Sedimentation in small dams

Development of a catchment characterisation and sediment yield prediction procedure

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Executive Summary

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NGO's and Government Agencies have constructed thousands of small dams in semi-arid regions of East and Southern Africa to provide water for livestock and small-scale irrigation. The effective life of many of these dams is reduced by excessive siltation – some small dams silt up after only a few years. This issue is poorly covered in the many small dam design manuals that are available, which mostly focus on civil engineering design and construction aspects. While a capability to estimate future siltation is needed to ensure that dams are sized correctly, and are not constructed in catchments with very high sediment yields, little guidance is available to small dam planners and designers.

The British Government's Department for International Development commissioned HR Wallingford to develop guidelines presenting appropriate methods for predicting, and where possible reducing, siltation rates in small communal dams in semi-arid zones in Eastern and Southern Africa. Small dam designers must be able to use these methods; they typically need to carry out assessments rapidly using limited local data, and may not have software skills or access to computers.

The report describes the development of a method for predicting small dam catchment sediment yields. The objective was to develop a simple procedure which would distinguish between dams that will silt up rapidly from dams that will have a sedimentation lifetime well in excess of twenty years.

The report describes:

a) Surveys of small dams located in Tanzania and Zimbabwe, to quantify small dam catchment sediment yields (chapter 2).

b) The development and testing of a rapid qualitative catchment characterisation procedure (chapter 3).

c) The development of an approximate predictive relationship using the results of a) and b) above to provide a means of predicting sediment yields from small dam catchments (chapter 4).

Executive Summary continued

Surveys of seventeen small dams in Zimbabwe and Tanzania showed annual sedimentation rates ranging between 50 % and 0.5 %, which translate to approximate sedimentation lifetimes ranging between two and two hundred years. The median sedimentation rate was 2.6 %/year, giving a sedimentation lifetime for a “typical ” small dam of approximately thirty-eight years. Of course the useful life of a “typical ” small dam would be far shorter than thirty-eight years, due to the proportionately larger evaporative losses that occur as siltation reduces water depths, resulting in an increasingly larger proportion of the stored water being lost to evaporation. In the guidelines a siltation life of forty years is taken as the minimum sedimentation lifetime required to ensure that useful quantities of water can be stored and abstracted over the twenty-year economic life usually assumed for small dam studies. About 15% of the surveyed dams were, or will be, completely filled with sediment within twenty years of construction.

Sediment yields derived from small dam surveys range between 120 $t/km^2/y$ and 3400 $t/km^2/y$, a wide enough range to provide the data needed to calibrate the sediment yield relationship.

Requirements for data and computational modelling skills rule out the use of more sophisticated methods to predict sediment yields, and a simple regional sediment yield predictor was chosen for this application. Sediment yields are estimated by carrying out a rapid catchment characterisation procedure, to score qualitative factors describing soil type, crop cover, and signs of erosion. These are included with quantitative information on slopes, rainfall and catchment area in a simple predictive function calibrated using measured catchment sediment yields. The text descriptions used to assign qualitative catchment parameters into one of four classes, and the numerical weighting used in the scoring system, incorporate the extensive combined knowledge and experience of the teams that developed the procedure.

Characterisation involves completing a checklist during a field visit. Assessments are based on information collected from interviewing local residents, and observations made while walking a number of randomly chosen transects across the catchment. It is possible to carry out an assessment in a typical small dam catchment within a day’s work. Assessments are best carried out at the end of the main dry season, when vegetation cover is at its lowest, and the soils most prone to erosion.

Catchment factors were selected for inclusion in the predictive relationship on the basis of their correlation with the measured sediment yields, they are:

- Signs of active soil erosion (SASE);
- Soil type and drainage (STD);
- Vegetation conditions over the whole catchment (VC);
- Catchment slope (Slope).

When combined, these factors are taken as a proxy for erosion hazard. This is converted to a sediment yield by including two additional factors to account for sediment delivery effects, the catchment area (Area), and the mean annual rainfall (MAR).

The predictive equation is:

$$SY = 0.0194\ Area^{-0.2}\ MAR^{0.7}\ Slope^{0.3}\ SASE^{1.2}\ STD^{0.7}\ VC^{0.5}$$

Executive Summary continued

Regression analysis was used to derive the constant and exponents in the equation, which has a correlation coefficient of 0.95 and a standard error of 198. In this case 88% of the predicted annual sediment yields are within the "half to twice" range when compared with observed yields. Although the comparison is for data used in the derivation of the equation, and not an independent data set, this is an encouraging result given the large uncertainties involved in measuring catchment sediment yields, and compares well with the performance of empirical predictors based entirely on quantitative factors developed in the past for use in much larger catchments. The wide range of sediment yields predicted by the equation are similar to the range in observed sediment yields in East and Southern Africa compiled for the study, a result that provides further support for the utility of the method.

Contents

Title page *i*
Document Information *ii*
Executive Summary *iii*
Contents *vii*

1. Background ... 1
   1.1 Introduction ... 1
   1.2 Sediment yields in East and Southern Africa ... 2

2. Small dam sedimentation rates and catchment sediment yields ... 4
   2.1 Dam sedimentation surveys ... 4
   2.2 Sedimentation Rates and Catchment Sediment Yields ... 5

3. Catchment characterisation ... 8
   3.1 Review of methods for predicting soil erosion and sediment yield ... 8
   3.2 Development of the Catchment Characterisation Procedure ... 9
   3.3 Carrying out a catchment characterisation ... 9
   3.4 Application of the catchment characterisation procedure to the catchments in Zimbabwe and Tanzania ... 10

4. A regional small catchment sediment yield predictor ... 11
   4.1 Development of the predictive function ... 11
   4.2 Application to different regions ... 13

5. Summary of principle conclusions ... 14
   5.1 Small dam sedimentation rates and catchment sediment yields ... 14
   5.2 Catchment characterisation procedure ... 14
   5.3 Regional small catchment sediment yield predictor ... 15

6. Acknowledgements ... 16

7. References ... 17
   7.1 Sources of sediment yield data for East and Southern Africa ... 17
   7.2 Small dam design references ... 17
   7.3 General references ... 18

Tables

Table 1 Distribution of median sediment yields by world region (from Lawrence and Dickinson (1995)) ... 2
Table 2 Summary of dam sedimentation rates and catchment sediment yields ... 6

Figures

Figure 1 Sediment Yield Data for East and Southern Africa ... 3
Figure 2 Location of surveyed dams in Zimbabwe ... 4
Figure 3 Location of surveyed dams in Tanzania ... 5
Figure 4 Small dam siltation rates ... 7
Figure 5 Observed and predicted sediment yields ... 12

Contents continued

Annexes

Annex 1 Dam sedimentation rates and catchment sediment yields
Annex 2 Details of dam surveys
Annex 2a CARE Dams Survey Cross-sections
Annex 2b Kiteto Dams Survey Results
Annex 3 Catchment Characterisation

1. Background

1.1 INTRODUCTION

There are strong links between the availability of water for agriculture and livestock production, and incomes of the rural poor (HR Wallingford, 2003a). One means of increasing the resilience of the rural poor to the shocks produced by rainfall variations, particularly droughts, is to store water in small dams to irrigate crops and water cattle. NGO's and Government Agencies have constructed thousands of small dams in semi-arid regions of East and Southern Africa, but the useful life of many of these dams is reduced by excessive siltation - some small dams silt up after only a few years. This issue is poorly covered in the many small dam design manuals that are available, which mostly focus on civil engineering design and construction aspects[1]. Procedures for assessing the viability and sustainability of small dams are mostly covered in a very rudimentary way, or ignored.

A capability to estimate future siltation rates in small dams is essential to ensure that:

- Dams are sized correctly;
- Dams are not constructed in catchments with excessively large sediment yields;
- Catchments where the rapid introduction of soil and water conservation measures will be essential if a reasonable dam life is to be obtained are identified early enough for conservation activities to have a significant impact on dam siltation.

The British Government's Department for International Development (DFID) commissioned HR Wallingford to develop guidelines presenting appropriate methods for predicting, and where possible reducing, siltation rates in small communal dams in semi-arid zones in Eastern and Southern Africa. Small dam designers must be able to use these methods; they typically need to carry out assessments rapidly using limited local data, and may not have software skills or computers.

The series of reports describing the outputs from the project are listed below:

Report Title	Report Number
Guidelines for predicting and minimising sedimentation in small dams	OD 152
Sedimentation in small dams – impacts on the incomes of poor rural communities	OD TN 118
Sedimentation in small dams – hydrology and drawdown computations	OD TN 119
Sedimentation in small dams – development of catchment characterisation and sediment yield prediction procedures	OD TN 120
Sedimentation in small dams – the potential for catchment conservation, check dams and sediment bypassing to reduce dam siltation rates	OD TN 121

[1] The design manuals reviewed as part of this study are listed in chapter 7.

Sedimentation rates in dams are controlled by two parameters. The first, the proportion of the annual runoff from the dam catchment that is stored, is to some extent under the control of the designer through the selection of the dam height and storage capacity. The second is the sediment yield from the dam catchment, which is determined by soil erosion rates, and the sediment transport processes that control the delivery of eroded sediment via the fluvial system to the dam. This has to be estimated if future sedimentation rates in a dam are to be predicted. This report describes the development of a simple regional sediment yield prediction method that is used in the guidelines to predict the sediment yields from the catchments of existing or proposed small dams. It is based on a rapid qualitative catchment characterisation procedure that was developed with the assistance of project collaborators listed in Chapter 6.

The activities supporting the development of the sediment yield predictor included:

a) Surveys of small dams located in Tanzania and Zimbabwe, to quantify dam sedimentation rates and catchment sediment yields, as described in chapter 2.

b) Developing and testing a rapid qualitative catchment characterisation procedure, as described in chapter 3.

c) Developing an approximate predictive relationship using the results of a) and b), to provide a means of predicting sediment yields from small dam catchments, as described in chapter 4.

1.2 SEDIMENT YIELDS IN EAST AND SOUTHERN AFRICA

Catchments in Africa have a median sediment yield a little larger than the global average, as illustrated in table 1.

Table 1 Distribution of median sediment yields by world region (from Lawrence and Dickinson (1995))

Region	**Median annual sediment yield t/km^2**
North America and Europe	52
South America	178
Africa	**299**
Asia	391
Oceania	770
World	**252**

Lowest sediment yields are associated with the developed regions of North America and Europe, while Asia has larger than average yields. The highest yields are found in Oceania, a region with many small steep catchments in geologically unstable zones.

An expanded data set describing sediment yields for East and Southern Africa was compiled for this study from the references listed in chapter 7. These are plotted in figure 1, which indicates that annual sediment yields may vary over three orders of magnitude, from less than 5 t/km^2 to more than 5000 t/km^2. The mean annual sediment yield is 490 t/km^2, while the median yield is 208 t/km^2. (The median yield from this data set is lower than that for "Africa" shown in table 1, as the latter includes data from North Africa where some extremely high sediment yields are observed.)

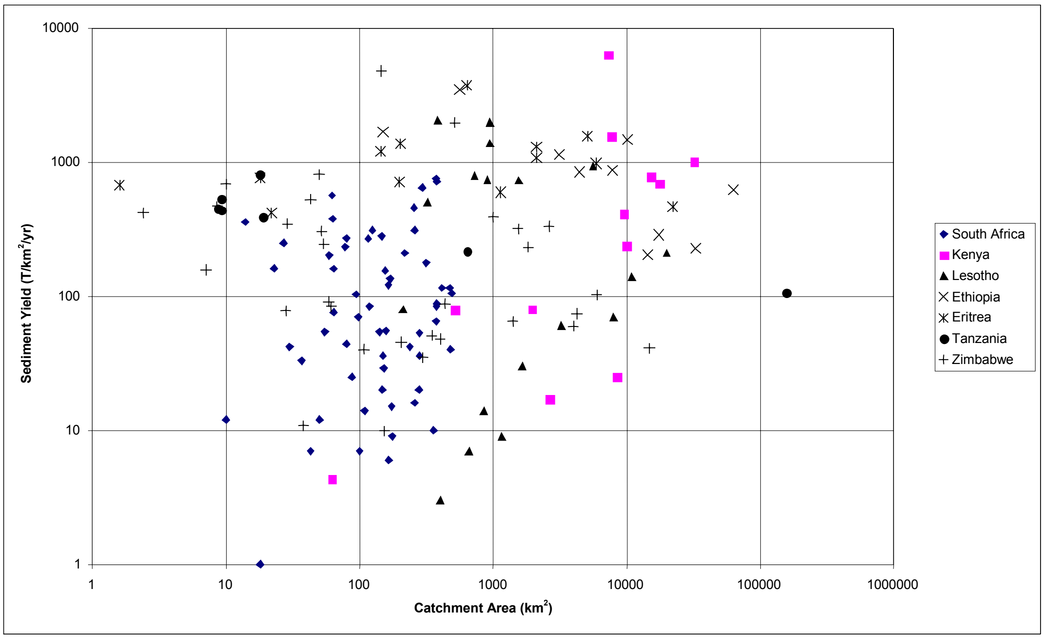

Figure 1 Sediment Yield Data for East and Southern Africa

Most of the data in figure 1 are for catchments with areas that are several orders of magnitude larger than the catchment areas of typical small dams. In general, sediment yields expressed on a per unit area basis tend to increase with reducing catchment area, and many of the existing data are not directly applicable to small dam studies without adjustment to reflect the effects of catchment size. However for a typical small dam the observed range of sediment yields translates to approximate dam sedimentation life times ranging from hundreds of years to only one or two years. This is of course what is observed – some small dams constructed in the 1940's and 1950's are still functioning, while others have silted up within a few years following construction.

The procedure described later has to be capable of predicting this very wide range of observed sediment yields. On the other hand, precise predictions, even if these were possible given the low accuracy of available methods for predicting soil erosion and sediment transport, are not essential. Quite a large tolerance on predicted yields will be acceptable, provided the prediction procedure allows dams that will have a very short lifetime to be identified rapidly at the design stage of projects. The objective is to develop a simple procedure, with minimal data requirements, that will distinguish dams that will silt up rapidly from dams that will have a sedimentation lifetime of forty years or longer[2].

[2] A sedimentation lifetime of forty years is adopted in the guidelines as the minimum required if the dam is to provide useful water yields at the end of the twenty year economic life usually assumed in small dam projects.

2. Small dam sedimentation rates and catchment sediment yields

2.1 DAM SEDIMENTATION SURVEYS

In order to determine sedimentation rates hydrographic surveys were carried out at twelve small dams in Zimbabwe, and two small dams in Tanzania. As most of these dams were surveyed annually over three wet seasons a total of thirty-eight surveys were carried out by the project. Information on sedimentation rates at three further dams in Tanzania, reported by Christiansson (1981) and Edvinsson (2001), were also utilised. The survey methods adopted at each dam are described in annex 1. Dam survey results are presented in detail in annex 2. The locations of the surveyed dams are shown in figures 2 and 3.

