Assessing the impact of uncertainties in the locations of "baselines from which the breadth of the Territorial Sea is measured" on the outer limit of the juridical Continental Shelf.

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Baselines

Abstract
There is one circumstance under which the outer limit of a Continental Shelf can be influenced by the location of a baseline, namely where the Outer Limit coincides with the Constraint Line and the Constraint Line is a line "350 nautical miles from the baseline from which the breadth of the Territorial Sea is measured". Over those sections of Outer Limit, uncertainty in location will be a combination of uncertainty in choosing the baselines, uncertainty in locating them, and uncertainty in measuring 350 M. Overlaying all will be the geometry of arcs 350 M long, which has the effect of minimising the number of points on baselines that contribute to the Outer Limit. This paper determines these uncertainties through a rigorous examination of the Canadian baselines, and produces error budgets and impact on area of the Continental Shelf for various possible locations. The methods developed will be applicable to other Coastal States.

1. Introduction

In its elucidation of the rules that define the outer limit of a legal Continental Shelf, Article 76 imposes a constraint seawards of which the claimscannot be made. Coastal States have some flexibility in that the outer constraint can be composed of either a line 350 nautical miles (M) from the "Baselines from which the breadth of the Territorial Sea is measured" or a line 100 M seaward of the 2500m-depth contour. Exceptionally, over "ridges", the Outer Constraint is restricted to 350 M, which may increase the areas where the 350 M cutoff is applied. While not all Continental Shelves will extend as far as the Outer Constraint, it is possible that for those that do, the locations of points on baselines will have some influence on the location of at least some portions of the Outer Limit of the juridical Continental Shelf.

This paper examines where and to what extent uncertainties in the location of baselines propagates as uncertainty in the location of the outer limit.

2. Terminology

With the increased interest in claiming Continental Shelves drawing more specialists from land-based earth sciences into the marine realm, there is some cross-fertilization as well as confusion in the use of terminology in the process. Consequently we have adapted the following terminology and use it throughout this paper. In Figure 2.1, the Boundary Delimitation Processes are [Nichols, 1983]:

Baselines

a) Definition: Specifying the “locus” of the boundary (e.g., from land mapping “midline of a stream”, from UNCLOS “350M from Baselines from which the breadth of the Territorial Sea is measured”). The Convention (UN, 1982) defines the oceanic boundaries.

b) Delineation: Description of the boundary in words, numbers, and/or graphics. Continental Shelves are delineated by a Coastal State by submission of the description to the Commission on the Limits of the Continental Shelf (CLCS),consideration of its recommendations, and publication of the location of the limits. The CLCS Guidelines (UN, 1999) provide advice to a Coastal State on how to prepare a submission.

c) Demarcation:

On land, this is the process of physically marking or “monumenting” the geographical location of a boundary on the earth’s surface. Since this is generally impossible at sea, the boundary is marked on charts and stored in co-ordinates which are deposited with the Secretary-General of the United Nations who “shall give due publicity thereto.” In fact, many portions of jurisdictional boundaries on land are not demarcated either, due to the cost of survey and/or maintenance.[1]

d) Delimitation:

Boundary delimitation, therefore, is the process of establishing boundaries through:

- declaration
- agreement
- judicial settlement or
- application of recognized legal principles

in which establishment refers to the definition of the locus of the boundary, its delineation graphically, numerically or in words, and in most cases (at least on land), its physical demarcation.

