fig. 14 and Plates 2 to 4) comprises two concentric circles of spear bores, with radii of 48 and 74 metres. Spears were connected in groups of four to each of six main radial lines. The radial lines joined at a central manifold (Plate 5) to which was connected a temporary diesel-powered pump and discharge line (Plate 6).

Each spear comprised a vertical length of 65 mm diameter PVC casing, the lower two metres of which were slotted to provide an interval for groundwater to enter the bore (Plate 7). Gravel packing around the slotted interval during installation (Plate 8) was unnecessary because of the grain size distribution of the aquifer. A vertical 25 mm diameter riser tube in each spear bore (Plate 9) was fitted with a non-return valve to prevent the central manifold from draining of water, and connected to header lines joining neighbouring spear bores.

The 148 m diameter array covered a circular area of 1.7 hectares. The water table prior to the pump test was approximately 2.4 m below the ground surface.

Observation bores

Before pump testing, nine observation bores (all prefixed 'ob') were drilled and cased to monitor the effects of pumping. The bores were arranged in two roughly radial lines at right angles to each other, at varying distances from the array centre (fig. 15). Two existing investigation bores (BH18 and BH26) became ob8 and ob11 respectively. BH18 had previously been fitted with an automatic water level recorder on 5 September 1979 to provide background readings of the depth to, and fluctuations of, the water table.

Pump testing the array

On 15 October 1979, the 24 spear bores in the array were simultaneously pumped at a combined flow rate of approximately 34 000 L/hour. This rate was equivalent to 1400 L/hour/spear, or 23 L/min/spear, which was less than half the average yield of the individual spears pump tested previously. Water samples were collected for chemical analysis.

Water levels were measured in all observation bores for the next 21 days (31 100 minutes), during which time a five-hour period of pump failure occurred between 11 700 and 12 000 minutes (day 8). Figure 17 shows drawdowns (i.e. the difference between the original water table elevation, and the water level drawn down by pumping) for each of the eleven observation bores for the full test duration.

The test ended after 21 days, at the discretion of the operators, after a total of 17 ML of groundwater was pumped from the aquifer. This water was discharged to the low-lying swampy area at the rear of the spit (Plate 10), from where the water flowed southwest to the Meredith River.

Observations arising from Figure 17 are:

☐ The greatest observed drawdown was not unexpectedly at ob1, 21 m from the centre of the array. Observation bores ob2, ob3 and ob4 on the perimeter of the spear array showed the next largest drawdowns. All four drawdowns were broadly similar (0.62 to 0.66 m) so that at the end of the test the water table inside the array remained as horizontal as at the start of the test. This observation accords with that found after a 13-day pump test of a 12-spear bore array in coastal sand at Greens Beach (Cromer, 1979, Cromer and Leaman, 1980), near the mouth of the River Tamar.

☐ The 300-minute pump failure between days 8 and 9 appears as a kink in the drawdown curves for the four closest observation bores, but was not evident in the data for the other bores.

☐ The rate of drawdown decreased with time for the four closest bores; half of the total drawdown of about 0.62 m occurred in the first four days, and the other half over the remaining 17 days. For remaining observation bores, the rate of drawdown appears relatively constant, although a slight decrease is apparent in several. Half of the drawdown had occurred after about ten days in these outside bores.

☐ Of the observation bores outside the array, drawdowns at any time generally decreased with increasing distance from the centre of the array. This was not the case with observation bores ob5 and ob10, on opposite sides of the array, in a northwesterly and southeasterly direction respectively. These bores exhibited a noticeably lower than expected drawdown, which might be explained by postulating that the aquifer is more permeable in a lengthwise or longshore direction, rather than in a landward direction.

Plate 2
The 24-spear array next to the Dolphin Sands Road, looking northeast, November 1979.

[Photo: E. L. Martin; MRT 2290]

Plate 3
The 24-spear array next to the Dolphin Sands Road, looking southeast, November 1979.

[Photo: E. L. Martin; MRT 2294]

Plate 4
A detailed aerial view of the 24-spear bore array, November 1979, looking south towards the coast. A spear bore is installed at each end of the short radial trenches. The pump and manifold are located at the array centre, and the pump discharge line is the thin wavy line extending from the centre towards the camera.

[Photo: E. L. Martin; MRT 1577]

Plan of 24-spear bore array at Nine Mile Beach

Section of each spear bore (not to scale)

GN

100
80
60
40
20
0
20
40
60
80
100

metres from array centre

Observation bore

ob2
ob3
ob1
ob4

i

Pump

e
h
b
c
f
d
g
a

Spear bore

100 80 60 40 20 0 20 40 60 80 100
metres from array centre

Surface

Flow

Non return valve

Dry sand

Riser pipe

Water table

Wet sand

Screen or slots

l

k

m

j

Key to pipe lengths and diameters
a = 61 m of 65 mm Class 6 PVC (radial line)
b = 32.6 m of 40 mm Class 6 PVC (tangent line)
c = d = 13 m of 32 mm Class 12 PVC (header line)
e = f = 26 m spacing between inner spear bores
g = h = 39 m spacing between outer spear bores
i = pump discharge line of 100–125 mm diameter
j = 65 mm diameter spear bore of Class 6 PVC
k = approximate spear bore length = 6–7 m
l = depth to water table = approximately 2.5–2.8 m in October 1979 before pump testing started
m = length of screen or slotted PVC spear = approximately 2 m

Figure 14

500
400
300
200
100
0
100
200
300
400
500

metres from array centre

GN

Dolphin Sands Road

Discharge

ob5

ob1 to ob4 at or inside array

Array

ob6

ob9

ob7

ob8

ob10

ob11

500 400 300 200 100 0 100 200 300 400 500
metres from array centre

Observation bore	Distance (m) from array centre
ob1	21
ob2	67
ob3	70
ob4	74
ob5	182
ob6	291
ob7	401
ob8	528
ob9	126
ob10	282
ob11	549

Figure 15

Distribution of observation bores for the 24-spear bore array

Plate 5

Detail of the steel manifold at the centre of the array, October 1979. Each of the six 65 mm diameter PVC radial lines enters the manifold with water from four spears. The 100 mm diameter PVC line on the left leads to the diesel pump.
[Photo: E. L. Martin; MRT 1570]
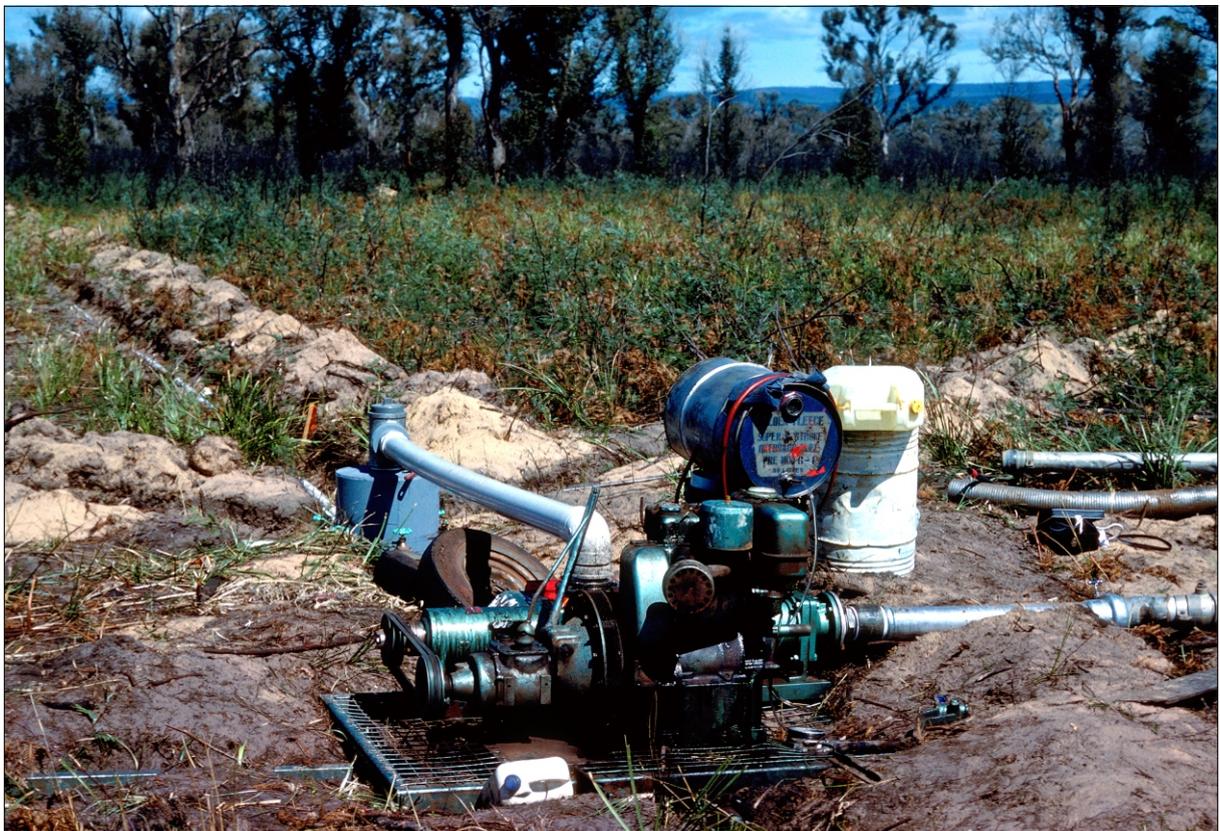
Plate 6

The manifold and temporary diesel pump at the centre of the array, October 1979. [Photo: E. L. Martin; MRT 1569]

Plate 9.

Prior to burial, each spear bore was installed so that its top was 0.6 to 0.8 m below ground, and fitted with a 25 mm diameter riser tube and brass non-return valve to keep water in the suction line. [Photo: E. L. Martin; MRT 1514]

Plate 8.

David Wyatt (at rear) and Michael Triffett installing a spear bore at the array in October 1979, using a sludge pump to clean out 100 mm PVC casing which was installed ahead of the spear, and later removed. [Photo: E. L. Martin; MRT 1505]

Plate 7.

Slotting a 65 mm diameter PVC spear prior to installation. [Photo: E. L. Martin; MRT 1502]
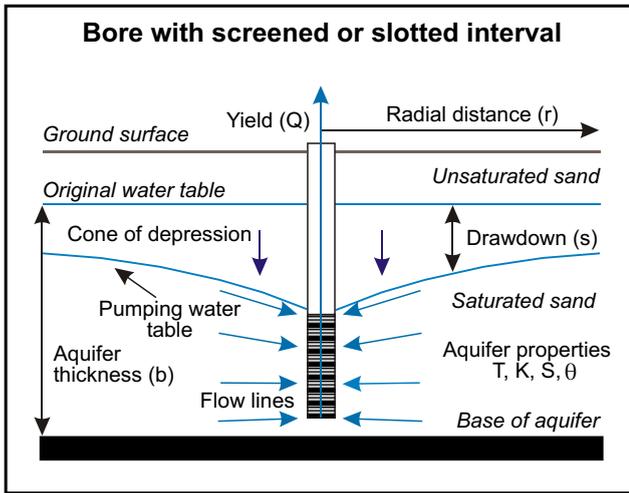
Figure 16

The formation of the cone of depression in an unconfined aquifer. With continued pumping, the cone widens to encompass more aquifer. Its outer edge is called the radius of influence, beyond which pumping has no noticeable effect on the original water table. Water within the cone of depression moves towards the bore. Aquifer properties which determine the size and shape of the cone include its transmissivity (T), specific yield (S) and porosity (θ).

Plate 10

Geologists John Sloane (left) and Bill Cromer at the discharge point of the 24-spear bore array in November 1979. The array produced a flow of 34 000 L/hour during the test. [Photo: E. L. Martin; MRT 1558]

☐ After 21 days pumping, the drawdown was 0.04 m (40 mm) at ob11, 549 m to the southeast. As a rough approximation, this could be regarded as the radius of influence of the array for the specified yield and pumping time.

☐ The irregular drawdowns experienced by ob11 are unexplained.

In Figure 18, the drawdown curves of Figure 17 are straightened out by the use of a log-log scale. The exception is the curve for ob11, where small fluctuations in drawdown are exaggerated by the scale change. Estimates of drawdown for periods longer than the pump test may be made by extending the straight-line segments of the curves. In Figure 18, the straight line segments past the end of the test suggest that drawdown would be about one metre in the centre of the array after about 60 days pumping, with a similar amount in ob9 after about 70 days. Drawdown after 100 days would be about 0.85 m, 0.65 m and 0.5 m in ob6, ob7 and ob8 respectively.

Aquifer transmissivity and specific yield

The drawdown results in Figures 17 and 18 have been replotted on a semi-log scale in Figure 19 so that aquifer transmissivity (T) and specific yield (S) can be estimated using the modified Theis non-equilibrium equations (Cromer, 1979; Cromer and Leaman, 1980).

After 21 days of pumping, transmissivity was about $250 \, \text{m}^2/\text{day}$ in the bores closest to the array centre. This is thought to be a reliable result because the aquifer near the spear bore array would be in a near-complete dewatered situation after this time. This value is between about three and five times the transmissivity of the Greens Beach aquifer derived from the 13-day pump test of a 12-spear bore array.

A transmissivity of $250 \, \text{m}^2/\text{day}$ and an average aquifer thickness of about 7.5 m (fig. 9) results in an aquifer permeability of 33 m/day. This represents the permeability of the relatively large volume of aquifer affected by pumping, and is a combination of vertical and horizontal permeabilities. The former may be an order of magnitude less than the latter (Cromer, 1979). The calculated permeability is also between three and ten times greater than the permeabilities reported by Palfreyman (2002) from falling head tests. These tests, in the unsaturated zone above the water table, probably intersected the finer-grained and lower-permeability aeolian sand capping the Unit 3 beach sand and may have measured more of the vertical permeability component than the horizontal component.

Figure 19 shows that using the modified Theis non-equilibrium equations the specific yield of the dewatered aquifer near the array was 0.17 after the 21-day pump test. This compares with a range in specific yield of 0.16 to 0.33 for the Greens Beach aquifer, where it was shown that the precision of the results is more a function of the duration of the test rather than the methods of analysis used.
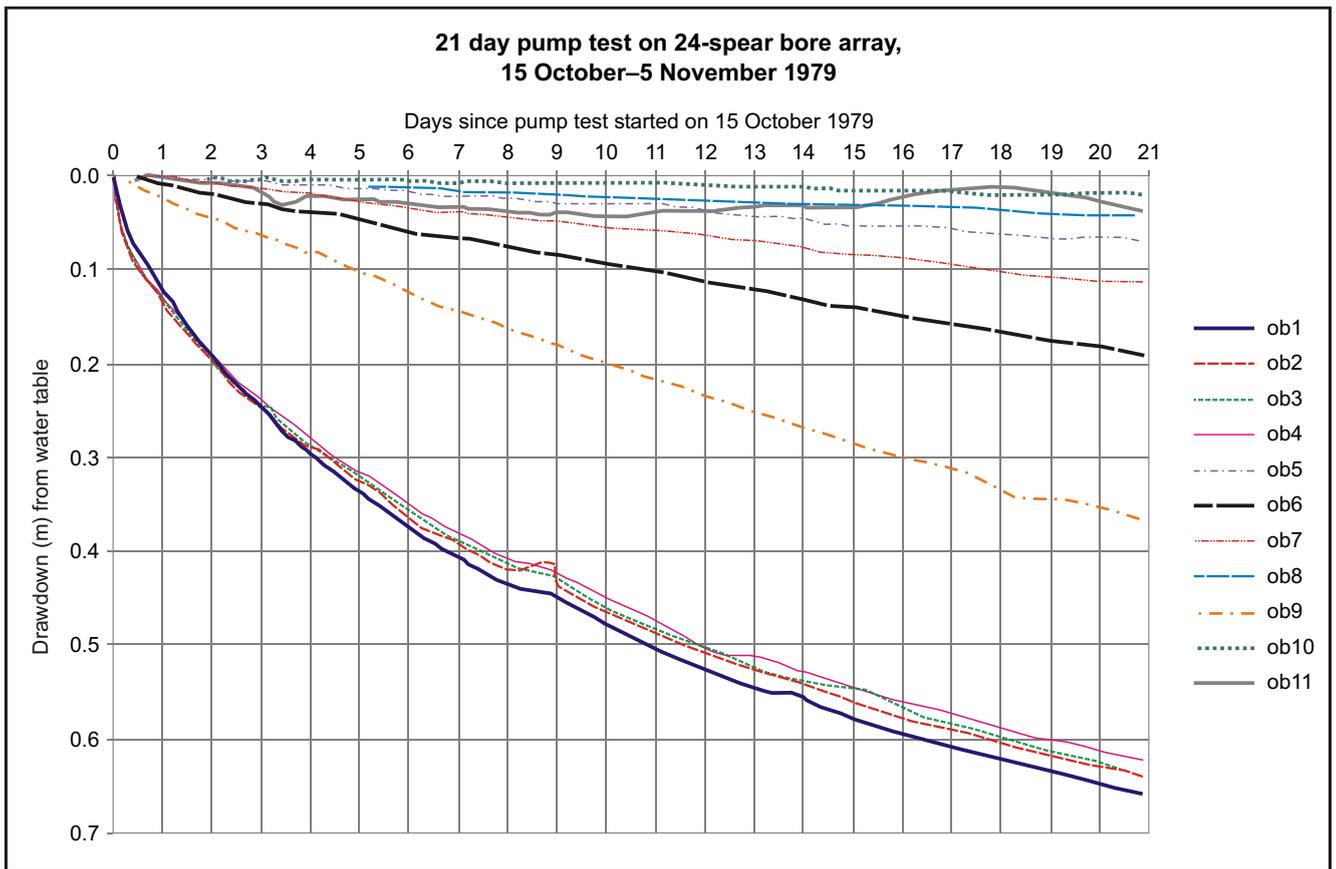
Figure 17