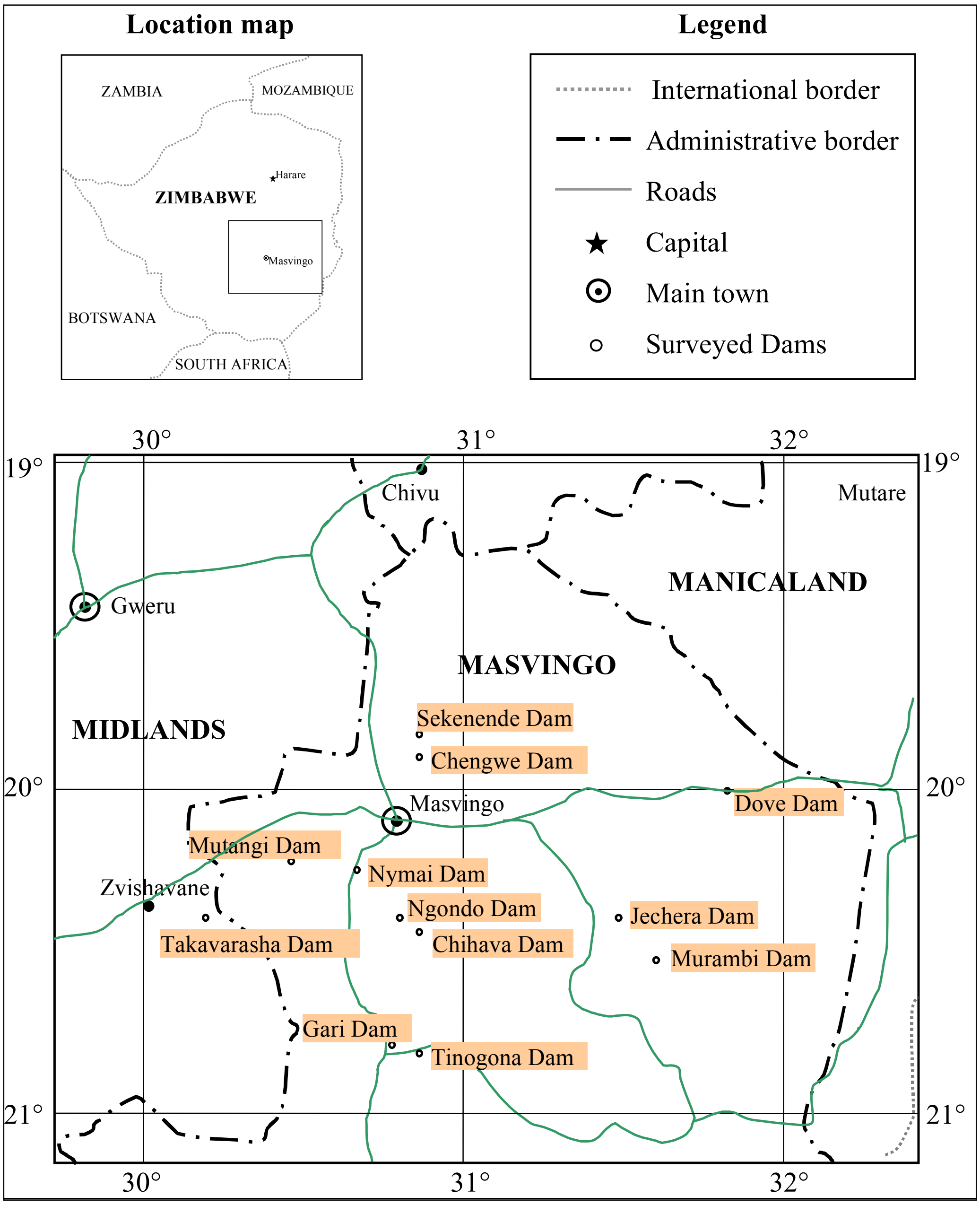

Figure 2 Location of surveyed dams in Zimbabwe

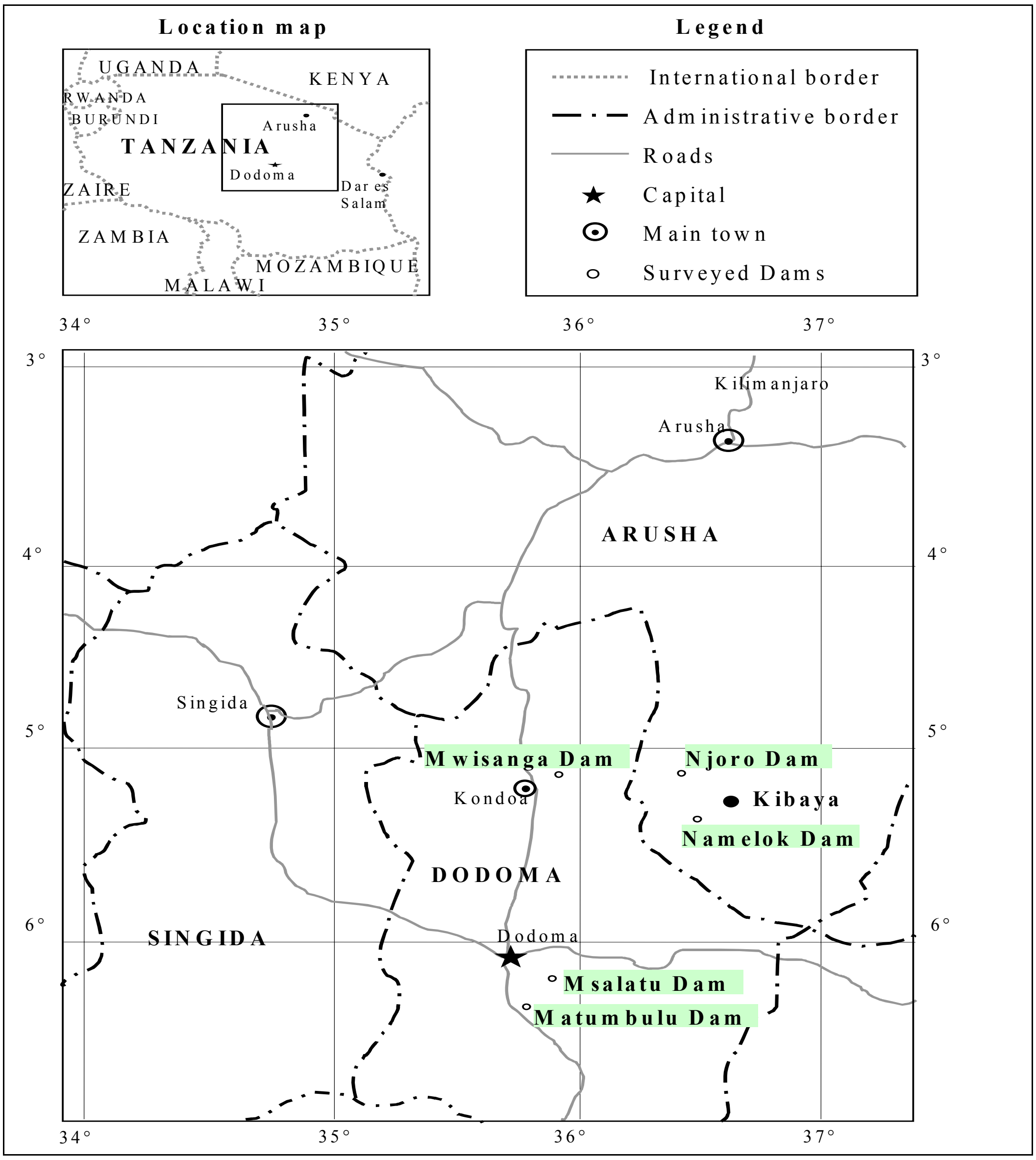

Figure 3 Location of surveyed dams in Tanzania

2.2 SEDIMENTATION RATES AND CATCHMENT SEDIMENT YIELDS

Sedimentation rates derived from the dam surveys were used to estimate the sediment yields from catchments, as described in annex 1. The procedure involves adjusting the measured sedimentation rates to account for the portion of the sediment load that is passed over a dam spillway, and a conversion of the volume of the accumulated sediment in a dam to a mass (see HR Wallingford report OD TN 119 (2003)). In order to establish a reasonably reliable estimate of average sediment yields surveys would ideally have been repeated at long intervals, ten to twenty years, to allow for natural variation in rainfall and runoff patterns.[3]

[3] In semi-arid zones, where the coefficient of variation in annual sediment load data series is 1 or more, the standard error in an estimate of a mean annual sediment yield over twenty years will be around 40% to 50 % (Olive and Rieger, 1992). The standard error could rise to 100% when the measurement period is reduced to three years.

In this study in most cases sediment accumulations were measured over three wet seasons[4], and thus may not be very representative of the long-term means. The measured dam sedimentation rates, and estimated catchment sediment yields are listed in table 2.

Table 2 Summary of dam sedimentation rates and catchment sediment yields

Dam	Period sedimentation monitored (years)	Dam – mean annual sedimentation rate (%)	Catchment sediment yield ($t/km^2/year$)	Dam capacity/ inflow ratio
Chengwe	3	2.61	269	0.11
Sekenende	3	3.05	123	0.04
Gari	3	1.17	126	0.34
Mutangi	3	2.11	406	0.31
Nyimai	3	3.22	212	0.07
Tinogona	3	2.53	858	0.56
Jechera	3	1.71	203	0.07
Murambi	3	1.17	370	0.28
Dove	15	2.95	152	0.05
Chihava	11	8.22	1823	0.30
Ngondo	22	4.50	657	0.16
Takavarasha	2	50.0	330	0.005
Namelok	47	0.47	122	0.39
Njoro	25	1.25	157	0.18
Msalatu	27	1.15	736	0.80
Mwisanga	14	4.00	3392	0.47
Matumbulu	12	2.60	588	0.45

Annual sedimentation rates ranged between 0.5 % and 50 %, which translate to approximate dam sedimentation lifetimes ranging between two and two hundred years. The largest annual sedimentation rate (50%) occurred in the Takavarasha dam in Zimbabwe, which is a small dam located in a very large catchment. In this case the sediment yield from the dam catchment is not particularly large, and the excessively rapid sedimentation rate is attributed to the gross mismatch between the dam capacity and the annual inflow. The capacity inflow ratio is only 0.005, i.e. the dam could store only 0.5 % of the mean annual runoff, but will have trapped a large percentage of the annual sediment inflow.

The median annual siltation rate, excluding the result for Takavarasha, is 2.6 % per year, giving a sedimentation lifetime for an "average" small dam of approximately thirty-eight years. The useful life of the "average" dam would of course be far less than thirty-eight years, due to the proportionately larger evaporative losses that occur in the later years as siltation reduces the dam depth, and an increasingly larger proportion of the stored water is lost to evaporation. Evaporative losses are large in small dams, which typically have average water depths of only a few metres, and are located in regions where the evaporation rates range between one and two metres per

[4] The maximum period that could be accommodated within DFID's project funding cycle.

year. When a dam is heavily silted most of the stored water will be evaporated unless it is abstracted very early in the dry season.

Only 46% of surveyed dams will have a sedimentation life of forty years or longer. Forty years is the minimum sedimentation lifetime adopted in the guidelines to ensure that useful quantities of water can be stored and abstracted at the end of the twenty year economic life usually assumed for small dam studies. About 15 % of the surveyed dams were, or will be, filled with sediment in less than twenty years following construction.

The surveyed small dam siltation rates are compared with data from larger dams in Zimbabwe (Bake, 1986), and average siltation rates for dams in the USA (White, 2001) in Figure 4.

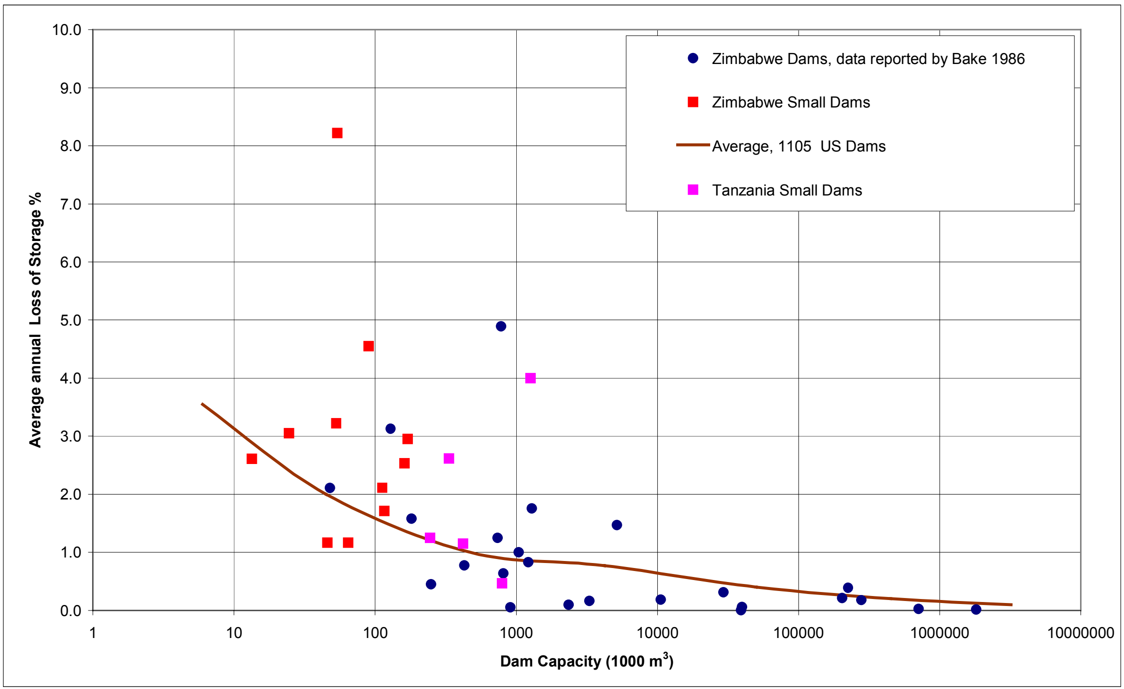

Figure 4 Small dam siltation rates

The figure indicates that the trend (observed in American dams) for increasing sedimentation rates as dam capacities reduce is also apparent in the data collected for small dams by this study and the larger dams in Zimbabwe. This is attributed to sediment delivery effects, which result in decreasing sediment yields in larger catchments, and the increased erosion and sediment transport associated with the steeper slopes that tend to characterise smaller catchments. Small dams are constructed on small rivers draining small catchments, and thus tend to silt up much more rapidly than major dams located on the main stem of large rivers. Small dams also usually have smaller ratios of storage capacity to annual inflow than large dams, and this also has a major impact on siltation rates.

Sediment yields derived from the dam surveys range between 120 t/km^2/y and 3400 t/km^2/y. This is a smaller range than that observed in the larger data set presented in Figure 1, but covers a wide enough range of sediment yields to provide the data needed to develop the sediment yield predictor described later.