Boundary Delimitation Processes

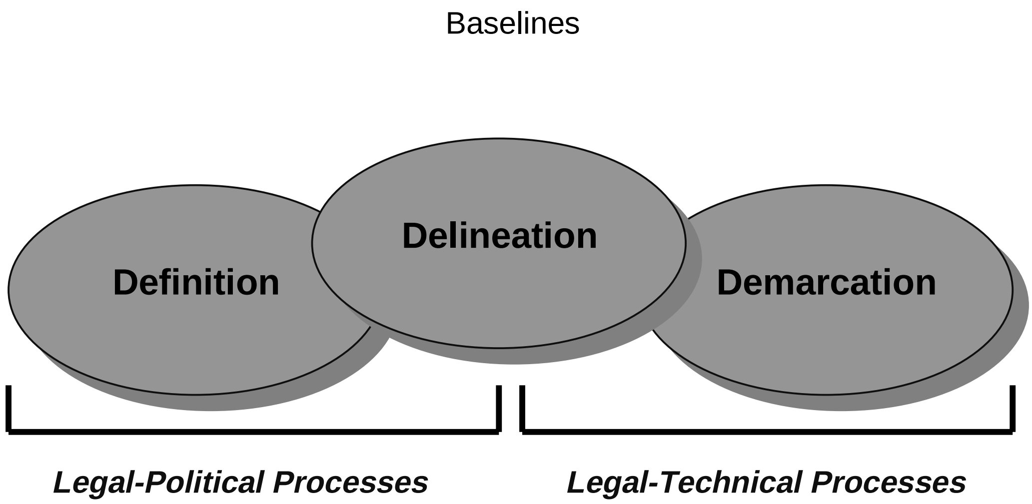

Figure 1: Boundary Delimitation Processes [Nichols, 1983]

3. Baselines within UNCLOS

<u>a) The need for and use of baselines within Article 76</u>

During the extensive period that UNCLOS was being developed, many and varied groups of states with specific goals coalesced with a particular view to espouse. The limits to the Continental Shelf attracted a number of view points, and opinion on the width of the shelf varied from narrow to wide, from strictly circumscribed to virtually limitless. Article 76 is a compromise resulting from the interaction of these groups.

Those who opposed the idea of Coastal States claiming wide margins wanted restraints placed on how wide the shelf could become, and their actions forced the inclusion of two constraints. One, founded in the belief that the intent of Article 76 was to give the physical continental margin to the Coastal State, is the 2500m-isobath +100M line.

Isobaths seemed too esoteric to others who insisted on a measurement that could be more easily understood, i.e., one that went from some known point to the outer constraint. Since the intent of Article 76 was to grant to the Coastal State the “natural prolongation” underwater of its landmass, the “shoreline” seemed a reasonable known point to start from. However, the shoreline had become codified through several Articles into “the Baselines from which the breadth of the Territorial Sea is measured”. No doubt there was considerable debate over how far the measurement should go, with 350 M being the distance immortalized in the treaty.

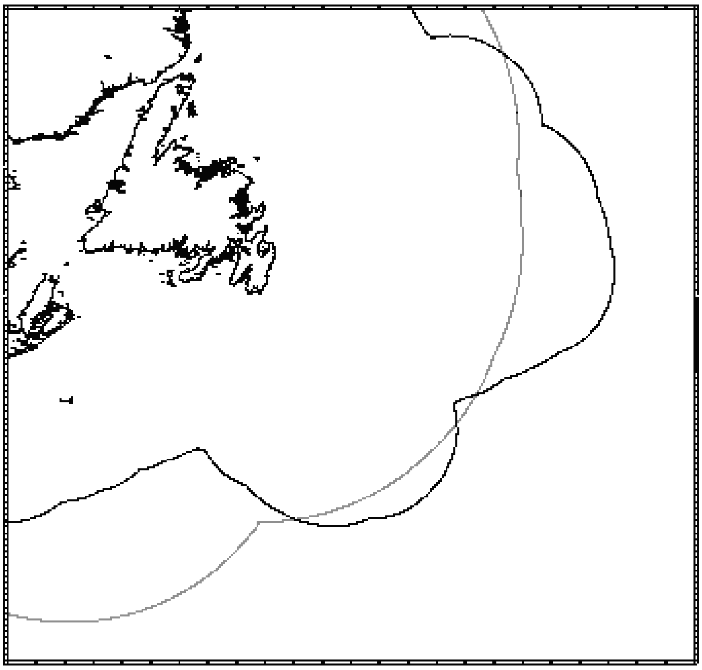

Figure 2: Sketch illustrating the concept of the 2500m + 100M (black line) and the 350M from the baselines combine to form the Outer Constraint.

b. The need for and use of baselines within UNCLOS

Baselines from which the breadth of the Territorial Sea is measured had been included in the Convention because treaties that refer to geographic entities (e.g., international air travel) need to identify the spatial area they apply to. The framers of UNCLOS were faced with defining in legal terms where the sea and land met in order that the contents of the Convention would be clearly applied to an area that could be legally accepted as being the sea.

