The Automated Delimitation of Maritime Boundaries - An Australian Perspective

P.A. Collier, B.A. Murphy, D.J. Mitchell and F.J. Leahy, Department of Geomatics, The University of Melbourne, Australia

Determining the accurate location of maritime boundaries and computing the outer limits of the extended continental shelf can be a mathematically demanding and computationally intensive task. This paper considers the relevant issues, particularly from an Australian perspective. An efficient and automated solution to maritime boundary and extended continental shelf delimitation has been designed and implemented in the form of a software package known as MarZone. This paper introduces the MarZone software. In the design of MarZone, emphasis was placed on a geodetically rigorous methodology while at the same time maintaining strict agreement with the relevant provisions of the United Nations Convention on the Law of the Sea. The reasons for such an emphasis are explained in the paper.

Keywords

Maritime boundaries, boundary delimitation, software, United Nations Convention on the Law of the Sea, territorial sea baseline, territorial sea, exclusive economic zone, extended continental shelf

Introduction

The United Nations Convention on the Law of the Sea (UNCLOS) establishes the jurisdictional regimes under which a coastal State can claim, manage and utilise its ocean territories. With an increasing need to administer competing interests in ocean and seabed resources and the requirement to ensure sustainable exploitation of these resources, Australia has embarked upon an ambitious program to redefine its maritime zone boundaries, including the outer limits of the extended continental shelf, to an unprecedented level of accuracy. For this purpose, comprehensive maritime boundary delimitation software has been developed. This software, known as MarZone, takes full account of the provisions and requirements of UNCLOS, while at the same time employing a rigorous geodetic methodology to provide an automated solution to the maritime boundary delimitation problem.

Maritime Boundary Administration in Australia

As the world's largest island, Australia has a coastline length of approximately 36,700 kilometres, which is amongst the longest of any coastal State. Apart from Papua New Guinea and the Republic of Indonesia lying immediately to the north, Australia's relative isolation from other coastal States enables it to claim one of the largest maritime jurisdictions in the world, extending into the Indian, Southern and Pacific Oceans.

Proclaimed in August 1994, the Australian Exclusive Economic Zone (AEEZ) covers an area of 11.1 million square kilometres (sq km) of which 8.6 million sq km lie off the Australian mainland, while a further 2.5 million sq km lie off the Australian Antarctic Territory (AAT). Beyond the AEEZ, Australia may be entitled to claim an extended continental shelf that covers an estimated 4.6 million sq km (Kaye, 1995). The extent of the AEEZ associated with continental Australia, together with several areas of claimable extended continental shelf, are shown in Figure 1.

Following ratification of UNCLOS on 5 October 1994, Australia became an original Party to the Convention when it entered into force on 16 November in the same year. Under the provisions of Annex II, Article 4 of the Convention, a coastal State seeking entitlement to extended continental shelf must lodge a claim, together with supporting scientific and technical data, with the United Nations Commission on the Limits of the Continental Shelf (CLCS) within ten years of the Convention entering into force for that State. However, at the Eleventh meeting of States Parties to UNCLOS, held in New York in May 2001, it was resolved that:

> *In the case of a State Party for which the Convention entered into force before 13 May 1999, it is understood that the ten-year time period referred to in article 4 of Annex II to the Convention shall be taken to have commenced on 13 May 1999.*
> *United Nations (SPLOS/72, 2001)*

Consequently, the date by which Australia must lodge its claim for extended continental shelf has changed from 16 November 2004 to 13 May 2009.

