
North Stradbroke Island
The Hydrology & Ecology
Leon Leach, Glenn McGregor and John Ruffini
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Some Island Metrics

Length	41km
Max Width	10.5km
Max Height	220m
Area	$240km^2$

Some Island Metrics

Total Volume of Sand	24,817,433,000m^3
Total Volume of Saturated Sand	12,786,300,000m^3
Total Volume of Fresh Water(June 2007)	2,812,000,000m^3
Total Volume of Fresh Water above mean sea level (June 2007)	757,705,000m^3

Some Island Metrics

Volume of water as average Annual rainfall	$377{,}776{,}000 m^3$
Volume of water as average annual recharge	$138{,}000{,}000 m^3$

Conceptualization Water Assessment

Water Assessment of North Stradbroke Island requires a common understanding of :

- the physical geometry of the island
- the hydrology of the island
- the total water balance
- knowledge gaps
- other

Conceptualization Water Assessment

Water Assessment of North Stradbroke Island also requires an understanding of :

- The management questions being asked, by whom and in what context (hypothetical , historical or actual)
  - Hydrology water budget, impacts , water grid optimisation
  - Ecology Groundwater dependent systems
  - Finance Water supply optimisation and total cost of delivery
  - Social and cultural values

Conceptualization Water Assessment

Water Assessment of North Stradbroke Island also requires the implementation of practical :

- Adaptive management
- Setting of performance indicators
- Monitoring
- Reporting
- Continuous improvement and

Conceptualization Water Assessment

Water Assessment of North Stradbroke Island also requires an understanding of :

- The management questions being asked and in what context (cont)
  - Spatial at what scale
  - Temporal time frames immediate, short , medium long term
  - Are impacts permanent or intermittent

Conceptualization Water Assessment

Water Assessment of North Stradbroke Island also requires :

- Good quality data
  - spatial and
  - temporal
- Tools for assessment
- Acceptance by the community

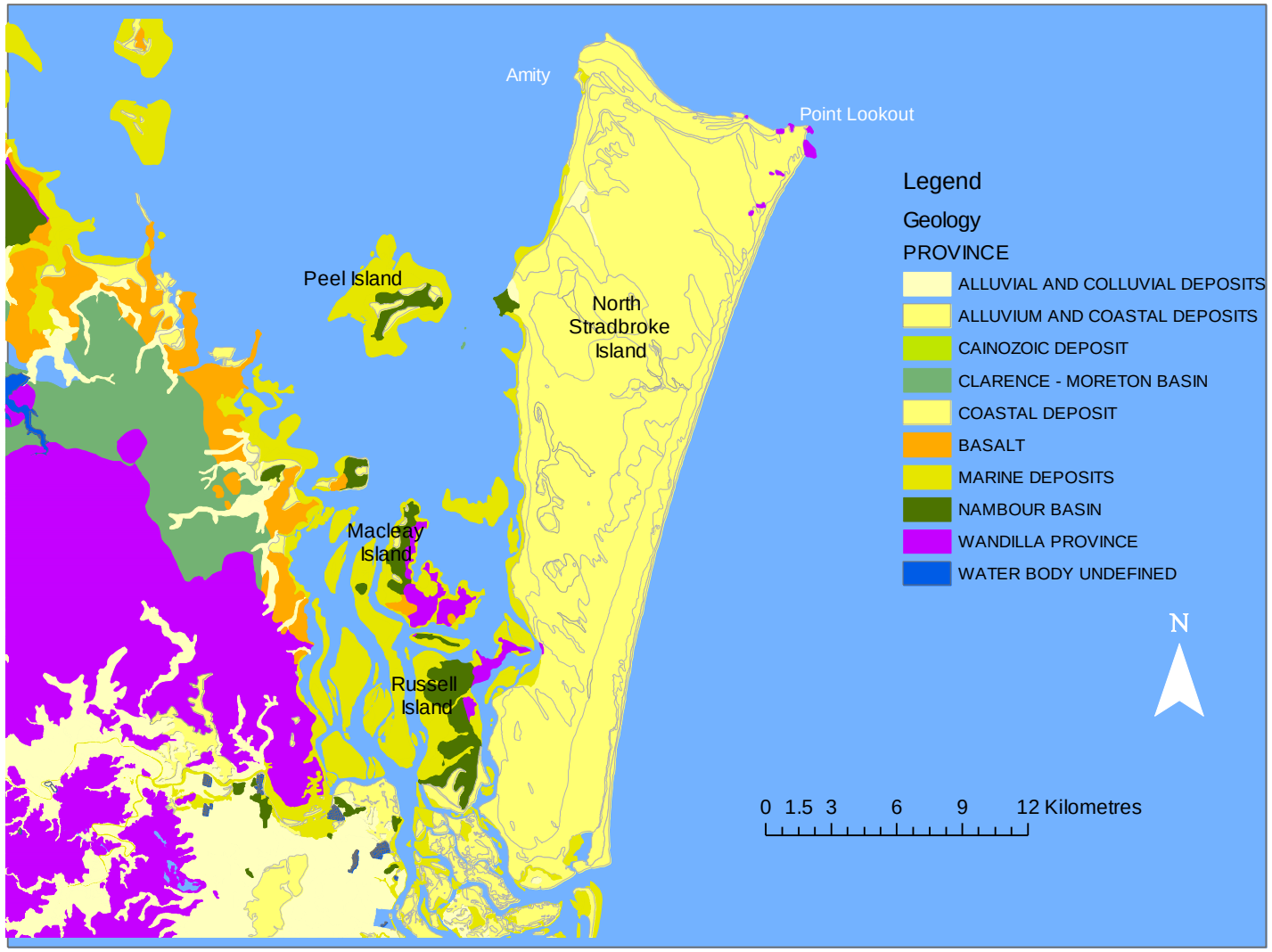
RE


North Stradbroke Island
Macleay Island
Russell Island
South Stradbroke Island


Amity
Point Lookout
North Stradbroke Island
Brown Lake
Key Holes
Dunwich
Peel Island
Blue Lake
Macleay Island
Russell Island
N
0 1.5 3 6 9 12 Kilometers

NS[illegible]

Geology


Amity
Point Lookout
Peel Island
North Stradbroke Island
Macleay Island
Russell Island
Legend
Geology
PROVINCE
ALLUVIAL AND COLLUVIAL DEPOSITS
ALLUVIUM AND COASTAL DEPOSITS
CAINOZOIC DEPOSIT
CLARENCE - MORETON BASIN
COASTAL DEPOSIT
BASALT
MARINE DEPOSITS
NAMBOUR BASIN
WANDILLA PROVINCE
WATER BODY UNDEFINED
N
0 1.5 3 6 9 12 Kilometres

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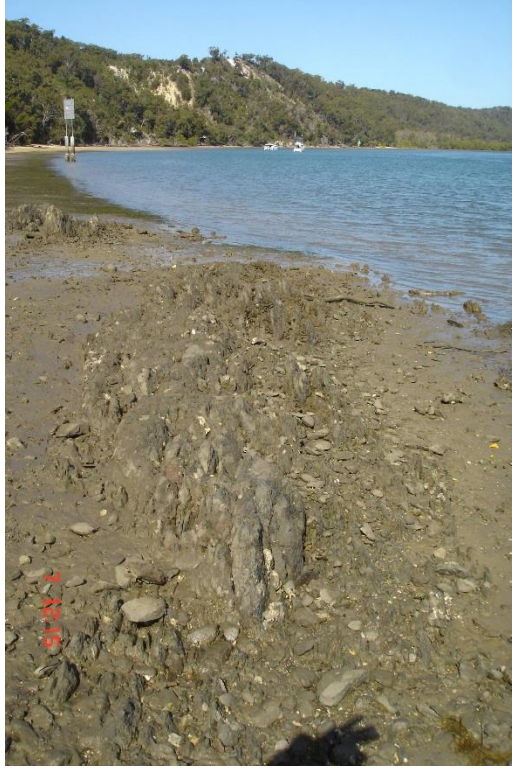


Palaeozoic Greenstone near Canaipa Point

Woogaroo

Woogaroo Sandstone at Dunwich

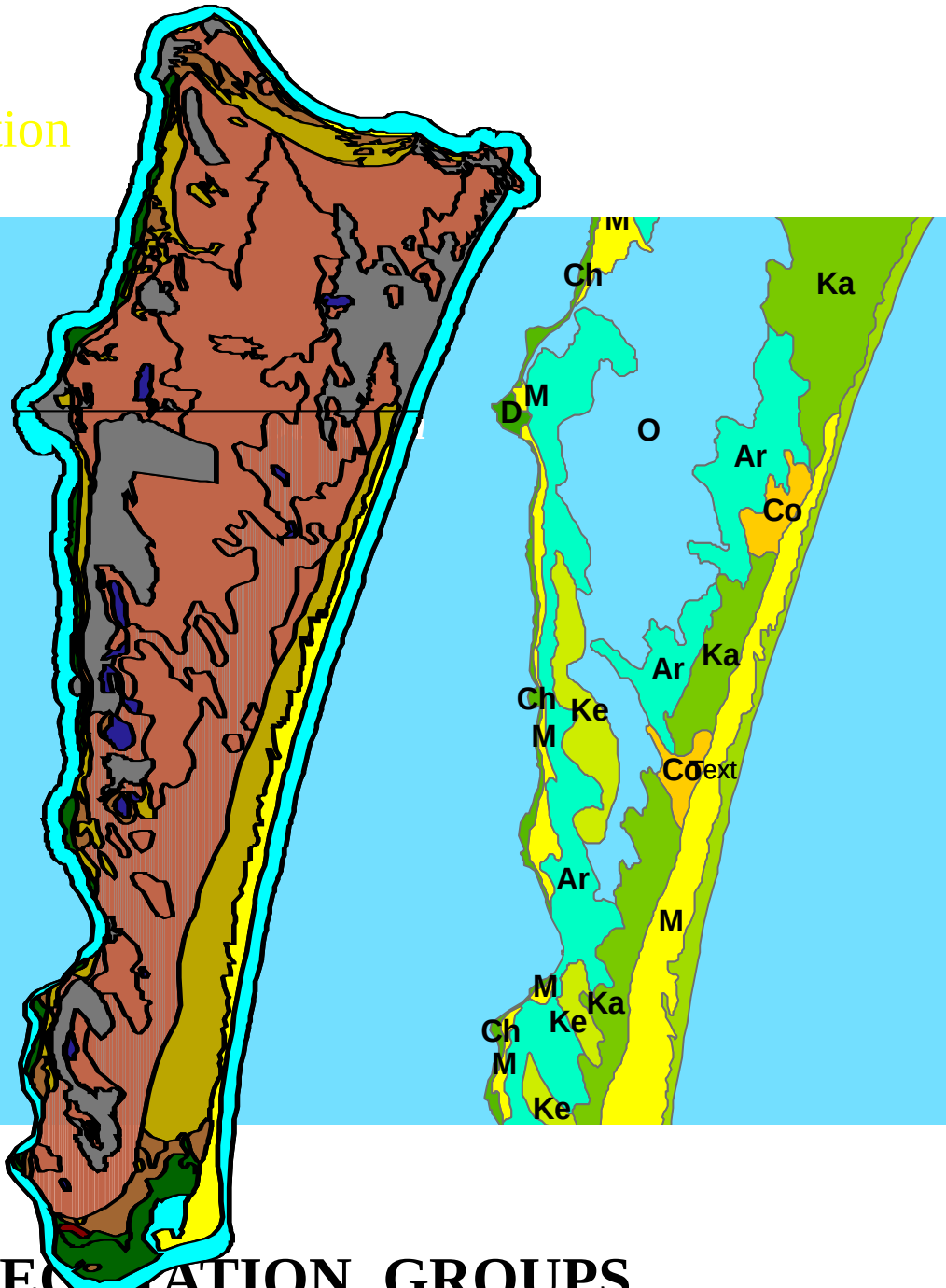
Po

Rhyolite

No[illegible]

- Consists mostly of wind blown fine sand
- Has some some localized areas of peat and alluvial deposits.
- Has some areas of sandstones,rhyolite and greenstone.

Vegetation



North Stradbroke Island
SOILS MAP

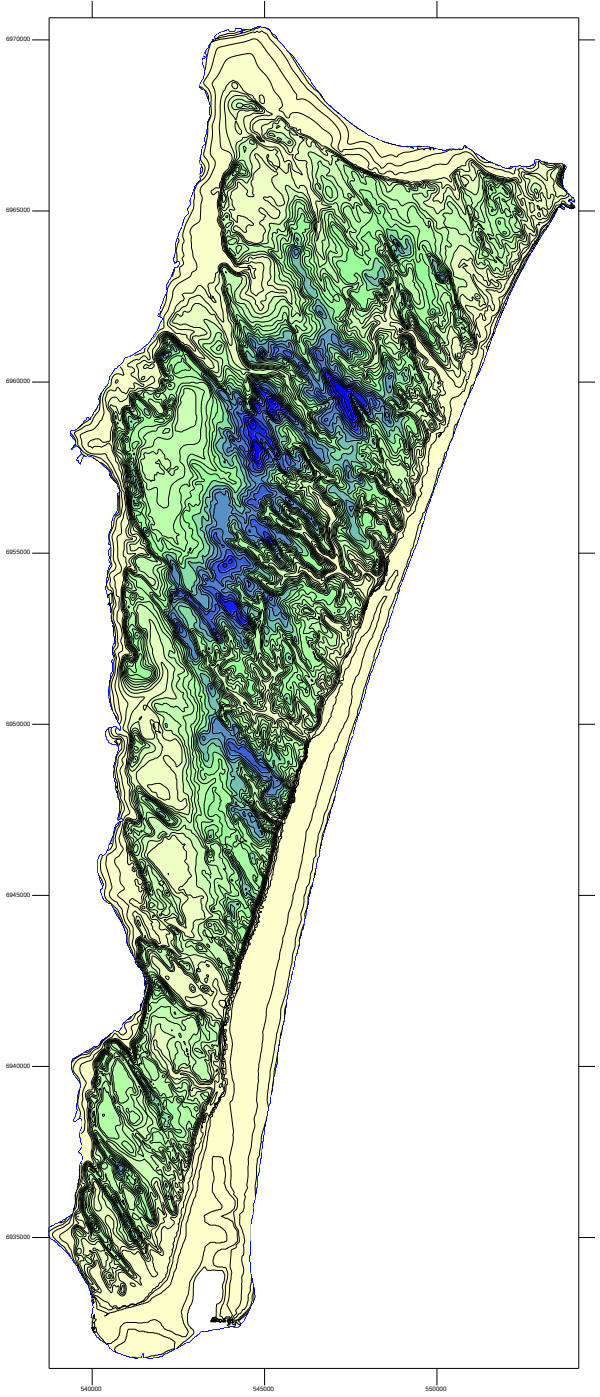
CSIRO Division of Soils
1966 — 1974
Soil Surveyor C.H. Thompson