Both the customary and codified law of the sea has attempted to be realistic and produce a result that is understandable and defensible. The framers of UNCLOS took *'the low-water line along the coast as marked on large-scale charts officially recognised by the coastal State"* as the "normal" component of the legal division between land and sea.[2] Most Coastal States produced or participated in the production of "large-scale charts" through their Hydrographic Offices (HO) or

[2]2 It should be noted, however, that the low water line is rarely the boundary separating private ownership rights from rights of the public or state along the seashore. This is generally some form of high water line (e.g., highest wash of the waves in civil law or "ordinary high water" in common law). Mean sea level might have been a compromise, but this is only traditionally shown on topographic maps of the land. Since Law of the Sea is concerned more with chart data, it seems logical that the low water chart datum intersection serves as a reference line for seaward territories.

through agreements with one of the larger HOs. As members of the International Hydrographic Organisation (IHO), the HOs produced charts to a uniform international standard promulgated by the international body that the UN accepts as the world authority on hydrography.

However, '*the low-water line along the coast…"* did not cover all possibilities. How far upstream from the ocean did a river become part of the Coastal State, for instance? Furthermore, before the drafting of UNCLOS, many Coastal States had claimed jurisdiction over certain bays, which they had defined by "straight baselines" across their mouths, and these existing baselines had to be incorporated into the Convention [see, e.g., Reed, 2000]. The International Court of Justice in the *Anglo-Norwegian Fisheries Case*[3] had also recognized that an island fringed coast such as Norway could be enclosed with Straight Baselines. Consequently, in addition to the "Normal" Baselines along the low-water line, Coastal States have the option of constructing Straight Baselines that join points on the mainland, on islands, on certain rocks and on certain low tide elevations. This has the advantage of straightening complicated stretches of shoreline and resolving, to some extent, the status of waters between islands and other bodies of land.

While Article 5 specifying the use of the low water line on charts as Normal Baselines was straightforward, the use of Straight Baselines required more complex treatment. Straight baselines could not be drawn haphazardly, and the Convention needs 3 Articles to provide rules governing their generation. (Beazley, 1971). Coastal States may use one or both types of baselines. The net effect is that UNCLOS allows the definition of a line, parts of which follow the cartographic portrayal of the low water line, parts of which may consist of straight lines joining points on the low water line, as the boundary between land and sea. Collectively, this line is referred to as **The Baseline**, and in general conversation the distinction between straight and normal baselines is not made.

4. Baselines and the CLCS Guidelines

a. Role of the CLCS vis-à-vis baselines

Being fully aware that the legal wording they were creating in parts of the 1982 UNCLOS Convention would require specialized and detailed interpretation, the drafters of the Convention created, among other bodies, the Commission on the Limits of the Continental Shelf (CLCS) which

> *… shall make recommendations to coastal States on matters related to the establishment of the outer limits of their continental shelf. The limits of the shelf established by a coastal State on the*

[3] *United Kingdom vs Norway* [1951. I.C.J. 116.

> *basis of these recommendations shall be final and binding.* (Paragraph 7, Article 76).

While it is clear that the CLCS has the outer limits as its purview, it cannot make any recommendations concerning inner limits, nor over limits where the Continental Shelf of opposite or adjacent states abut. What about the baselines, which are well away from the CLCS's mandated area, but which nevertheless might impact the outer limit? In its Guidelines, the CLCS addresses this as follows:

