VOLUMETRIC MODEL OF MONASAVU LAKE, FIJI

Robert Smith[1] and Edward Saphore[2]

November 1993 *SOPAC Technical Report 180*

[1] **SOPAC Technical Secretariat**
[2] **Islandtronics**

Prepared for: **South Pacific Applied Geoscience Commission (SOPAC)**

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figure

Tables

SUMMARY

The Monasavu dam located in northern central Viti Levu is one of Fiji's important public assets. The performance of this reservoir, particularly in periods of low rainfall, has a direct bearing on the performance of the FEA. A detailed volumetric model of the reservoir, giving an accurate reservoir height - volume relationship that can be used for energy planning, was requested by the Energy Department of the Fiji Government.

Acquisition of data for compiling this model was carried out from 16-21 March 1993 at which time the lake was at full capacity. For the survey, navigation control was by the microwave trisponder system and depth was recorded by a Raytheon DE791E echo sounder. Data were logged digitally.

Based on current figures available for the surface area of the lake at full capacity it is estimated that 63% of the lake was surveyed.

The current model comprises some 6787 data points which have been compiled from the survey data, known bench marks and data digitised from 1:5000 reservoir contour maps.

Preliminary results from the model appear to correlate well with the current formula used to calculate the available service volume capable of generating electricity.

ACKNOWLEDGEMENTS

The major contributors to this study were the Australian Government and EC. The project had the support of the Government of Fiji through the Ministry of Energy, and the Fiji Electricity Authority.

OBJECTIVE

The main objective of the survey was to map the bathymetry of the lake at its full supply level to develop a 3-dimensional digital model of the lake to allow calculation of service volumes for energy management. This work was carried out to fulfil the requirements of Task 93.FJ.13d: Volumetric model of Monasavu Lake.

INTRODUCTION

The Monasavu Dam is one of Fiji's important public assets (Figure 1). The performance of the reservoir, particularly in periods of low rainfall, has a direct bearing on the performance of the FEA. A detailed hydrogeological model of the reservoir for an accurate reservoir height-volume relationship that can be used for energy planning was requested by the Energy Department of the Fiji Government.

Acquisition of data for compiling this model was carried out from 16-21 March 1993. Equipment and methodology employed in collecting this data is described in SOPAC Preliminary Report 54.

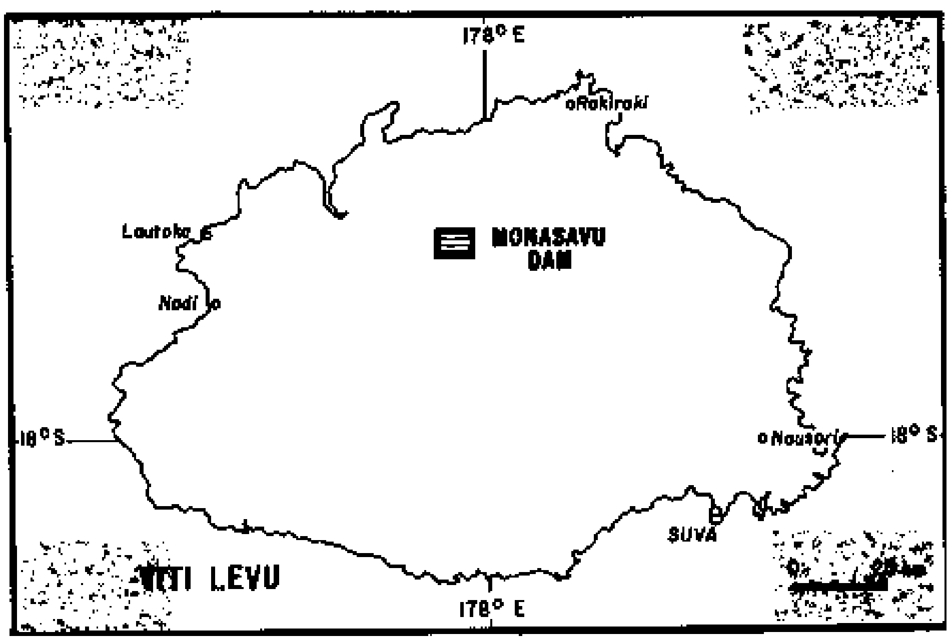

Figure 1. Location map.

RESULTS

Survey Area

Figure 2 illustrates the areas of the lake which were not surveyed because to maintain positional accuracy, very short base lines would have been required for the shore based transponders. Line-of-sight restrictions due to rapid elevation changes along the lake perimeter, the dense foliage and the narrow, long, winding tributaries that feed into the lake made these areas impracticable to survey using this method.

In the upper reaches of the lake, the lack of accessible bench marks for the shore based transponders restricted any further survey work in this area.

