

## **General Disclaimer**

### **One or more of the Following Statements may affect this Document**

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

05

"Made available under NASA sponsorship  
in the interest of early and wide dissemination of Earth Resources Data  
and information and without restriction  
of any kind made thereto."

TITLE OF INVESTIGATION:

Mapping islands, reefs and shoals in the oceans  
surrounding Australia.

INVESTIGATION NUMBER:

2896B

INVESTIGATOR:

Leonard G. Turner  
Division of National Mapping  
PO Box 548  
QUEANBEYAN NSW 2620  
AUSTRALIA

FINAL REPORT

PERIOD OF INVESTIGATION:

8 August 1975  
to  
8 August 1976

DATE OF REPORT:

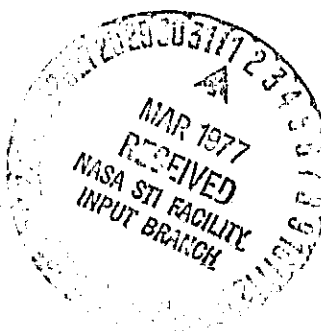
8 November 1976

2896B

RECEIVED

JAN 31 1977

SIS/902.6



7.7-10.091  
CR-149574

(E77-10091) MAPING ISLANDS, REEFS AND  
SHOALS IN THE OCEANS SURROUNDING AUSTRALIA  
Final Report, 8 Aug. 1975 - 8 Aug. 1976  
(Division of National Mapping) 14 p  
HC A02/ME A01

CSCCL 08B G3/43

Unclas  
00091

N77-18512

## II. Technique

The aim of the investigation has been to develop, and if possible apply, techniques for the mapping of islands, reefs and shoals in offshore areas using LANDSAT imagery. First priority in this investigation has been given to the determination of the planimetric accuracy of the Multi-Spectral Scanner imagery. Attention has also been directed to the development of techniques for then transforming the same imagery into maps of specified planimetric accuracy. The extent to which water depth information can be abstracted from the imagery has also been studied. Consequently, the techniques in use may be discussed under a number of headings.

### (a) Planimetric Accuracy of MSS Imagery

The basic method of determining the planimetric accuracy of the MSS imagery has been to compare, via mathematical transformations, a set of image co-ordinates for a number of points on the image with the Australian Map Grid co-ordinates of the corresponding points on the ground. The transformation relationships correspond to the systems which would project the original control onto the Landsat image; the residuals after least-squares comparison of the two sets of co-ordinates indicate the remnant distortions which are not eliminated in the transformation.

A number of different techniques have been used in this study:-

- (i) The imagery used has varied from diapositives at 1:1 000 000 scale to paper prints at 1:250 000 and 1:1 000 000 scale and to a TV screen display derived from a computer-compatible tape;
- (ii) Both conventional survey control stations and identifiable map features have been used as control points;
- (iii) Various mathematical transformations - Helmert, Affine, Second Order Conformal and Bilinear - have been used to relate the image and map grid co-ordinates;
- (iv) A co-ordinatograph has been used to measure the image co-ordinates, and digital methods have also been used to obtain image co-ordinates in terms of scan line numbers and picture-element number.

Such tests have been undertaken on two Landsat scenes so far; results are reported in Section IV.

The recommended procedures listed in Section III will indicate that the problem of control point usage has received more attention than was originally expected to be necessary in the Statement of Work.

It may seem that the examination of the cartographic application of Landsat imagery is a possible duplication of work being done by other workers in the same field. However, offshore mapping is considered to involve problems and solutions different from those encountered in onshore mapping. Offshore imagery features include:-

- (i) a lack of relief displacement;
- (ii) a lack of cultural features which may either assist in identification, or hinder the correction of distortions;
- (iii) expanses of open water which are not involved in distortion measurements or corrections;

- (iv) inaccessibility, so that control stations often do not exist or are difficult to place;
- (v) limited options for control configuration; and
- (vi) the existence of tides which can alter the apparent shapes and sizes of islands and reefs.

The investigation has used scenes of ocean areas, rather than terrestrial scenes, whenever possible in order to maximise experience with this type of imagery.

(b) Map Production and Distortion Corrections

In the Statement of Work it was proposed that the rectification of bulk imagery by optical projection methods would be attempted. However, experience with the imagery, and with the distortions thereon, has led to the recognition that other methods of using the imagery deserve consideration. Such methods include the use of imagery other than that in bulk form, and the preparation of the maps from the imagery by methods such as the direct application of a best-fitting rectangular grid.