> *3.3.1. The Commission is not entitled by the Convention to issue any recommendations with respect to the delineation of baselines from which the breadth of the territorial sea is measured. Its role is limited to a potential request for information about the geodetic position and definition of the baselines used in a submission made by a coastal State.*
>
> *3.3.2. There are only two instances in which the Commission might request geodetic information about baselines. First, it must be satisfied that the test of appurtenance has been positively met. Secondly, if the 350 M limit is employed as a constraint in a submission, the Commission might also find it useful to make recommendations in relation to the methodology employed in the delineation of this limit.*

b. Demands imposed by the CLCS's Guidelines

> *3.3.9. The Commission remains open to consider all forms and combinations of methods used to determine the position of baselines by a State in a submission. The Commission may request during the consideration of a submission the following geodetic information about baselines:*
>
> - *Source of the data;*
> - *Positioning survey technique;*
> - *Time and date of the survey;*
> - *Corrections applied to the data;*
> - *A priori or a posteriori estimates of random and systematic errors;*
> - *Geodetic reference system; and*
> - *Geometric definition of straight, archipelagic and closing lines.*

5. The Physical Manifestation of the Baselines

Baselines were created as lines " from which the breadth of the Territorial Sea is measured". They have a number of other uses including: basis for median lines; and breadth of the territorial sea, contiguous zone, and exclusive economic zone and establishing the extent of the internal waters of the State. The rules required for the delineation of lines to perform all these roles are not simple. In this paper we are concerned with their role as the inner end of the 350M constraint.

a. Normal baselines

Normal baselines are defined in Article 5 as '*the low-water line along the coast as marked on large-scale charts*', with the understanding that the charts referred to are hydrographic charts. Hydrographic charts delineate the low water line and show depths from low water for safety reasons: the mariner is almost certainly guaranteed more water depth than is shown. (Storm waves, wind push and other meteorological effects might on very rare occasions create less water depths).

However, until recently, there has been no uniform international practice as to which 'low water' to use. Some HOs have used a low-water line showing the water level at "lowest normal" tides, i.e., the level that sea water normally reaches, with the time period that defines "normal" being one or two years. Others have favoured the use of Lowest Astronomical Tides (L.A.T.), the lowest in the 18.61 year tidal cycle. The IHO has recently (IHO, 1997) adopted a resolution that will see the Lowest Astronomical Tides (L.A.T.) become the world standard, but it will take many years before existing charts based on other datums can be converted to LAT.

Tide ranges are measured at permanent gauges at selected points, and the duration of time over which the gauge operates contributes to the value of its results. Spatial distribution of tide gauges is not uniform, with busy ports and active shipping channels usually benefiting from a concentration of them, while remote areas have only a few widely scattered instruments. During a hydrographic (depth) survey, a temporary gauge will be established in the proximity of the survey; the data it records is used to adjust the depths collected as well as providing input to the tidal model for the region. Tidal range along the shoreline between gauges is estimated or predicted by models, and there are several different models in use. Using the predictions to correct raw numerical depths to a common datum is straightforward; applying them to determine the position of a low water line which might occur only once a year or once every 18 years, is much more difficult.

In the Guidelines, the CLCS deals with this situation as follows:

> *3.3.4. … The Commission acknowledges that many different definitions are used in State practice and that some define a lower tidal datum than others.*
>
> *3.3.5. The Commission feels that there is a uniform and extended State practice which justifies the acceptance of multiple interpretations of the low water line. All of them are regarded as equally valid in a submission.*

b. Straight baselines

Coastal States are welcomed by Article 14 to use a combination of Normal and Straight baselines "to suit different conditions", thereby avoiding the complications imposed by the physiography of some coasts. There are a number of UNCLOS Articles that provide instruction on how to construct these straight baselines. Collectively the ambiguity of these clauses will likely allow Coastal States to take considerable latitude in what they choose their baselines to be. It is only where their choice of baselines impacts upon another Coastal State, or where other States strongly object to the territory included by the use of straight baselines, that there may be some challenge to any claimed baselines.

c. The choice of which type of baseline to use

While there are many other considerations when choosing to use either straight or normal baselines, in terms of the 350 M constraint, the choice of normal or straight baselines only makes a difference to the outer location in cases where points on the baseline are further than 60 M apart. Seawards of every pair of points on a baseline, be it normal or straight, it is possible to construct a rectangle the long side of which is 350M and the short side is the distance between the two points. The outer short side of the rectangle forms the 350M constraint, as long as the distance between the two points is less than 60M, since Article 76, Paragraph 7 specifies "*The coastal State shall delineate the outer limits of its continental shelf, … by straight lines not exceeding 60 nautical miles in length..".*