3. Catchment characterisation

3.1 REVIEW OF METHODS FOR PREDICTING SOIL EROSION AND SEDIMENT YIELD

Aerial photographs can be used to make qualitative, or with calibration, quantitative assessments of soil erosion rates. Most countries of Southern Africa have national coverage of high quality aerial photographs. This has enabled a large number of regional studies to be carried out (Goldsmith, 2000). However using aerial photographs to assess soil erosion can be both subjective and time consuming, and there is no guarantee that air photographs are routinely available for use by junior Government Officers, NGOs or consultants. Methods based on the analysis of aerial photographs were thus ruled out for this application.

The most widely used empirical equation for the prediction of soil erosion is the Universal Soil Loss Equation (USLE) (Wischmeier, 1965), which estimates erosion rates by multiplying factors including rainfall intensity, soil erodibility, slope length and percentage, ground cover, and the presence (or absence) of soil conservation structures. The Soil Loss Estimation Model for Southern Africa (SLEMSA), which was originally developed in Zimbabwe, uses similar parameters (Elwell, 1978). While these equations were developed to predict long-term average rates of soil loss from fields subject to commercial crop rotations, and only predict sheet and rill erosion, they and their later adaptations are often used in distributed models applied to catchments.

A number of other methods are used to predict soil erosion rates, and by applying more-or-less sophisticated sediment routing techniques, sediment yields at catchment outlets. Useful reviews are presented in Hudson (1995), Morgan (1995) and Schmidt (2000). Methods range from complex distributed process-based models with substantial data requirements, semi-empirical lumped models (often based on the application of the Universal Soil Loss Equation or its later adaptations) and simple empirical predictors. Requirements for data and computational modelling skills rule out all but the last of these approaches for the current application.

This is not necessarily a disadvantage as simple empirical models can be more successful at predicting soil erosion and sediment yield than more complex models (Morgan, 1995). An early example of a successful application of this approach to predicting sediment yields from large catchments (>5000 km^2) is described in Jansen and Painter (1974), who predicted sediment yields from empirical functions including catchment area, slope, altitude, rainfall, runoff, temperature, plus factors indicating vegetation cover and proneness to erosion. Milliman and Syvitski (1992) successfully correlated sediment yields with catchment area and topographic factors using seven topographic categories.

Hudson (1995) describes the use of a factorial scoring system to rank erosion hazard, and the same approach is adopted here, with "calibration" to estimate sediment yields. Factorial scoring classification systems are subjective, but they can represent factors that cannot easily be quantified on the ground without expensive and time consuming field measurements.

3.2 DEVELOPMENT OF THE CATCHMENT CHARACTERISATION PROCEDURE

The following factors were identified for consideration in a preliminary catchment characterisation procedure (Goldsmith 2000):

- Catchment relief;
- Soil type and drainage;
- Vegetation conditions over the whole catchment;
- Signs of active soil erosion;
- Vegetation conditions along water courses;
- Surface water storage in catchment (trapping sediment);
- Village population density.

The factors can all be assessed during a rapid catchment appraisal. Four classes were identified for each characteristic: extreme, high, normal and low, with a numerical value assigned to each class. There is clearly an element of double or even triple counting in the factors listed above. Most will for example contribute to "signs of active erosion". The significance of the individual factors was evaluated during the development of the predictive equation, when the last three factors listed above were discarded.

The scoring system, described in more detail in annex 3, was developed jointly with collaborators in Zimbabwe and Tanzania. The text descriptions used to assign factors into classes, and the numerical weighting used in the scoring system, incorporate the extensive combined knowledge and experience of the teams that developed the procedure.

3.3 CARRYING OUT A CATCHMENT CHARACTERISATION

Characterisation is carried out by completing a checklist, shown in appendix 3, during a rapid field appraisal. The only essential field tools required are:

- A 1: 50 000 topographic map covering the catchment area.
- A compass.

Other useful (but not essential) items are:

- An up-to-date aerial photograph of the catchment (at a scale of about 1:25 000).
- Hand held GPS (global positioning satellite) equipment.

Assessments are based on information collected partly from interviewing people resident in the catchment, and observations made while walking a number of randomly chosen transects across the catchment. The direction and siting of transects are selected after careful study of a 1:50 000 topographic map. They may follow footpaths and tracks where they cross the catchment (running down from the upper slopes down to the watercourses and up the other side). Where there are no suitable footpaths, transects are walked following a bearing. It is particularly important to walk along random sections of the main watercourses to examine the condition of the riverbanks and riverbeds.

Ideally a local informant who knows the location and direction of the footpaths will accompany the person(s) making the assessment. They can be important sources of information on the past land use and land conditions within the catchment.

It is possible to assess catchment characteristics at a rate of about 1.5 km^2/hour, and to finish a typical small dam catchment within a day's work. If there are roads and motorable tracks across the catchment, these may be used to speed up the work rate, but to avoid missing key characteristics some transects must be walked. Assessments are best carried out at the end of the main dry season, when the vegetation cover is at its lowest, with the soils bare or almost bare. It is under these conditions that soils are most prone to erosion during intensive storms in the early part of the rainy season, storms that usually generate a large part of the sediment runoff from catchments.

3.4 APPLICATION OF THE CATCHMENT CHARACTERISATION PROCEDURE TO THE CATCHMENTS IN ZIMBABWE AND TANZANIA

Field testing of the characterisation procedure was carried out in the catchments of the dams that were surveyed in Zimbabwe and Tanzania. Results of the catchment scoring exercises are listed in annex 3. To provide additional information for the development of the predictive equation three additional catchments of dams in Tanzania, Msalatu, Matumbulu and Mwisanga were characterised "on paper" using the descriptions of the catchment conditions reported in Christiansson (1981) and Edvinsson (2001).

4. A regional small catchment sediment yield predictor

The final stage in the development of the sediment yield predictor was to correlate the measured sediment yields derived from the dam surveys with the catchment characterisation scores. It should be borne in mind that the catchment characterisation represents a "snapshot" of conditions in the catchments on a single day, whereas the dam surveys measured sediment yields over three years or much longer periods, when catchment conditions may have changed due to climatic variations or man's activities. The high standard error associated with sediment yield measurements collected over a short period was mentioned in chapter 1. In light of these, and some other potentially large sources of error, we expect a large scatter in correlations linking sediment yields with catchment factors.

4.1 DEVELOPMENT OF THE PREDICTIVE FUNCTION

Each of the catchment factors derived from catchment characterisation was investigated to determine the degree of correlation with measured sediment yields, using multiple linear regression with log transformed variables to fit power relationships. For this exercise the qualitative factor for relief was replaced with a measured catchment slope. This is defined as the gradient of the main stem river from the catchment boundary to the dam, and this could be determined relatively simply from 1:50 000 maps, which are needed to carry out a characterisation.

The factors selected for inclusion in the predictive relationship are:

- Signs of active soil erosion (SASE);
- Soil type and drainage (STD);
- Vegetation conditions over the whole catchment (VC);
- Catchment slope (Slope).

These factors when combined in an index are taken as a proxy for erosion hazard. This was "converted" to a sediment yield by including two additional factors. These are the catchment area and the rainfall. A number of methods of estimating sediment delivery ratios from catchment characteristics are described in the literature, see for example Walling (1983). In the simplest the delivery ratio is assumed to be a function of catchment area only:

$$SDR = k\ \text{Area}^{-n} \qquad (1)$$

Where:
SDR = Sediment Delivery Ratio
Area = Catchment Area (km^2)
n and k are constants

Abernethy (1987) compared ten published methods for predicting sediment delivery ratio by adjusting the constants in equation 1 above, and transposing the various authors' published relationships to parallel positions, through a common point (SDR = 1 for catchment area = 1 km^2). This yielded a mean value for n of -0.2. An $\text{Area}^{-0.2}$ relationship was adopted as the delivery factor included in the predictive equation.

The second additional factor is annual rainfall. In semi-arid zones significant runoff events are usually triggered by intense convective rainfall, and annual rainfall totals are approximately proportional to the number of storms that occur. The number of events that erode sediment, and then transport it to a catchment outlet, are thus broadly correlated with annual rainfall. In "wetter" semi-arid catchments, there will be more runoff events, and more sediment transported to the catchment outlet.

The predictive equation, with some rounding of coefficients, is:

$$SY = 0.0194\ Area^{-0.2}\ MAP^{0.7}\ Slope^{0.3}\ SASE^{1.2}\ STD^{0.7}\ VC^{0.5} \quad (2)$$

$r^2 = 0.95$

SE = 198

Where:

SY	=	Sediment yield (t/km^2/year)
Area	=	Catchment area (km^2)
MAP	=	Mean annual precipitation (mm)
Slope	=	River slope from the catchment boundary to the dam
SASE	=	Signs of active soil erosion (Score from catchment characterisation)
STD	=	Soil type and drainage (Score from catchment characterisation)
VC	=	Vegetation condition (Score from catchment characterisation)

In Figure 5 observed sediment yields are compared with predicted sediment yields, calculated using equation 2.

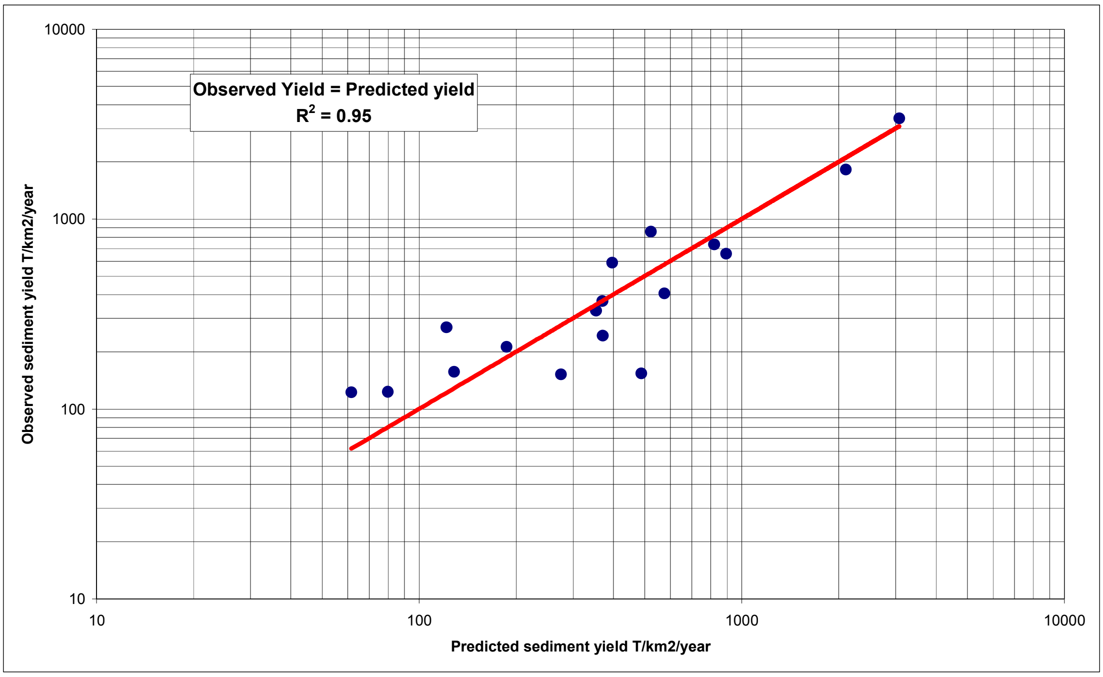

Figure 5 Observed and predicted sediment yields

The correlation coefficient is strongly influenced by the two data points with the highest sediment yields. A relationship fitted to a reduced data set, with the points for the two largest sediment yields removed, reduces the r^2 to 0.54, but still predicts sediment yields only 12% lower than equation 2 above.

The predictive ability of equation 2 can also be assessed by quantifying the proportion of the data for which the ratio of observed to predicted sediment yields lies within the half to twice range often used for assessing the performance of sediment transport functions. This is typically 60% or 70% for the best performing functions, see for example Reid *et al*. (1996). This is a rigorous test as the factors and processes controlling sediment detachment and transport through a fluvial system to a catchment outlet are more numerous and more complex than those controlling the transport of bed material sediments in steady flows in rivers or laboratory channels. In this case 88% of the predictions fall within the half to twice range. Although the comparison is for data used to derive the equation, and not an independent data set, this is an encouraging result given the large uncertainties involved in measuring sediment yields and characterising catchments.

A further test is to check that the developed equation reproduces the very wide range of observed catchment yields in the region. The sediment yield predicted with minimum scores for the catchment characterisation factors, a (large) catchment area of 20 km^2, a (low) slope of 0.001 and a (low) mean annual rainfall of 400 mm, is 9 $t/km^2/y$. A yield of 8600 $t/km^2/y$ is predicted with maximum values for the catchment characterisation factors, a (small) catchment area of 1.0 km^2, a (large) slope of 0.1 and a (large) mean annual rainfall of 1000 mm. This range is similar to the range in observed sediment yields in East and Southern Africa presented in figure 1, a result that provides further support for the utility of the method.

4.2 APPLICATION TO DIFFERENT REGIONS

The prediction function was developed using data from semi-arid zones in Zimbabwe and Northern Tanzania. The applicability of the function outside these zones and similar regions should be checked by users before it is applied. The catchments of small dams where estimates of siltation rates have been obtained from simple hydrographic surveys, or where siltation rates can be estimated from the initial volumes of older dams that have silted up, should be characterised. Observed and predicted sediment yields derived using the methods described in annex 1 can then be compared, and if necessary a “correction” factor can then be applied to the sediment yields derived using equation 2. As a large scatter is expected correction factors should be based on as many comparisons as possible, spanning a wide range of catchment characteristics. It is suggested that an absolute minimum of five comparisons is used to determine correction factors.

5. Summary of principal conclusions

5.1 SMALL DAM SEDIMENTATION RATES AND CATCHMENT SEDIMENT YIELDS

- Surveys of seventeen small dams in Zimbabwe and Tanzania show annual sedimentation rates ranging between 50 % and 0.5 %.

- Excluding one dam with an abnormally large sedimentation rate, the median sedimentation rate was 2.6 % per year, giving a sedimentation lifetime for an "average" small dam of approximately thirty-eight years. The useful life of the "average" dam would of course be far less than thirty-eight years, due to the proportionately larger evaporative losses that occur in the later years as siltation reduces the dam depth, and an increasingly larger proportion of the stored water is lost to evaporation.

- Only 46% of surveyed dams will have a siltation life of forty years or longer. Forty years could be taken as the minimum sedimentation lifetime required to ensure that useful quantities of water can be stored and abstracted over the twenty year economic life usually assumed for small dam studies. About 15 % of the surveyed dams would be completely filled with sediment after twenty years.

- The trend observed in American data of increasing annual sedimentation rates as dam capacities reduce, is also apparent in the data collected for small dams by this study and for larger dams in Zimbabwe. This is attributed to sediment delivery effects, which result in decreasing sediment yields in larger catchments and the effects of the steeper slopes that tend to characterise small catchments.