(c) Water Depth Determination with MSS Imagery

The possibility of successfully determining water depths from the MSS imagery was not known at the commencement of the project, and in fact this aspect of the investigation was not developed in the Statement of Work. Some success by overseas workers has prompted the application of some effort in this direction. Simple methods only have been used so far to compare water depths with Band 4 intensity levels; complex techniques can be developed now that the basic principle has been verified. Profiles of image intensities have been digitally abstracted from Landsat scenes and correlated with water depths in the corresponding ocean areas. The computer hardware and software has been provided by the Department of Engineering Physics at the Australian National University, Canberra. Bathymetric information was obtained from published and unpublished hydrographic charts. Results of trials in shallow water areas on three different scenes are reported in Section IV.

III. Accomplishments

As this investigation has been aimed at the development of techniques rather than at the abstraction of new information from imagery, the techniques which have been developed so far can be reported as "achievements". Some such principles relate to the use of control points. For example:-

- a) Existing trigonometrical stations are invariably unsuitable control points for identification on satellite imagery.
- b) Topographic and cultural features which are identifiable on existing maps, particularly at 1:100 000 scale provide good control points whose accuracy is known to a satisfactory level. However, maps of offshore areas which would be mapped using Landsat data do not generally exist.
- c) Cultural features, such as roads (especially road intersections) landing strips, wharves and fence corners are also points which are easily identifiable, whereas topographical features are not; however such cultural features are not found on offshore areas for which maps are needed.

- d) Particularly as a result of a), b) and c) above, control points must be specially selected from the Landsat image and then fixed before the Landsat map can be produced.
- e) The identification of the control points on aerial photographs even if special photography runs are required, is also advantageous.
- f) The control points must be selected on the basis of two criteria: the point must be identifiable on the Landsat scene and on the earth's surface from a land or sea craft. The former criterion can be satisfied by, for example, using a blow-up of the Landsat image to 1:250 000 scale; to satisfy the latter criterion on reefs, points would have to be placed close to reef edges at locations which could be identified from a ship.

The practice of determining the control point image co-ordinates using the digital image analysis system of the Australian National University has also been adopted.

An arrangement by which the Royal Australian Navy Hydrographic Services would fix twenty control points in the Great Barrier Reef according to the above principles verified the feasibility of the recommended procedures. Weather conditions at the time of the survey eventually permitted the fixing of only six of the proposed 20 control points, so that it has not been possible to test procedures through to the stage of final preparation of a map of this reef area. Nevertheless, procedures relating to planimetric accuracy testing can now be accepted as having been verified. The Hydrographic Service plans to complete the survey at a later date if possible.

None of the achievements which were proposed in the Statement of Work have failed by reason of insurmountable difficulty. Only delays arising from the volume of work required, the time required for image processing and delays such as the abovementioned survey misfortune have prevented the full development of techniques for mapping shallow water marine features. (Some problems have arisen in the water depth measurement study but this program was not developed in the Statement of Work.)

#### IV. Significant Results

##### a) Significant results from planimetric accuracy tests

Results obtained in the planimetric tests which were discussed in Section II are summarised in Table 1. The latest tests, 1b and 2c, which were carried out with optimum procedures, suggest that the MSS imagery has excellent geometric fidelity. Accuracy specifications for mapping in Australia require that 90% of points tested have residual errors less than 0.5 mm (i.e. less than 125 m on the ground for a 1:250 000 scale projection or 500 m for 1:1 000 000 scale). The earlier tests had deficiencies in point identification and measurement and consequently the apparent residuals would exceed the true residuals.

Figure 1 depicts "contours" of residual errors, in metres, in the east and north directions, on scene 2125-01091. The contours were constructed from the residuals which were determined at 22 ground control points, as shown in figure 1. Residuals at two control points were rejected from the contour determination, as their magnitudes were not in keeping with surrounding values.

b) Results from depth measurement tests

The results obtained so far from these tests are only tentative. Figure 2 depicts both successful and unsuccessful correlations between the imagery intensities and bathymetric data. Using the results from 9 profile comparisons abstracted from a scene (1026-00035) over Torres Strait, where water is generally very clear, an empirical relationship between image intensity I and water depth d (metres) was derived:-

$$I = 30 - 0.75 d$$

Further investigations will be undertaken to expand, verify or disprove this relationship which has not been compared with theoretical developments which have been reported in the literature.

V. Publications

Details relating to the investigation procedures, recommendations and results have not been published. A paper in Cartography\* (Australian Institute of Cartographers) has included a reference to early results of estimates of the planimetric accuracy and refers to plans for making use of the Landsat imagery for bathymetric mapping purposes. It is felt that after some further work, a more complete report and other articles could be produced with NASA's permission, for communication with surveying, mapping, cartographic and navigation communities. A report for presentation to the Annual Congress of the Institution of Surveyors, Australia, in mid 1977, is presently being planned.