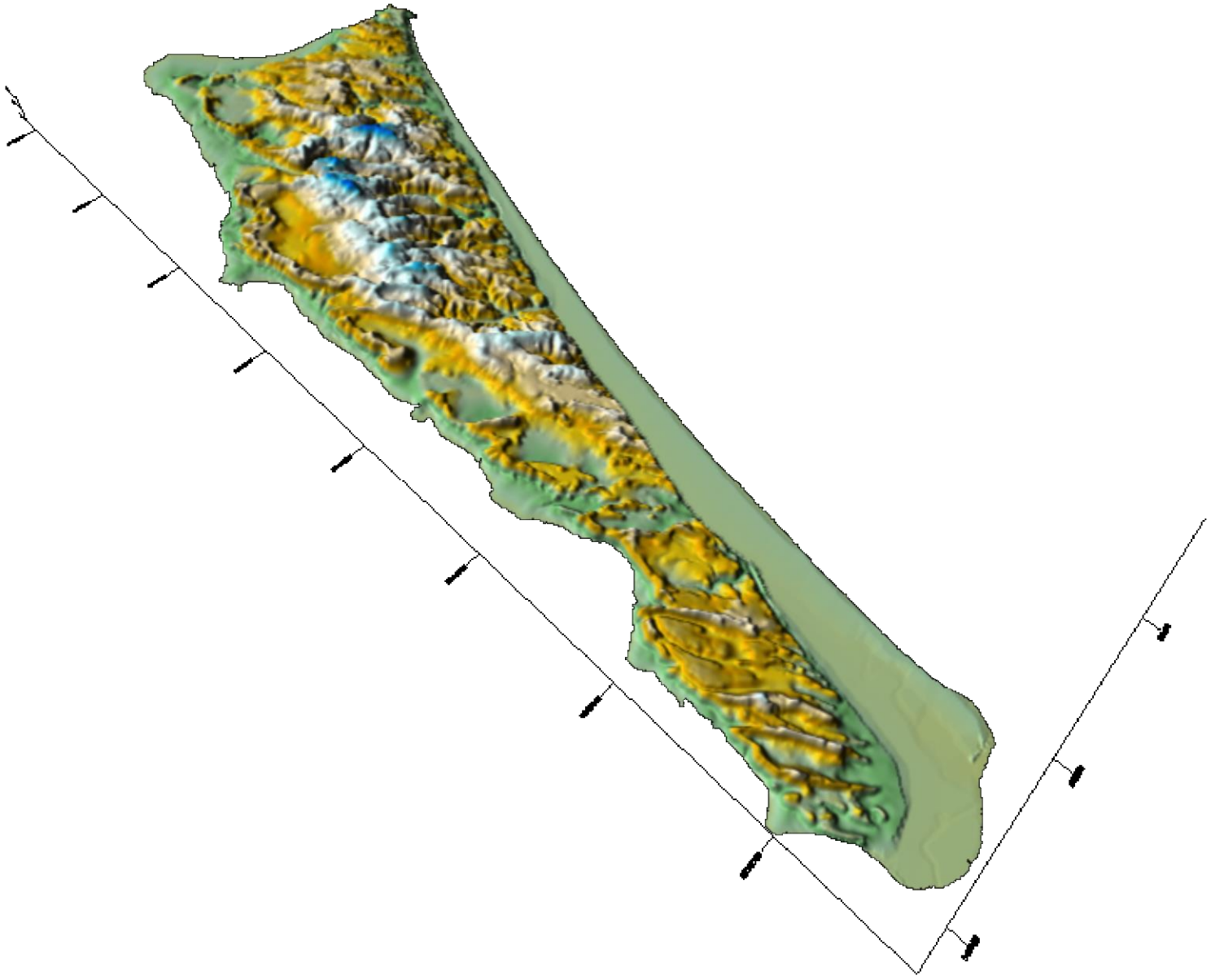
Legend

NSI_Soil_Landscape
SYMBOL

- AMITY
- ARAWOOLUM
- CHIGGIL
- CORRIE
- DUNWICH
- JUMPINPIN
- KOUREYABBA
- KOUNPEE
- MINJERRIBA

NSI VEGETATION GROUPS





Surface Elevations


7 11:39

pe

pe

pe

NSI landscapes

Blue Lake

pe

NSI landscape Perched Lakes

pe

NSI landscape Brown Lake a Perched Lake

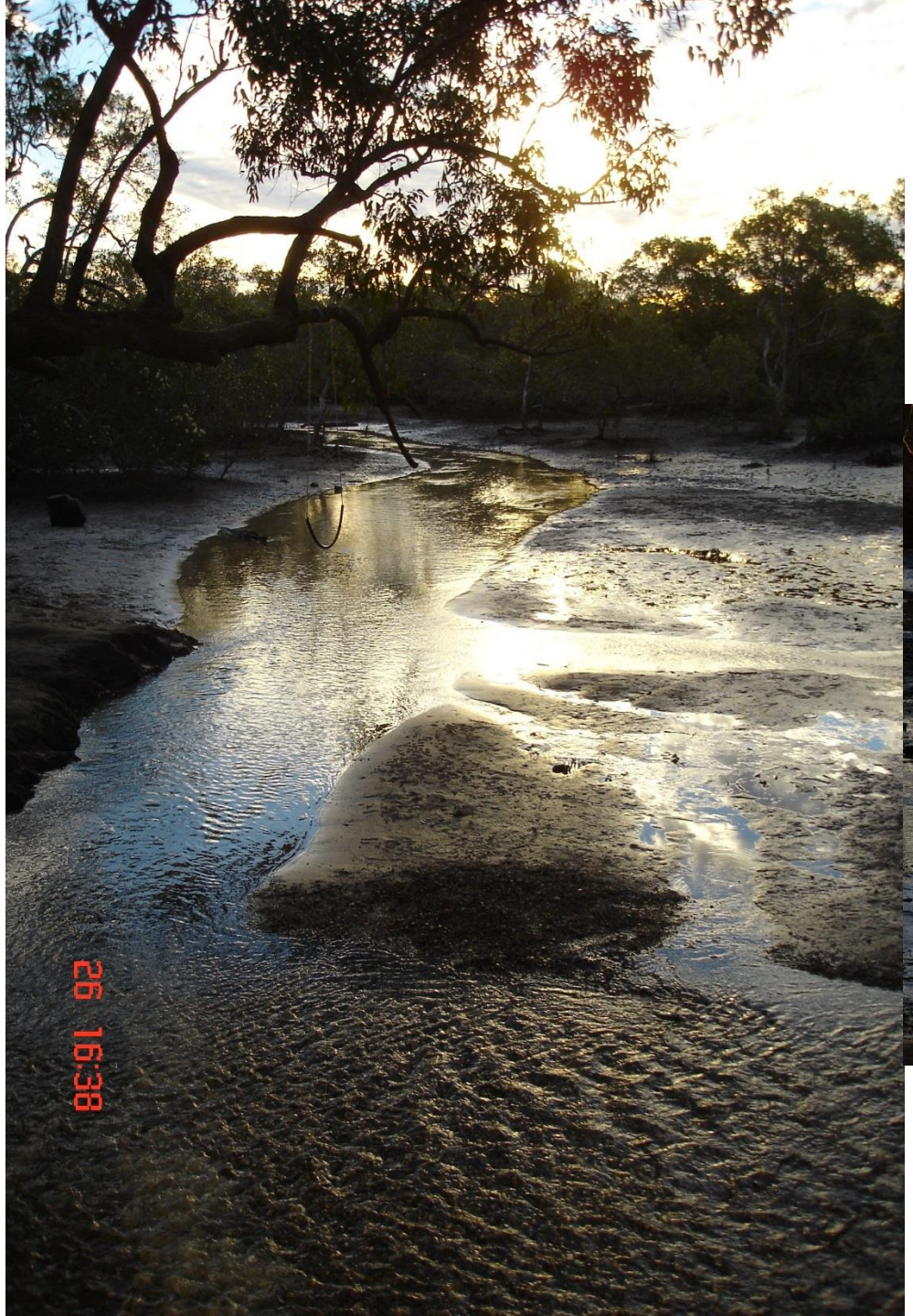
pe

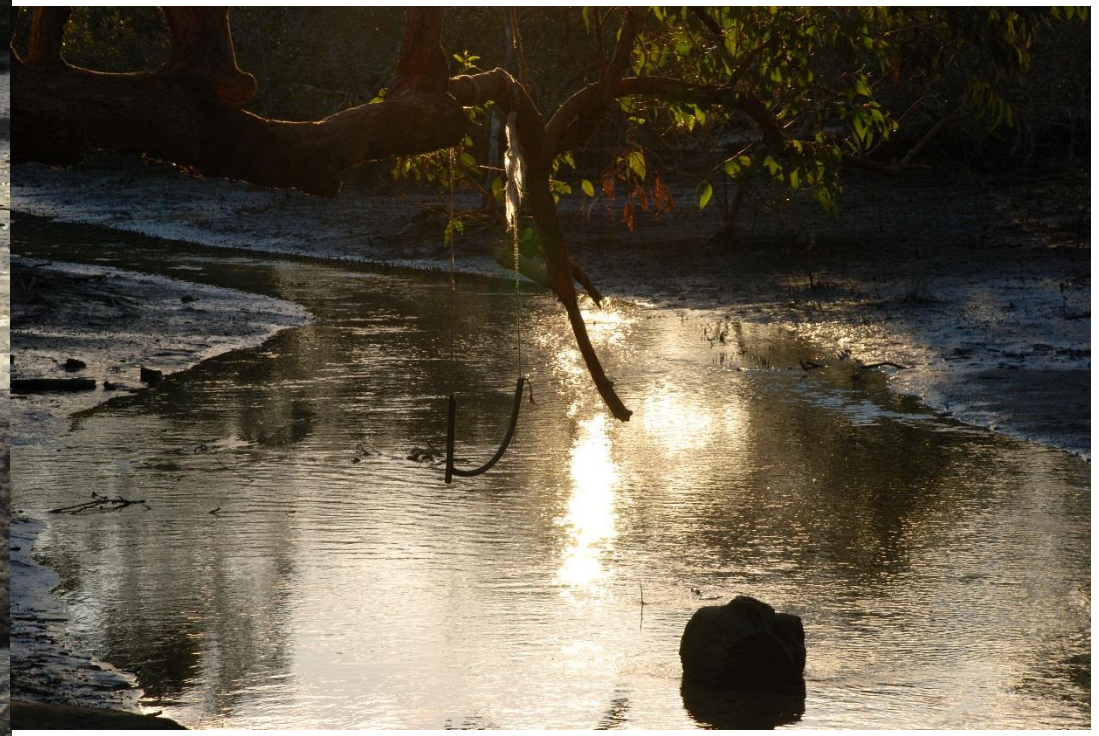
Brown Lake

GE

Myora at High Tide

GE





Myora at low tide

GE

NSI drainage Blue Lake Overflow

GE

NSI coastal discharge

GE

NSI coastal discharge

GE

NSI coastal discharge

GE

NSI coastal discharge at low tide

GE

NSI discharge Man Made Features the Key Hole

de

NSI is there any discharge High Tide?

de

NSI discharge Low Tide

ace

NSI the Sub Surface? finding the depth of sand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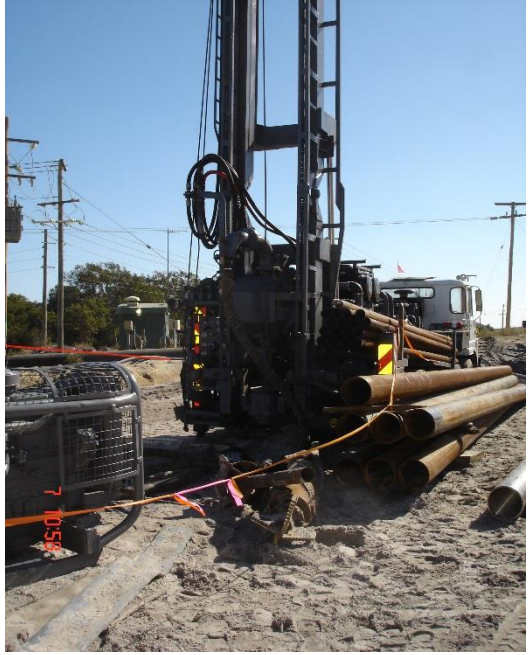


NG

NSI Drilling

NG

NSI Drilling

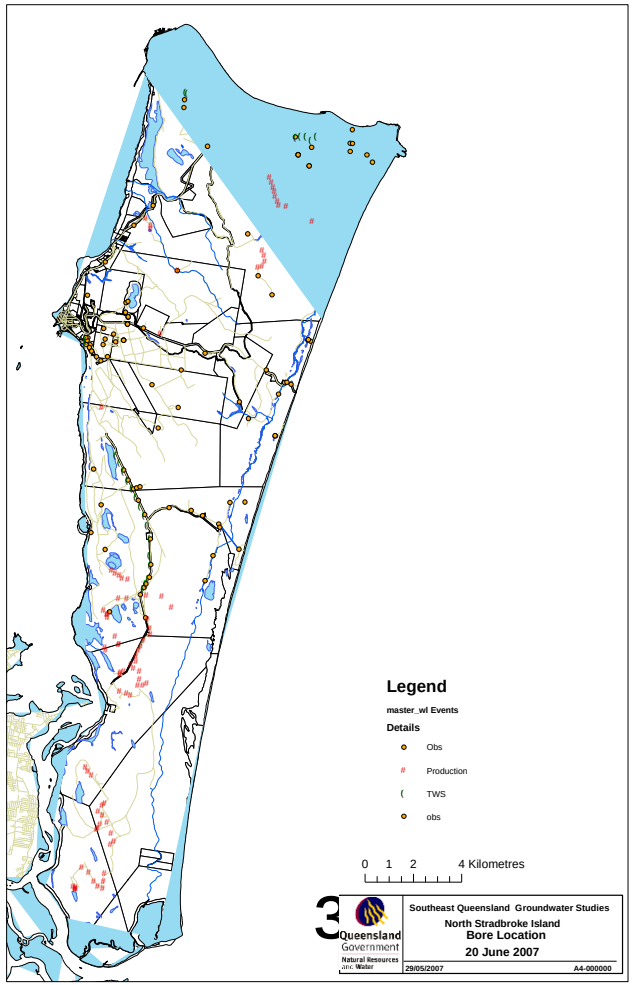
NG

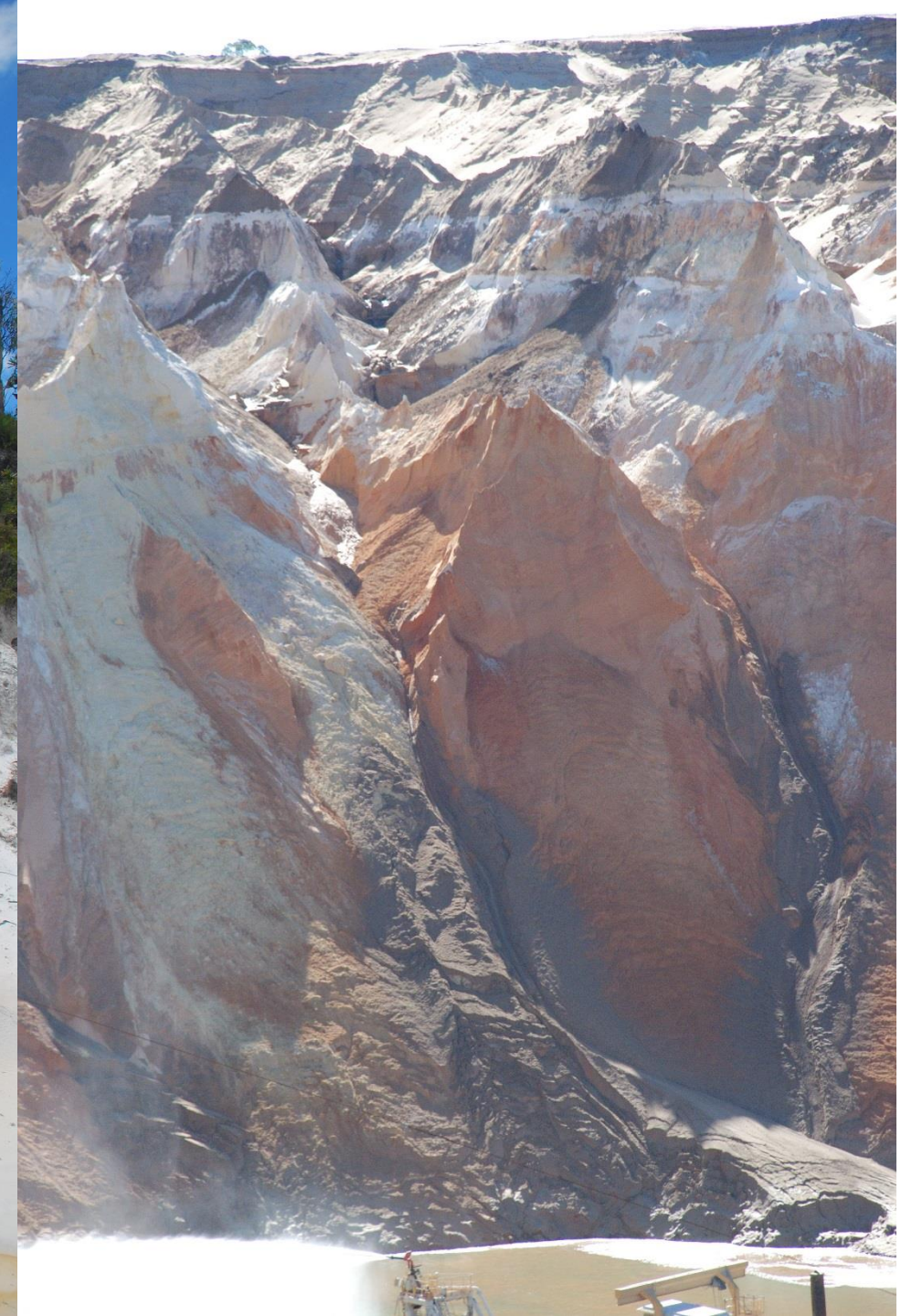
NSI Drilling

NG

NSI Drilling Samples from drilling

New Bore Locations





Bedrock Contours

- Bedrock was assessed from 603 bores or exploration holes
- Areas of bedrock out crop.
- Hand drawn contours where fluvial drainage was imposed.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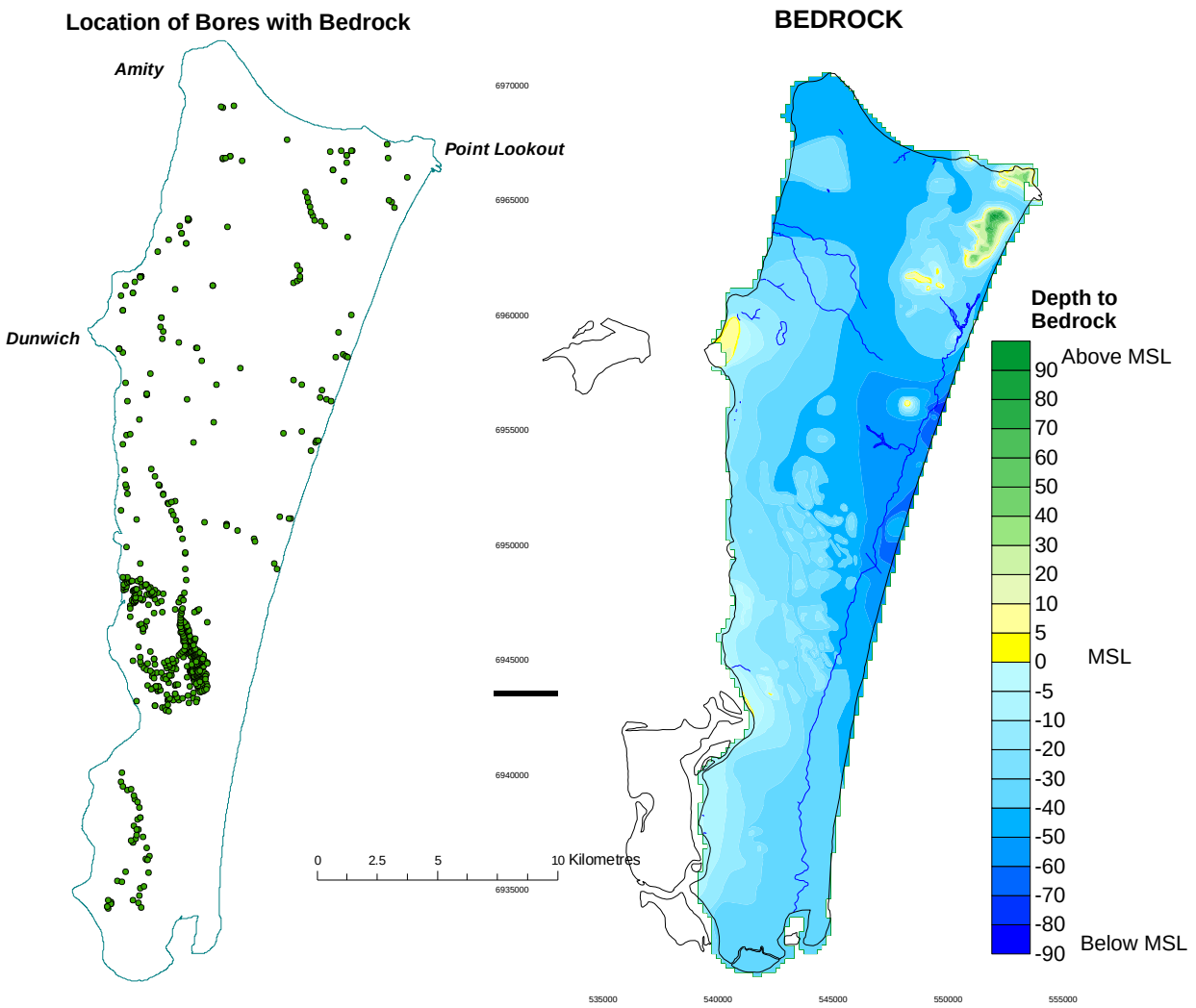
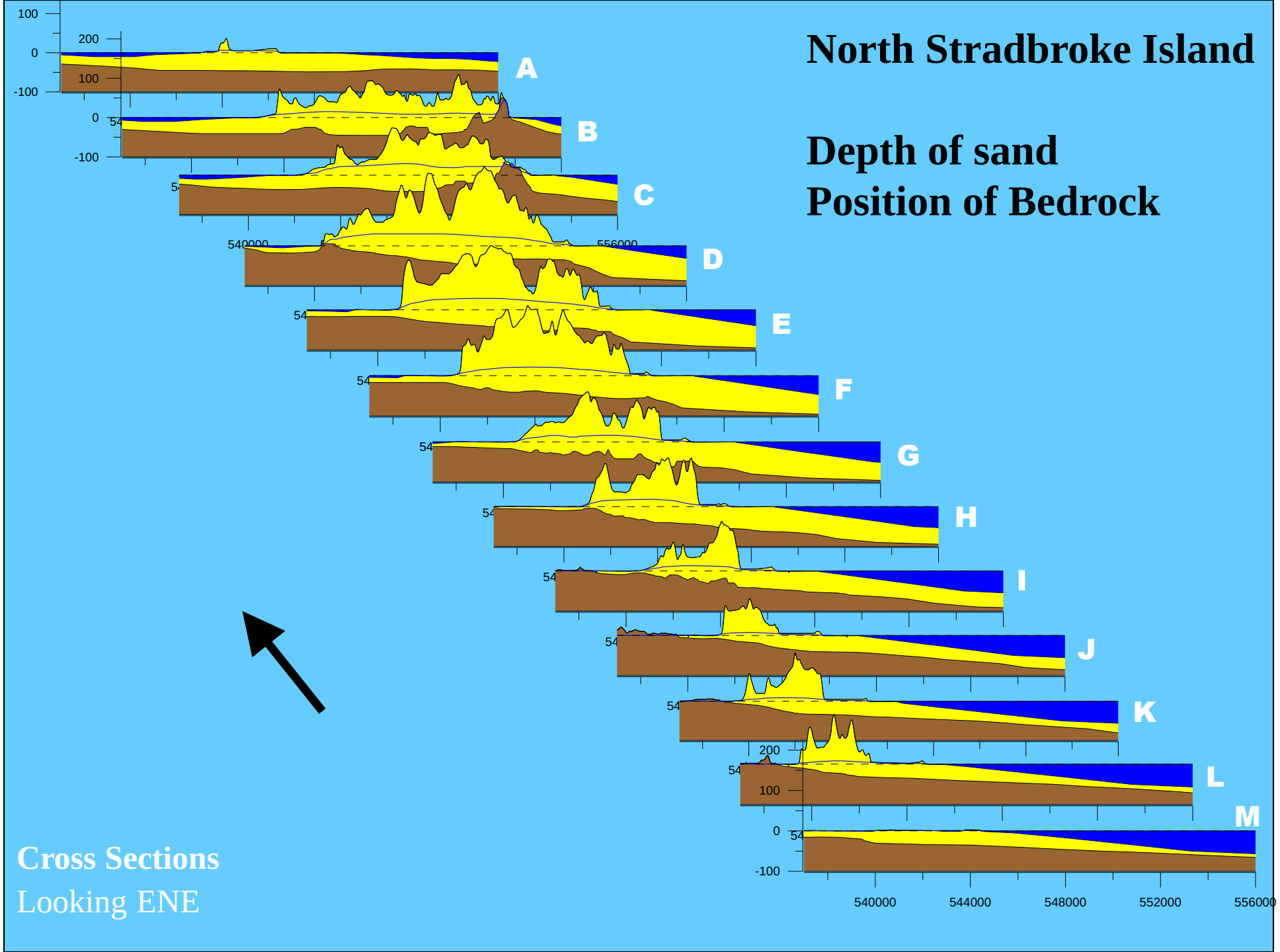
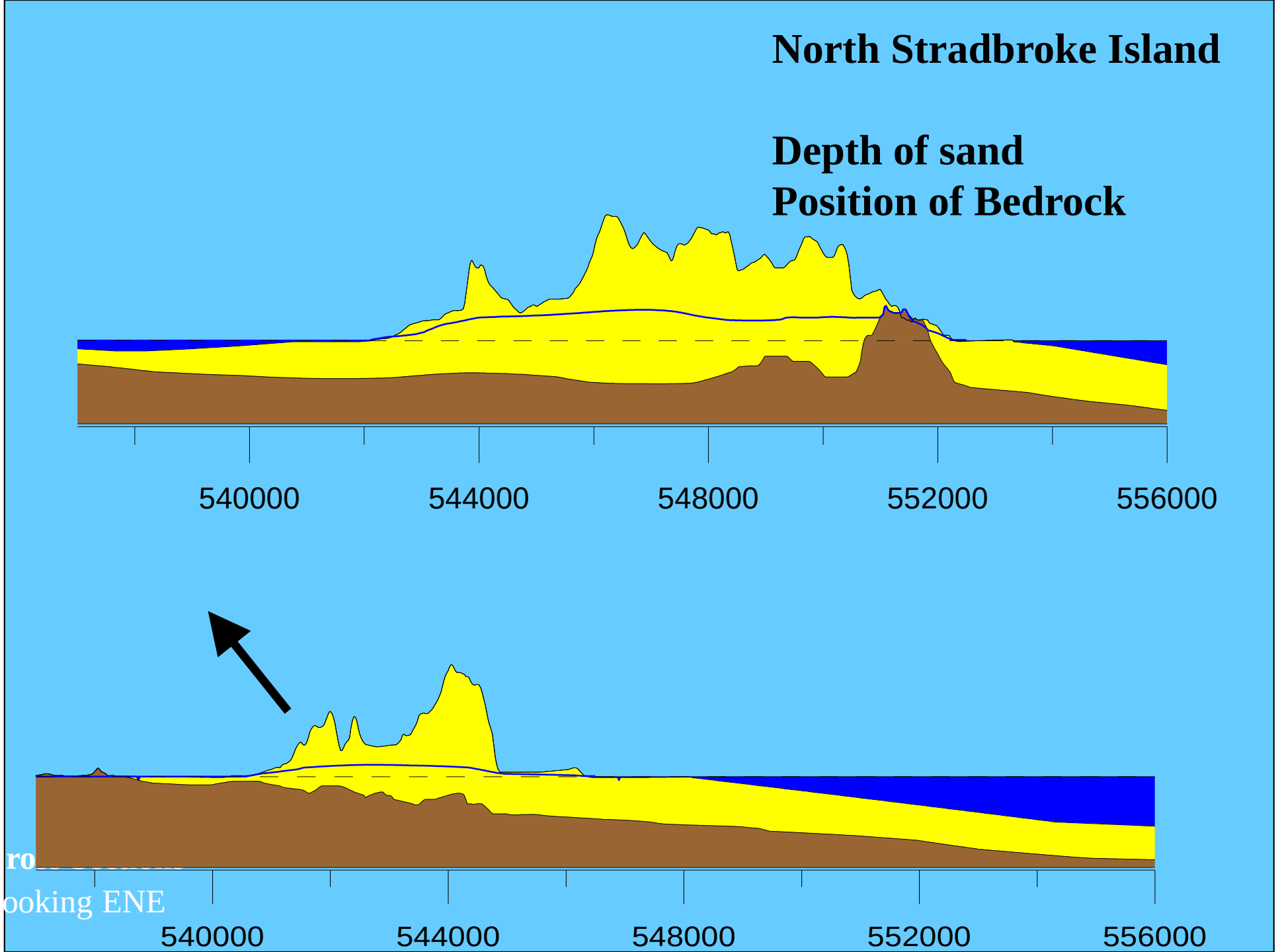
Bedrock



- As base of sand


North Stradbroke Island
Depth of sand
Position of Bedrock
A
B
C
D
E
F
G
H
I
J
K
L
M
100
0
-100
200
100
0
-100
540000
544000
548000
552000
556000
Cross Sections
Looking ENE