- Sediment yields derived from small dam surveys range between 120 $t/km^2/y$ and 3400 $t/km^2/y$, a wide enough range to provide the data needed to calibrate the sediment yield predictor.

5.2 CATCHMENT CHARACTERISATION PROCEDURE

- A simple regional sediment yield predictor was selected for use in this application. The method is based on a rapid catchment characterisation procedure to score factors describing soil type, crop cover, and signs of erosion.

- The catchment factor scoring system was developed jointly with collaborators in Zimbabwe and Tanzania. The descriptors are used to assign parameters into one of four classes, and the numerical weightings used in the scoring system incorporate the extensive combined knowledge and experience of the teams that developed the procedure.

- Characterisation is carried out by completing a checklist during a field visit. Assessments are based on information collected from interviewing people resident in the catchment, and observations made while walking a number of randomly chosen transects across the catchment. It is possible to assess catchment characteristics in a typical small dam catchment within a day's work. Assessments are carried out at the end of the main dry season, when vegetation cover is at its lowest, with the soils bare or almost bare.

5.3 REGIONAL SMALL CATCHMENT SEDIMENT YIELD PREDICTOR

- The catchment factors selected for inclusion in the predictive relationship, on the basis of correlation with the measured sediment yields, are:

- ♦ Signs of active soil erosion (SASE);
- ♦ Soil type and drainage (STD);
- ♦ Vegetation conditions over the whole catchment (VC);
- ♦ Catchment slope (Slope).

- When combined these factors are taken as a proxy for erosion hazard. This was "converted" to a sediment yield by including two additional factors to account for sediment delivery effects. These are the catchment area (Area) and the mean annual precipitation (MAP).
- Regression analysis was used to derive the constant and exponents of a predictive equation, which is:

  $$SY = 0.0194 \ Area^{-0.2} \ MAP^{0.7} \ Slope^{0.3} \ SASE^{1.2} \ STD^{0.7} \ VC^{0.5}$$

  $r^2 = 0.95$
  SE = 198

- The relatively high correlation coefficient is strongly influenced by the two data points with the largest sediment yields. A relationship fitted to a reduced data set, with the points for the two largest sediment yields removed, reduces r^2 to 0.54, but still predicts sediment yields only 12% lower than the equation above.

- 88% of the predictions fall within the half to twice range often used to assess the performance of sediment transport functions. Although the comparison is for data used in the derivation of the equation, and not an independent data set, this is an encouraging result.

- Sediment yields predicted by the equation range between 9 t/km^2/y and 8600 t/km^2/y. This is similar to the range in observed sediment yields in East and Southern Africa shown in figure 1, a result that provides further support for the utility of the method.

- The prediction function was developed using data from semi-arid zones in Zimbabwe and Northern Tanzania. The applicability of the function outside of these and similar regions should be verified by users before it is applied.

6. Acknowledgements

The writers wish to acknowledge the enormous contribution made to this study by collaborators in Zimbabwe and Tanzania. In Zimbabwe these included staff and officials from the Harare and Masvingo offices of CARE and Agritex. Most of the small dam surveys in Zimbabwe were carried out by Hart Frost Consultants, Harare, with support and assistance from CARE. Silsoe Research Institute UK also provided advice and socio-economic data.

In Tanzania principal collaborators were KINNAPA in Kibaya, and the Engineers from the regional water office in Arusha. Small dam surveys in Tanzania were carried out by WEGS Consultants, Arusha, with KINNAPA's assistance and facilitation.

Assistance and encouragement in setting up and carrying out the study was received from the DFID office in Harare, and officials of the Irrigation Department of the Ministry of Agriculture in Tanzania.

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Annexes

Annex 1 Dam sedimentation rates and catchment sediment yields

A1.0 Surveyed dams.

Surveyed dams are located in figures 2 and 3 in chapter 2 of the main report. The latitude and longitude of each dam are listed in the table below.

Table A1.1 Dam location

Country	Dam Name	Location (Lat^0, Long^0)
Zimbabwe	Chengwe	19.54S, 30.54E
Zimbabwe	Dove	20.01S, 31.52E
Zimbabwe	Gari	20.47S, 30.41E
Zimbabwe	Jechera	20.21S, 31.26E
Zimbabwe	Murambi	20.37S, 31.44E
Zimbabwe	Mutangi	20.25S, 30.5E
Zimbabwe	Nymai	20.16S, 30.39E
Zimbabwe	Sekenende	20.50S, 30.55E
Zimbabwe	Tinogona	19.90S, 30.90E
Zimbabwe	Chihava	20.23S, 30.47E
Zimbabwe	Ngondo	20.21S, 30.45E
Zimbabwe	Takavarasha	20.20S, 30.17E
Tanzania	Namelok	5.26S, 36.33E
Tanzania	Njoro	5.14S, 36.27E
Tanzania	Msalatu	6.19S, 35.55E
Tanzania	Matumbulu	6.28S, 35.43E
Tanzania	Mwisanga	5.14S, 35.55E

Other characteristics of the surveyed dams are listed below:

Table A1.2 Dams' baseline data

Dam Name	Year constructed	Initial Capacity (m^3) (3)	Estimated Capacity: Inflow Ratio	Catchment Area (km^2)
Chengwe	1994	13388	0.11	1.60
Dove	1956	24594	0.04	55.1
Gari	1992	64656	0.34	3.50
Jechera	1958	112490	0.31	17.0
Murambi	1964	53135	0.07	1.65
Mutangi	1945	162210	0.56	6.62
Nymai	1993	116640	0.07	10.5
Sekenende	1981	45947	0.28	9.05
Tinogona	1993	170000	0.05	5.30
Chihava	1991	54000	0.30	2.76
Ngondo	1940	90000	0.16	8.75
Takavarasha	1985	200000	0.00	541
Namelok	194	794070	0.39	40.0
Njoro	1976	245000	0.18	27.0
Msalatu (1)	1944	420000	0.80	8.51
Matumbulu (1)	1962	333000	0.45	18.0
Mwisanga (2)	1986	1260000	0.47	18.0

Note 1 Data from Christiansson (1981)
Note 2 Data from Edvinsson (2001)
Note 3 At the start of the period over which sediment accumulations were measured

A1.1 Zimbabwe dam surveys

Nine dams that had been or were in the process of being rehabilitated under CARE's DFID funded communal dam rehabilitation project were selected for dam surveys and catchment characterisation.[5] Baseline surveys were carried out in 1999 and thereafter annually to determine annual sediment accumulations. The first two surveys were carried out by CARE, following the methods established with HR Wallingford's surveyor. The remaining two surveys were commissioned to a local consultant (HART FROST) who carried out the surveys with assistance from CARE.

Each survey was carried out by measuring cross-sections along a series of range lines. This involved setting out permanent beacons located at, or just above, the full supply level around the periphery of each reservoir. The position and level of the beacons were established in an initial survey, then cross-sections along the range lines were measured using a combination of conventional survey methods and sounding from a small inflatable boat. A local datum level of 100.00 m at the spillway crest level was adopted at each dam. In some cases, where construction was still in progress, the final spillway

[5] The same dams and catchments had already been selected as lead dams to represent a cross-section of dam types, catchment areas, agro-ecological region, land use, and socio-economic conditions for a University of Zimbabwe Phd study of dam sedimentation funded by CARE, Zirebwa (2000). This study remains to be completed.

level had to be estimated when the local datum was established, so was not exactly at EL 100.00.

The measured cross-sections of the surveyed dams are listed in Annex 2a.

The measured cross-sections were used to estimate the dam volume storage at the time of each survey and hence annual siltation rates. Reservoir volumes were determined using the stage width modification method, which exploits the close relationship between stage width and stage area curves. This method makes better use of sparse input data from range line surveys in calculating reservoir volumes than competing methods. The method is available as an option in HR Wallingford's RESSASS software. The software computes the storage volume for a range of water levels at the time of pre-impoundment and first or later surveys, and estimates the volume of sediment deposits from the differences in water volumes. The results are shown below.

Table A1.3(a) Siltation rates at CARE dams

Dam Name	**Dam Volume (m^3)**				**Siltation rate (%)**			
	1999	2000	2001	2002	99-00	00-01	01-02	Annual Average
Chengwe	13388	13307	12690	12340	0.61	4.64	2.76	2.61
Gari	64656	63880	63875	62395	1.20	0.01	2.32	1.17
Jechera	116640	112208	111410	110670	3.80	0.71	0.66	1.71
Murambi	45947	44797	44567	44341	2.50	0.51	0.51	1.17
Mutangi	112490	111150	107880	105370	1.19	2.94	2.33	2.11
Nyimai	53135	51647	49936	48006	2.80	3.31	3.86	3.22
Sekenende	24594	24200	23561	22344	1.60	2.64	5.17	3.05
Tinogona	162210	-	157430	149890	0.00	2.95	4.79	2.53

Table A1.3(b) Siltation rates at CARE dams

Dam Name	**Original Dam Volume (m^3)**	**Year**	**Dam Volume (m^3)**	**Year**	**Annual Average siltation rate (%)**
Dove	170000	1984	94800	1999	2.95

The average siltation rate for Dove was estimated from data derived from an Interconsult survey of 1984 and the HR Wallingford/Care survey of 1999. This result is the most reliable long-term estimate for a siltation rate in the CARE dams.

Surveys were also carried out at three other heavily silted dams that were not part of the CARE project, which excludes dams with a history of rapid siltation from the rehabilitation programme. In this case after attempts at coring to estimate the depth of sediment accumulations had failed due to de-watering problems, and difficulties caused by flood flows resulting from early rains, siltation rates were derived using RESSASS and a 2002 survey with estimates of the original capacity. The results are shown in table A1.4

Table A1.4 Siltation rates at other Zimbabwe dams

Dam Name	Original Dam Volume (m^3)	Year	Dam Volume (m^3)	Year	Annual Average siltation rate (%)
Chihava	54000	1991	5200	2002	8.22
Ngondo	90000	1940	0	1962	4.5
Takavarasha	200000	1985	0	1987	50.0

A1.3 Siltation rates at Tanzania dams

Two dams in Tanzania were surveyed by the project. A full range line survey was carried out at Namelok in 2001, and the sediment volume derived using RESSASS from a survey carried out shortly after the dam was constructed with the 2001 survey. At Njoro a pre-construction survey was not available, and sediment volumes were estimated from coring in the bed of the empty reservoir. The results were adjusted to account for some coarser sediment deposits located at the head of the dam, outside the area where coring took place. Results are shown in table A1.5 below.

Table A1.5 Siltation rates of Tanzania dams

Dam Name	Original Dam Volume (m^3)	Year	Dam Volume (m^3)	Year	Annual Average siltation rate (%)
Namelok	794070	1954	620360	2001	0.47
Njoro	245000	1976	168690	2001	1.25

Data on dam capacity changes, reported by Christiansson (1981) and Edvinsson (2001), were used to extend the data set for Tanzania. Three of the dams described in the papers had reasonably small catchment areas, and catchment conditions reported in enough detail to allow a "paper" catchment characterisation exercise to be attempted. Survey methods are described in detail in the original papers. The results are shown in table A1.6 below.

Table A1.6 Siltation rates of other dams in Tanzania

Dam Name	Original Dam Volume (m^3)	Year	Dam Volume (m^3)	Year	Annual Mean siltation rate (%)
Msalatu	420000	1944	290000	1971	1.2
Mwisanga	1260000	1986	505000	2001	4.0
Matumbulu	333000	1962	228500	1974	2.6

A1.4 Catchment sediment yields

In order to convert sedimentation rates to catchment sediment yields it is necessary to account for the sediment trapping efficiency of the dams. This was estimated using the Brune (1953) relationship, relating trapping efficiency to a dam capacity/inflow ratio. It is also necessary to select an appropriate value for the density of the settled sediments. On the basis of the densities of sediment deposits in Zimbabwean dams reported by Interconsult (1985), a density of 1.3 t/m^3 was adopted for "old" sediment deposits, (consolidated over more than 20 years). For fresher, less consolidated sediment deposits lower values were used depending on the age of the consolidated sediments. A value of

1.1 t/m^3 was adopted for the newly deposited sediments in the CARE dams surveyed over three years.

Catchment mean annual sediment yields were computed from:

Sediment yield (t/km^2/y) =

$$\frac{\text{Annual sedimentation rate (m}^3\text{/y) * Sediment Density (t/m}^3\text{)}}{\text{Catchment Area (km}^2\text{) * trap efficiency}}$$

The results are shown in table A1.7.

Table A1.7 Catchment sediment yields

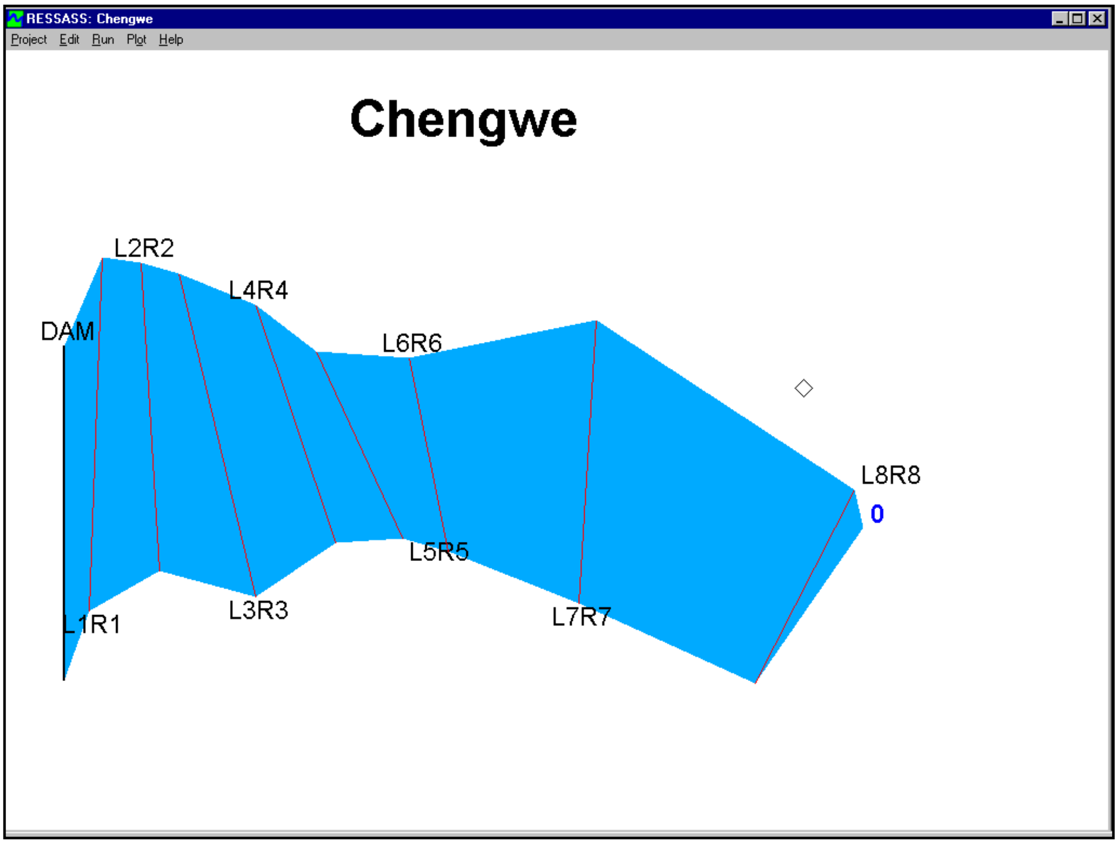
Dam Name	**Catchment Area (km^2)**	**Annual siltation rate (m^3)**	**Assumed sediment density (t/m^3)**	**Capacity/ inflow ratio**	**Trapping Efficiency**	**Sediment yield (t/km^2/year)**
Chengwe	1.60	349	1.1	0.11	0.89	269
Sekenende	9.05	750	1.1	0.04	0.74	123
Gari	3.50	391	1.1	0.34	0.98	126
Mutangi	6.62	2373	1.1	0.31	0.97	406
Nyimai	10.5	1710	1.1	0.07	0.84	212
Tinogona	5.30	4107	1.1	0.56	0.99	858
Jechera	17.00	2615	1.1	0.07	0.84	203
Murambi	1.65	535	1.1	0.28	0.97	370
Dove	55.1	5013	1.3	0.05	0.78	152
Chihava	2.76	4436	1.2	0.30	0.97	1823
Ngondo	8.75	4091	1.3	0.16	0.93	657
Takavarasha	541.0	100000	1.1	0.02	0.63	330
Namelok	40.0	3696	1.3	0.39	0.98	122
Njoro	27.0	3052	1.3	0.18	0.94	157
Msalatu	8.51	4815	1.3	0.80	0.99	736
Mwisanga	18.0	50333	1.2	0.47	0.99	3392
Matumbulu	18.0	8708	1.2	0.45	0.99	588

