Yorkshire Water
Services Limited

Gouthwaite Reservoir LiDAR Analysis

October 2006

FINAL REPORT

JBA Consulting
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
UK
t: +44 (0)1756 799 919
f: +44 (0)1756 799 449
e: info@jbaconsulting.co.uk

Yorkshire Water Services Ltd
PO Box 500, Buttershaw Depot
Western Way, Halifax Road
BRADFORD
BD6 2LZ

REVISION HISTORY

Revision Ref./ Date Issued	Amendments	Issued to
Revised Final Report October 2006	Adjustment to recorded water level on 24 October 2003.	One Copy
Final Report November 2004		One Copy
Minor Revisions March 2005		One Copy

CONTRACT

This report describes work commissioned by Yorkshire Water Service Limited under Order Number 4500040302 of 28 January 2004. Yorkshire Water Service Limited's representative for the contract was of JBA Consulting carried out the work.

Prepared by: ....

Reviewed by: ....

Approved by: ....

Date : October 2006

© Jeremy Benn Associates Ltd

DISCLAIMER

This document has been prepared solely as a Draft Report for Yorkshire Water Services Limited. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

ACKNOWLEDGMENTS

We would like to acknowledge the assistance provide by throughout this study. In addition to this assistance was also provided by of the Environment Agency.

CONTENTS

LIST OF TABLES

ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
DEM	Digital Elevation Model
EA	Environment Agency
GIS	Geographical Information System
JBA	Jeremy Benn Associates
mAOD	Metres Above Ordnance Datum
TCM	Thousand Cubic Metres
TWL	Top Water Level
YW	Yorkshire Water

1 INTRODUCTION

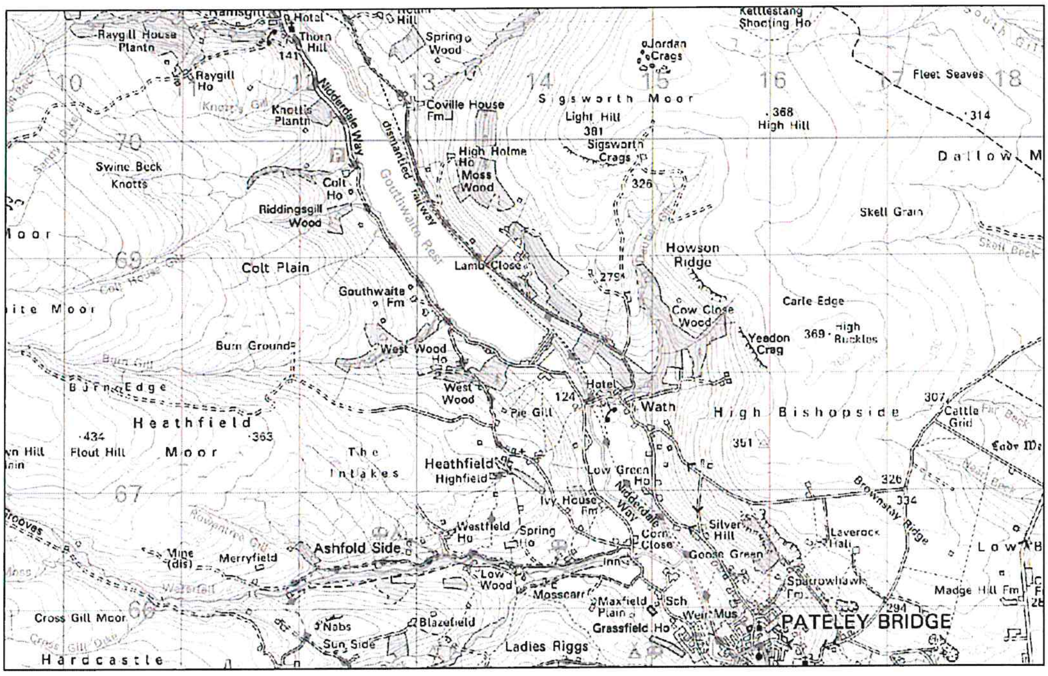
1.1 General

In early January 2004 Jeremy Benn Associates (JBA) were approached by the Environment Agency (EA) and Yorkshire Water Services Limited (YW) with a request for consultancy services to assist with the analysis of LiDAR the digital elevation model (DEM) data captured for Gouthwaite reservoir in November 2003.

JBA's proposal was submitted on 12 January 2004 under cover of our letter ADG\2003s0384-S-L001-1.doc. This was accepted and approved on 2 February 2004 under YW's order number 4500040302.

1.2 Reservoir Location

The location of the reservoir is shown in the figure below.



This left intentionally blank.

2 DATA SOURCES

2.1 General

The two primary data sources for this project were YW and the EA. However, other reports prepared by the University of Huddersfield were also made available.

2.2 Yorkshire Water

Historic survey drawings were made available. A total of some 23 drawings providing data for the 1991 and 1997 surveys were provided. A further 18 drawings presenting details of the reservoir bed level changes that had occurred between 1901 and 1971 were also provided.

Some 15 contour maps were also made available under the project.

A summary of the work undertaken by the University of Huddersfield was provided. This contained details of the bathymetric analysis that was undertaken as well as a summary of their estimate of the capacity of the reservoir. Concerns were raised about the accuracy of the various surveys and as such the accuracy of any results associated with them. A copy of the University of Huddersfield report is included in Appendix A.

2.3 Environment Agency

The EA provided details of their depth–volume survey that was prepared in July 1992. This was submitted as a spreadsheet with details in both metric and imperial units. This is included in Appendix B.

The details provided cover a depth range from 5.5 to 13.9 m (18 feet 0 inches to 45 feet 11 inches).

In addition to the above the EA captured LIDAR data of the reservoir in October 2003 when the water level fell to the lowest recorded level. These data were submitted as text files and converted into a three dimensional grid and formed the basis of the analysis to be undertaken in the project. The approach adopted is discussed in more detail in Section 3.

This page left intentionally blank.

3 ANALYSIS

3.1 Introduction

The approach to the analysis of the LiDAR was addressed under five stages. These were:

- Data Conversion
- Data Extraction
- Data Export
- Data Infill
- Storage calculations.

3.2 Data Conversion

LiDAR data for the reservoir were provided by the EA in a standard text file format. These data required conversion into a geographical information system (GIS) format in order that the required analysis could be undertaken.

These data were imported into MapInfo's Vertical Mapper for analysis.

3.3 Data Extraction

Once the data were imported it was necessary to reduce the dataset to the extents of the reservoir. An approximate reservoir boundary was digitised beyond the extent of the reservoir boundary in order to ensure that the volume calculations could be determined to a sufficient height beyond the spill level of the reservoir. The extent of the data is shown in the figure overleaf.

3.4 Data Export

Having determined the extent of the DEM required these data were exported to an American Standard Code for Information Interchange (ASCII) file that was compatible with a bespoke application that we had previously developed for this type of stage-volume calculation.

3.5 Data Infill

LiDAR does not return a signal from water surfaces. Therefore a series of null values are recoded where water exists when the data were captured. In the case of the reservoir data this may represent small areas of local ponding as well as the final volume retained within the reservoir.

Any null values were assigned the elevation from adjacent points.

3.6 Storage Calculations

The application was configured to undertake analysis from a level of 129.19 metres above ordnance datum mAOD) to 139.00 mAOD with a sampling interval of 0.01 m. The level of 129.19 mAOD represents the bank full level on the day the LiDAR data were captured. The top water level (TWL) is 135.76 mAOD with the level of 139.00 mAOD being selected to ensure that the storage calculations capture data too marginally beyond the TWL.

As explained above the LiDAR data extends from the water surface and as such these calculations include no provision for the storage within the reservoir on the day the LiDAR data were captured.

3.7 Base Volume Determination

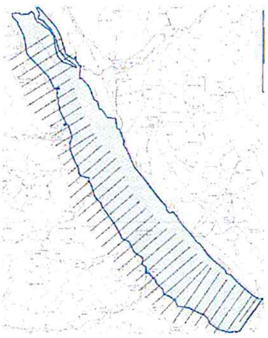
A number of approaches were adopted in an attempt to determine the base volume of the reservoir, or the volume of water retained within the reservoir below the minimum level recorded by the LiDAR data.

The EA have quoted that 13% of the maximum reservoir capacity was retained on the day that the LiDAR data were captured. This equates to some 756 thousand cubic metres (tcm).

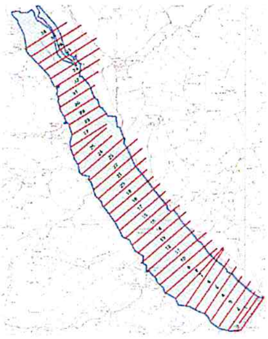
However, YW refer to a level of 6.32 m down being recorded on 24 October 2003 and a volume of 832 tcm.

The 'base' volume on the day which the LiDAR data were captured that provides the least level of confidence.

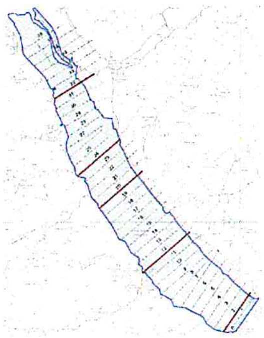
3.8 Base Volume Validation



The cross section locations were digitised from these plans into AutoCAD via a digitising tablet. The plans were calibrated on the local grid detailed on them with the grid lines extended and calibration points identified at four intersection points. The resulting data were relocated to British National grid by identifying common points on the cross section plans and the Ordnance Survey 1:10k series of maps. The imported cross sections were subsequently rotated in order that the dam wall in the digitised data matched the orientation of the dam wall as shown on the 1:10k maps. Whilst reasonable alignment was achieved at the downstream sections, Nos 1, 2 and 3 it proved to be less good at the remaining sections. Poor correlation was also achieved with respect to the length of the majority of sections. As shown in the adjacent figure.



Each cross section was translated along its digitised alignment in order that the right hand (looking downstream) end point coincided with the edge of the road as it is assumed that the survey is unlikely to have extended beyond this feature. The intention being to determine if the length of each section matched reasonably well with the width of the reservoir at the location determined. As can be observed from the adjacent figure a number of the cross sections extend beyond the far bank of the reservoir and even beyond the dismantled railway embankment on the left bank of the reservoir. We consider that it is unlikely that the survey would have extended either beyond the road or beyond the railway embankment. It would therefore appear that the length of these sections is incorrect. It may be that the location shown on the drawings is intended to be indicative only. One further observation on the data is that the cross sections do not extend the full length of the reservoir, although they do appear reasonable positioned along the length of the reservoir.



Of the 38 cross sections available 18 were provided by the EA. Further, it was decided that only five of these sections should be digitised in the first instance in order to undertake a comparison of the levels record by the hydrographic surveys (1901 and 1971) and the LiDAR data (Oct 2003). It was originally decided to assess cross sections at approximately equal intervals along the length of the reservoir. However, once the data had been imported it appeared more logical to review the up and down stream sections available, No 2 and 32 and three other sections. The three remaining sections were selected based not only on their location along the reservoir but also because they provided an apparently better length comparison. The sections selected were numbers, 2, 12, 20, 24 and 32. These are presented in the

North

Rev.	Modifications	Date	Drawn	Approved

jba CONSULTING

for

YORKSHIRE WATER

GOUTHWAITE RESERVOIR
LIDAR ELEVATION MODEL AND CONTOURS

Scale	Drawn	12 MARCH '04
[illegible]	Checked	12 MARCH '04
	Approved	12 MARCH '04

File Reference: 2003-5-0384-D001.WOR

Drawing Number	Sheet No.	Status	Rev.
2003-5-0384-D001	1 of 1	DRAFT	1

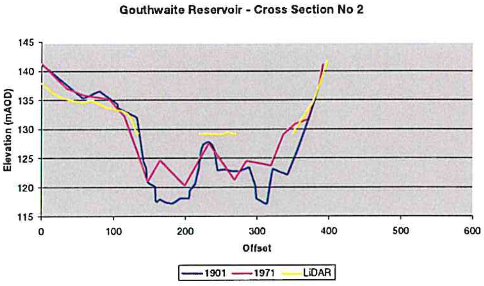
adjacent figure and represented by solid lines.

