

**Report
on

Water Resources Component
Cocos (Keeling) Islands GIS**

**by
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**prepared for
Cocos Island Administration,
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&
the Australian Geological Survey Organisation**

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Abbreviations

AGSO Australian Geological Survey Organisation

DTRS Department of Transport and Regional Services

1. Executive Summary

1.1. Introduction

As outlined in the “Proposal for developing water resources ‘layers’ for the Cocos GIS”, water resources data has been collated and entered into digital format for the following islands on the South Keeling atoll of the Cocos (Keeling) Islands;

- Home Island,
- West Island, and
- South Island.

The following data layers have been collated on a CD in ArcView shapefile format:

- Locations of freshwater lenses showing boundaries as best current information will allow.
- Locations of salinity monitoring and pollution monitoring boreholes, including co-ordinates.

Additional data and information on the CD includes:

- Tabular and graphical data showing variation of salinity (expressed in electrical conductivity units) monitoring borehole data. Data collected covers the full period of record from commencement of monitoring to late 2000.
- Tabular water quality data have been obtained from the pollution monitoring boreholes between 1998 and early 2001.
- Locations of pumping wells and manholes at the Settlement and galleries on Home Island and in the northern part of West Island (for former Quarantine Station and horticultural block), as best current information will allow.
- List of relevant reports and additional reference information.

1.2. Outputs

As required, outputs of this project include:

- Water resources layers with spatial data and attribute data on a CD (entitled Cocos Water Resources CD). This CD will be made available to the Australian Geological Survey Organisation for incorporation into the overall Cocos GIS and for subsequent distribution to the Cocos Island Administration, the Department of Transport and Regional Services and other authorised users. Separate copies of the CD can be made available, on request, to the Cocos Island Administration and the Department of Transport and Regional Services.
- This report summarising the data layers on the accompanying CD.

1.3. Recommendations

(a) Need for greater accuracy of some locations

While this project has mapped boreholes and water supply pumping infrastructure as accurately as possible, it is recommended that the location of boreholes and pumping wells be obtained more accurately in the field. In particular, boreholes and pump wells in the northern part of West Island should be more accurately located with differential GPS or surveyed by standard procedures. In addition, the position of gallery 8 in the northern part of Home island should be more accurately located once as-constructed drawings are finalised by others.

(b) Need for updating of water quality data at 2 year intervals

The water quality data obtained from boreholes and other sites (e.g. gallery pump wells) is obtained at regular intervals and databases are updated as part of regular monitoring program. It is recommended that the water resources information contained in this GIS be updated at appropriate intervals (e.g. every 2 years).

2. Data Location and CD Structure

The Cocos Water Resources CD consists of the following files and directories:

- Cocos.apr file
- Data directory
- Documentation directory

Details of each of these are described below:

2.1. Cocos.apr

“Cocos.apr” is an Arcview project which includes base data from “Cocos (Keeling) Islands GIS Stage 1 Report” CD data, and rectified aerial photography, as obtained from AGSO.

The project is in the same projection as the base data using Cocos (Keeling) Islands Grid 1992 (CKIG92) projection.

The project is set up with six Views:

- (a) Cocos Islands Working View. (Views the entire Cocos Island water resources data set including all data sets.)
- (b) West Island South View. (Detailed View of southern part of West Island including the airfield and Settlement showing boreholes, pumping wells and the approximate boundary of the “Airfield” freshwater lens.)
- (c) West Island North View. (Detailed View of northern part of West Island showing boreholes, galleries for former Quarantine Station and horticultural block and the approximate boundary of the “West Island Northern” freshwater lens.)
- (d) Home Island View (Detailed View of Home Island showing boreholes and approximate boundary of “Home Island Main” and “Home Island Northern” freshwater lenses.)
- (e) South Island View. (Detailed View of South Island showing boreholes and approximate boundary of freshwater lenses.)
- (f) Home Island Infiltration Galleries View. (Detailed View of Home Island, including boreholes and Infiltration Gallery Layouts.).

The hotlink tool (in all views of Cocos.apr) has been set up to connect salinity monitoring borehole locations with graphs showing the change in salinity from 1987 through to 2000 at each borehole. To access the hotlink, click on the hotlink button and then click on a borehole point. This will bring up an image of the graph in Internet Explorer.

There are also six layout windows (A4 paper size), one per view.

2.2. Documentation Directory

The contents of the Documentation Directory are summarised in the table below.

Contents of the Documentation Directory

File Name and Type	Properties/Description
Report.doc	- Summary of Data collection process, and data collected - Outlines the type and location of data on the CD - Outlines the metadata for all shapefiles on the CD - Lists other references to the data, and includes other sources of information for Cocos Islands water resources
Cocos Gallery Cross section (from Woodroffe and Falkland, 1997).bmp	Cross sectional Diagram of a buried infiltration gallery (Home island type)
Salinity_monitoring_bore.bmp	Cross sectional Diagram of a Salinity Monitoring Borehole
Pollution_monitoring_bore.bmp	Cross sectional Diagram of a Pollution Monitoring Borehole

2.3. Data Directory

The Data Directory consists of the following sub-directories:

- Shapefiles sub-directory
- Images sub-directory
- Excel&dbf sub-directory

2.3.1. Shapefiles Sub-Directory

The contents of the shapefiles sub-directory are summarised in the table below. Additional metadata for each shapefile, has been recorded in the metadata section of this report.