Annex 2 Details of dam surveys

Annex 2a CARE Dams Survey Cross-sections

Name: Chengwe
Location: Masvingo (Zimbabwe)
Full Supply Water Level: 99.42 m

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	0.00	0.00	99.42	0.00	96.70	99.42
'L1R1'	7.30	19.90	100.00	11.10	122.40	99.81
'L2R2'	27.70	31.40	100.47	22.30	120.60	99.70
'L3R3'	55.50	24.00	99.55	33.30	117.60	100.25
'L4R4'	78.50	39.70	99.39	55.30	108.50	100.17
'L5R5'	98.00	41.00	100.23	73.10	95.00	99.92
'L6R6'	111.00	37.00	101.36	99.80	93.20	102.38
'L7R7'	149.00	22.00	99.70	154.00	104.00	100.23
'L8R8'	200.00	-1.00	100.46	229.00	55.00	100.08
'UPST'	231.50	44.00	99.42	231.50	44.00	99.42

Note: - Elevation refers to local datum of 99.42 m at the spillway.
- Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1 Chainage (m)	L1R1 Elevation (m)	L2R2 Chainage (m)	L2R2 Elevation (m)	L3R3 Chainage (m)	L3R3 Elevation (m)	L4R4 Chainage (m)	L4R4 Elevation (m)
0.00	100.00	0.00	100.47	0.00	99.55	0.00	99.39
51.00	98.31	5.50	99.21	13.50	98.68	8.20	99.01
70.90	98.31	12.50	98.68	26.10	98.31	20.50	98.29
74.00	98.44	22.75	98.00	31.49	98.07	25.83	97.84
75.90	98.32	29.20	98.30	36.87	97.89	31.15	97.61
76.45	98.16	34.54	98.11	42.26	97.81	36.48	97.61
81.90	97.41	39.88	97.91	47.45	97.78	41.81	97.63
87.35	97.36	45.22	97.75	53.04	97.56	47.14	97.77
92.81	97.26	50.56	97.62	58.42	97.43	52.46	97.90
98.26	97.61	55.90	97.66	63.81	97.33	57.79	98.12
102.60	98.31	61.24	97.42	69.20	97.43	61.70	98.29
103.50	99.81	66.57	97.34	74.58	97.41	71.70	100.17
		71.91	97.03	79.97	97.48		
		77.25	97.12	85.36	97.48		
		82.59	97.25	90.75	97.98		
		86.50	98.31	92.90	98.31		
		89.70	99.70	95.50	100.25		

L5R5 Chainage (m)	L5R5 Elevation (m)	L6R6 Chainage (m)	L6R6 Elevation (m)	L7R7 Chainage (m)	L7R7 Elevation (m)	L8R8 Chainage (m)	L8R8 Elevation (m)
0.00	100.23	0.00	101.36	0.00	99.70	0.00	100.46
8.10	98.29	3.40	100.48	10.00	98.98	20.60	99.05
13.54	98.08	7.30	98.70	20.00	99.00	22.40	98.73
18.99	97.99	9.90	98.37	24.00	98.72	30.00	98.73
24.43	97.84	10.70	98.32	39.50	98.49	32.00	98.25
29.88	97.86	16.20	98.29	65.50	99.40	41.00	98.25
35.30	97.84	21.40	98.30	80.60	100.23	54.90	99.67
40.76	97.74	26.70	98.31			61.40	100.08
44.40	97.80	31.30	98.17				
46.40	97.90	37.20	98.13				
51.00	98.32	42.50	98.04				
58.70	99.92	47.90	98.10				
		51.90	98.37				
		57.00	102.38				

Cross-sections Survey 2000

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.00	0.00	100.47	0.00	99.55	0.00	99.40
38.90	98.68	12.50	98.68	13.50	98.68	13.50	98.68
43.90	98.43	22.75	98.03	23.82	98.34	23.62	98.06
48.90	98.28	33.00	98.07	34.14	97.95	33.74	97.69
53.90	98.31	43.25	97.78	44.46	97.78	43.86	97.68
58.90	98.18	55.50	97.54	54.78	97.58	53.98	98.01
63.90	98.15	63.75	97.36	65.10	97.43	63.90	98.58
68.90	98.10	74.00	97.09	75.42	97.43	64.10	98.68
73.90	98.43	84.25	98.03	85.74	97.60	71.70	100.18
78.90	97.71	87.20	98.68	93.10	98.68		
83.90	97.50	89.40	99.70	95.60	100.28		
88.90	97.32						
93.90	97.42						
98.90	98.38						
99.50	98.68						
103.50	99.81						

L5R5		L6R6		L7R7		L8R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.23	0.00	101.29	0.00	99.70	0.00	100.46
6.00	98.68	6.80	98.68	24.80	98.68	11.60	98.68
16.87	98.00	16.98	98.25	35.09	98.56	28.95	98.42
27.74	97.86	27.16	98.29	45.38	97.98	46.30	97.98
38.61	97.78	37.34	98.09	47.00	98.68	47.00	98.68
49.48	98.13	47.52	98.08	80.70	100.22	61.50	100.08
54.92	98.54	52.61	98.35				
57.00	98.68	56.50	102.39				
63.40	99.92						

Cross-sections Survey 2001

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.00	0.00	100.46	0.00	99.55	0.00	99.40
10.00	99.61	10.00	99.00	10.00	98.93	10.00	98.87
20.00	99.28	11.60	98.81	13.30	98.72	13.00	98.72
30.00	99.27	20.00	98.11	20.00	98.44	20.00	98.22
39.00	98.81	30.00	98.22	30.00	97.99	30.00	97.62
40.00	98.67	40.00	97.87	40.00	97.82	40.00	97.59
50.00	98.23	50.59	97.59	50.00	97.58	50.00	97.85
60.00	98.21	60.00	97.46	60.00	97.30	60.00	98.34
70.00	98.27	70.00	97.01	70.00	97.42	62.00	98.72
70.90	98.31	80.00	97.13	80.00	97.47		
74.00	98.44	89.70	99.70	84.00	98.47		
75.90	98.32			84.30	98.81		
76.45	98.16			95.60	100.28		
80.00	97.78						
90.00	97.02						
100.00	98.03						
103.5	99.81						

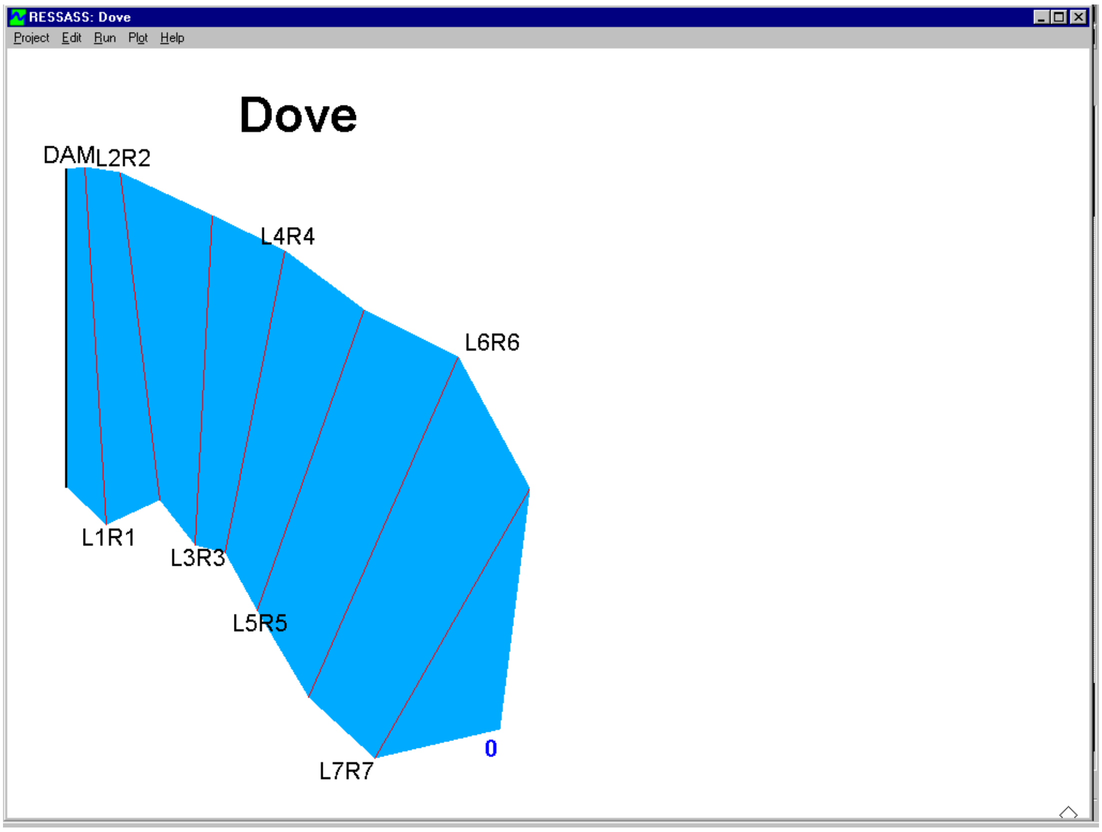
L5R5		L6R6		L7R7		L8R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.23	0.00	101.36	0.00	99.70	0.00	100.46
6.00	98.81	7.20	98.81	10.00	98.98	10.00	99.86
10.00	98.20	10.00	98.28	20.00	99.04	20.00	99.10
20.00	97.92	20.00	98.24	24.00	98.72	30.00	98.79
30.00	97.84	30.00	98.11	30.00	98.71	40.00	98.70
40.00	97.71	40.00	97.97	40.00	98.56	50.00	99.20
50.00	98.02	50.00	98.31	46.60	98.72	61.20	100.08
52.30	98.68	51.00	98.81	50.00	98.88		
56.54	99.91	57.30	102.39	60.00	99.27		
				70.00	99.79		
				80.65	100.22		

Cross-sections Survey 2002							
L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100	0	100.47	0	99.55	0	99.4
11.5	99.52	4	99.54	14.07	98.74	9.56	98.99
22.4	99.28	12	98.78	23.72	98.47	19.83	98.38
29.5	99.26	18.2	98.25	31.67	98.04	28.47	97.81
42	98.65	24.6	98.01	45.24	97.84	38.23	97.68
49.5	98.38	29.5	98.29	53.58	97.6	50.07	97.82
58.3	98.31	40	97.96	57.3	97.54	62.17	98.58
70.2	98.2	47	97.74	66.75	97.45	70.71	100
75.6	98.45	60	97.52	76.7	97.44		
78.5	97.69	68.3	97.53	86.45	97.51		
86	97.51	74	97.14	93.59	98.6		
91.5	97.32	83.6	97.51	96.2	100.26		
97.1	97.52	87	98.68				
102.6	98.46	89.4	99.7				

L5R5		L6R6		L7R7		L8R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100.23	0	101.29	0	99.7	0	100.46
8.4	98.24	10	98.41	10.82	99.02	12.06	99.63
22.45	98.01	19	98.32	17.87	99.12	19.65	99.46
31.48	98.05	29.5	98.25	25.53	98.76	31.65	99.15
41.53	97.88	42.5	98.04	32.17	98.74	34.65	98.57
47.89	98.2	51.81	98.35	37.93	98.53	40.76	98.48
52.92	98.74	56.31	102.38	50.5	98.86	50.03	99.25
58.65	99.93			68.53	99.56	58.09	99.89
				80.78	100.24	61.28	100.09

Name: Dove
Location: Bikita (Zimbabwe)
Full Supply Water Level: 100m (1999), 100.83 (2001)
Note: the reservoir wasn't surveyed in the year 2000

Location of survey beacons



Section Name	Left bank point East (m)	North (m)	Elevation (m)	Right bank point East (m)	North (m)	Elevation (m)
'DAM	0.00	0.00	100.00	0.00	253.00	100.00
'L1R1'	31.50	-28.98	101.39	14.93	254.43	102.06
'L2R2'	73.80	-10.16	101.61	42.34	249.98	101.33
'L3R3'	102.00	-45.36	102.69	115.82	215.90	101.25
'L4R4'	126.01	-51.54	101.95	173.44	188.05	101.42
'L5R5'	151.68	-96.92	103.36	236.61	141.25	101.20
'L6R6'	192.56	-165.69	102.82	311.51	104.00	101.27
'L7R7'	244.53	-214.73	101.45	368.31	-0.80	102.09
'UPST'	343.94	-191.88	100.00	343.94	-191.88	100.00

