

The Geodetic Datum Problems of the Territorial Sea Boundary Between the Republic of Indonesia and the Republic of Singapore

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Key words: datum, Indonesia, boundary, Singapore, territorial sea

SUMMARY

In the 1973, Indonesia and Singapore agreed the middle segment of their territorial sea boundary in the Strait of Singapore. The Agreement did not solve all segments of maritime boundary between the two countries. Indonesia and Singapore still have several other segments to be settled, among them namely the east and the west segment.

The two countries agreed that the datum used for the undelineated segments will be the World Geodetic System 1984 (hereafter: WGS'84). It is worth noting that the new boundary lines supposedly a continuation of the boundary line agreed in 1973. This raised a problem since the 1973 boundary agreement did not specifically mention the datum used for its boundary coordinates. Applying two different types of datum in this case arguably is unacceptable.

In order to solve the problem, several methods had been examined by the two countries, such as the transformation datum method, the reconstruction method and the chart-fitting method. This paper will discuss all those methods and try to recommend the most suitable and acceptable method to transform the 1973 boundary coordinates in WGS'84, so that the 1973 boundary line could be connected with the new boundary lines.

SUMMARY

Indonesia dan Singapura telah memiliki kesepakatan batas laut wilayah di segmen tengah Selat Singapura pada tahun 1973. Namun hal tersebut tidak menyelesaikan batas laut wilayah antara Indonesia dan Singapura karena kedua negara masih memiliki dua segmen batas lainnya yang harus diselesaikan, yaitu segmen barat dan segmen timur.

Kedua negara menyepakati datum yang digunakan untuk segmen batas yang belum didelineasi akan menggunakan *World Geodetic System* 1984 (WGS'84). Hal ini dikarenakan garis batas yang baru sekiranya merupakan kelanjutan dari garis batas yang disepakati pada tahun 1973. Hal ini menyebabkan masalah karena koordinat batas Perjanjian tahun 1973 tidak menyebutkan secara khusus datum geodetik yang digunakan. Penggunaan dua datum yang berbeda dalam hal ini tentunya sulit untuk dapat diterima.

Dalam rangka menyelesaikan masalah tersebut, beberapa metode telah diuji oleh kedua negara. Metode-metode tersebut adalah metode transformasi datum, metode rekonstruksi dan metode *chart-fitting*. Makalah ini akan memaparkan mengenai metode yang paling sesuai dan paling dapat diterima untuk mentransformasi koordinat Perjanjian tahun 1973 ke dalam WGS'84 agar garis batas tahun 1973 dapat dihubungkan dengan garis batas yang baru..

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1. INTRODUCTION

The width of the Singapore Straits separating the Republic of Indonesia and the Republic of Singapore is less than 24 nautical miles. This forces the two neighboring countries to settle their territorial sea boundary in accordance to the international law and the technical principles of maritime boundary delimitation.¹

Both countries have carried out a long process of negotiations to complete their territorial sea boundary. This was started with a negotiation to settle the first segment of the boundary which was held on early of May 1973. This led to the signing of a boundary Treaty on May 25 of the same year². The Treaty then was ratified by the Government of the Republic of Indonesia with Law no. 7 of 1973 on the Ratification of the Treaty between the Republic of Indonesia and the Republic of Singapore on the territorial Sea Boundary Line between two countries in the Strait of Singapore.

The 1973 Treaty agreed on six boundary coordinates which are located on the middle segment of the Strait of Singapore. It is worth underlining that the treaty did not solve the entire territorial sea boundary between two countries, since they still have several other segments to be solved; among them namely the west and the east segment.

Referring to the need to solve the undelineated segments, the 1973 boundary negotiation between the two countries was then resumed in 2005. In the early stages of the resumed negotiations, both countries agreed to solve the west segment first while waiting for the decision of the International Court of Justice (ICJ) on a dispute between Malaysia and Singapore over the sovereignty of several natural features in the east segment of the Straits of Singapore.³

It is worth noting the fact that 1973 Treaty does not specifically mention the geodetic datum used for the six boundary coordinates specified in the treaty. Meanwhile, both countries agreed to use the WGS84 datum for the undelineated segments, as it is used in the

¹ See Section 2 of the Law of the Sea Convention 1982 (hereafter LOSC), especially Article 3 and 15. Both countries are parties to the LOSC

² The Agreement states that The Governments of the Republic of Indonesia and the Republic of Singapore signed a territorial sea boundary agreement on May 25, 1973. Indonesia ratified the agreement on December 3, 1973; Singapore ratified it on August 29, 1974. Neither country was a party to the 1958 Geneva Convention on the Territorial Sea and Contiguous Zone.