Drawdowns measured at the eleven observation bores during the 21-day pump test
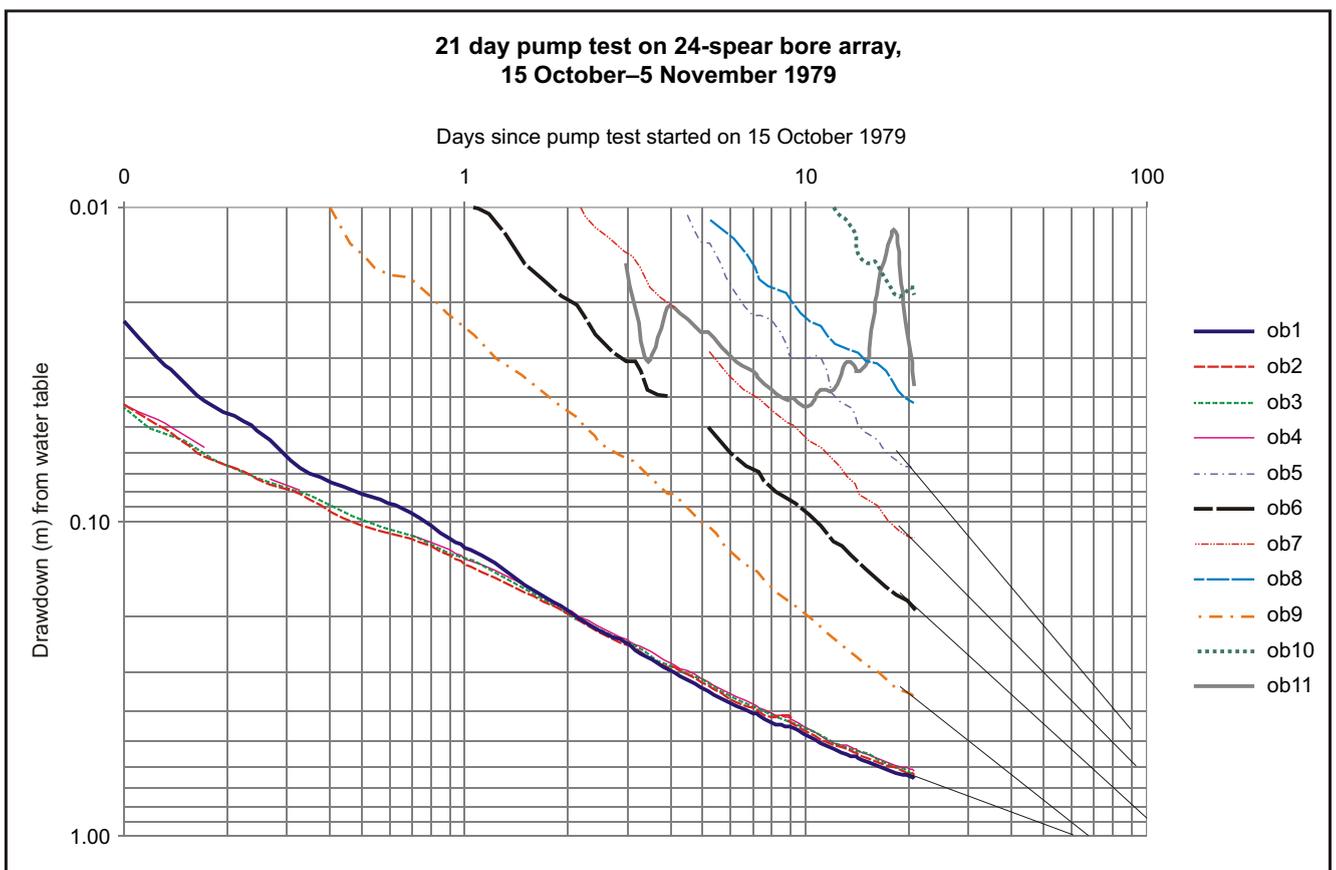
Figure 18

Drawdowns measured at the eleven observation bores during the 21-day pump test. This graph incorporates the same data as Figure 17, except that the results have been plotted on log-log axes.

**21 day pump test on 24-spear bore array,
15 October–5 November 1979**
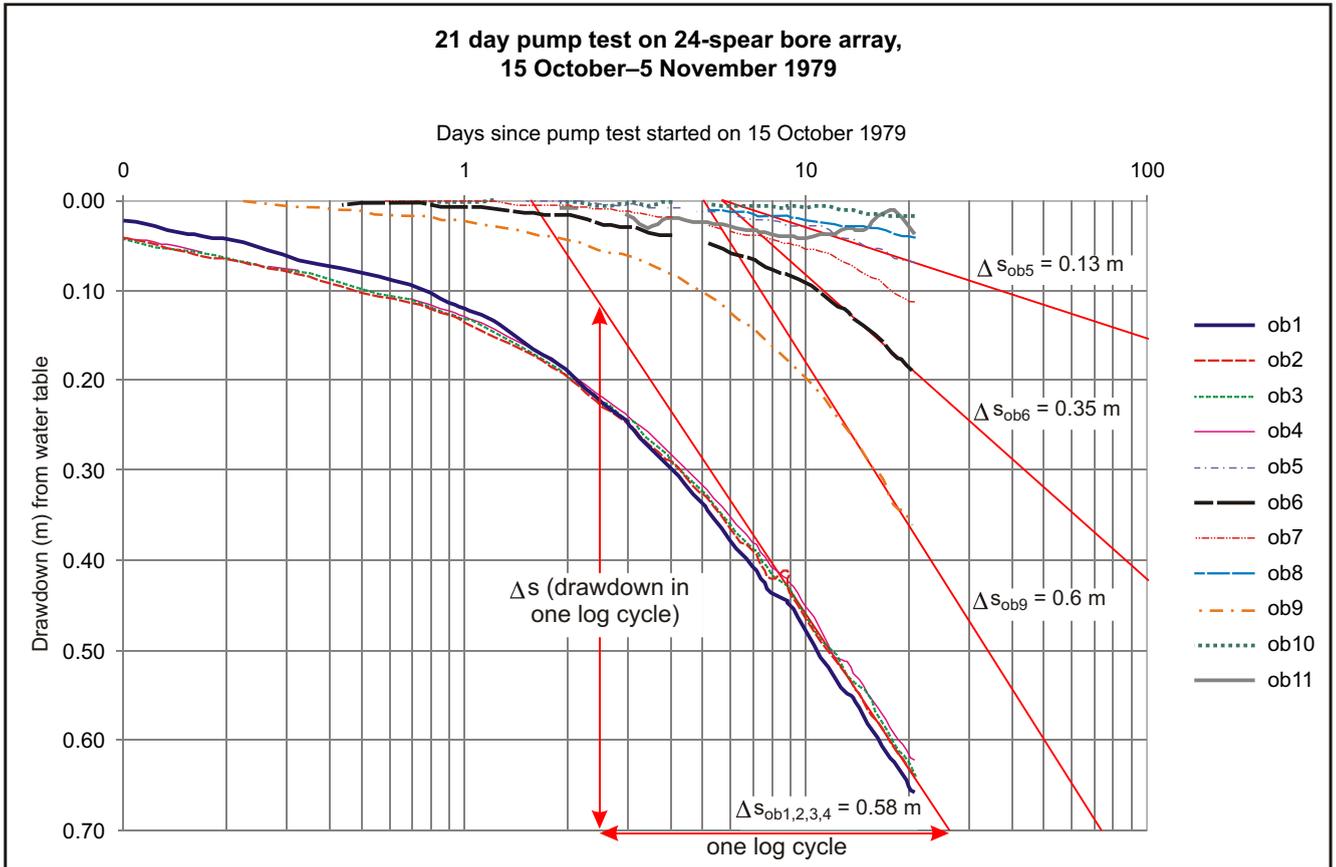
Modified Theis non-equilibrium equations

Pump rate (Q) = 34 000 L/hour = 816 m³/day

Transmissivity (T)
$T_{ob1, 2, 3, 4} = 2.3Q/(4\pi\Delta s) = 2.3*(816 \text{ m}^3/\text{day})/(4\pi*0.58 \text{ m}) = 257 \text{ m}^2/\text{day}$

Specific Yield (S)
$S_{ob1, 2, 3, 4} = 2.25 \ Tt_0/r^2 = (2.25*281 \text{ m}^2/\text{day}*1.5 \text{ day})/(75 \text{ m}*75 \text{ m}) = 0.17$

Figure 19

Drawdowns measured at the eleven observation bores during the 21-day pump test. This graph incorporates the same data as Figure 17, except that the results have been plotted on semi-log axes.
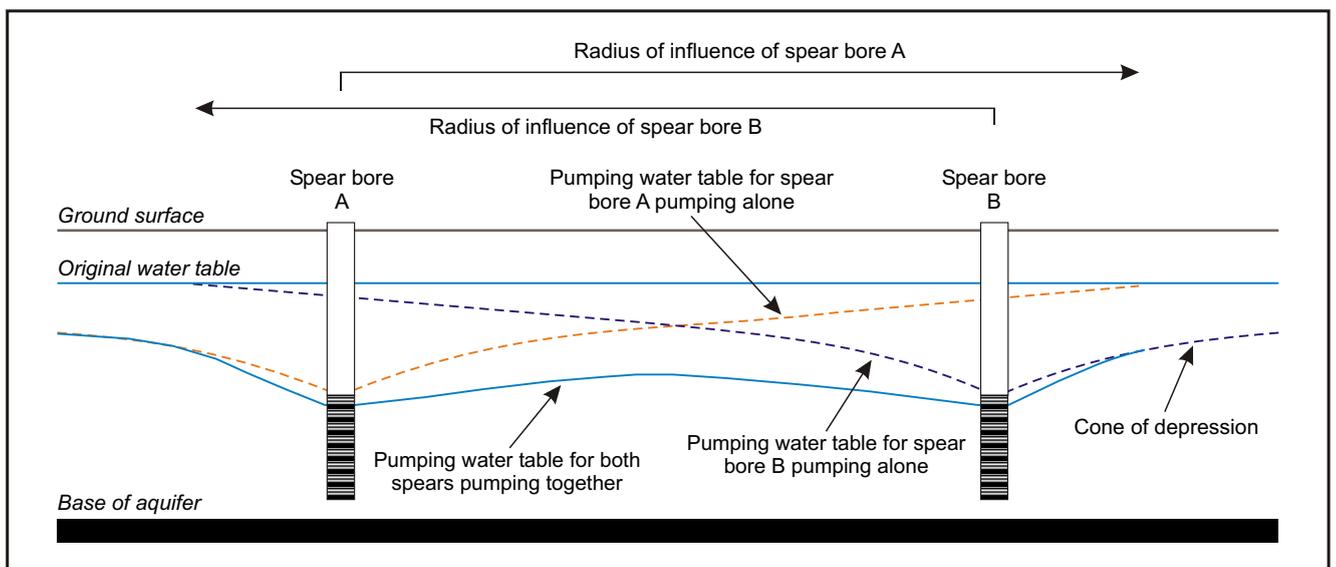
Figure 20

Neighbouring bores interfere if they are each located within the other's radius of influence.

Other methods of calculating S are available. For example, Ramsahoye and Lang (1961) used a simple solution which computes the volume of dewatered aquifer and compares it with the total volume of pumped water. When this technique is applied to drawdowns after 21 days at Nine Mile Beach, it produces S varying from 0.08 in ob7, to 0.12 in ob6 and 0.4 in ob4. The average of these is 0.2, similar to the value of S obtained above. Further techniques to assess pump tests in unconfined aquifers are available in Bentall (1963, 1964) and Jacob (1963).

Sustainable yield of the aquifer

The 21-day pump test on the 24-spear bore array demonstrated that large amounts of groundwater can be extracted from the aquifer from shallow spear bores. As previously discussed (p. 25) pumping could have continued at the same rate of 0.8 ML/day for almost two years[12].

Continued pumping on such a scale mines the groundwater, and exceeds the sustainable yield of the aquifer. The sustainable yield is the total amount of groundwater which can be extracted without reducing average groundwater reserves. In unconfined aquifers this is usually taken to mean the long-term average recharge to the aquifer from infiltrating rain. However this neglects the recycling of groundwater pumped to the surface and applied again to the same aquifer.

It has previously been estimated (see p. 26) that about 7% of annual rainfall replenishes the Nine Mile Beach aquifer, and that in an average rainfall year, this represents about 40 mm of water, or 400 000 L (0.4 ML) per hectare. This is about 1000 L/day/hectare, and if recycling is ignored, in a normal rainfall year approximates the sustainable yield of the aquifer.

Over an area of 15 km², the approximate areal extent of the aquifer, the sustainable yield is about 600 ML/year, ignoring recycling. This figure will vary as the annual rainfall varies.

Groundwater quality

Sampling and analysis

In 1972, two groundwater samples were collected and analysed from the exploratory borehole drilled on Lot 209 at the eastern end of the Nine Mile Beach spit (Cromer, 1972). These, and one analysis from Lot 211 collected in August 1979, are presented in Table 3.

Nine groundwater samples were collected and analysed (Table 4) from boreholes BH7 to BH10, BH12, and BH15 to BH18 during the 1979 hydrogeological investigations which preceded the pump testing of the 24-spear bore array. Groundwater samples collected at the start and end of the 21-day pump test of the

| **Table 3** |
| *Analyses of groundwater from the eastern end of the Nine Mile Beach spit, 1972 and 1979* |

Laboratory No.	726821	726822	791395
Date collected	Dec 1972	01-Dec-72	13-Aug-79
Location	Lot 209	Lot 209	Lot 211
Depth (m)	3	15	
pH	7.7	7.7	7.6
EC (µS/cm)			490
TDS (mg/L)	550	630	340
Temp H (mg/L)			140
Perm H (mg/L)			18
Alkalinity (mg/L)			140
CO_3 (mg/L)			nil
HCO_3 (mg/L)	350	490	170
Cl (mg/L)	91	74	78
SO_4 (mg/L)	22	66	15
SiO_2 (mg/L)	65	100	11
Ca (mg/L)			50
Mg (mg/L)	11	24	80
Fe (mg/L)			0.2
Al (mg/L)			<0.2
K (mg/L)			2
Na (mg/L)	68	52	45

Notes:

1. Analyses by Department of Mines Laboratories, Launceston.

2. All samples submitted to the laboratory by W. C. Cromer.

3. EC = electrical conductivity;
    TDS = total dissolved solids;
    Temp H = temporary hardness;
    Perm H = permanent hardness;
    CO_3 = carbonate; HCO_3 = bicarbonate;
    Cl = chloride; SO_4 = sulphate; SiO_2 = silica; Ca = calcium; Mg = magnesium; Fe = iron;
    Al = aluminium; K = potassium;
    Na = sodium.

4. On Lot 209, TDS measured in the field was 560 mg/L at 8 m, and 525 mg/L at 12 m.

24-spear bore array, and on days 1, 3, 6, 10 and 13, were analysed (Table 5) to assess whether groundwater quality varied within the radius of influence of the array.

A total of 19 groundwater analyses is presented in the three tables. Appendix 2 contains assessment sheets for each of the analyses in Tables 4 and 5.

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12 This figure is calculated from the volume of groundwater stored within the radius of influence of the array. The pump test affected bores up to at least 500 m from the array, so that the radius of influence after 21 days covered perhaps 100 hectares (1 million m², or 1 km²). The volume of groundwater stored beneath this area and able to be extracted by the array is estimated at 1 000 000 m² × 3 m × 0.17, or about 500 000 m³ (500 ML), where the 3 m is the available drawdown in each of the 24 spears, and 0.17 is the specific yield of the aquifer. It would take over 600 days to extract this volume, at 0.8 ML/day.