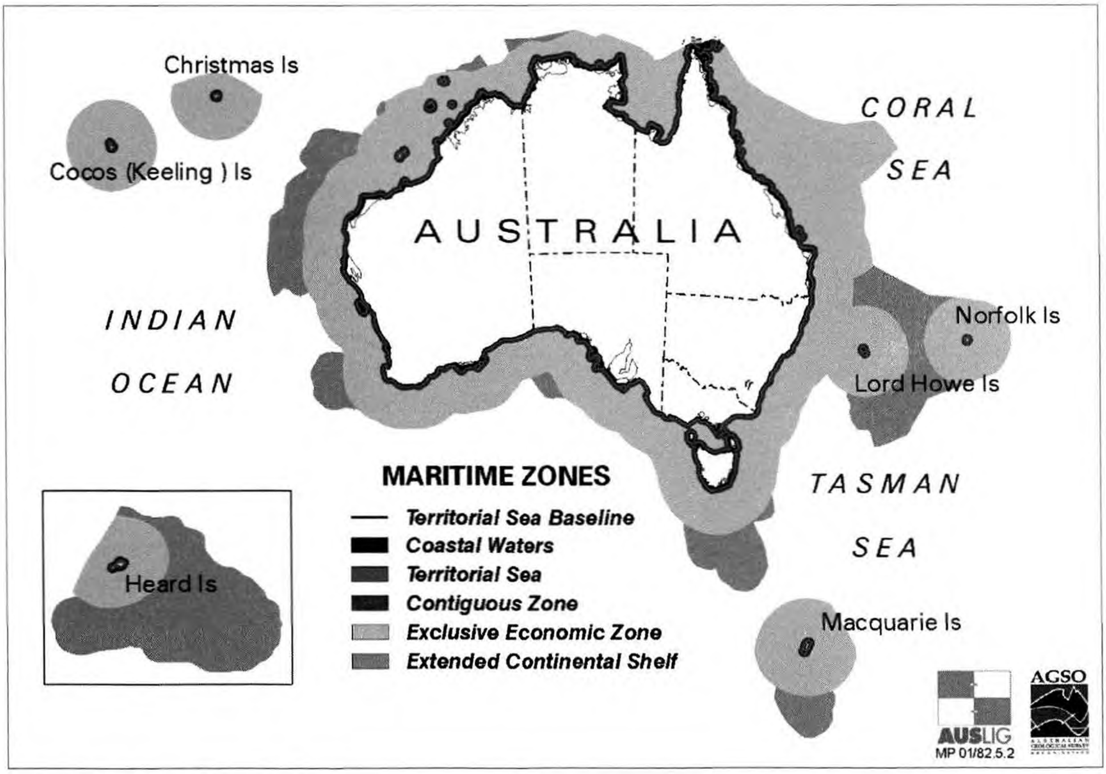

Figure 1: Australia's maritime zones

The strategic, economic and political benefits to Australia of securing rights to vast areas of the ocean and seabed need no elaboration, but these come with significant responsibilities in relation to delineation, administration, exploitation, and conservation of the marine environment.

In late 1990, following an earlier feasibility study, the Australian Surveying and Land Information Group (AUSLIG), now the National Mapping Division of Geoscience Australia, commenced building the Australian Maritime Boundaries Information System (AMBIS) utilising the capabilities and sophistication of a modern Geographic Information System (GIS). The decision to proceed with the implementation of AMBIS at that time was influenced by several closely related factors, including:

- The implications of the impending entry into force of UNCLOS, bringing with it specific international obligations and rights in relation to the accurate delineation of claimable ocean territory and seabed jurisdictions
- GIS support for complex national maritime boundary legislation and maritime boundary treaty negotiations with neighbouring coastal States
- A growing requirement for the establishment of a national repository of digital maritime boundary data of common interest to federal, state and territory government agencies

Whilst maintenance and enhancement of AMBIS is on-going, today the system provides a comprehensive and sophisticated management and display environment for all spatial data used in the definition and administration of Australia's maritime boundaries, including internationally agreed boundaries and those still subject to negotiation and delineation (Hirst et al., 1999). In addition to storing spatial data, AMBIS contains comprehensive details regarding the source, heritage and quality of that data. A principal component of AMBIS is the set of co-ordinates that define the Territorial Sea Baseline (TSB), the line from which the majority of Australia's maritime zone boundaries are generated. Consequently, during the early stages of development, priority was given to the acquisition of data which would enable the compilation and validation of the TSB, as zone boundaries could not be computed until this task was completed.

Agency	**Role**
National Mapping Division, Geoscience Australia www.auslig.gov.au/mapping/marbound/	- Maintenance of national repository of maritime boundary data (AMBIS) - Compilation and validation of territorial sea baseline - Computation of zone boundaries - Provision of technical advice on boundary delimitation - Computation of the outer limits of the extended continental shelf
Petroleum and Marine Division, Geoscience Australia www.agso.gov.au/projects/oceans/20010917_13.jsp	- Acquisition and analysis of bathymetric, geological and geomorphological data required for extended continental shelf delimitation
Australian Hydrographic Service, Department of Defence	- Acquisition of hydrographic data - Publication and maintenance of national charting series
Attorney General's Department	- Expert advice on international law - Administration of national maritime legislation - Treaty negotiations - Interpretation and application of UNCLOS
Department of Foreign Affairs and Trade	- Treaty negotiations - Interface with the United Nations
State and Territory Governments	- Provision of large scale coastal mapping data

Table 1: The role of agencies in maritime boundary administration in Australia

A number of federal, state and territory government agencies contribute to the management and administration of Australia's maritime boundaries. Table 1, derived from Hirst et al. (1999), generally summarises the role of each agency.

The Petroleum and Marine Division of Geoscience Australia, formerly the Australian Geological Survey Organisation (AGSO), plays a key role in relation to the acquisition and analysis of data needed for the delimitation of Australia's extended continental shelf. Marine geophysical surveys provide the data essential for determination of the location of the foot of the continental slope and the 2,500 m isobath, together with the data necessary for determination of sedimentary rock thickness near the foot of the continental slope. A fuller explanation of the significance and role of this data in relation to continental shelf delimitation is given later in the paper.