Contents of the Shapefiles sub-directory

Shapefile Name	Description
Bores.shp	Point location of salinity and pollution monitoring boreholes on all islands
Homeis_Galleries.shp	Line location of buried infiltration galleries on Home Island on Home Island
Homeis_Saline_testpts.shp	Point location of salinity testing sites situated on an infiltration gallery on Home Island
Homeis_Pumpst.shp	Point location of pump stations, pumping from an infiltration gallery on Home Island
Homeis_Manholes.shp	Point location of manholes providing access to infiltration galleries on Home Island
Homeis_lens.shp	Polygon shapefile, delineating the approximate location of the freshwater lens on Home Island
Homeislens_line.shp	Line shapefile, outlining the approximate boundary of the freshwater lens on Home Island

Westis_lens.shp	Polygon shapefile, delineating the approximate location of the freshwater lens on West Island
Westislens_line.shp	Line shapefile, outlining the approximate boundary of the freshwater lens on West Island
Westis_pumpst.shp	Point location of pump stations, pumping from an infiltration gallery on West Island
Westis_manholes.shp	Point location of manholes providing access to infiltration galleries on West Island
Westis_galleries.shp	Line location of buried infiltration galleries on West Island
Southis_lens.shp	Polygon shapefile, delineating the approximate location of the freshwater lens on South Island
Southis_lensli.shp	Line shapefile, outlining the approximate boundary of the freshwater lens on South Island
Possiblelens_extent.shp	Line shapefile indicating the possible further extent of the freshwater lens on Home Island.
Cocos_line.shp, Cocos_land.shp, and Cocos.shp	Base data collected in the initial data collection and stored on the "Cocos Stage 1 CD.

2.3.2. Images Sub-Directory

There are 89 Mr Sid rectified images for the whole of South Keeling atoll in the images sub-directory. Mr Sid files can only be read in ArcView if the Mr Sid Image Support extension tool has been selected via the files/extension menu.

2.3.3. Excel&dbf Sub-Directory

The contents of the Excel&dbf sub-directory are summarised in the table below.

Contents of the Excel&dbf sub-directory

File Name and Type	Properties/Description
AGAL_test_results_environmental_galleries&borholes.xls	Water quality data from both galleries and pollution monitoring boreholes. Data has been recorded for June 1998, April 1999, May 1999, June 2000, April 2000, October 2000 and January 2001.
Cocos_bore_data.xls	Cocos borehole salinity data from 1987 to 2000, at approximately 3 month intervals.
Graphs_Images sub-Directory	This sub-directory contains 82 files in wmf and jpg format showing graphs of salinity (electrical conductivity or EC) variations for each salinity monitoring borehole over the full period of monitoring. The monitoring periods vary according to the year of drilling, the earliest being 1987. The graphs show the depth below ground surface to the following salinity (EC) values: 1000, 2500, 10,000, 25,000 and 40,000 $\mu\text{S}/\text{cm}$, based on linear interpolation from measurements at specific depths. These EC values correspond to salinities of 2%, 5%, 20%, 50% and 80% of seawater.

3. Shapefiles Metadata

All shapefiles collected on the CD have been converted to Cocos (Keeling) Islands Grid 1992 (CKIG92) projection, World Geodetic System 1984 (WGS 84) Datum. Metadata and a description of each shapefile is provided below.

3.1. Bores.shp

The 'bores' shapefile contains point locations of salinity monitoring and pollution monitoring boreholes.

Accuracy: Data was originally digitised from points surveyed by Nolan and Partners Surveyors, Perth. Points have been modified based on data collected from hand drawn maps, reports and local island knowledge (see references). Accuracy is within $\pm 20\text{m}$ for 80% of the points. 20% of the points, especially some of those situated on the northern part of West Island and Home Island have an accuracy of $\pm 50\text{m}$.

Field	Properties/Description
Shape	Shapefile type (points)
Label	Borehole Labels (Excluding Island Prefix)
Borehole	Borehole Name (Including Island Prefix)
Bore Type	Salinity or Pollution Monitoring Borehole
Graph_link	Hotlink to Graphs of salinity (EC) v's time for each borehole
x-coord	X coordinates of boreholes in CKIG92, WGS 84 projection
y-coord	Y coordinates of boreholes in CKIG92, WGS 84 projection

3.2. Homeis_Galleries.shp

Homeis_Galleries.shp is a line shapefile showing location of infiltration galleries.

Accuracy: Lines have been recorded based on data collected from hand drawn maps and reports and local knowledge (see references). Location of Galleries should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (line)
ID	Identifier
Name	Gallery Name and Number

3.3. Homeis_Pumpst.shp

The 'Homeis_Pumpst' shapefile contains point locations of water pumping wells, either as part of an infiltration gallery (Home Island and northern West Island) or as wells with short lateral pipes (West Island Settlement).