Section No 2 also indicates a datum of 400 feet. Although this is hand written, an attempt to utilise this in the comparison of the cross section datasets was made.

Graphs have been prepared for each of the above cross sections. Three sections are presented on each graph:

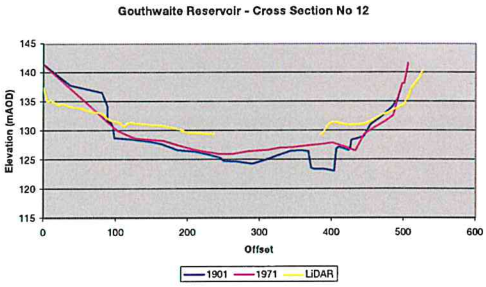
- 1901
- 1971
- LiDAR (2003).

Cross Section No 2



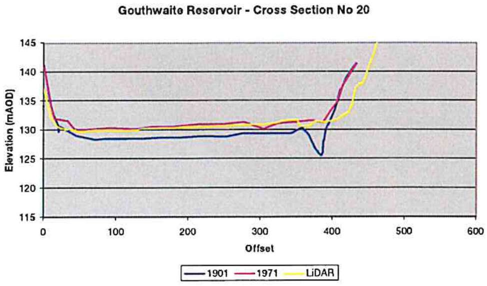
In cross section no 2 the left and right banks compare relatively well in both horizontal and vertical position. The reservoir bed in both the hydrographic surveys generally correlates well although there appears to be a rise in the bed level between the 1901 and 1971 surveys. However, relatively few points have been recorded in the latter and this may adversely influence the profile. The bed level determined by the LiDAR survey shows a further increase in elevation. This is located at the peak bed level identified by the two earlier surveys. It is possible that further siltation has occurred between the two apparent channels where this section was recorded.

Cross Section No 12



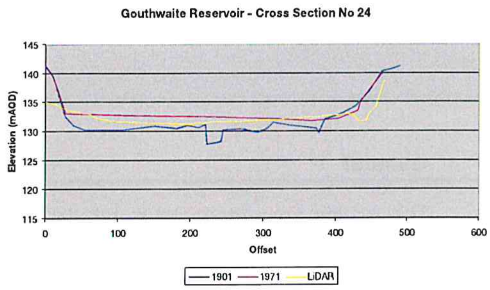
The three surveys recorded at cross section no 12 on the left hand bank correlate reasonably well from the point of view of their shape although they are offset marginally. However, the bed level is noticeably higher in the LiDAR dataset. These sections could be raised in an attempt to produce a more accurate comparison through these sections however this will result in a significant difference between the banks that are more remote from the main channel. It is considered that these are the least likely areas to be affected by siltation. Conversely, reducing the hydrographic survey data so that a better fit with the LiDAR data is achieved in these sections will result in a far more significant depth of siltation being demonstrated. This would be in the region of 5m.

Cross Section No 20



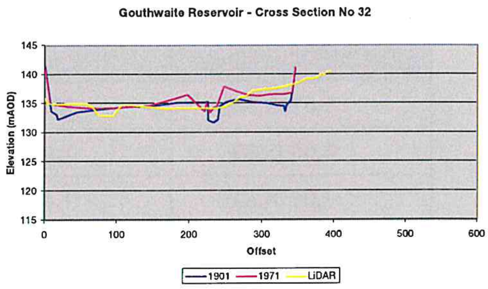
The profiles provide a reasonable match at both banks and across the bed. The LiDAR dataset indicates a slightly wider section than the two hydrographic surveys. This is slightly surprising considering that the length of the sections shown on the hydrographic survey extend beyond the banks of the reservoir. The bed levels for the two more recent surveys (1971 and LiDAR) are noticeably higher than those determined in 1901 but they correlate well. There appears to have been in the region of 2m siltation over the life of the reservoir. Also noticeable is the lack of channel through this section.

Cross Section No 24



The two hyrdographic surveys demonstrate common bank details and a bed level difference of some 2 to 3 m. Poor correlation occurs between the hydrographic and LiDAR surveys with the bed level reported by the LiDAR data lying between the 1901 and 1971 surveys. A possible shift in the 1971 dataset is unlikely to provide any more confidence in the data recorded.

Cross Section No 32



Little correlation between any of the three datasets is apparent at this section. Bed levels appear reasonably consistent in the centre of the section however, on either side significant differences in both level and offset are noticeable.

The variation between the five cross sections selected suggested that there is little benefit in digitising the remaining sections. It had been hoped that a comparison of the three series of data would enable a more detailed understanding of the sections and the potential storage volume, specifically the 'base volume', of the reservoir to be obtained.

However, the relatively low confidence in the digitised cross section locations, as demonstrated by the length and original location of these sections suggest that any possibility of undertaking a realistic comparison is low. There is no reason to suggest that the more recent dataset, LiDAR, is anything other than accurate partially because of the data collection technique employed but also because the data are calibrated against ground stations to ensure that they are of acceptable quality. Whilst we have not been provided with these calibration data there is no reason to suspect that the data do not conform to the specification applied by the EA.

It was therefore decided that further comparison of the hydrographic cross section data was unlikely to provide any further useful information or to increase confidence in these data.

4 RESULTS

4.1 General

The results are presented in tabular format in Table 4-1 below and graphically in the figures that follow.

Table 4-1 Stage – Volume Data

Elevation (mAOD) (Depth Down (m))	Volume based on 806 tcm at 5.5m	Volume based on 13% Base Volume	Percentage Difference (%)
5.57 (6.32)	832	756	90.9
6.00 (5.89)	1,001	929	93.8
7.00 (4.89)	1,477	1,370	92.8
8.00 (3.89)	2,094	1,946	92.9
9.00 (2.89)	2,832	2,649	93.5
10.00 (1.89)	3,695	3,476	94.1
11.00 (0.98)	4,722	4,436	93.9
11.89 (0.00)	5,821	5,499	94.4
Average			**93.3**

The figure includes three sets of two graphs. The one to the left presents the data in metric units while the one on the right presents the same data in imperial units.

4.2 Chart A

The two curves presented in this chart represent the EA and YW stage – storage curves based on a 'base volume' of 806 tcm. The YW current depth capacity curve consistently demonstrates a slightly higher volume than the EA curve.

4.3 Chart B

In a similar manner to the data presented in Chart A, the volume predicted using the YW analysis exceeds that quoted by the EA. The actual volumes differ from those in Chart A because the 'base volume' is assumed to be 13% of the maximum available storage, namely 757 tcm.

4.4 Chart C

The four stage – storage curves produced in Chart C are:

- 806 tcm base volume
- 13% base volume
- EA volume
- YW current depth capacity.

The latter curve is the only one that deviates significantly from the other three. However, the difference is again associated with the derivation of the 'base volume' of the reservoir on the day the LiDAR data were captured.

4.5 Reservoir Schematic

A schematic of the various levels and volumes provided and/or determined under the project is also presented.

5 CONCLUSIONS

The data with which the least confidence exists is the 'base volume' the volume of water retained within the reservoir on the day the LiDAR data was captured. Attempts were made to enhance the level of confidence in respect of this volume using comparisons of historic survey data. However, these comparisons were inconclusive and as such did not provide the increased level of confidence anticipated.

The 'base volume' therefore remains the element of the analysis that determines the differences between the figures determined by the two approaches.

The storage volume above the minimum water level will have been more accurately determined than was previously possible as these calculations were based on LiDAR data, the most accurate data available for the study area.

The maximum storage capacity for Gouthwaite Reservoir based on a volume of 805 tcm at a level of 5.5 m up (the approached preferred by YW) is 5,821 tcm. However, assuming that the retained storage when the LiDAR data was captured is represented by 13% (as reported by EA) of the maximum storage capacity a total volume of 5,865 tcm is available. There is a difference of 44 tcm or approximately 1%.

The Gouthwaite Reservoir Depth/Volume Survey dated July 1992 reports a volume of 5,815 tcm at a level of 11.89 m up (135.76 mAOD), the top water level of the reservoir. This indicates a difference of 6 tcm when compared to the latest YW approach that determined 5,821 tcm. When compared to the EA approach this results in a difference of some 35 tcm. These vary by +0.1% and 0.8% respectively.

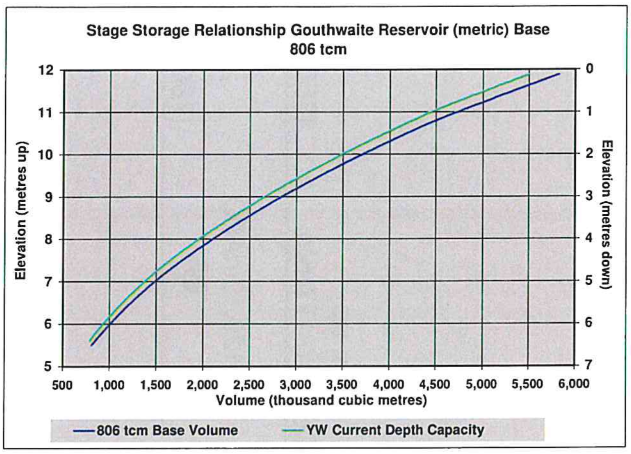
Other capacities provided by the investigations carried out by Huddersfield University are presented below.

Year	Volume (tcm)	Percentage Difference from 5,821 tcm
1901	6,748	15.9
1971	5,834	0.2
1991	5,811	-0.2
YW - **2003**	5,821	0
EA (13%) – **2003**	5,865	0.8

Using the base volume recorded by YW on the day of the LiDAR survey, the maximum storage capacity for Gouthwaite Reservoir is 5821tcm, and included in Appendix C is the revised Depth/Volume Survey resulting from the analysis.

Gouthwaite Reservoir Stage Storage Relationship Graphs

Chart A



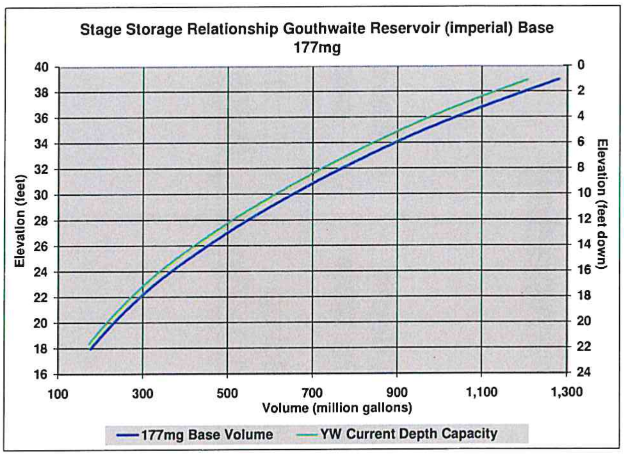
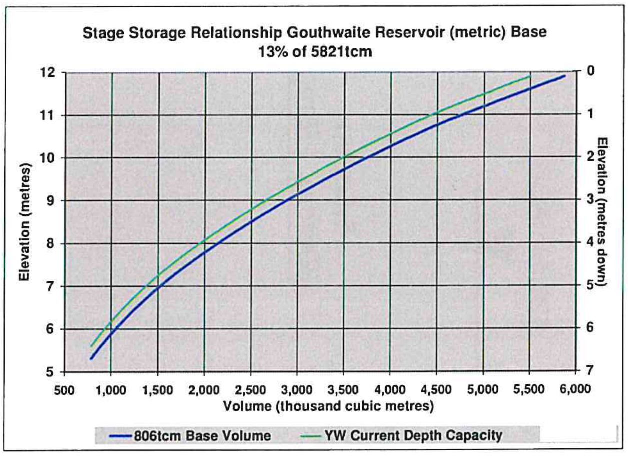