Table 4

Analyses of groundwater from selected investigation boreholes at the western end of the Nine Mile Beach spit, 1979

Laboratory Number	791396	791397	791399	791400	791401	791402	791403	791404	791405
Date collected	13-Aug-79	08-Aug-79	07-Aug-79	07-Aug-79	07-Aug-79	07-Aug-79	08-Aug-79	08-Aug-79	09-Aug-79
Investigation Hole	BH7	BH8	BH9	BH10	BH12	BH15	BH16	BH17	BH18
Sampled interval (m)	2.2 to 5.3	2.0 to 4.7	1.7 to 3.0	1.2 to 3.3	2.2 to 5.5	1.6 to 4.5	1.7 to 5.0	2.0 to 5.0	1.3 to 3.0
Depth below water table (m)	0–3.0	0.2–2.7	0 to 1.3	0 to 2.1	0 to 3.3	0 to 2.9	0 to 3.3	0.4 to 3.4	0 to 1.7
pH	7.3	7.8	7.6	7.4	7.6	7.5	7.5	7.6	7.6
EC (µS/cm)	570	570	380	460	600	14,700	500	490	620
TDS (mg/L)	360	370	250	300	370	12,180	360	320	410
Temp H (mg/L)	200	210	150	180	210	360	210	190	210
Perm H (mg/L)	nil	nil	nil	nil	nil	3,230	nil	nil	nil
Alkalinity (mg/L)	200	230	170	190	220	360	230	200	230
CO_3 (mg/L)	nil	nil	nil	nil	nil	nil	nil	nil	nil
HCO_3 (mg/L)	250	280	210	210	270	430	280	250	280
Cl (mg/L)	71	60	25	39	76	5,830	58	39	74
SO_4 (mg/L)	9	7	<5	<5	<5	870	<5	<5	6
SiO_2 (mg/L)	12	13	13	12	18	27	14	13	12
Ca (mg/L)	72	72	55	64	71	630	73	67	76
Mg (mg/L)	6	8	3	4	8	490	7	5	6
Fe (mg/L)	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Al (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
K (mg/L)	1	1	0.5	1	2	13	2	1	1
Na (mg/L)	40	34	13	20	46	2,700	40	22	41

Notes:

1. Analyses by Department of Mines Laboratories, Launceston.

2. All samples submitted to the laboratory by W. C. Cromer.

3. EC = electrical conductivity; TDS = total dissolved solids; Temp H = temporary hardness; Perm H = permanent hardness; CO_3 = carbonate; HCO_3 = bicarbonate; Cl = chloride; SO_4 = sulphate; SiO_2 = silica; Ca = calcium; Mg = magnesium; Fe = iron; Al = aluminium; K = potassium; Na = sodium.

4. Iron is dissolved iron at time of analysis.

Table 5

Analyses of groundwater at various times during the 21 day pump test of the 24-spear bore array,
October–November 1979

Lab No.	792316	792317	792318	792319	792320	792321	792322
Date collected	15-Oct-79	16-Oct-79	18-Oct-79	21-Oct-79	25-Oct-79	28-Oct-79	05-Nov-79
Time	1125	1200	0900	1100	1100	1100	1100
	Start test	+1 day	+3 days	+6 days	+10 days	+13 days	End test
pH	6.8	6.9	7.0	7.0	7.1	7.4	7.1
EC (μS/cm)	500	510	510	520	510	510	530
TDS (mg/L)	340	330	350	340	350	370	340
Temp H (mg/L)	190	190	200	180	200	200	190
Perm H (mg/L)	10	nil	nil	nil	nil	nil	nil
Alkalinity (mg/L)	190	200	210	210	210	220	210
CO_3 (mg/L)	nil	nil	nil	nil	nil	nil	nil
HCO_3 (mg/L)	240	240	250	250	260	260	260
Cl (mg/L)	47	47	47	47	47	49	49
SO_4 (mg/L)	<5	<5	<5	<5	<5	<5	<5
SiO_2 (mg/L)	11	11	11	11	11	11	11
Ca (mg/L)	73	67	73	63	70	70	68
Mg (mg/L)	5	5	5	5	5	5	6
Fe (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Al (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
K (mg/L)	1	1	1	1	1	1	1
Na (mg/L)	26	26	26	27	27	28	29

Notes:

1. Analyses by Department of Mines Laboratories, Launceston.

2. All samples submitted to the laboratory by D. J. Sloane on 12 November 1979.

3. EC = electrical conductivity; TDS = total dissolved solids; Temp H = temporary hardness; Perm H = permanent hardness; CO_3 = carbonate; HCO_3 = bicarbonate; Cl = chloride; SO_4 = sulphate; SiO_2 = silica; Ca = calcium; Mg = magnesium; Fe = iron; Al = aluminium; K = potassium; Na = sodium.

4. Iron is dissolved iron at time of analysis.

5. Pump test: 24-spear bore array pumped for 21 days at a combined rate of 34 000L/hour. Total volume pumped in 21 days was 17 million litres (17 ML).

Suitability of the groundwater for agriculture and human consumption

Groundwater salinity within the Nine Mile Beach aquifer ranged from 250 mg/L total dissolved solids (TDS) to 610 mg/L TDS. Typically, based on the 1979 analyses, the water is a medium salinity, near-neutral groundwater, mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, suitable for all agricultural uses, and, subject to satisfactory bacteriological analysis, suitable for human consumption[13].

Variability of groundwater quality

The analyses in Table 4 were mainly collected from depths of up to three metres below the water table at the western end of the aquifer. Excluding the high salinity water in BH15 (outside the aquifer), the analyses demonstrate a relatively small range of salinities. Furthermore, groundwater salinity during the 21-day pump test remained within the range 330 mg/L to 370 mg/L, with no significant changes to any of the analysed constituents.

Vertical extent of useable groundwater

In common with every other coastal sand body investigated in Tasmania, 'fresh' groundwater at Nine Mile Beach extends below mean sea level. This is demonstrated in the December 1972 analyses from Lot 209 (Table 3), where salinities of 550 mg/L and 630 mg/L were returned from three and fifteen metres below ground respectively. Fresh groundwater was also pumped from depths below mean sea level in most of the sampled investigation holes (Table 4), and during the 21-day pump test (Table 5). As discussed earlier (see p. 27), not only does fresh water extend below sea level, but it extends from the water table to

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13 500 mg/L TDS is commonly regarded as a desirable maximum salinity for human consumption, although up to 1000 mg/L is acceptable. Acceptability varies between consumers, and many commercially-available mineral waters have higher salinities.

the base of the aquifer represented by the top of the Unit 1 clays (fig. 9).

Saline water boundaries to the aquifer

Fresh groundwater is only present in the spit, which includes the foredunes and the beach ridge and swale system. The spit is bordered by saline waters along the coast, in the Swan River estuary, and along the backswamp barrier at its western end. This latter occurrence is demonstrated by the surface water salinities shown on Figure 3, and by analysis 791402 (Table 4) from BH15 in the Unit 4 estuarine materials at the rear of the sand spit. This groundwater had a salinity of 12 180 mg/L TDS and is unfit for human consumption and almost all agricultural uses. More importantly it demonstrates that:

☐ the freshwater aquifer does not extend (either laterally or vertically) further than the beach ridge and swale system; and

☐ the only source of the fresh water at Nine Mile Beach is infiltrating rain, because the saline groundwater is a barrier to any lateral movement of water into the spit.

Using the groundwater

Extraction methods

Groundwater for domestic or more substantial use at Nine Mile Beach is best obtained from small-diameter, screened or slotted spear bores. Yields of 1000–3000 L/hour/spear are achievable if the base of the spear is installed to depths of three metres or more below the water table. Spears are best installed by pre-drilling to total depth, followed by hand bailing.

Sustainability and groundwater recycling

The most common current domestic uses for the Nine Mile Beach groundwater is garden watering, and in toilets and laundries. For permanent residences, daily usage might exceed the estimated 1000 L/day/hectare. This is unlikely to lead to unacceptable environmental effects because:

☐ the area affected by pumping is relatively small on each lot;

☐ there are several hundred lots at Nine Mile Beach but their combined area is only a small proportion of the total aquifer area, and many lots are either vacant or are only temporarily occupied; and

☐ part of the water on each lot is recycled, therefore reducing effective groundwater use.

In relation to groundwater recycling, water pumped from the aquifer, perhaps temporarily stored in tanks, and re-applied as garden irrigation, is partly evapotranspired and partly infiltrated. Infiltration back to the aquifer is at a maximum at night, when evaporation is least, so night watering is best. Groundwater used in toilets connected to septic tanks is almost fully recycled, as after discharge from the tank (perhaps to absorption trenches) it re-enters the

aquifer closer to the water table and beneath the root zone of many plants.

Interference between neighbouring bores

Simultaneously pumped spear bores may interfere if their radii of influence overlap (fig. 20). Interference results in greater than normal drawdown in each spear, and if continued, may lead to decreased yields. In extreme cases, either or both bores may 'go dry'.

The radius of influence of any particular bore increases as the time of pumping, or the flow rate, or both, increases.

For small-scale domestic groundwater use at Nine Mile Beach, a typical spear bore between 4 m and 6 m deep, and pumped for an hour or two each day at about 1000 L/hour, would develop a radius of influence of less than about seven metres. If neighbouring spears are placed at least about 15 m apart, interference under these conditions is very unlikely, and at worst, of minimal impact. If the same spear was pumped for (say) ten hours a day at 1000 L/hour, its radius of influence increases to about 10–12 m, and neighbouring bores pumped at the same rate would need to separated by twice this distance to avoid interference.

Under almost all conceivable pumping conditions, spear bores at Nine Mile Beach placed more than about 50 m apart will have no measurable effect on one another.

Sea water intrusion

There are no documented cases of sea water intrusion in Tasmania, despite the widespread extraction of groundwater from coastal sand aquifers for both domestic and large-scale irrigation uses. This in turn suggests that for most practical situations the perceived risks of sea water contamination are exaggerated and are based on a lack of understanding of the dynamics of the systems.

The *Groundwater discharge from an aquifer* section (p. 27) discussed the shape and inland extent of the fresh water–sea water interface which exists in all unconfined coastal aquifers, whether they comprise sand or fractured solid rock. At Nine Mile Beach, in the non-pumping conditions which prevailed when BH26 and BH40 were drilled in 1979 and 1980, no sea water was encountered to the base of the aquifer. BH40 was 35 m inland from high water mark (fig. 9), so the slope of the dipping interface could not have exceeded about 13°. This is consistent with theoretical considerations. The water table in BH40 in June 1980 was 0.4 m above mean sea level (Table 2), sufficient to support a column of fresh water 16 m below mean sea level. A spear bore installed at BH40, and pumped for a sufficient time, would locally lower the water table below mean sea level, but would not induce sea water incursion until the radius of influence of the bore extended at least 35 m horizontally to the mean sea level line. Most domestic spear bores would never develop a radius of

influence of this size, but (as is illustrated by the 24-spear bore array) it could easily be accomplished by closely-spaced bores pumping simultaneously.

Sea water intrusion is extremely unlikely for most current domestic-scale uses at Nine Mile Beach.

Groundwater contamination

The potential exists to affect groundwater quality and use at Nine Mile Beach through a variety of sources, including seawater intrusion, garden and agricultural chemicals, domestic wastewater disposal, runoff from metal roofs and bitumen roads, accidental spills of oils, greases and fuels, and deliberate burial of solid or liquid wastes.

These potential effects can only be assessed by monitoring and analysis — principally of groundwater, but in some cases also of soil or air.

Evidence for contamination of the Nine Mile Beach aquifer

Although some groundwater part-analyses (electrical conductivity, pH) are currently being done by Nine Mile Beach residents in association with the Glamorgan–Spring Bay Landcare Committee, no systematic sampling program has been attempted to measure a full range of potential contaminants. Data are therefore very limited.

Domestic wastewater disposal is a potential source of contamination (principally bacteria and nutrients) which has received some attention at Nine Mile Beach, and elsewhere where shallow groundwater resources exist.

The first indication of possible bacteria in groundwater was a single water analysis collected during the 21-day pump test of the 24-spear array in 1979. This analysis returned detectable bacteria at low levels, but this single unrepeated result may have been a result of surface contamination during sampling.

Palfreyman (2002) investigated groundwater quality in the vicinity of an operating septic tank and absorption trench at the eastern end of the Nine Mile Beach spit. Seven sampling bores were installed in a north–south line extending from the trench coastwards for about 55 m, and the groundwater from each was analysed for bacteria and nutrients (nitrogen and phosphorus species). The depth to groundwater was between 3.6 and 5.5 metres. The water table gradient in the vicinity of the trench was about 0.1 (which seems unusually high), but less than 0.01 at greater distances down gradient.

Bacteria (*E. coli*) levels in the trench of 400 000/100 mL reduced to 5000/100 mL in groundwater immediately below the trench. Bacteria were undetected (<1/100 mL) in groundwater at greater distances, except for a presumptive[14] 300/100 mL reported from a bore about 15 m down gradient. Ammonia nitrogen at 200 mg/L in the trench was converted to nitrate nitrogen during vertical infiltration to the water table beneath the trench, and thereafter nutrient levels in the groundwater attenuated in a down-gradient direction. The author suggested that wastewater impacts on groundwater are restricted to small areas around operating absorption trenches and similar installations, but recommended more monitoring of these effects, and suggested that drinking water bores be located either up-gradient (rather than down-gradient) from disposal systems, or be placed ('set back') at least 40 m down-gradient from disposal systems.

Setback distances between water bores and disposal systems in unconfined aquifers can also be estimated using the viral die-off method, suggested by Beavers and Gardner (1993), extended by Cromer *et al*. (2001), and routinely used in the computer programme *Trench 3.0* (Cromer, 1999*a*, 1999*b*).

A range of wastewater disposal methods, other than standard septic tanks and absorption trenches, would be acceptable at Nine Mile Beach. These include low water (e.g. composting) toilets and separate greywater disposal in beds or trenches, and aerated treatment systems and spray or shallow surface drip irrigation of secondary treated (i.e. chlorinated) effluent. Each of these would impact on the aquifer to different degrees.

Evidence for contamination of other unconfined coastal sand aquifers

In relation to Palfreyman's (2002) wastewater sampling at Nine Mile Beach, Cromer (2001) reported similar but more definitive results from the shallow coastal sand aquifer at Lauderdale near Hobart[15]. About 500 houses on small suburban lots dispose of domestic wastewater in septic tanks and absorption trenches. In addition, all stormwater, including roof and bitumen road runoff, discharges directly to the aquifer via soakage pits. The potential clearly exists for groundwater contamination from a wide range of domestic sources, including wastewater, garden chemicals, detergents and other household chemicals, and fuels. There is minimal groundwater usage, so the risk of seawater intrusion is absent.

Despite the high residential density at Lauderdale, testing within the township for bacteria, nutrients,

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14 A presumptive result lacks a confirmation analysis, and so may not necessarily be accurate.

15 The sand spit at Lauderdale is very similar to that at Nine Mile Beach. It comprises unconsolidated Quaternary beach sand with a capping of wind-blown sand, but sand permeability is lower at about 5 m/day. The sand extends vertically to a clay basement about 8 to 10 metres below sea level. Unconfined groundwater at depths of 1 to 2 metres is moving coastwards at 5 to 15 metres/year. Investigations involved sampling twelve shallow groundwater bores and six surface waters in the town. A more detailed survey involved sampling of seven water bores, a well, and effluent from an absorption trench at a selected house. Water samples were collected in June and December 1997, and in May 1998.

metals, organics (including petroleum hydrocarbons), and pesticides showed no significant effects on the groundwater or marine environment. No bacteria, petroleum hydrocarbons or pesticides were detected in any of the groundwater samples from within the aquifer.

These results were explained by follow-up, detailed sampling in and near a single septic tank absorption trench. Bacteria levels in the trench ranged up to 8,600,000 cfu/100 mL. After one metre of wastewater infiltration through unsaturated sand to the water table, bacteria were reduced to non-detectable levels, total nitrogen was reduced by 90%, nitrogen as ammonia (NH_3-N; 140 mg/L) was reduced to around 1 mg/L, and nitrogen as nitrate (NO_3-N) increased from about 0.01 mg/L to 10 to 30 mg/L. Importantly, NO_3-N decreased with distance downgradient from the trench, so that after 10 to 20 m it was reduced to 1 mg/L. Orthophosphate (PO_4-P) at 15 mg/L in the trench decreased to 5 mg/L beneath the trench, to 1 mg/L after 10 to 20 m of groundwater travel, and to 0.1 mg/L after 50 metres. These results indicate that each absorption trench is probably underlain by a restricted halo of groundwater with elevated nitrate and phosphate and little else, and that a short distance downgradient (probably less than a few tens of metres) the contaminants merge with background levels.