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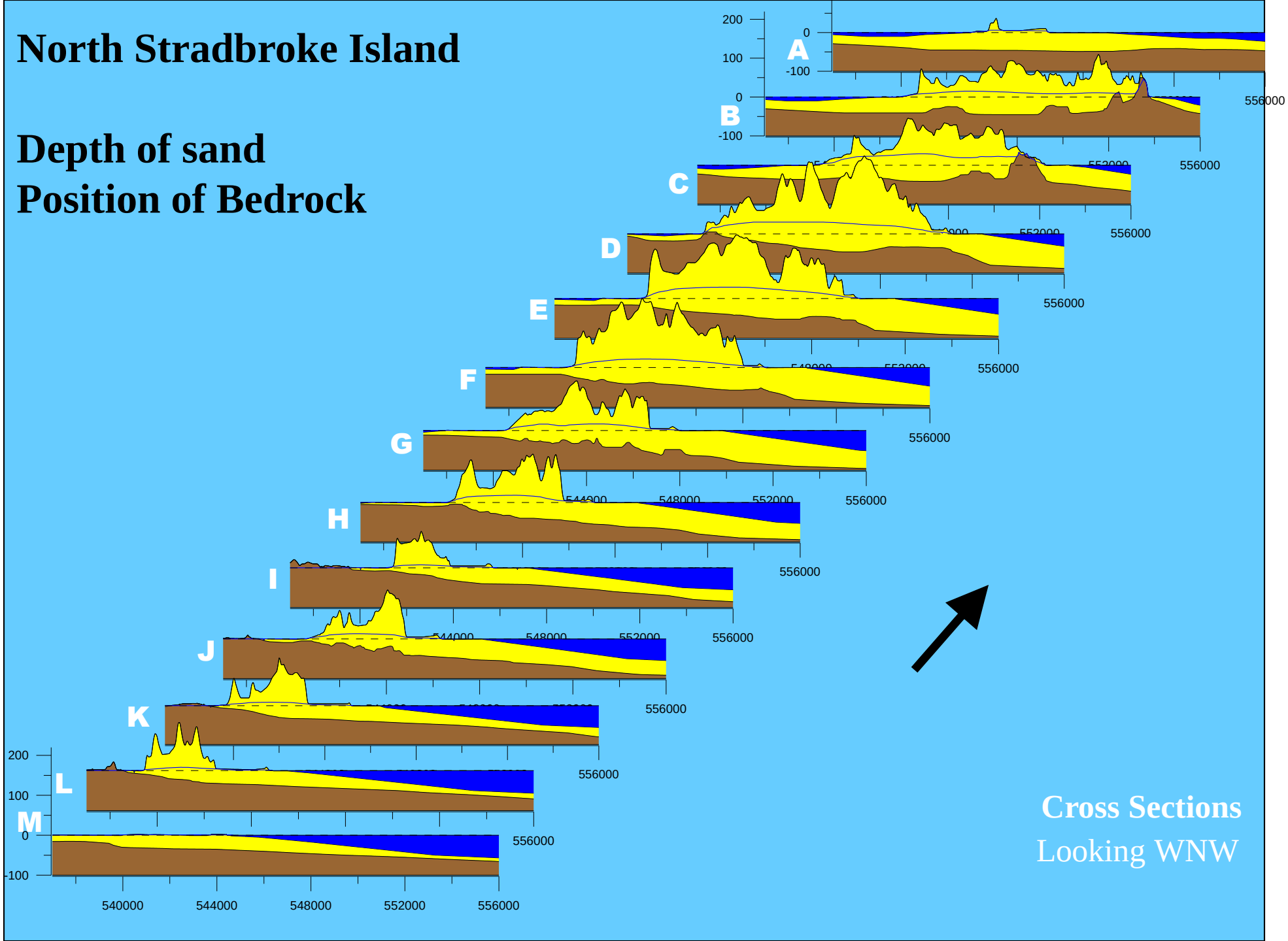
North Stradbroke Island

Depth of sand
Position of Bedrock



Cross Sections
Looking WNW

Groundwater Levels

- Includes
  - regional groundwater table
  - Open water bodies that intersect the regional water table
- Excludes
  - Localised shallow groundwater tables (perched systems)
  - Open water bodies that intersect the perched systems(Brown Lake)

Gr

- In

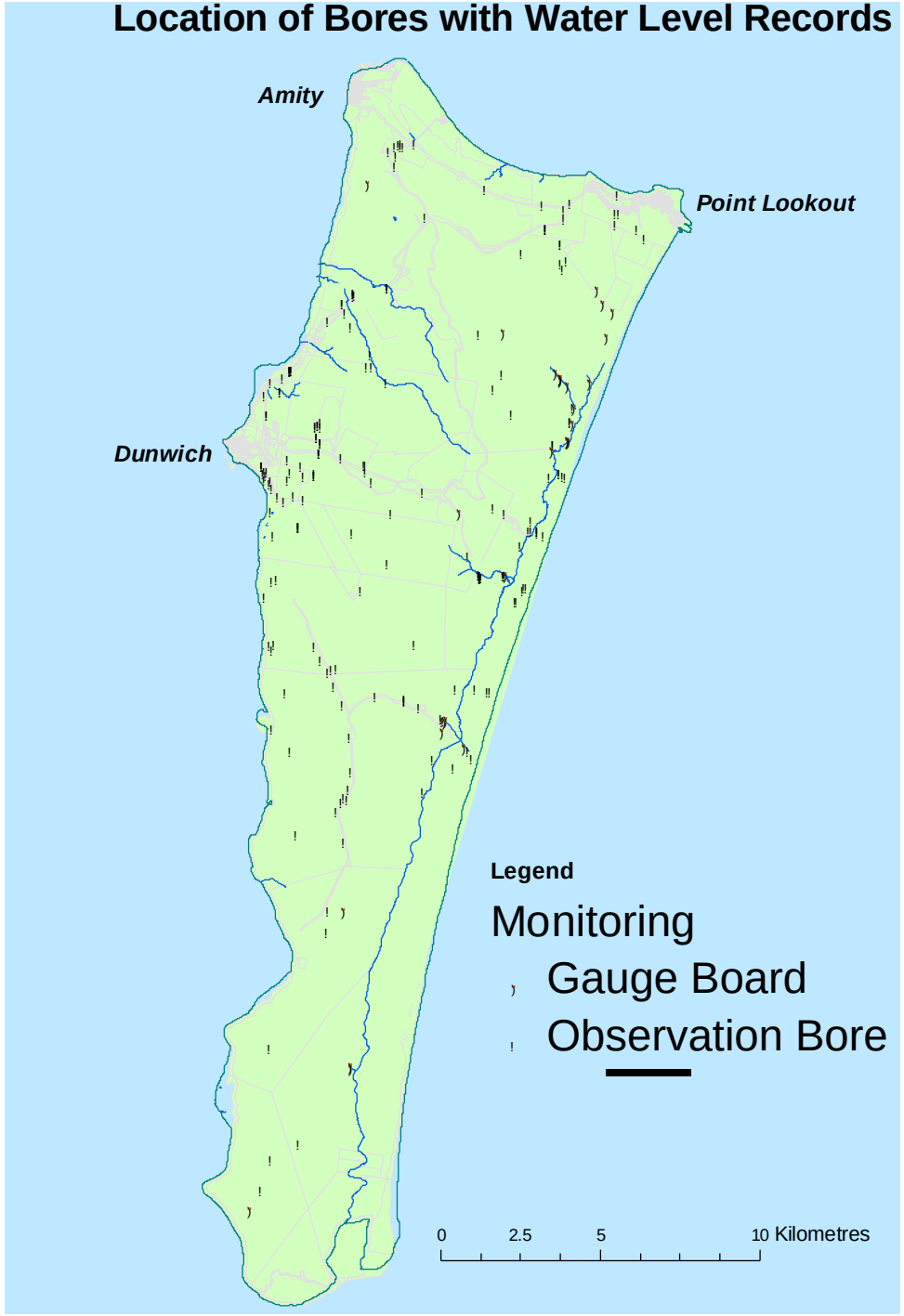
- Ex

Groundwater Levels

- Groundwater levels have been monitored on the island since the late 1960s
- Water levels are monitored by
  - Redland Shire Council
  - CRL
  - Dept Natural Resource and Water

Groundwater Levels

- Water levels are available for over 250 bores, including Gauge Boards
- Only a few bores have a near continuous record from 1960 to the present
- Recent drilling has augmented the network

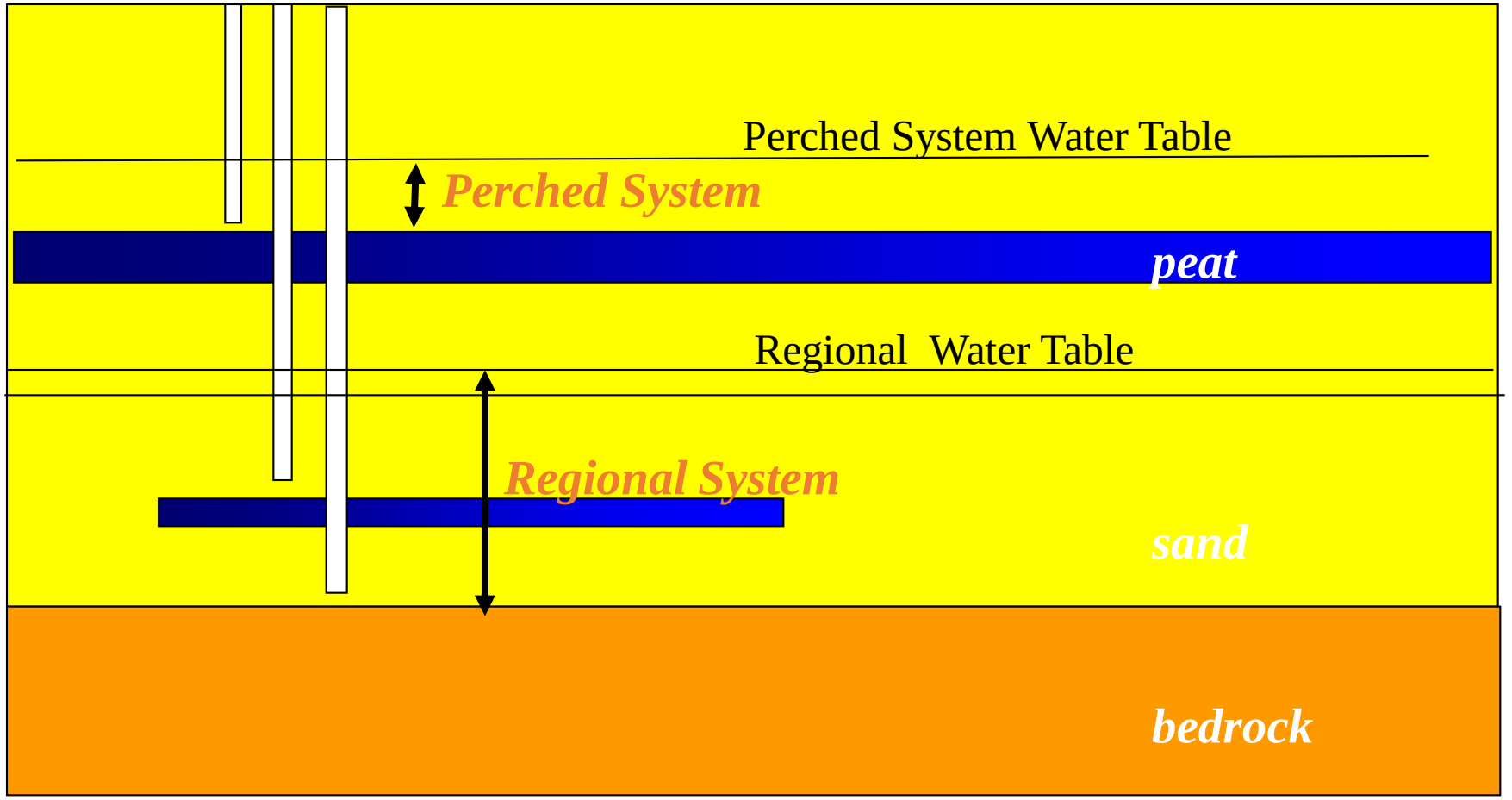


Bore
Location

- The island has had a complex geological history probably extending back at least 3 to 5 million years
- There are indications that the island has experienced a vast range of climatic conditions from dry to wet and a range of geomorphologic processes
- The net result is
  - locally perched groundwater systems, and
  - a regional groundwater system

Each systems has to be monitored.