Chart B



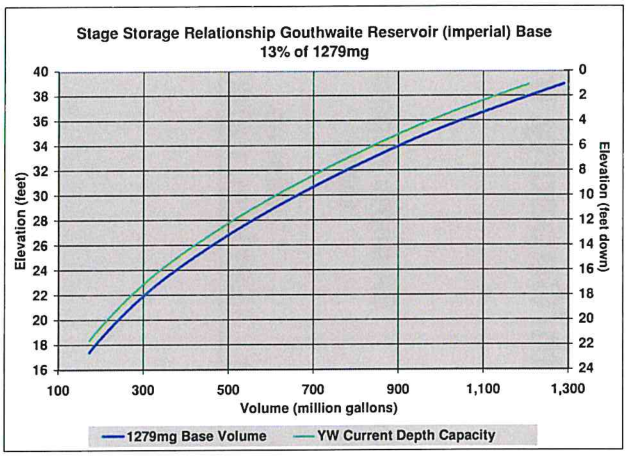
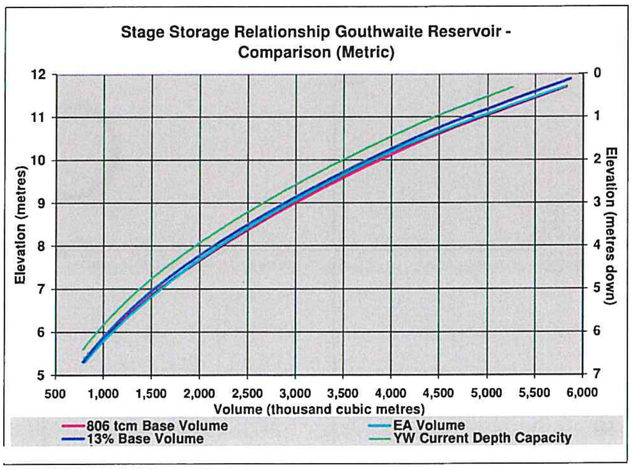
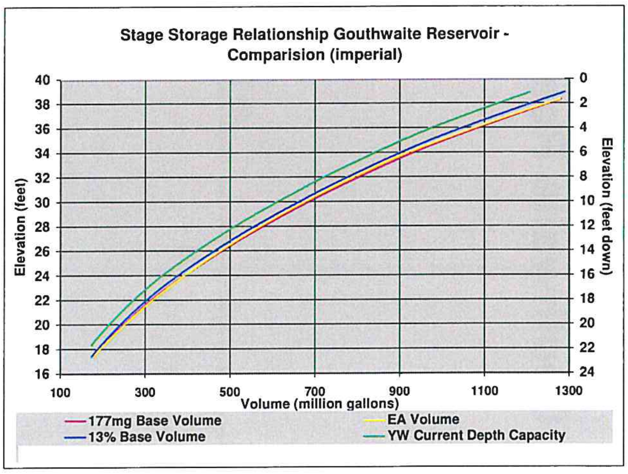
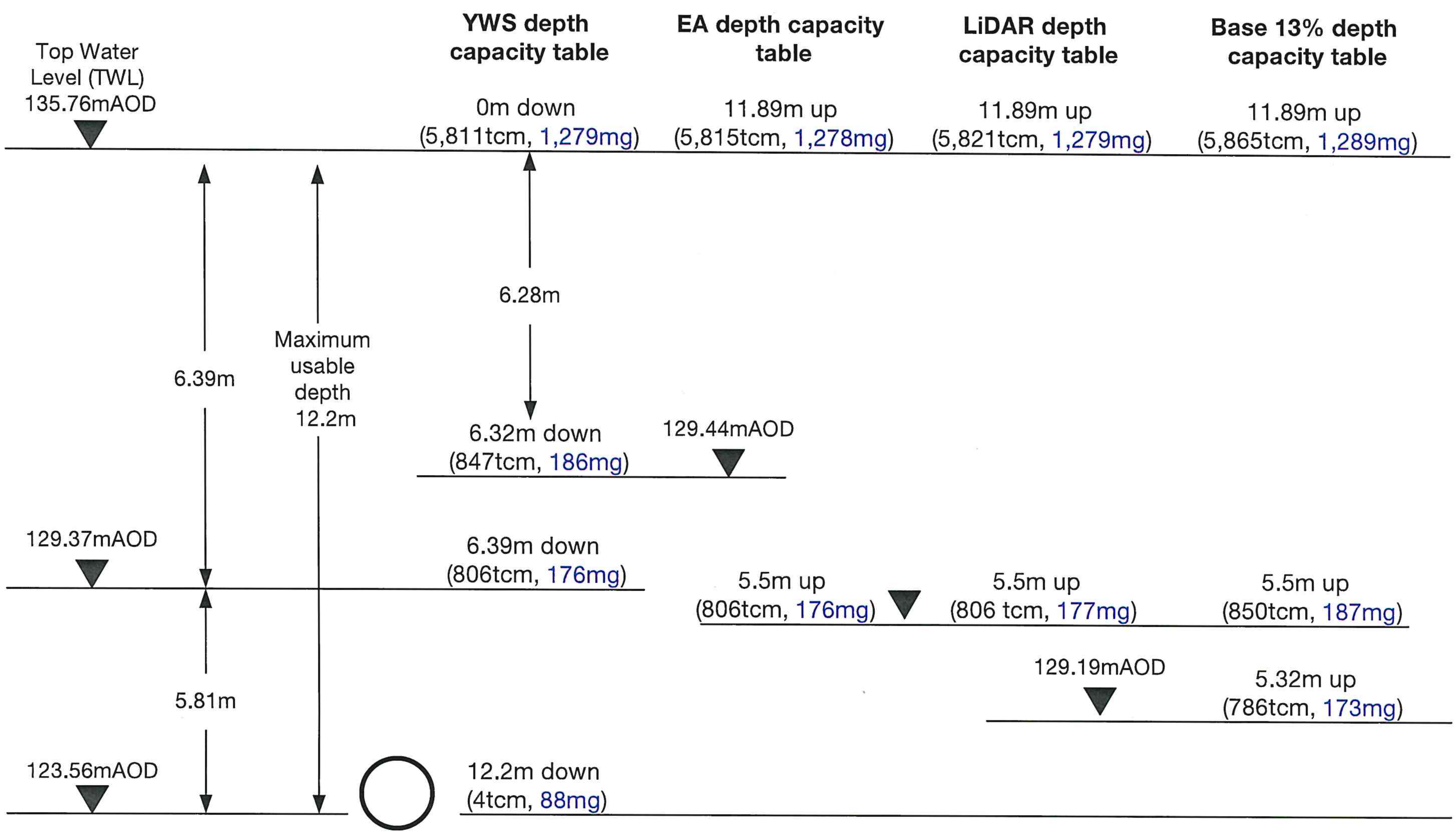


Chart C





Gouthwaite Reservoir Depth/Capacity (metric and imperial)



This page left intentionally blank.

APPENDICES

This page is intentionally left blank.

Appendix A: - University of Huddersfield - Summary

This page is intentionally left blank.

2003S0304
10/2/04.

GOUTHWAITE RESERVOIR - BATHYMETRIC ANALYSIS
SUMMARY OF WORK DONE

The work which has been done is all based on the bathymetric maps produced by Huddersfield University (HU) and so all results and conclusions are of the assumption that these have been accurately reproduced.

Bathymetric maps - These have been produced with a Computer Aided Drawing (CAD) package using all available survey information. They show the reservoir bed profile using contours at one metre intervals below the Top Water Level (TWL).
1901 - The detail of the 1901 map suggests that it was taken from a ground survey completed before the reservoir filled up, and therefore should be relatively accurate.
1971 - It is suspected that this was done by boat and plumb-line, though some may have been done on the ground during drawdown of the reservoir.
There are two main reasons to suggest this map maybe suspect :
a) The bed features do not look typical of a reservoir bed and it maybe that a Cartographer has interpreted the survey their own way.
b) The line of the old channel can hardly be made out which considering it is quite clear on the 1991 survey, indicates that it may have been missed on the 1971 survey. Plumb-line takes depths at points across a section and could easily miss a relatively small feature.
Also no levees shown at inlet end. Perhaps missed on survey.
1991 - Completed using a total survey station for position and an echo sounder to obtain a continuous section. Should be fairly accurate though may miss features between sections. Also made a long section of the reservoir to tie in the cross-sections.

Capacity of reservoir (see attached data sheet)
Calculated by the CAD package from the bathymetric maps.
1901 - Five different values for the original total capacity of the reservoir exist ranging from 1610 mg (1913 map) to 1485 mg (6748 tcm)(HU bathymetric analysis). Obviously the value chosen will have a large effect on the capacity loss of the reservoir since 1901, and if the HU value is to be believed then the reservoir never held the original legal requirement (1510 mg) anyway. Given that we don't know where the original figures came from (and may have been estimated), the HU figure is probably the most reliable.
1971 - The 1971 capacity has been calculated at 5834 tcm (1283 mg). This compares well with the figure calculated in 1971 from the same survey - 5825 tcm.
Rate of loss of capacity 1901-1971 = 13.06 tcm (2.87 mg) per annum.
1991 - Total capacity calculated at 5811 tcm (1278 mg).
Rate of loss of capacity 1971-1991 = 1.17 tcm (0.26 mg) per annum.
Rate of loss of capacity 1901-1991 = 10.41 tcm (2.29 mg) per annum.
This shows a big reduction in the overall rate of deposition over the last 20 years.

Graph of 'capacity change at 0.5m increments'
This graph compares each bathymetric map with the other two in turn, to show how the capacity of each 0.5m increment, or layer, within the reservoir has changed over the period concerned. This tells us the depths in the reservoir where deposition or erosion is occurring and also at what rate.
1901-1991: This line appears to do as expected i.e. high deposition at shallower depths due to an inlet delta being pushed further out into the reservoir. As time progresses it would be expected that the maximum deposition increment would progress to deeper depths as the delta moves down the reservoir.
At deeper depths (>10m) there is very little change in capacity as would be expected because the sediment from the inlet end is deposited before it gets that far. Slight deposition caused by deep channel deposits and reservoir tributaries.

As the 1901 and 1991 bathymetric maps are considered the most accurate, the 1901-1991 line should also be accurate.

1901-1971: This shows deposition at all depths as expected. However, the maximum deposition occurs at intermediate depths (6-8m) rather than shallow depths as might be expected. The amount of deposition at depths >8m also appears to be greater than we would expect at this location, so far from the inflow.

1971-1991: This shows high deposition at the shallow upstream end as might be expected. However, at deeper depths (>6m) there is shown high erosion. Some erosion might occur in the vicinity of the dam during times of high discharge, but we would not expect such a high rate of erosion at intermediate depths, being so far from the dam.

<u>Suspect 1971 survey</u>

All of the above information points to the 1971 bathymetric map as being significantly erroneous and there are a number of features which cannot reasonably be explained:

1) There are several unrealistic features and inconsistencies on the 1971 bathymetric map itself.

2) The bathymetric analysis shows the overall rate of capacity loss has decreased significantly from 13.07 tcm per annum pre-1971, to 1.17 tcm per annum post-1971. This appears odd and goes against certain believes that the amount of sediment in the reservoir has actually increased in the last 20 years due to change in land use and 'dykeing' on the surrounding moors.

3) The unrealistic features on the 'capacity change at 0.5m increments' graph when comparing the 1971 results. These are as follows:

1901-1971 : - major deposition at intermediate and deep depths
- relatively very little deposition at shallow depths

1971-1991 : - major erosion at intermediate and deep depths.