Accuracy: Points have been recorded based on data collected from hand drawn maps and reports (see references). Location of pumping wells should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (points)
Id	Identifier
Code	Name and number of Pump station

3.4. Homeis_Manholes.shp

The 'Homeis_Manholes' shapefile contains point locations of manholes providing access to infiltration galleries shown in "homeis_galleries.shp".

Accuracy: Points have been recorded based on data collected from hand drawn maps and reports (see references). Location of manholes has been based on the location of infiltration galleries, therefore the location of manholes should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (points)
Id	Identifier

3.5. Homeis_Saline_testpts.shp

The 'Homeis_saline_testpts' shapefile contains point locations of salinity testing sites located along Home Island infiltration galleries.

Accuracy: Points have been recorded based on data collected from hand drawn maps and reports (see references). Location of salinity testing points has been based on the location of infiltration galleries. Therefore, the location of salinity testing points should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (points)
ID	Identifier
Name	Gallery Name and Number of the test point

3.6. Homeis_lens.shp

The 'Homeis_lens' shapefile contains polygon data indicating the approximate boundary of the Home Island freshwater lenses.

Accuracy: See comments under Westis_lens.shp.

Field	Properties/Description
Shape	Shapefile type (polygons)
Fid	Identifier
Perimeter	Total lens perimeter
Area	Total lens area

3.7. Homeislens_line.shp

The 'Homeislens_line' shapefile contains line data indicating the approximate boundary of the Home Island freshwater lenses.

Accuracy: See comments under Westis_lens.shp.

Field	Properties/Description
Shape	Shapefile type (line)
Id	Identifier
Fid	Identifier
Length	Line length

3.8. Westis_Galleries.shp

Westis_Galleries.shp is a line shapefile showing location of infiltration galleries.

Accuracy: Lines have been recorded based on data collected from hand drawn maps and reports and local knowledge (see references). Location of Galleries should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (line)
ID	Identifier
FID	Identifier
Name	Gallery Name and Number

3.9. Westis_Pumpst.shp

The 'Westis_Pumpst' shapefile contains point locations of water pumping wells, either as part of an infiltration gallery (Home Island and northern West Island) or as wells with short lateral pipes (West Island Settlement).

Accuracy: Points have been recorded based on data collected from hand drawn maps and reports (see references). Location of pumping wells should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (points)
Id	Identifier
FID	Identifier
Code	Name and number of Pump station

3.10. Westis_Manholes.shp

The 'Westis_Manholes' shapefile contains point locations of manholes providing access to infiltration galleries shown in "homeis_galleries.shp".

Accuracy: Points have been recorded based on data collected from hand drawn maps and reports (see references). Location of manholes has been based on the location of infiltration galleries, therefore the location of manholes should fall within $\pm 20\text{m}$ accuracy.

Field	Properties/Description
Shape	Shapefile type (points)
FID	Identifier
Id	Identifier

3.11. Westis_lens.shp

The 'Westis_lens' shapefile contains polygon data indicating the approximate boundary of the West Island freshwater lenses.

Accuracy: Estimated extent of the freshwater boundary is based on information from salinity monitoring boreholes and some estimation based on knowledge of freshwater lens behaviour near the edges of coral islands. The boundaries are somewhat subjective and in fact are not fixed as they will move according to wet and dry periods. Hence, it is difficult to provide a general accuracy estimate. It could be said that the freshwater lens boundary would normally be within $\pm 30\text{m}$ of the boundary shown, but that this could be greater during very dry or very wet periods

Field	Properties/Description
Shape	Shapefile type (polygons)
Fid	Identifier
Perimeter	Total lens perimeter
Area	Total lens area

3.12. Westislens_line.shp

The 'Westislens_line' shapefile contains line data indicating the approximate boundary of the West Island freshwater lenses.

Accuracy: See comments under Westis_lens.shp.

Field	Properties/Description
Shape	Shapefile type (line)
Id	Identifier
Fid	Identifier
Length	Line length

3.13. Possiblelens_extent.shp

The 'Possiblelens_extent' shapefile contains line data indicating possible further extent of the freshwater lenses on Home Island.

Accuracy: See comments under Westis_lens.shp.

Field	Properties/Description
Shape	Shapefile type (line)
Id	Identifier

3.14. Southis_lens.shp

The 'Southis_lens' shapefile contains polygon data indicating the approximate boundary of the South Island freshwater lenses.

Accuracy: See comments under Westis_lens.shp.

Field	Properties/Description
Shape	Shapefile type (polygons)
Fid	Identifier
Area	Total lens area
Perimeter	Total lens perimeter

3.15. Southis_lensli.shp

The 'Southis_lensli' shapefile contains line data indicating the approximate boundary of the South Island freshwater lens.

Accuracy: See comments under Westis_lens.shp.

Field	Properties/Description
Shape	Shapefile type (line)
Id	Identifier
Length	Line length

3.16. Cocos_line.shp, Cocos_land.shp and cocos.shp

These shapefiles have been used as base data, from the original Cocos stage 1 CD. Data type and accuracy relates directly to initial data collection, carried out by AGSO. This has been reported in:

'Cocos (Keeling) Islands GIS Stage 1 Report' for Territories Office, DTRS, K Porritt, B McKay and A Lucas, AGSO, 10/2/2000.

