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Morphometry of Bransfield Strait, West Antarctica

ABSTRACT: On the basis of about 12500 depth measurements of which 6700 were taken from r/v *Profesor Siedlecki*, 1300 from r/v *Polarstern* and the remainder from British navigation charts, a bathymetric chart of the Bransfield Strait in the scale 1:500 000 has been prepared. Within the assumed boundaries the total area of the Bransfield Strait covers 65308.6 square kilometres, of which the Western Basin covers 23.5%, Central Basin — 47.3%, and Eastern Basin 29.2%. Capacity of the whole Bransfield Strait amounts to 38451 km³. The average depth of the Bransfield Strait is 592 m.

K e y   w o r d s: Antarctica, Bransfield Strait, morphometry measurements, cartography.

Introduction

Bransfield Strait is situated in West Antarctica between the South Shetland Islands in the North, and Antarctic Peninsula in the South. The first bathymetric measurements in the South Shetland region to the west of Livingston Island, were made by Arctowski (1900) during Belgica's Expedition in years 1898/99. Modern navigation charts of this region, mostly British (No. 3205, 3570, 1776) and American (No. 6941, 6942, 6944, 29101, 29122) are not good for morphometric measurements for which bathymetric charts are essential. The bathymetric chart of the Bransfield Strait prepared by Szeliga (1991) at the scale 1:500 000, allowed to measure this region for the first time. The Bransfield Strait in one the most intensively researched areas in West Antarctica and knowledge of its morphometry is useful for specialists from various disciplines.

Methods

A bathymetric chart was prepared for the region between parallels 60°40', and 65°00'S, and between meridians 53°00' and 66°00'W. The outlines of the Antarctic Peninsula and the South Shetlands were transferred from Britihs navigation charts No. 3205 and 3570. 6700 depth measurement points were taken from r/v *Profesor Siedlecki* during three expeditions: FIBEX-1981, SIBEX-1983/84 and BIO-MASS-3 in 1986/87 using Simrad-EK-38 and SU-2 echo sounders. Results were recorded at 1 nM intervals. Geographical coordinates of the vessel were defined with the use of the Redifon Satellite receiver connected to a printing set recording results every 10 minutes. This material was supplemented with 1300 measurements obtained from r/v Polarstern's expeditions which were kindly mode accessible by the Alfred-Wegener-Institute in Bremerhaven. 4500 depth measurement points were transferred from the British navigation charts No. 3205 and 3570 at a scale 1 :500 000 and also from No. 1776 at a scale of 1 :200 000. Althogether, about 12500 depth points formed the basis of the izobaths. These were drawn for the depths 100, 200, 300, 400, 500, 750, 1000, 1250, 1500 and thereafter for every 250 meters, down to 4500 m. The chart was drawn in Mercator Projection with the latitude of 67°S as the standard parallel. It is a conformal projection. Areas and distances are distorted. The size of linear distortions $\left(m = n = \dfrac{\cos_{vo}}{cis_v}\right)$ and the area distortions $\left(p = m \cdot n = \dfrac{\cos^2 v_0}{\cos^2 v}\right)$ at intervals 30', are shown in Table 1.

vo — latitude of the standard parallel, in our case 67°00',

v — latitude of a given parallel.