The 2001 report commented that "…it is contrary to current environmental dogma that a high septic tank density could result in relatively minor changes in groundwater quality. Furthermore, the environmental and economic benefits of such wastewater disposal outweigh the beneficial uses of the groundwater".

Similar results were found by Geary *et al*. (1999), who investigated possible groundwater contamination of shallow sand aquifers at Dodges Ferry in southeastern Tasmania. The residential density is locally high, and there is no reticulated water supply. An initial survey of bore waters showed low levels of bacteria, and some isolated but relatively high nitrate levels, but generally the affect of wastewater disposal on groundwater quality was limited.

Conclusions and Recommendations

This report has attempted to demonstrate that the unconfined aquifer at Nine Mile Beach:

☐ extends the full length and width of the spit, and covers an area of about 15 km²;

☐ is bounded to the south and north by sea water, the Swan River estuary, and high salinity groundwater;

☐ is bounded beneath by relatively impermeable clay at depths ranging from about 5 to 10 m below mean sea level;

☐ is completely full of relatively fresh groundwater except in the vicinity of the coast and estuary;

☐ contains about 25 000 ML of groundwater with salinities in the approximate range 250 mg/L to 600 mg/L of total dissolved solids, which is within the potable range provided it contains no deleterious constituents (e.g. bacteria);

☐ is recharged only via infiltrating rain;

☐ has permeabilities in the range 5 to 30 m/day and a specific yield in the range 0.17 to 0.2;

☐ is able to produce yields in individual shallow spear bores of up to 3000 L/hour depending on bore construction and installed depth;

☐ has a sustainable yield roughly equal to rain less evapotranspiration, which varies monthly and annually, but in normal years may be 600 ML/year, (400 000 L/year/hectare, or about 1000 L/day/hectare);

☐ is not under stress from current levels of groundwater use which are partly recycling the resource and are, in any case, sustainable under normal rainfall regimes;

☐ is able to supply larger quantities of water on a short term basis, and in this regard the 24-spear bore array remains available to supplement Swansea's town water supply; and

☐ is locally affected by domestic wastewater disposal in the vicinity of on-site wastewater disposal systems, but is probably generally uncontaminated by other current activities.

Management issues for interested parties, including the Glamorgan–Spring Bay Council, residents of the Nine Mile Beach spit, Landcare and Waterwatch organisations, and Mineral Resources Tasmania, should focus on co-operatively maintaining and expanding the sustainable beneficial uses of the aquifer.

Managing the aquifer should, in the short and intermediate term, involve the collection of at least the following information from within the Nine Mile Beach spit:

☐ rainfall (daily, at several locations);

☐ depth to groundwater in bores at widely spaced locations (weekly in non-pumped bores);

☐ groundwater quality, particularly from regularly-used and widely spaced bores (quarterly, tested for bacteria, nutrients, TDS, electrical conductivity, pH);

☐ an up-to-date record of existing and all new bores, on standard forms which provide details of location (GPS co-ordinates), owner, date installed, depth, diameter, pump, usage, etc. This field work should also include locations and types of on-site wastewater disposal systems; and

☐ groundwater use from all residents (estimated weekly, reported monthly or quarterly, on standard forms).

Most of this information collection is currently being co-ordinated by the Spring Bay–Glamorgan Landcare Committee as a result of the May 2001 Groundwater Forum. Data reviews and management decisions will follow, and should be disseminated to stakeholders.

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[30 September 2003]

APPENDIX 1

Engineering logs of drill holes at Nine Mile Beach

These original log sheets have not been amended since they were compiled in 1980.

ENGINEERING LOG – BOREHOLE

project SWANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates 592311 m E	drill type TRIEFUS	hole commenced 19.6.79
5339254 m N	drill method AUGER	hole completed 19.6.79
R.L. 3·50m AMSL		drilled by B. Cox
inclination VERTICAL	drill fluid NONE	logged by W. Cromer, D.J. Sloane
bearing —		checked by

penetration 1 2 3	support	water	D₅₀	S₀ notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
					+3 / +2 2 +1 3 0		SP	SAND, light brown, F-M, WS, with trace C sand and fines, trace sand-sized shell fragments	D	L		
		19.6.79 (approx. level)								M W		
				0·24 1·14								
					4 -1 5 -2 6 -3 7 -4 8		SP	SAND, grey, F, WS, with trace fines and fine gravel, and M-C sand. White and fragmented shells common.				
				0·18 1·22								
				0·15 1·22								
				0·15 1·22								

Hole stopped at limit of augers, 8·1m (-4·60m)

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ENGINEERING LOG – BOREHOLE

project	SWANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates	592276mE	drill type TRIEFUS	hole commenced 20.6.79
	5339503mN	drill method AUGER PULL	hole completed 20.6.79
R.L.	3.75m AMSL		drilled by B. Cox
inclination	VERTICAL	drill fluid NONE	logged by W. Cromer, D.J. Sloane
bearing	–		checked by

penetration 1 2 3	support	water	D_{50} S_o notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				+3 1		SP	SAND, light brown, F, WS, with fine shell fragments, trace calcareous nodules and patches (near 2.44m) and calcified roots	D	L		
			0.20 1.10								
			0.21 1.10	+2 2							
			0.23 1.16	+1 3							
			0.26 1.18					M			
				0 4			SAND, light brown, F, WS, as above, with trace fine gravel, and more abundant shells	W	MD		
			0.22 1.24								
			0.23 1.26	-1 5							
			0.21 2.31			SP to SW	SAND, grey, F, WS, in places shelly SAND, with occasional shelly lenses, grading at base to shelly, gravelly SAND (grey, MS, with fine quartzite gravel, shell fragments)				
			0.15 1.19	-2 6							
				-3 7							
			0.20 3.42	-4 8							
							Hole stopped at limit of augers, 8.24m (-4.95m)				
				9							

project SWANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates 592241mE	drill type TRIEFUS	hole commenced 21. 6.79
5339719mN	drill method AUGER PULL	hole completed 21. 6. 79
R.L. 3.50m AMSL		drilled by B. Cox
inclination VERTICAL	drill fluid NONE	logged by W. Cromer, D. J. Sloane
bearing —		checked by

penetration 1 2 3	support	water	D₅₀ S₀ notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			0.50 2.93	+3		SW	Shelly SAND, bright brown (7.5YR 5/6), M-C, MS, with some iron-oxide stained white and fragmented shell	D			
				1		SP	Shelly SAND, bright yellowish brown (10YR 6/6 and 10YR 7/6), M, MS, with trace fine quartzite gravel. Occasional fine sandy gravel and shell lenses				
			0.50 2.39	+2							
				2							
			0.27 1.47	+1							
			0.60 2.24	3					M		
				0					W		
				4			SAND, dull yellow (2.5Y6/4), F, WS, with fragmented and whole shell, and trace fine quartzite gravel; grades to yellowish brown (2.5Y5/3) below 4.3m				
			0.17 1.28	-1							
			0.21 0.35	5							
				-2			SAND, dark olive (5Y4/2), F, WS, with whole and fragmented shell, and trace fine quartzite gravel, heavy minerals and large shell				
			0.13 1.22	6							
				-3							
			0.13 1.82	7							
				-4			SAND, olive brown (2.5Y4/3), F, WS				
			0.13 1.41	8			Hole stopped at limit of augers, 7.93m (-4.43m)				

Note: water level marked 21. 6.79 (approx. level)

ENGINEERING LOG – BOREHOLE

project	SWANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates	592159 mE	drill type TRIEFUS	hole commenced 21.6.79
	5340123 mN	drill method AUGER PULL	hole completed 21.6.79
R.L.	0.90 m AMSL		drilled by B. Cox
inclination	VERTICAL	drill fluid NONE	logged by W. Cromer, D.J. Sloane
bearing	—		checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			21.6.79	0 /		OH	CLAY, dark grey, organic, grading to orange-brown sand	W			
						SP	SAND, brown-grey, F, WS, with trace shell fragments.				
						SC	clayey SAND, grey				
				-1 2		CH – OH	CLAY, grey green, stiff, moderate – high plasticity, with trace sand and minor charcoal				
				-2 3							
				-3 4			Hole stopped at required depth, 3.66m (-2.76m)				

project SWANSEA GROUNDWATER   location NINE MILE BEACH

| co-ordinates | 592205 mE |
| | 5340018 mN |

R.L. 3.25 m AMSL
inclination VERTICAL
bearing –

drill type TRIEFUS
drill method AUGER POWL

drill fluid NONE

hole commenced 21.6.79
hole completed 21.6.79
drilled by B. Cox
logged by W. Cromer, D.J. Sloane
checked by

penetration 1 2 3	support	water	D50 So notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
			0·19 1·21	+3		SP	SAND, brown (7·5YR4/4) 0 - 0.9 m; grading to yellow brown (10YR5/8), dull yellow brown (10YR7/4) and bright yellowish brown (10YR6/6), F, WS, trace shell fragments and VF dark minerals	D	L		
			0·18 1·18	+2 1							
		21.6.79 (upper level)	0·21 1·22								
			0·26 1·28	2 +1		SP to SW	SAND, yellowish brown (10YR5/6) and below 3.3m dull yellowish brown (10YR6/4), F-M, trace fines, fine quartzite gravel; some fragmented and white shell.	M			
			0·18 1·32	3 0				W	MD		
			0·27 1·58	4 -1		GW	Pebbles or sandy gravel lens, horizon, consisting of well-rounded dolerite up to 50mm, with F-M sand matrix				
				5		CH	CLAY, grey green; high plasticity Hole stopped at required depth, 4·88m (-1·63m				

ENGINEERING LOG – BOREHOLE

project	SWANSEA GROUNDWATER	location	NINE MILE BEACH

co-ordinates	592219 mE	drill type	TRIEFUS	hole commenced	21·6·79
	5339901m N	drill method	AUGER PULL	hole completed	21. 6·79
R.L.	3·50m AMSL			drilled by	B.Cox
inclination	VERTICAL	drill fluid	NONE	logged by	W.Cromer, D.J.Sloane
bearing	—			checked by	

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
		21.6.79 ▼		+3 / +2 2 +1 3 0 4		SP	SAND, orange-brown, F, WS; yellow brown 0.9-1.5m	D	L		
						SP, in places SW	SAND, buff-orange brown, M-C, MS (PS 3-3.4m) with trace fine quartzite gravel and some whole and fragmented shell (more common towards base	M W	-- MD		
				-1 5		SW	SAND, pale grey, with some fine quartzite gravel and gravel lenses.				
				-2 6 -3 7 -4		SP	SAND, pale grey, F, WS, with some shell and fine gravel				
							SAND, green-grey, F, WS, shell-free.				
				8			Hole stopped at limit of augers, 7.93m (-4.43m)				

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ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

co-ordinates *FP 913393*	drill type *TRIEFUS*	hole commenced *16. 7. 79*
	drill method *AUGER PULL*	hole completed *16. 7. 79*
R.L. *Approx. 3·5m AMSL*		drilled by *B. Cox*
inclination *VERTICAL*	drill fluid *NONE*	logged by *W. Cromer*
bearing –		checked by

penetration 1 2 3	support	water	D₅₀ / S₀ notes samples, tests MM	metres R.L. Approx / depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			0·20 1·08	+3 — 1		SP	SAND, yellowish brown, F, WS, with trace fine shell fragments and minor charcoal; slightly coarser near base; shells increase in content.	D	L		
			0·24 1·18	+2							
			0·29 1·19	2 +1					M		
			0·29 2·04	3 0		SW and SP	Shelly SAND, buff-brown, F-M, MS, with trace fine quartzite and dolerite (up to 10mm); trace gravel lenses and CaCO₃-cemented sand aggregate. Shells and shell fragments >10%	W	MD		
			0·23 2·03	4 −1		SP	SAND, grey, F, WS, in places VF, WS; trace white and fragmented shell, rare dolerite pebbles (up to 5mm) and well-rounded quartzite gravel; occasional basalt? pebbles up to 25mm.				
			0·21 1·28	5 −2							
				6 −3							
			0·13 1·26	7 −4							
			0·14 1·83	8 −5		SW	Shelly, gravelly SAND, grey-green, MS-PS; approx. 16% fine quartzite gravel; sand C, shells white, fragmented, coarse-ribbed				
			0·67 2·67	9 −6 10							

project SWANSEA GROUNDWATER   location NINE MILE BEACH

co-ordinates FP 913393

drill type TRIEFUS
drill method AUGER PULL

R.L. Approx. 3.5m AMSL

inclination VERTICAL
bearing −

drill fluid NONE

hole commenced 16.7.79
hole completed 16.7.79
drilled by B.Cox
logged by W.Cromer
checked by

penetration 1 2 3	support	water	D₅₀ S₀ notes samples, tests мм	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				-7		SP	SAND, greenish brown, VF-F, WS; trace minor shell	W	MD		
			0.16 1.21	11							
				12			Hole stopped at limit of augers, 11.3m (-7.8m				

ENGINEERING LOG – BOREHOLE

project **SWANSEA GROUNDWATER**	location **NINE MILE BEACH**

co-ordinates **589847mE**	drill type **TRIEFUS**	hole commenced **17.7.79**
5338395mN	drill method **AUGER FULL**	hole completed **17.7.79**
R.L. **2.01m AMSL**		drilled by **B.Cox**
inclination **VERTICAL**	drill fluid **NONE**	logged by **W. Cromer, D.J. Sloane**
bearing —		checked by

penetration 1 2 3	support	water	D₅₀ S₀ notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			0.21 1.15	+1 1		SP	SAND, dull yellow orange (10YR 7/4, dry), F, WS; Fines include some organics (grass stems, charcoal); sand light yellow orange (10YR 8/3, dry) 0.6-1.5m; Some CaCO₃-cemented sand patches, shell fragments, occasional intact shell (Donacilla nitida, Fulvia) near base. Trace F-VF heavy dark minerals	D	L		
			0.24 1.18						M		
			0.27 1.13	0 2				W	MD		
			0.21 1.22	-1 3							
			0.24 1.43	-2 4		SP	SAND, light grey (10YR 8/2, dry), yellowish grey (2.5Y 6/1, wet, in situ), F, WS, with some shell and shell fragments [including D. nitida, Fulvia Glycimeris striatularis, Clanculus, Austroginella muscaria, Polynices, Scaeoleda crassa, Bankivia fasciata] trace platy dolerite fragments and composite granitic? quartzitic grains				
			0.18 1.36	-3 5							
			0.12 1.18	-4 6			SAND, yellowish grey (2.5Y 6/1), F to VF, WS. trace quartzite and sandstone? fragments up to 10mm, some shells and shell fragments [species as above and also including Zeacumantus diemenensio, Nassarius pauperatus, Guraleus pictus, Subminella undulata, Tawera gallinula, echinoderm spines]. trace CaCO₃-cemented sand aggregates, rare dolerite fragments				
				-5 7							
			0.13 2.24	-6 8		SW	SAND, shelly, grey (5Y 4/1), F-M, M-PS; generally as above, including shells as above as well as Mactra rufescens, Pullastra fabayella, Nassid sp, Placamen placida, Fulvia tennicostata, Mytilus flamulatus				
				-7 9							
			0.16 3.30	-8 10			Hole stopped at limit of augers, 9.76m (-7.75m)				

project *SWANSEA GROUNDWATER*   location *NINE MILE BEACH*

co-ordinates *588 574 m E*
5 337 545 m N
R.L.   *2·60 m AMSL*
inclination *VERTICAL*
bearing   –

drill type *TRIEFUS*
drill method *AUGER PULL*

drill fluid *NONE*

hole commenced *17. 7. 79*
hole completed *17. 7. 79*
drilled by *B. Cox*
logged by *W. Cromer*
checked by

penetration 1 2 3	support	water	D_{50} / S_o notes samples, tests MM	metres R.L. / depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			0·20 / 1·11	+2 / 1		SP	SAND, bright yellowish brown (10YR 6/6), F, WS, shell free; some root fragments and trace angular quartz grains	D	L to VL		
		17.7.79	0·25 / 1·19	+1 / 2			SAND, dull yellow orange (10YR 7/4), F–M, WS; trace M–C shell fragments and white shells near base	M / W	MD to L		
			0·24 / 1·15	0 / 3							
			0·32 / 6·45	–1 / 4		SW	Pebbly SAND, PS, bimodal, with well-rounded low sphericity dolerite pebbles in matrix of F–M sand; shell fragments common.				