New Monitoring Bores **each pipe is to a different depth**



Allows identification of different groundwater flow systems

Age,, temperature, chemistry,, etc

Bores

New Monitoring Bores **each pipe is to a different depth**

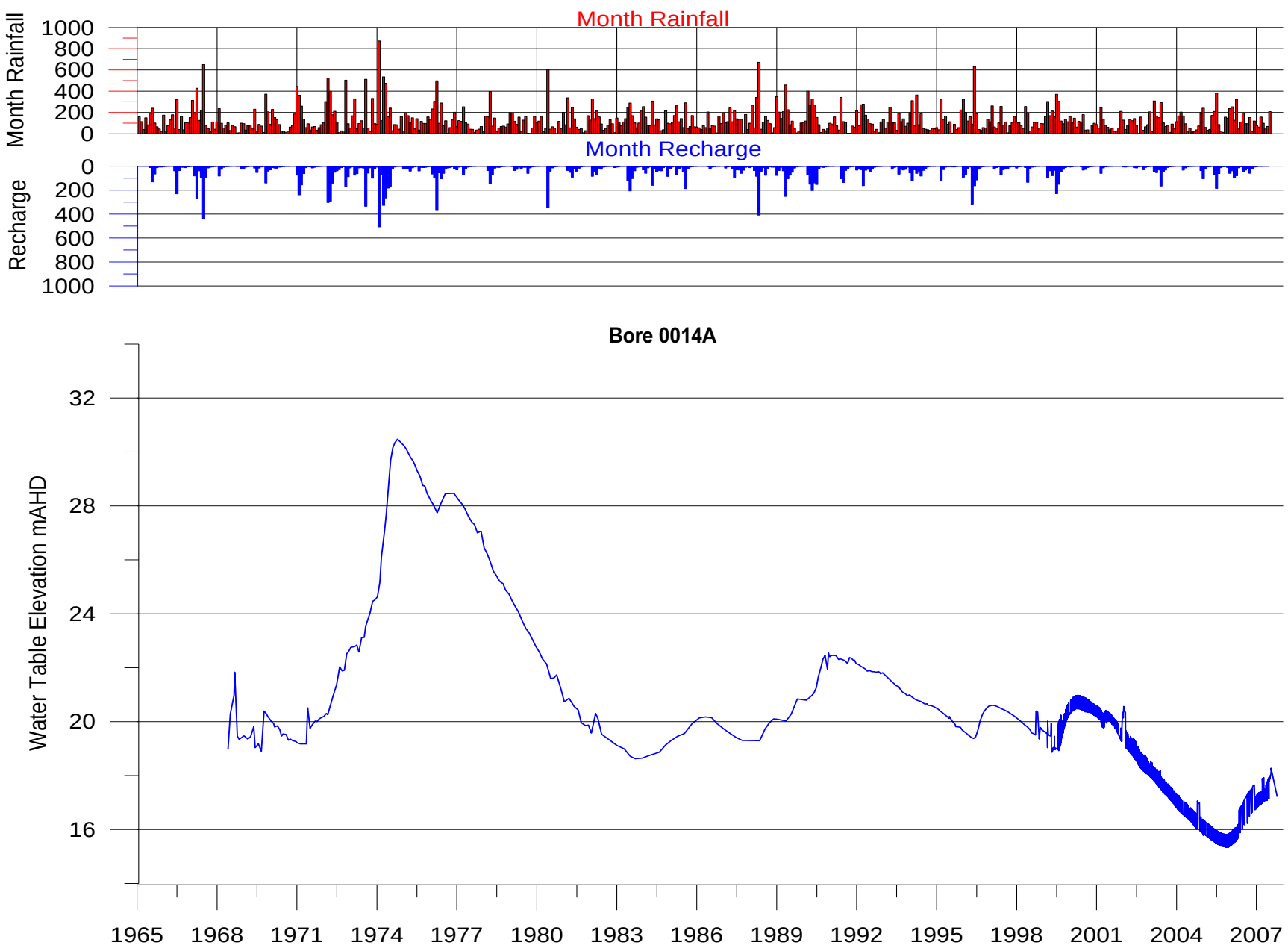
Bores

New Monitoring Bores **each pipe is to a different depth**

Bores

Bore with Automatic Recorder

14400073



Bore with Automatic Recorder 14400014 Fishermen Road

Surface Water Gauge Board

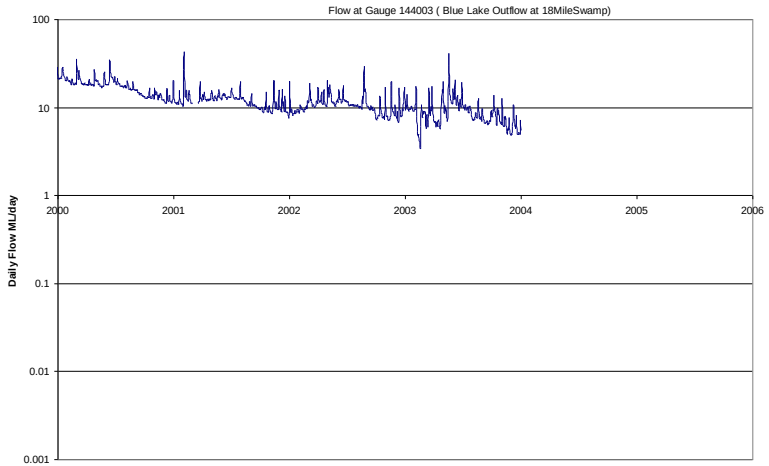
Pressures

Surface Water Measuring Flume

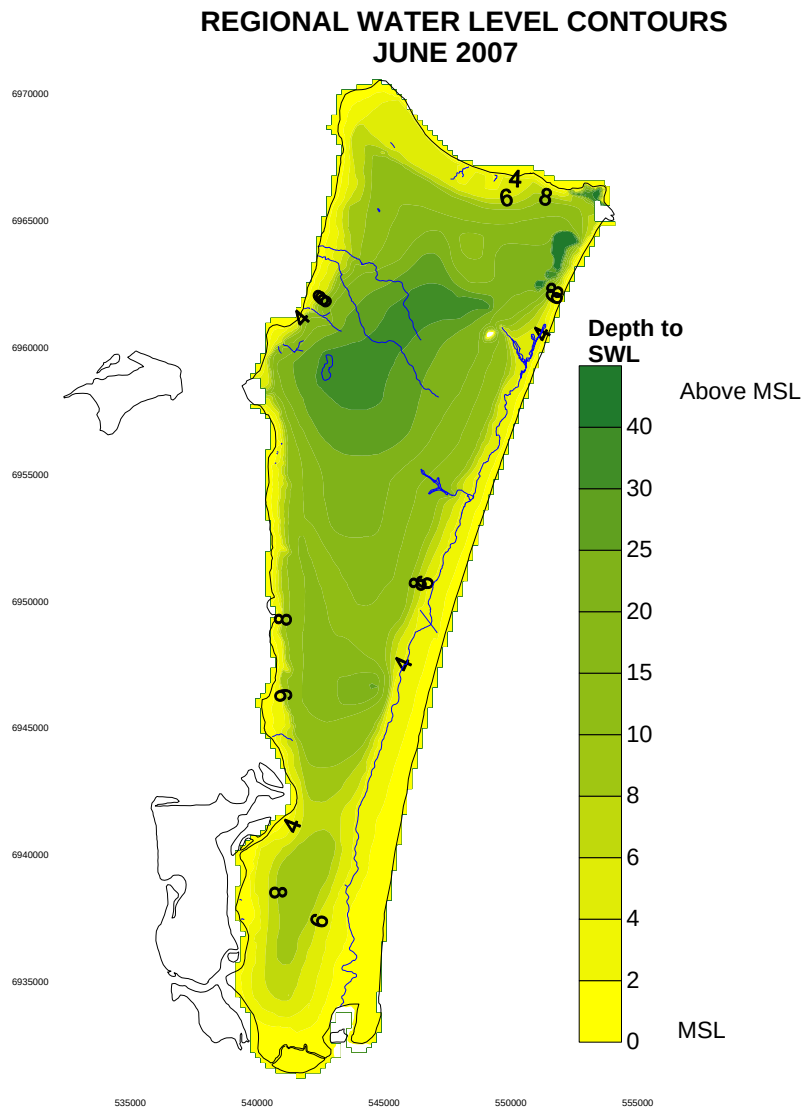
Surface Water Gauge Board

Stream flow measurement

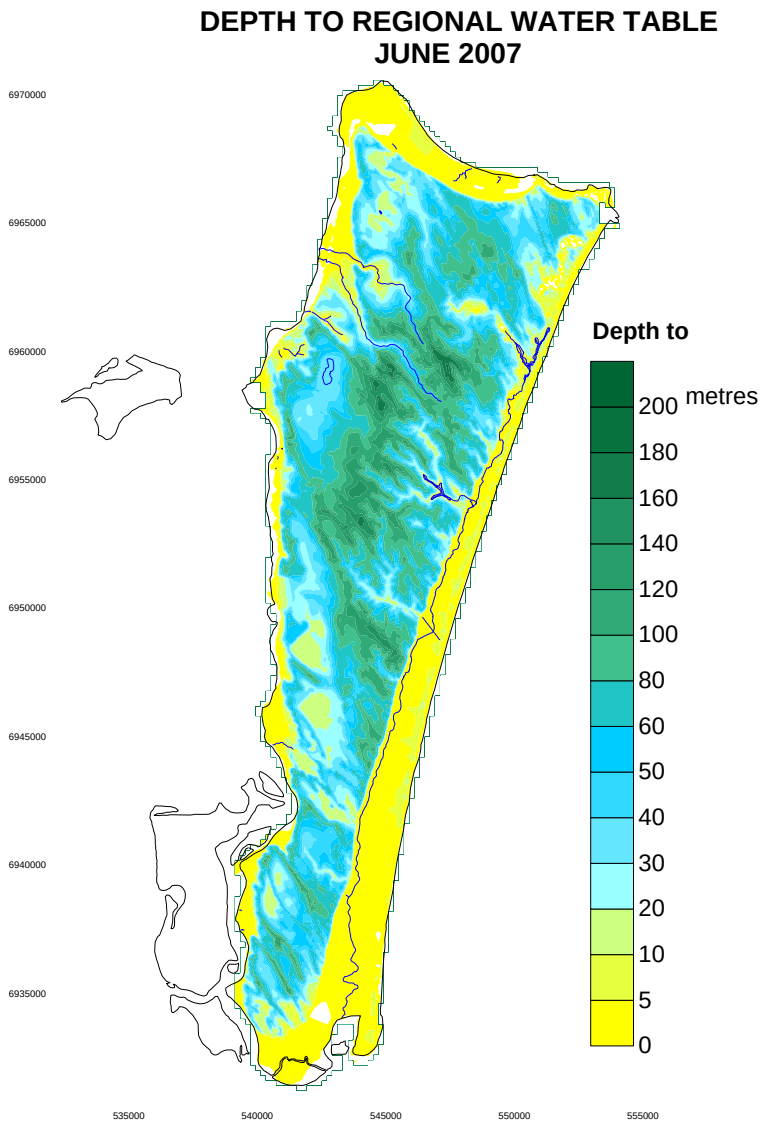
Blue Lake Overflow



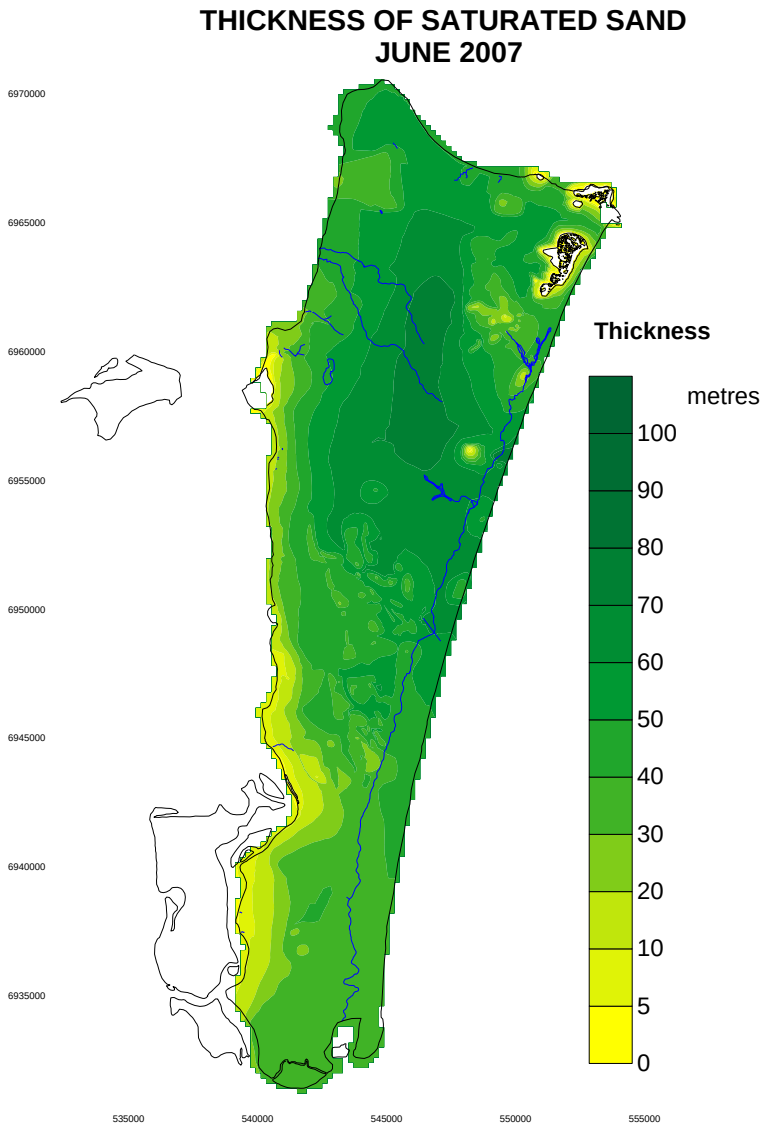
Regional Water Table Contours



Depth to Regional Water Table



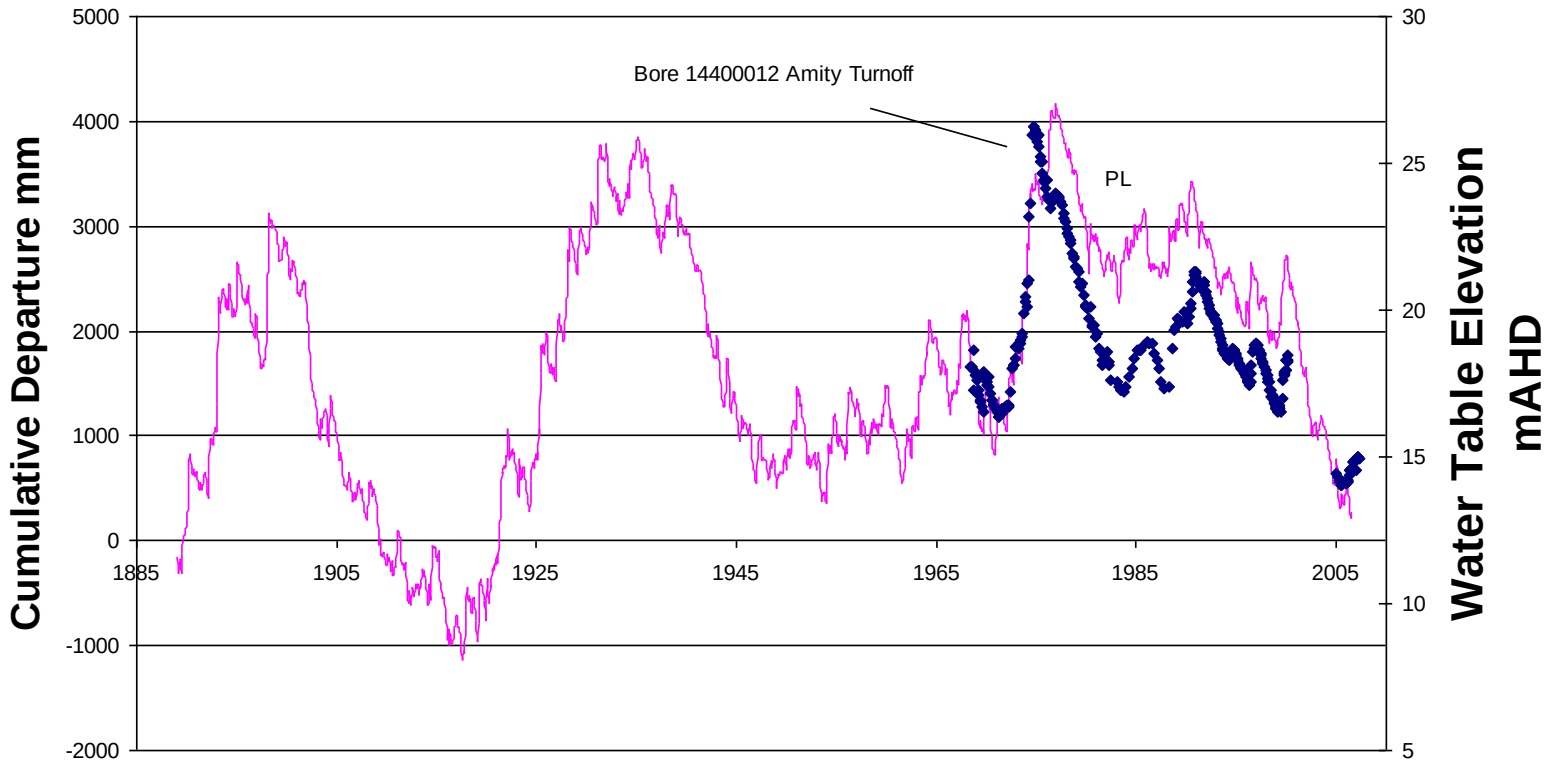
As distance between Natural Surface and Regional Water Table



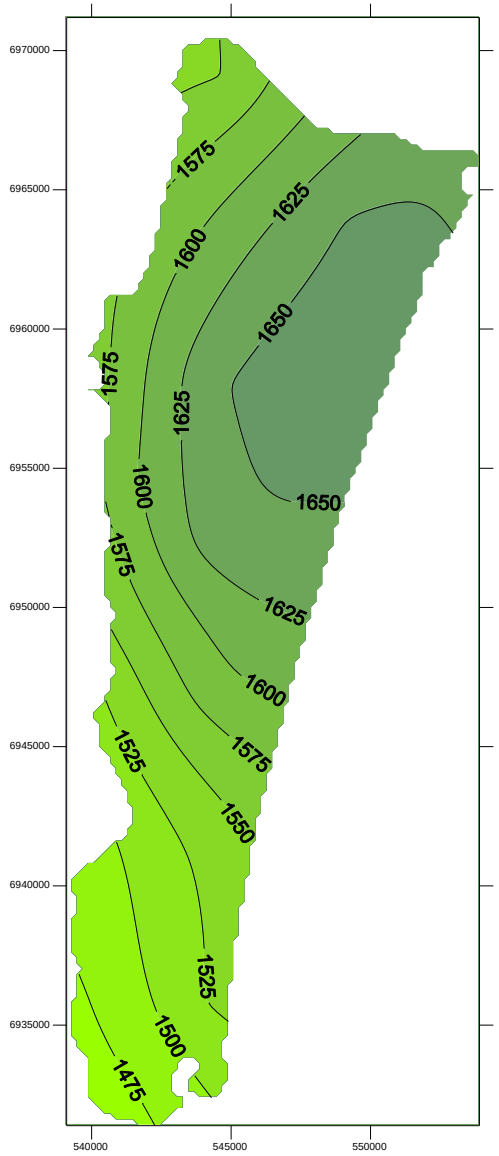
Saturated Thickness

As distance between SWL and Bedrock

Comparison between Water Table and Cumulative Departure from the Mean Month rainfall



Avearage Annual Rainfall



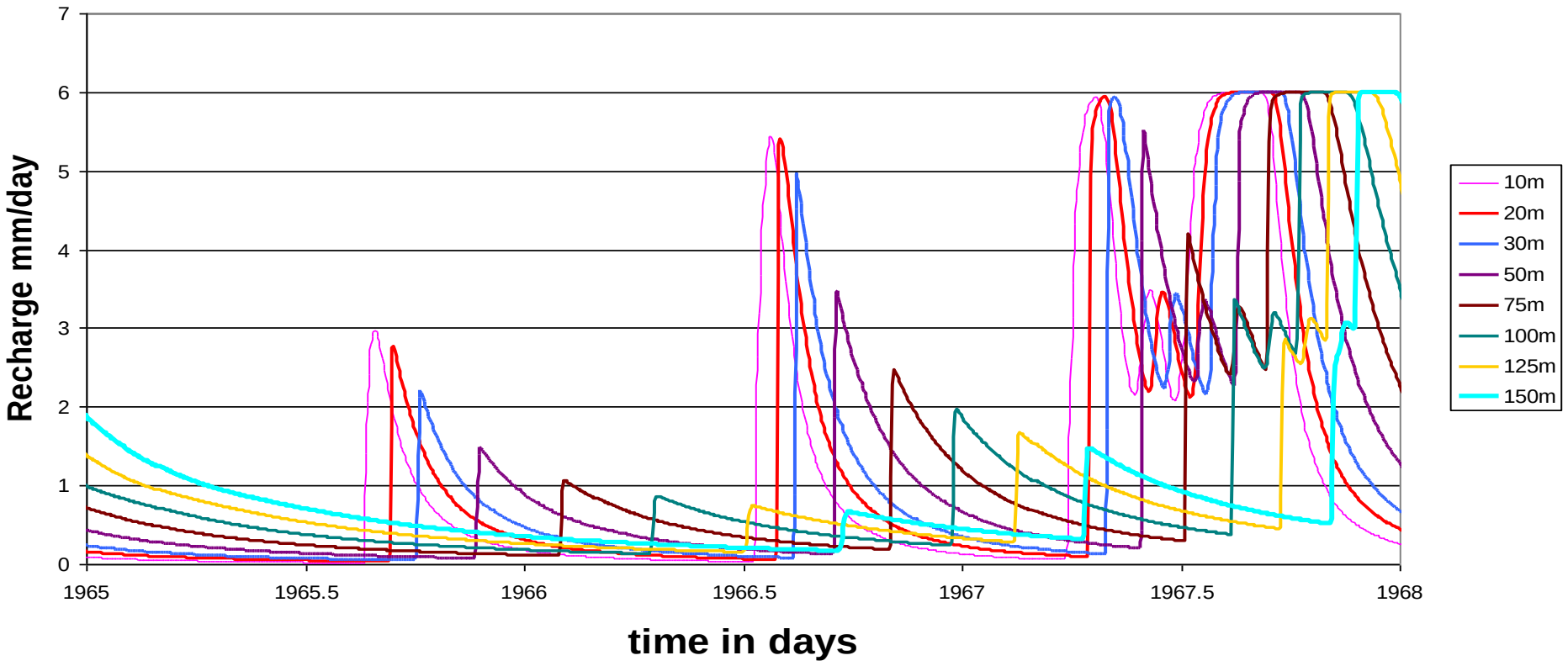
Recharge

- There are numerous soil moisture models
- Layer models
- Hydrus
- SPLASHMulti

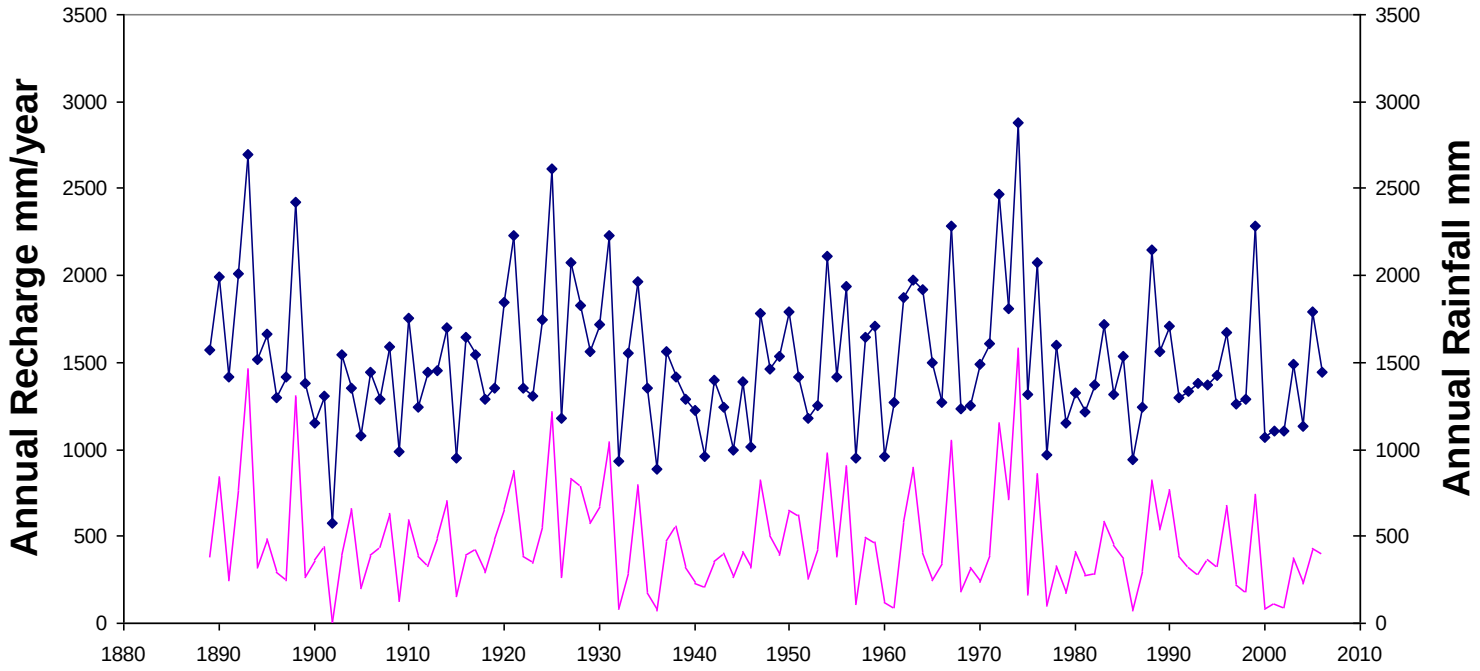
Recharge

- Existing software attenuated the percolation with depth.
- water levels show there is a delay with increasing depth to the water table.
- New software was developed to assess the percolation through the unsaturated zone at the day scale.
- It incorporates adaptive time stepping within one day to accommodate rainfall events.

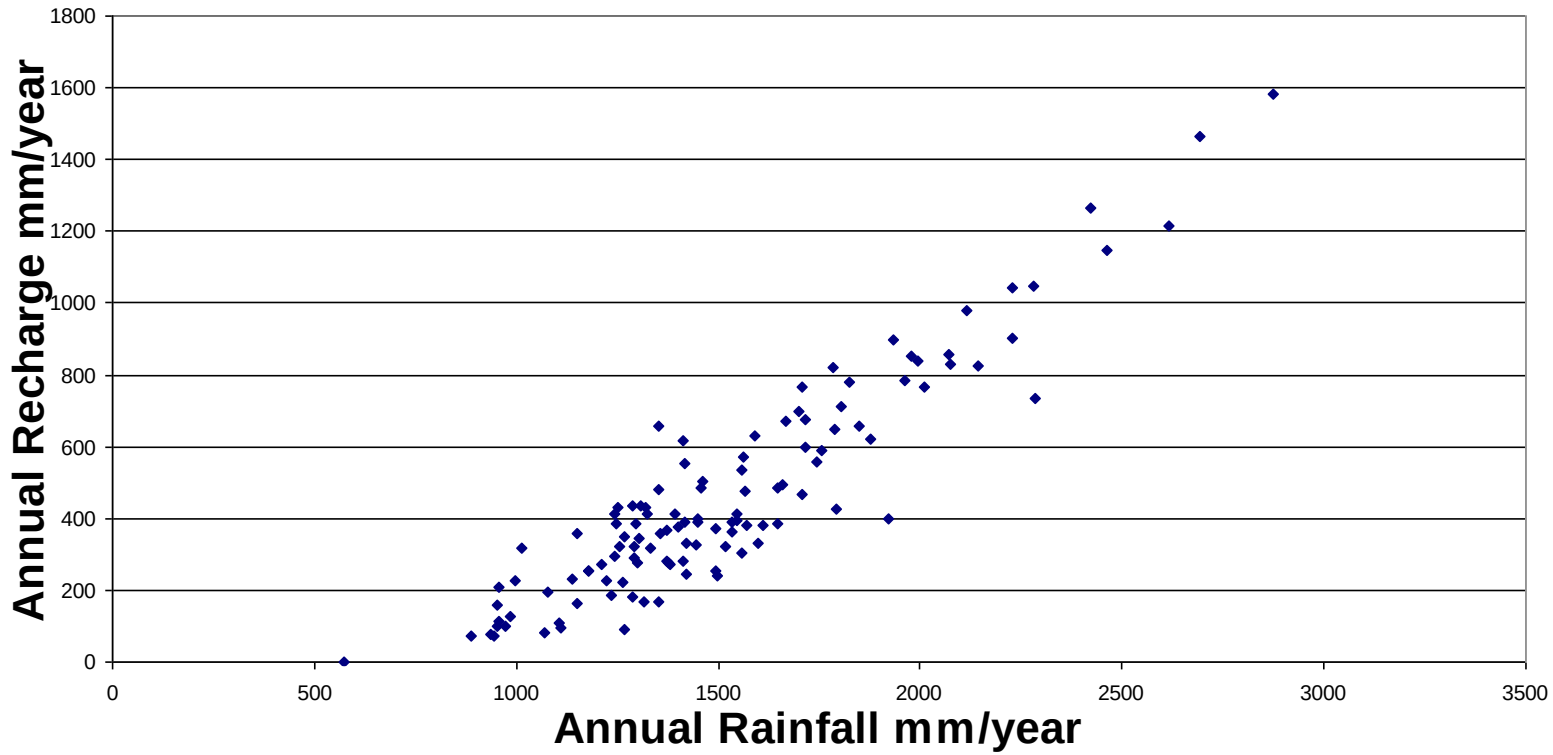
Hydrographs of Daily Recharge for various depth to the water table



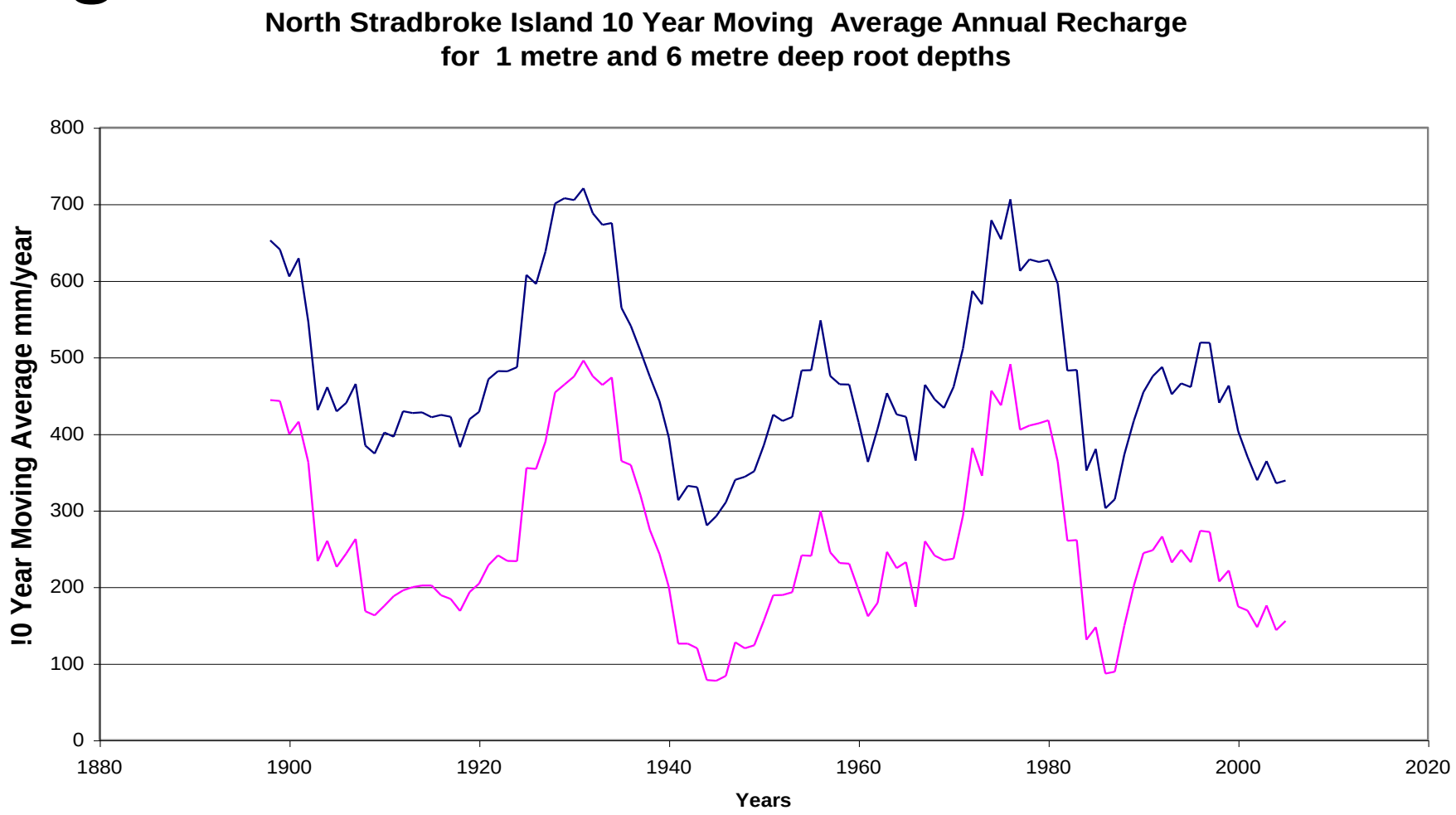
North Stradebroke Island
Annual Recharge for a root depth of 2 m
Annual Rainfall at Dunwich