It appears that the bed levels >5.5m below TWL (i.e. between the dam and half way up the reservoir) on the 1971 survey were mostly drawn as being higher than they really were. If the 1971 intermediate and deeper surfaces were lower (i.e. the capacities of these increments were greater), there would be less erosion shown from 1971-91 at these depths and also the amount of deposition at these depths from 1901-71 would be less.

Perhaps the survey was done in two halves. If a different Bench Mark was used for each then maybe the one used for the downstream sections 1-18 was incorrect (high).

When comparing the 1901 and 1991 bathymetric maps, the results appear quite acceptable. However, as soon as the 1971 map is compared the results appear very dubious, especially at deeper depths.

Because of these uncertainties with the 1971 survey it is difficult to come to any conclusions when comparing the 1901-1971 and 1971-1991 surveys. Therefore, the 1971 survey has not been considered from here on, and all remaining comments refer to the 1901 and 1991 bathymetric analysis only.

<u>**Isopachyte maps**</u> - These have also been produced on the CAD system by taking one bathymetric map away from another to leave the difference, which corresponds to the deposition or erosion over the timescale involved.

1901-1991, main features:

- Deep deposits in the old river channel as expected. Deposition almost everywhere upstream of section 8 (700m from dam), apart from a few areas of local erosion; mainly erosion down valley of this apart from deep channel deposits and a large area of deposition off the west bank around sections 6 & 7 (600m from dam). The latter appears as a delta deposit from an inflow but there is no inflow here.
- There is an inflow on the west bank between sections 10 and 11 (950m from dam) but little deposition is shown here.
- The large deposition visible on the isopachyte map between sections 16-30 is

also seen on the 'capacity change at 0.5m increments' graph as the large deposition between 1.5-7m depth. This entire area is made up of deposits 1-4m deep.
- The levees at the inlet end are very prominent as expected.

Assuming the 1901 and 1991 surveys are relatively accurate, the 1901-1991 isopachyte map should also be fairly accurate with the main feature being the significant deposition at shallow and intermediate depths. At deeper depths there is very little change in the bed profile apart from deep channel deposits local deposits from tributaries and local erosion. Nearly all the sediment appears to enter the reservoir from the main river and there is no sign of tributaries contributing a great deal, i.e. large delta type deposits.

Conclusions

The capacity loss of 10.41 tcm per annum (total 937 tcm) between 1901 and 1991 should be an accurate representation of the overall average capacity loss durin the life of the reservoir. This figure represents the following average sedimen input to the reservoir:
- 1.2 cubic metres (264 gallons) of sediment per hour
- 19.8 litres (4.4 gallons) of sediment per minute
- 0.33 litres (half pint) of sediment per second

The striking feature on the 1901-1991 isopachyte map is the distance that the deep sediment deposition stretches from the inflow. One would expect deep deposits in the vicinity of the inflow, but it can be seen that the deep deposition continues over 1300m from the inflow. This implies that a significan proportion of deposition occurs during drawdown, for the following reasons:
1) If the reservoir was at or near full it is difficult to believe that sedimen would be thrown so far out into the reservoir, i.e. between 900-1300m from the inflow.
2) If the reservoir was low, sediment entering the reservoir within the river would be carried to the point where the extended river meets the reservoir and be deposited. The exposed bed of the reservoir may also be eroded and the sediment transported to the river and into the still water. Therefore, during drawdown, sediment will be deposited further down the reservoir past the still water line.

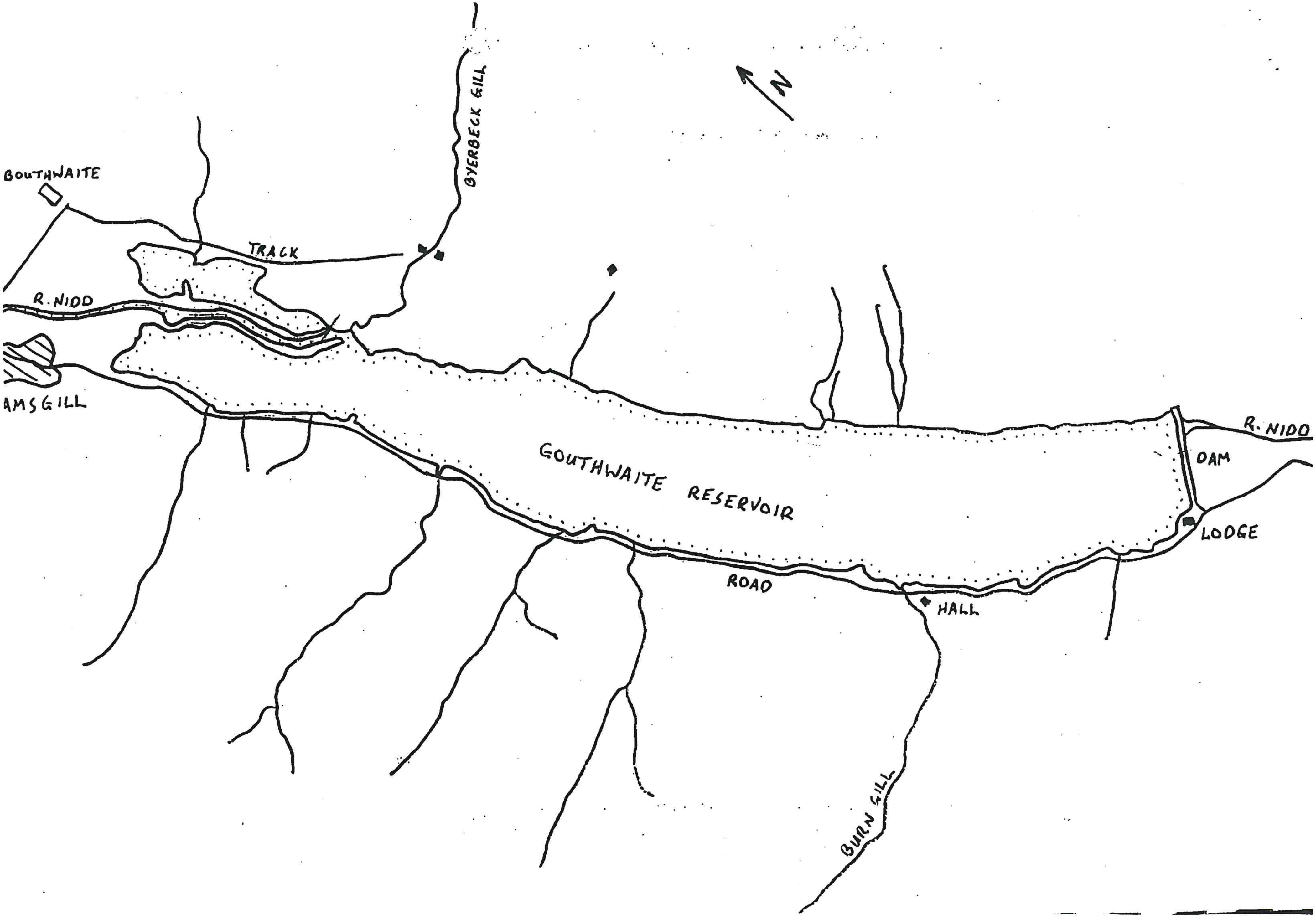
However, the reservoir level-frequency record, summarised on the attached map, shows that large drawdowns are relatively infrequent, e.g. the average annual lowest level is 11ft or 3.35m below TWL (approx. 700m from the inflow), which implies that there must be huge sediment deposition during these drawdowns. Realistically, during drawdown and the associated dry period, there will be ver little sediment input from the low river, and significant sediment transportation into the reservoir will only occur during a storm. Due to the nature of the reservoir, this storm is likely to signal the end of the drawdown period, so although the sediment would initially be deposited past the original drawdown location, the associated flood would eventually fill the reservoir and the scope for deposition at intermediate depths would be limited. The timing of the annual low is usually such that it occurs at the end of the summer in preparation for the Autumn rains. Therefore, this suggests that a significant proportion of deposition occurs during the first storm of the Autumn, at depths >4m below TWL.