It is estimated, however, that 63% of the lake was covered by this survey representing some 4 456 672 square metres of the lakes surface area at full supply level (spill point). This percentage was calculated from comparing the area coverage of Figure 2 with the calculated surface area of the dam at the full supply level of 745 m (the Monasavu DATUM) from figures currently available.

At the full supply level, the surface area of the lake is reported to be 7.16 million square. metres.

Data Processing

Two hundred and seventy eight lines comprising 6164 data points were collected (Smith et al 1993), navigation being in the form of range - range data which required correction for slant range and processed into easting and northing co-ordinates. Both slant range and conversion to easting and northing was done using software utility "HZZ.EXE" developed by the co-author of this report.

The base map on which the track data were plotted was digitised from two map sets (references 1, 2) at 1:5000 scale using AutoCAD. The lake at its full service volume would be defined by the 745 m contour. For this work the 750 m contour was digitised from the two map sets. The reason for choosing this contour level was that it was the only contour that could be confidently digitised from the two map sets.

Figure 3 illustrates the relationship between the 750 m contour, which has been used as a reference for the (upper boundary) of the lake, and the final track plot of data collected to date.

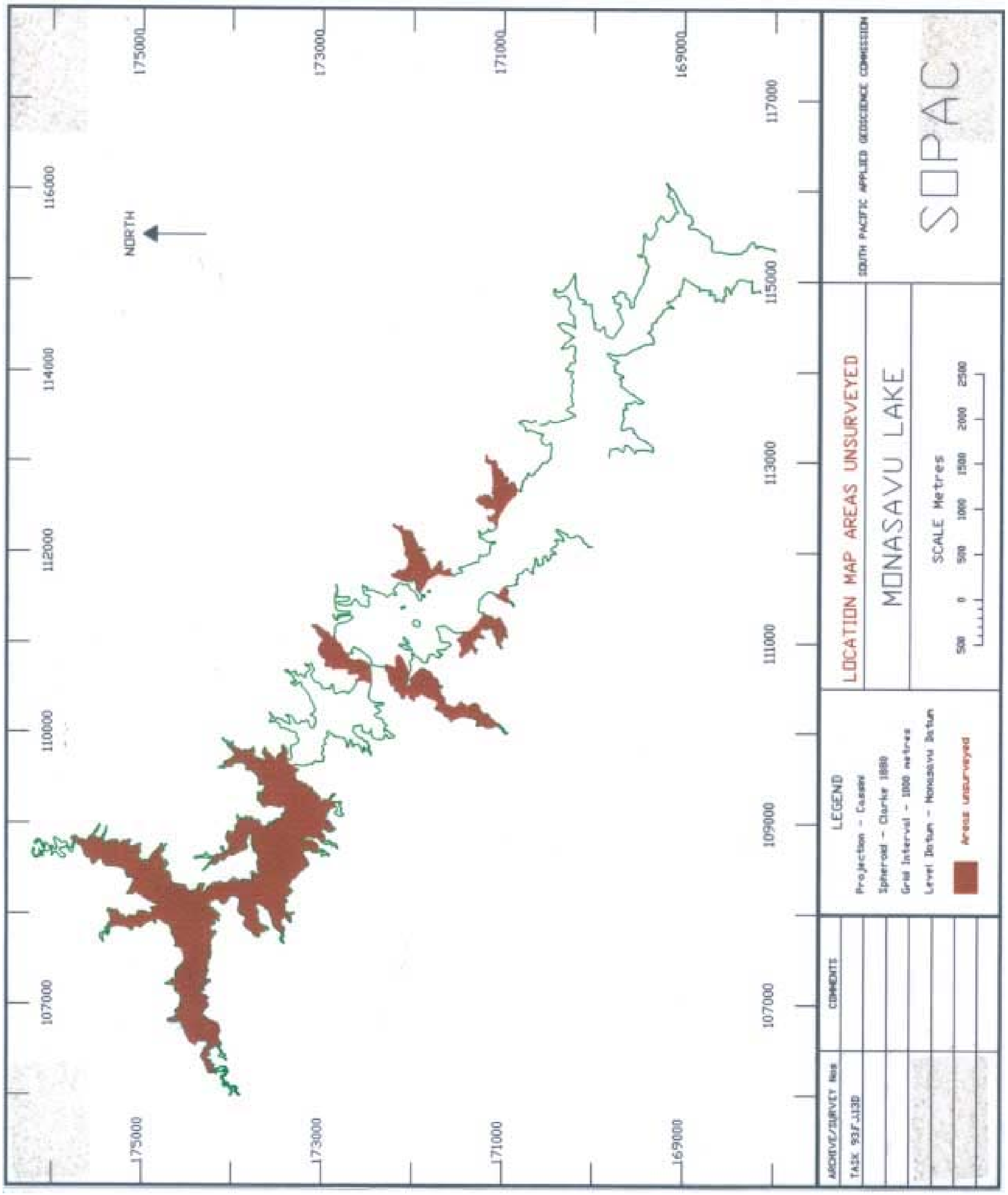

Figure 2. Surveyed vs unsurveyed.