VI. Problems

The progress forecast in the Statement of Work has been delayed but not halted by the need to expand the examination of the use of control points. The control that is available from geodetic traverses, Aerodist and satellite fixes has not provided suitable identifiable points. Not only has this resulted in further study, but it has also led to the previously mentioned work by the Hydrographic Service.

Some problems have been encountered in the use of imagery for the measurement of shallow water depth. Firstly, distinguishing between shallow water and dirty or discoloured water is causing difficulty, but a proposed initial solution is to eliminate confusion by undertaking studies in water which is known to be clear. Difficulty also arises from the limited range of useful signal over ocean areas, as a result of the scanner being designed for terrain analysis rather than for oceanographic application. The imagery is consequently insensitive to fine variations in water depth; noise levels of a single grey-scale unit correspond to very significant changes in depth. Image deficiencies such as six-line striping, and banding in general, must be resolved before water depth and image radiometric levels can be correlated digitally.

VII. Data Quality and Delivery

Under the investigation agreement, the Landsat-2 imagery to be provided by NASA consisted of bulk 70 mm monochromatic transparencies

---

\* Cartography 9(4), July 1976, 217-223: Notes on the Application of Satellite Imagery to Topographic, Bathymetric, and Land-Use Mapping in Australia.

tape coverage of two Landsat-2 MSS scenes was approved by NASA.

A total of 156 scenes on 70 mm imagery were received between 11 September 1975 and 12 December 1975; 106 scenes covered Test Area No. 1, 45 scenes were over Area No. 2; five scenes were received for the remaining two Test Areas. On receipt of the imagery, it was catalogued and coverage of shallow water features and coastal areas was noted: 32 scenes depicted no water features at all and were classified as being of no value; 51 scenes were of land areas which could not be applied to this particular investigation; repetitive coverage was received for about 72% of scenes. It is a disappointment that only 18 usable scenes were received for Test Area No. 2, presumably as a result of persistent cloud coverage of the region. This area includes the Great Barrier Reef which consists of an abundance of oceanic features, close to or above the surface of some of the world's clearest water which is presently inadequately mapped; the area is therefore eminently suited to Landsat mapping. However, coverage of the area was sufficient to allow selection of a scene on which the map production processes are to be tested.

The late arrival in Australia of much of the imagery delayed the commencement of the study - until November 1975, only 30 scenes had been received. The aforementioned CCT's of two scenes did not arrive until July 1976 so that they have not made a valuable contribution to the investigation. However, in the period before their arrival, tapes of Landsat-1 scenes were used as satisfactory, and presumably equivalent, substitutes.

Considering that the Multi-Spectral Scanner imagery was originally designed for monitoring earth resources, and not for cartographic application, the resolution and quality of the imagery must be considered to be certainly adequate. However, for mapping application, the maximum level of detail extraction is sought. Here, the imagery has been examined for the purpose of mapping at 1:250 000 scale. The planimetric accuracy of the MSS imagery has already been described as approaching accuracy specifications for this scale of mapping, but the resolution of the imagery is considered to be inferior to that which is normally presented on maps at this scale. The use of aerial photographs to enhance detail on imagery obtained at satellite altitudes should remedy this deficiency. Further, the adoption of specially placed control points should assist their identification on the imagery. Scenes which were reproduced as diapositives directly from digital tapes were superior to reproductions obtained from 70 mm bulk images, which at 1:250 000 scale was degraded further; imagery of the lowest possible generation number will be sought for final mapping purposes. The existence of deleterious aspects such as banding and striping can spoil maps which are to be produced in "photographic form" and can disrupt the analysis of the imagery, particularly for depth determination.

#### VIII. Recommendations

It is recommended that the investigation continue on the lines that have been followed to date, with an immediate and foreseeable goal being the production of exemplary, presentable, planimetrically accurate maps of offshore areas, utilising techniques which are now well developed. It was hoped that such an achievement would be attained before the time of preparation of this Report. It is also suggested that further testing of planimetric distortions should continue concurrently with the above study in order to collect a greater volume of data and experience on the nature

of the distortions, and on their spatial and temporal variation. The bathymetry study should continue simultaneously, with accentuation of the digitization of the procedures for correlating image and ocean data.

#### IX. Conclusions

The study has been aimed at examining the extent to which Landsat imagery could be applied to the Division's bathymetric mapping program. The idea for the investigation stems from a recognition that, although the Landsat satellite series is oriented towards monitoring earth resources and not towards accurate offshore mapping, the imagery nevertheless depicts, quite accurately, features such as islands and reefs and even shoal waters.

The use of the imagery for its intended purpose must be viewed in the light of needs for this mapping. The Division's bathymetric mapping program is aimed at mapping the Australian continental shelf area to a depth of 300 metres at a mapping scale of 1:250 000. Furthermore, the major portion of this area has yet to be mapped in the program; much of it contains islands, reefs and other features which are discernable on the satellite imagery. Even though hydrographic charts cover some of these areas, the extent of the charts, their age and the accuracy, is variable and not always satisfactory to the program's requirements.