Although originally claiming a territorial sea of 3 M in width under the provisions of the 1958 Convention on the Territorial Sea and the Contiguous Zone, Australia extended this claim to 12 M in November 1990. The consequence was that jurisdiction over the territorial sea was divided between the federal government on the one hand and six state and one territory governments on the other, giving the latter jurisdiction over the original 3 M territorial sea, while jurisdiction over the remaining 9 M is exercised by the federal government.

The belt of water 3 M in width immediately adjacent to the coastlines of the six states and the Northern Territory is defined in national maritime legislation as *coastal waters*. The divided jurisdiction over the territorial sea is by no means unique, as similar arrangements exist in other countries. In the Australian context, a further consequence of the divided jurisdiction is that, in certain situations specifically relating to low-tide elevations, a dual baseline system arises whereby one baseline is used to define the outer limits of the 3 M width of coastal waters (the coastal waters baseline), while a different baseline is used to define the outer limits of the 12 M territorial sea (the TSB). This situation is very much the exception rather than the rule, as along most parts of the Australian coastline both baselines are coincident.

Data for Maritime Boundary Delimitation in Australia

Although the scale of Figure 1 does not permit a detailed depiction of the two inner-most zones (3M and 12 M), there are five maritime zones defined within Australian waters. The establishment of each of these zones is promulgated in national maritime legislation, consistent with the relevant provisions of UNCLOS.

Maritime zones can be classified into two groups, namely those generated wholly by distance as measured from the relevant baseline and those generated from geophysical, hydrographic and geomorphological data, in some cases using distance offsets in conjunction with these data. Each group requires specific and unique data sets for the solution of the zone boundary delimitation problem.

Group 1 – Zones Defined by Distance

The strategy used for the delimitation of maritime zone boundaries measured from the coastal waters or the territorial sea baseline is described later in the paper. Four of the five maritime zones shown in Figure 1 fall wholly within this category, as described below.

- *Coastal Waters* - the part or parts of the territorial sea that are within 3 M of the baseline appurtenant to a state or internal territory
- *Territorial Sea* - the belt of sea measured 12 M seaward from the TSB (UNCLOS Part II, Sections 1 and 2)
- *Contiguous Zone* - the belt of sea, contiguous to the territorial sea, measured 24 M seaward from the TSB (UNCLOS Part II, Section 4)

- *Exclusive Economic Zone* - the area beyond and adjacent to the territorial sea measured 200 M seaward from the TSB (UNCLOS Part V)

The TSB, from which maritime zones defined by distance are measured, can consist of either normal baseline, which includes bay closing lines and river closing lines, or a combination of *normal baseline* and *straight baselines*.

Normal Baseline
Article 5 UNCLOS defines the normal baseline as being :

> *"...the low-water line along the coast as marked on large-scale charts officially recognised by the coastal State."*

In Australia, the normal baseline is explicitly defined in national maritime legislation as the line corresponding with the level of Lowest Astronomical Tide (LAT). Hirst et al. (1999) explain that data to define the TSB were originally compiled in the late 1960's and early 1970's from topographic mapping, tide-controlled infra-red photography and Royal Australian Navy (RAN) hydrographic charting data then available. In more recent times an extensive program of TSB validation has been undertaken, in conjunction with the ongoing development of AMBIS. This program has utilised information from modern large-scale topographic mapping, charting, remote sensing, aerial photography and Laser Airborne Depth Sounder (LADS) data as well as hydrographic surveys of selected straight baseline terminal points.

Straight Baselines
In addition to the normal baseline, Australia has proclaimed 397 straight baselines in relevant national maritime legislation. These baselines are explicitly defined as geodesics, where a geodesic is the line of shortest distance between two points on the surface of the reference ellipsoid. The situation in Australia is somewhat unique since in the maritime legislation of many other coastal States such an explicit definition of line type is not given. Similarly, UNCLOS remains silent on the line type that can or should be used when defining straight baselines (see Articles 7, 9, 10 and 47). Thus coastal States are free to