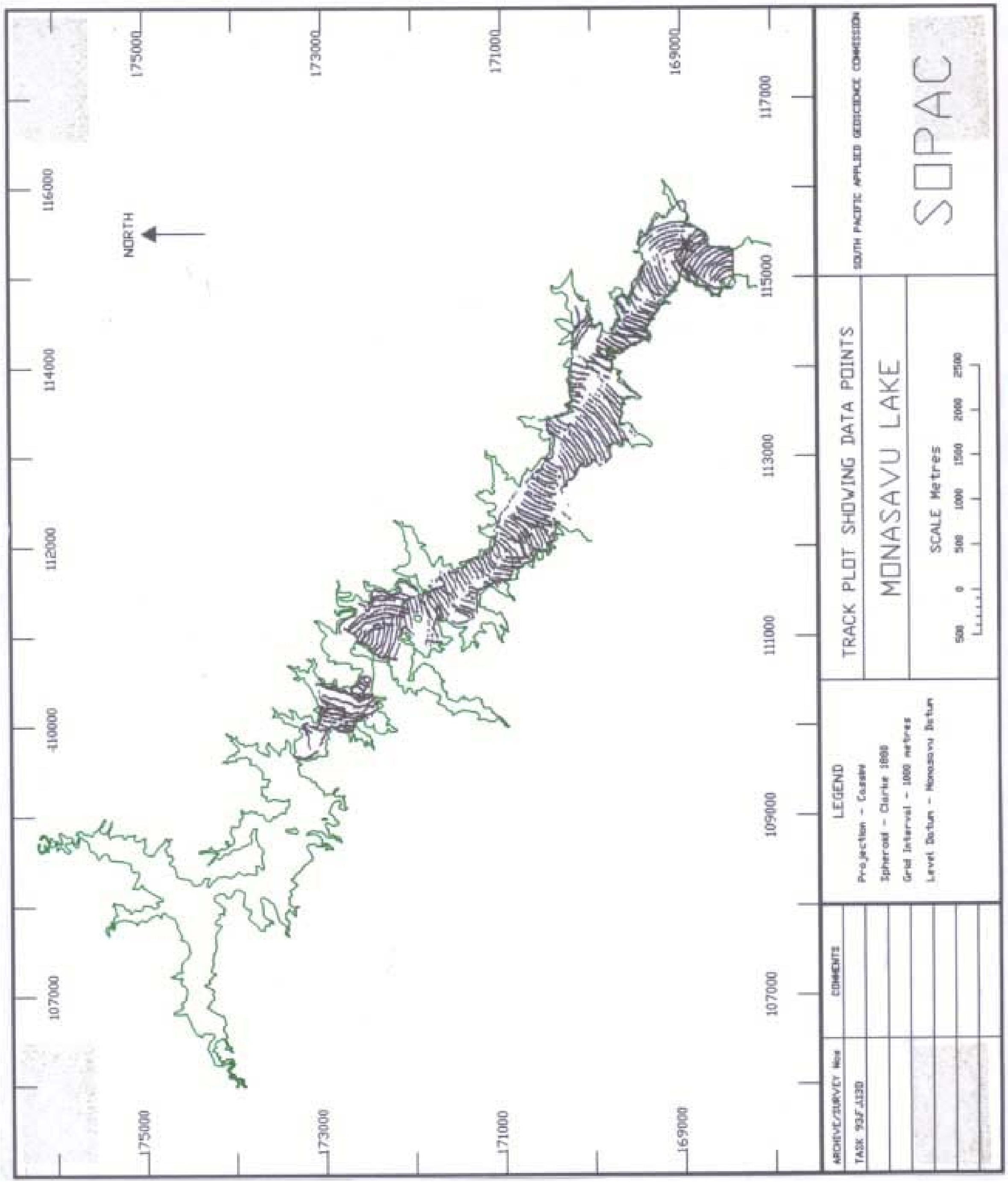

Figure 3. Track plot.

Once the final survey tracks were located, the bathymetry data and the navigation data were merged using the software utility HZZ.EXE. However a major problem was encountered comparing the digitally recorded data with the hard copy records of the bathymetry. The digital depth recorded quite frequently was not a reflection of the lake floor but a reflection from the remains of the forest in the flooded valley. Figure 4 illustrates this problem of false echoes as seen on hard copy. This therefore necessitated editing of all the data points against the hard copy echo sounder records. As a result, of the 6164 data points logged, 439 points were discarded as unreliable either for clear depth value or missing range - range data to calculate easting and northing co-ordinates. This left a data set with 5625 points.