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ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

co-ordinates *588802 mE*	drill type *TRIEFUS*	hole commenced *17.7.79*
5338161 mN	drill method *AUGER PULL*	hole completed *17.7.79*
R.L. *2·05m AMSL*		drilled by *B.Cox*
inclination *VERTICAL*	drill fluid *NONE*	logged by *W.Cromer, D.J. Sloane*
bearing *–*		checked by

penetration 1 2 3	support	water	D_{50} S_o notes samples, tests *mm*	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
							Organic SAND, brown -black (10YR2/2)				
			0.22 1.26			SP	*SAND, bright yellowish brown (10YR6/6), F, WS*				
		17.779	*0.42 1.87*	*+1* *1*			*SAND, dull yellow orange (10YR6/4), F, WS, with trace F-M shell fragments and occasional well-rounded dolerite pebbles (up to 50mm)*				
			0.25 1.14								
			0.29 1.22	*0* *2*			*SAND, shelly, brownish grey (10YR5/1 -10YR4/1), in places containing wood fragments; F-M, WS, trace shells - locally up to 15%*				
			0.34 2.23								
			1.9 3.26	*-1*		SP - SW	*Pebbly SAND, bright yellowish brown (10YR6/6), FS-MS, shelly in places, mainly fragmented; trace rounded dolerite pebbles (up to 50mm), possibly in lenses and layers.*				
			0.24 2.60	*3*							
			0.29 2.79	*-2* *4*		SW	*Shelly SAND, grey (5Y5/1), FS, with lenses, layers of rounded dolerite pebbles (up to 50mm); some shells, locally abundant; trace quartzite fine gravel*				
			0.12 1.26	*-3* *5*		SP	*SAND, grey (10Y4/1), F, WS, trace fine shell fragments*				
				-4 *6*		SW	*Pebbly SAND, FS, grey, trace rounded dolerite pebbles, cobbles.*				
							Refusal on pebbles at 6.1m (~4.05m)				

ENGINEERING LOG – BOREHOLE

project	S WANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates	588524 m E	drill type TRIEFUS	hole commenced 18.7.79
	5338339 m N	drill method AUGER PULL	hole completed 18.7.79
R.L.	1.90 m AMSL		drilled by B. Cox
inclination	VERTICAL	drill fluid NONE	logged by W. Cromer
bearing			checked by

penetration 1 2 3	support	water	D₅₀ S₀ notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			0.20 1.14	+1 1		SP	SAND, yellowish brown (10YR5/8), F, WS with occasional dolerite cobbles up to 250 mm. Below 0.6m, trace fragmented shells (up to 25 mm), and less cobbles				
		▼	0.21 1.13								
			0.18 1.15	0 2			SAND, dull yellow orange (10YR6/4), F, WS, with some fine shell fragments				
			0.24 2.50	-1 3		SP to SW	SAND, dark greyish yellow (2.5Y4/2), F-M, WS-PS, with occasional patches, lenses of fine quartzite gravel. Some fragmented shell, and occasional dolerite pebbles (up to 50mm). Better sorted, brownish grey, 3.05 – 3.36 m				
			0.19 1.46								
			0.26 5.77	-2 4							
			0.11 1.23			SW	Pebbly, shelly SAND, greyish olive (7.5Y4/2), PS, shells little, fragmented; some fine quartzite gravel/lenses, rare dolerite pebbles (up to 75mm; well rounded, low sphericity)				
				5		SC	Clayey SAND, dark olive (7.5Y4/2), VF, WS grading at 4.27 m to sandy CLAY				
							Hole stopped at required depth 4.27m (-2.37m)				

project	*SWANSEA GROUNDWATER*	location	*NINE MILE BEACH*

co-ordinates	*588959 m E*	drill type	*TRIEFUS*	hole commenced	*18.7.79*
	5338692 m N	drill method	*AUGER FULL*	hole completed	*18.7.79*
R.L.	*2.92 mAMSL*			drilled by	*B. Cox*
inclination	*VERTICAL*	drill fluid	*NONE*	logged by	*W. Cromer*
bearing	–			checked by	

penetration 1 2 3	support	water	D50 So notes samples, tests num	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			0.19 1.11	+2 1		SP	SAND, yellowish brown (10YR5/8), F, WS, shell-free. Trace VF dark mineral, and in places stained with darker iron oxide cement. Trace fragmented shell below 1.5m, where sand is bright yellowish brown (10YR6/6				
			0.21 1.22								
			0.28 1.40	+1 2							
			1.1 2.14	0 3		SP to SW	Shelly SAND, yellowish brown (10YR6/6), M, MS-FS; shell common, locally abundant. Trace fine quartzite gravel, and occasional rounded dolerite pebbles				
			0.27 2.13	-1 4							
			0.17 1.46	-2 5			SAND, dark greyish yellow (2.5Y4/2), F, WS-MS, shells abundant, whole and fragmented				
			0.21 1.91	-3 6							
				-4 7			Hole stopped at limit of augers, 6.1m (-3.18m)				
				-5							

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*   location *NINE MILE BEACH*

co-ordinates *589393 m E*
5339133 m N
R.L. *Approx. 2m AMSL*
inclination *VERTICAL*
bearing *—*

drill type *TRIEFUS*
drill method *AUGER PULL*

drill fluid *NONE*

hole commenced *18.7.79*
hole completed *18-7.79*
drilled by *B. Cox*
logged by *W-Cromer*
checked by

penetration 1 2 3	support	water	D_{50} S_0 notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
		Specific Conductance = 7500µS/cm 18.7.79	0·20 1·25			SP	SAND, dull yellowish brown (10YR5/3) to dull yellow orange (10YR6/4), F, WS				
			0·22 1·37	1		SC	Clayey SAND, dull yellow (2·5Y6/3) to bright yellowish brown (10YR6/8), mottled, with some clay and silt, WS, shell-free.				
			0·22 1·25								
			0·25 1·67	2			Clayey SAND, mottled dull brown (2·5Y4/6), M, MS, with trace c sand sized quartzite grains				
							Hole stopped at 2·44m, required depth.				
				3							

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*		location *NINE MILE BEACH*

co-ordinates *589361m E* *5339149m N*	drill type *TRIEFUS* drill method *AUGER FULL*	hole commenced *19.7.79* hole completed *19.7.79*
R.L. *Approx. 2m AMSL* inclination *VERTICAL* bearing *—*	drill fluid *NONE*	drilled by *B. Cox* logged by *W. Cromer, D. Sloane* checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
		NOT PRESENT.		*1*		SP	*SAND, black (10YR 1.7/1), F, WS, organic*				
						SC	*Clayey SAND, dull yellowish brown (10YR 5/3)*				
						SP to SC	*SAND, dull yellow orange (10YR 6/4), F, WS, grading at 0.7m to mottled bright yellow orange and dull yellow orange sandy clay*				
						CH	*Sandy CLAY, olive grey (5GY 5/1), high plasticity; trace fine sand*				
				2			*Hole stopped at required depth, 1.45m.*				

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*		location *NINE MILE BEACH*	

co-ordinates *588 414m E* *5338 422m N*	drill type *TRIEFUS* drill method *AUGER PULL*	hole commenced *19.7.79* hole completed *19.7.79*
R.L. *1.48m AHSL* inclination *VERTICAL* bearing *—*	drill fluid *NONE*	drilled by *B. Cox* logged by *W.Cromer, D.J.Sloane* checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			19.7.79	*+1* *1* *0*		SM	*silty SAND, dark brown (10YR3/4)*	*D* *M* *>* *PL*	*St*		
						CH	*CLAY, yellowish brown (10YR5/8); trace sand patches and calcareous material; moderate–high plasticity*				
				2 *-1* *3* *-2* *4* *-3* *5*		SP	*SAND, yellowish brown (10YR5/6), VF-F, WS, trace fines. Below 2.5m, bright yellowish brown (10YR6/8), M, WS-MS; trace fine shell.*	*W*	*MD*		
							SAND, olive black (5Y3/2), F-M, MS-PS; some shells, locally abundant. Some small patches of pale grey clay?				
							Pebbly CLAY?	*M*	*VSt*		
				-4 *6*			*Refusal at 5.1m (-3.62m)*				

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*		location *NINE MILE BEACH*	
co-ordinates *589515 mE* *5338855 mN*	drill type *Triefus* drill method *AUGER PULL*	hole commenced *8.8.79* hole completed *8.8.79*	
R.L. *2·24m AMSL* inclination *VERTICAL* bearing —	drill fluid *NONE*	drilled by *B.Cox* logged by *D.J.Sloane* checked by	

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr- ometer kPa 25 50 100 200 400	structure, geology
		8.8.79		+2 1 +1 2 0 3 -1 4 -2 5		SP	*SAND, yellowish brown (10YR5/6), F, WS*	*D*			
							SAND, dull yellow orange (10YR6/4), F–M WS–MS, trace fragmented and whole shell; below 1·5m changes to bright yellow (2·5Y7/4)	*M* *W*			
							SAND, grey (7·5Y5/1), M, MS, with trace –some shell and shell fragments, trace well-rounded fine quartzite gravel				
						SP to SW	*Shelly SAND, grey (7·5Y5/1), M, PS, with shells and shell fragments; trace –some fine quartzite gravel·*				
							Hole stopped at required depth, 4·7m (–2·46m)				

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

co-ordinates *FP 892382*	drill type *TRIEFUS* drill method *AUGER*	hole commenced *8. 8. 79* hole completed *8. 8. 79*
R.L. *approx. 2.1m AMSL* inclination *VERTICAL* bearing —	drill fluid *NONE*	drilled by *B. Cox* logged by *W. Cromer* checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			8.8.79	+2 / +1		SP	SAND, dull yellow orange (10YR7/4), F-VF, WS. Trace fragmented shell below 1.5m; colour change to dull yellow orange (10YR6/4)				
				0 / 2		SP to SW	SAND, yellowish brown (2.5Y3/3), F-M, WS, trace-some fragmented shell; changes below about 2.5m to grey shelly SAND, PS, with trace fine quartzite gravel. (interval 2.5-5m not logged in detail)				
				-1 / 3							
				-2 / 4							
				/ 5			Hole stopped at required depth, 5.0m (approx. -3.9m)				

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

co-ordinates 589089m E	drill type *TRIEFUS*	hole commenced 8.8.79
5338410 m N	drill method *AUGER PULL*	hole completed 8.8.79
R.L. 2.10m AMSL		drilled by *B.Cox*
inclination *VERTICAL*	drill fluid *NONE*	logged by *W.Cromer*
bearing –		checked by

penetration 12	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
		8.8.79		+2		SP	SAND, grey, F, WS				
						SP	SAND, bright-yellowish brown (10YR6/6) and yellowish brown (10YR5/6), F, WS				
				+1 /			SAND, bright-yellowish brown (10YR6/6), F, WS-MS trace-some white and fragmented shell; CaCO₃ concretions near water table				
				2 / 0							
				3 / -1		GW	Shelly GRAVEL, yellowish brown, fine grained, with white and fragmented shells in fine quartzite gravel. Some sand, trace rounded aderik pebbles				
				4			Hole stopped at required depth, 3.5m (-1.4m)				

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*		location *NINE MILE BEACH*
co-ordinates *588899 mE* *5339260 mN* R.L. *4.27m AMSL* inclination *VERTICAL* bearing –	drill type *TRIEFUS* drill method *AUGER PULL* drill fluid *NONE*	hole commenced *28.8.79* hole completed *28.8.79* drilled by *B. Cox* logged by *D.J. Sloane* checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				+4		ML	*Sandy SILT, dark brown (10YR3/3)*	D			
			NOT ENCOUNTERED	1— +3		SC to CH	*Sandy CLAY, bright brown (7.5YR5/6), mottled in places with yellowish brown (10YR5/6). Trace CaCO₃ concretionary patches and F-M quartz sand. High plasticity*	M > PL			
				2— +2		SC	*Clayey SAND, yellowish brown (10YR5/6) and dull yellowish brown (10YR5/4) with some sandy clay. Occasional charcoal, ironstone and calcareous fragments.*				
				3—							

ENGINEERING LOG – BOREHOLE

project	SWANSEA GROUNDWATER	location	NINE MILE BEACH

co-ordinates	5895 51m E	drill type	TRIEFUS	hole commenced	29·8·79
	533879 0 m N	drill method	AUGER PULL	hole completed	29.8.79
R.L.	2·75 m AMSL			drilled by	B. Cox
inclination	VERTICAL	drill fluid	NONE	logged by	D.J. Sloane
bearing	–			checked by	

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
						SP	SAND, brownish black (10YR3/2), F, WS				
						SP	SAND, bright yellowish brown (10YR7/6), F, WS				
		29.8.79		+2 / +1 2		SP, SW to GW	Shelly, gravelly SAND, dull yellow orange (10YR7/4); abundant shell and shell fragments, and quartz granules (up to 4 mm). Some -three platy, well rounded dolerite pebbles (up to 75 mm), trace Calcarenite pebbles and CaCO₃ -cemented sand patches				
				0 3 -1 4							
				-2 5 -3		SP	SAND, grey, F-M, WS, with trace-some fragmented and white shell, and quartz granules and well-rounded dolerite pebbles				
				6			Hole stopped at required depth, 5.7m (-2.95m)				

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

co-ordinates *588918 m E*	drill type *TRIEFUS*	hole commenced *29.8.79*
533923 9m N	drill method *AUGER PULL*	hole completed *29.8.79*
R.L. *2.75 m AMSL*		drilled by *B. Cox*
inclination *VERTICAL*	drill fluid *NONE*	logged by *D.J. Sloane*
bearing —		checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
		29.8.79. Salinity = 480 mg/L		+2 / +1 2 0 3 -1 4 -2 5 -3 6		SC to CH / SC / SC / CH	*Sandy CLAY, mottled dull yellow (2.5Y6/3), reddish brown (5YR4/8) and dark greyish yellow (2.5Y4/2); trace F-M sand, and occasional quartz granules (up to 3mm)* / *Clayey SAND, bright brown (7.5YR5/8), F-M; trace well-rounded quartzite granules (up to 2mm). Trace silt* / *Sandy CLAY, mottled reddish brown (2.5YR4/6) and brown (7.5YR4/6); trace quartzite granules. Thin ironstone concretionary layer at 3.05 m. Drilling hard.* / *CLAY, light bluish grey (5B7/1); high plasticity* / *CLAY, dull yellowish brown (10YR5/4), mottled in places with red (10R5/8) near 4.6m. High plasticity* / *Hole stopped at required depth, 6.05m (-3.30m)*				

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

| co-ordinates *588997m E*
 5339152 m N

 R.L. *1.18 m AMSL*
 inclination *VERTICAL*
 bearing *–* | drill type *TRIEFUS*
 drill method *AUGER PULL*

 drill fluid *NONE* | hole commenced *29.8.79*
 hole completed *29.8.79*
 drilled by *R. Cox*
 logged by *D.J. Sloane*
 checked by |

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
		29.8.79	water salinity = 7400 mg/c	+1 0		SC	*Sandy CLAY, mottled olive brown (2.5Y4/3) and yellowish brown (10YR5/6); F-M sand, with trace pebbles up to 15mm, and ironstone fragments*	D	St to VSt		
							Clayey SAND, dark greenish grey (5G4/1), F-M	W	St		
				2 -1		SP	*SAND, greyish olive (7.5Y4/3) and olive grey (10YR5/2) F-M, WS, trace fines*		MD		
				3 -2							
				4 -3		CH	*CLAY mottled grey-blue and yellowish brown (10YR5/6), with trace ironstone fragments (up to 20mm). High plasticity*	M > PL	VSt.		
				5 -4							
				6			*Hole stopped at required depth, 5.49m (-4.31m)*				

project SWANSEA GROUNDWATER		location NINE MILE BEACH	
co-ordinates 589139 m E 5338996 m N R.L. 0.72 m AMSL inclination VERTICAL bearing –	drill type TRIEFOS drill method AUGER FULL drill fluid NONE	hole commenced 29.8.79 hole completed 29.8.79 drilled by B. Cox logged by D.J. Stone. checked by	

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
		▽	29.8.79 Salinity = 620 mg/L.	0 1 -1 2 -2		SC	Clayey SAND, greyish yellow brown (10YR6/2) and yellowish brown (10YR5/6), F-M, trace ironstone fragments				
							Sandy CLAY, dark bluish grey (5B4/1), trace organics				
							Clayey SAND, greyish olive (5Y5/3) and grey (5Y5/1), F-M, with trace C sand				
				3 -3		SW	Clayey SAND, yellowish brown (2.5Y5/3), F-M, PS, with trace quartz granules (up to 4mm)				
				4 -4		SC	Clayey SAND, yellowish brown (2.5Y5/3), some shell and shell fragments, including gastropods. trace organics				
				5			Pebbly SAND, F-M, PS, with some well-rounded dolerite pebbles (up to 50mm) Hole stopped at 4.88m (-4.16m)				