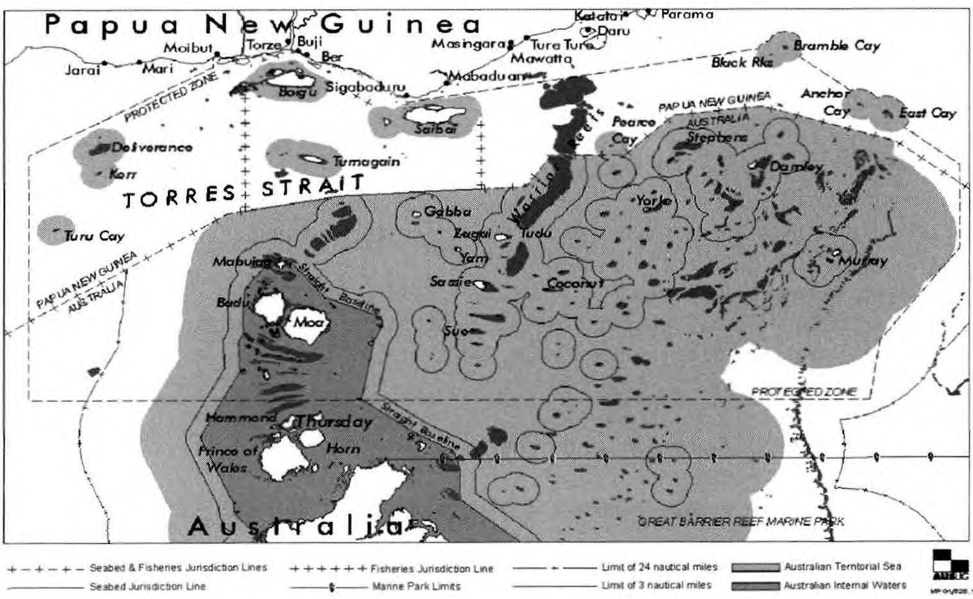

Figure 2: Maritime boundaries in the Torres Strait region between Australia and Papua New Guinea

choose the line type, which may include geodesics, loxodromes, great circles and normal sections. The rigorous definition and treatment of geodesic straight baselines in the context of maritime boundary delimitation is discussed by Murphy et al. (1999).

The Influence of Islands, Rocks and Low-tide Elevations

When dealing with zones defined by distance, the most complex situations arise in areas where the full complement of maritime features must be used for zone boundary delimitation. Such areas will include a combination of islands, low-tide elevations, rocks and the mainland interspersed with straight baseline systems. This situation is further complicated by restrictions imposed by UNCLOS on the use of certain low-tide elevations and rocks for zone boundary delimitation purposes (see Articles 13 and 121(3) respectively).
An example of the complexity of the various inter-relationships between maritime features in the region of the Great Barrier Reef adjacent to Torres Strait is shown in Figure 2.

Delimitation Strategy for Distance-based Zone Boundaries

With regard to the outer limit of the territorial sea, UNCLOS Article 4 states :

> *"The outer limit of the territorial sea is the line every point of which is at a distance from the nearest point of the baseline equal to the breadth of the territorial sea [12 M]."*

The clear implication of such a statement is that the limit of the territorial sea must be defined by arcs centred on critical points on the baseline and lines offset from straight baselines where appropriate. This is the method known as the envelopes of arcs originally attributed to Boggs (1930). The method has subsequently been generalised to apply to all zone boundaries generated by distance from a baseline:

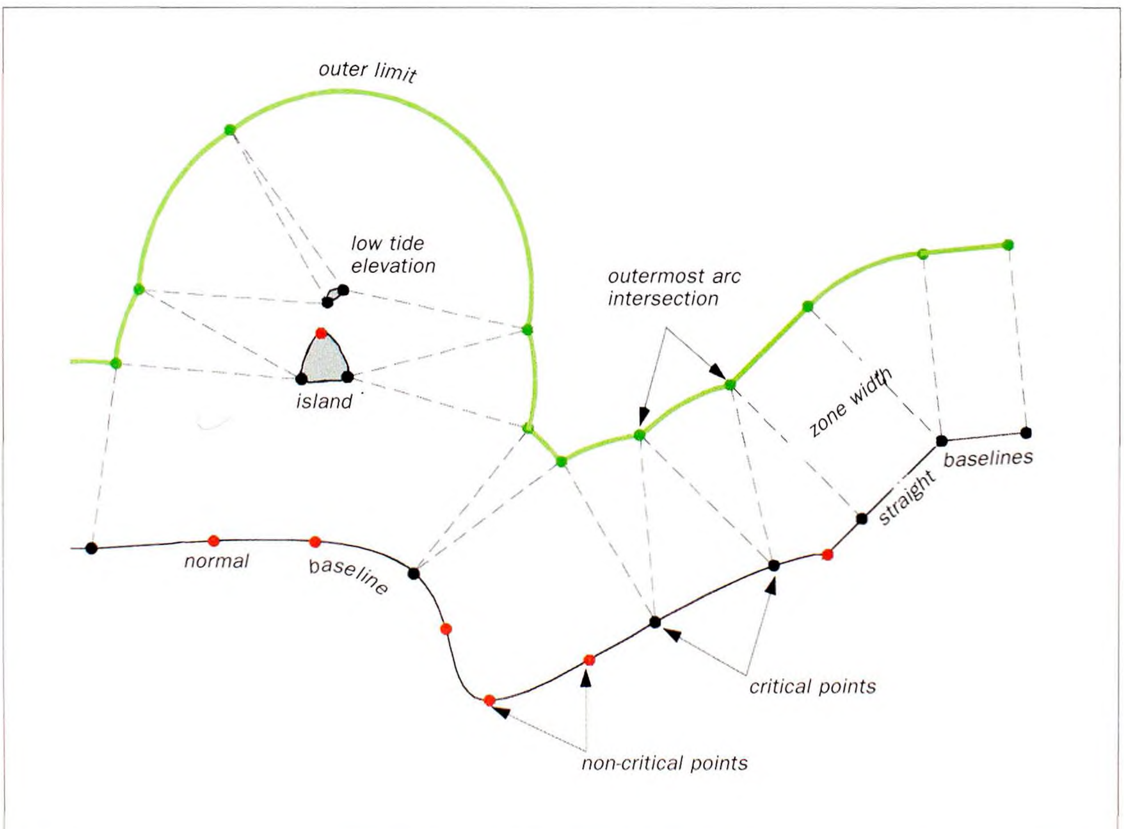

Figure 3: Generating the limits of a maritime zone boundary by distance

> *"The application of the method of envelopes of arcs is independent of the actual breadth of the limit. Thus, although the method was originally designed as a tool to determine the outer limit of the territorial sea, its mathematical application remains equally valid to determine the outer limit of other maritime spaces based on metric criteria."*
>
> *United Nations (1999, p.27)*

A simple example of the process of delimitation based on distance is illustrated in Figure 3 which shows:

- A section of normal baseline defined by a series of points
- An island and a low-tide elevation similarly defined
- Two straight baselines defined by terminal (end) points

To generate the outer limit of the zone boundary from the given baseline information, arcs of radius w (where w is the zone width) are swung from points on the normal baseline of the mainland, the island and the low-tide elevation to determine the location of the outermost arc intersection points. Similarly, these arcs are intersected by lines offset from the straight baselines where appropriate. The final outer limit is then defined by the envelopes of arcs, which inter-connect the outermost arc intersection points, as well as the sections offset from the straight baselines. Clearly such a process satisfies the requirements of UNCLOS Article 4, in that all points on each of the arcs and the lines offset from the straight baselines are exactly the zone width from the nearest point on the baseline (the critical point).

Group 2 – The Outer Limits of the Extended Continental Shelf

Sources of Data

Article 76 UNCLOS sets out the conditions under which a coastal State may be entitled to claim an extended continental shelf beyond 200 M from the TSB.

In the most complex situations, the outer limits of the extended continental shelf can be defined by a combination of lines which are derived from geophysical, hydrographic and geomorphological data. In certain circumstances part or all of the outer limits can also be defined by a line measured 350 M from the TSB. The various lines that must be considered in delineating the outer limits of the extended continental shelf are:

- *1 per cent sediment thickness formula line*	*The line joining "...the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope."* [Article 76(4)(a)(i)]
- *Foot of slope + 60 M formula line*	The line measured 60 M seaward from the foot of the continental slope. [Article 76(4)(a)(ii)]
- *2500 m isobath + 100 M constraint line*	The line measured 100 M seaward of the 2500m isobath. [Article 76(5)]
- *350 M distance constraint line*	The line measured 350 M from the TSB. [Article 76(5)]

The CLCS, through its publication *'Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf'* (United Nations, 1999), sets out detailed criteria which must be satisfied to support any claim for extended continental shelf and the delineation of its outer limits. In 1999 and 2001 the International Hydrographic Bureau, Monaco, hosted technical conferences directly related to these criteria. Both conferences were jointly organised by the International Hydrographic Organisation, the

International Association of Geodesy and the International Oceanographic Commission Advisory Board on the Law of the Sea (ABLOS). Copies of the conference reports and technical papers can be downloaded from the ABLOS web site: http://www.gmat.unsw.edu.au/ablos/.

Delimitation Strategy
The *'Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf'* describe the steps required to determine an entitlement to extended continental shelf. A summary of the process is given below :

- Before a coastal State can claim extended continental shelf, there must be evidence to prove that the *foot of the continental slope plus 60 M formula line* (FOS + 60 M) or *the 1 per cent sediment thickness formula line* extend beyond 200 M from the TSB
- If this condition is satisfied, the outer limit of the extended continental shelf is defined by the *outer envelope of the two formulae lines*. If only one formula line is definable, then the outer limit is defined by that line. Figure 4 shows an area where a claim for extended continental shelf is to be made. In the example, both the FOS + 60 M formula line and the 1 per cent sediment thickness formula line extend beyond the 200 M EEZ. The outer envelope of the two formulae lines is depicted as the thick continuous line made up of parts of both the FOS + 60 M and 1 per cent sediment thickness formulae lines
- However, the *outer envelope of the two formulae lines* is limited by either, or a combination of the two constraint lines. One of these lines is the distance constraint line measured 350 M seaward of the TSB, while the other is the depth constraint line measured 100 M seaward of the 2500 m isobath. Again referring to Figure 4, the distance constraint and the depth constraint lines are both shown, together with the *outer envelope of the distance and depth constraint lines*, which is shown as a thick dashed line
- As the penultimate step, the outer limit of the extended continental shelf is defined by the *inner envelope of the formulae and constraint lines* shown in Figure 5, as derived from the data depicted in Figure 4
- Finally, the provisions of UNCLOS Article 76(7) must be satisfied by delineating the outer limit of the extended continental shelf by straight lines not exceeding 60 M in length (this step is not shown in Figure 5)