4. List of References

(a) Reports (prepared by former Department of Housing & Construction and by ACTEW Corporation and Ecowise Environmental)

Falkland A.C. (1988). Cocos (Keeling) Islands Water Resources and Management Study. Report HWR 88/12. Hydrology and Water Resources Section, ACT Electricity and Water. prepared for Australian Construction Services, WA Region.

Falkland A.C. (1991). Cocos (Keeling) Islands. South Island Water Resources Study. Report HWR 91/002. prepared for the Cocos (Keeling) Islands Administration and the Cocos (Keeling) Islands Section of the Department of the Arts, Sport, the Environment, Tourism and Territories.

Falkland A.C. (1992). Cocos (Keeling) Islands. Review of Groundwater Resources on Home and West Islands. Report HWR 92/001. prepared for Australian Construction Services, Department of Administrative Services.

Falkland A.C. (1992). Cocos (Keeling) Islands. Further Investigations of the Northern Freshwater Lens, West Island. Report HWR92/002, Hydrology and Water Resources Branch, ACT Electricity and Water. prepared for Australian Construction Services, Department of Administrative Services.

Falkland A.C. (1993). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos HWR93/01 to HWR93/06. Hydrology and Water Resources Branch, ACT Electricity and Water. prepared for Asset Services, Cocos (Keeling) Islands.

Falkland A.C. (1994). Home Island water supply options. Rpt No. HWR94/05, ACT Electricity and Water Canberra, Australia, prepared for Cocos (Keeling) Islands Section, Territories Branch, Department of the Arts, Sport and Territories

Falkland A.C. (1994). Cocos (Keeling) Islands. South Island Water Supply Scheme, Preliminary Design & Costs. Report HWR94/01, Hydrology and Water Resources Branch, ACT Electricity and Water. prepared for Australian Construction Services, Department of Administrative Services.

Falkland A.C. (1994). Cocos (Keeling) Islands. Water Monitoring Reports. Reports Nos HWR94/02 (Jan-Feb), HWR94/06 (Mar-Apr), HWR94/07 (May-Jun), HWR94/08 (Jul-Aug), HWR94/10 (Sep-Oct), HWR95/04 (Annual). Hydrology and Water Resources Branch, ACT Electricity and Water. prepared for Asset Services, Cocos (Keeling) Islands.

Falkland A.C. (1995). Cocos (Keeling) Islands. Guidelines for Water Supply Galleries. Report No HWR94/09. Hydrology and Water Resources Branch, ACT Electricity and Water. prepared for Asset Services, Cocos (Keeling) Islands.

- Falkland A.C. and Pink B.J. (1995). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos HWR95/07 (Jan-Mar), HWR95/08 (Apr-Jun), HWR95/11 (Jul-Sep), HWR96/03 (Annual). Hydrology Services, ACTEW Corporation, prepared for Asset Services, Cocos (Keeling) Islands.
- Pink B.J. and Falkland A.C. (1996). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos HWR96/05 (Jan-Mar), HWR96/07 (Apr-Jun), HWR96/09 (Jul-Sep), HWR97/01 (Annual). Ecwise Environmental, ACTEW Corporation. prepared for Asset Services, Cocos (Keeling) Islands.
- Falkland A.C. (1997). Drilling of Salinity and Environmental Pollution Monitoring Boreholes, Cocos (Keeling) Islands. Report No HWR96/10, ECOWISE Environmental, ACTEW Corporation, prepared for WORKS Australia, April 1997.
- Alam K. and Falkland A.C. (1997). Home Island Groundwater Modelling and Potential Future Groundwater Development. Report No HWR97/02, ECOWISE Environmental, ACTEW Corporation, prepared for WORKS Australia, April 1997.
- Falkland A.C. (1997). Drilling of Salinity and Environmental Pollution Monitoring Boreholes, Cocos (Keeling) Islands. Report HWR96/06, Ecwise Environmental, ACTEW Corporation. prepared for Works Australia, March 1997.
- Pink B.J. and Falkland A.C. (1997). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos HWR97/06 (Jan-Mar), HWR97/07 (Apr-Jun), HWR97/12 (Jul-Sep), HWR98/01 (Annual). Ecwise Environmental, ACTEW Corporation. prepared for Asset Services, Cocos (Keeling) Islands.
- Falkland A.C. (1998). Report on May 1998 Drilling Program (further salinity and environmental pollution monitoring boreholes), Cocos (Keeling) Islands. Report HWR98/09, Ecwise Environmental, ACTEW Corporation. prepared for GHD Pty Ltd and the Cocos Islands Administration, June 1998.
- Falkland A.C. (1998). Report on Monitoring at New Boreholes, Northern Part of Home Island. Report HWR98/09, Ecwise Environmental, ACTEW Corporation. prepared for GHD Pty Ltd and the Territories Office, Department of Transport and Regional Development, September 1998.
- Falkland A.C. (1998). Report on Water Quality Test Results from Pollution Monitoring Boreholes. Report HWR98/19, Ecwise Environmental, ACTEW Corporation. prepared for GHD Pty Ltd and the Territories Office, Department of Transport and Regional Services, October 1998.
- Pink B.J. and Falkland A.C. (1998). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos EHYD98/07 (Jan-Mar), EHYD98/11 (Apr-Jun), EHYD98/171 (Jul-Sep), EHYD99/03 (Annual). Ecwise Environmental, ACTEW Corporation. prepared for Cocos Island Administration, Cocos (Keeling) Islands.
- Falkland A.C. (1999). Cocos (Keeling) Islands. Guidelines for Water Supply Galleries – Revision 1. Report No EHYD99/02, Ecwise Environmental, ACTEW Corporation.. prepared for GHD Pty Ltd and the Territories Office, Department of Transport and Regional Services, March 1999.
- Barratt R. & Falkland A.C. (1999). Report on Water Quality Test Results from Pollution Monitoring Boreholes, Stage 2, Cocos (Keeling) Islands. Report EHYD99/05, Ecwise Environmental, ACTEW Corporation. prepared for GHD Pty Ltd and the Territories Office, Department of Transport and Regional Services, May 1999.
- Pink B.J. and Falkland A.C. (1999). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos EHYD99/06 (Jan-Mar), EHYD99/10 (Apr-Jun), EHYD99/12 (Jul-Sep), EHYD99/15 (Annual). Ecwise Environmental, ACTEW Corporation. prepared for Cocos Island Administration, Cocos (Keeling) Islands.
- Falkland A.C. (2000). Report on Water Quality Test Results at Monitoring Boreholes and Water Supply Galleries, Home and West Islands, Cocos (Keeling) Islands. Report No EHYD99/16. prepared for Cocos Island Administration, Cocos (Keeling) Islands, February 2000.
- Pink B.J. and Falkland A.C. (2000). Cocos (Keeling) Islands. Water Monitoring Reports. Report Nos EHYD2000/01 (Jan-Mar), EHYD2000/03 (Apr-Jun), EHYD2000/04 (Jul-Sep), EHYD2001/01