In cases where the spacing between two points on a straight baseline exceeded 60M, a Coastal State could simply pick an intermediate point on the straight baseline, and construct two rectangles based on the three points. However, if the two points are on a normal baseline, once they are more than 60M apart, a rectangle can no longer be constructed. What had been the straight outer edge of the rectangle is transformed into a line composed of the intersection between a 60M long straight line and two arcs 350M long centered on the two baseline points. In this case, the outer edge line is closer to land than the straight edge of a rectangle would be, and that might mean a reduction in a Coastal State's Continental Shelf.

d. Number of baseline points required

Delineation of the limits based on baselines. i.e., the Territorial Sea, the Contiguous Zone, the Exclusive Economic Zone and the 350M Constraint use successively fewer points on the baselines. The paradox is that while delineating any of these limits does not require baseline points for the entire coastline, finding the critical points may require mapping the points along the entire coast.

6. Error budget for baselines as they effect the 350M constraint

In order to classify the uncertainties, the authors have first outlined the steps in delineating and demarcating a 350M constraint line. These are summarized in Figure 3. In this paper, we only consider uncertainties due to Steps 1-6, i.e., uncertainties arising from the way in which baseline points, and in particular the critical baseline points, are defined and delineated.

The Error Budget for Baselines is thus broken into two components:

- **Definition and Selection** of the critical baseline points to be used as ends of the arcs creating the 350M line, including the definition and selection of procedures and standards to be used (e.g., use of digital or graphical means)

- **Delineation and Selection** of the actual critical baseline points (including delineation of other baseline points for selection of critical points and in the case of Normal Baselines, charting the actual low water line)

a. Definition and Selection Uncertainties:

The Definition and Selection components can be dominant yet are difficult to put numbers on. If a single point that could be used is missed, the area it generates is probably larger than the errors in all the points that are used. How could points be “missed”? A revised tidal regime could permit inclusion of a point, for instance, at some future date. In the Arctic and Labrador, Canada has not charted all low tide elevations that might become critical baseline points. (Gray, 1994)

More important is the approach used in defining points. Should there be an aggressive search for end points that will push the Territorial Sea (and thus the 350M constraint line) as far offshore as possible or should an approach that stays close to shore be used? Will Straight Baselines be used? The approach chosen represents a significant strategic-political uncertainty.

Process of Delimiting 350M Constraint Line

Defining and Delineating the Baselines	1. Define Baseline Criteria (UNCLOS) 2. Choose Baseline Strategy or OR Accept Existing Baselines 3. Choose Medium, Procedures, Standards, etc. 4. Delineate Baseline Points for Measuring 350 M (Based on survey or charts) 5. Determine Critical Baseline Points 6. Delineate Baseline Points on Chart and/or Calculate Co-ordinates
Defining and Delineating the 350 M Constraint Line	7. Delineate Series of Intersecting Arcs at 350M (on chart or analytically) 8. On arcs, Choose 60 M (max) Line Endpoints 9. Delineate Representative Lines on Chart and Measure Co-ordinates (optional) OR 10. Calculate Co-ordinates of Endpoints
Demarcation and/or Reestablish-ment	11. Demarcate Baseline Points (not required) 12. Establish Position Relative to Critical Baseline Points

Figure 3: Process of Establishing Constraint Lines

But what about the procedure of defining the endpoints of a baseline? Several authors have discussed (at length) the uncertainty in location of these baseline endpoints. However, a brief summary of some of the mathematical model uncertainty issues is appropriate at this point.

Section 3.2.8 of the Guidelines [UN, 1999] indicates that the submitting State may be required by the Commission to provide:

1. Coordinates of the outer limit of the continental shelf in an International Terrestrial Reference System (ITRS) adopted by the Commission;

2. Transformation parameters between the reference system used in the submission and an ITRS adopted by the Commission; and

3. Full information relating to the scientific methodology employed to determine these transformation parameters.

In requesting the above information from a submitting State, the Commission expects the following broad categories of sources of error:

Errors in Transformation Parameters
Transformation parameters are often defined by several organizations. Inconsistency in determining these parameters is obviously a source of error. In particular, the guidelines [UN, 1999] indicate that the Commission will merely "pay special attention" to the determination of transformation parameters and their mathematical formulation when a national reference system different from ITRF94 or WGS84 is used in a submission made by a coastal State.