The Need for Delimitation Software

Fundamental Requirements
Following the decision by AUSLIG in late 1990 to commence the implementation of AMBIS, it was recognised that Australia's maritime boundaries would need to be defined with a greater degree of accuracy than that which is usually required for charting and navigation purposes. The ability to accurately determine position at sea, the requirement to manage competing maritime interests and the need to enforce and protect rights in the maritime environment combine to create the need to accurately know the location of maritime boundary. Although the DELMAR package developed by Carrera (1989) had been acquired in 1990, it was subsequently found to have limitations in terms of AUSLIG's future requirements since it could not handle the very large and complex input data sets that were envisaged. Additionally, DELMAR was designed to operate under the now obsolete MS-DOS environment. Consequently, in the mid 1990's, AUSLIG undertook an international search to identify other software packages which might be capable of meeting the full range of Australia's complex maritime boundary delimitation requirements. This search proved unsuccessful.
The essential software characteristics identified by AUSLIG included:

1. The ability to undertake the delimitation of all zone boundaries (3, 12, 24, 200 and 350 M) in strict accordance with the relevant provisions of UNCLOS, taking into account all combinations of maritime features such as:
   - Normal baseline, including bay and river closing lines
   - Straight baselines
   - Low-tide elevations
   - Islands
   - Rocks

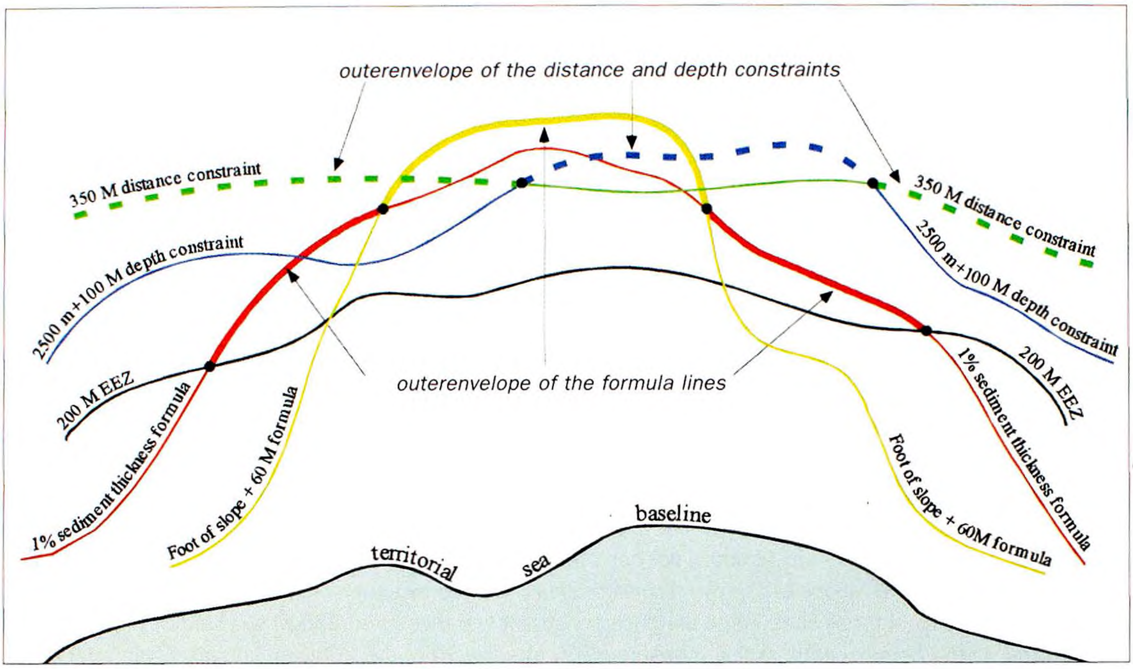

Figure 4: Determining the outer limit of the extended continental shelf

2. The ability to cope with the dual baseline system, where one baseline is used to define the 3 M width of coastal waters while the other is used to delimit the 12 M territorial sea, the 24 M contiguous zone, the 200 M exclusive economic zone and the 350 M distance constraint on the outer limits of the continental shelf

3. The application of geodetically rigorous methods in performing all delimitation computations

4. The ability to compute the outer limits of the extended continental shelf in accordance with the provisions of UNCLOS Article 76

As illustrated in Figure 2, Australia has some very complex stretches of coastline. The Great Barrier Reef and the Torres Strait regions are examples of areas where the interaction and relationship between a diverse range of maritime features must be considered when solving the delimitation problem. The rigorous treatment of all available data in the generation of various maritime zone boundaries in accordance with the relevant UNCLOS provisions is both technically and computationally demanding.