³ On May 2008, the ICJ delivered its judgement that Singapore has sovereignty over Pedra Branca/Pulau Batu Puteh; that Malaysia has sovereignty over Middle Rocks; and that sovereignty over South Ledge belongs to the State in the territorial waters of which it is located. At the time of writing, Malaysia and Singapore are still negotiating their maritime boundary around that area. Boundary delimitation involving Indonesia in that area can be conducted after a settlement reached by Malaysia and Singapore. While waiting for that, Indonesia and Singapore are preparing to settle their boundary on a small segment located south off coast of Changi.

west segment which was agreed in 2009⁴. The consequence of this is the need to transform the 1973 boundary coordinates into the WGS84 in order to have the same system for the whole boundary. Some methods had been studied to solve this problem. The purpose of this paper is to examine several available methods to transform the 1973 boundary coordinates to the WGS84, so that at the end, it is not only going to be much easier to complete all the undelineated segments, but also much easier to enforce the boundary line in practice.

2. BASIC THEORIES

Geodetic datum defines the size and shape of the earth and the origin and orientation of the coordinate systems used to map the earth. Hundreds of different datum have been created and used to frame the position descriptions since the first estimation of the earth's size was made by Aristotle. From time to time, datum has evolved from those describing a spherical earth to ellipsoidal models derived from years of satellite measurements.(Dana., H., P., 1999)

Many countries have used different geodetic datum for positioning purposes. This is certainly giving effect to the development of many datum systems worldwide, either regional or local datum system. Furthermore, along with the development of science and technology, the latest positioning system has been familiarly attached with the Global Positioning System (GPS) which refers to the WGS84 datum. WGS84 itself is a geodetic reference system developed by the United States Defense Mapping Agency (hereafter DMA), which is now known as National Imagery and Mapping Agency (hereafter NIMA).(GDA, 2001)

With regard to the fact that there are many types of datum, there are thus also several techniques or methods that can be used to transform coordinates from one datum system to another, including the transformation from one particular datum to the WGS84. Generally, those methods are known as datum transformation. This includes different techniques or approaches, such as the reconstruction method and the so-called chart-fitting method.

Transforming coordinates from one particular datum to the WGS84 commonly can be done by using three parameters and seven parameters which is known as the Bursa Wolf transformation.(Al Marzooqi, Y, 2005) The transformation of 3 parameters involves parameter of translational (shift) in all directions x, y, z. While the transformation of 7 parameters is used to transform three dimensions (3D) coordinates in two different datums which involve translational and rotational parameters in all directions (x, y, z) and scale parameters.

⁴ Article 1 point 2 of the 2009 Treaty states that the co-ordinates of points 1A, 1B and 1C specified in paragraph 1 are geographical coordinates based on the World Geodetic System 1984 and the boundary line connecting points 1 to 1C is indicated in Annexure "A" to the Treaty.

The datum transformation with 3 parameters model can be calculated using:

$$\begin{bmatrix} X_{WGS84} \\ Y_{WGS84} \\ Z_{WGS84} \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} X_{Beda} \\ Y_{Beda} \\ Z_{Beda} \end{bmatrix} \quad (1)$$

Note:

ΔX , ΔY , ΔZ are the translation parameter

X , Y , Z are the geographic coordinates of a point

While the datum transformation with 7 parameters can be calculated using:

$$\begin{bmatrix} X_{WGS84} \\ Y_{WGS84} \\ Z_{WGS84} \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} 1 + \Delta L & R_Z & -R_Y \\ -R_Z & 1 + \Delta L & R_X \\ R_Y & -R_X & 1 + \Delta L \end{bmatrix} \begin{bmatrix} X_{Beda} \\ Y_{Beda} \\ Z_{Beda} \end{bmatrix} \quad (2)$$

Note:

(ΔX , ΔY , and ΔZ) as translation parameter

($1 + \Delta L$) as the scale factor and,

(R_x , R_y and R_z) as the rotation parameter.