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

project SWANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates 588173m E	drill type TRIEFUS	hole commenced 29.8.79
5338955m N	drill method AUGER DRILL	hole completed 29.8.79
R.L. 2·71m AHSL		drilled by R.Cox
inclination VERTICAL	drill fluid NONE	logged by D.J. Sloane
bearing —		checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetr-ometer kPa 25 50 100 200 400	structure, geology
			29·8·79	+2		SP	SAND, bright yellowish brown (10YR6/6), F, WS				
				1 +1		SP to SW	SAND, dull yellow orange (10YR6/4), F,M, WS, with trace shell fragments esp. 1.8-2.8m; trace well-rounded dolerite pebbles and CaCO₃-cemented patches				
				2 -0							
				3 -1							
				4		SC	Sandy CLAY, grey				
				-2 5		SC	Clayey SAND, dull brown (2.5Y4/4), F-M, WS-PS, trace rounded quartzite granules, and rounded dolerite pebble. Trace olive black clay patches				
				-3 6		SP	SAND, grey (7.5Y4/1) and olive black (7.5Y3/2), F-VF, WS; trace organics. Fragmented shells common; intact shells rare. Occasional thin lenses of grey sandy clay, and near 7m rounded dolerite pebbles and ironstone fragments.				
				-4 7							
				-5 8		CH	CLAY, brownish black (2.5Y3/2), high plasticity				
							Hole stopped at required depth 7.7m (-4.99m)				

project SWANSEA GROUNDWATER	location NINE MILE BEACH

co-ordinates 589548mE	drill type Failing	hole commenced 28. 8. 79
5338789mN	drill method Rotary	hole completed 28. 8. 79
R.L. 2.68 m AMSL		drilled by K. Richardson
inclination VERTICAL	drill fluid Mud	logged by W. Comer, O.J. Sloane
bearing —		checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
		▽		0		SP	SAND, bright yellowish brown (10YR7/6), F, WS				
						SP, Sw, GW	Shelly, gravelly SAND, dull yellow orange (10YR7/4) with abundant shells, fine gravel lenses and dolerite pebbles				
				5 -5		SP to Sw	SAND, grey, F–M, WS, with trace – some whole and fragmented shell, quartzite granules and well-rounded dolerite pebbles				
				10 -10		CH	CLAY, dull yellow, grey blue and dine brown (2.5Y 4/3); plasticity high; some harder bands? near 11.3m.				
				15 -15			CLAY, yellowish grey (2.5Y 4/1), high plasticity				
				20 -20							
				25 -25							
				30 -30							
				35 -35			Hole stopped at required depth, 36.6m (-33.9m)				
				40							

project _SWANSEA GROUNDWATER_		location _NINE MILE BEACH_	

co-ordinates	589877mE	drill type _FAILING_	hole commenced 2.9.79
	5338340mN	drill method _ROTARY_	hole completed 2.9.79
R.L.	1.98mAMSL		drilled by K. Richardson
inclination	VERTICAL	drill fluid _MUD_	logged by K. Richardson
bearing	–		checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
	▽			0		SP to SW	SAND, dull yellow brown, orange and grey, F, WS at top (aeolian), grading to F-M, MS-PS; shelly marine sand, locally enriched in fine granite gravel and dolerite pebbles				
				5 -5							
				10 -10		CH	CLAY, dull grey				
				15			HOLE STOPPED AT REQUIRED DEPTH, 13.7m (-11.7m)				

project _SWANSEA GROUNDWATER_		location _NINE MILE BEACH_	

co-ordinates 589464m E	drill type _TRIEFUS_	hole commenced 26.6.80
5333805m N	drill method _AUGER PULL_	hole completed 26.6.80
R.L. 2.86m AMSL		drilled by _B. Cox_
inclination VERTICAL	drill fluid _NONE_	logged by _W. Cromer_
bearing -		checked by

penetration 1 2 3	support	water	D50 So notes samples, tests mm	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				+2 1		SP	SAND, bright yellowish brown (10YR7/6) to dull yellow orange (10YR7/4), F, WS, trace dark organic streaks and calcareous patches, and rounded dolerite pebbles near 1.5m.				
		26.6.80		+1 2			SAND, dull yellowish orange (10YR7/4), M, WS-MS, shelly in places with sand-sized shell fragments and whole shells; darkening at 2.4m to dull yellow orange (10YR6/4). Occasional shelly coarse sand lenses near 3m				
			0.18 1.15	0 3							
			0.19 1.32	-1 4			SAND, olive black (10Y3/1), F, WS, flecked with cream-white sand sized shell fragments and occasional larger white shell. Occasional thin lenses of coarse sand. Colour lightens to grey (5Y4/1) near 4.2m				
			1.2 1.91			SP to SW	SAND, grey (5Y4/1), M, MS-PS, with larger shell fragments and fine quartzite gravel; some organically enriched (sponge spicules) shelly lenses containing charcoal at 4.8-4.9m. Fine gravel - C sand lenses common below 4.5m. Sand flecked with fine shell fragments below 5m				
			0.21 1.58	-2 5							
			0.12 1.26	-3 6							
			0.14 1.10	-4 7		SP	SAND, F, WS, grey (10Y4/1), with trace fine shell and some large broken shell (up to 10mm). Occasional thin coarse sand lenses. Distinctive mint				
				-5 8		SC	Clayey SAND, olive grey (5G4 5/1), F, WS, shell-free 7.5-7.8m, but shells, whole and fragmented, common below 7.8m				
				-6 9		CH to SC	CLAY, dark olive (5Y4/4), high plasticity, shelly in places, with cream shell fragments. Locally grades to sandy clay, and contains patches of blue-grey (5BG6/1) clay.				
				10			Hole stopped at required depth, 9.6m (-6.74m)				

ENGINEERING LOG – BOREHOLE

borehole no. *28*

sheet *1* of *1*

project *SWANSEA GROUNDWATER*	location *NINE MILE BEACH*

co-ordinates *589430 mE* *5338711 mN* R.L. *2.32 mAMSL* inclination *VERTICAL* bearing *-*	drill type *TRIEFUS* drill method *AUGER PULL* drill fluid *NONE*	hole commenced *26.6.80* hole completed *26.6.80* drilled by *B. Cox* logged by *W. Cromer* checked by

penetration 1 2 3	support	water	notes samples, tests D_{50} S_0 MM	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				+2		SP	SAND, yellowish brown (10YR5/8), F-M, WS; some fine roots and trace charcoal. Trace C sand and fine gravel				
				1 / +1		SP to SW	SAND, dull yellow/orange (10YR7/3), M, MS, with trace-some whole and fragmented shell, CaCO₃-cemented sand patches, coarse shelly lenses and trace well-rounded dolerite pebbles up to 50mm. Grades to very shelly PS sand, bright yellowish brown (10YR6/6); large shells abundant, with fine gravel lenses, and near 3m some fine sand lenses				
			0.60 2.45 0	2							
				3 -1							
			0.30 3.16	4 -2			SAND, greyish olive (5Y5/2), VF, WS, flecked with fine white shell fragments. Below 5.1m, shell fragments slightly larger (up to 5mm). Some coarse sand and fine shelly gravel lenses at 6m.				
			0.13 1.22	5 -3							
				6							
				-4			Hole stopped at required depth, 6.0m (-3.68m)				
				7							

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

project	*SWANSEA GROUNDWATER*		location *NINE MILE BEACH*

co-ordinates *589536mE*	drill type *TRIEFUS*	hole commenced *26.6.80*
5338684m N	drill method *AUGER FULL*	hole completed *26.6.80*
R.L. *2.44m AMSL*		drilled by *B. Cox*
inclination *VERTICAL*	drill fluid *NONE*	logged by *W. Cromer*
bearing —		checked by

penetration 1 2 3	support	water	D_{50} S_0 notes samples, tests	metres RL depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				+2		SP	SAND, bright yellowish brown (10YR7/6) and dull yellow orange (10YR7/4), F, WS	D			
				1							
		26.6.80		+1			SAND, dull yellow orange (10YR7/4), F-M, WS, with trace-some F-C sand sized shell fragments, trace rounded dolerite pebbles (up to 75mm), some shelly coarse sand and fine gravel lenses. Below 1.5m very shelly, with abundant whole shells.	M			
			0.25 1.32	2 0				W			
				3							
			0.19 1.34	-1			SAND, dull yellow orange (10YR6/4), F, WS, with trace F shell fragments and CaCO₃-cemented sand patches				
				4		SP	SAND, dull yellow orange (10YR6/4) F-M, MS-PS, with abundant rounded dolerite pebbles and whole shells. Some shelly fine gravel lenses at 5m. Coarsens slightly near 5.6m.				
			0.20 1.05	-2							
				5 -3							
			0.10 1.20	6			SAND, grey (7.5Y4/1), VF, WS, flecked with F white shell fragments				
				-4			Hole stopped at 6.05m (-3.61m)				
				7							
				-5							

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

project *SWANSEA GROUNDWATER*			location *NINE MILE BEACH*	

co-ordinates 589145mE	drill type *TRIEFUS*	hole commenced 25.6.80
5338968mN	drill method *AUGER PULL*	hole completed 25.6.80
R.L. /·02m AMSL		drilled by *B.Cox*
inclination *VERTICAL*	drill fluid *NONE*	logged by *W.Cromer*
bearing —		checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
		▼ 25.6.80		0 /		SP	SAND, F, WS, black, organic				
							SAND, dark brown (10YR3/3), M, PS, with trace fine quartzite gravel, grading at 0.4m to greyish yellow brown (10YR4/2) M, WS shell-free sand. Greyish blue (7.5Y5/2) at 1.2m.				
				-1 2		SC	Clayey SAND, olive grey (5G4/5/1). Poor recovery.				
						SP	SAND, dark greyish yellow (2.5Y5/2) and olive brown (2.5Y4/2) M, MS, with trace fine quartzite gravel and rock fragments.				
				-2 3							
							SAND, dark olive (5Y4/3) F, WS, trace fines, greyish olive (7.5Y4/2) at 3.3m				
				-3 4			SAND, grey (5Y4/1), very shelly, with fragmented and whole shells; trace fine granule quartz and rounded dolerite pebbles up to 50mm. Olive black (5Y3/1) at 5.9m.				
				-4 5							
				-5 6		CH	CLAY, grey (10YS/1) and dark olive (5Y4/4), stiff, moderately plastic; grades rapidly to mottled bluish grey (5BG5/1) and dark olive (5Y4/3)				
				-6 7			Hole stopped at required depth 6.9m, (-5.88m)				

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG — BOREHOLE

Project:	**SWANSEA GROUNDWATER SUPPLY**	Location:	**NINE MILE BEACH**

Co-ordinates: 589 150 mE, 5 338 980 mN	Drill type: Triefus	Hole commenced: 25.6.1980
RL: 0.59 m AMSL	Drill method: Auger pull	Hole completed: 25.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
						SP	SAND, greyish yellow brown (10YR6/2), fine–medium grained, well sorted, some roots, minor charcoal and fine quartzite granules.	M		HOLOCENE AEOLIAN SAND
				1		SC	CLAY, sandy dark greenish grey (10GY4/1), mottled in places with olive grey (5GY5/1), root fragments common, save angular quartz granules up to 2 mm; olive brown patches (2.5Y4/4)	W		
				2		SW-SC	SAND, grey (5Y4/1), poorly-moderately sorted. Some well-rounded quartz granules up to 5 mm, fine-medium grained. Some clay. Grades to yellowish brown (2.5Y5/4)			
						GW	Gravelly CLAY, dark greenish grey (5G4/1), and clayey GRAVEL			
				3		SC	Clayey SAND, olive grey (10Y4/2), fine grained, well sorted, some minor quartz granules, changes to yellowish brown (2.5Y5/4) near 3.2 m			
				4 5		SP	SAND, olive black (5Y3/1) and greyish blue (5Y5/3), fine grained, well sorted, shelly, flecked with shell fragments and whole shells. Slightly clayey in places. Below 4.2 m grades to very shelly sand, greyish olive (5Y4/2), with whole shells, occasional CaCO$_3$-cemented patches. Fine quartz granules and rare dolerite pebbles up to 10 mm			
				6		CH	CLAY, olive brown (2.5Y4/3) and olive grey (2.5GY6/1), plastic, stiff, some greyish white (N7/C) patches	M		
				7		CH	CLAY, yellowish brown (10YR5/6), friable and crumbly. Drilling hard.	D		
							Hole stopped at 6.9 m (-6.31 m)			

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG — BOREHOLE

Project:	**SWANSEA GROUNDWATER SUPPLY**	Location:	**NINE MILE BEACH**

Co-ordinates: 588 984 mE, 5 339 422 mN	Drill type: Triefus	Hole commenced: 25.6.1980
RL: 3.96 m AMSL	Drill method: Auger pull	Hole completed: 25.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
						CH	CLAY, dull yellow orange (10YR6/4) mottled with yellowish brown (10YR5/6), plastic. Some root fragments and charcoal	D		
				1		SC	Sandy CLAY, yellowish brown (10YR5/6) with small patches of olive green (5Y6/3) and occasional nodular calcarenite.			
				2		CH	CLAY, light grey (7.5Y7/2), stiff, plastic, with streaks and patches of orange (5YR6/8) and bright yellowish brown (10YR6/6)			
				3		GW	Silty gravelly CLAY, yellowish brown (10YR5/8), with fragments of concretionary limonite			
						CH	CLAY, light yellow (2.5Y7/4), plastic, some darker patches			
							Hole stopped at 3.3 m (+0.66 m)			
				4						

TASMANIA DEPARTMENT OF MINES
ENGINEERING LOG — BOREHOLE

Project:	SWANSEA GROUNDWATER SUPPLY		Location:	NINE MILE BEACH

Co-ordinates: 589 010 mE, 5 339 453 mN	Drill type: Triefus	Hole commenced: 24.6.1980
RL: 3.13 m AMSL	Drill method: Auger pull	Hole completed: 24.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
						CH	CLAY, dull yellowish brown (10YR5/4), in places (10YR4/3). Stiff, some charcoal fragments	D		LAST INTERGLACIAL ESTUARINE
				1		CH	CLAY, mainly light grey (7.5Y7/2), plastic, but with streaks and patches of orange (5YR6/8), bright yellow brown (10YR7/6), and dull yellow (2.5Y6/4) at 2.4 m			TERTIARY?
				2						
				3		CH	Silty, gravelly CLAY, yellowish brown (10YR5/8). Friable, with fragments of concretionary limonite, possibly some manganese dioxide patches			TERTIARY?
							Hole stopped at 3.35 m (-0.22 m)			
				4						
				5						
				6						
				7						
				8						
				9						

TASMANIA DEPARTMENT OF MINES
ENGINEERING LOG — BOREHOLE

Project:	SWANSEA GROUNDWATER SUPPLY	Location:	NINE MILE BEACH

Co-ordinates: 588 039 mE, 5 339 484 mN	Drill type: Triefus	Hole commenced: 24.6.1980
RL: 2.20 m AMSL	Drill method: Auger pull	Hole completed: 24.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
						CH	CLAY, olive brown (2.5Y4/4), mottled in places with brown (10YR4/6) and yellowish brown (2.5Y5/3), plastic, charcoal fragments common	D		LAST INTERGLACIAL ESTUARINE
				1		CH	CLAY, dull yellow (2.5Y6/3), mottled with yellowish brown (10YR5/6) numerous nodular concretionary calcarenite fragments, some charcoal, grading at about 2 m to a mottled dull yellowish brown (10YR5/4) and greyish olive (5Y6/2) clay with calcarenite nodules. Mottled yellowish brown (10YR5/8) and greenish grey (10GY6/1) stiff clay at 3 m, some silt and charcoal fragments			LAST INTERGLACIAL ESTUARINE
				2 3						
				4		CH	CLAY, dark greenish grey (10G4/1), stiff, plastic, mottled with some small patches and diffuse areas of olive brown (2.5Y4/3), with some small dark reddish brown (2.5YR3/3) patches			LAST INTERGLACIAL ESTUARINE
						SC	Clayey SAND and sandy CLAY, yellowish brown (10YR5/6) mottled in places with olive grey (10Y5/2) gleying, grading at 4.8 m to yellowish brown (10YR5/6) well sorted, slightly clayey sand, medium grained, slightly clayey near 5.1 m	W		LAST INTERGLACIAL ESTUARINE
				5			CLAY, dark greenish grey (7.5GY4/1), stiff, plastic, with some charcoal			"
							Recovery poor. possibly yellow brown clayey sand, with concretionary limonite fragments up to 25 mm			
				6			CLAY, dark greenish grey (10GY6/1), stiff, plastic, with some brown (10YR4/4) patches	M		
							Hole stopped at 6.1 m (3.90 m)			
				7						
				9						