Since no suitable software for maritime boundary delimitation was identified, AUSLIG prepared technical specifications for the development of such software within Australia [1]. The specifications divided the project into two parts following the classification of zone boundaries presented previously. Part 1 dealt with the generation of zone boundaries based on distance. Part 2 dealt with the requirements of the delimitation of the outer limit of the extended continental shelf.

Geodetic Rigour

A key requirement of the technical specifications was that all computations should employ a rigorous geodetic methodology. This is in contrast to earlier attempts at maritime boundary delimitation in Australia where comprehensive geodetic calculations could not be practically carried out and more emphasis was placed on cartographic correctness. The representation of maritime boundaries on hydrographic charts by graphical means may be suitable for many purposes, but it is not sufficiently accurate for others where the shift in boundary location of only a few metres may equate to a substantial monetary loss (or gain)

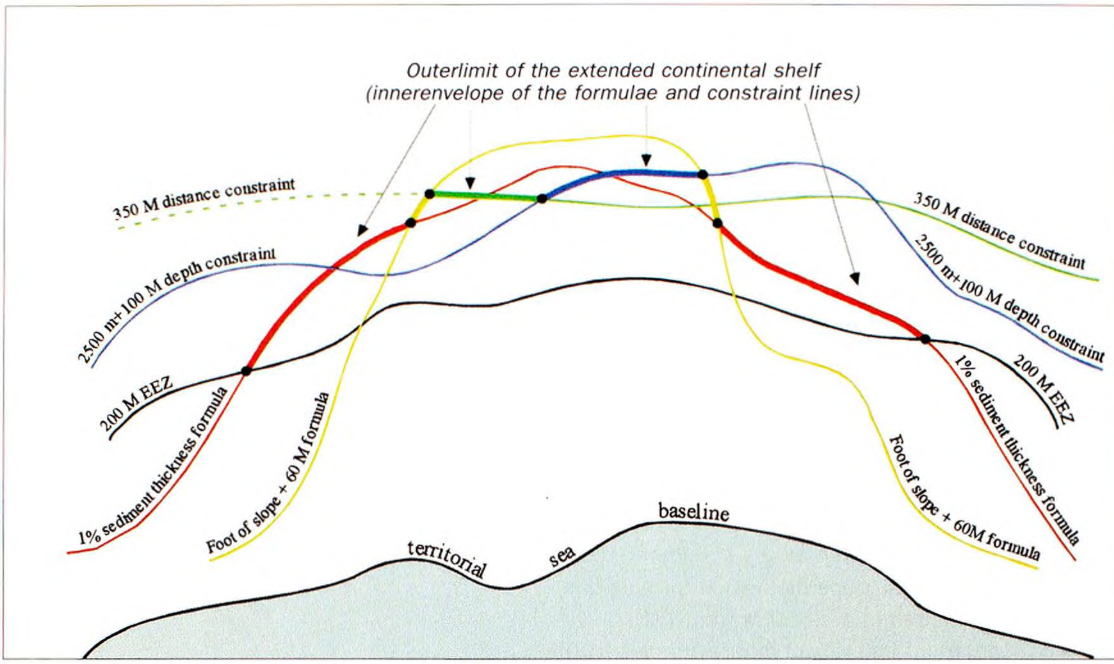

Figure 5: The final definition for the outer limit of the extended continental shelf

in terms of gaining or not gaining access to underlying oil, gas and mineral reserves.

Examples of typical geodetic computations required in the context of maritime boundary delimitation include:

- Defining arcs on the surface of the reference ellipsoid by a locus of points equidistant from the circle centre
- Calculating the intersection point between such arcs
- Offsetting lines from straight baselines defined as geodesics
- Intersecting geodesics with arcs
- Computing geodesic azimuths and distances over very long lines (up to 350 M)

Some details of the geodetic methodologies used in *MarZone* can be found in Leahy et al. (2001).

MarZone – Maritime Boundary Delimitation Software

Background

In July 1998, AUSLIG called public tenders for the development of maritime boundary delimitation software which would satisfy the requirements and meet the technical specifications discussed above. A small team comprising researchers from the Department of Geomatics at the University of Melbourne and a consultant from GeoFix Pty Ltd, a Canberra-based firm specialising in maritime boundaries, was the successful tenderer. Work commenced on the project in late 1998. Algorithm and software development was carried out at the University of Melbourne. GeoFix Pty Ltd provided expert technical advice and independent software testing. AUSLIG provided overall contract management, software testing and technical input. Additional advice on continental shelf delimitation was provided by AGSO as required.
The project proved technically demanding and challenging. Considerable emphasis was given to develop-

Though not avaiable at the time, the intervening period has seen the development of commercial maritime boundary demilition software such as Caris LOTS (www.caris.com) ing an efficient and robust solution based on strict implementation of the relevant UNCLOS provisions and a rigorous geodetic methodology. After almost two years of development, testing and refinement, the first production version of the software, MarZone, was delivered to AUSLIG in September 2000.