But take the case of transforming from DGPS to ED50 using UKOOA and DMA EUR-M transformation sets reported by Elema and Jong [1999]. Vertical and horizontal differences of 3 and 1.5 m respectively in the final ED50 coordinates were observed. What should a State do in such a case? The Commission indicates in section 3.2.17 of the guidelines that Commission X of the International Association of Geodesy (IAG) is currently developing transformation methodologies between different reference systems. However, the Commission feels that the ultimate responsibility lies with the submitting State.

Errors in the Mathematical Datum Transformation Model
The mathematical model used to determine the coordinates of the endpoints of a baseline is in itself a source of uncertainty. The errors in the model can be attributed to assumptions in the model and the process of formulating the mathematical model. For example, assume that the Least Squares method is used to connect a lower order network (used in locating the coordinates of the endpoints of a normal baseline) to a higher order network. Clearly, errors will be distributed in the new integrated network and will be used to provide false precision to the endpoint coordinates.

The problem of transforming coordinates from one datum to another can also be used to demonstrate mathematical model uncertainty. Discussions by several authors (e.g. Elema and Jong, 1999, Vanicek and Krakiwsky, 1982), together with those in section 3.2.17 of the new guidelines, indicate that datum transformations are a source of great uncertainty. Consider the following two categories of datum transformation error sources:

- For geodetic coordinate transformation, the Molodensky datum transformation formulas are used. They are known to have sufficient accuracy only when local rather than mean datum shifts are used. However, only mean datum shifts are available.

- For Cartesian coordinate transformation, the7-parameter Helmert transformation is used. Scale and orientation factors of this mathematical model are often set to zero leaving just 3 translation factors (and reducing this to a 3-parameter transformation). Clearly, a 7-parameter transformation is more representative of the mathematical model than the 3-parameter transformation.

b. Delineation Uncertainties

Under spatial uncertainties, it is usually the manifestation of errors in the horizontal direction that is paramount, since these dictate the accuracy of the positions of lines drawn at various distances. Consider a shore face sloping at some angle x. A difference of y in the vertical measurement of tide, for example, will manifest itself as a horizontal displacement of magnitude = y/tan x, perpendicular to the shore face. The vertical difference could arise from uncertainty in measuring tide, or a change of vertical datum. Magnitudes of vertical differences are likely to be in the decimetre range, and Table 1 summarises the magnitudes of horizontal uncertainty these would generate.

Table 1: Showing the horizontal uncertainty that vertical differences in tidal heights can cause over various bottom slopes

Vertical Difference(m)	**Bottom Slope in degrees**						
	15	10	5	2	1	0.5	0.25
Tides	**Resulting horizontal uncertainty (m)**						
0.1	0.4	0.6	1.1	2.9	5.7	11.5	22.9
0.2	0.7	1.1	2.3	5.7	11.5	22.9	45.8
0.3	1.1	1.7	3.4	8.6	17.2	34.4	68.8
0.4	1.5	2.3	4.6	11.5	22.9	45.8	91.7
0.5	1.9	2.8	5.7	14.3	28.6	57.3	114.6
0.6	2.2	3.4	6.9	17.2	34.4	68.8	137.5
0.7	2.6	4	8	20	40.1	80.2	160.4
0.8	3	4.5	9.1	22.9	45.8	91.7	183.3
1	3.7	5.7	11.4	28.6	57.3	114.6	229.2
1.5	5.6	8.5	17.1	43	85.9	171.9	343.8
2	7.5	11.3	22.9	57.3	114.6	229.2	458.4

If we assume that differences are usually less than .3m and slopes generally greater than .5 degrees, then this part of the error budget is not a major issue in Law of the Sea continental shelf determinations.