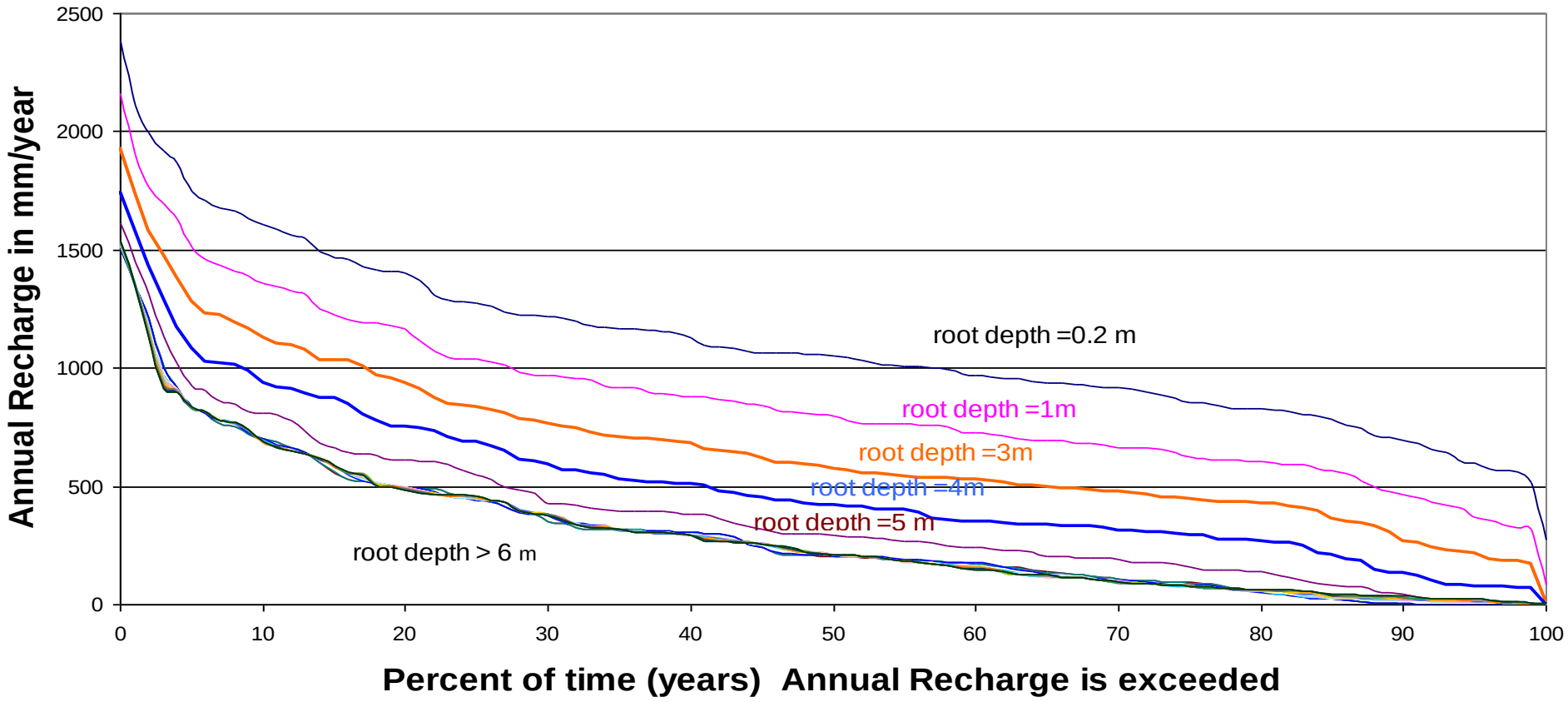
Comparison between Annual Recharge and Annual Rainfall



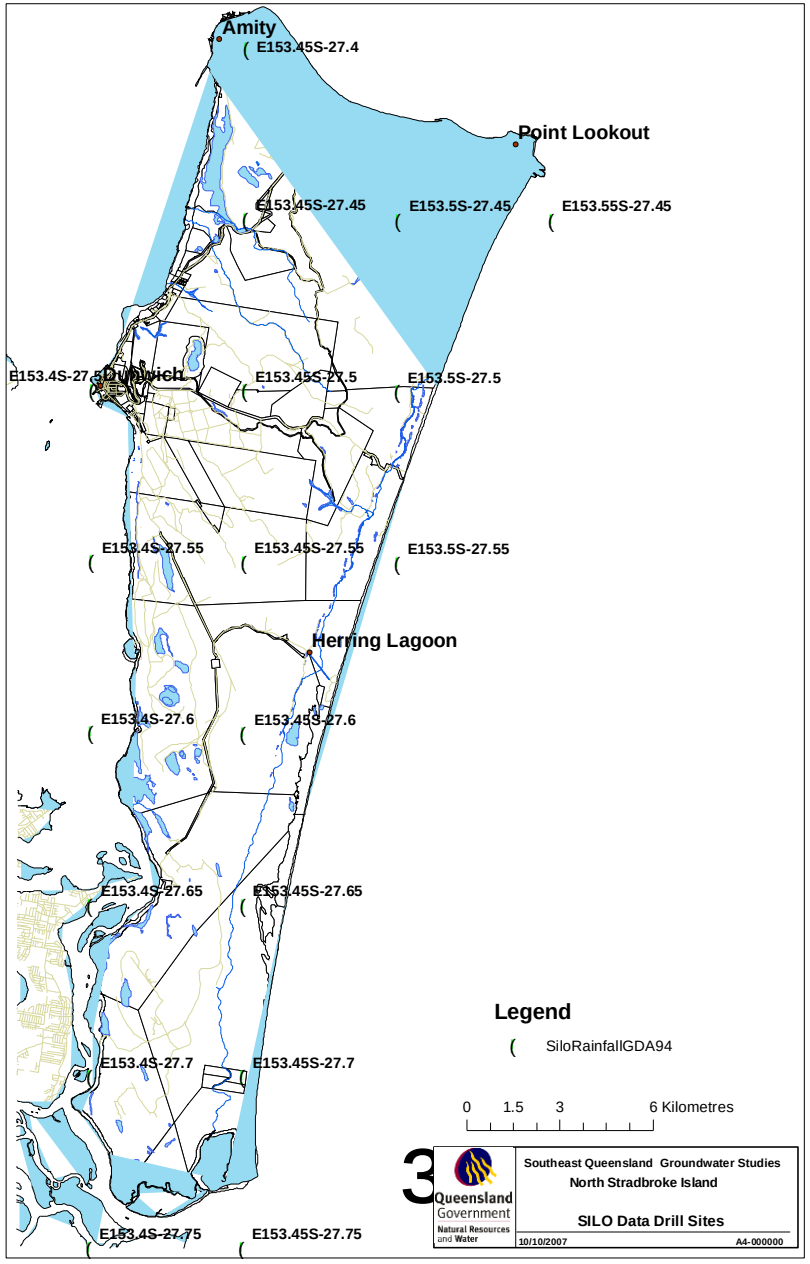
Recharge


North Stradbroke Island 10 Year Moving Average Annual Recharge
for 1 metre and 6 metre deep root depths
!0 Year Moving Average mm/year
800
700
600
500
400
300
200
100
0
1880
1900
1920
1940
1960
1980
2000
2020
Years

Percentile Distribution of Annual Recharge
Period of Analysis 1889 to 2008 for a root depth of 6 metres



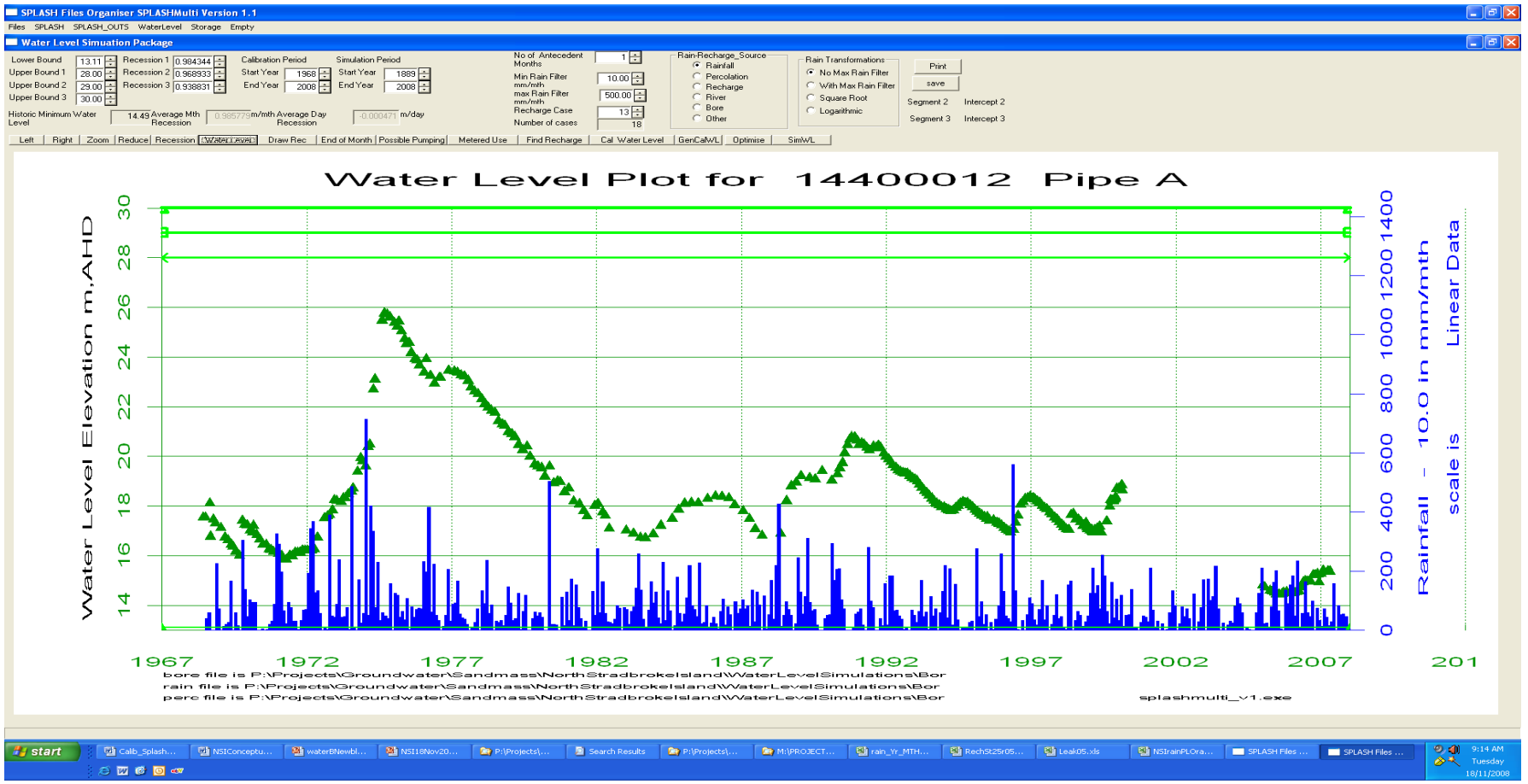
Recharge
Silo Locations



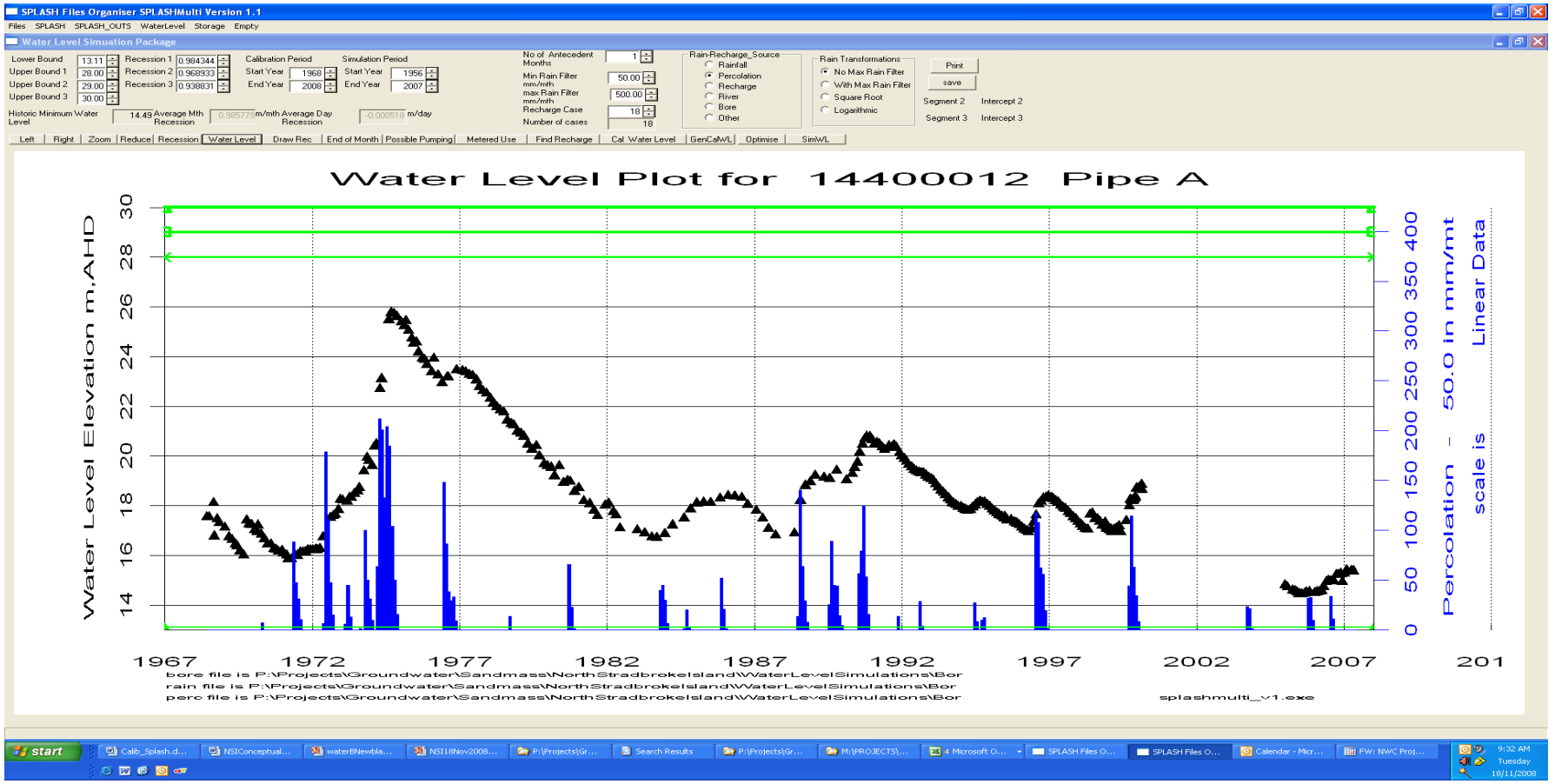
Distributed Recharge

- For each 100m *100m cell recharge has been calculated based on
- Rainfall at near by Silo locations
- Evaporation and Leaf Area Index
- Depth of root
- Depth to water table
- Soil/sand permeability

SPLASH_multi using raw daily rainfall



SPLASH_multi using process daily recharge



Recharge Results

- Recharge is from local rainfall on the island
- Recharge is water that penetrates below the root zone and perching layers.
- It is seasonal and is dependent on antecedent conditions.
- The enhance distributed recharge data set has greatly improved the calibration of the transient groundwater flow model