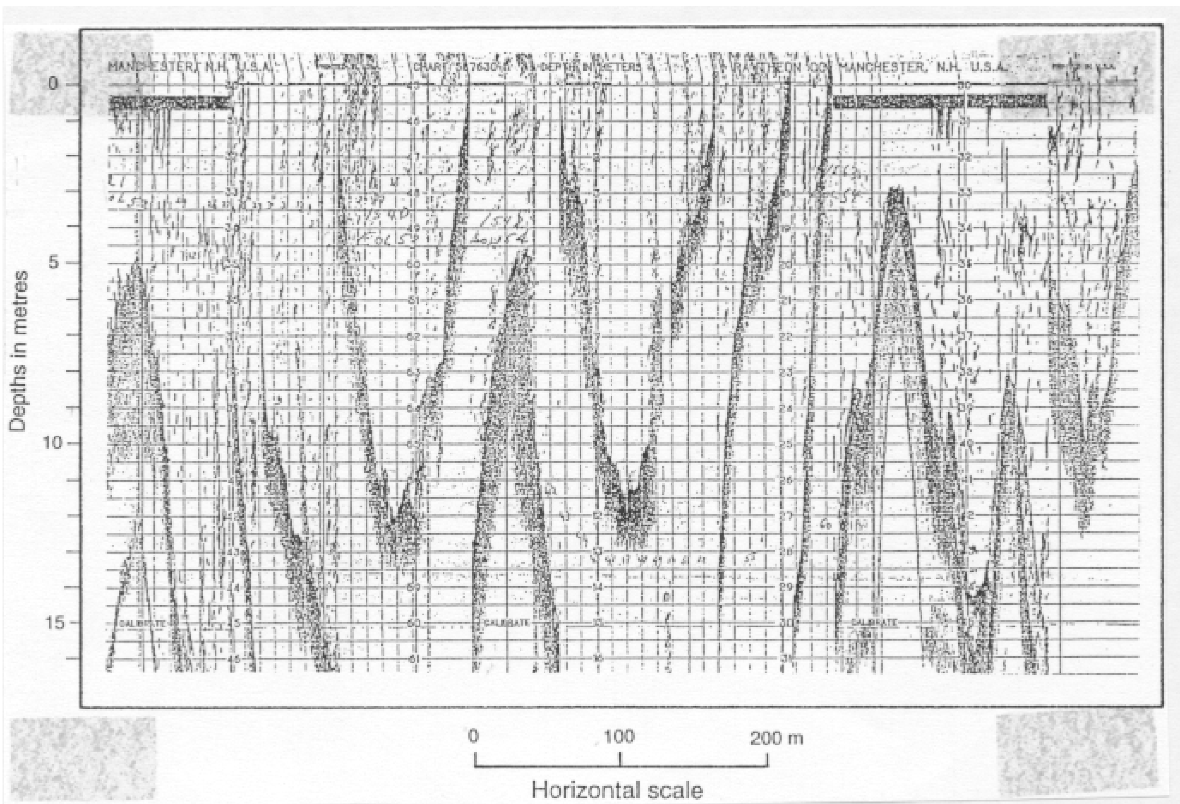

Figure 4. Bathymetric profile illustrating numerous tree stump-generated echoes. Note also the rapid variation in depth by the discontinuous nature of the lake bed profile. This is an artifact of numerous scale changes which required the operator's complete concentration to know whether the lake bed was ascending or descending.

Appendix 1 contains the compiled computer data files for the model on 3.5 diskette. Formats of the files vary depending on the software used.

Model Compilation

The Monasavu datum is 745 m the level at which the lake spills. To tie the different data sets including the collected data shown in Figure 3, the full supply level of 745 m (i.e. the Monasavu datum) is used. Table 1 is a record of the lake's water height during the survey.

Table 1. Water level heights.

Date	Water Level	Lines surveyed
19 March 1993	745.12 m	1 - 26
20 March 1993	745.11 m	26-47
21 March 1993	745.09 m	48-106
22 March 1993	745.07 m	107-204
23 March 1993	744.98 m	205-261
24 March 1993	744.92 m	262 - 278

To complete a working model for the lake additional data sets were compiled. The location of all data sets is illustrated in Figure 5.

All these data sets were then appended together and a model data set created. These random data were then gridded in SURFER^{tm} to produce a gridded data set.

A boundary control file for the model was also compiled. This was intended to represent the interpreted extent of the lake at full supply level. AutoCAD was used to construct the boundary file based on all data currently available to the authors. This boundary file was needed to prevent ambiguous extrapolation of the contours beyond the lake perimeter.

Figure 6 is a series of maps illustrating the interpreted lake surface area for 710, 720, 730 and 745 m datum's based on the data available in the current model. These were constructed out of the compiled bathymetry map produced in SURFER^{tm} and imported into the AutoCAD base map.