The boundary of Bransfield Strait and of the lower rank units

Bransfield Strait's boundaries were not accurately fixed. In this paper it was accepted that the southern and northern boundary was marked by the coastline of the islands and peninsula. The eastern and western boundaries were marked artificially (Fig. 1). To mark out boundaries only large forms shown in the chart were taken into account (Szeliga 1991). The Bransfield Strait includes three basin separated from each other by the features of the sea bed. Within these basins 19 smaller units were defined and their boundaries were fixed with homogenous criteria. The basic assumption was to fix the boundaries of these units so as to obtain not only convex-shallow, but also concave-deep forms at the same time. The areas of these units after summing gave the area of the basins. The boundaries between them were marked out along the 500 m isobath. They isolate shallow areas which are either island or continental shelves, or midsea shallows. The areas beneath 500 m constitute basins or valleys.
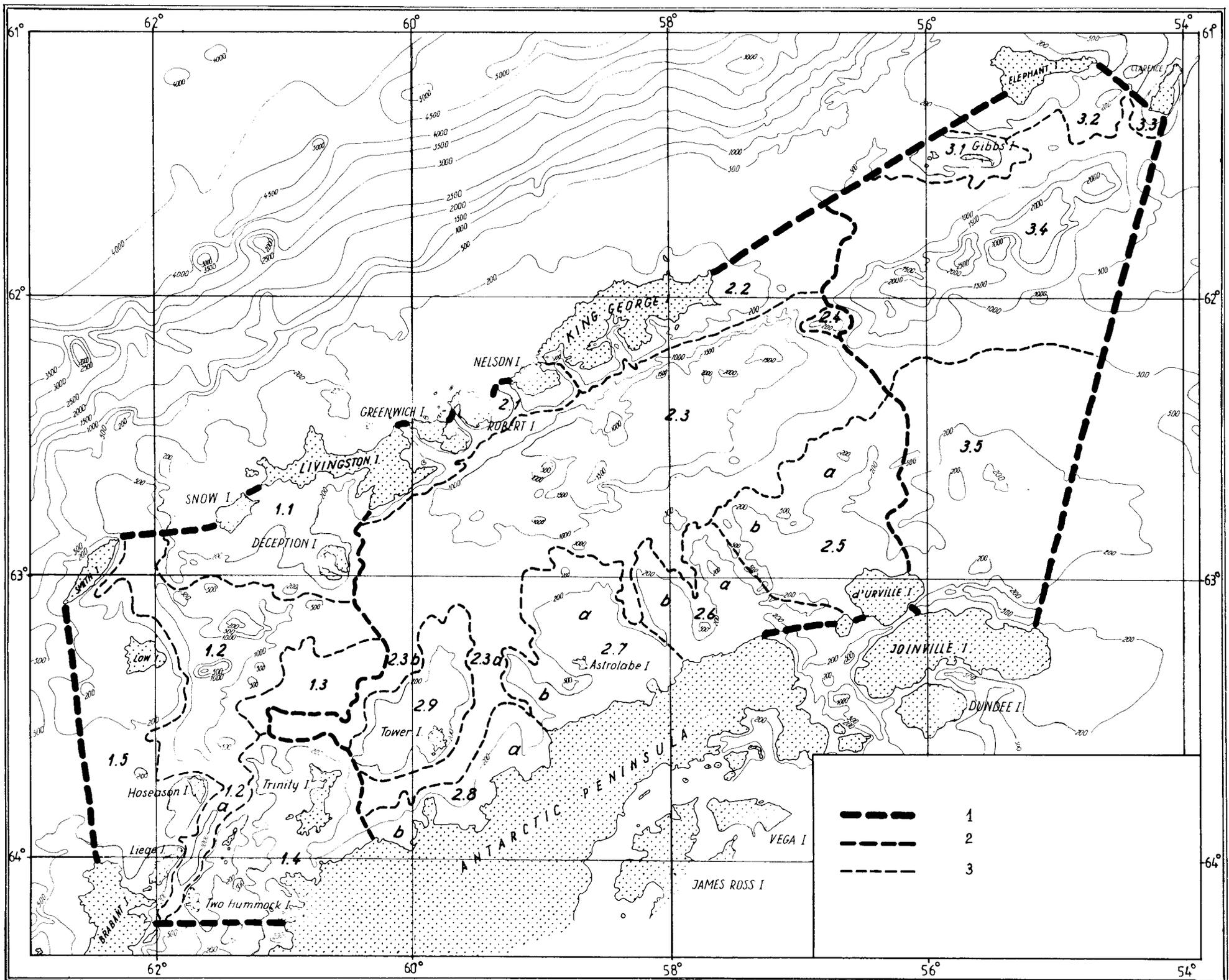
Fig. 1. The boundary of Bransfield Strait and of the lower rank units. 1 — Bransfield Strait bouindary, 2 — boundaries of basins, 3 — boundaries of units.

Although the actual boundary of the shelf in this region runs at different, usually shallower depths (Zarichin 1982) but in our calculations the areas to 500 m were treated as shelves.