Mapping from satellite imagery has some advantages over conventional hydrographic survey techniques:

- a) delineating reefs and islands and mapping in shallow water by conventional ship-borne techniques can be dangerous, slow, difficult, at times impossible, and in comparison to Landsat imagery, probably much more expensive, and
- b) because each Landsat image covers such a large area at a time, it also can have valuable application in cases where aerial photographs cannot bridge large expanses of featureless ocean areas.

From this background, then, the Landsat imagery was considered to be worth some investigatory effort; the work was also stimulated by some overseas success in determining water depths using satellite imagery.

Although the investigation may appear to duplicate work being undertaken elsewhere on the cartographic application of this imagery, it is considered that the problems and solutions encountered in offshore mapping with the satellite products are not the same as those encountered in the mapping of onshore, topographical features.

The mapping technique using Landsat imagery is still being developed; however it has been found in quantitative tests that the geometric accuracy of the Multi-Spectral Scanner imagery approaches accuracy requirements for 1:250 000 mapping.

The examination of the abstraction of water depths from the imagery has not been conclusive, but it does seem that judicious use of the imagery will provide qualitative, if not quantitative, information on the existence and nature of shallow water areas.



Some recommended procedures for the use of Landsat imagery for mapping purposes are now being prepared. Using scene number 2213-23200 two planimetrically accurate, but undetailed, maps of an area of the Great Barrier Reef have been prepared at a scale of 1:250 000, to verify the procedures which are being proposed for the mapping of offshore reefs and islands. For one map, a best-fitting grid was applied to the Landsat scene; in the second case, distortions were corrected by relocating, or block-shifting, groups of reefs: see figures 4 and 5. Features on the latter map have been improved by transferring detail from aerial photographs of the region onto the Landsat image map.

It can be concluded that the imagery has proved itself of value to bathymetric mapping. Moreover, the production of maps by this technique would, it is felt, be an achievement of significance to offshore mapping. It would not be difficult to regard the impact of satellite imagery on some forms of mapping to be revolutionary in the same manner that aerial photography has affected topographical mapping.

Table 1

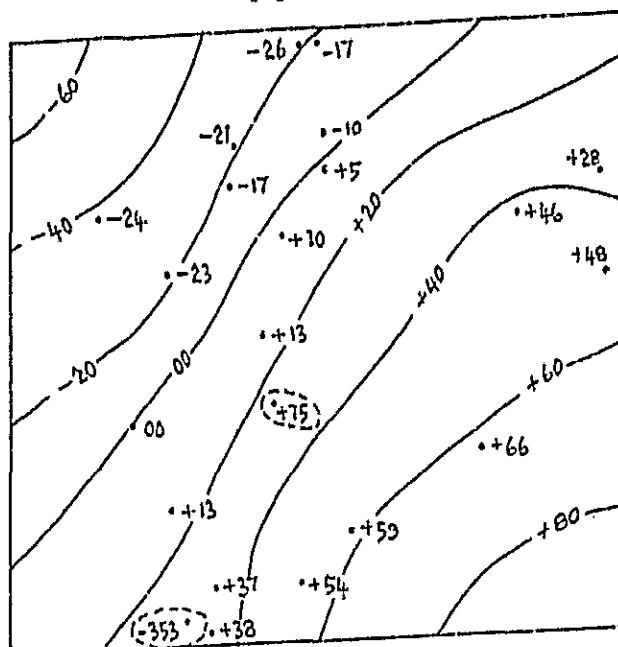
RESULTS OF DISTORTION TESTS  
ON LANDSAT MSS IMAGERY

		TEST 1		TEST 2		
		a	b	a	b	c
LANDSAT IMAGE NUMBER		1026-00035		2125-01091		
AREA		TORRES STRAIT		LACEPEDE IS., BROOME, KING SOUND		
Test image form		B&W, dia-positive	TV screen display	B&W, Stable-based, magnified from 70 mm transparency.		
MSS BAND		4		5	5	5
Image scale		1:1000 000	Variable on TV screen	1:1000 000	1:250 000	
Source of ground control		Trig. stations, identified mainly by aerial spot photographs.				Points on 1:100 000 maps.
Number of points used		28		12	11	22
M.S.E. after transmem (in m. on ground)	H	540	*	371	278	99
	A	210	132	284	220	92
	C	490	*	315	228	96
	B	210	102	229	162	98
Residual which is not exceeded by 90% of points	H	750	Not determined *	555	350	70
	A	230		290	335	65
	C	680		550	295	75
	B	250		315	220	80
Percentage of points with a residual less than 0.5 mm on image.	H	72		83	9	92
	A	98		100	27	92
	C	68		100	27	92
	B	96		83	45	92