Note:
Elevation refers to local datum of 100.00 m at the spillway.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.39	0.00	101.61	0.00	102.69	0.00	101.95
20.20	100.70	3.60	101.38	8.40	101.29	12.70	101.23
38.20	100.02	9.60	100.72	14.10	101.56	41.20	99.78
39.20	99.78	18.60	100.61	19.40	101.58	51.10	99.00
50.10	98.97	34.50	99.78	31.90	100.99	61.00	98.15
61.10	98.69	54.70	98.85	56.70	99.78	71.00	97.60
72.00	98.62	64.70	98.46	66.70	98.99	80.90	97.61
83.00	98.49	74.80	98.07	76.80	98.42	90.80	97.76
93.90	98.39	84.90	97.60	86.80	97.71	100.70	97.91
104.90	98.16	95.00	97.52	96.90	97.56	110.70	98.18
115.80	97.75	105.10	97.53	106.90	97.62	120.60	98.51
126.80	97.40	115.10	97.57	117.00	97.73	130.50	98.67
137.70	97.42	125.20	97.74	127.00	97.85	140.40	98.65
148.70	97.69	135.30	98.00	137.10	97.95	150.30	98.68
159.60	97.80	145.40	98.03	147.10	98.07	160.30	98.73
170.60	97.89	155.50	97.96	157.20	98.32	170.20	98.85
181.50	98.27	165.50	98.18	167.20	98.40	180.10	98.99
192.50	98.68	175.60	98.38	177.30	98.56	190.00	99.36
203.40	98.87	185.70	98.62	187.30	98.67	207.10	99.78
214.40	99.26	195.80	98.98	197.40	98.97	236.80	100.97
236.30	99.12	228.40	99.78	207.40	99.61	244.20	101.42
255.20	99.78	246.90	100.39	224.00	99.78		
273.50	101.03	262.00	101.33	248.80	100.68		
283.50	102.06			261.60	101.25		

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	103.36	0.00	102.82	0.00	101.45
21.20	102.21	10.30	102.27	21.30	100.52
43.10	100.73	41.50	100.88	35.10	100.23
55.90	99.78	83.20	99.78	49.70	99.98
66.80	98.98	108.10	98.98	71.30	99.78
77.70	98.47	113.10	98.95	92.70	98.97
88.70	98.12	123.10	98.73	130.20	98.97
99.60	97.88	133.00	98.53	135.60	98.90
110.50	97.72	143.00	98.43	146.30	98.88
121.40	97.62	153.00	98.32	157.00	98.84
132.30	97.81	162.90	98.23	167.70	98.82
143.20	98.36	172.90	98.21	173.10	98.97
154.20	98.88	182.90	98.20	178.40	99.28
165.10	98.91	192.80	98.10	195.80	99.78
176.00	98.92	202.80	97.94	223.70	100.90
186.90	99.04	212.80	97.81	247.20	102.09
197.80	99.07	222.70	97.60		
208.70	98.76	232.70	99.06		
219.70	99.11	242.70	99.06		
235.70	99.78	252.60	99.11		
252.90	101.20	266.20	99.78		
		294.80	101.27		

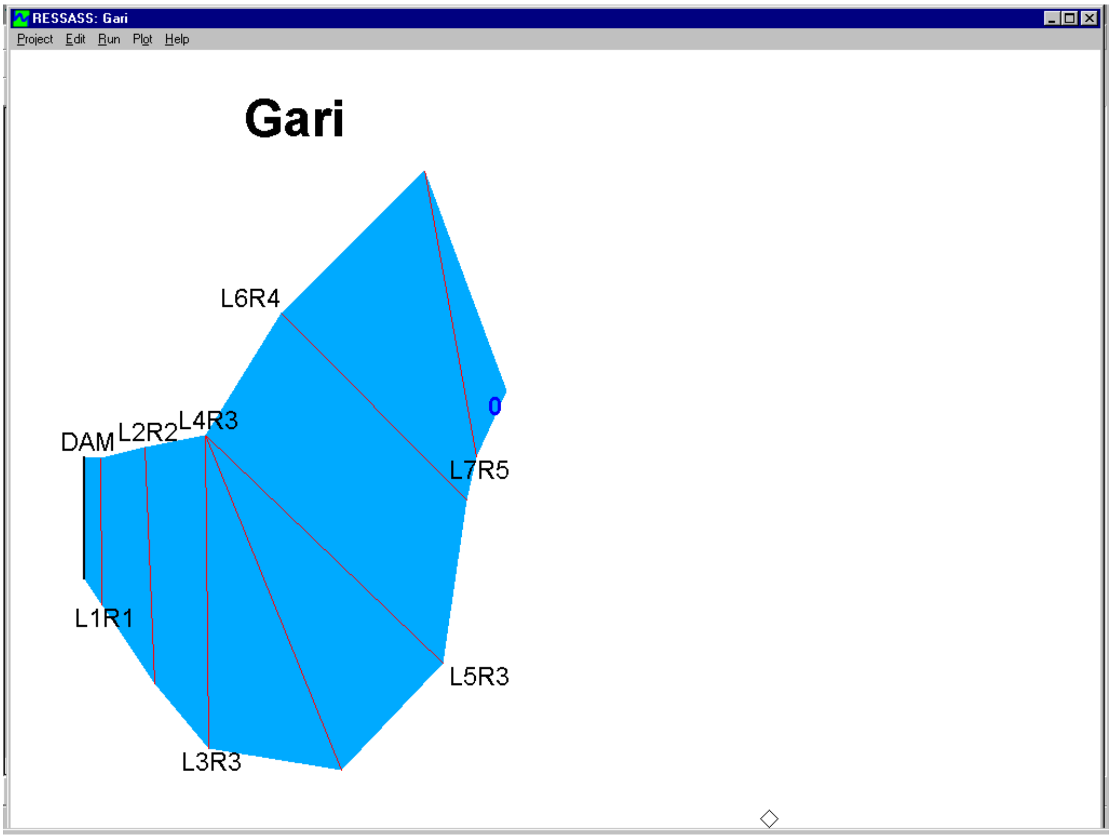
Cross-sections Survey 2001							
L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.39	0.00	101.61	0.00	102.69	0.00	101.96
10.71	101.01	9.87	100.44	10.47	101.22	9.63	101.31
21.43	100.73	10.97	100.36	20.95	101.57	18.29	100.80
22.50	100.72	21.94	99.99	31.42	101.01	19.25	100.82
32.14	100.18	32.91	99.37	34.04	100.84	28.88	100.73
53.56	98.91	43.87	99.00	41.89	100.37	38.51	99.91
64.28	98.82	54.84	98.64	73.31	98.99	48.13	98.84
74.99	98.52	65.81	98.24	83.79	97.64	57.76	97.95
85.70	98.45	76.78	97.24	94.26	96.96	67.39	97.49
96.42	98.33	87.75	97.24	104.73	96.85	77.01	97.47
107.13	98.07	98.72	97.40	115.21	97.43	86.64	97.56
117.84	97.52	109.69	97.64	125.68	97.51	96.27	97.75
128.55	97.31	120.65	97.62	136.15	97.65	105.89	98.07
139.27	97.38	131.62	97.89	146.62	97.60	115.52	98.31
149.98	97.58	142.59	97.96	157.10	97.88	125.15	98.59
160.69	97.72	153.56	97.89	167.57	98.02	134.77	98.63
171.40	97.84	164.53	98.04	178.04	98.15	144.40	98.57
182.12	98.16	175.50	98.29	188.52	98.37	154.03	98.61
192.83	98.16	186.47	98.49	198.99	98.46	163.65	98.70
203.54	98.79	197.43	98.97	209.46	98.64	173.28	98.85
214.26	99.26	208.40	99.19	219.94	99.20	182.91	99.12
224.97	99.13	219.37	99.29	230.04	100.16	192.53	99.66
235.68	99.01	230.34	99.67	240.88	100.16	211.79	100.26
246.40	99.42	241.31	100.07	251.36	100.50	231.04	100.76
257.11	99.89	252.28	100.53	256.59	100.84	233.16	100.81
267.07	100.72	257.21	100.84	261.62	101.25	244.23	101.39
267.82	100.73	262.04	101.34				
278.53	101.62						
283.89	102.06						

Cross-sections Survey 2001 continued

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	103.37	0.00	102.82	0.00	101.45
10.15	102.85	10.36	102.29	21.30	100.52
20.30	102.20	20.71	101.73	35.10	100.23
30.45	101.63	31.07	101.33	49.70	99.98
40.60	100.86	41.43	100.90	71.30	99.78
41.21	100.85	43.29	100.84	92.70	98.97
50.76	100.24	51.78	100.61	130.20	98.97
60.91	99.41	103.57	98.97	135.60	98.90
71.06	98.79	119.10	98.77	146.30	98.88
81.21	98.29	129.46	98.54	157.00	98.84
91.36	97.97	139.82	98.36	167.70	98.82
101.51	97.74	150.17	98.27	173.10	98.97
111.66	97.59	160.53	98.35	178.40	99.28
121.81	97.59	170.88	98.14	195.80	99.78
131.96	97.84	181.24	98.15	223.70	100.90
142.11	98.37	191.60	98.05	247.20	102.09
152.26	98.89	201.95	97.97		
162.41	98.98	212.31	97.75		
172.57	98.91	222.67	97.47		
182.72	98.99	233.02	98.04		
192.87	99.14	243.38	99.14		
203.02	99.00	253.74	98.96		
213.17	99.01	264.09	99.36		
223.32	99.44	274.45	100.11		
233.47	100.20	284.81	100.57		
243.62	100.49	289.05	100.84		
247.73	100.82	294.75	101.25		
252.86	101.17				

Name: Gari
Location: Chivi (Zimbabwe)
Full Supply Water Level: 100m

Location of survey beacons



Section	Left bank point			Right bank point		
Name	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	0.00	0.00	100.00	0.00	59.50	100.00
'L1R1'	8.70	-12.60	101.62	8.10	59.20	100.96
'L2R2'	34.70	-51.50	101.26	29.60	64.60	100.45
'L3R3'	60.80	-83.10	101.01	59.30	70.50	100.25
'L4R3'	126.00	-93.50	100.44	59.30	70.50	100.25
'L5R3'	175.70	-41.40	100.00	59.30	70.50	100.25
'L6R4'	187.30	38.60	100.25	96.10	129.80	100.28
'L7R5'	192.00	59.70	100.27	166.40	199.90	100.45
'UPST'	206.70	92.10	100.00	206.70	92.10	100.00

Note:
Elevation refers to local datum of 100.00 m at the spillway.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L3R3		L4R3	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.62	0.00	101.26	0.00	101.01	0.00	100.44
11.20	99.13	9.00	99.13	11.17	99.13	9.70	99.93
22.20	94.08	19.26	97.60	21.99	98.29	10.70	99.81
32.20	94.65	29.52	96.77	32.82	97.53	29.70	98.85
42.20	96.61	39.78	96.25	43.64	97.16	40.42	97.33
52.20	97.89	50.04	95.02	54.47	96.76	51.15	97.79
61.20	99.13	60.30	94.74	65.29	96.69	61.87	97.77
72.40	100.96	70.56	96.25	76.12	95.54	72.60	97.44
		80.82	97.63	86.94	95.39	83.32	96.99
		91.08	96.87	97.72	95.14	94.05	96.48
		101.34	97.68	108.59	95.93	104.77	96.02
		110.65	99.13	119.42	96.10	115.50	96.43
		116.20	100.45	141.08	98.52	126.22	95.40
				147.78	99.13	136.94	95.46
				153.60	100.25	158.38	96.80
						172.69	99.13
						177.00	100.25

L5R3		L6R4		L7R5	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.00	0.00	100.25	0.00	100.27
42.21	99.13	31.00	99.13	30.80	99.13
52.85	98.71	41.58	98.81	41.38	98.56
63.48	98.43	52.17	97.77	51.96	98.54
74.12	97.85	62.75	97.26	62.54	98.91
84.76	97.23	73.33	97.18	73.12	98.93
95.39	97.29	83.92	97.81	83.70	98.62
106.03	97.34	94.50	98.02	94.28	98.73
116.67	96.43	105.09	98.39	104.86	98.59
127.30	96.14	115.67	99.04	115.44	99.13
137.94	96.71	117.50	99.13	145.44	100.45
148.57	98.28	129.10	100.28		
155.81	99.13				
161.50	100.25				

Cross-sections Survey 2000

L1R1		L2R2		L3R3		L4R3	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.63	0.00	101.26	0.00	101.01	0.00	100.44
12.70	99.45	5.90	99.45	7.20	99.45	20.50	99.45
22.81	94.71	16.60	97.68	17.57	98.39	31.09	98.82
32.92	94.94	27.30	96.97	27.94	97.83	41.68	97.77
43.03	96.96	38.00	96.50	38.31	97.36	52.27	97.90
53.14	98.19	48.70	95.81	48.68	96.87	62.86	97.80
63.00	99.45	59.40	95.05	59.05	96.85	73.45	97.31
71.80	100.97	70.10	96.07	69.42	96.23	84.04	96.97
		80.80	97.25	79.79	95.92	94.63	96.22
		91.50	96.93	90.16	95.85	105.22	96.65
		102.20	97.40	100.53	95.24	115.81	96.35
		112.90	99.15	110.90	96.59	126.40	96.08
		114.20	99.45	121.27	95.93	136.99	95.89
		116.20	100.46	131.64	97.66	147.58	96.74
				142.01	98.77	158.17	97.05
				148.00	99.45	168.76	98.90
				152.80	100.25	172.70	99.45
						176.50	100.24

L5R3		L6R4		L7R5	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.95	0.00	100.25	0.00	100.27
26.60	99.45	24.70	99.45	0.30	99.45
37.29	99.08	35.23	97.77	13.23	99.09
47.98	98.74	45.76	98.22	26.16	98.44
58.67	98.44	51.09	97.80	39.09	98.51
69.36	98.02	66.82	97.09	52.02	98.84
80.05	97.39	77.36	97.52	64.95	98.89
90.74	96.55	87.89	97.94	77.88	98.56
101.43	97.94	98.42	97.75	90.81	98.66
112.12	96.91	108.95	98.64	103.74	98.54
122.81	95.53	119.27	99.45	116.67	99.40
133.50	96.25	129.00	100.26	117.20	99.45
144.19	97.80			143.00	100.46
154.88	99.24			145.03	100.46
156.60	99.45				
161.60	100.24				

Cross-sections Survey 2001

L1R1		L2R2		L3R3		L4R3	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.63	0.00	101.26	0.00	101.01	0.00	100.44
11.00	99.20	8.82	99.20	9.12	99.20	10.19	99.85
22.37	94.20	12.11	98.70	10.73	99.01	20.38	99.32
32.63	94.70	21.99	97.55	21.46	98.27	22.01	99.20
41.78	96.50	31.87	96.60	32.19	97.55	30.57	98.75
52.60	97.90	41.75	96.28	42.92	97.24	44.01	97.75
61.91	99.19	51.63	94.90	53.65	96.75	54.20	97.88
62.49	99.34	61.51	94.80	64.38	96.74	64.39	97.85
72.36	100.96	71.39	96.25	75.11	95.71	74.58	97.45
		81.27	98.07	85.84	95.60	84.77	97.07
		91.15	96.85	96.57	95.68	94.96	96.70
		101.03	97.84	107.30	95.40	105.15	96.53
		103.30	99.20	118.03	96.48	116.73	96.30
		116.20	100.46	128.76	98.08	127.38	95.20
				139.49	98.08	135.72	95.40
				145.93	99.19	145.91	96.07
				150.22	99.79	156.10	96.61
				153.61	100.25	166.29	98.10
						173.01	99.19
						177.04	100.24