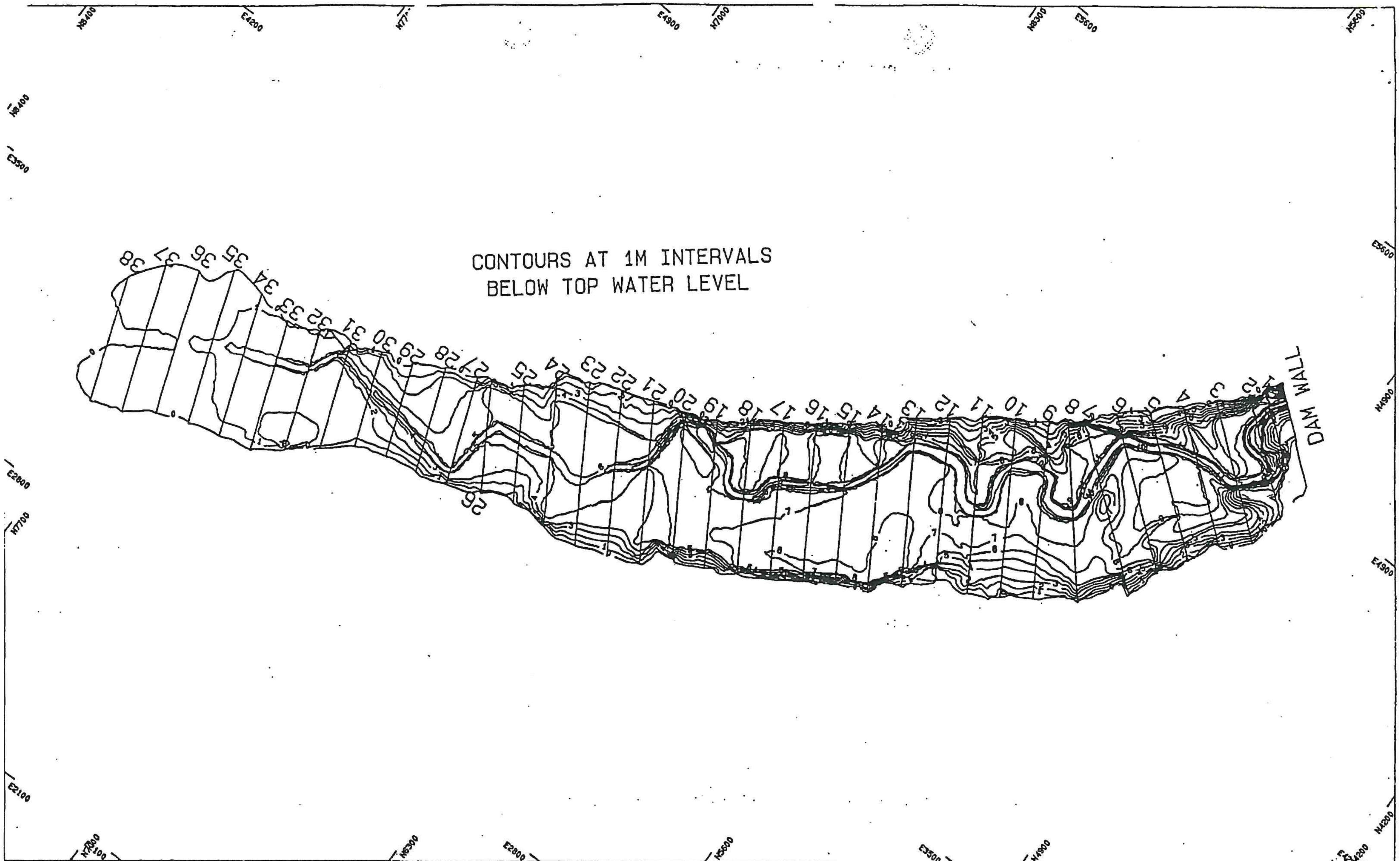
Other issues

1:10000 map

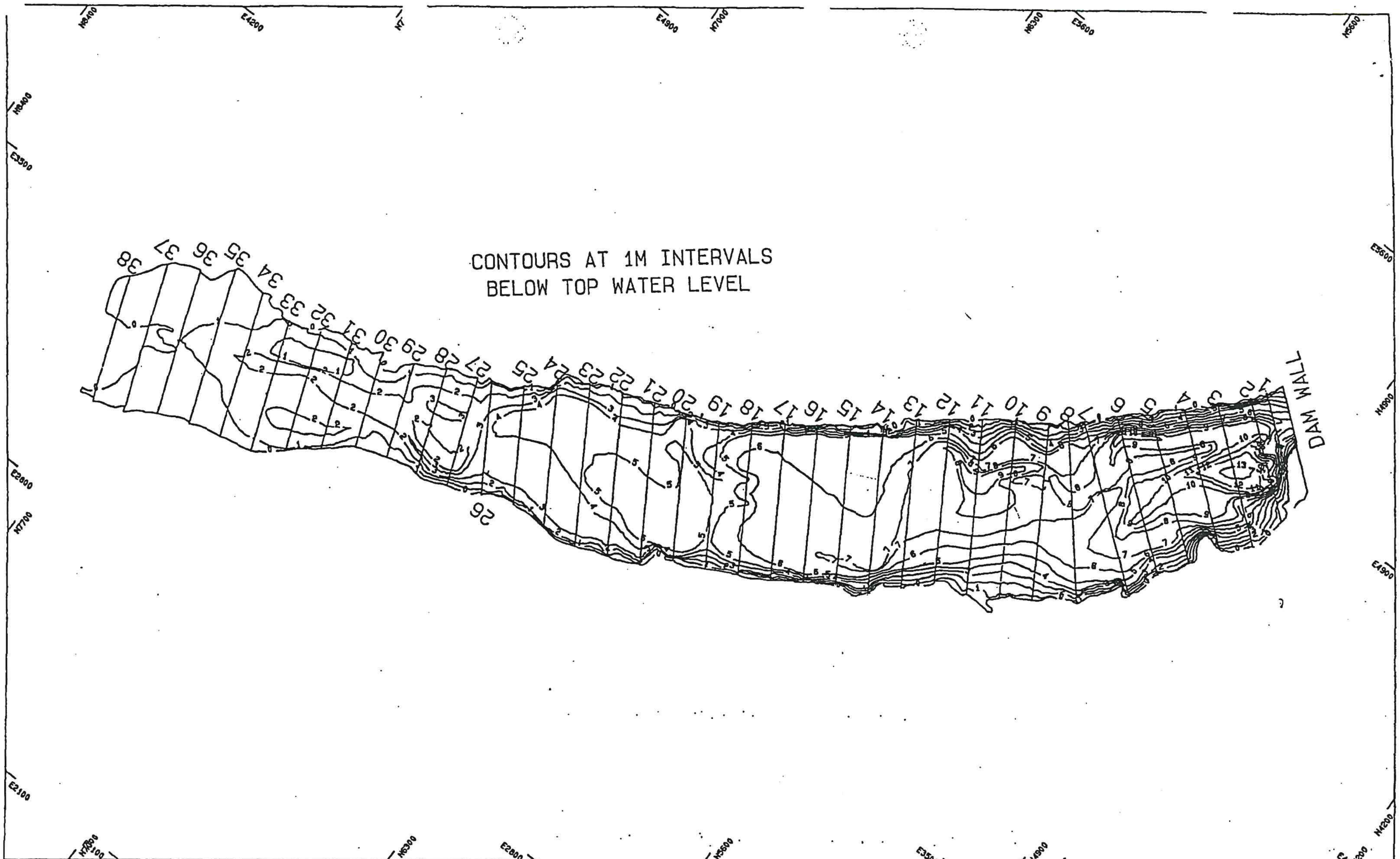
The 1956 Ordnance Survey map shows inlet levees extending out approx. 300m, whereas the 1981 OS map shows levees extending out approx. 600m and the Eastern levee meeting the East shore. 1991 HU survey shows 10m gap between East levee and shore.

Either the inlet levees are constantly changing size and position, or the maps are incorrect. Obviously the further into the reservoir the levees extend the further out sediment will be thrown.

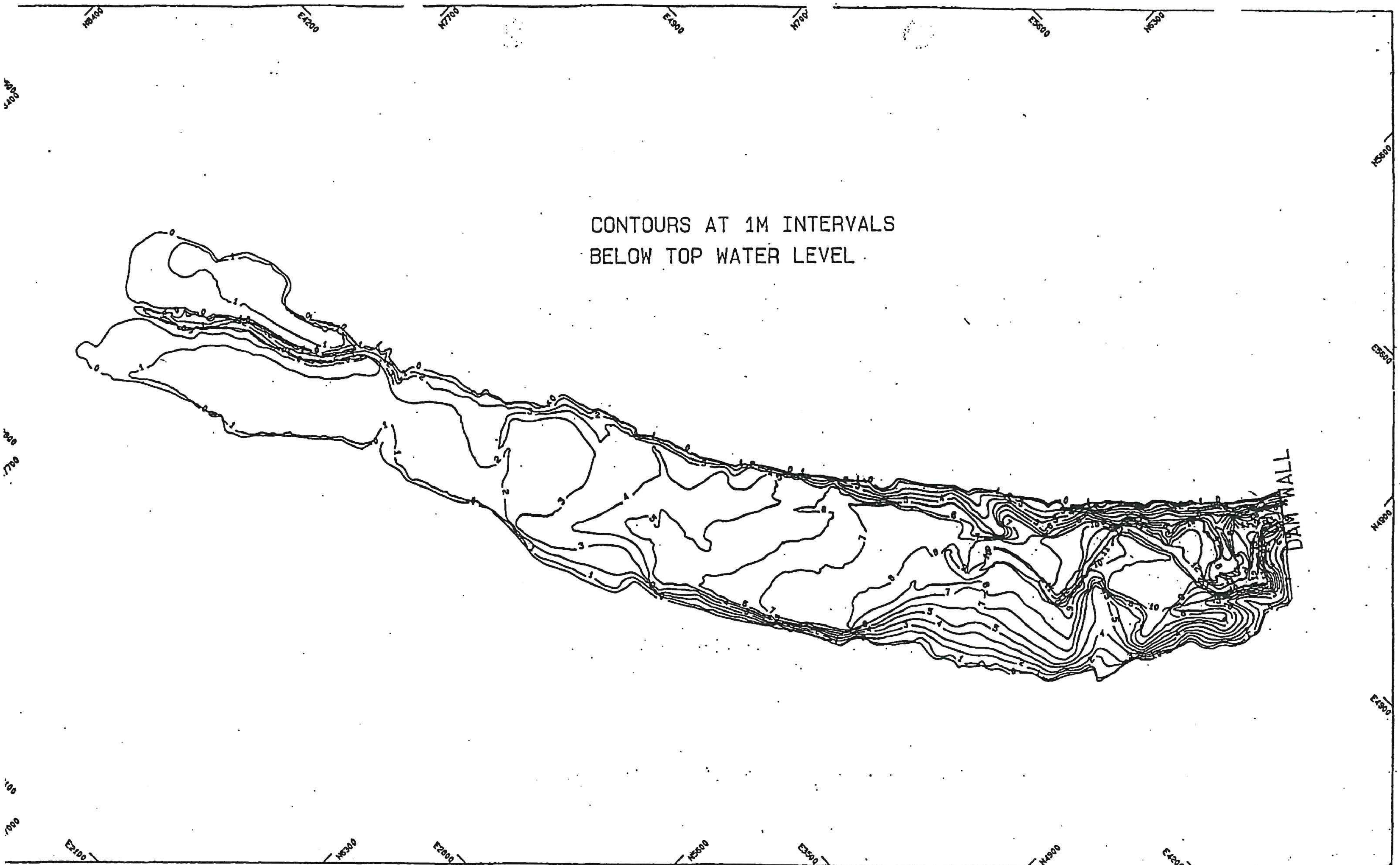

N
BOUTHWAITE
TRACK
GYERBECK GILL
R. NIDD
AMSGILL
GOUTHWAITE RESERVOIR
ROAD
HALL
LODGE
DAM
R. NIDD
BURN GILL



CENTRE FOR WATER AND ENVIRONMENTAL MANAGEMENT University of Huddersfield	GOUTHWAITE RESERVOIR: METRIC RECONSTRUCTION OF 1901 SURVEY	SCALE 1: 7000	DATE JAN 1994
		DRAWN BY	MAP NO 3



CENTRE FOR WATER AND ENVIRONMENTAL MANAGEMENT University of Huddersfield	GOUTHWAITE RESERVOIR: METRIC RECONSTRUCTION OF 1971 SURVEY	SCALE 1: 7000	DATE JAN 1994
		DRAWN BY	MAP NO 2



CENTRE FOR WATER AND ENVIRONMENTAL MANAGEMENT University of Huddersfield	GOUTHWAITE RESERVOIR: 1991 SURVEY	SCALE 1: 7000	DATE JAN 1994
		DRAWN BY	MAP NO 1

GOUTHWAITE RESERVOIR

Statistics using minimum 1901 capacity value

RESERVOIR CAPACITY	YEAR			
	1901	1971	1991	
tcm	6748.063	5834.240	5810.789	using HU 1901 capacity
mg	1484.396	1283.379	1278.220	

CAPACITY LOSS	PERIOD			
	1901-1991	1901-1971	1971-1991	
tcm	937.274	913.823	23.451	using HU 1901 capacity
mg	206.176	201.017	5.159	
tcm p.a.	10.414	13.055	1.173	
mg p.a.	2.291	2.872	0.258	
% total	13.89	13.54	0.40	
% p.a.	0.15	0.19	0.02	