Code: H Helmert Transformation,  
A Affine Transformation,

C Second Order Conformal Transformation,  
B Bilinear Transformation

- A -



- B -

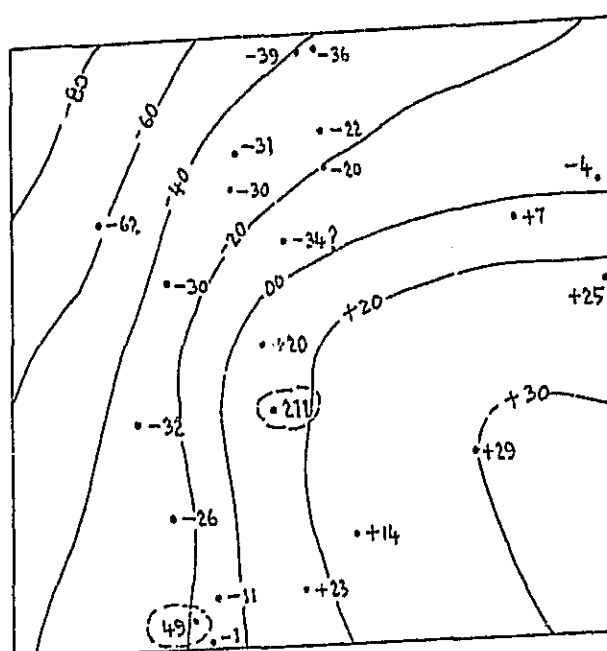


Figure 1: Residuals in the a) east and b) north directions, on Landsat scene 2125-01091.