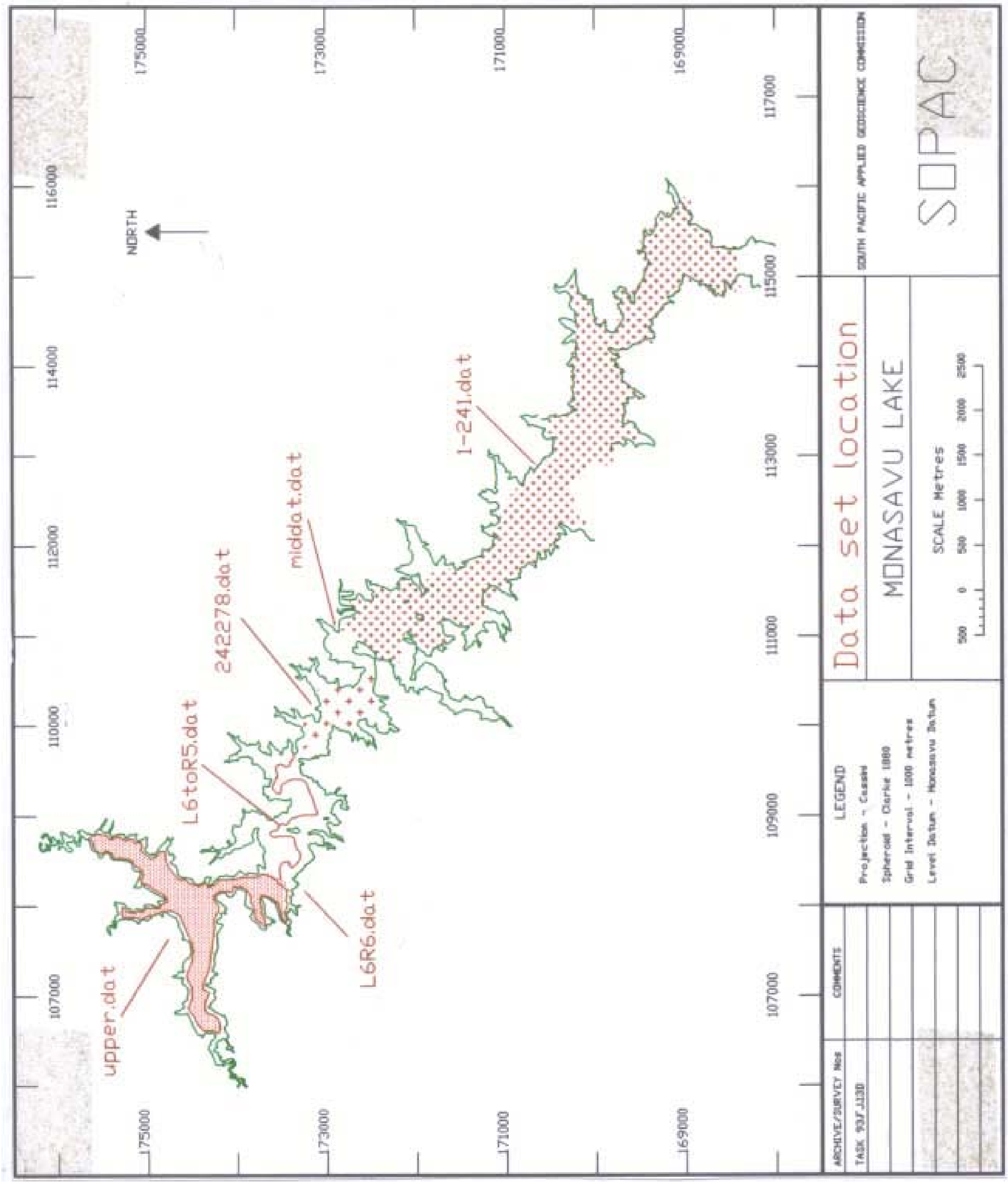

Figure 5. Data set location map.