NOTES : tcm = thousand cubic metres
mg = million gallons

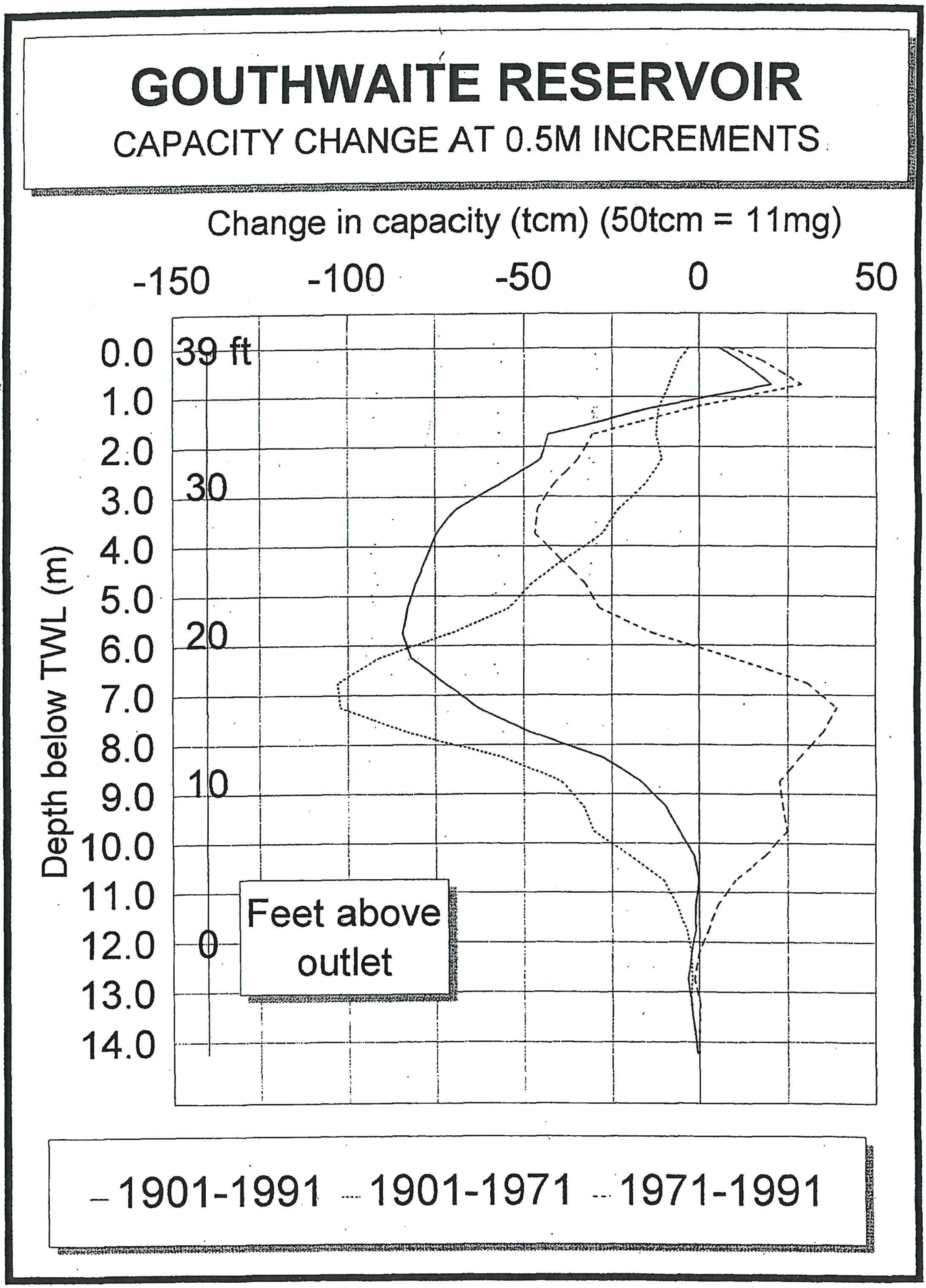
GOUTHWAITE RESERVOIR

Statistics using maximum 1901 capacity value

RESERVOIR CAPACITY	YEAR			
	1901	1971	1991	
tcm	7319	5834.24	5810.789	using '1913 map'
mg	1610	1283.379	1278.22	1901 capacity

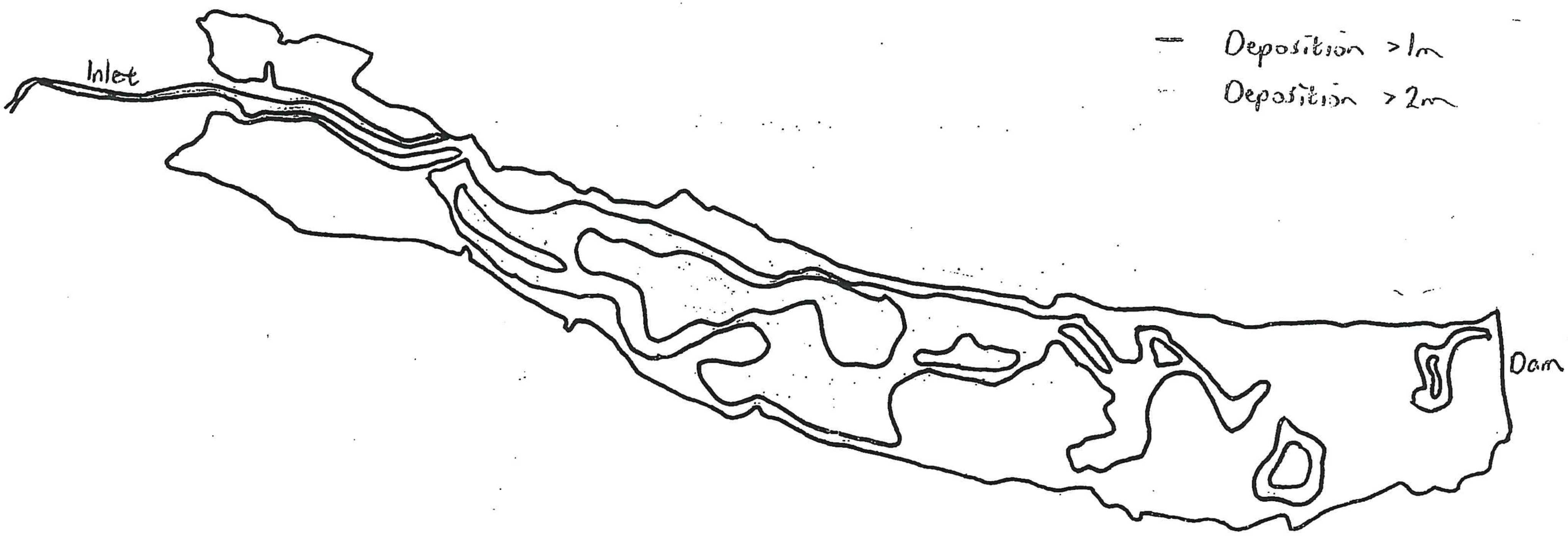
CAPACITY LOSS	PERIOD			
	1901-1991	1901-1971	1971-1991	
tcm	1508.211	1484.760	-	
mg	331.780	326.621	-	using
tcm p.a.	16.758	21.211	-	'1913 map'
mg p.a.	3.686	4.666	-	1901 capacity
% total	20.61	20.29	-	
% p.a.	0.23	0.29	-	

NOTES : tcm = thousand cubic metres
mg = million gallons


GOUTHWAITE RESERVOIR
CAPACITY CHANGE AT 0.5M INCREMENTS
Change in capacity (tcm) (50tcm = 11mg)
-150
-100
-50
0
50
Depth below TWL (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
39 ft
30
20
10
0
Feet above outlet
1901-1991
1901-1971
1971-1991

GOUTHWAITE RESERVOIR

AREAS OF DEPOSITION 1901 - 1991



Appendix B: - Gouthwaite Reservoir Depth/Volume Survey 1992

This page is intentionally left blank.

GOUTHWAITE RESERVOIR DEPTH/VOLUME SURVEY JULY 1992 (METRIC)

Depth (m)	Equation (Volume in tcmd)
5.46 to 10.41	Vol=17.1055*(depth-0.4255)^2.3717
10.42 to 11.89+	Vol=54.6041*(depth-2.7345)^2.1081

Imperial table

	Reservoir capacity (thousand cubic metres)									
metres	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
5.5	806	809	813	817	821	825	828	832	836	840
5.6	844	848	852	855	859	863	867	871	875	879
5.7	883	887	891	895	899	903	907	911	915	919
5.8	923	927	931	935	940	944	948	952	956	960
5.9	964	969	973	977	981	985	990	994	998	1002
6.0	1007	1011	1015	1020	1024	1028	1033	1037	1041	1046
6.1	1050	1054	1059	1063	1068	1072	1077	1081	1086	1090
6.2	1095	1099	1104	1108	1113	1117	1122	1126	1131	1135
6.3	1140	1145	1149	1154	1159	1163	1168	1172	1177	1182
6.4	1187	1191	1196	1201	1205	1210	1215	1220	1225	1229
6.5	1234	1239	1244	1249	1254	1258	1263	1268	1273	1278
6.6	1283	1288	1293	1298	1303	1308	1313	1318	1323	1328
6.7	1333	1338	1343	1348	1353	1358	1363	1368	1373	1379
6.8	1384	1389	1394	1399	1404	1410	1415	1420	1425	1430
6.9	1436	1441	1446	1452	1457	1462	1467	1473	1478	1484
7.0	1489	1494	1500	1505	1510	1516	1521	1527	1532	1538
7.1	1543	1549	1554	1560	1565	1571	1576	1582	1587	1593
7.2	1599	1604	1610	1615	1621	1627	1632	1638	1644	1649
7.3	1655	1661	1667	1672	1678	1684	1690	1695	1701	1707
7.4	1713	1719	1724	1730	1736	1742	1748	1754	1760	1766
7.5	1772	1778	1783	1789	1795	1801	1807	1813	1819	1826
7.6	1832	1838	1844	1850	1856	1862	1868	1874	1880	1887
7.7	1893	1899	1905	1911	1917	1924	1930	1936	1942	1949
7.8	1955	1961	1968	1974	1980	1987	1993	1999	2006	2012
7.9	2018	2025	2031	2038	2044	2051	2057	2064	2070	2077
8.0	2083	2090	2096	2103	2109	2116	2122	2129	2136	2142
8.1	2149	2156	2162	2169	2176	2182	2189	2196	2202	2209
8.2	2216	2223	2229	2236	2243	2250	2257	2263	2270	2277
8.3	2284	2291	2298	2305	2312	2319	2326	2333	2339	2346
8.4	2353	2360	2367	2375	2382	2389	2396	2403	2410	2417
8.5	2424	2431	2438	2445	2453	2460	2467	2474	2481	2489
8.6	2496	2503	2510	2518	2525	2532	2540	2547	2554	2562
8.7	2569	2576	2584	2591	2598	2606	2613	2621	2628	2636
8.8	2643	2651	2658	2666	2673	2681	2688	2696	2703	2711
8.9	2719	2726	2734	2741	2749	2757	2764	2772	2780	2788
9.0	2795	2803	2811	2819	2826	2834	2842	2850	2858	2865
9.1	2873	2881	2889	2897	2905	2913	2921	2929	2936	2944
9.2	2952	2960	2968	2976	2984	2992	3001	3009	3017	3025
9.3	3033	3041	3049	3057	3065	3074	3082	3090	3098	3106
9.4	3115	3123	3131	3139	3148	3156	3164	3172	3181	3189
9.5	3197	3206	3214	3223	3231	3239	3248	3256	3265	3273
9.6	3282	3290	3299	3307	3316	3324	3333	3341	3350	3359
9.7	3367	3376	3384	3393	3402	3410	3419	3428	3436	3445
9.8	3454	3463	3471	3480	3489	3498	3507	3515	3524	3533
9.9	3542	3551	3560	3569	3577	3586	3595	3604	3613	3622
10.0	3631	3640	3649	3658	3667	3676	3685	3694	3704	3713
10.1	3722	3731	3740	3749	3758	3768	3777	3786	3795	3804
10.2	3814	3823	3832	3842	3851	3860	3869	3879	3888	3897
10.3	3907	3916	3926	3935	3945	3954	3963	3973	3982	3992
10.4	4001	4011	4021	4032	4043	4054	4065	4076	4087	4098
10.5	4109	4121	4132	4143	4154	4165	4177	4188	4199	4211
10.6	4222	4233	4245	4256	4267	4279	4290	4301	4313	4324
10.7	4336	4347	4359	4370	4382	4393	4405	4417	4428	4440
10.8	4451	4463	4475	4486	4498	4510	4521	4533	4545	4557
10.9	4568	4580	4592	4604	4616	4628	4640	4651	4663	4675
11.0	4687	4699	4711	4723	4735	4747	4759	4771	4783	4795
11.1	4808	4820	4832	4844	4856	4868	4881	4893	4905	4917
11.2	4930	4942	4954	4966	4979	4991	5003	5016	5028	5041
11.3	5053	5066	5078	5090	5103	5115	5128	5141	5153	5166
11.4	5178	5191	5203	5216	5229	5241	5254	5267	5280	5292
11.5	5305	5318	5331	5343	5356	5369	5382	5395	5408	5421
11.6	5433	5446	5459	5472	5485	5498	5511	5524	5537	5550
11.7	5563	5577	5590	5603	5616	5629	5642	5655	5669	5682
11.8	5695	5708	5722	5735	5748	5761	5775	5788	5802	5815
11.9	5828	5842	5855	5869	5882	5896	5909	5923	5936	5950
12.0	5963	5977	5990	6004	6018	6031	6045	6059	6072	6086
12.1	6100	6113	6127	6141	6155	6169	6182	6196	6210	6224
12.2	6238	6252	6266	6280	6293	6307	6321	6335	6349	6363
12.3	6378	6392	6406	6420	6434	6448	6462	6476	6490	6505
12.4	6519	6533	6547	6562	6576	6590	6604	6619	6633	6648
12.5	6662	6676	6691	6705	6720	6734	6748	6763	6777	6792
12.6	6807	6821	6836	6850	6865	6879	6894	6909	6923	6938
12.7	6953	6967	6982	6997	7012	7027	7041	7056	7071	7086
12.8	7101	7116	7130	7145	7160	7175	7190	7205	7220	7235
12.9	7250	7265	7280	7295	7310	7326	7341	7356	7371	7386
13.0	7401	7417	7432	7447	7462	7478	7493	7508	7523	7539