ENGINEERING LOG — BOREHOLE

Project: SWANSEA GROUNDWATER SUPPLY	Location: NINE MILE BEACH

Co-ordinates: 589 141 mE, 5 339 531 mN	Drill type: Triefus	Hole commenced: 25.6.1980
RL: 2.73 m AMSL	Drill method: Auger pull	Hole completed: 25.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
				1		SC	Clayey SAND, brown (7.5YR4/6), medium grained, well sorted, mottled in places with dull yellow (2.5Y6/3) and bright reddish brown (5YR5/8), occasional limonite fragments up to 25 mm especially near 1 m, nodular calcarenite fragments common at 1.2 m	D		TERTIARY
				2		CH	CLAY, light bluish grey (5B7/1), plastic			TERTIARY
				3 4 5		CH	CLAY, mainly light bluish grey (5B7/1), mottled in places with irregular patches of red (7.5R4/8) and bright brown (7.5YR5/6), moderately plastic. Some larger patches or lenses of red near 4 m, and generally colours more patchy below 4.5 m, including bright reddish brown (5YR5/6)			TERTIARY
				6 7 8 9			Hole stopped at 6.0 m (-3.27 m)			

TASMANIA DEPARTMENT OF MINES
ENGINEERING LOG — BOREHOLE

Borehole no. **36**
Sheet 1 of 1

Project:	SWANSEA GROUNDWATER SUPPLY	Location:	NINE MILE BEACH

Co-ordinates: 588 813 mE, 5 339 742 mN	Drill type: Triefus	Hole commenced: 24.6.1980
RL:	Drill method: Auger pull	Hole completed: 24.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
						CH	CLAY, olive brown (2.5Y4/4) mottled in places with dark greyish yellow (2.5Y4/2), stiff plastic, with nodules concretionary patches of calcarenite, some organic material and roots. Grades to yellowish brown (2.5Y5/4) near 1.5 m	M		LAST INTERGLACIAL ESTUARINE
				2		SC	Clayey SAND, dull yellow (2.5Y6/3), mottled with yellowish brown (10YR5/8), medium grained, moderately sorted, some gleying patches (10GY5/1), shell fragments. Nodular, concretionary calcarenite at 3.3 m	W		LAST INTERGLACIAL ESTUARINE
				4		SC	Sandy CLAY, yellowish brown (10YR5/6), mottled with greenish grey (10GY5/1) gleying, and numerous small (up to 10 mm) specks and patches of calcarenite. Mainly brown (10YR4/6) sandy clay and clayey sand below 4.2 m)			LAST INTERGLACIAL ESTUARINE
				6		GC	Gravelly sandy CLAY, brown (10YR4/6), with fine granules, fragments and well-rounded pebbles of dolerite (up to 50 mm), and fragmented concretionary limonite, in clay and clayey sand matrix	M		TERTIARY?
				7			CLAY, mottled brown (10YR4/6) and yellowish brown 2.5Y5/6) with olive grey (10Y4/2) gleying, stiff, with some minor sand and fine granules			
							Hole stopped at 6.15 m			
				9						

TASMANIA DEPARTMENT OF MINES
ENGINEERING LOG — BOREHOLE

Project:	SWANSEA GROUNDWATER SUPPLY	Location:	NINE MILE BEACH

Co-ordinates: 587 984 mE, 5 339 359 mN	Drill type: Triefus	Hole commenced: 23.6.1980
RL:	Drill method: Auger pull	Hole completed: 23.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
				1		CH	CLAY, dull yellowish brown (10YR5/4), plastic, some small nodular calcarenite concretions up to 20 mm, some root fragments. Grades to yellowish brown (2.5Y5/3) near 1.5 m	D		LAST INTERGLACIAL ESTUARINE
			▶	2		CH	CLAY, dull yellowish brown (10YR5/4) and mottled with olive brown (2.5Y4/6). Some roots and minor iron oxide staining and gleying (10GY5/1) around roots. Some minor fine silt			LAST INTERGLACIAL ESTUARINE
						SC	Clayey SAND, yellowish brown (2.5Y5/4) with some minor clay	W		"
				3		CH	CLAY, mottled bright yellow brown (10YR6/8), dull yellow orange (10YR6/3) and grey (10Y5/1). Some minor silty and fine sand patches and lenses?	M		LAST INTERGLACIAL ESTUARINE
			▶	4		SP	SAND, yellowish brown, very fine grained, silty in places with some clay. Some small rock fragments and angular quartz grains			"
				5		SC	Clayey SAND, brown (7.5YR4/6) with dark brown (10YR3/3) patches and some dark greenish grey (10GY4/1) mottling. Medium grained, some sand-sized rock fragments, grading rapidly to brown (7.5YR4/4) gravelly clay and gravelly sandy clay. Gravel fraction is mainly fragments of concretionary limonite, pisolotic ironstone. Some small patches of dark greenish grey (10GY3/1) and red			TERTIARY
				6						
				8						
				9						

TASMANIA DEPARTMENT OF MINES
ENGINEERING LOG — BOREHOLE

Project:	SWANSEA GROUNDWATER SUPPLY	Location:	NINE MILE BEACH

Co-ordinates: 587 656 mE, 5 339 379 mN	Drill type: Triefus	Hole commenced: 23.6.1980
RL:	Drill method: Auger pull	Hole completed: 23.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
				1		CH	CLAY, dark brown (10YR3/4) grading to brown (10YR4/4), mottled in places with bright brown (7.5YR5/8), some root fragments, charcoal and angular concretionary limonite fragments. Mottled yellowish brown(10YR5/6) and dark olive (5Y4/3) between 0.9 and 1.5 m. Some silty clay at 1.4 m, reddish brown (5YR4/6) and brown (10YR4/6)	D		LAST INTERGLACIAL ESTUARINE
				2		CL-GC	Silty CLAY, mainly brown (10YR4/6) and mottling as above, but brownish grey (10YR5/1) near 2 m, in places pebbly CLAY with prominent pebbles and nodules of concretionary calcarenite up to 50 mm			As above
				3			No recovery; probably saturated fine clayey sand			
				4		SC	Sandy CLAY, mottled greyish yellow brown (10YR5/2) and brown (10YR4/6); contains rare shell fragments			As above
							Gravelly CLAY, reddish brown (5YR4/8) with fragments, pebbles of concretionary limonite underlying dark bluish grey (10BG4/1) clay, possibly a palaeosol			TERTIARY?
				5			Hole stopped at 4.2 m			
				6						
				7						
				8						
				9						

TASMANIA DEPARTMENT OF MINES
ENGINEERING LOG — BOREHOLE

Project:	SWANSEA GROUNDWATER SUPPLY		Location:	NINE MILE BEACH

Co-ordinates: 587 628 mE, 5 339 109 mN	Drill type: Triefus	Hole commenced: 24.6.1980
RL:	Drill method: Auger pull	Hole completed: 24.6.1980
Inclination: Vertical	Drill fluid: None	Drilled by: BC
Bearing: –		Logged by: WCC

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
				1 2 3 4 5 6		CH	CLAY, mottled brown (10YR4/4) and brownish black (7.5YR3/2), stiff, plastic, minor organics in places, with occasional small reddish brown (5YR4/8) aggregated silty fragments; colour changes to brown (10YR4/4) below 0.3 m. Some small $CaCO_3$-cemented patches, nodules up to 2 mm. Slightly silty in places, with some small (2 mm) black patches (organic? or MnO_2?). Colour brightens to brown (10YR4/6) at 2.4 m and brown (10YR4/4) at 3.3 m. Some brownish-black (10YR3/1) patches and streaks, and occasional calcareous patches, at 4.2 m	M		LAST GLACIAL CLAY LUNETTE
				7		CH	CLAY, dark greyish yellow (2.5Y4/2), slightly mottled with yellowish grey (2.5Y4/1), and darkening to mottled black (7.5YR2/1) at 6.9 m. Brown (10YR4/4) at 7.8 m. Clay stiff, plastic			LAST INTERGLACIAL ESTUARINE
				8 9						

APPENDIX 2

Assessment sheets for groundwater analyses
from Nine Mile Beach, 1979

These original sheets have not been amended since they were compiled in 1979.

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 7
Lab. reg. no.	791396
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	FQ913393	Date sampled:	8/8/79	Date analysed:	3/9/79
		Sampled by: W.C.Cromer		Analysed by:	Dept. of Mines, Launceston

Sampling conditions From single spear pumped for 15 minutes at 60 litres/minute.

Landowner and address (if applicable)

Field observations

Colour	none	Odour	none	Taste	very slight

pH	Eh	Temperature (°C)	Specific conductance (µS/cm at 25° C)	600

Turbidity	Precipitates	Other

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	250	4.10	33.7
Chloride (Cl)	71	2.00	16.5
Sulphate (SO₄)	9	0.19	1.6
Silica (SiO₂)	12		
Calcium (Ca)	72	3.59	29.5
Magnesium (Mg)	6.1	0.50	4.1
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.4	0.04	0.3
Sodium (Na)	40	1.74	14.3
Total dissolved solids (TDS)	360	12.16	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	200		
Alkalinity as CaCO₃	200		
Other			

pH	7.3
Specific conductance (µS/cm at 25°C)	570
Colour	
Turbidity	
% difference in anion and cation meq/l	3.5

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		No
Date		
Lab. reg. number		

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
Very hard	more than 180

IONIC RATIOS

Ca: Mg =	7.18	Cl: total =	0.16
Na: total =	0.14	SO₄: total =	0.02
Na: Cl =	0.87	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a-b
Cl/alkalinity ratio	b	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2-C3	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	30.3	a
Sodium adsorption ratio	1.22	a
Residual sodium carbonate	0.01	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 8
Lab. reg. no.	791397
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	589847 mE 5338495 mN	Date sampled: Sampled by:	7/8/79 W.C. Cromer	Date analysed: Analysed by:	3/9/79 Dept. of Mines, Launceston

Sampling conditions From single spear pumped for 15 minutes at 45 litres/minute.

Landowner and address (if applicable)

Field observations

Colour	none	Odour	none	Taste	very slight

pH		Eh		Temperature (°C)		Specific conductance (μS/cm at 25° C)	615

Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	280	4.59	37.8
Chloride (Cl)	60	1.69	13.9
Sulphate (SO₄)	7	0.15	1.2
Silica (SiO₂)	13		
Calcium (Ca)	72	3.59	29.6
Magnesium (Mg)	7.5	0.62	5.1
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	34	1.48	12.2
Total dissolved solids (TDS)	370	12.15	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	210		
Alkalinity as CaCO₃	230		
Other			

pH	7.8
Specific conductance (μS/cm at 25°C)	570
Colour	
Turbidity	
% difference in anion and cation meq/l	5.8

Remarks   A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	No
Date	
Lab. reg. number	

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
Very hard	more than 180

IONIC RATIOS

Ca: Mg =	5.79	Cl: total =	0.14
Na: total =	0.12	SO₄: total =	0.01
Na: Cl =	0.88	SiO₂: total =	0.04

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a-b
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2-C3	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	26.4	a
Sodium adsorption ratio	1.02	a
Residual sodium carbonate	0.38	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 9
Lab. reg. no.	791399
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	588514 mE 5337595 mN	Date sampled: 7/8/79 Sampled by: W.C. Cromer	Date analysed: 3/9/79 Analysed by: Dept. of Mines, Launceston

Sampling conditions From single spear pumped for 15 minutes at 4 litres/minute

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	none

pH		Eh		Temperature (°C)		Specific conductance (µS/cm at 25° C)	390

Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	210	3.44	43.9
Chloride (Cl)	25	0.71	9.1
Sulphate (SO₄)	<5	<0.10	<1.3
Silica (SiO₂)	13		
Calcium (Ca)	55	2.74	35.0
Magnesium (Mg)	3.3	0.27	3.4
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	0.4	0.01	0.13
Sodium (Na)	13	0.57	7.3
Total dissolved solids (TDS)	250	7.84	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	150		
Alkalinity as CaCO₃	170		
Other			

pH	7.6
Specific conductance (µS/cm at 25°C)	380
Colour	
Turbidity	
% difference in anion and cation meq/l	8.4

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		No
Date		
Lab. reg. number		

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	10.15	Cl: total =	0.09
Na: total =	0.07	SO₄: total =	<0.01
Na: Cl =	0.80	SiO₂: total =	0.05

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	16.2	a
Sodium adsorption ratio	0.46	a
Residual sodium carbonate	0.43	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 10
Lab. reg. no.	791400
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	588802 mE 5338161 mN	Date sampled:	7/8/79	Date analysed:	3/9/79
		Sampled by:	W.C. Cromer	Analysed by:	Dept. of Mines Launceston

Sampling conditions From single spear pumped for 20 minutes at 53 litres/minute

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	none

pH		Eh		Temperature (°C)		Specific conductance (μS/cm at 25° C)	430

Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO$_3$)	nil		
Bicarbonate (HCO$_3$)	240	3.94	41.2
Chloride (Cl)	39	1.10	11.5
Sulphate (SO$_4$)	<5	<0.10	<1.1
Silica (SiO$_2$)	12		
Calcium (Ca)	64	3.19	33.4
Magnesium (Mg)	4.1	0.34	3.6
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	0.9	0.02	0.2
Sodium (Na)	20	0.87	9.1
Total dissolved solids (TDS)	300	9.56	
Permanent hardness as CaCO$_3$	nil		
Temporary hardness as CaCO$_3$	180		
Alkalinity as CaCO$_3$	190		
Other			
pH			7.4
Specific conductance (μS/cm at 25°C)			460
Colour			
Turbidity			
% difference in anion and cation meq/l			7.5

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	No
Date	
Lab. reg. number	

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	9.38	Cl: total =	0.12
Na: total =	0.09	SO$_4$: total =	<0.01
Na: Cl =	0.79	SiO$_2$: total =	0.04

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value		Suitability (a,b, or c)
Salinity class (C1 — C4)	C2		a-b
Sodium class (S1 — S4)	S1		a
Percent Sodium	20.1		a
Sodium adsorption ratio	0.65		a
Residual sodium carbonate	0.41		a

Remarks
A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 12
Lab. reg. no.	791401
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	588959 mE 5338692 mN	Date sampled:	7/8/79	Date analysed:	3/9/79
		Sampled by:	W.C. Cromer	Analysed by:	Dept. of Mines, Launceston

Sampling conditions From single spear, pumped for 40 minutes at 53 litres/minute

Landowner and address (if applicable)

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (μS/cm at 25° C)	625
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	270	4.43	34.4
Chloride (Cl)	76	2.14	16.6
Sulphate (SO₄)	<5	<0.10	<0.8
Silica (SiO₂)	18		
Calcium (Ca)	71	3.54	27.5
Magnesium (Mg)	7.5	0.62	4.8
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	2.4	0.06	0.5
Sodium (Na)	46	2.00	15.5
Total dissolved solids (TDS)	370	12.89	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	210		
Alkalinity as CaCO₃	220		
Other			

pH	7.6
Specific conductance (μS/cm at 25°C)	600
Colour	
Turbidity	
% difference in anion and cation meq/l	3.0

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		No
Date		
Lab. reg. number		

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	5.71	Cl: total =	0.17
Na: total =	0.16	SO₄: total =	<0.01
Na: Cl =	0.93	SiO₂: total =	0.05

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a–b	Chloride	a–b
Cl/alkalinity ratio	b	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2–C3	a–b
Sodium class (S1 — S4)	S1	a
Percent Sodium	33.1	a
Sodium adsorption ratio	1.39	a
Residual sodium carbonate	0.27	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 15
Lab. reg. no.	791402
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	588414 mE 5338422 mN	Date sampled:	9/8/79	Date analysed:	3/9/79
		Sampled by:	W.C. Cromer	Analysed by	Dept. of Mines, Launceston

Sampling conditions	From single spear	Landowner and address (if applicable)	Burbury, 'Cambria'

Field observations

Colour	slight	Odour	salty	Taste	salty
pH	Eh	Temperature (°C)		Specific conductance (μS/cm at 25° C)	12000
Turbidity	none	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	430	7.05	1.9
Chloride (Cl)	5830	164.4	43.4
Sulphate (SO₄)	870	18.1	4.8
Silica (SiO₂)	27		
Calcium (Ca)	630	31.4	8.3
Magnesium (Mg)	490	40.3	10.6
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	13	0.33	0.1
Sodium (Na)	2700	117.5	31.0
Total dissolved solids (TDS)	12180	379.1	
Permanent hardness as CaCO₃	3230		
Temporary hardness as CaCO₃	360		
Alkalinity as CaCO₃	360		
Other			

pH	7.5
Specific conductance (μS/cm at 25°C)	14700
Colour	
Turbidity	
% difference in anion and cation meq/l	0.0

Remarks

An extremely high salinity groundwater.