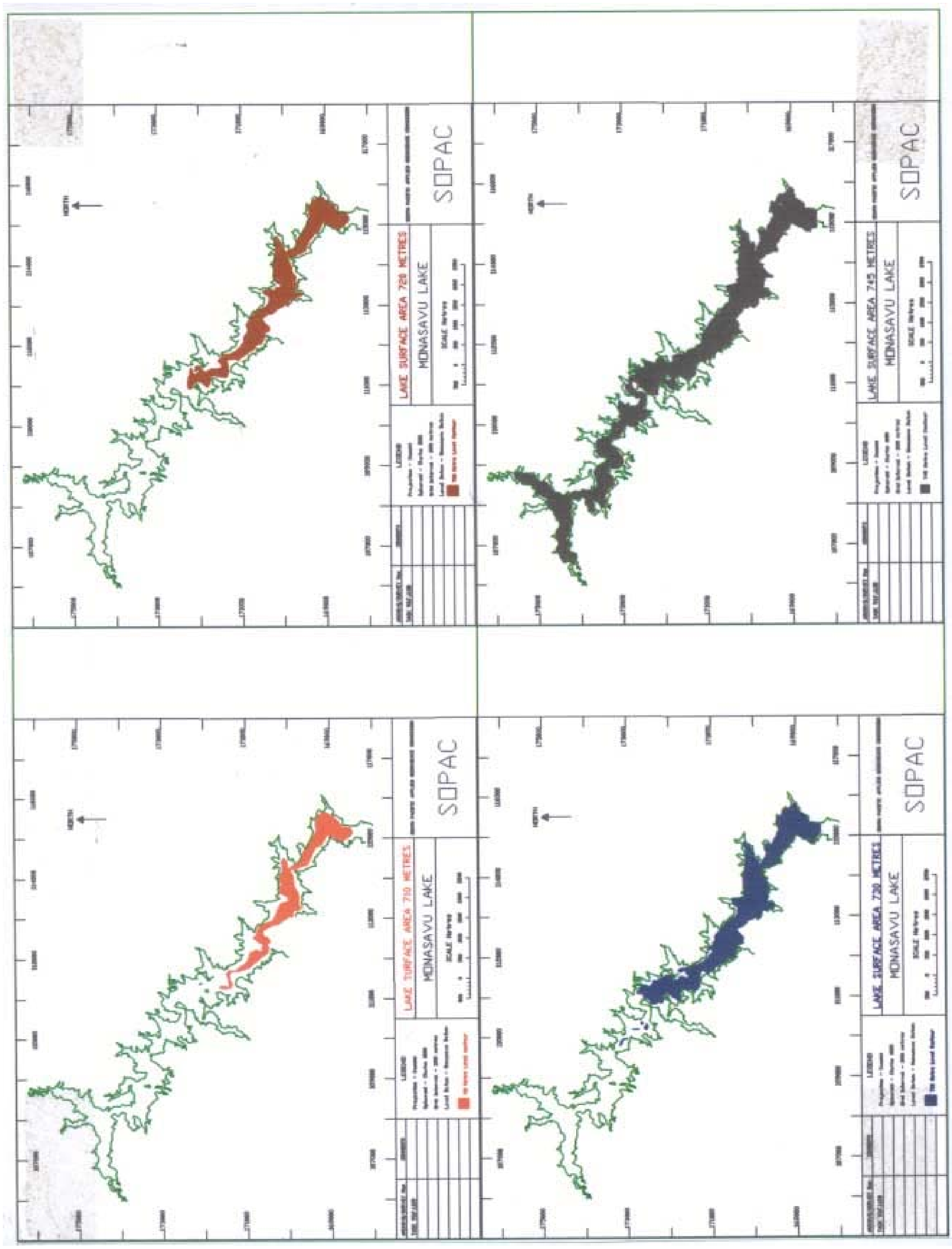

Figure 6. Lake surface area for 710 m, 720 m, 730 m, 745 m.

Data set Descriptions

1-241.dat

This data set is of the bathymetry data collected from line 1 through to line 241. To reduce this data to the 745m datum, the daily recorded dam level for the respective survey days data was used. This is the largest data set representing 4.039 million square meters of the surface area of the lake, with 5047 data points, approximating a data point every 800 square metres.

Middat.dat

This data set is small and represents the area between *1-241.dat* and *242278.dat*. This was compiled from the 750 m contour digitised from the 1:5000 map set. Depth values assigned were extrapolated between the two data sets *1-241.dat* and *242278.dat*.

242278.dat

This data set is from lines 242 to 278. It covers 417178.5 sq. meters a data point every 708 square metres. This data set ends just north of the location of the cross section profile R 5 to L5.

L6toR5.dat

This data set is compiled from the digitised location of Nanuku Creek. Assigning depth attributes to the easting and northing co-ordinates extracted from AutoCAD was by extrapolation of the depth to the creek bed from profile location R6 - L6 and assuming a gradient for the creek to where data set *242278.dat* ended.

L6R6.dat

This data set was extracted from the survey work done in May 1991 (Smith 1991).

Upper.dat

This last data set was compiled from the digitised 750 m contour of the dam. In this area, little to no data are available to tighten up the *X Y Z* control for the model. Spot height control appears to be very sparse. The only spot height control known to be available was noted on the 1:5000 maps (References 1,2).

Volume Calculations

Preliminary volumetric figures calculated from the model are presented in Table 2.

These were calculated using the VOLUME utility programme available in SURFER. Volume estimates are calculated from the model where the lower surface of the solid is defined by the gridded data set representing the lake floor and the upper surface defined as a plane representing the lake level at any one time. The volume computations are best if the defined surface is as smooth as possible from the data available, with a dense grid line spacing and grid cells that are square. For this model a 200 x 200 m grid cell was calculated using the Kriging algorithm with an octant search method (SURFER). The result of this gridding procedure is shown in Figure 7 as a surface plot of the computer lake model.

The volume between any two surfaces(either gridded or planar) is computed using three different methods: the Trapezoidal Rule ,Simpson's Rule and Simpson's 3/8 Rule.