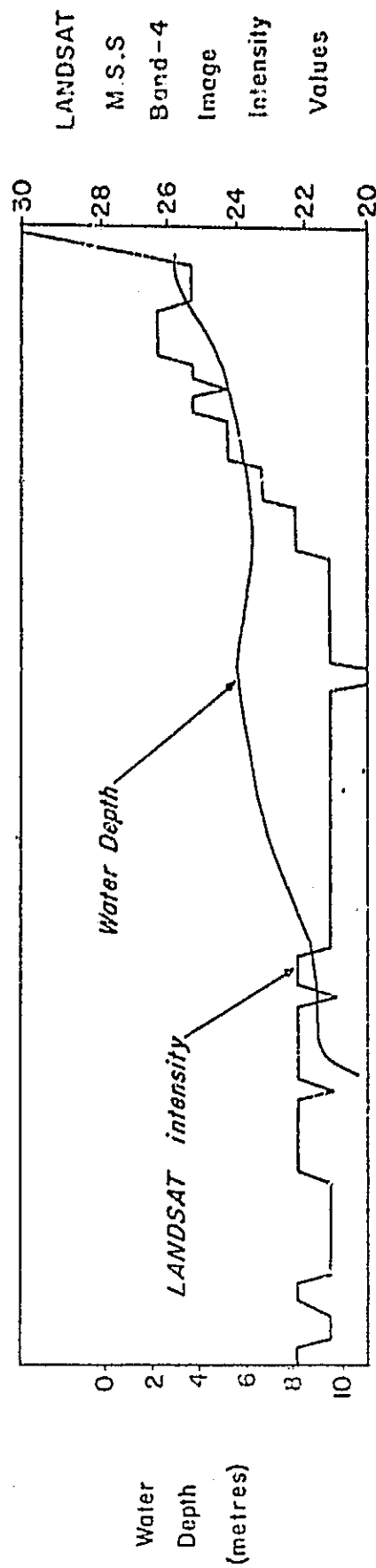
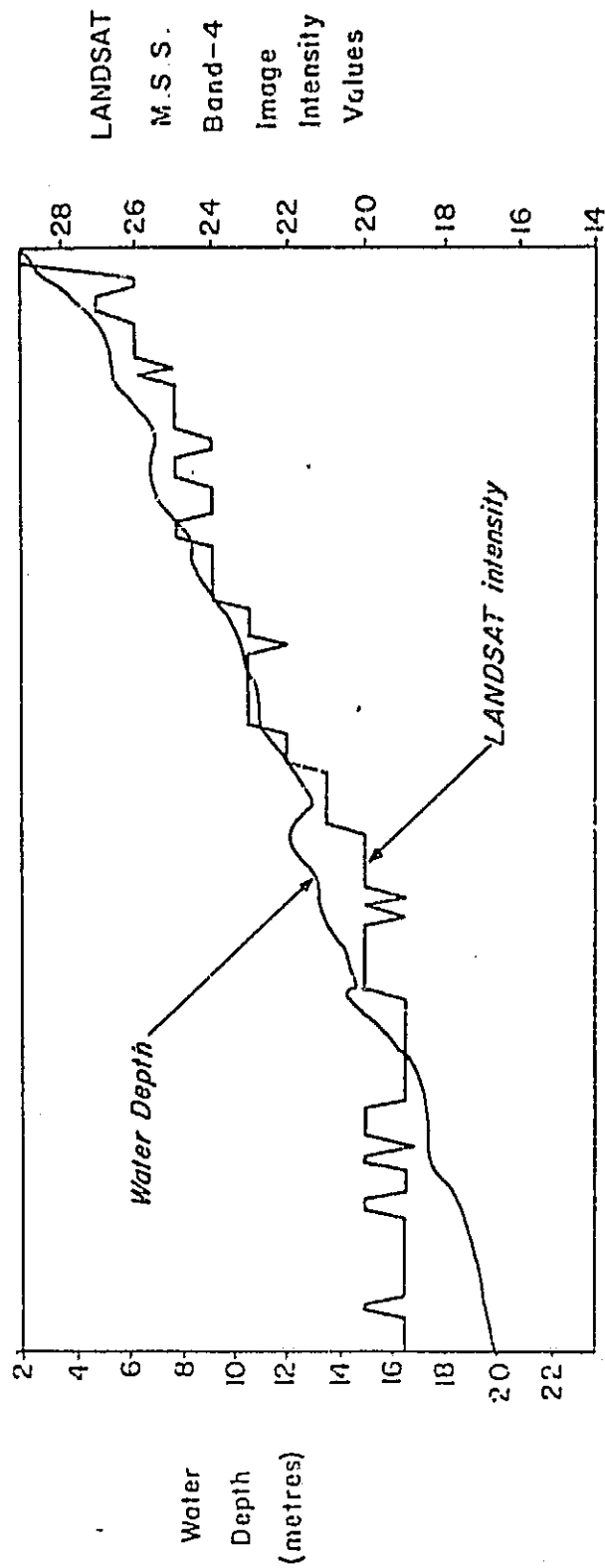
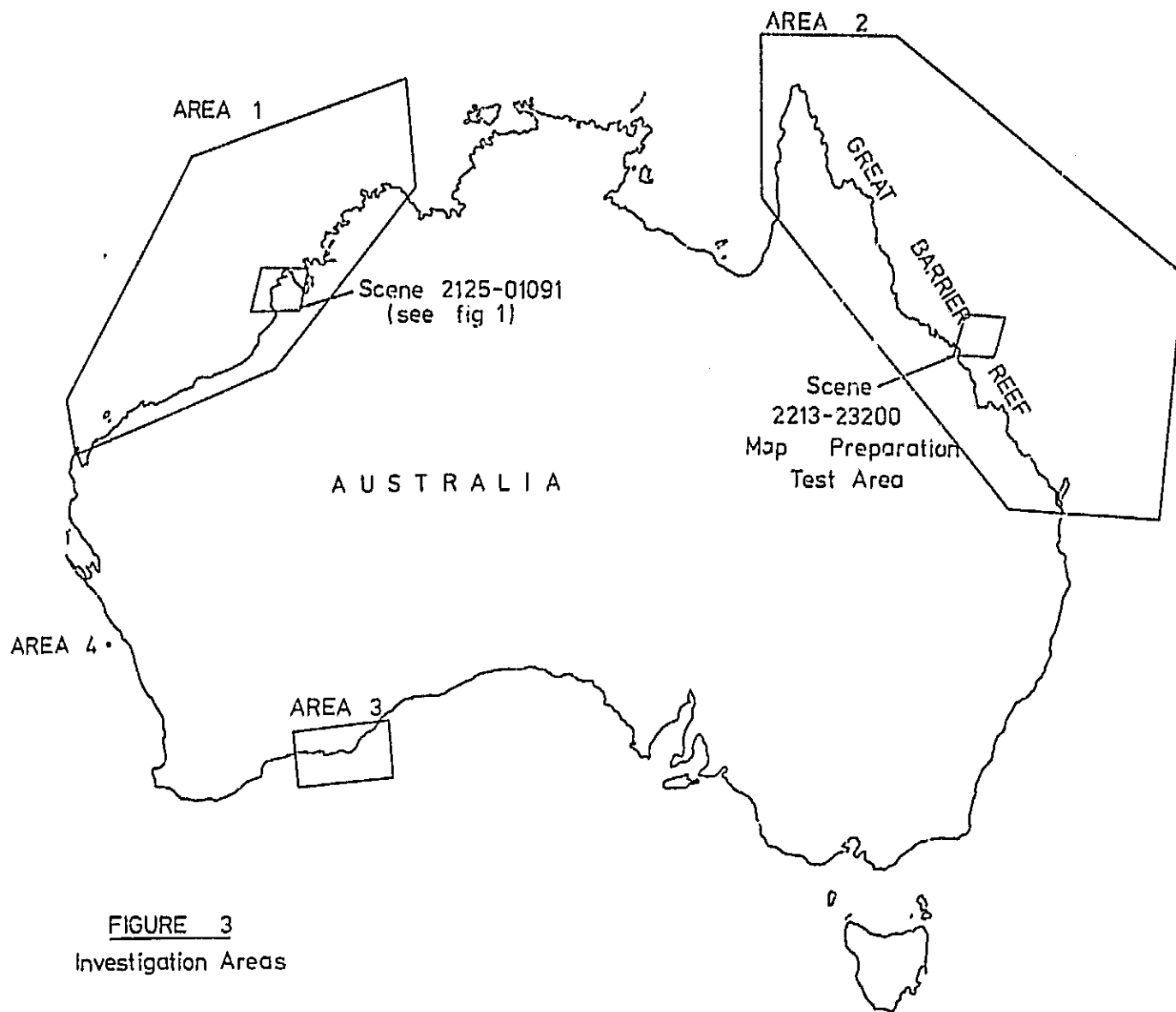