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	No
Date	
Lab. reg. number	

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
Very hard	more than 180

IONIC RATIOS

Ca: Mg =	0.78	Cl: total =	0.43
Na: total =	0.31	SO₄: total =	0.05
Na: Cl =	0.71	SiO₂: total =	0.002

SUITABILITY
a = no problems,   b = doubtful,   c = excessive

DOMESTIC   DRINKING

Total dissolved solids	c	pH	a
Total hardness	c	Iron	a
Chloride	c	Sulphate	c
Sodium	c	Magnesium	c
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	c	Chloride	c
Cl/alkalinity ratio	a	pH	a

AGRICULTURAL   USE

	Value		Suitability (a,b, or c)
Salinity class (C1 — C4)	C5		c
Sodium class (S1 — S4)	S4		c
Percent Sodium	62.2		c
Sodium adsorption ratio	19.62		c
Residual sodium carbonate	0		a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 16
Lab. reg. no.	791403
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	589515 mE 5338855 mN	Date sampled:	8/8/79	Date analysed:	3/9/79
		Sampled by:	W.C. Cromer	Analysed by:	Dept. of Mines, Launceston

Sampling conditions From single spear pumped for 45 minutes at 68 litres/minute

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (µS/cm at 25° C)	570
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	280	4.59	37.2
Chloride (Cl)	58	1.64	13.3
Sulphate (SO₄)	<5	<0.10	<0.8
Silica (SiO₂)	14		
Calcium (Ca)	73	3.64	29.5
Magnesium (Mg)	7.0	0.58	4.7
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.6	0.04	0.3
Sodium (Na)	40	1.74	14.1
Total dissolved solids (TDS)	360	12.33	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	210		
Alkalinity as CaCO₃	230		
Other			

pH	7.5
Specific conductance (µS/cm at 25°C)	500
Colour	
Turbidity	
% difference in anion and cation meq/l	2.7

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	No
Date	
Lab. reg. number	

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	6.28	Cl: total =	0.13
Na: total =	0.14	SO₄: total =	<0.01
Na: Cl =	1.06	SiO₂: total =	0.04

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a-b
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2-C3	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	29.7	a
Sodium adsorption ratio	1.20	a
Residual sodium carbonate	0.37	a

Remarks

A medium-salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard but suitable for drinking and all agricultural uses.

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	hole 17
Lab. reg. no.	791404
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	FP902382	Date sampled:	8/8/79	Date analysed:	3/9/79
		Sampled by:	W.C. Cromer	Analysed by:	Dept. of Mines, Launceston

Sampling conditions From single spear pumped for 10 minutes at 55 litres/minute

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (μS/cm at 25° C)	500
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO_3)	nil		
Bicarbonate (HCO_3)	250	4.10	40.8
Chloride (Cl)	39	1.10	11.0
Sulphate (SO_4)	<5	<0.10	<1.0
Silica (SiO_2)	13		
Calcium (Ca)	67	3.34	33.3
Magnesium (Mg)	5.0	0.41	4.1
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	22	0.96	9.5
Total dissolved solids (TDS)	320	10.04	
Permanent hardness as $CaCO_3$	nil		
Temporary hardness as $CaCO_3$	190		
Alkalinity as $CaCO_3$	200		
Other			

pH	7.6
Specific conductance (μS/cm at 25°C)	490
Colour	
Turbidity	
% difference in anion and cation meq/l	5.6

Remarks A medium-salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		No
Date		
Lab. reg. number		

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	8.15	Cl: total =	0.11
Na: total =	0.10	SO_4: total =	<0.01
Na: Cl =	0.87	SiO_2: total =	0.04

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a–b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a–b
Sodium class (S1 — S4)	S1	a
Percent Sodium	20.9	a
Sodium adsorption ratio	0.70	a
Residual sodium carbonate	0.35	a

Field No.	hole 18
Lab. reg. no.	791405
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater		Location	Nine Mile Beach

Co-ordinates	589089 mE 5338410 mN	Date sampled:	9/8/79	Date analysed:	3/9/79
		Sampled by:	W.C. Cromer	Analysed by:	Dept. of Mines, Launceston

Sampling conditions From single spear pumped for 60 minutes at 70 litres/minute

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (µS/cm at 25° C)	620
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	280	4.59	35.6
Chloride (Cl)	74	2.09	16.2
Sulphate (SO₄)	6	0.12	0.9
Silica (SiO₂)	12		
Calcium (Ca)	76	3.79	29.4
Magnesium (Mg)	5.9	0.48	3.7
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.1	0.03	0.2
Sodium (Na)	41	1.78	13.8
Total dissolved solids (TDS)	410	12.88	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	210		
Alkalinity as CaCO₃	230		
Other			

pH	7.6
Specific conductance (µS/cm at 25°C)	620
Colour	
Turbidity	
% difference in anion and cation meq/l	5.6

Remarks

    A medium-salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		No
Date		
Lab. reg. number		

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	7.90	Cl: total =	0.16
Na: total =	0.14	SO₄: total =	0.06
Na: Cl =	0.85	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a-b
Cl/alkalinity ratio	b	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2-C3	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	29.8	a
Sodium adsorption ratio	1.22	a
Residual sodium carbonate	0.32	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24-spear array
Lab. reg. no.	792316
Surface sample?	
Groundwater sample?	Yes

Project	Swansea Groundwater	Location	Nine Mile Beach

Co-ordinates	FP895387	Date sampled:	15/10/79	Date analysed:	12/11/79
		Sampled by:	D.J. Sloane	Analysed by:	Dept. of Mines, Launceston

Sampling conditions 21 day pump test on 24 spears pumping simultaneously at 818 m³/day, 25 mins. after pump started

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight

pH		Eh		Temperature (°C)		Specific conductance (µS/cm at 25° C)	440

Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	240	3.94	37.2
Chloride (Cl)	47	1.33	12.6
Sulphate (SO₄)	<5	<0.10	<0.9
Silica (SiO₂)	11		
Calcium (Ca)	73	3.64	34.3
Magnesium (Mg)	5.2	0.43	4.1
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	26	1.13	10.7
Total dissolved solids (TDS)	340	10.60	
Permanent hardness as CaCO₃	10		
Temporary hardness as CaCO₃	190		
Alkalinity as CaCO₃	190		
Other			

pH	6.8
Specific conductance (µS/cm at 25°C)	500
Colour	
Turbidity	
% difference in anion and cation meq/l	1.3

Remarks A medium-salinity near-neutral groundwater, mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		Yes
Date		29/10/79
Lab. reg. number		–

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	8.47	Cl: total =	0.13
Na: total =	0.11	SO₄: total =	<0.01
Na: Cl =	0.85	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a–b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a–b
Sodium class (S1 —S4)	S1	a
Percent Sodium	22.2	a
Sodium adsorption ratio	0.79	a
Residual sodium carbonate	0	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24-spear array
Lab. reg. no.	792317
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	FP895387	Date sampled:	16/10/79
		Sampled by:	D.J.Sloane
		Date analysed:	12/11/79
		Analysed by:	Dept. of Mines, Launceston

Sampling conditions 21 day pump test on 24 spears pumping simultaneously at 818 m^3/day, 25 hours after pumping started

Landowner and address (if applicable)

Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (μS/cm at 25° C)	460
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO$_3$)	nil		
Bicarbonate (HCO$_3$)	240	3.94	38.3
Chloride (Cl)	47	1.33	12.9
Sulphate (SO$_4$)	<5	<0.10	<1.0
Silica (SiO$_2$)	11		
Calcium (Ca)	67	3.34	32.4
Magnesium (Mg)	5.2	0.43	4.2
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	26	1.13	11.0
Total dissolved solids (TDS)	330	10.30	
Permanent hardness as CaCO$_3$	nil		
Temporary hardness as CaCO$_3$	190		
Alkalinity as CaCO$_3$	200		
Other			

pH	6.9
Specific conductance (μS/cm at 25°C)	510
Colour	
Turbidity	
% difference in anion and cation meq/l	4.3

Remarks A medium salinity near-neutral groundwater, mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	Yes
Date	29/10/79
Lab. reg. number	–

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0—60 mg/l
Moderately Hard	61—120
Hard	121—180
Very hard	more than 180

IONIC RATIOS

Ca: Mg =	7.77	Cl: total =	0.13
Na: total =	0.11	SO$_4$: total =	<0.01
Na: Cl =	0.85	SiO$_2$: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1—C4)	C2	a-b
Sodium class (S1—S4)	S1	a
Percent Sodium	23.5	a
Sodium adsorption ratio	0.82	a
Residual sodium carbonate	0.17	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24-spear array
Lab. reg. no.	792318
Surface sample?	
Groundwater sample?	Yes

Project	Swansea Groundwater	Location	Nine Mile Beach

Co-ordinates	FP895387	Date sampled:	18/10/79	Date analysed:	12/11/79
		Sampled by:	D.J. Sloane	Analysed by:	Dept. of Mines, Launceston

Sampling conditions 21 day pump test on 24 spears pumping simultaneously at 818 m³/day, 71 hours after pumping started

Landowner and address (if applicable)

Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (µS/cm at 25° C)	462
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	250	4.10	38.1
Chloride (Cl)	47	1.33	12.4
Sulphate (SO₄)	<5	<0.10	<0.9
Silica (SiO₂)	11		
Calcium (Ca)	73	3.64	33.8
Magnesium (Mg)	5.2	0.43	4.0
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	26	1.13	10.5
Total dissolved solids (TDS)	350	10.76	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	200		
Alkalinity as CaCO₃	210		
Other			

pH	7.0
Specific conductance (µS/cm at 25°C)	510
Colour	
Turbidity	
% difference in anion and cation meq/l	2.8

Remarks A medium salinity near-neutral ground-water mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		Yes
Date		29/10/79
Lab. reg. number		–

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	8.47	Cl: total =	0.12
Na: total =	0.11	SO₄: total =	<0.01
Na: Cl =	0.85	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	22.2	a
Sodium adsorption ratio	0.79	a
Residual sodium carbonate	0.03	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24-spear array
Lab. reg. no.	792319
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates FP895387	Date sampled: 21/10/79		Date analysed: 12/11/79
	Sampled by: D.J. Sloane		Analysed by: Dept. of Mines, Launceston

Sampling conditions 21 day pump test on 24 spears pumping simultaneously at 818 m^3/day, 6 days 6 hours after pumping started.

Landowner and address (if applicable)
Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste very slight
pH	Eh	Temperature (°C)		Specific conductance (μS/cm at 25° C) 465
Turbidity	clear	Precipitates		Other

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	250	4.10	39.8
Chloride (Cl)	47	1.33	12.9
Sulphate (SO₄)	<5	<0.10	<0.9
Silica (SiO₂)	11		
Calcium (Ca)	63	3.14	30.5
Magnesium (Mg)	5.4	0.44	4.3
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	27	1.17	11.4
Total dissolved solids (TDS)	340	10.31	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	180		
Alkalinity as CaCO₃	210		
Other			

pH	7.0
Specific conductance (μS/cm at 25°C)	520
Colour	
Turbidity	
% difference in anion and cation meq/l	7.3

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	Yes
Date	29/10/79
Lab. reg. number	

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	7.14	Cl: total =	0.13
Na: total =	0.11	SO₄: total =	<0.01
Na: Cl =	0.88	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	25.1	a
Sodium adsorption ratio	0.87	a
Residual sodium carbonate	0.52	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24-spear array
Lab. reg. no.	792320
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	FP895387	Date sampled:	25/10/79	Date analysed:	12/11/79
		Sampled by:	D.J. Sloane	Analysed by:	Dept. of Mines, Launceston

Sampling conditions 21 day pump test on 24 spears pumping simultaneously at 818 m³/day, 10 days after pumping started.

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (μS/cm at 25° C)	460
Turbidity	none	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	260	4.26	39.4
Chloride (Cl)	47	1.33	12.3
Sulphate (SO₄)	<5	<0.10	<0.9
Silica (SiO₂)	11		
Calcium (Ca)	70	3.49	32.3
Magnesium (Mg)	5.4	0.44	4.1
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	27	1.17	10.8
Total dissolved solids (TDS)	350	10.82	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	200		
Alkalinity as CaCO₃	210		
Other			

pH	7.0
Specific conductance (μS/cm at 25°C)	510
Colour	
Turbidity	
% difference in anion and cation meq/l	5.2

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		Yes
Date		29/10/79
Lab. reg. number		—

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	7.93	Cl: total =	0.12
Na: total =	0.11	SO₄: total =	<0.01
Na: Cl =	0.88	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	23.4	a
Sodium adsorption ratio	0.83	a
Residual sodium carbonate	0.33	a

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24 spear array
Lab. reg. no.	792321
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	FP895387	Date sampled:	28/10/79	Date analysed:	12/11/79
		Sampled by:	D.J. Sloane	Analysed by:	Dept. of Mines, Launceston

Sampling conditions 21 day pump test, 24 spears pumping simultaneously at 818 m³/day, 13 days after pumping started

Landowner and address (if applicable) Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (µS/cm at 25° C)	
Turbidity	clear	Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	260	4.26	39.0
Chloride (Cl)	49	1.38	12.6
Sulphate (SO₄)	<5	<0.10	<0.9
Silica (SiO₂)	11		
Calcium (Ca)	70	3.49	32.0
Magnesium (Mg)	5.4	0.44	4.0
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.0	0.03	0.3
Sodium (Na)	28	1.22	11.2
Total dissolved solids (TDS)	370	10.92	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	200		
Alkalinity as CaCO₃	220		
Other			

pH	7.4
Specific conductance (µS/cm at 25°C)	510
Colour	
Turbidity	
% difference in anion and cation meq/l	5.1

Previous chemical analysis available?	No
Date	
Lab. ref. number	
Bacteriological analysis available?	Yes
Date	29/10/79
Lab. reg. number	—

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	7.93	Cl: total =	0.13
Na: total =	0.11	SO₄: total =	<0.01
Na: Cl =	0.88	SiO₂: total =	0.03

SUITABILITY
a = no problems, b = doubtful, c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value	Suitability (a,b, or c)
Salinity class (C1 — C4)	C2	a-b
Sodium class (S1 — S4)	S1	a
Percent Sodium	24.1	a
Sodium adsorption ratio	0.87	a
Residual sodium carbonate	0.33	a

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

TASMANIAN DEPARTMENT OF MINES

WATER ANALYSIS

Field No.	24-spear array
Lab. reg. no.	792322
Surface sample?	
Groundwater sample?	Yes

Project	Swansea groundwater	Location	Nine Mile Beach

Co-ordinates	FP895387	Date sampled:	4/11/79	Date analysed:	12/11/79
		Sampled by:	D.J. Sloane	Analysed by:	Dept. of Mines, Launceston

Sampling conditions 21 days pump test on 24 spears pumping simultaneously at 818 m³/day, 21 days after pumping started

Landowner and address (if applicable)
Burbury, 'Cambria'

Field observations

Colour	none	Odour	none	Taste	very slight
pH	Eh	Temperature (°C)		Specific conductance (µS/cm at 25° C)	
Turbidity		Precipitates		Other	

LABORATORY ANALYSIS

	mg/l	meq/l	% meq/l
Carbonate (CO₃)	nil		
Bicarbonate (HCO₃)	260	4.26	39.2
Chloride (Cl)	49	1.38	12.7
Sulphate (SO₄)	<5	<0.10	<0.9
Silica (SiO₂)	11		
Calcium (Ca)	68	3.39	31.2
Magnesium (Mg)	5.6	0.46	4.2
Iron in solution (Fe)	<0.1		
Aluminium (Al)	<0.2		
Potassium (K)	1.1	0.03	0.3
Sodium (Na)	29	1.26	11.6
Total dissolved solids (TDS)	340	10.88	
Permanent hardness as CaCO₃	nil		
Temporary hardness as CaCO₃	190		
Alkalinity as CaCO₃	210		
Other			

pH	7.1
Specific conductance (µS/cm at 25°C)	530
Colour	
Turbidity	
% difference in anion and cation meq/l	5.5

Remarks A medium salinity near-neutral groundwater mainly of the calcium bicarbonate type (with subordinate sodium chloride), very hard, but suitable for drinking and all agricultural uses.

Previous chemical analysis available?		No
Date		
Lab. ref. number		
Bacteriological analysis available?		Yes
Date		29/10/79
Lab. reg. number		—

HARDNESS SCALE
(Total hardness as Calcium Carbonate)

Soft	0 — 60 mg/l
Moderately Hard	61 — 120
Hard	121 — 180
(Very hard)	more than 180

IONIC RATIOS

Ca: Mg =	7.37	Cl: total =	0.13
Na: total =	0.12	SO₄: total =	<0.01
Na: Cl =	0.91	SiO₂: total =	0.03

SUITABILITY
a = no problems,   b = doubtful,   c = excessive

DOMESTIC DRINKING

Total dissolved solids	a	pH	a
Total hardness	c	Iron	a
Chloride	a	Sulphate	a
Sodium	a	Magnesium	a
Colour	a		

DOMESTIC HOT WATER CYLINDER

Total dissolved solids	a-b	Chloride	a
Cl/alkalinity ratio	c	pH	a

AGRICULTURAL USE

	Value		Suitability (a,b, or c)
Salinity class (C1 — C4)	C2		a-b
Sodium class (S1 — S4)	S1		a
Percent Sodium	25.1		a
Sodium adsorption ratio	0.91		a
Residual sodium carbonate	0.41		a