(Annual). Ecowise Environmental. prepared for Cocos Island Administration, Cocos (Keeling) Islands.

Falkland A.C. (2000). Fresh Groundwater Resources at Quarantine Station, West Island, Cocos (Keeling) Islands. Report on current state of knowledge and recommendations regarding future development. Report No EHYD2000/05, Ecowise Environmental, prepared for Cocos Island Administration, December 2000.

(b) Papers and journal articles

Falkland, A.C. (1994). Climate, Hydrology and Water Resources of the Cocos (Keeling) Islands. Atoll Research Bulletin, No. 400.

Falkland, A.C. (1994). Management of Freshwater Lenses on Small Coral Islands. Proc. Water Down Under '94 Conference, Adelaide, Australia, November, No. 1, 417-422.

Woodroffe C. D and Falkland A.C. (1997). Geology and hydrogeology of the Cocos (Keeling) Islands, Chapter 31, in Geology and Hydrogeology of Carbonate Islands, Developments in Sedimentology 54 (editors Vacher, H.L. and Quinn, T.M., 1997, Elsevier, Amsterdam, 948 pp.

Cocos (Keeling) Islands

Pacific Ocean

Home Island

South Keeling Lagoon

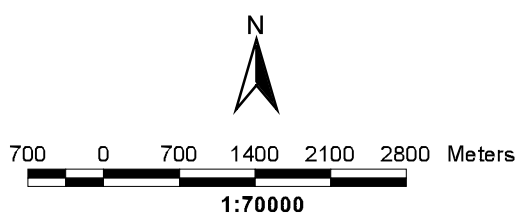
West Island (North)

West Island (South)