North Stradbroke Island
Groundwater Model

Model Development,

Calibration Performance and Predictive Uncertainty Analysis

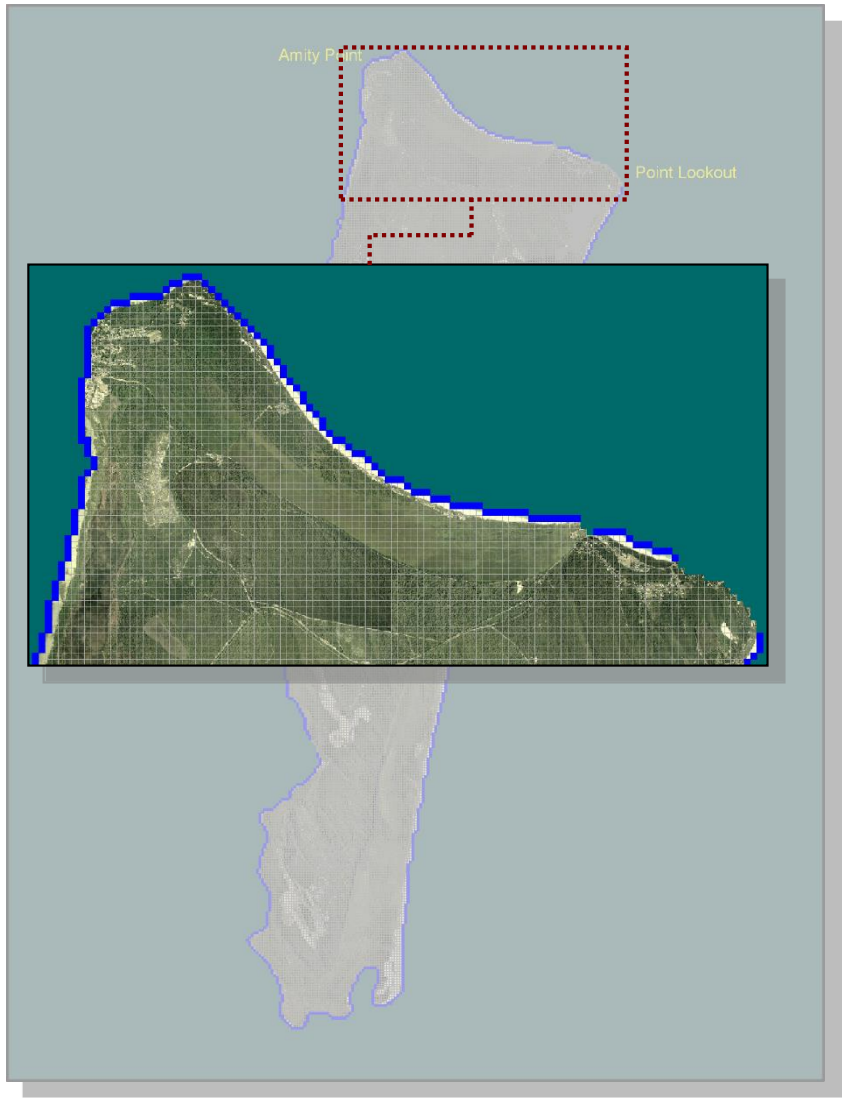

Amity Point
Point Lookout
Dunwich

Lake Features

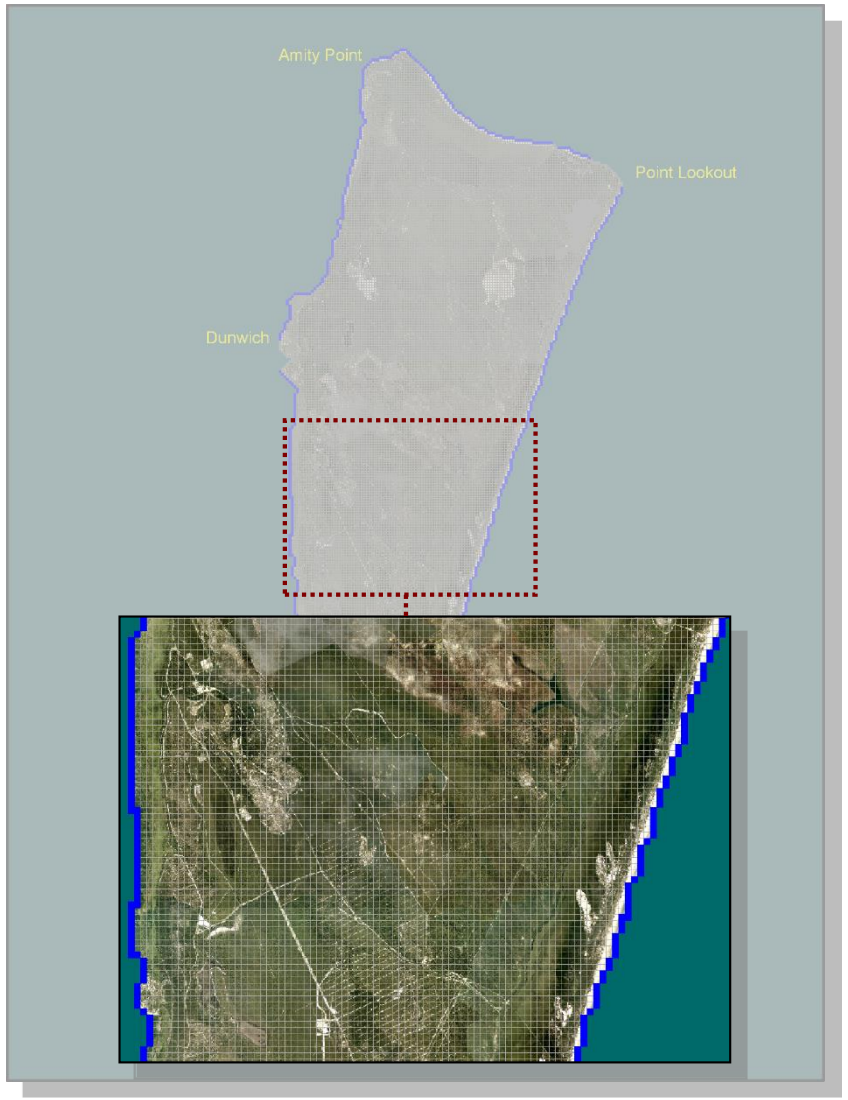
Coastal Boundary Conditions

100m x 100m Model Grid

100m x 100m Model Grid

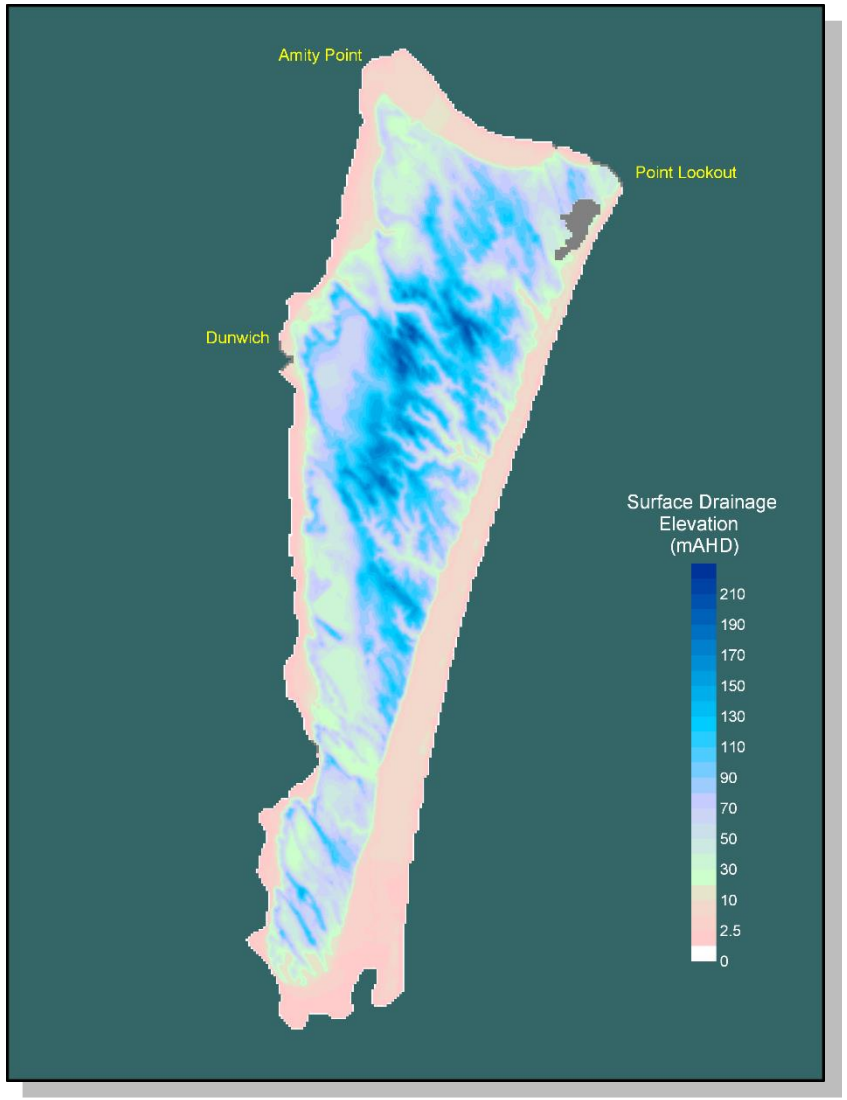


100m x 100m Model Grid

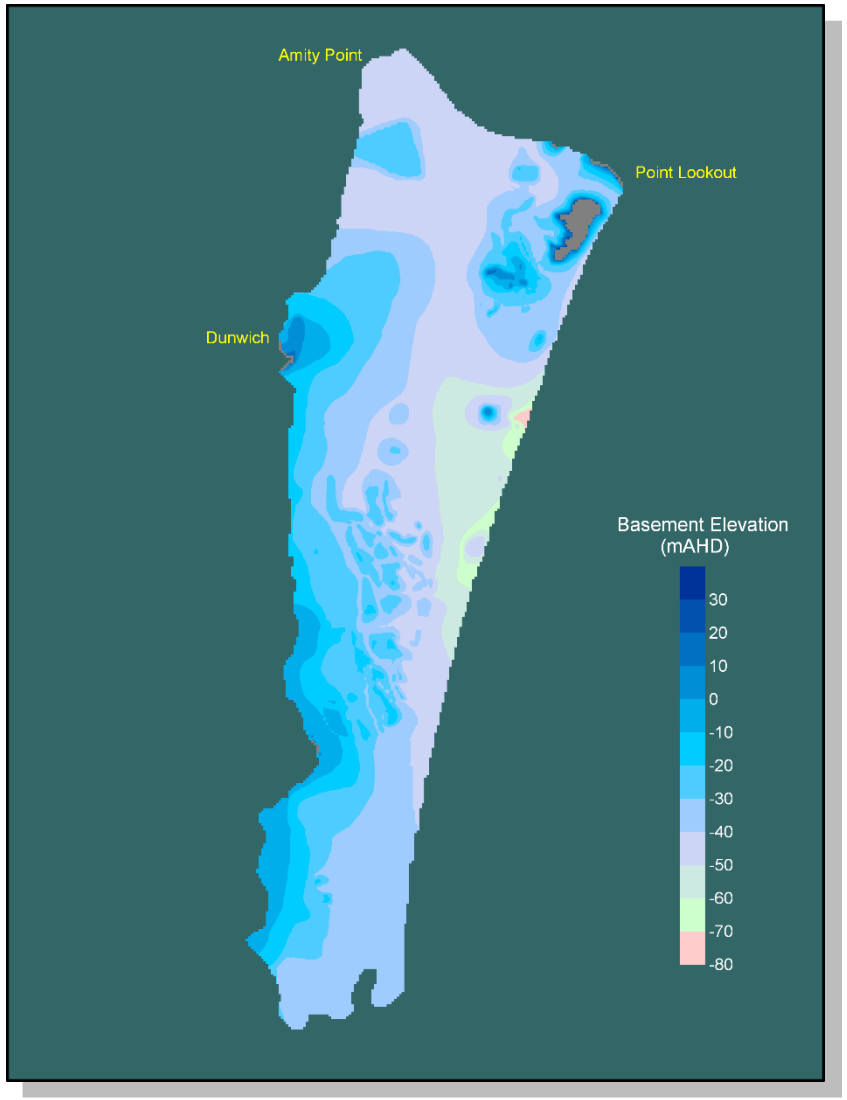


100m x 100m Model Grid

Model Surface Drainage Elevation



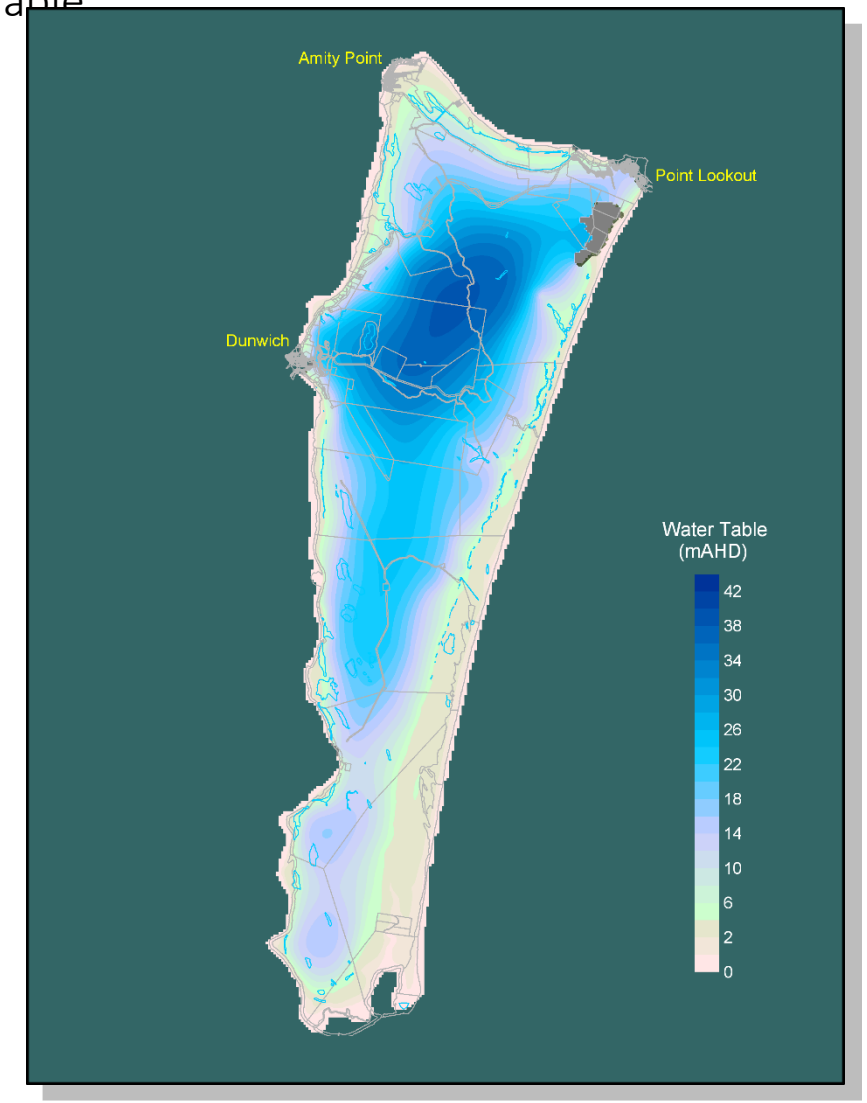
Model Basement Elevation



Steady State Calibration - Observations

Steady State Calibration – “K” Pilot Points

Steady State Calibration – Water Table



Transient Calibration – Observations

Transient Calibration – K Pilot Points

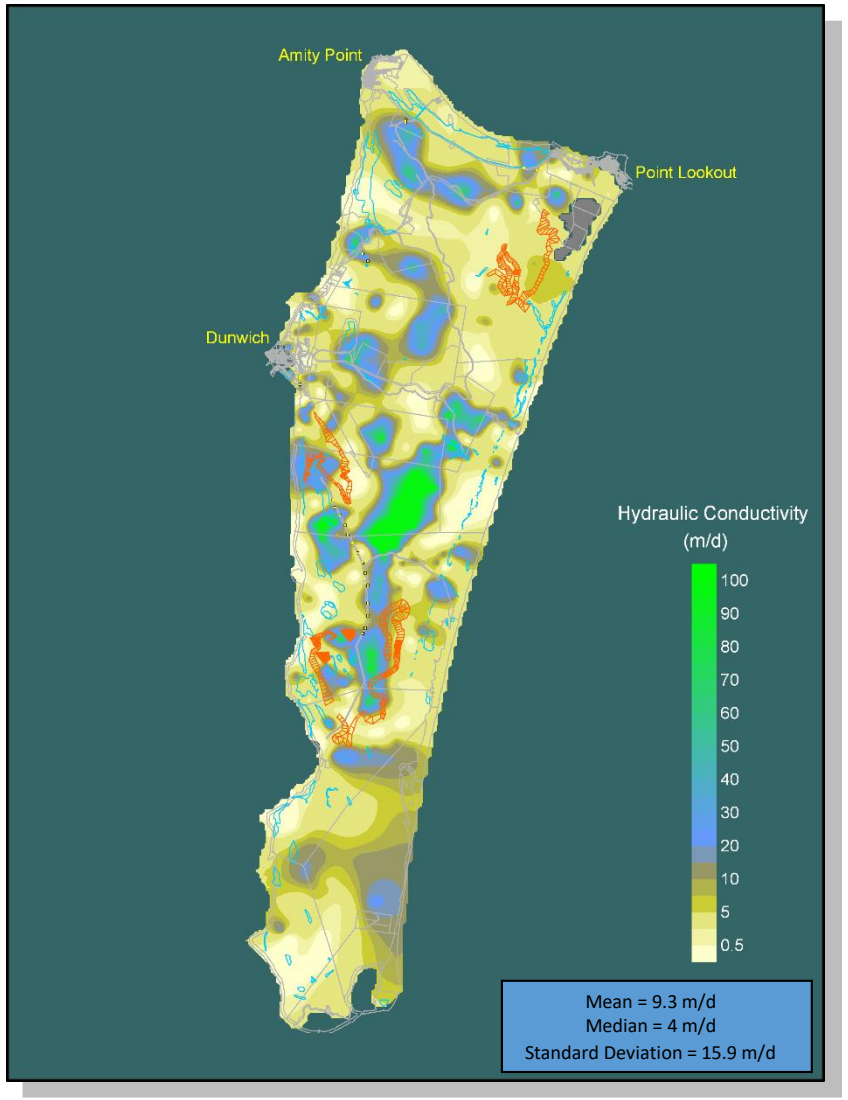
Transient Calibration – S_y Pilot Points

Transient Calibration – Local Extractions

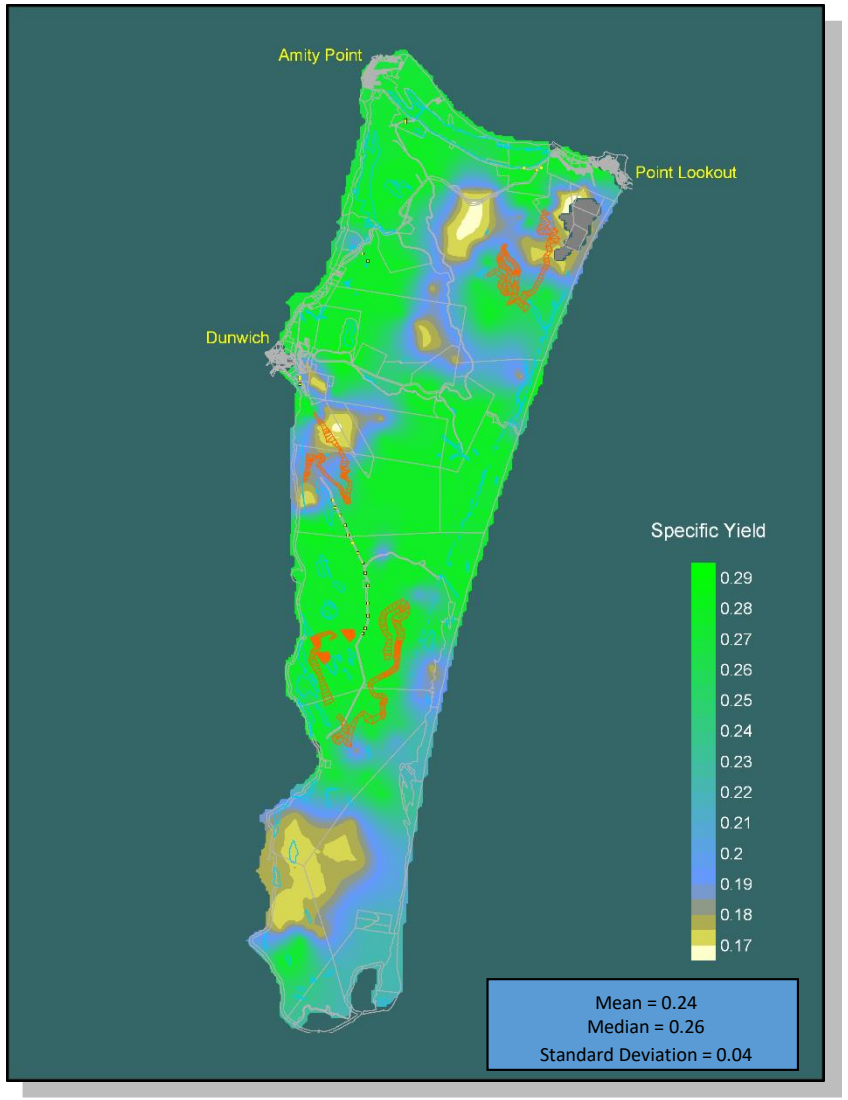
Transient Calibration – RSC Extractions

Transient Calibration – CRL Mine Paths

Calibrated Hydraulic Conductivity

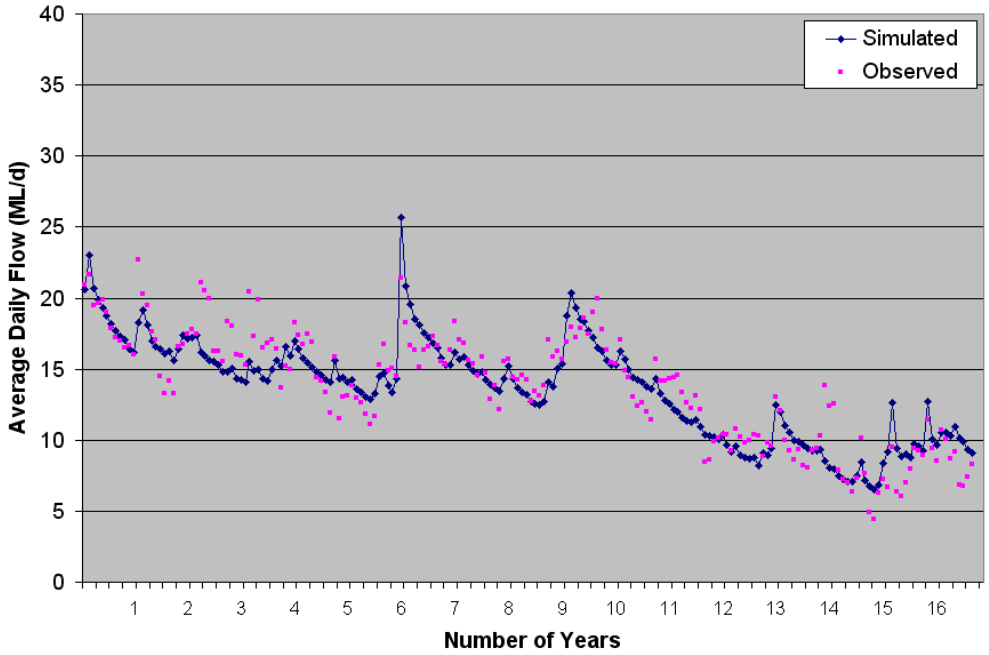


Calibrated Specific Yield

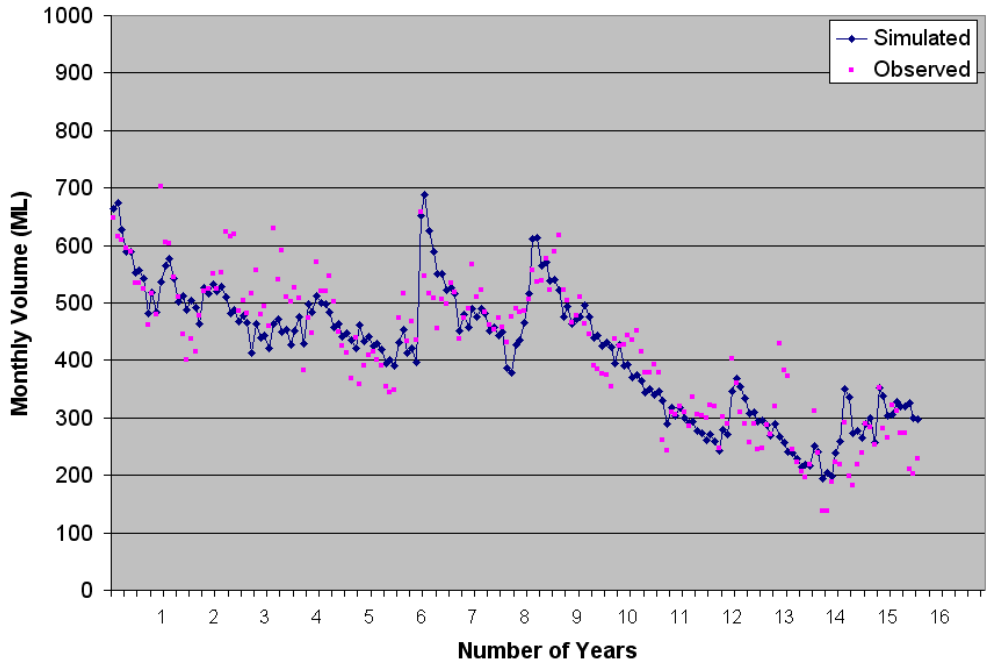


Calibration Performance – Water Table “Variance”

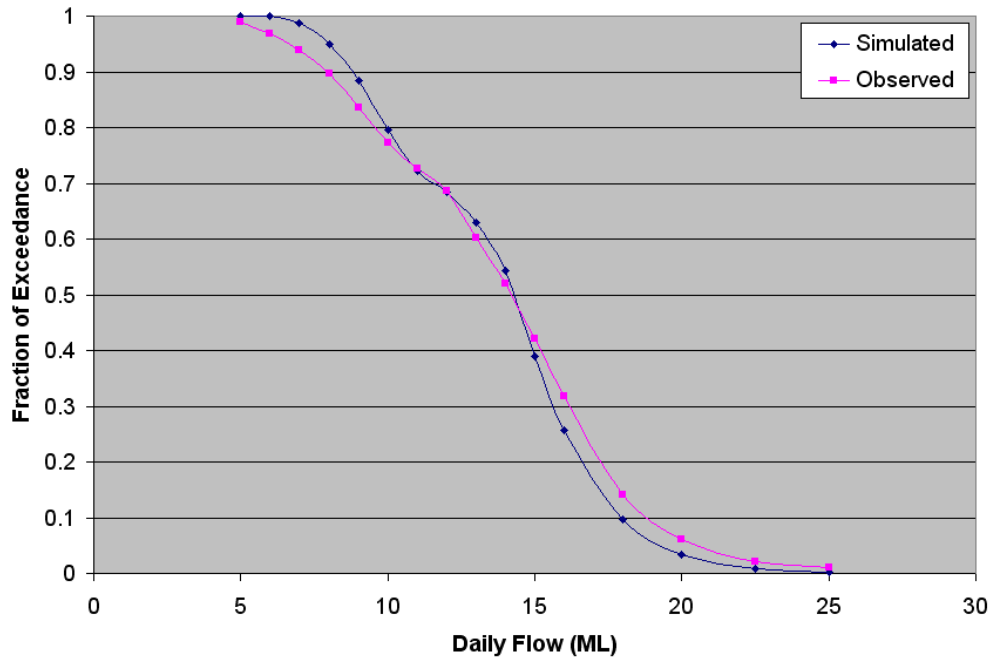
Calibration Performance – Blue Lake Outflow