GOUTHWAITE RESERVOIR DEPTH/VOLUME SURVEY JULY 1992 (IMPERIAL)

Depth range	Equation (Volume in million gallons)
18' to 34'2":	Vol=1.0217*(depth-1.396)^2.3717
34'2" to 39'+:	Vol=4.461*(depth-8.972)^2.1081

	Reservoir capacity (million gallons)											
	Inches											
Feet	0	1	2	3	4	5	6	7	8	9	10	11
18	176	178	180	182	185	187	189	191	193	196	198	200
19	202	205	207	209	211	214	216	219	221	223	226	228
20	231	233	236	238	241	243	246	248	251	253	256	258
21	261	264	266	269	272	274	277	280	283	285	288	291
22	294	297	299	302	305	308	311	314	317	320	323	326
23	329	332	335	338	341	344	347	350	353	356	360	363
24	366	369	372	376	379	382	385	389	392	395	399	402
25	406	409	412	416	419	423	426	430	433	437	440	444
26	448	451	455	458	462	466	469	473	477	481	484	488
27	492	496	499	503	507	511	515	519	523	527	531	535
28	539	543	547	551	555	559	563	567	571	575	580	584
29	588	592	596	601	605	609	613	618	622	626	631	635
30	640	644	649	653	657	662	667	671	676	680	685	689
31	694	699	703	708	713	717	722	727	732	736	741	746
32	751	756	761	766	770	775	780	785	790	795	800	805
33	810	815	821	826	831	836	841	846	852	857	862	867
34	873	878	883	889	895	902	908	914	920	927	933	939
35	946	952	958	965	971	978	984	991	997	1004	1011	1017
36	1024	1031	1037	1044	1051	1057	1064	1071	1078	1085	1092	1098
37	1105	1112	1119	1126	1133	1140	1147	1154	1162	1169	1176	1183
38	1190	1197	1205	1212	1219	1227	1234	1241	1249	1256	1263	1271
39	1278	1286	1293	1301	1308	1316	1324	1331	1339	1347	1354	1362
40	1370	1377	1385	1393	1401	1409	1417	1425	1432	1440	1448	1456
41	1464	1472	1481	1489	1497	1505	1513	1521	1529	1538	1546	1554
42	1562	1571	1579	1588	1596	1604	1613	1621	1630	1638	1647	1655
43	1664	1672	1681	1690	1698	1707	1716	1725	1733	1742	1751	1760
44	1769	1778	1786	1795	1804	1813	1822	1831	1840	1849	1859	1868
45	1877	1886	1895	1904	1914	1923	1932	1941	1951	1960	1969	1979

Appendix C: - Gouthwaite Reservoir Depth/Volume 2004 Analysis

This page is intentionally left blank.

GOUTHWAITE RESERVOIR DEPTH/VOLUME SURVEY (METRIC) BASED ON LIDAR DATA SURVEYED NOVEMBER 2003

Assumes that 13% of the maximum volume of the reservoir (5,821tcm) was retained when the LIDAR data was collected. This represented a water surface level of 129.19 mAOD (5.32m)

Depth (metres)
No data
5.32 to 10.41
10.42 to 11.88
11.89

		Reservoir capacity (thousand cubic metres)										
mAOD	metres	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	
129.17	5.3			786	792	795	798	801	804	808	811	
129.27	5.4	814	818	821	825	828	832	835	839	843	846	
129.37	5.5	850	853	857	861	865	868	872	876	879	883	
129.47	5.6	887	891	894	898	902	906	910	913	917	921	
129.57	5.7	925	929	933	937	940	944	948	952	956	960	
129.67	5.8	964	968	972	976	980	984	988	992	996	1,000	
129.77	5.9	1,004	1,008	1,012	1,016	1,020	1,025	1,029	1,033	1,037	1,041	
129.87	6.0	1,045	1,049	1,054	1,058	1,062	1,066	1,070	1,075	1,079	1,083	
129.97	6.1	1,087	1,092	1,096	1,100	1,105	1,109	1,113	1,118	1,122	1,126	
130.07	6.2	1,131	1,135	1,139	1,144	1,148	1,153	1,157	1,161	1,166	1,170	
130.17	6.3	1,175	1,179	1,184	1,188	1,193	1,198	1,202	1,207	1,211	1,216	
130.27	6.4	1,221	1,225	1,230	1,234	1,239	1,244	1,249	1,253	1,258	1,263	
130.37	6.5	1,267	1,272	1,277	1,282	1,287	1,291	1,296	1,301	1,306	1,311	
130.47	6.6	1,316	1,320	1,325	1,330	1,335	1,340	1,345	1,350	1,355	1,360	
130.57	6.7	1,365	1,370	1,375	1,380	1,385	1,390	1,395	1,400	1,405	1,410	
130.67	6.8	1,415	1,420	1,425	1,431	1,436	1,441	1,446	1,451	1,456	1,462	
130.77	6.9	1,467	1,472	1,477	1,483	1,488	1,493	1,499	1,504	1,510	1,515	
130.87	7.0	1,520	1,526	1,531	1,537	1,542	1,548	1,553	1,559	1,565	1,570	
130.97	7.1	1,576	1,582	1,587	1,593	1,599	1,604	1,610	1,616	1,622	1,627	
131.07	7.2	1,633	1,639	1,645	1,651	1,656	1,662	1,668	1,674	1,680	1,686	
131.17	7.3	1,692	1,698	1,704	1,710	1,716	1,722	1,728	1,734	1,740	1,746	
131.27	7.4	1,752	1,758	1,764	1,770	1,776	1,783	1,789	1,795	1,801	1,807	
131.37	7.5	1,813	1,820	1,826	1,832	1,638	1,845	1,851	1,857	1,864	1,870	
131.47	7.6	1,876	1,882	1,889	1,895	1,902	1,908	1,914	1,921	1,927	1,933	
131.57	7.7	1,940	1,946	1,953	1,959	1,966	1,972	1,979	1,985	1,992	1,998	
131.67	7.8	2,005	2,011	2,018	2,024	2,031	2,038	2,044	2,051	2,058	2,064	
131.77	7.9	2,071	2,077	2,084	2,091	2,098	2,104	2,111	2,118	2,124	2,131	
131.87	8.0	2,138	2,145	2,152	2,158	2,165	2,172	2,179	2,186	2,193	2,199	
131.97	8.1	2,206	2,213	2,220	2,227	2,234	2,241	2,248	2,255	2,262	2,269	
132.07	8.2	2,276	2,283	2,290	2,297	2,304	2,311	2,318	2,325	2,332	2,339	
132.17	8.3	2,346	2,353	2,361	2,368	2,375	2,382	2,389	2,396	2,404	2,411	
132.27	8.4	2,418	2,425	2,433	2,440	2,447	2,454	2,462	2,469	2,476	2,484	
132.37	8.5	2,491	2,499	2,506	2,513	2,521	2,528	2,536	2,543	2,551	2,558	
132.47	8.6	2,566	2,573	2,581	2,588	2,596	2,603	2,611	2,618	2,626	2,634	
132.57	8.7	2,641	2,649	2,657	2,664	2,672	2,680	2,687	2,695	2,703	2,711	
132.67	8.8	2,718	2,726	2,734	2,742	2,749	2,757	2,765	2,773	2,781	2,789	
132.77	8.9	2,796	2,804	2,812	2,820	2,828	2,836	2,844	2,852	2,860	2,868	
132.87	9.0	2,876	2,884	2,892	2,900	2,908	2,916	2,924	2,932	2,940	2,949	
132.97	9.1	2,957	2,965	2,973	2,981	2,989	2,998	3,006	3,014	3,022	3,030	
133.07	9.2	3,039	3,047	3,055	3,064	3,072	3,080	3,088	3,097	3,105	3,113	
133.17	9.3	3,122	3,130	3,139	3,147	3,155	3,164	3,172	3,181	3,189	3,198	
133.27	9.4	3,206	3,215	3,223	3,232	3,240	3,249	3,257	3,266	3,275	3,283	
133.37	9.5	3,292	3,300	3,309	3,318	3,326	3,335	3,344	3,353	3,361	3,370	
133.47	9.6	3,379	3,387	3,396	3,405	3,414	3,422	3,431	3,440	3,449	3,458	
133.57	9.7	3,467	3,476	3,484	3,493	3,502	3,511	3,520	3,529	3,538	3,547	
133.67	9.8	3,556	3,565	3,574	3,583	3,592	3,601	3,610	3,619	3,628	3,637	
133.77	9.9	3,647	3,656	3,665	3,674	3,683	3,692	3,701	3,711	3,720	3,729	
133.87	10.0	3,738	3,748	3,757	3,766	3,775	3,785	3,794	3,803	3,813	3,822	
133.97	10.1	3,831	3,841	3,850	3,859	3,869	3,878	3,888	3,897	3,907	3,916	
134.07	10.2	3,926	3,935	3,945	3,954	3,964	3,973	3,983	3,993	4,002	4,012	
134.17	10.3	4,021	4,031	4,041	4,050	4,060	4,070	4,080	4,089	4,099	4,109	
134.27	10.4	4,119	4,129	4,139	4,148	4,158	4,168	4,178	4,188	4,198	4,208	
134.37	10.5	4,218	4,229	4,239	4,249	4,259	4,269	4,279	4,290	4,300	4,310	
134.47	10.6	4,321	4,331	4,341	4,352	4,362	4,372	4,383	4,394	4,404	4,415	
134.57	10.7	4,425	4,436	4,447	4,457	4,468	4,480	4,491	4,502	4,513	4,524	
134.67	10.8	4,536	4,547	4,558	4,570	4,581	4,592	4,604	4,615	4,627	4,638	
134.77	10.9	4,650	4,661	4,673	4,684	4,696	4,707	4,719	4,731	4,742	4,754	
134.87	11.0	4,766	4,778	4,790	4,801	4,813	4,825	4,837	4,849	4,861	4,873	
134.97	11.1	4,885	4,897	4,909	4,921	4,933	4,945	4,957	4,969	4,981	4,994	
135.07	11.2	5,006	5,018	5,030	5,042	5,054	5,067	5,079	5,091	5,103	5,116	
135.17	11.3	5,128	5,140	5,152	5,165	5,177	5,189	5,202	5,214	5,226	5,239	
135.27	11.4	5,251	5,263	5,276	5,288	5,300	5,313	5,325	5,337	5,350	5,362	
135.37	11.5	5,375	5,387	5,399	5,412	5,424	5,437	5,449	5,462	5,474	5,486	
135.47	11.6	5,499	5,511	5,524	5,536	5,549	5,561	5,574	5,586	5,599	5,611	
135.57	11.7	5,624	5,637	5,649	5,662	5,674	5,687	5,700	5,712	5,725	5,738	
135.67	11.8	5,750	5,763	5,776	5,788	5,801	5,814	5,827	5,839	5,852	5,865	TWL

Notes: TWL - Top Water Level

GOUTHWAITE RESERVOIR DEPTH/VOLUME SURVEY (IMPERIAL) BASED ON LIDAR DATA SURVEYED NOVEMBER 2003

Assumes that 13% of the maximum volume of the reservoir (1279mg) was retained when the LIDAR data was collected. This represented a water surface level of 129.19 mAOD (17feet 5inches)

Depth (feet)
No data
17'11" to 34'1"
34'2" to 39'