South Island

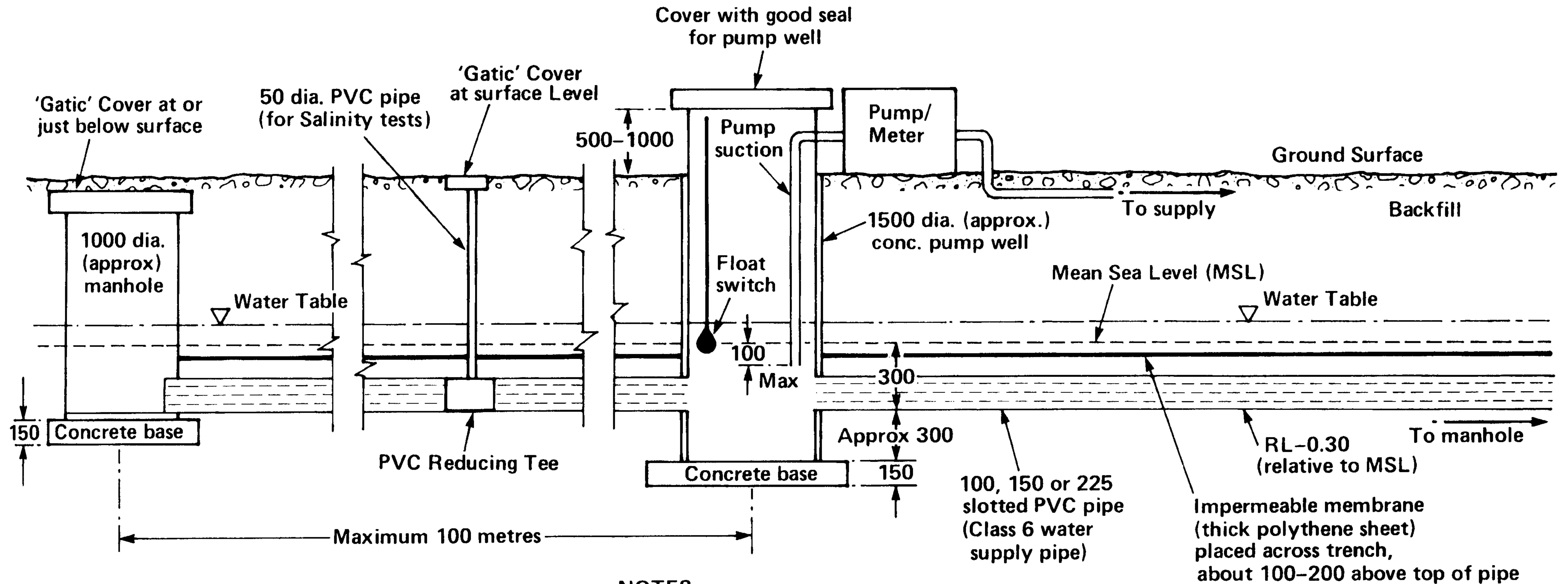
Map Legend

-  Approximate Boundary of Freshwater Lens
-  Cocos (Keeling) Islands
-  Possible further extent of freshwater lens



Projection: CKIG 1992
Datum: WGS 84





NOTES:

1. All joints between pipes and pump wells/manholes to be well sealed
2. Float switch level to be as close above base of pump suction as possible (without causing vortex)
3. Optional housing over pump well and pump/meter (not shown)
4. All figures in mm but drawing not to scale