Measurements in chart

In the chart (Szeliga 1991) fhe following elements of Bransfield Strait were measured: lenghts and widths, lengths of the boundaries, areas. To obtain areas which lack distortions the measurements were divided by the calculated distortion values (Table 1).

Table 1

Linear and area distortion of the Chart (in Fig. 1)

α	60°40′	61°00′	61°30′	62°00′	62°30′
m = n	0.7976	0.8059	0.8188	0.8322	0.8462
p = m·n	0.6359	0.6459	0.6705	0.6927	0.7160

α	63°00′	63°30′	64°00′	64°30′	65°00′
m = n	0.8606	0.8757	0.8913	0.9076	0.9245
p = m·n	0.7407	0.7668	0.7945	0.8237	0.8548

The length of the Bransfield Strait was measured along the central axis and along the diagonal SW-NE, this being its maximum length. The width was measured in the eastern, middle and western parts along lines perpendicular to the central axis. The Bransfield Strait boundary's length being in the most curved line, was measured by low compasses. The measurements were carried our three times and the arithmetical mean gave the final result. The areas were measured with a Robotron-Reiss planimeter. For each unit the area divided into parts in chosen isobaths (bathymetric degrees) was measured, namely: 0−200, 200−500, 500−1000, 1000−1500, 1500−2000, 2000−2500 and 2500−2640 m. Each measurement was again carried out three times and the arithmetical mean was take as the final result. The capacity was calculated by 3 methods. The 1st one consists of calculating the càpacity of layers included between individual bathymetric levels. In the 2nd method, water capacity was calculated between individual bathymetric levels with the use of a truncated cone formula, and beneath the lowest level with the use of the cone formula. In the 3rd method the capacity was obtained by multiplying the basins' area and the average depth. Differences between the results acquired by these three methods are not substantial, being 1.2% for the Southern Basin., 2.4% for the

Central Basin and 3% for the Western Basin. The final result was the average value of water capacity obtained from these 3 methods.

Results and discussion

The Bransfield Strait boundary (Fig. 1), basins and differentiated surfaces were marked out arbitrarily according to the rules accepted in methodology. The length of the Bransfield Strait measured along the central axis amounts to the 458 km, and the length measured along diagonal SW-NE between Brabant Island and Clarence Island amounts to 520 km. The width varies from 103 km in the western part between Brabant Island and Smith Island, to 232 km in the eastern part between Joinville Island and Elephant Island. In the central part the width is about 120 km. The global length of the Bransfield Strait boundary amounts to 1770 km. The length of the bundary running along the coast line and islands is 1115 km and the sea boundary is 655 km (Table 2). The

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Boundary lengths of Bransfield Strait

Boundary	Length in km		Total	
	sea	land	km	%
Eastern	214	—	214	12
Southern	90	549	639	36
Western	103	35	138	8
Northern	248	531	779	44
Total:				
km	655	1115	1770	
%	37	63		100

development of the Bransfield Strait boundary, accepted as the relation of its real length to the circumference of the same area is very small and amounts to 1.95.

The total area of the Bransfield Strait is 65308.6 km^2 of which the Western Basin covers the areas of 15361.3 km^2, Central Basin 30913.4 km^2 and the Eastern Basin 19033.3 km^2 (Table 3). The areas of the isolated units in the indivudal basins are presented in tables 4—7.

The average depth of the Bransfield Strait is 592 m, of the Western Basin 396 m, Central Basin 630 m, and the Eastern Basin 684 m.

Water capacity in the Bransfield Strait is 38451 km^3 of which more than a half is in the Central Basin. Water capacity in indivudual basins and also in the whole Bransfield Strait were calculated and shown in the following way:

a) capacities of water masses between isolated bathymetric levels whose sum equals water capacity of the whole vasins and Bransfield Strait (Table 8),

Bransfield Strait — basin areas according to bathymetric degrees (km²)