Basic Functionality

MarZone has been written in Visual C++ to run on a PC under the Windows NT or Windows 95/98 operating systems. From a development and logic perspective, the software is divided into two components, although the same interface, with some minor changes to menu items and options, is used to control interaction with the user in either case.

MarZone Part 1 is designed for the generation of any maritime zone boundary based on distance criteria. Typical applications of this component of the software include the generation of the following limits:

- Coastal waters (3 M from the coastal waters baseline)
- Territorial sea (12 M from TSB)
- Contiguous zone (24 M from TSB)
- Exclusive economic zone (200 M from TSB)
- User-selected zone width at any nominated distance from the TSB
- *Foot of continental slope plus 60 M formula line*
- Distance constraint line (350 M from TSB)
- Depth constraint line (2500 m isobath plus 100 M)

The last three applications arise in the context of preparing data for use in *MarZone* Part 2, which relates to the delimitation of the outer limits of the extended continental shelf. Through the performance of calculations necessary for the definition of the outer limits of the extended continental shelf, *MarZone* will play a key role in the process of preparing Australia's claim for extended continental shelf to be lodged with the United Nations in due course.

MarZone does not provide the capability for analysing sediment thickness or bathymetric data. The data defining the location of the terminals of the 1 per cent sediment thickness formula line(s), the location of points defining the foot of the continental slope and the location of the 2500 metre isobath(s) must be assembled by the user before computations for the delimitation of the extended continental shelf can be carried out. Of course, within *MarZone*, it is possible to use various combinations of foot of continental slope points, 1 per cent sediment thickness points and 2500 m isobath locations in order to compute different solutions and identify the optimum location of the outer limits of the extended continental shelf.

A *MarZone* web page has been developed which includes detailed information relating to current status. A demonstration version of the software and user documentation can also be downloaded through this page located at: www.geom.unimelb.edu.au/marzone

Conclusions

The vast extent of Australia's coastline, together with the requirement to manage and administer claimed maritime zones, have given rise to the need for an unprecedented and accurate knowledge of the location of national maritime boundaries. Two fundamental criteria must be considered when delineating the location of a maritime zone: one is the need to satisfy the legal provisions of the United Nations Convention on the Law of the Sea; the other is the objective that the delimitation problem be solved with geodetic rigour. In order to meet these two objectives and to provide Australia with a comprehensive tool for maritime boundary delimitation, the MarZone software has been developed. Not only can this software be used to accurately compute the locations of distance-based zone boundaries such as the territorial sea and exclusive economic zone, but also to determine the outer limits of the extended continental shelf in accordance with the provisions of UNCLOS Article 76.

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Biographies

Philip Collier is a Senior Lecturer in the Department of Geomatics at the University of Melbourne. Recent research has involved working with the co-authors of this paper on the development of the MarZone software, used for the automated delimitation of Australia's maritime boundaries and limit of the legal continental shelf.

Brian Murphy, a registered surveyor, is a maritime boundary delimitation consultant. At the time of his retirement from the Australian Surveying and Land Information Group (now the National Mapping Division, GeoScience Australia) in 1998, he was managing the Maritime Boundaries Program and was responsible for the implementation and development of the Australian Maritime Boundaries Information System (AMBIS). He subsequently worked as a technical consultant to the University of Melbourne in the development of maritime boundary delimitation software (MarZone) for the support of AMBIS. Brian is widely experienced in a number of facets of surveying and mapping, including geodesy and topographic and bathymetric mapping.

David Mitchell completed his Bachelor of Surveying with honours and Bachelor of Science (Computer Science) at the University of Melbourne in 1993. In 1994 he commenced full-time employment with the Department of Geomatics and has been involved in a number of research projects primarily as a computer programmer. In the period 1998-2001, David took primary responsibility for coding and testing of the MarZone software. David now works for the company "We_Do_IT" which specialises in providing IT services to the geo-spatial industry.

Frank Leahy has lectured in geodesy at the University of Melbourne for over thirty years. His research interests include computer algorithms for the adjustment of very large geodetic networks, Kalman Filters for kinematic mapping and more recently, development of algorithms for the computation of maritime boundaries. He is currently the Deputy Dean of the Faculty of Engineering at the University of Melbourne.

E-mail : p.collier@unimelb.edu.au
E-mail : bmurphy500@ozemail.com.au