Calibration Performance – Blue Lake Volume

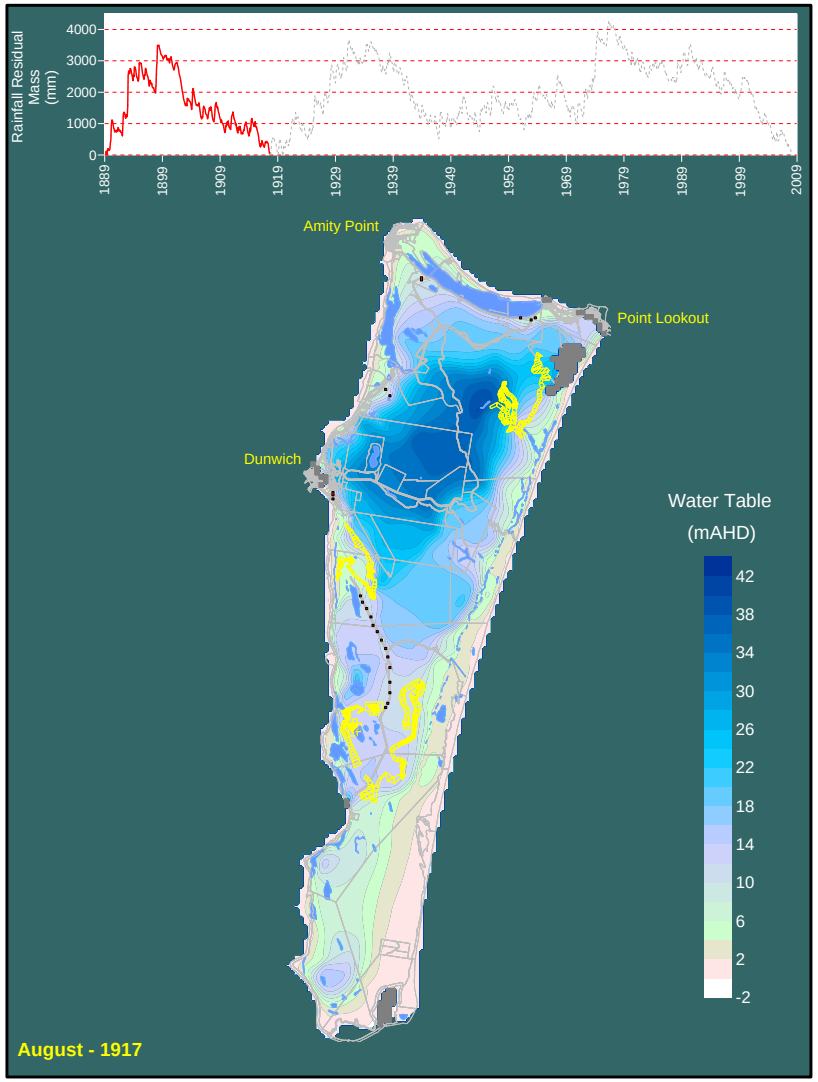


Calibration Performance – Blue Lake Flow Exceedance

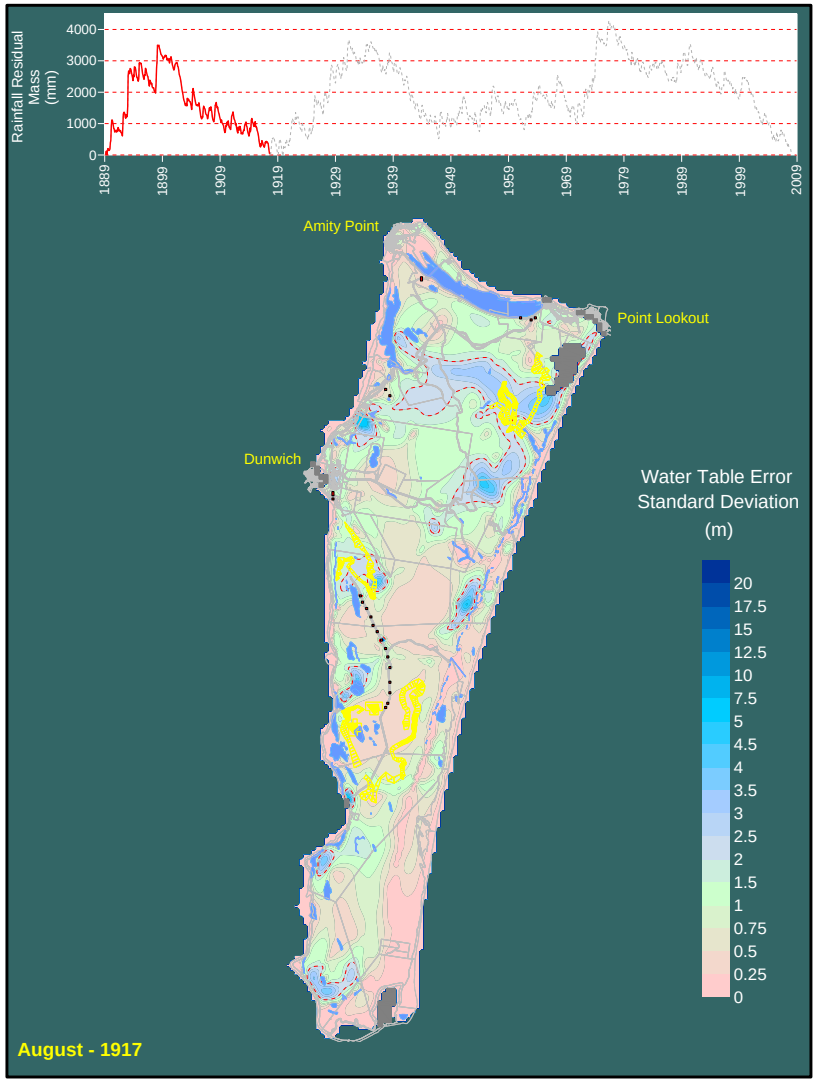


Calibration Performance – Animation

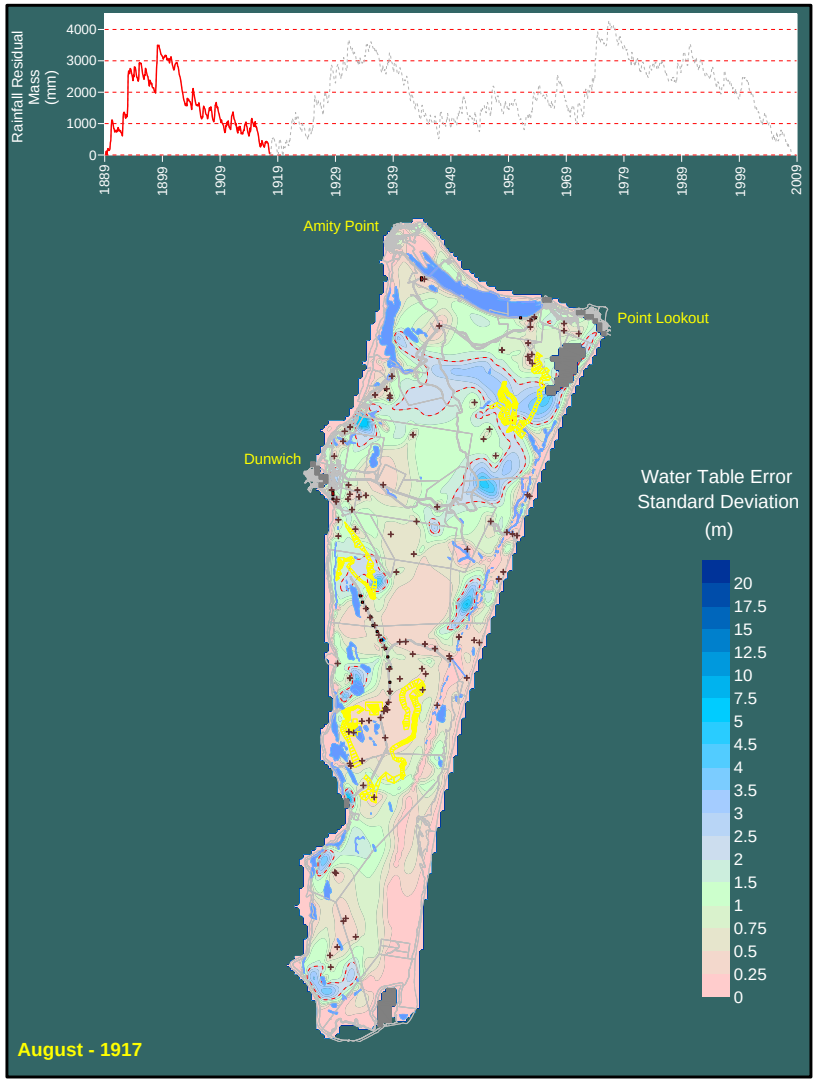
Predictive Scenarios– Extended Dry



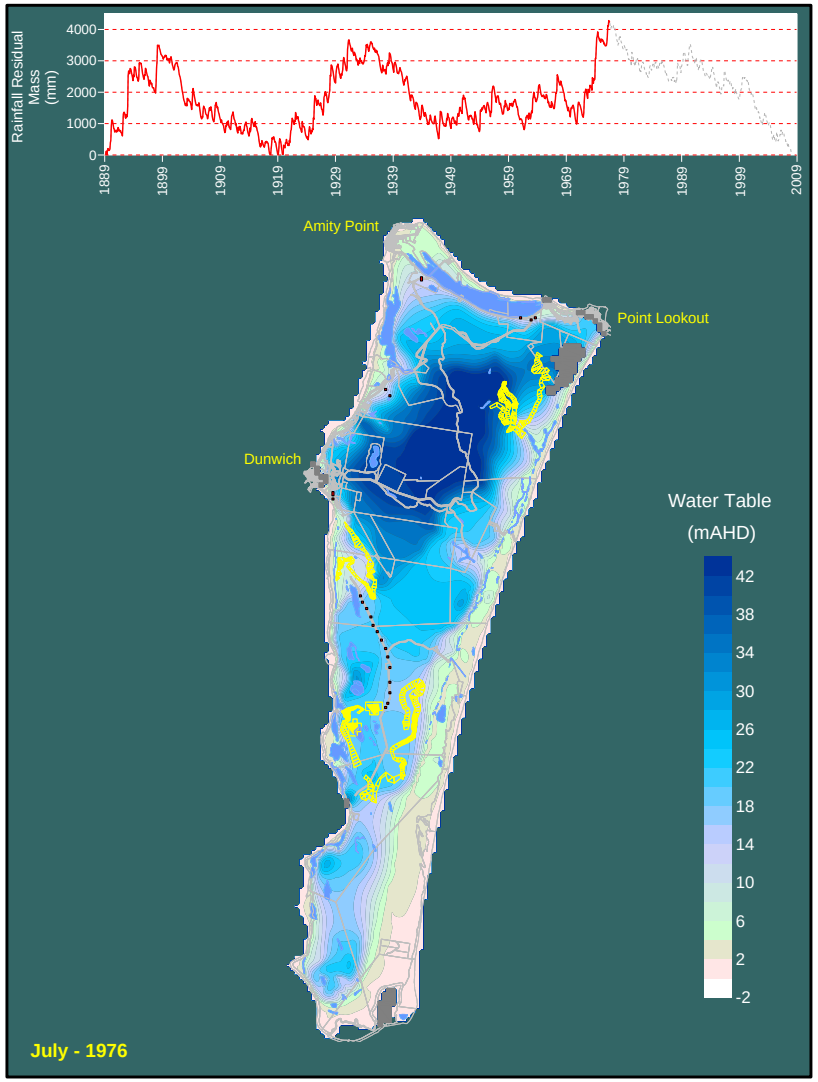
Model Predictive Error Analysis – Extended Dry



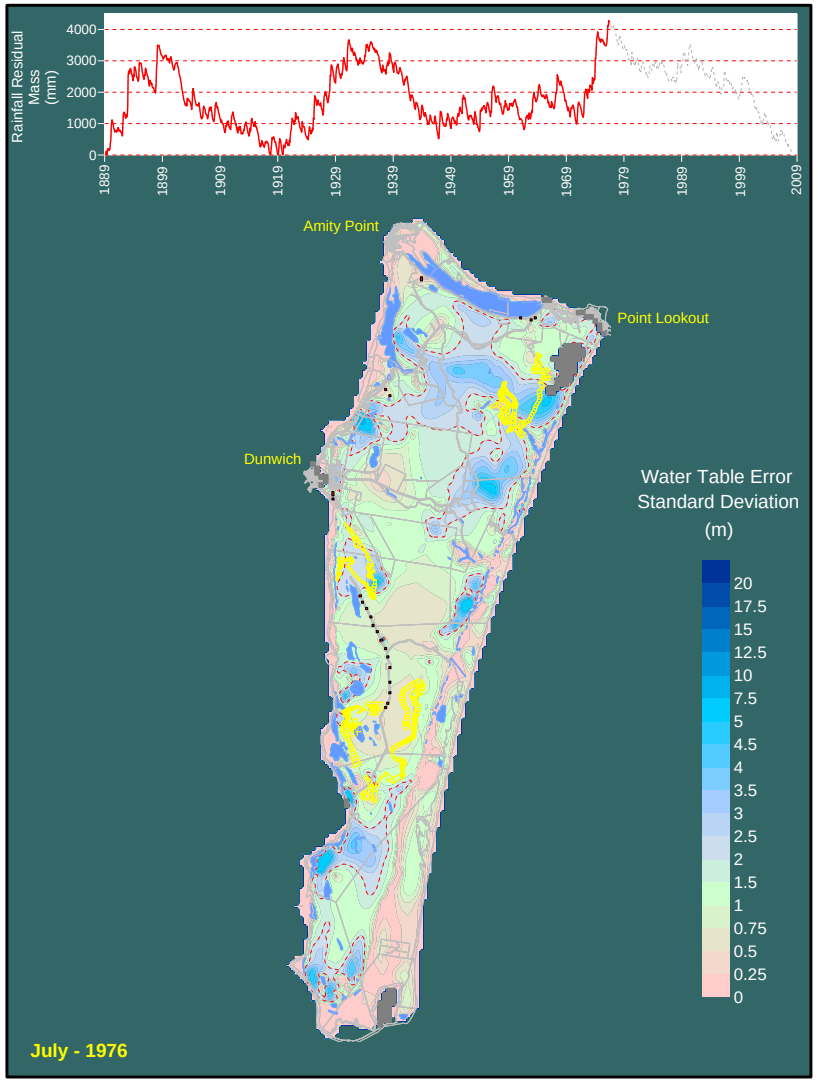
Model Predictive Error Analysis – Extended Dry



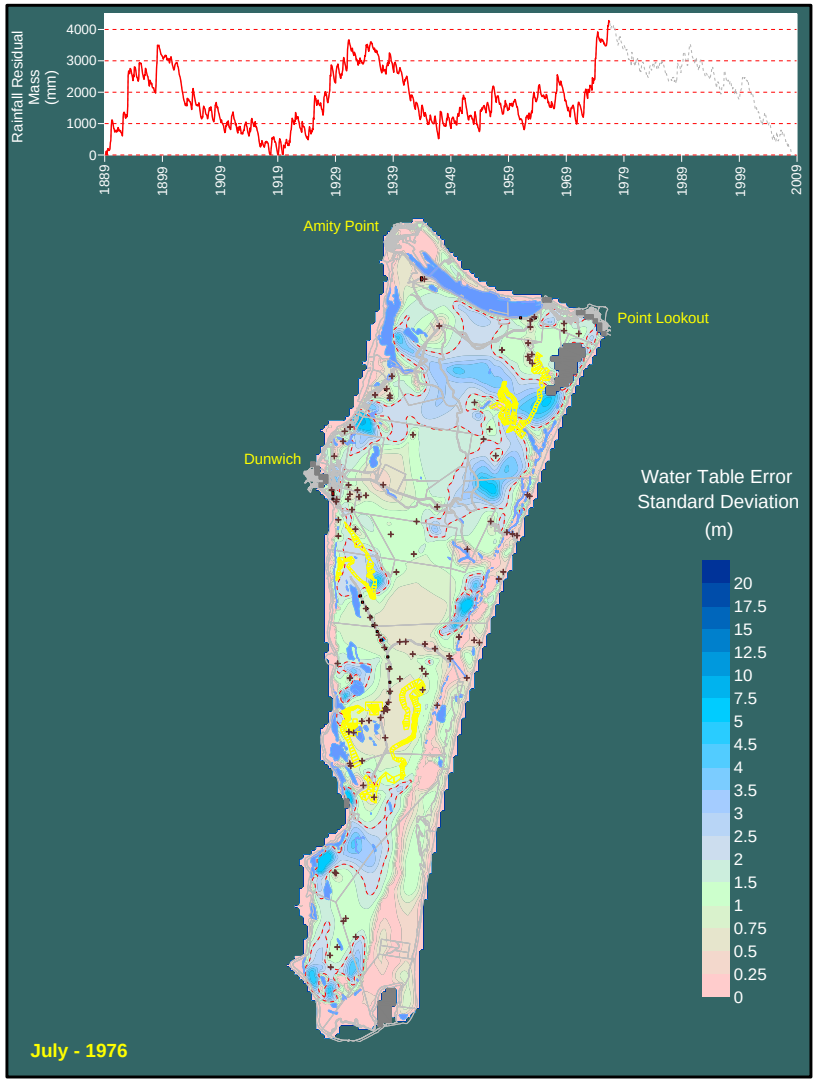
Predictive Scenarios– Extended Wet



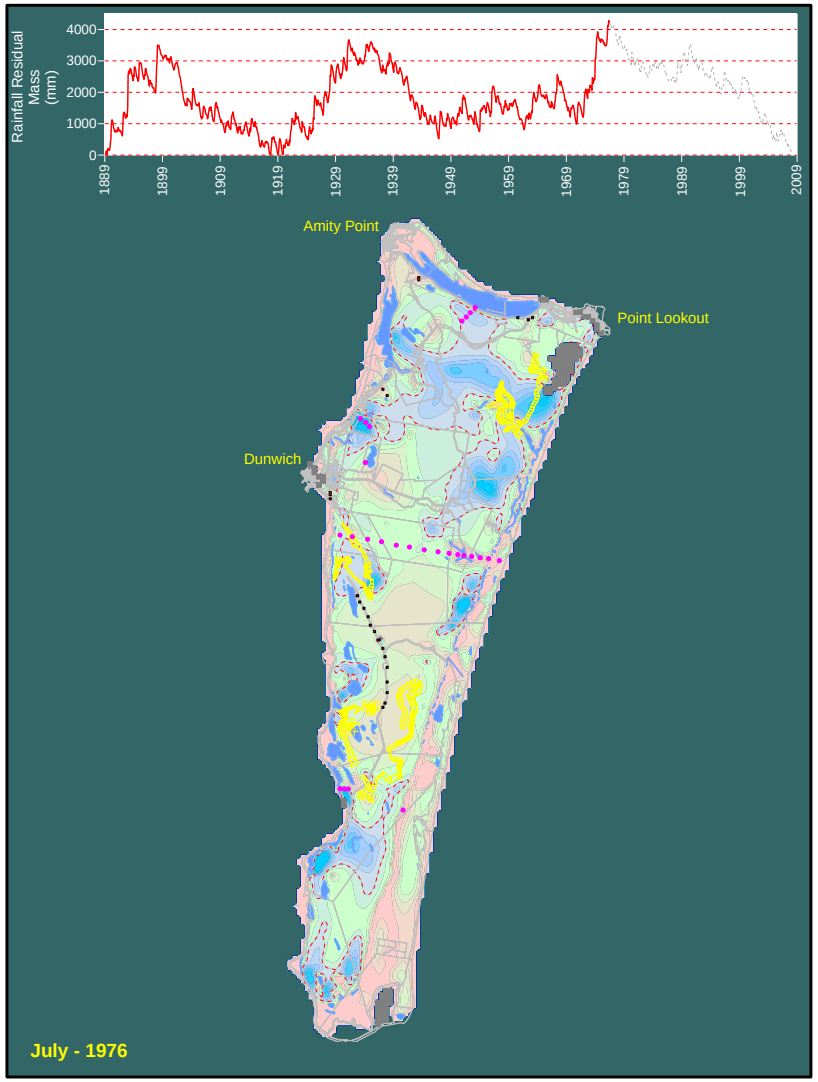
Model Predictive Error Analysis – Extended Wet



Model Predictive Error Analysis – Extended Wet



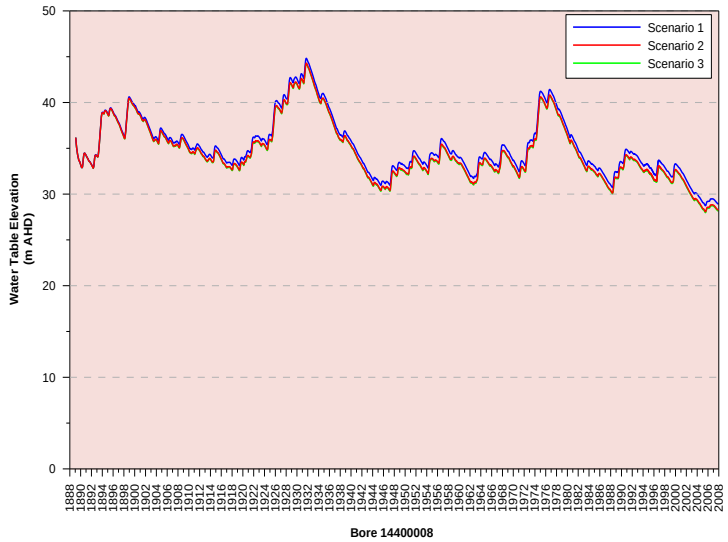
Model Predictive Error Analysis – GDE Locations