Figure 2 Examples of successful and unsuccessful correlation between water depths and image intensity values.



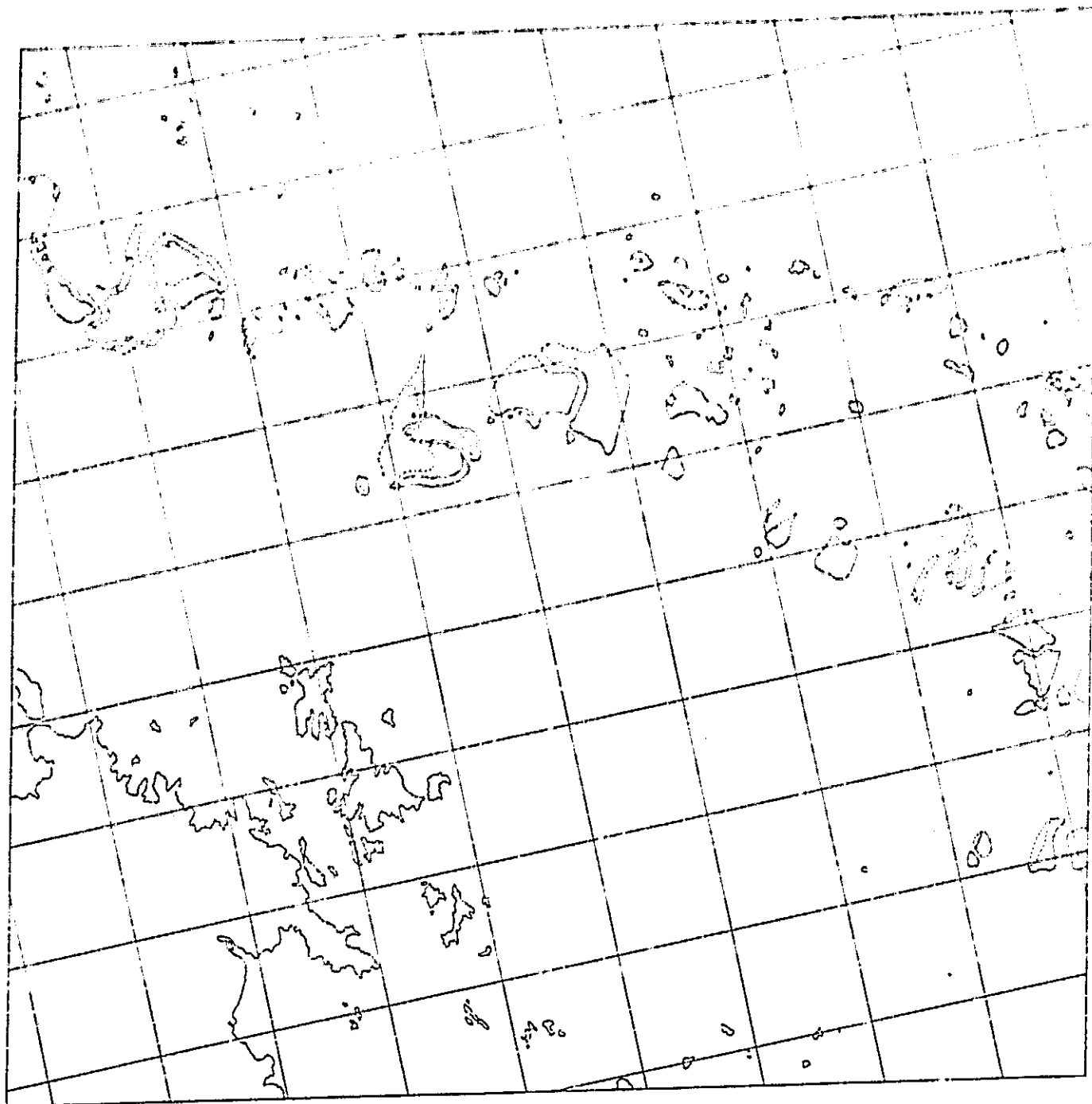


Figure 4: Map of portion of Great Barrier Reef derived from Landsat scene 2213-23200 by method of best-fitting grid. Original at 1:250 000 scale.