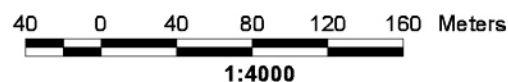
Cocos (Keeling) Islands

Home Island Infiltration Galleries

Map Legend

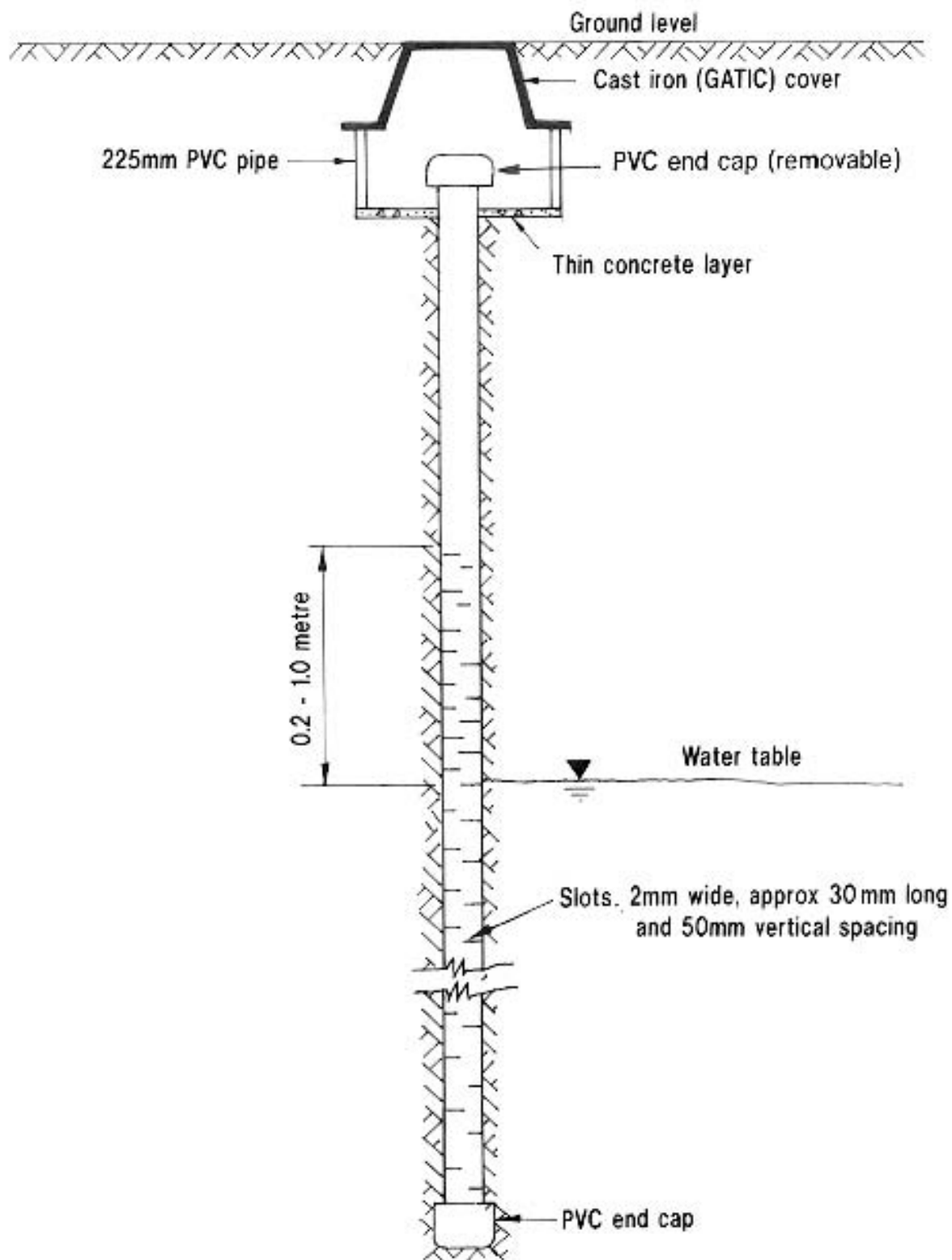
Boresholes

- Pollution Monitoring
- Salinity Monitoring
- Salinity Test Points
- ▲ Pumping Stations
- ⊕ Manholes
- Gallery Pipes
- Approximate Boundary of Freshwater Lens
- - - Possible further extent of Freshwater lens



Projection: CKIG 1992
Datum: WGS 84





Pollution monitoring borehole: Typical installation

Cocos (keeling) Islands Home Island

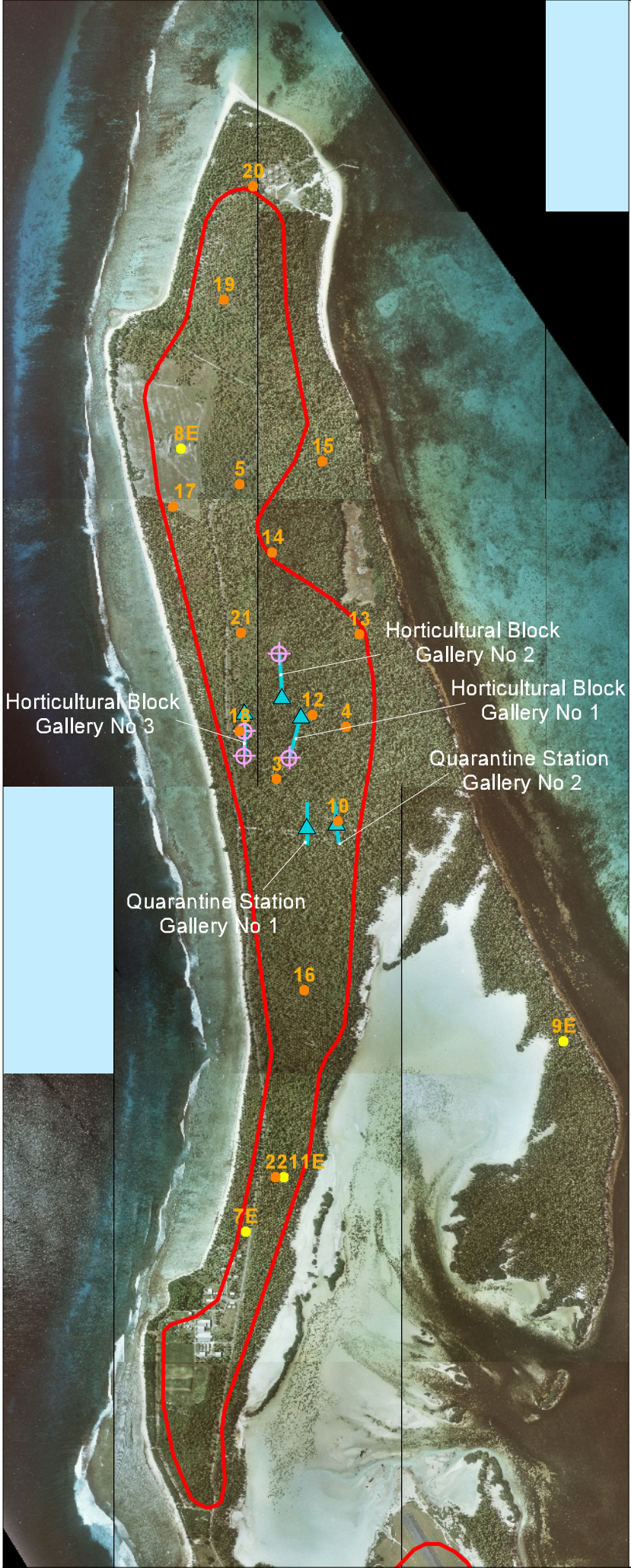
Map Legend

- Boresholes
- Pollution Monitoring
 - Salinity Monitoring
- Possible further extent of freshwater lens
- Approximate Boundary of Freshwater Lens