Table 2. Total volume.

Lake level (m)	Estimated volume (million cubic metres)	Formula volume (million cubic metres)	Volume difference (million cubic metres)
MOL 710	14.5	17.56	3.06
715	22.40	25.932	3.532
720	32.407	36.792	4.385
725	44.629	50.519	5.89
730	59.248	67.510	8.26
735	76.957	88.177	11.22
740	99.095	112.945	13.85
FSL 745	124.239	142.25	18.011

For comparison with the figures in Table 2, the respective volumes for lake levels 710 m through 745 m in 5 m increments were calculated using the formula:

$$V = \frac{(EL-669)^{3.39}}{16.707} \times 10^3$$

where V = volume and EL = lake level.

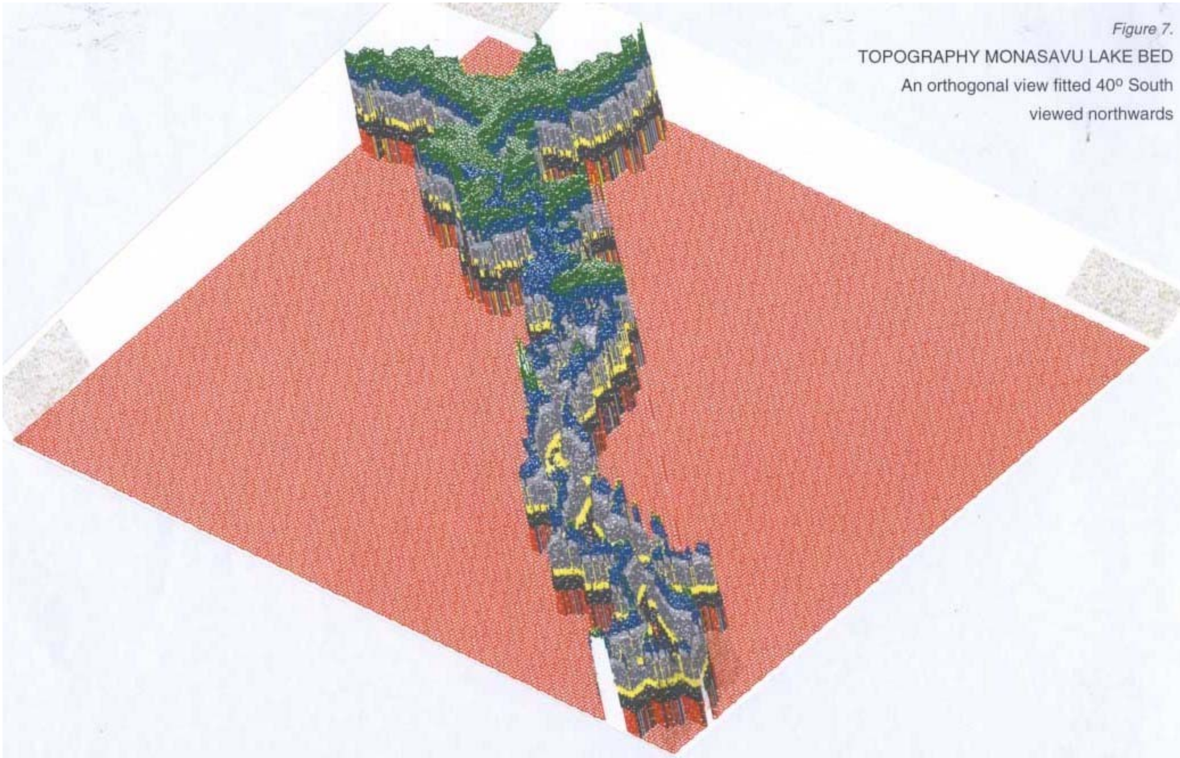

Figure 7.
TOPOGRAPHY MONASAVU LAKE BED
An orthogonal view fitted 40º South
viewed northwards

Table 3 is a comparison of the survey with the formula-calculated estimates of the available live storage volume for electrical generation form the lake. In this table the Minimum Operating Level (MOL) volume is subtracted from the Supply Level (SL) at any given time for the available live storage volume.

Table 3. Estimated Live Storage Volumes.

Lake level (metres)	Survey live volume (million cubic metres) (SL-MOL)	Formula live volume (million cubic metres) (SL-MOL)	Volume difference (million cubic metres)
710	0	0	0
715	7.9	8.372	0.472
720	17.907	19.232	1.325
725	30.12	32.959	2.839
730	44.748	49.95	5.502
735	62.457	70.617	8.16
740	84.595	95.385	10.79
745	109.739	124.69	14.951

The resultant live storage volume available for lake levels 710 m to 745 m are shown graphically in Figure 8. From the graph, the model curve appears to follow the formula curve quite well. At the top end of the graph, the divergence shown by the survey curve from the formula is attributed to the lack of depth data in the unsurveyed areas of the lake as shown in Figure 2.