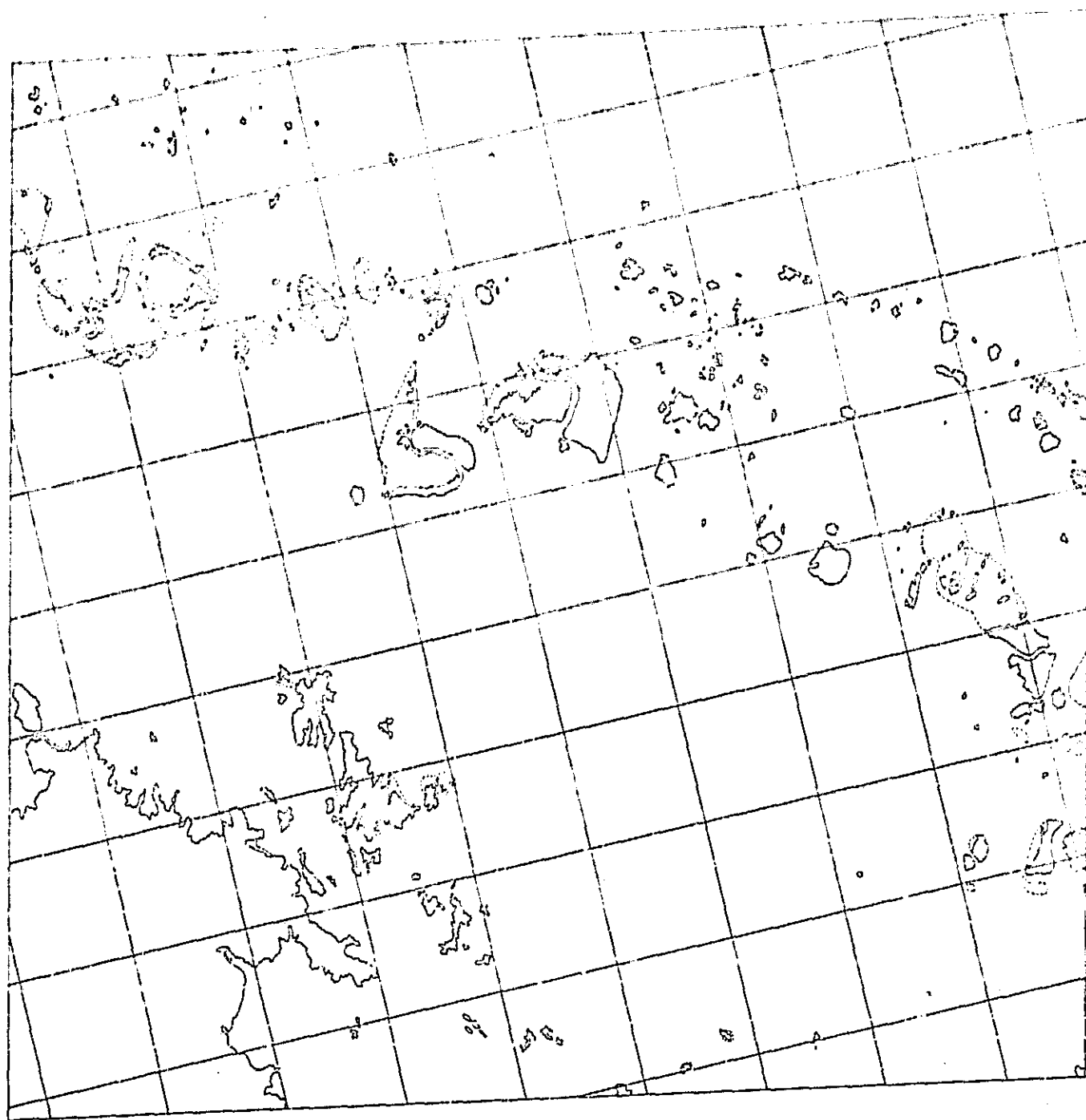


Figure 5: Map of portion of Great Barrier Reef derived from Landsat scene 2215-25200 by regional or localised block - shifts. Original at 1:250 000 scale.