Another method to obtain coordinates in WGS84 from another datum system is what so-called the reconstruction method. The map which is used as the base map for the reconstruction should be already referred to the WGS84. In this method, the position of one point in one particular datum is reconstructed using tie points which then the coordinate of that point is extracted by reading the coordinates in the WGS'84.

The next method is what so-called as the chart-fitting method. The first thing to do in this method is to plot the points which are being sought their coordinates in WGS84 on the chart that has not been referred to the WGS84 (original chart). Then several common points should be identified and determined the original chart and the chart which is already referred to the WGS84. It is worth noting that the common points should be well distributed throughout the charts. Having identified common points on both maps, then they are overlaid to each other referring to the determined common points. This is in order to get the positions on both maps as similar as possible. After that, then the coordinates of points which have been plotted on the original chart can be extracted in the WGS84.

3. RESEARCH METHOD

The data used in this research are the British Admiralty Chart (BAC) number 3833 of 1967 (which is believed to be the chart used as the base chart to delineate the 1973 boundary line and also as the annexure of 1973 Treaty); BAC 3833 of 2005, 1973 boundary coordinates, the data of 1973 boundary line published by the Geographer (U. S. Department of State), the transformation parameters of South Asia datum, Genuk datum, Kertau Datum 1948 and 1968 to the WGS84 datum were published by the Malaysian Mapping Agency (*Juru Ukur dan Pemetaan Malaysia-JUPEM*) and the Singaporean Maritime Port Authority (MPA).

The method used in this research is data processing of both graphically and calculation using the datum transformation methods from the 1973 boundary coordinates using the formula (1) and (2), the reconstruction method created by the Geographer, and the so-called chart-fitting method. Those three methods were going to be examined to choose the most suitable and acceptable to transform the 1973 boundary coordinates to the WGS84 datum. The Blue Marble software Geographic, Trimble Geomatics Office (TGO) and Global Mapper were used in the research for the datum transformation method, the AutoCADmap was used in the reconstruction method, and the Global Mapper software was used in the chart-fitting method.

4. RESULT AND DISCUSSION

The first method that was examined in this research was the datum transformation method with known parameters. Through this method, the 1973 boundary coordinates (Table 1) are assumed as in one particular datum system.

Table 1. The Coordinates of Territorial Sea Boundary Points of 1973 Treaty between Indonesia – Singapore

Point#	Latitude (N)			Longitude (E)		
1	1°	10'	46,0''	103°	40'	14,6''
2	1°	07'	49,8''	103°	44'	26,5''
3	1°	10'	17,2''	103°	48'	18,0''
4	1°	11'	45,5''	103°	51'	35,4''
5	1°	12'	26,1''	103°	52'	50,7''
6	1°	16'	10,2''	104°	02'	00,0''

The 1973 Treaty contained six boundary coordinates which can be illustrated in Figure 1 as follow:

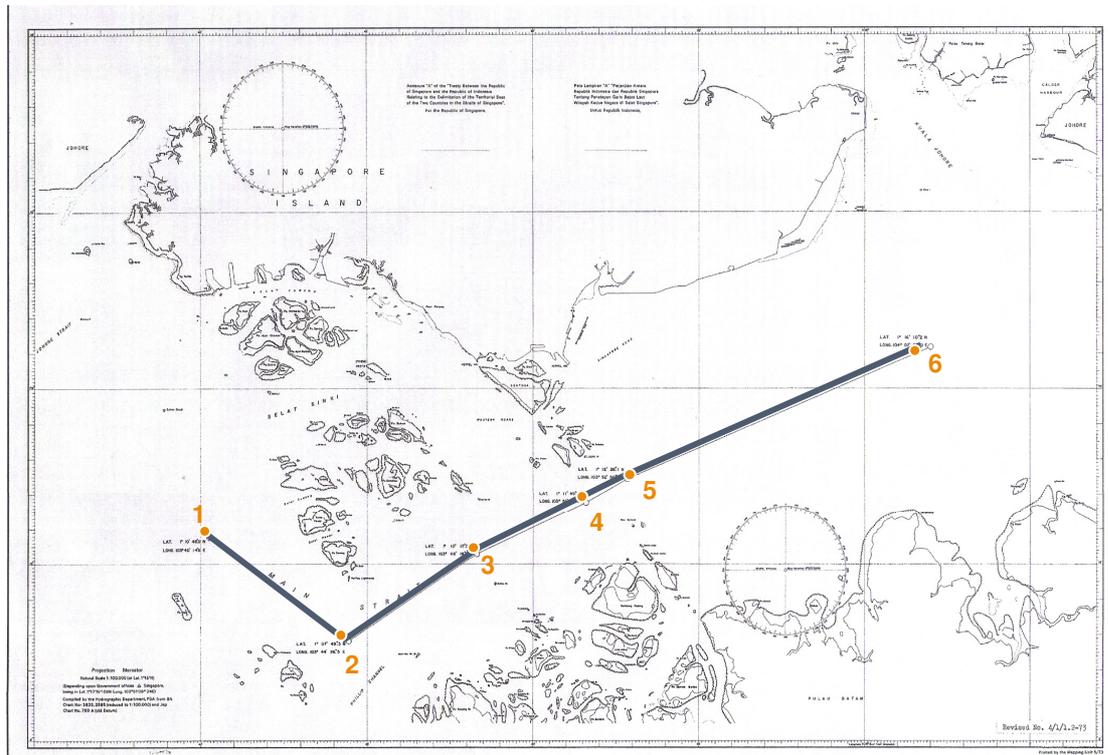


Figure 1. Annexure Map of the 1973 Treaty and the six boundary coordinates

Referring to the date of the signing of the Treaty and its relevant area of delimitation, there were several datums possibly used to delineate the 1973 Boundary line. Those datums are as appeared in Table 2.

Table 2. The Possible Datum Used in the 1973 Treaty

Maritime Boundary	Alternatives datum
Territorial Sea Boundary Indonesia-Singapore	Kertau 48
	Kertau 68
	Genuk
	South Asia

According to the information on Table 2, the calculation of datum transformation for all possible datum to WGS84 is conducted using the formula (1) and (2) from the 1973 boundary coordinates.

The information on the transformation parameters of Kertau 1948, Genuk and South Asia to WGS84 datum is relatively limited. The three transformation parameters, i.e. from

Kertau 1948 datum, Genuk, and datum South Asia datum to WGS84 are based on the data published by NIMA are shown in Table 3. The parameter for Kertau 1968 which contains 7 transformation parameters, including three translation parameters, three rotation parameters and a scale parameter. Datum transformation parameters of Kertau 1968 to the WGS84 that were provided by JUPEM and MPA can be seen in Table 4.

Table 3. Transformation Parameters from Kertau 1948 datum, South Asia datum and Genuk datum to WGS'84

Transformation Parameter	Kertau 1948 Datum	South Asia Datum	Genuk Datum
ΔX	-11±10m	-377±3 m	+7±10 m
ΔY	+851±8 m	+681±3 m	-10±8 m
ΔZ	+5±6m	-50±3 m	-26±6 m

Table 4. Transformation Parameters from Kertau 1968 datum to WGS'84 (Source: JUPEM and MPA)

Transformation Parameter	Transformation Parameters from JUPEM	Transformation Parameters from MPA
ΔX	379.9477 m,	201.317 m
ΔY	-770.555 m	906.791 m
ΔZ	88.069 m	158.387 m
Rx	2.698"/ ρ , $\rho = 206264.8''$	6.107067''
Ry	1.522"/ ρ	-3.844985''
Rz	-12.133"/ ρ	-7.300325''
K	= 0.791 x 10 ⁶ ppm	0.773297 ppm

Table 3 and Table 4 above show that the transformation parameters are different from one datum to another. The difference of value of the transformation parameters will also be affecting the calculation of datum transformation. Specifically for Kertau 1948 datum, South Asia and Genuk datum, the calculation should use the formula (1) since they only have 3 transformation parameters, while the Kertau 1968 should use the Bursa wolf because it has 7 transformation parameters. If the 1973 boundary coordinates were transformed using the above mentioned alternatives datums then the results obtained are as it is shown in Table 5.

Table 5. Coordinates of Transformation Results of Points of 1973 Treaty from Kertau 1948, Genuk and South Asia datum to WGS'84 position (Z. A., Hasanuddin, 2005).