		Reservoir capacity (million gallons)											
		Inches											
mAOD	feet	0	1	2	3	4	5	6	7	8	9	10	11
129.06	17												184
129.37	18	186	188	190	192	195	197	199	201	203	205	208	209
129.67	19	212	214	216	219	221	223	225	228	230	232	234	237
129.98	20	239	242	244	247	249	251	254	256	259	261	264	266
130.28	21	269	271	274	278	280	283	285	288	290	293	296	299
130.59	22	301	304	307	310	313	316	319	321	325	327	331	333
130.89	23	337	339	343	346	349	353	355	359	361	365	368	372
131.20	24	374	378	381	385	389	392	396	399	403	405	410	412
131.50	25	417	419	424	428	431	435	438	442	445	449	452	457
131.81	26	460	464	467	471	476	479	483	486	491	494	499	502
132.11	27	506	509	514	519	522	527	530	535	538	543	546	551
132.42	28	554	559	562	567	572	575	581	584	589	592	597	601
132.72	29	606	609	615	620	623	629	632	637	641	646	650	655
133.03	30	659	664	668	673	679	682	688	692	697	701	707	710
133.33	31	716	720	725	731	735	741	744	750	754	760	764	770
133.64	32	774	780	784	789	795	799	805	809	816	820	826	830
133.94	33	836	840	846	852	857	863	867	873	877	884	888	894
134.25	34	899	905	910	916	923	927	934	938	945	950	956	961
134.55	35	968	973	980	987	992	999	1004	1012	1017	1024	1029	1037
134.86	36	1042	1050	1055	1063	1071	1076	1084	1089	1097	1103	1111	1116
135.16	37	1124	1130	1138	1146	1151	1159	1165	1173	1178	1187	1192	1200
135.47	38	1206	1214	1220	1228	1236	1242	1250	1255	1264	1269	1278	1283
135.77	39	1289											

GOUTHWAITE RESERVOIR DEPTH/VOLUME SURVEY (METRIC) BASED ON LIDAR DATA SURVEYED NOVEMBER 2003

Assumes level of 129.37mAOD (5.5m) represents a volume of 806tcm

Depth (metres)
No data
5.50 to 10.41
10.42 to 11.88
11.89

		Reservoir capacity (thousand cubic metres)									
mAOD	metres	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
129.17	5.3										
129.27	5.4										
129.37	5.5	806	810	813	817	821	824	828	832	836	839
129.47	5.6	843	847	851	854	858	862	866	870	873	877
129.57	5.7	881	885	889	893	897	901	904	908	912	916
129.67	5.8	920	924	928	932	936	940	944	948	952	956
129.77	5.9	960	964	968	972	977	981	985	989	993	997
129.87	6.0	1,001	1,006	1,010	1,014	1,018	1,022	1,027	1,031	1,035	1,039
129.97	6.1	1,044	1,048	1,052	1,056	1,061	1,065	1,069	1,074	1,078	1,082
130.07	6.2	1,087	1,091	1,096	1,100	1,104	1,109	1,113	1,118	1,122	1,127
130.17	6.3	1,131	1,136	1,140	1,145	1,149	1,154	1,158	1,163	1,167	1,172
130.27	6.4	1,177	1,181	1,186	1,191	1,195	1,200	1,205	1,209	1,214	1,219
130.37	6.5	1,224	1,228	1,233	1,238	1,243	1,248	1,252	1,257	1,262	1,267
130.47	6.6	1,272	1,277	1,281	1,286	1,291	1,296	1,301	1,306	1,311	1,316
130.57	6.7	1,321	1,326	1,331	1,336	1,341	1,346	1,351	1,356	1,361	1,366
130.67	6.8	1,371	1,377	1,382	1,387	1,392	1,397	1,402	1,407	1,413	1,418
130.77	6.9	1,423	1,428	1,434	1,439	1,444	1,450	1,455	1,460	1,466	1,471
130.87	7.0	1,477	1,482	1,487	1,493	1,498	1,504	1,510	1,515	1,521	1,526
130.97	7.1	1,532	1,538	1,543	1,549	1,555	1,560	1,566	1,572	1,578	1,583
131.07	7.2	1,589	1,595	1,601	1,607	1,613	1,618	1,624	1,630	1,636	1,642
131.17	7.3	1,648	1,654	1,660	1,666	1,672	1,678	1,684	1,690	1,696	1,702
131.27	7.4	1,708	1,714	1,720	1,727	1,733	1,739	1,745	1,751	1,757	1,763
131.37	7.5	1,770	1,776	1,782	1,788	1,795	1,801	1,807	1,813	1,820	1,826
131.47	7.6	1,832	1,839	1,845	1,851	1,858	1,864	1,870	1,877	1,883	1,890
131.57	7.7	1,896	1,903	1,909	1,915	1,922	1,928	1,935	1,941	1,948	1,954
131.67	7.8	1,961	1,968	1,974	1,981	1,987	1,994	2,000	2,007	2,014	2,020
131.77	7.9	2,027	2,034	2,040	2,047	2,054	2,060	2,067	2,074	2,081	2,087
131.87	8.0	2,094	2,101	2,108	2,115	2,121	2,128	2,135	2,142	2,149	2,156
131.97	8.1	2,162	2,169	2,176	2,183	2,190	2,197	2,204	2,211	2,218	2,225
132.07	8.2	2,232	2,239	2,246	2,253	2,260	2,267	2,274	2,281	2,288	2,295
132.17	8.3	2,302	2,310	2,317	2,324	2,331	2,338	2,345	2,353	2,360	2,367
132.27	8.4	2,374	2,381	2,389	2,396	2,403	2,411	2,418	2,425	2,433	2,440
132.37	8.5	2,447	2,455	2,462	2,470	2,477	2,484	2,492	2,499	2,507	2,514
132.47	8.6	2,522	2,529	2,537	2,544	2,552	2,559	2,567	2,575	2,582	2,590
132.57	8.7	2,598	2,605	2,613	2,620	2,628	2,636	2,644	2,651	2,659	2,667
132.67	8.8	2,674	2,682	2,690	2,698	2,706	2,713	2,721	2,729	2,737	2,745
132.77	8.9	2,753	2,761	2,768	2,776	2,784	2,792	2,800	2,808	2,816	2,824
132.87	9.0	2,832	2,840	2,848	2,856	2,864	2,872	2,880	2,889	2,897	2,905
132.97	9.1	2,913	2,921	2,929	2,937	2,946	2,954	2,962	2,970	2,978	2,987
133.07	9.2	2,995	3,003	3,011	3,020	3,028	3,036	3,045	3,053	3,061	3,070
133.17	9.3	3,078	3,086	3,095	3,103	3,112	3,120	3,129	3,137	3,145	3,154
133.27	9.4	3,162	3,171	3,179	3,188	3,197	3,205	3,214	3,222	3,231	3,239
133.37	9.5	3,248	3,257	3,265	3,274	3,283	3,291	3,300	3,309	3,317	3,326
133.47	9.6	3,335	3,344	3,352	3,361	3,370	3,379	3,387	3,396	3,405	3,414
133.57	9.7	3,423	3,432	3,441	3,449	3,458	3,467	3,476	3,485	3,494	3,503
133.67	9.8	3,512	3,521	3,530	3,539	3,548	3,557	3,566	3,575	3,585	3,594
133.77	9.9	3,603	3,612	3,621	3,630	3,639	3,648	3,658	3,667	3,676	3,685
133.87	10.0	3,695	3,704	3,713	3,722	3,732	3,741	3,750	3,759	3,769	3,778
133.97	10.1	3,788	3,797	3,806	3,816	3,825	3,835	3,844	3,853	3,863	3,872
134.07	10.2	3,882	3,891	3,901	3,910	3,920	3,930	3,939	3,949	3,958	3,968
134.17	10.3	3,978	3,987	3,997	4,007	4,016	4,026	4,036	4,046	4,055	4,065
134.27	10.4	4,075	4,085	4,095	4,105	4,115	4,124	4,134	4,144	4,154	4,164
134.37	10.5	4,175	4,185	4,195	4,205	4,215	4,225	4,236	4,246	4,256	4,266
134.47	10.6	4,277	4,287	4,297	4,308	4,318	4,329	4,339	4,350	4,360	4,371
134.57	10.7	4,381	4,392	4,403	4,413	4,425	4,436	4,447	4,458	4,469	4,481
134.67	10.8	4,492	4,503	4,514	4,526	4,537	4,548	4,560	4,571	4,583	4,594
134.77	10.9	4,606	4,617	4,629	4,640	4,652	4,664	4,675	4,687	4,699	4,710
134.87	11.0	4,722	4,734	4,746	4,758	4,769	4,781	4,793	4,805	4,817	4,829
134.97	11.1	4,841	4,853	4,865	4,877	4,889	4,901	4,913	4,925	4,938	4,950
135.07	11.2	4,962	4,974	4,986	4,998	5,011	5,023	5,035	5,047	5,059	5,072
135.17	11.3	5,084	5,096	5,109	5,121	5,133	5,145	5,158	5,170	5,182	5,195
135.27	11.4	5,207	5,219	5,232	5,244	5,256	5,269	5,281	5,294	5,306	5,318
135.37	11.5	5,331	5,343	5,356	5,368	5,380	5,393	5,405	5,418	5,430	5,443
135.47	11.6	5,455	5,468	5,480	5,493	5,505	5,518	5,530	5,543	5,555	5,568
135.57	11.7	5,580	5,593	5,605	5,618	5,631	5,643	5,656	5,669	5,681	5,694
135.67	11.8	5,707	5,719	5,732	5,745	5,757	5,770	5,783	5,796	5,808	5,821 TWL

Notes: TWL - Top Water Level

GOUTHWAITE RESERVOIR DEPTH/VOLUME SURVEY (IMPERIAL) BASED ON LIDAR DATA SURVEYED NOVEMBER 2003

Assumes level of 129.37mAOD (18 feet) represents a volume of 806tcm

Depth (feet)
No data
17'11 to 34'1"
34'2" to 39'

		Reservoir capacity (million gallons)											
		Inches											
mAOD	feet	0	1	2	3	4	5	6	7	8	9	10	11
129.06	17												
129.37	18	177	179	180	183	185	187	189	191	194	195	198	200
129.67	19	202	204	207	209	211	214	216	218	220	223	225	227
129.98	20	230	232	234	237	240	242	245	247	250	252	255	257
130.28	21	260	262	265	268	270	273	275	278	281	284	286	289
130.59	22	293	295	297	300	304	306	309	312	315	317	321	323
130.89	23	327	329	333	337	339	343	345	349	352	356	358	362
131.20	24	366	369	371	375	379	382	386	389	393	396	400	403
131.50	25	407	410	414	418	421	425	428	432	435	440	443	447
131.81	26	451	454	457	462	466	469	474	477	481	484	489	492
132.11	27	497	500	504	509	512	517	520	525	528	533	536	541
132.42	28	546	549	553	558	563	566	571	574	579	583	588	591
132.72	29	596	600	605	610	614	619	622	628	631	637	640	646
133.03	30	651	655	658	664	669	673	678	682	688	691	697	701
133.33	31	706	710	716	721	725	731	735	741	745	750	754	760
133.64	32	766	770	774	780	786	790	796	800	806	810	816	820
133.94	33	826	830	837	843	847	853	857	864	868	874	878	885
134.25	34	891	896	900	906	913	917	924	929	935	940	947	951
134.55	35	958	963	970	977	982	990	995	1002	1007	1015	1020	1028
134.86	36	1035	1040	1046	1053	1061	1067	1075	1080	1088	1093	1101	1107
135.16	37	1115	1120	1128	1136	1142	1150	1155	1163	1169	1177	1183	1191
135.47	38	1199	1204	1210	1218	1226	1232	1240	1246	1254	1260	1268	1274
135.77	39	1279											