UNCLOS Article 16 permits Coastal States to either plot their Baselines *on charts of a scale or scales adequate for ascertaining their position. Alternatively, a list of geographical co-ordinates of points, specifying the geodetic datum, may be substituted.*

Although section 3.3.8 of the guidelines [UN, 1999] specifically indicates that baselines should not be drawn on projected maps and used in a submission, various countries might still be employing cartographic solutions to endpoint location. Assume that a baseline endpoint is 0.25mm in diameter when drawn on a nautical chart that is at a scale of 1:10000. This represents an error of 2.5 m in endpoint location. However, if a small scale map is used (1:100000 or 1:150000) so that one can see a considerable length of coast, then the precision of baseline points varies between 25m and 37.5 m respectively.

Uncertainty associated with the above mentioned delineation issues varies in magnitude. The use of charts produces the greatest uncertainties, and these are probably greater than all other errors combined. It is not specified what precision the geographical coordinates of baseline endpoints should be reported and that in itself opens up the door to various interpretations. Most endpoints are reported to the nearest 1/10th or 1/100th of a minute, or to nearest second (i.e. 1/60th of a minute) which is 180m, 18m and 30m at the equator respectively.

Further Uncertainties

The previous section gives some examples of uncertainty in factors that contribute to the location of the 350 M Constraint. Table 2 is a preliminary attempt to capture all the contributing uncertainties.

Table 2: Uncertainties in the 350M constraint line due to Baseline delimitation

	Process of Delimiting 350 N. Mile Limit		
	STAGES	TYPES OF UNCERTAINTY	REFERENCE TO DISCUSSION
1	Baseline Uncertainty		
1.1	Choose Baseline Criteria		
		legal uncertainty (straight or normal baselines)	
		political/strategic uncertainty (historical bays, maximum limits)	
1.2	Choose Medium, Procedures, Standards		
		data uncertainty (age, accuracy, and scale of chart data)	
		standards uncertainty (datum definition, line types)	See section 6a for discussion
		cartographic uncertainty (scale, resolution, projection)	
		other data uncertainty (age, accuracy, and scale of chart data)	
		other standards uncertainty (line type, line width, tangent points)	See section 6b for discussion
1.3	Delineate Baseline Points- Chart and/or Co-ordinates		
		description error	
		measurement error	
		technology uncertainty (compass, scales, round-off)	

2	350 n.mi Limit Uncertainty		
2.1	Define Baseline Points for Measuring 350 n miles	measurement error mathematical model uncertainty (assumptions in the model, methodology)	See for example Vanicek [1999]
2.2	Delineate Intersecting Arcs at 350 n miles	measurement error mathematical model uncertainty (assumptions in model, methodology)	See for example Murphy et al. [1999]
2.3	On arcs, Choose 60 n mi (max) Line Endpoints	measurement error mathematical model uncertainty (# of iterations, methodology)	See for example Hirst et al. [1999]
3	Physical Demarcation Uncertainty.		
3.1	Delineate Representative Line Chart or Coordinates	cartographic uncertainty (scale, resolution, projection) measurement error description error	By coordinates to sec – 30m to 1/100- 18m
3.2	Demarcate Baseline Points Used	cartographic uncertainty (scale, resolution, projection) description error measurement error	Discussed in section 6b of this paper
3.3	Establish Position Relative to Representative Lines	measurement error	

Conclusions

1. The uncertainties can be classified as those due to definition and selection (independent of Coastal State coastline) and those due to actual delineation and selection of actual points (i.e., location on a chart of the defined baselines for a specific coastline).

2. The definition related uncertainties are largely a result of:

- how "low water on a large scale chart" is interpreted
- choice by a Coastal Nation of the political strategy to employ (e.g., maximum enclosure)
- choice by a Coastal Nation of the type(s) of baseline to use
- choice of medium

3. The delineation related uncertainties are a result of:

- quality of the low water datasets (e.g., tidal models)
- actual characteristics of the shoreline (e.g., slope, configuration)
- selection of critical baseline points
- actual drawing of lines and calculation of co-ordinates

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Baselines

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