Point	Assumption in Kertau 1948 transformed to WGS'84		Assumption in Genuk transformed to WGS'84	
	Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)
1	1° 10' 45.85"	103° 40' 08.44"	1° 10' 43.96"	103° 40' 21.24"
2	1° 07' 49.17"	103° 44' 20.31"	1° 07' 47.28"	103° 44' 33.11"
3	1° 10' 17.05"	103° 48' 11.78"	1° 10' 15.16"	103° 48' 24.59"
4	1° 11' 45.35"	103° 51' 29.15"	1° 11' 43.45"	103° 51' 41.96"
5	1° 12' 25.95"	103° 52' 44.44"	1° 12' 24.05"	103° 52' 57.25"
6	1° 16' 10.03"	104° 01' 53.67"	1° 16' 08.13"	104° 01' 06.49"
Point	Assumption in South Asia transformed to WGS'84		Assumption in Kertau 1968 transformed to WGS'84	
	Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)
1	1° 10' 45.16"	103° 40' 14.46"	1° 10' 45.82"	103° 40' 08.52"
2	1° 07' 48.46"	103° 44' 26.36"	1° 07' 49.13"	103° 44' 20.39"
3	1° 10' 16.36"	103° 48' 17.86"	1° 10' 17.02"	103° 48' 11.86"
4	1° 11' 44.67"	103° 51' 35.26"	1° 11' 45.32"	103° 51' 29.23"
5	1° 12' 25.27"	103° 52' 50.56"	1° 12' 25.91"	103° 52' 44.52"
6	1° 16' 09.37"	104° 01' 59.86"	1° 16' 10.00"	104° 01' 53.75"

Table 5 shows that each assumption, when the 1973 boundary coordinates are transformed to WGS84, this resulting to different numbers. These due to the transformation parameters are different from one datum to another. The employment of the wrong datum will change the coordinate value on the actual position. If it is assumed that the 1973 boundary coordinates are already referred to the WGS84, and then the datum is changed, this absolutely will change also the actual position of the agreed boundary line.

Table 6 shows how far the boundary points will move from their original position on the surface of the earth if they are transformed to WGS84 using the methods above. It also shows that the smallest changes in term of distance is made by the South Asia datum, with the range between 25-26m, and while the largest change made by the Genuk datum with the range between 210-215m.

Table 6. Coordinates Difference of Boundary Point in WGS'84 and the Shift of geographical Position in WGS'84
(Source: Z. A., Hasanuddin, 2005)

Point	Coordinates of KERTAU 1948 reduced by its coordinates in WGS'84			Coordinates of KERTAU 1968 reduced by its coordinates in WGS'84		
	dφ	dλ	d (m)	dφ	Dλ	d (m)
1	0".15	6".16	190.5	0".18	6".08	188.0
2	0".13	6".19	191.4	0".17	6".11	189.0
3	0".15	6".22	192.4	0".18	6".14	189.9
4	0".15	6".25	193.3	0".18	6".17	190.8
5	0".15	6".26	193.6	0".19	6".18	191.1
6	0".17	6".33	195.8	0".20	6".25	193.3
Point	Coordinates of GENUK reduced by its coordinates in WGS'84			Coordinates of SOUTH ASIA reduced by its coordinates in WGS'84		
	dφ	dλ	d (m)	dφ	Dλ	d (m)
1	2".04	-6".64	214.7	0".84	0".14	26.02
2	2".02	-6".61	213.7	0".84	0".14	26.03
3	2".04	-6".59	213.0	0".84	0".14	26.02
4	2".05	-6".56	212.4	0".83	0".14	26.01
5	2".05	-6".55	212.2	0".83	0".14	26.00
6	2".07	-6".49	210.5	0".83	0".14	25.98

Another method of datum transformation was also applied to complete this research. A government office building located on the Singapore side was used to support the coordinates transformation. The coordinate of point of the building pre 1968 before triangulation, post 1968 after triangulation and WGS'84 were collected. The difference between two coordinates was made as deviation or as parameter of translation of Kertau 1948 to Kertau 1968 and this was made by assuming that pre 1968, before triangulation, datum was used was Kertau 1948 and post 1968, after triangulation, was Kertau 1968 datum. The next step was to apply the deviation to all 1973 boundary coordinates and calculate the datum transformation using the transformation parameter from Kertau 1968 to WGS'84.