Bathymetric degrees (m)	Western Basin		Cental Basin		Eastern Basin		Total	
	km²	%	km²	%	km²	%	km²	%
0 – 200	5280.6	34.4	8982.7	29.1	4325.8	22.7	18589.1	28.5
200 – 500	5887.5	38.3	7062.5	22.8	5384.7	28.3	18334.7	28.1
500 – 1000	3220.0	21.0	7783.1	25.2	5072.3	26.6	16075.4	24.6
1000 – 1500	973.2	6.3	3979.1	12.9	2006.4	10.6	6958.7	10.6
1500 – 2000	–	–	3073.8	9.9	1369.0	7.2	4442.8	6.8
2000 – 2500	–	–	32.2	0.1	824.6	4.3	586.8	1.3
2500 – 2640	–	–	–	–	51.1	0.3	51.1	0.1
Total:								
km²	15361.3		30913.4		19033.9		65308.6	
%	23.5	100.0	47.3	100.0	29.2	100.0		100.0

Western Basin: area of units according to bathymetric degrees (km²)

Num ber	Unit	Bathymetric degress (m)				Area	
		0 – 200	200 – 500	500 – 1000	1000 – 1426	km²	%
1.1	Shelves of islands: Snow — Livingston — Deception	1556.6	1200.3	4.1	–	2761.0	18.0
1.2	Proper basin with Croker Valley (1.2a)	19.6	217.8	3207.1	973.2	4417.7	28.8
1.3	Austin Shallow	63.7	1090.0	–	–	1153.7	7.5
1.4	Shelves of islands: Trinity — Two Hummock — Christiania	1726.0	1185.4	8.8	–	2920.2	19.0
1.5	Shelves of islands: Brabant — Liege — Hoseason — Low — Smith	1914.7	2194.0	–	–	4108.7	26.7
Total: km²		5280.6	5887.5	3220.0	973.2	15361.3	
%		34.4	38.3	21.0	6.3		100.0

b) capacities of water columns over the sea bottom in isolated bathymetric degrees, whose sum also equals water capacity of the whole basins and Bransfield Strait (Table 9).

This cartographic work presents for the firs time in literature, a picture of the Bransfield Strait from numeric approach.

Central Basin: area of units according to bathymetric degrees (km²)

Number	Unit	Bathymetric degrees (m)						Area	
		0–200	200–500	500–1000	1000–1500	1500–2000	2000–2048	km²	%
2.1	Shelves of islands: Nelson, Robert, Greenwich	624.5	491.2	–	–	–	–	1115.7	3.6
2.2	Shelf of King George Is.	972.1	1441.1	10.2	–	–	–	2423.3	7.8
2.3	Proper basin with Orlean Valley (2.3a) and Austin Valley (2.3b)	–	89.7	7772.2	3979.1	3073.8	33.2	14948.7	48.4
2.4	Bridgeman Height	58.4	101.7	–	–	–	–	160.1	0.5
2.5	d'Urville Bank (a) and Zeele Bank (b)	1914.1	1954.7	–	–	–	–	3868.8	12.5
2.6	Siedlecki Bank (a) and Montravel (b)	1422.2	778.2	–	–	–	–	2200.4	7.1
2.7	Astrolabe Bank (a) and Hombron Bank (b)	2000.5	983.6	–	–	–	–	2984.1	9.7
2.8	Charcot Bank (a) and Lanchester Bank (b)	796.0	563.8	–	–	–	–	1359.8	4.4
2.9	Tower Bank	1194.9	658.6	–	–	–	–	1953.5	6.0
	Total: km²	8982.7	7062.5	7783.1	3979.1	3073.8	33.2	30914.4	
	%	29.1	22.8	25.2	12.9	9.9	0.1		100.0

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Eastern Basin: area of units according to bathymetric degrees (km²)

Num-ber	Unit	Bathymetric degrees (m)							Area	
		0–200	200–500	500–1000	1000–1500	1500–2000	2000–2500	2500–2640	km²	%
3.1	Gibbs Height	421.3	493.1	–	–	–	–	–	914.4	4.8
3.2	Shelf of Elephant I.	603.1	707.7	5.3	–	–	–	–	1316.1	6.9
3.3	Shelf of Clarence I.	41.3	108.7	–	–	–	–	–	150.0	0.8
3.4	Proper basin	–	320.0	4925.7	2006.4	1369.0	824.6	51.1	9496.8	49.9
3.5	Joinville Bank	3260.1	3755.2	141.3	–	–	–	–	7156.6	37.6
Total:	km²	4325.8	5384.7	5072.3	2006.4	1369.0	824.6	51.1	19033.9	
	%	22.7	28.3	26.7	10.5	7.2	4.3	0.3		100.0