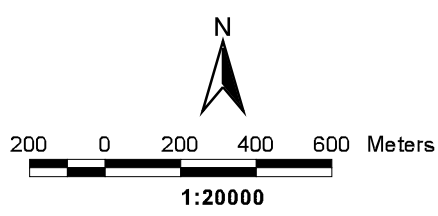
Cocos (keeling) Islands

West Island (North)



Map Legend

- Boresholes
- Pollution Monitoring
 - Salinity Monitoring
 - Pumping Stations
 - Manholes
 - Infiltration Gallery
 - Approximate Boundary of Freshwater Lens



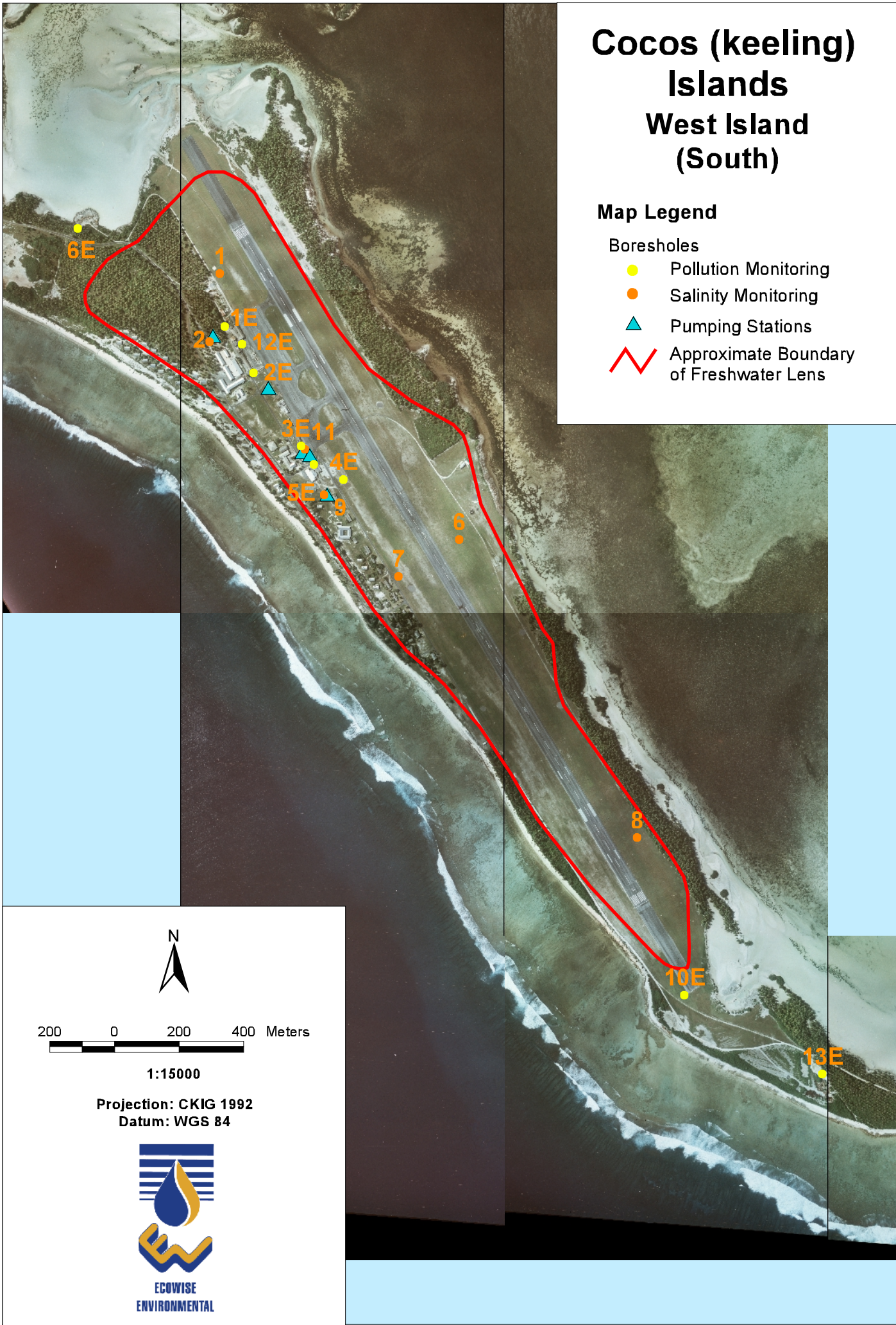
Projection: CKIG 1992
Datum: WGS 84

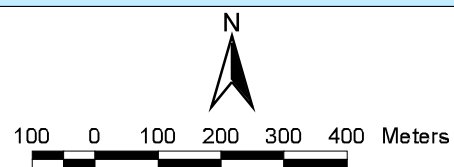


Cocos (keeling) Islands West Island (South)

Map Legend

- Boresholes
- Pollution Monitoring
 - Salinity Monitoring
 - ▲ Pumping Stations
 - ↗ Approximate Boundary of Freshwater Lens





1:12000

Projection: CKIG 1992
Datum: WGS 84

Cocos (keeling) Islands

South Island

Map Legend

Boreholes

- Pollution Monitoring
- Salinity Monitoring
- ~ Approximate Boundary of Freshwater Lens