Another method which was analyzed was to compute the 1973 boundary coordinates in WGS 84 using the bearing and distance. This method computed bearing and distance from lighthouses or beacons to points 1, 2, and 3 of the 1973 Treaty and transferred them to WGS'84 coordinates. There are several limitations of this datum transformation method such as there should be such transformation parameters that have to be agreed by both countries. It may occur that one country has the coordinates of point in another datum and also the coordinates in WGS'84 so that they can compute the transformation parameter while the other country doesn't have that kind of data. Since the boundary points are owned by the two countries, to discuss this transformation off course normally each of them should have the specific data so that they can jointly examining, comparing and analyzing the data. This also

was one of the reasons causing datum transformation was not the method that suitable enough to solve the problem, even though it is known that datum transformation in most cases will produce an accurate result since it examines the coordinates and transformation parameters through a computation method.

Another method is the reconstruction method that had been done by the Geographer, U.S. Department of State (hereafter Geographer Method). The chart was used as base chart was BAC number 3833 of 2005, this was the latest chart which was available in the market and it was likely will be used by the two countries. The 1973 boundary coordinates are plotted on the mentioned BAC based on the data shown in Table 7.

Table 7. Physical Characteristics of the Indonesia-Singapore Territorial Sea Boundary (The Geographer, 1974)

TSB	Distance between Basepoint (nm)	Depth	Indonesian Territory	Distance land to TSB (nm)	Singaporean Territory
1	4.8	17	Pulau Nipa	1.7 2.8	Pulau Sudong
2	4.75	13	Pulau Takong Besar	1.35 1.75	Pulau Satumu
3	3.8	12	Buffalo Rock	1.1 1.8	Pulau Sebarok
4	1.35	20	Bt. Berhanti	1.3	Pulau Sakijang Bendera
5	9.85	25	Bt. Berhanti	1.35	Unnamed Islet east of Pulau Sakijang Petepah
6		20	Tg. Sengkuang	4.65	Tg. Bedok

From the data shown in Table 7, it can be seen that point 4, 5, 6 have almost the same distance from the basepoints located both on Indonesian side and Singaporean side. This occurs since those three points are determined using the equidistant method.

The other points (number 1, 2 and 3) have various distances from both countries' basepoints. The 1973 coordinates of points in WGS84 datum resulted from the reconstruction method are appeared in Table 8.

Table 8. Coordinate Points of 1973 Treaty from the Reconstruction Method

Point	Coordinates in WGS'84	
	Latitude (N)	Longitude (E)
1	1° 10' 44.44"	103° 40' 02.65"
2	1° 7' 49.57"	103° 43' 57.86"
3	1° 10' 12.5"	103° 48' 01.55"
4	1° 11' 40.04"	103° 51' 45"
5	1° 12' 27.44"	103° 52' 44.97"
6	1° 16' 09.14"	104° 01' 59.85"

In this method, the accuracy of the reading of the 1973 Treaty points' coordinates depends on the plotting of the basepoints which are used to reconstruct the points. The selection of basepoints located both on Singaporean territory and Indonesian territory just was relied on the technicians' perceptions since most of the basepoints were not in fix position. Another obstacle occurs in implementing this method is that some natural and man made features are already changed. For example, the basepoint at Tanjung Bedok could not be found on BAC number 3833 of 2005 since that area had been affected by the reclamation project conducted by the Singapore. This forces the technicians to determine and to put the basepoint at least in the vicinity of their actual position.

The last method that was examined was the chart-fitting method. Basically the reconstruction and chart fitting method are both graphical method. This method used the two charts mentioned above, the BAC 3833 of 1967 which was called as the old chart and BAC 3833 of 2005 (has been referred to the WGS84) which was called as the new chart. The 1973 boundary coordinates were plotted on the old chart. Then, both charts were overlaid to each other using 11 common feature points as shown in Figure 2. Those common points are located on: Iyu Kecil, Sultan Shoal, Nipa, Sinki, Raffles, Takong Kecil, Mount Faber, Sebarok, Buffalo Rock, Sakijang Pelepah dan Batu Berhanti. Those features were chosen due to their fix location, either on the old map or on the new map. That, thus, did not cause any different perceptions during the plotting stage. The coordinates of the 1973 boundary points in WGS'84 datum resulted from the application of the chart-fitting method are shown in Table 9.