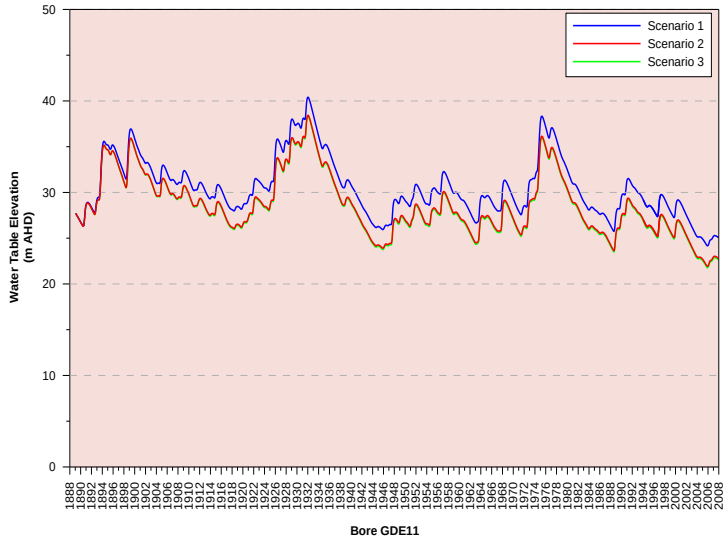
Model Predictive Error Analysis – GDE Locations

GDE	TOPO (mAHD)	STDEV - DRY (m)	STDEV - WET (m)
14400008	64.26	0.62	0.83
14400107	16.44	0.21	0.43
GDE1	5.27	0.27	0.38
GDE2	38.50	0.33	0.26
GDE3	8.54	0.03	0.03
GDE4	53.79	0.31	0.16
GDE5	19.44	0.06	0.04
GDE6	64.13	0.10	0.19
GDE7	96.21	0.48	0.92
GDE8	58.36	0.64	1.18
GDE9	76.13	0.75	1.26
GDE10	130.66	0.66	1.11
GDE11	156.15	0.71	1.13
GDE12	105.12	0.72	1.12
GDE13	82.72	0.86	1.19
GDE14	95.38	0.99	1.26
GDE15	37.48	1.07	1.43
GDE16	91.00	6.13	7.99
GDE17	8.64	0.16	0.40
GDE18	5.41	0.19	0.23
GDE19	76.51	1.45	2.62
GDE20	51.15	1.46	2.51
GDE21	67.08	1.27	2.14
GDE22	114.76	4.68	6.18
GDE23	96.60	3.23	4.49
GDE24	69.07	2.01	3.42
GDE25	74.67	1.56	1.99

Water Table Hydrographs at GDE Locations

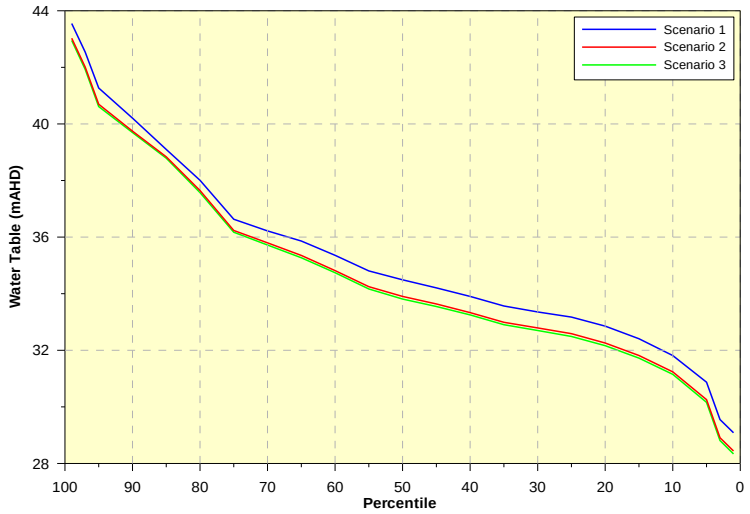


Bore 14400008

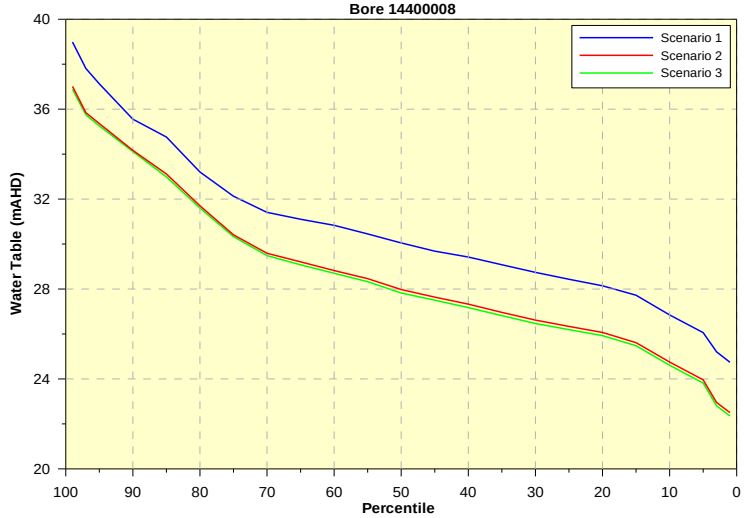


Bore GDE11

Water Table Percentiles at GDE Locations



Bore 14400008



Bore GDE11

Statistics at GDE Locations

Percentiles	Site		
	14400008	14400107	GDE1
1	28.3368	10.2482	2.77942
3	28.8097	10.2708	2.80834
5	30.1609	10.2924	2.8273
10	31.1491	10.3447	2.85893
15	31.7215	10.3892	2.88517
20	32.1624	10.409	2.91246
25	32.488	10.431	2.93444
30	32.6989	10.456	2.95825
35	32.9051	10.477	2.98215
40	33.2495	10.5001	3.00641
45	33.5473	10.5213	3.03552
50	33.812	10.5447	3.06566
55	34.167	10.5715	3.0958
60	34.7416	10.6003	3.12711
65	35.2698	10.6361	3.16621
70	35.7208	10.6769	3.21087
75	36.1732	10.7153	3.25393
80	37.573	10.7585	3.33484
85	38.7904	10.8509	3.41648
90	39.6957	10.9564	3.52814
95	40.6126	11.0897	3.79104
97	41.927	11.1412	3.93591
99	42.9523	11.2602	4.4074
Samples	1368	1368	1368
Minimum	27.9756	10.2116	2.73839
Maximum	44.2169	11.3745	4.84987
Mean	34.6131	10.5985	3.14809
Standard Deviation	3.28131	0.233019	0.313911
Lower 95% CI	34.4392	10.5861	3.13144
Upper 95% CI	34.7871	10.6108	3.16473
Failure Threshold	32.8529	10.4185	2.9126
Number of Failures	459	305	275
Minimum Departure	2.36E-03	2.50E-04	9.51E-05
Date of Minimum Departure	2/12/1989	2/5/1947	2/2/1990
Maximum Departure	4.87726	0.20691	0.174214
Date of Maximum Departure	2/7/2005	2/5/2005	2/11/1902
Percent Time in Failure	32.4713	21.2806	12.9356
Number of Sojourns	15	14	98
Average Duration of Sojourn	900.667	632.429	54.9184
Minimum Duration of Sojourn	28	62	29
Maximum Duration of Sojourn	3926	2312	424

ECOLOGY

Click to add subtitle


Strathpine
Brisbane
Indooroopilly
Redland Bay
Beenleigh
North Stradbroke Island (Minjerribah)
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2009 DigitalGlobe
Image © 2009 Sinclair Knight Merz & Fugro
© 2009 MapData Sciences PtyLtd, PSMA
©2007 Google™
Pointer 27°29'24.01" S 153°13'56.17" E
Streaming 100%
Eye alt 79.21 km

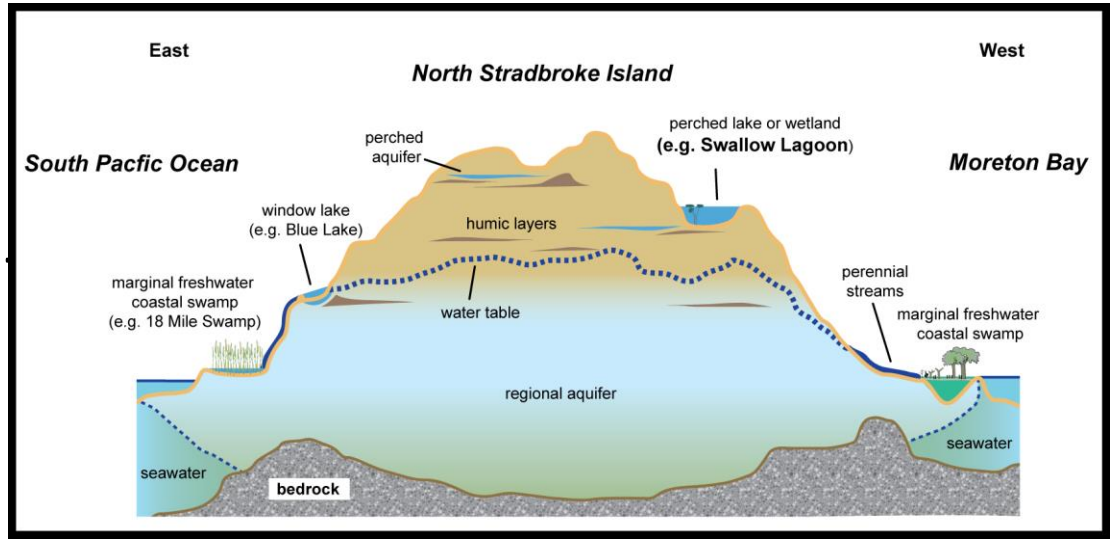
North Stradbroke Island (Minjerribah)

- One of the largest sand islands in the world
- The regional aquifer and numerous perched aquifers support over 70 wetlands
- The ‘millennium’ drought in SE Qld prompted consideration of all potential sources to supplement consumptive water supply
- The regional aquifer of North Stradbroke Island was considered as one potential source
- We undertook a number of collaborative research projects to better understand the risk of water extraction on the island environmental values

Complex eco-hydrology

- Surface-groundwater interactions
- Diverse range of wetland types
  - Lakes
  - Swamps
  - Streams
  - Mangroves
- Significant biodiversi

Endangered Oxleyan Pygmy Perch



Ecological risk assessment for DNRM in 2007/08

- Overton (CSIRO) – Terrestrial vegetation water use
- Marshall et al. (Qld Govt) – Blue Lake Bathymetry
- Specht et al. (UQ) – GDE Asset Inventory
- Page et al. (GU) – Genetic distinctness of NSI fauna
- Hawden (GU) – Coastal freshwater/seawater interface ecosystems
- Tibby et al. (UA) – Palaeolimnology of Blue Lal

- Simulations of groundwater extraction using MODFLOW Hydrological Model (100 m x 100 m grid)

Stability of Blue Lake (Karboora)

- Groundwater window lake
- Culturally and environmentally significant
- Supports population of endangered Pygmy Perch

Multi-proxy approach

- Coring lake sediments
- Pollen, diatoms, macrofossils, isotopes

ARC-linkage Grant (2010–2012)
University of Adelaide, Qld Govt, Sibelco

- Identify past climatic variability in SE Qld, particularly over ~ 6000 years
- Determine response of the landscape and the wetlands to climatic variations
  - Shifts in vegetation
  - Regional water table fluctuations
- Identify the impacts of past climate changes on different types of wetlands across the island (resilience?)
- Determine past vegetation communities, fire frequency, anthropogenic changes
- Provide information to assist water resource planning

Stability of Blue Lake (Karboora)

- 2.3 m sediment core sample collected from 7 metres
- Despite variability in regional climate over recent decades, the depth and water chemistry (inferred from the diatom community) of Blue Lake displayed little variation over the past ca. 7400 years.
- Blue Lake has exhibited exceptional stability and resistance to change, compared to other Australian Holocene lake records.
- This suggests that Blue Lake has been an important climate refuge for aquatic biota in the past and, with appropriate management, should continue in this capacity into the future.

Sediment core

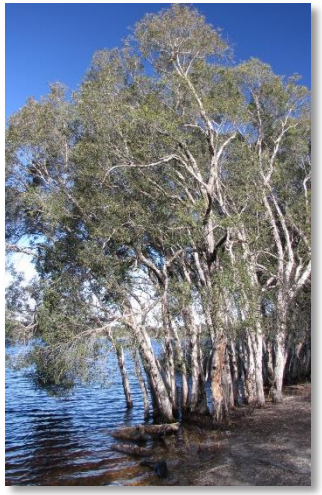
Diatoms

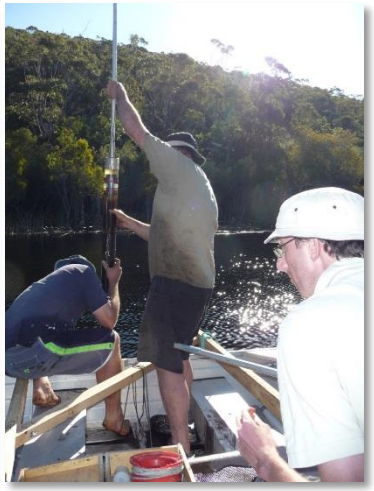
God's bathtub: Australian lake untouched by climate change

- **A UNIQUE Australian lake has remained untouched by climate change for thousands of years, say scientists.**
- **by Margaret Scheikowski**
- **AAP**OCTOBER 15, 2013**4:33PM**

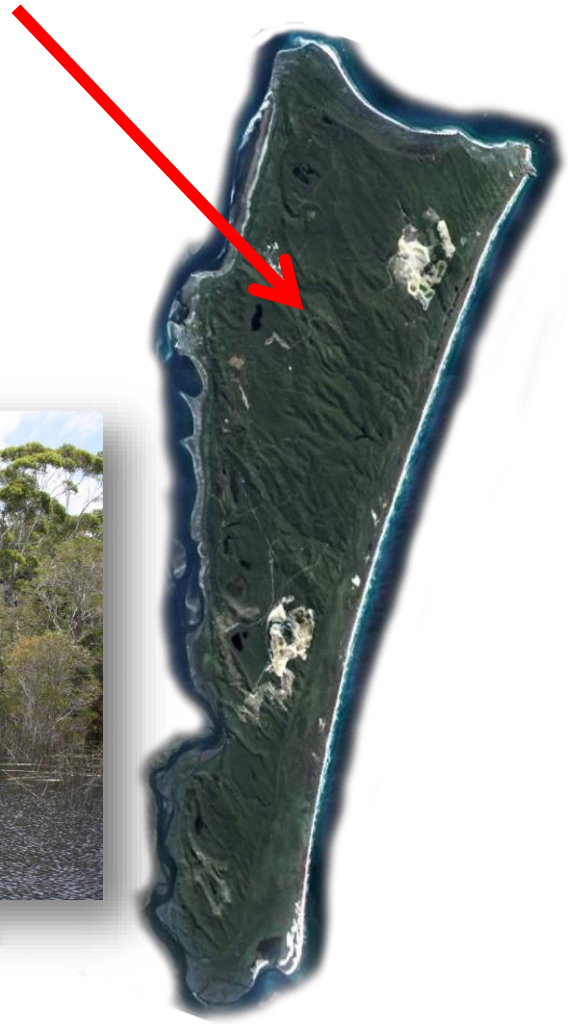
Holocene rainfall reconstruction for SE-Qld

- Swallow Lagoon
- 5.5 m deep perched lake, 151 m above sea level (highest perched dune lake in the world)
- Water level declined >3 m during Millennium Drought
- Unique preservation of leaves (0–7520 yr BP) from a single tree species (*Melaleuca quinquenervia*) in lake sediments





Swallow Lagoon



Holocene rainfall reconstruction for SE-Qld

- Data shows a shift from a generally wet mid-Holocene towards drier and more variable climate after ca. 3200 years before present
- Holocene increases in ENSO variability was primarily driven by increasing strength of the El Nino phase

Sediment core

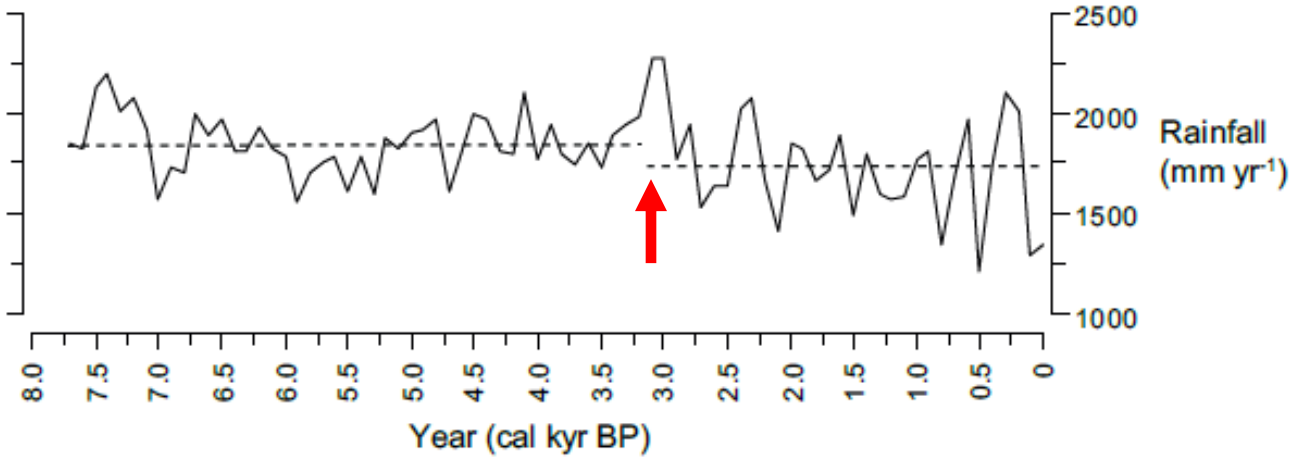


Fig. S5: Rainfall data interpolated to centennial-scale – the lowest temporal resolution of the record – illustrating a shift to drier conditions in the late-Holocene. Dashed lines represent mean inferred rainfall prior to 3.2 cal kyr BP (1844 mm yr^{-1}, σ = 145 mm yr^{-1}) and after 3.2 cal kyr BP (1742 mm yr^{-1}, σ = 267 mm yr^{-1}).

Other allied research activities and outcomes

- Cronology of Eighteen Mile Swamp (Mettham et al. 2011)
- Phylogeographic analyses of freshwater fish and decapod crustaceans (Page et al. 2012)
- Water Balance Model for Perched Lakes and Wetlands on North Stradbroke Island (Harp 2018)
- Variation in leaf wax n-alkane characteristics with climate in the broad-leaved paperbark (Andrae et al. in review)
- Reduced rainfall drives biomass modulation of long-term fire activity in Australia's sclerophyll forests (Mariani et al. in prep)
- Contemporary calibration of wetland algal pigments and phytoplankton community dynamics (ongoing)
- Groundwater–surface water depth monitoring network (ongoing)

18 Scientific papers
>30 Conference presentations
8 Post-graduate students

JOURNAL OF QUATERNARY SCIENCE (2017) 32(6) 770–781 ISSN 0267-8179. DOI: 10.1002/jqs.2981

JQS Journal of Quaternary Science QRA

Persistence of wetlands on North Stradbroke Island (south-east Queensland, Australia) during the last glacial cycle: implications for Quaternary science and biogeography

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DISTRIBUTIONS OF THE FRESHWATER FISH AND AQUATIC MACROINVERTEBRATES OF NORTH STRADBROKE ISLAND ARE DIFFERENTIALLY INFLUENCED BY LANDSCAPE HISTORY, MARINE CONNECTIVITY AND HABITAT PREFERENCE

MARSHALL, J.C., NEGUS, P.M., STEWARD, A.L. & MCGREGOR, G.B.

THE INFLUENCE OF WATER DEPTH ON THE DISTRIBUTION OF THE EMERGENT SEDGE *LEPIRONIA ARTICULATA* (CYPERACEAE) IN TWO DUNE LAKES OF SOUTHERN QUEENSLAND COASTAL WALLUM WETLANDS

MARSHALL, J.C. & McGREGOR, G.B.

Freshwater Biology

Freshwater Biology (2013) doi:10.1111/fwb.12154

Combining monitoring, models and palaeolimnology to assess ecosystem response to environmental change at monthly to millennial timescales: the stability of Blue Lake, North Stradbroke Island, Australia

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journal homepage: www.elsevier.com/locate/quaint

ELSEVIER

A 25,000-year record of environmental change from Welsby Lagoon, North Stradbroke Island, in the Australian subtropics

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Quaternary Science Reviews

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ELSEVIER

Development of a southern hemisphere subtropical wetland (Welsby Lagoon, south-east Queensland, Australia) through the last glacial cycle

Global Change Biology

Global Change Biology (2016) **22**, 3474–3486, doi: 10.1111/gcb.13277

Carbon isotope discrimination in leaves of the broad-leaved paperbark tree, *Melaleuca quinquenervia*, as a tool for quantifying past tropical and subtropical rainfall

JOHN TIBBY[1,2], CAMERON BARR[1,2], FRANCESCA A. MCINERNEY[2,3], ANDREW C. G. HENDERSON[4], MELANIE J. LENG[5,6], MARGARET GREENWAY[7], JONATHAN C. MARSHALL[8], GLENN B. MCGREGOR[8], JONATHAN J. TYLER[2,3] and VIVIENNE MCNEIL[8]
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Collaborations to date

- University of Adelaide
- The University of Queensland
- Newcastle University, England
- University of Nottingham
- British Geological Survey
- Griffith University
- University of Sydney
- University of Arizona
- University of Melbourne
- University of Michigan
- University of Wellington
- Sibelco
- CSIRO Land and Water
- QYAC

Summary

- North Stradbroke Island contains the highest concentration of ancient wetlands in Australia (600 to 280,000 years old)
- Many are remarkably stable in response to past climate
- Despite European settlement, most may be resilient to climate change due to interaction with groundwater systems
- Some are clearly vulnerable and require improved understanding for their effective management
- Swallow Lagoon study of international significance
- Collective findings have informed:
  - water policy and management
  - climate variability and water security for SEQ
  - NRM activities on the island

Acknowledgment

- We acknowledge Minjerribah (NSI) and the surrounding waters as Quandamooka Country.
- We thank Aunty Marg and Minjerribah Moorgumpin elders for their support of this research.