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T a b l e 7

Areas of bathymetric levels (km²)

Bathymetric levels (m)	Western Basin	Central Basin	Eastern Basin	Bransfield Strait
0	15361.3	30913.4	19033.9	65308.6
200	10081.0	21935.0	14708.0	46721.0
500	4193.0	14869.0	9323.0	28385.0
1000	973.0	7086.0	4251.0	12310.0
1500	—	3107.0	2248.0	5355.0
2000	—	33.0	876.0	909.0
2500	—	—	51.0	51.0

T a b l e 8

Water capacity between isolated bathymetric levels for Bransfield Strait basins

Bathymetric layers (m)	Western Basin		Central Basin		Eastern Basin		Total	
	km³	%	km³	%	km³	%	km³	%
0—200	2539	41.8	5277	27.1	3367	26.1	11183	29.1
200—500	2116	34.9	5508	28.3	3590	27.8	11214	29.2
500—1000	1254	20.7	5449	28.0	3360	26.0	10063	26.2
1000—1500	158	2.6	2526	13.0	1607	12.5	4291	11.1
1500—2000	—	—	716	3.6	761	5.9	1477	3.8
2000—2500	—	—	1	0.0	220	1.7	221	0.6
2500—2640	—	—	—	—	2	0.0	2	0.0
Tota: km³	6067		19477		12907		38451	
%	15.8	100.0	50.06	100.0	33.6	100.0		100.0

T a b l e 9

Water capacity over the sea bottom for Bransfield Strait basins

Bathymetric degress (m)	Western Basin		Central Basin		Eastern Basin		Total	
	km³	%	km³	%	km³	%	km³	%
0—200	525	8.6	898	4.6	433	3.6	1856	4.8
200—500	2037	33.6	2452	12.6	1880	14.5	6369	16.6
500—1000	2400	39.6	5841	30.0	3804	29.4	12045	31.3
1000—1500	1105	18.2	4879	25.0	2500	19.4	8484	22.1
1500—2000	—	—	5340	27.4	2362	18.2	7702	20.0
2000—2500	—	—	67	0.4	1800	13.9	1867	4.9
2500—2640	—	—	—	—	128	1.0	128	3.3
Tota: km³	6067		19477		12907		38451	
%	15.8	100.0	50.06	100.0	33.6	100.0		100.0

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Streszczenie

W pracy przedstawiono dane morfometryczne Cieśniny Bransfielda uzyskane w oparciu o mapę batymetryczną 1:500 000 (Szeliga 1991). Izobaty na mapie wykreślono na podstawie około 12 500 punktów głębokościowych pomierzonych w rejsach r/v *Profesor Siedlecki* (6700 punktów), r/v *Polarstern* (1300 punktów) oraz zaczerpniętych z brytyjskich map nawigacyjnych (4500 punktów). W oparciu o mapę wyznaczono granice Cieśniny Bransfielda, dokonano podziału Cieśniny na trzy baseny i 19 mniejszych jednostek (fig. 1). Pomiary i obliczenia objęły następujące elementy Cieśniny: długość i szerokość, długość granic, powierzchnie wydzielonych jednostek, objętość masy wodnej oraz średnie głębokości basenów. Długość Cieśniny Bransfielda wzdłuż osi centralnej wynosi 458 km, szerokość od 103 km w zachodniej części do 232 km w części wschodniej. Długość granicy Cieśniny Bransfielda wynosi 1770 km (tab. 2), zaś powierzchnia 65308.6 km² (tab. 7). Powierzchnie basenów w rozbiciu na mniejsze jednostki i stopnie głębokościowe przedstawiono w tabelach 4 — 6. Średnia głębokość Basenu Wschodniego 684 m a objętość całej Cieśniny Bransfielda wynosi 38451 km³, z czego ponad połowa przypada na Basen Centralny.