CONCLUSIONS

1. Preliminary results of the model indicate that the volumes calculated from the model follow the formula currently used to calculate the lake volume.

2. The navigation control used for the survey was not effective in the narrow tributaries that lead into the lake as in the main body of the lake where better line-of-sight from the shore based stations provided for better coverage resulting in less station moves and more area coverage.

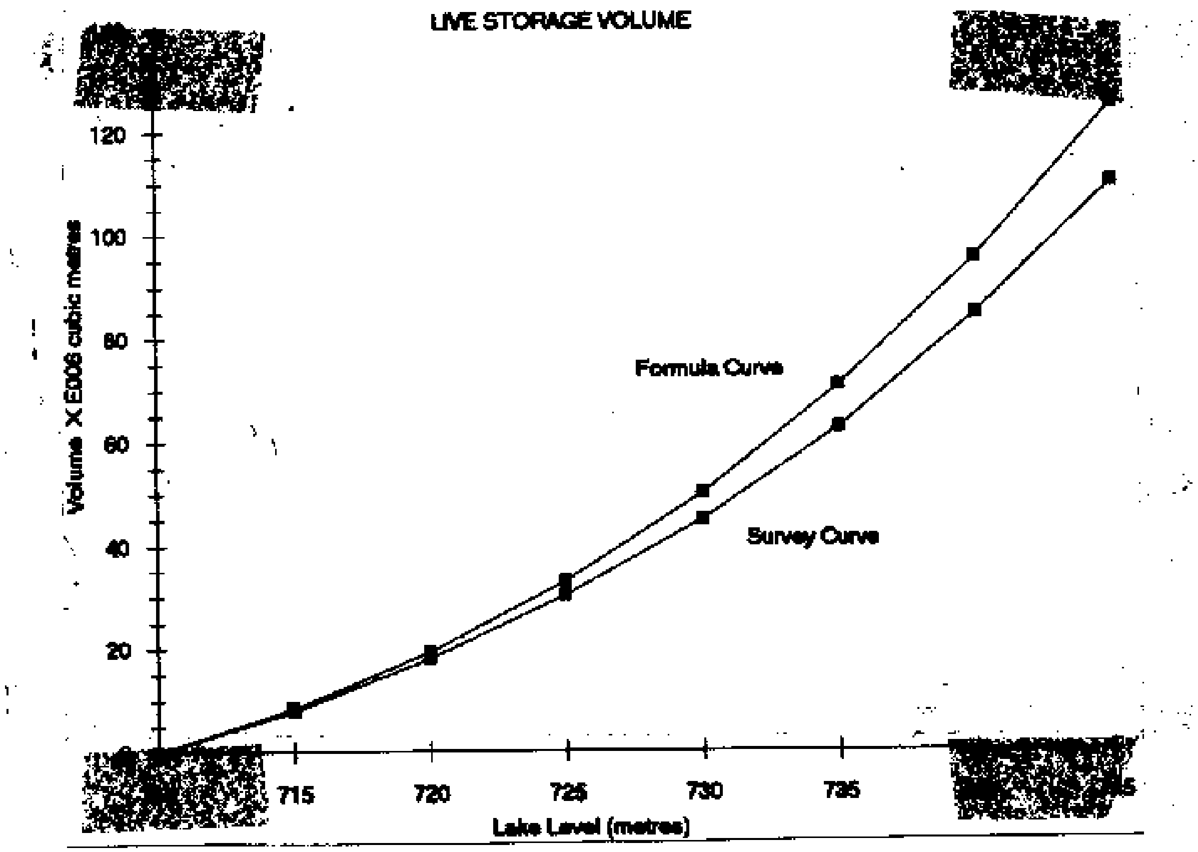

Figure 8. Graph live storage volume vs lake level.

RECOMMENDATION

The survey should be completed using a combination of microwave navigation and differential GPS.

To complete the model in difficult areas, a combination of microwave navigation and differential GPS would be the most appropriate tool to survey the remaining areas not covered during this survey. This would allow an accurate boundary file of the perimeter of Monasavu Lake to be constructed when it is at full supply level. It is estimated that the perimeter is between 50 and 60 kilometres long.

REFERENCES

Monasavu Reservoir Topographical Map 1983, 1:5000 9 sheet series. Fiji Electricity Authority Hydro - Electric Scheme.

Second Power Project - Wainisavulevu Diversions Topographical map: 5000 16 sheet series Fiji Electricity Authority.

Smith R. ,1991 Monasavu Siltation Control, Fiji .SOPAC Technical report 129.

Smith R., Young S., Saphore E.,1992 Bathymetric Survey of Monasavu Lake Fiji. SOPAC Preliminary Report 54.

SURFER Version 4 Reference Manual, Golden Software, Inc. Golden, Colorado USA.

APPENDIX 1

Digital Data Files
(3.5" Diskette)