L5R3		L6R4		L7R5	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.95	0.00	100.26	0.00	100.27
10.28	99.74	6.90	100.10	11.07	100.00
20.56	99.57	16.45	99.73	22.14	99.44
30.84	99.32	25.81	99.27	32.88	99.20
35.98	99.20	26.00	99.24	33.21	99.15
41.12	99.12	35.55	98.52	41.26	98.53
51.40	98.70	45.10	97.82	52.33	98.60
61.68	98.37	54.65	97.37	63.40	98.95
71.96	97.84	73.75	97.17	74.44	98.95
85.07	97.17	83.30	97.87	83.65	98.65
95.35	97.25	95.50	98.07	95.10	98.84
105.63	97.45	105.05	98.47	104.66	98.65
115.91	96.85	114.60	98.97	112.00	99.20
126.19	96.08	117.94	99.27	120.26	99.71
136.47	96.30	128.98	100.28	131.33	99.83
146.75	97.85			145.20	100.46
157.03	99.20				
161.46	100.24				

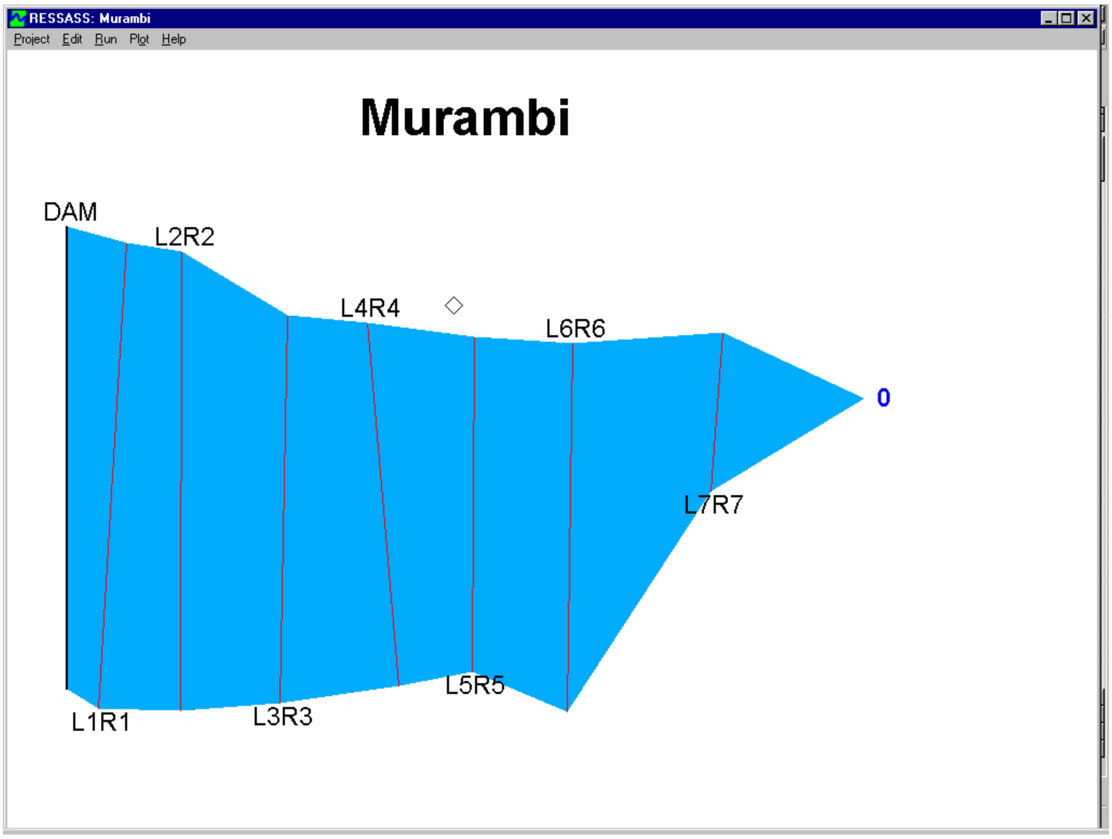
Cross-sections Survey 2002							
L1R1		L2R2		L3R3		L4R3	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.13	101.66	0.2	101.19	0.53	100.9	-0.46	100.44
11.07	99.21	9.1	99.08	11.39	99.12	8.54	99.83
18.12	96.18	25.23	97.56	28.24	97.8	17.54	99.67
20.89	94.48	30.23	96.76	33.24	97.54	26.54	99.19
25.89	94.8	35.23	96.52	38.24	97.38	42.19	97.82
30.89	94.87	40.23	96.39	43.24	97.16	46.39	97.57
35.89	95.4	45.23	95.72	48.24	96.96	51.39	97.67
40.89	96.54	50.23	95.2	53.24	96.78	56.39	97.82
45.89	97.52	55.23	95.07	58.24	96.81	61.39	97.79
50.39	97.8	60.23	94.95	63.24	96.73	66.39	97.73
71.29	100.78	65.23	95.24	68.24	96.31	71.39	97.62
		70.23	96.14	73.24	95.77	76.39	97.4
		75.23	96.54	78.24	95.77	81.39	97.13
		80.23	97.3	83.24	95.65	86.39	96.99
		90.23	96.82	88.24	95.89	91.39	96.82
		95.23	97.13	93.24	95.65	96.39	96.57
		110.52	99.13	98.24	95.26	101.39	96.1
		116.11	100.35	103.24	95.83	106.39	95.99
				108.24	96.31	111.39	96.55
				113.24	96.46	116.39	96.7
				118.24	96.46	121.39	96.22
				122.12	96.36	126.39	95.96
				128.24	96.93	131.39	96
				144.91	98.96	136.39	95.67
				153.73	100.25	141.39	95.67
						146.39	96.27
						151.39	96.7
						156.39	96.8
						158.15	96.81
						164.04	97.82
						177.46	100.25

Cross-sections Survey 2002 continued

L5R3		L6R4		L7R5	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	99.95	0	100.26	0	100.24
9	99.8	3.31	100.13	0.88	100.19
18	99.63	8.82	100.02	5.77	100.06
27	99.4	14.33	99.86	10.65	100.08
36	99.17	19.85	99.64	15.54	99.7
54	98.63	25.36	99.33	20.43	99.5
63	98.41	31.86	99.1	25.32	99.38
73.6	97.82	42.34	98.76	30.2	99.13
75.9	97.79	45.53	98.38	35.09	98.76
80.9	97.37	51.71	97.82	39.98	98.6
85.9	96.74	52.92	97.75	44.87	98.54
90.9	96.53	58.44	97.48	49.75	98.57
95.9	97.65	63.95	97.3	54.64	98.63
100.9	97.78	69.46	97.19	59.53	98.84
105.9	97.27	74.97	97.75	64.41	98.95
110.9	96.98	81.04	97.82	69.3	98.95
115.9	96.41	84.9	97.92	74.19	98.87
120.9	96.34	90.41	98.03	79.08	98.72
125.9	96.25	95.92	98.11	83.96	98.63
130.9	96.35	101.44	98.3	88.85	98.68
135.9	96.77	106.95	98.56	93.74	98.77
140.9	97.44	112.46	98.89	98.62	98.69
143.2	97.82	117.97	99.34	103.51	98.63
161.5	100.25	123.49	99.79	108.4	98.94
		129	100.28	118.17	99.45
				123.06	99.67
				127.95	99.74
				130.95	99.78
				135.83	100
				145.26	100.46

Name: Murambi
Location: Zaka (Zimbabwe)
Full Supply Water Level: 100m

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	0	0	100.00	0	186.00	100.00
'L1R1'	12.81	-7.80	99.90	24.14	179.47	100.18
'L2R2'	45.78	-8.70	100.25	45.93	175.88	100.34
'L3R3'	85.80	-5.80	100.37	88.81	150.17	100.64
'L4R4'	133.28	1.24	100.18	120.66	147.09	100.92
'L5R5'	162.98	6.77	100.18	163.90	141.44	100.46
'L6R6'	201.34	-9.20	100.43	203.27	139.10	100.33
'L7R7'	259.00	79.34	100.12	263.67	143.40	100.08
'UPST'	320.82	116.62	100.00	0	0	100.00

Note:
Elevation refers to local datum of 100.00 m at the spillway.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.90	0.00	100.25	0.00	100.37	0.00	100.13
13.40	98.79	19.40	98.79	24.10	98.79	26.20	98.79
23.86	98.08	29.98	98.33	35.58	98.31	36.69	98.35
34.31	97.71	40.57	97.74	45.06	97.87	47.18	98.06
44.77	97.51	51.15	97.00	55.54	97.43	57.66	98.01
55.23	97.01	61.74	97.04	66.02	97.34	68.15	97.72
65.68	97.04	72.32	97.27	76.50	97.24	78.64	97.58
76.14	97.25	82.90	97.22	86.98	97.69	89.13	98.09
86.60	97.54	93.49	97.71	97.46	98.64	99.62	98.71
97.05	97.87	104.07	98.05	99.60	98.79	101.40	98.79
107.51	98.10	114.66	98.49	155.00	100.64	146.20	100.88
117.97	98.30	123.40	98.79				
128.43	98.46	184.40	100.34				
138.88	98.79						
139.30	98.79						
188.80	100.15						

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.18	0.00	100.43	0.00	100.12
21.90	99.32	10.47	99.74	24.80	99.30
25.87	99.07	60.73	99.50	29.72	99.00
36.32	98.85	81.40	98.79	40.99	98.71
46.20	98.79	92.03	98.31	46.70	99.30
56.72	98.44	102.67	98.15	63.90	100.08
67.24	98.09	113.30	98.79		
77.76	97.86	147.40	100.33		
88.28	98.10				
98.80	98.79				
134.20	100.46				

Cross-sections Survey 2000

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.90	0.00	100.25	0.00	100.37	0.00	100.13
9.50	99.32	28.00	99.32	28.00	99.32	15.50	99.32
19.08	99.27	35.50	98.80	30.60	99.19	20.10	98.82
30.26	98.33	45.42	98.37	40.28	98.70	30.52	98.80
40.64	97.96	55.34	97.90	49.96	98.24	40.94	98.27
51.02	97.63	65.26	97.32	59.64	97.85	51.36	97.94
61.40	97.15	75.18	97.12	69.32	97.49	61.78	97.78
71.78	97.13	85.10	97.12	79.00	97.37	72.20	97.49
82.16	97.18	95.02	97.40	88.68	97.30	82.62	97.46
92.54	97.54	104.94	97.78	98.36	97.99	93.04	98.23
102.92	97.71	114.86	98.03	108.04	98.74	103.46	98.82
113.30	98.02	124.78	98.47	110.10	99.32	114.10	99.32
123.68	98.20	134.70	98.78	155.50	100.64	146.50	100.88
134.06	98.38	144.62	99.32				
144.44	98.63	192.00	100.34				
154.82	99.04						
155.20	99.32						

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.18	0.00	100.43	0.00	100.122
21.90	99.32	67.90	99.32	24.80	99.32
25.87	99.07	69.00	99.27	26.08	99.15
36.32	98.85	79.00	98.65	31.15	98.99
46.77	98.75	89.00	98.29	36.22	98.84
57.22	98.40	99.00	98.23	41.29	98.78
67.67	98.08	109.00	98.82	46.70	99.32
78.12	97.86	119.00	99.32	64.00	100.08
88.57	98.24	148.00	100.33		
99.02	98.81				
109.50	99.32				
112.60	100.46				

Cross-sections Survey 2001

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.90	0.00	100.25	0.00	100.37	0.00	100.18
14.59	99.21	10.25	99.37	10.20	99.55	10.25	99.62
16.97	99.04	15.37	99.04	19.04	99.04	20.50	99.14
24.93	98.26	20.50	98.76	20.41	98.97	30.76	98.76
35.27	97.89	30.75	98.31	30.61	98.50	41.01	98.29
45.62	97.56	40.99	97.74	40.81	98.04	51.26	98.08
55.96	97.08	51.24	97.17	51.01	97.63	61.51	97.99
66.30	97.07	61.49	97.09	60.09	97.43	78.56	97.66
76.64	97.26	71.74	97.10	70.29	97.32	82.02	97.77
86.98	97.38	81.99	97.25	80.49	97.41	92.27	98.36
97.32	97.72	92.24	97.71	90.69	98.24	102.52	98.91
107.66	97.98	102.49	97.99	100.9	98.88	108.02	99.13
118.00	98.23	112.74	98.47	104.33	99.03	112.77	99.35
128.34	98.40	122.99	98.75	111.10	99.38	123.03	99.79
138.68	98.62	127.08	99.03	121.30	99.72	133.28	100.25
148.59	99.03	133.23	99.26	131.51	100.03	143.53	100.77
149.03	99.04	143.48	99.57	141.71	100.28	146.40	100.92
159.37	99.31	153.73	99.78	151.91	100.52		
169.71	99.67	163.98	100.11	154.87	100.64		
180.05	99.83	174.23	100.20				
186.14	100.08	184.48	100.30				
189.04	100.18	184.58	100.34				

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.18	0.00	100.43	0.00	100.12
10.29	99.74	10.28	99.74	10.25	99.98
20.59	99.41	20.56	99.73	20.50	99.66
27.49	99.03	30.83	99.72	29.72	99.03
30.88	98.80	41.11	99.70	30.74	99.01
41.17	98.81	51.39	99.66	40.99	98.78
51.47	98.64	61.67	99.54	42.01	99.03
61.76	98.24	71.94	99.27	51.24	99.62
77.02	97.86	77.08	99.03	61.48	99.78
82.35	97.91	82.22	98.77	64.23	100.08
92.64	98.41	92.50	98.30		
102.93	98.95	102.78	98.19		
105.15	99.13	113.06	98.75		
113.23	99.39	119.22	99.03		
123.52	99.88	123.33	99.23		
133.82	100.33	133.61	99.58		
134.66	100.46	143.89	100.06		
		147.40	100.33		