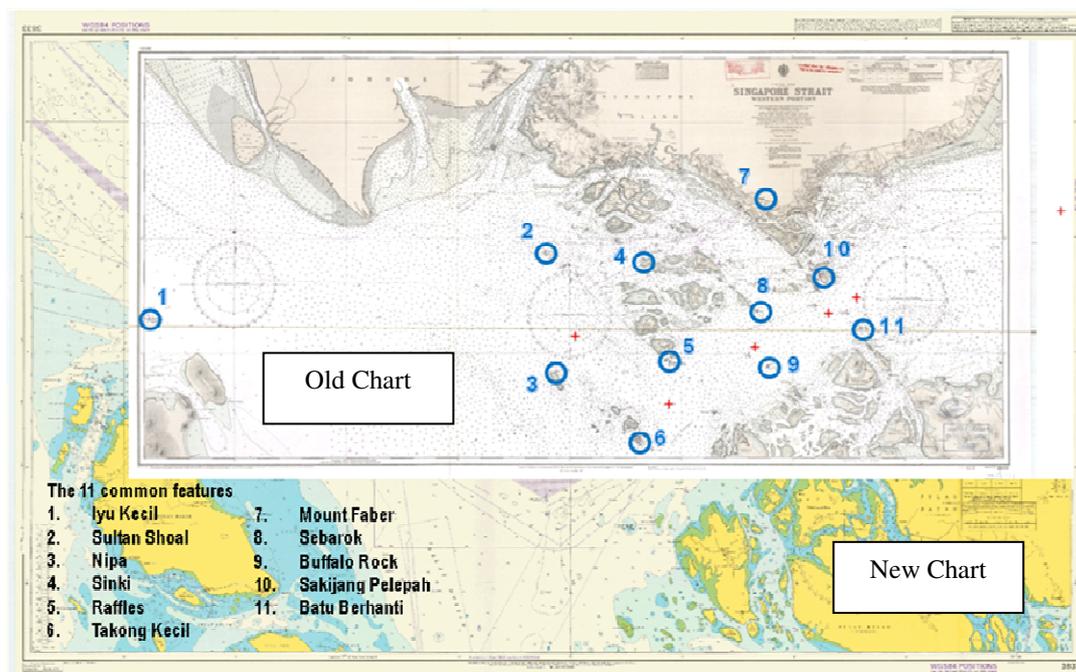


Figure 2. The Common Points

Table 9. The Coordinates of the 1973 Treaty resulted from the application of the Chart-fitting Method

Point	Coordinates in WGS'84	
	Latitude (N)	Longitude (E)
1	1° 10' 46.527"	103° 40' 14.791"
2	1° 07' 49.222"	103° 44' 26.544"
3	1° 10' 17.020"	103° 48' 17.205"
4	1° 11' 45.537"	103° 48' 17.205"
5	1° 12' 26.339"	103° 52' 50.313"
6	1° 16' 10.111"	104° 02' 00.471"

From the three methods discussed above, the chart-fitting method arguably should be considered as the most suitable and acceptable method since it not only used common points which are located throughout the territory of Singapore and Indonesia and can be viewed both in BAC 3833 of 1967 and in BAC 3833 of 2005. Another reason is that this method used two different charts which use different systems; even though the scale of the map should also be considered when using this method since it will influence the accuracy of the fitting. Among the common points, several beacons or lighthouses were selected due to their fix position both on the old and new chart.

5. CONCLUSION

It can be concluded that the chart fitting method, arguably is the most suitable and acceptable method to obtain the coordinates of 1973 Treaty into WGS'84. This is because of the natural correlation of the consistent features in both the real conditions or on the map. This arguably better than a condition where the parties should guess which datum used in 1973, which probably lead to a longer discussion since both parties will start comparing the difference between each datum.

During the later stage of the bilateral technical discussions on this matter between the two countries, it was agreed that the coordinates generated from chart-fitting method were going to be used as reference for practical activities.

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BIOGRAPHICAL NOTES

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