Cross-sections Survey 2002

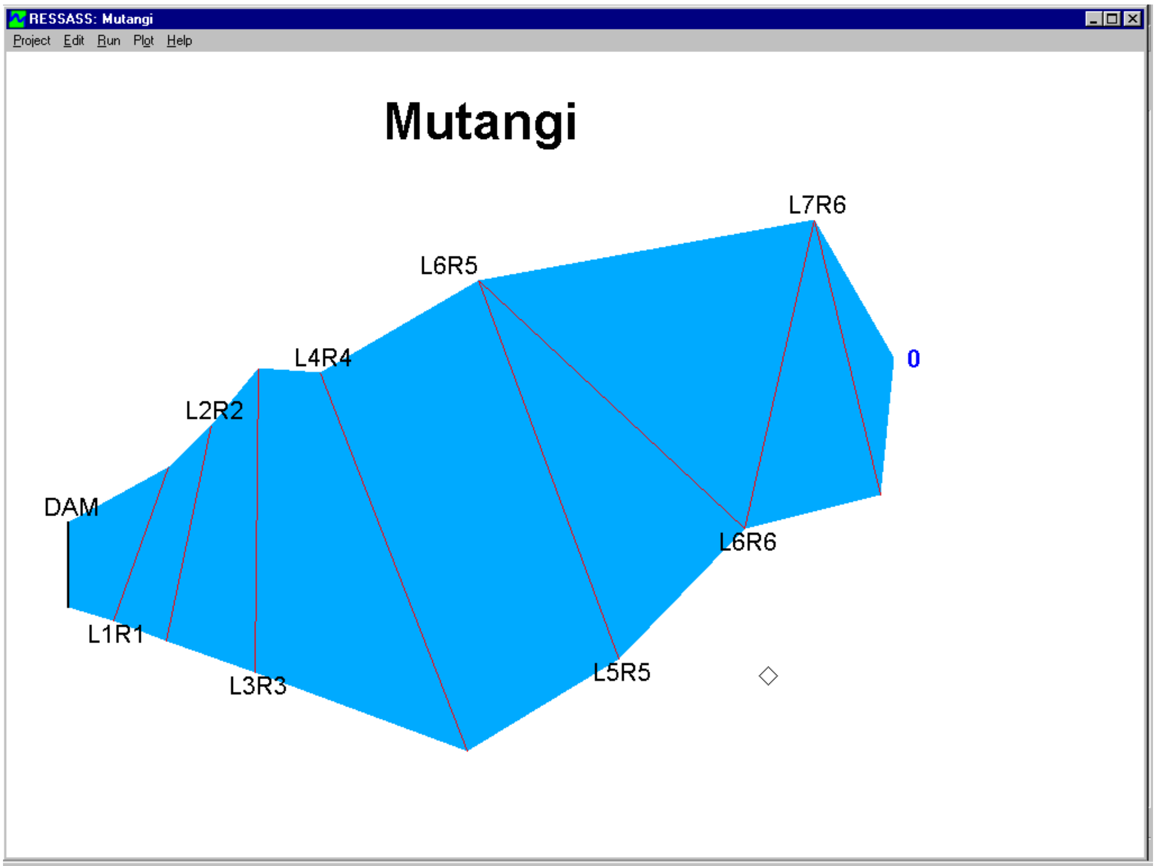
L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	99.9	0	100.25	0	100.37	-0.38	100.16
9	99.37	1.8	100.06	5.6	100.01	2.62	100.01
14.1	98.76	6.9	99.58	10.7	99.48	7.62	99.72
19.3	98.35	12	99.29	15.8	99.17	12.72	99.5
24.4	98.13	17.1	98.95	20.9	98.94	17.82	99.18
29.5	97.85	22.2	98.68	26	98.71	22.92	98.96
34.7	97.85	27.3	98.47	31.1	98.5	28.02	98.78
39.8	97.68	32.4	98.21	36.2	98.68	33.12	98.6
44.9	97.48	37.5	97.87	41.3	97.49	38.22	98.36
50	97.2	42.6	97.62	46.4	97.84	43.22	98.13
55.2	97.17	47.7	97.48	51.5	97.68	48.32	98.06
60.3	97.05	52.8	97.19	56.6	97.44	53.42	97.98
65.4	97.16	57.9	97.19	61.7	97.44	58.52	98.01
70.5	97.24	63	97.15	66.8	97.42	63.62	97.92
75.7	97.3	68	97.15	71.9	97.38	68.72	97.75
79.86	97.37	73.1	97.19	77.1	97.23	73.82	97.64
85.9	97.53	78.2	97.18	82.2	97.47	78.92	97.64
91	97.64	83.3	97.35	87.3	97.75	83.92	97.8
96.2	97.8	88.4	97.55	92.4	98.26	89.02	98.14
101.3	97.93	93.5	97.74	97.5	98.64	94.12	98.47
106.4	98.1	98.6	97.86	102.6	98.91	99.22	98.74
111.5	98.2	103.7	98	107.7	99.13	104.32	98.96
116.7	98.33	108.8	98.26	112.8	99.4	109.42	99.15
121.8	98.36	113.9	98.5	117.9	99.56	114.52	99.39
126.9	98.48	119	98.6	123	99.71	119.52	99.6
132.1	98.58	124.1	98.84	128.1	99.85	124.62	99.84
135.78	98.7	129.2	99.16	133.2	100.08	129.72	100.12
142.3	98.88	134.3	99.34	138.3	100.22	134.82	100.35
147.4	99.08	139.4	99.62	143.4	100.3	139.92	100.58
152.6	99.23	144.4	99.64	153.7	100.51	145.02	100.81
157.7	99.43	149.5	99.65	156	100.65	146.02	100.93
162.8	99.53	154.6	99.92				
167.9	99.65	159.7	99.98				
173.1	99.69	164.8	100.1				
176.31	99.83	169.9	100.06				
181.88	99.94	175	100.15				
187.6	100.16	180.1	100.19				
		184.6	100.35				

Cross-sections Survey 2002 continued

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
-0.33	100.22	0	100.43	0	100.12
4.77	99.97	4.5	100.13	5.1	100.1
9.77	99.82	9.6	99.76	10.1	99.99
14.87	99.68	14.7	99.7	15.2	99.86
19.97	99.48	19.8	99.7	20.3	99.67
25.07	99.21	24.9	99.65	25.3	99.29
30.07	98.92	30	99.71	30.4	99.03
35.17	98.91	35.1	99.75	35.5	98.87
40.27	98.92	40.2	99.74	40.5	98.77
45.37	98.85	45.3	99.71	46.26	99.28
50.37	98.69	50.4	99.69	51.53	99.54
55.47	98.53	55.5	99.61	55.2	99.68
60.57	98.33	60.6	99.55	57.99	99.81
65.67	98.2	65.7	99.47	64.2	100.08
70.67	98.01	70.8	99.32		
75.77	97.88	75.9	99.13		
80.87	97.86	81	98.87		
85.97	98.06	86.1	98.57		
90.97	98.38	91.3	98.38		
96.07	98.67	96.4	98.31		
101.17	98.91	101.5	98.24		
106.27	99.13	106.6	98.38		
111.27	99.35	111.7	98.69		
116.37	99.51	116.8	98.96		
121.47	99.79	121.9	99.17		
126.47	100.02	127	99.35		
131.57	100.28	132.1	99.59		
134.37	100.48	137.2	99.75		
		142.3	99.99		
		147.4	100.19		
		148.3	100.34		

Name: Mutangi
Location: Chivi (Zimbabwe)
Full Supply Water Level: 99.83m

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	0.00	0.00	99.83	0.00	51.30	99.83
'L1R1'	27.10	-8.50	101.18	60.90	85.10	100.34
'L2R2'	59.50	-20.50	101.28	86.80	110.30	100.10
'L3R3'	113.10	-39.80	101.09	115.40	144.50	100.45
'L4R4'	241.40	-87.00	101.22	152.70	142.10	100.13
'L5R5'	333.20	-31.60	100.06	248.70	197.80	100.15
'L6R5'	409.50	47.40	99.93	248.70	197.80	100.15
'L6R6'	409.50	47.40	99.93	451.50	234.20	100.22
'L7R6'	491.50	68.20	100.50	451.50	234.20	100.23
'UPST'	500.00	151.00	99.83	500.00	151.00	99.83

Note:
Elevation refers to local datum of 99.83 m at the spillway.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.18	0.00	101.28	0.00	101.09	0.00	101.22
0.63	100.93	0.85	100.99	0.75	100.90	1.64	100.84
5.70	98.93	5.20	98.93	4.40	98.93	6.20	98.93
16.24	98.59	8.17	98.64	10.41	97.75	27.14	97.48
26.78	98.59	10.15	98.35	20.83	97.53	48.07	97.33
37.33	98.67	15.75	98.32	26.36	97.74	69.01	97.27
47.87	98.73	26.29	98.35	48.33	98.17	89.94	97.32
58.41	98.93	36.83	98.35	70.29	98.28	110.88	97.25
99.91	100.34	47.38	98.36	92.26	98.44	131.81	97.46
		57.92	98.42	114.22	98.85	152.75	97.64
		68.47	98.53	116.80	98.93	173.69	98.18
		79.01	98.76	146.50	99.39	194.62	98.53
		87.30	98.93	168.97	99.70	206.00	98.93
		112.20	99.38	185.00	100.45	225.70	99.81
		124.56	99.66			246.50	100.13
		133.60	100.10				

L5R5		L6R5		L6R6		L7R6	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.06	0.00	99.93	0.00	99.93	0.00	100.50
10.70	99.47	1.80	99.74	15.45	99.55	27.00	99.84
13.20	99.14	16.30	99.26	31.04	99.23	46.60	99.65
16.80	98.93	31.50	98.93	46.63	99.06	62.80	99.92
37.89	98.44	52.96	98.39	62.30	98.97	122.30	99.18
58.98	98.03	63.69	98.24	92.60	99.37	141.30	99.55
80.07	97.65	74.42	98.20	120.30	99.08	150.30	99.21
101.16	97.66	95.88	98.17	133.10	99.42	170.00	100.23
122.25	97.80	117.34	98.24	146.20	99.06		
143.34	97.95	138.80	98.09	162.10	99.42		
164.43	98.25	160.26	98.18	170.30	99.21		
185.51	98.40	181.72	98.48	190.90	100.22		
206.60	98.76	202.60	98.93				
216.20	98.93	225.00	100.15				
226.60	99.19						
244.80	100.15						

Cross-sections Survey 2000

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.17	0.00	101.26	0.00	101.09	0.00	101.22
4.10	99.19	4.00	99.19	4.30	99.19	3.50	99.19
9.64	98.62	7.77	98.52	11.22	97.67	12.04	98.14
21.80	98.54	13.08	98.33	21.71	97.65	22.45	97.67
33.96	98.64	23.69	98.35	32.20	97.99	32.87	97.46
46.12	98.65	34.31	98.34	42.69	98.18	43.28	97.44
58.28	98.78	44.92	98.36	53.18	98.24	53.70	97.45
70.44	98.99	55.54	98.40	63.68	98.30	64.11	97.46
82.59	99.19	66.15	98.52	74.16	98.35	74.52	97.45
99.30	100.34	76.77	98.70	84.65	98.46	84.94	97.44
		87.38	98.94	95.13	98.55	95.35	97.44
		98.00	99.19	105.62	98.80	105.77	97.42
		132.90	100.10	116.11	99.03	116.18	97.44
				126.60	99.19	126.59	97.51
				185.70	100.48	137.01	97.66
						147.42	97.68
						157.84	97.85
						168.25	98.03
						178.66	98.29
						189.08	98.43
						199.49	98.73
						209.91	99.19
						244.70	100.16

L5R5		L6R5		L6R6		L7R6	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.06	0.00	99.93	0.00	99.93	0.00	100.50
12.50	99.19	16.30	99.19	62.30	98.97	25.10	99.99
23.21	98.84	26.72	99.08	92.60	99.37	52.00	99.90
33.92	98.59	37.44	98.79	120.30	99.08	76.30	100.02
44.63	98.69	48.16	98.54	133.10	99.42	100.50	99.21
55.34	98.21	58.88	98.34	146.20	99.06	127.80	99.71
66.05	98.03	69.60	98.25	162.10	99.42	152.10	99.51
76.76	98.01	80.32	98.23	170.30	99.21	170.80	100.19
87.47	97.72	91.04	98.34	190.90	100.22		
98.18	97.80	101.76	98.27				
108.89	97.78	112.48	98.29				
119.60	97.95	123.20	98.21				
130.31	97.98	133.92	98.19				
141.02	98.00	144.64	98.14				
151.73	98.06	155.36	98.19				
162.44	98.23	166.08	98.28				
173.15	98.32	176.80	98.44				
183.86	98.39	187.52	98.60				
194.57	98.52	198.24	98.85				
205.28	98.69	204.00	99.19				
215.99	98.94	222.10	100.20				
226.60	99.19						
245.80	100.18						

Cross-sections Survey 2001

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.17	0.00	101.26	0.00	101.09	0.00	101.22
6.50	98.89	6.18	98.87	5.21	98.88	13.73	98.88
10.00	98.58	10.29	98.33	10.41	97.75	27.45	97.99
20.00	98.56	20.59	98.23	20.83	97.56	41.19	97.34
30.00	98.63	30.88	98.38	31.24	97.93	54.90	97.24
40.00	98.68	41.18	98.30	41.65	98.05	68.62	97.29
48.10	98.92	51.47	98.38	52.06	98.13	82.35	97.34
50.00	99.07	61.77	98.45	62.48	98.23	96.07	97.24
60.00	99.25	72.06	98.58	72.89	98.33	109.80	97.14
70.00	99.46	82.35	98.79	83.30	98.41	123.52	97.29
81.20	100.12	85.44	98.87	93.72	98.50	137.25	97.49
99.50	100.34	92.65	99.06	104.13	98.74	150.97	97.94
		102.94	99.25	110.38	98.88	164.70	98.19
		113.24	99.39	114.54	98.99	178.42	98.29
		123.53	99.59	124.96	99.17	192.14	98.59
		133.62	100.10	135.37	99.31	203.12	98.88
				145.78	99.35	205.87	99.38
				156.19	99.49	219.59	99.72
				166.61	99.61	233.32	99.55
				177.02	99.99	245.67	100.13
				184.31	100.48		

L5R5		L6R5		L6R6		L7R6	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.06	0.00	99.93	0.00	99.93	0.47	100.50
10.11	99.56	16.30	99.19	18.47	99.48	16.86	100.10
12.64	99.06	26.72	99.08	29.38	99.25	27.11	99.85
15.42	99.00	37.44	98.79	40.29	99.11	37.36	99.91
25.28	98.75	48.16	98.54	51.20	99.02	47.61	99.72
37.92	98.45	58.88	98.34	62.11	98.97	57.86	99.87
50.56	98.18	69.60	98.25	73.02	99.13	68.11	99.82
63.20	98.05	80.32	98.23	83.93	99.31	78.36	99.64
75.84	97.75	91.04	98.34	94.84	99.40	88.61	99.59
88.48	97.61	101.76	98.27	98.19	99.32	98.86	99.82
101.13	97.75	112.48	98.29	109.10	99.20	109.11	99.61
113.77	97.90	123.20	98.21	120.01	99.25	119.36	99.62
126.41	97.90	133.92	98.19	130.92	99.41	123.00	99.50
139.05	97.90	144.64	98.14	141.83	99.51	133.25	99.41
151.73	98.06	155.36	98.19	152.74	99.31	143.50	99.50
162.44	98.23	166.08	98.28	163.65	99.41	153.75	99.45
173.15	98.32	176.80	98.44	174.56	99.41	164.00	99.79
183.86	98.39	187.52	98.60	182.64	99.79	170.28	100.22
194.57	98.52	198.24	98.85	190.99	100.22		
205.28	98.69	204.00	99.19				
215.99	98.94	225.05	100.17				
226.60	99.19						
245.80	100.18						

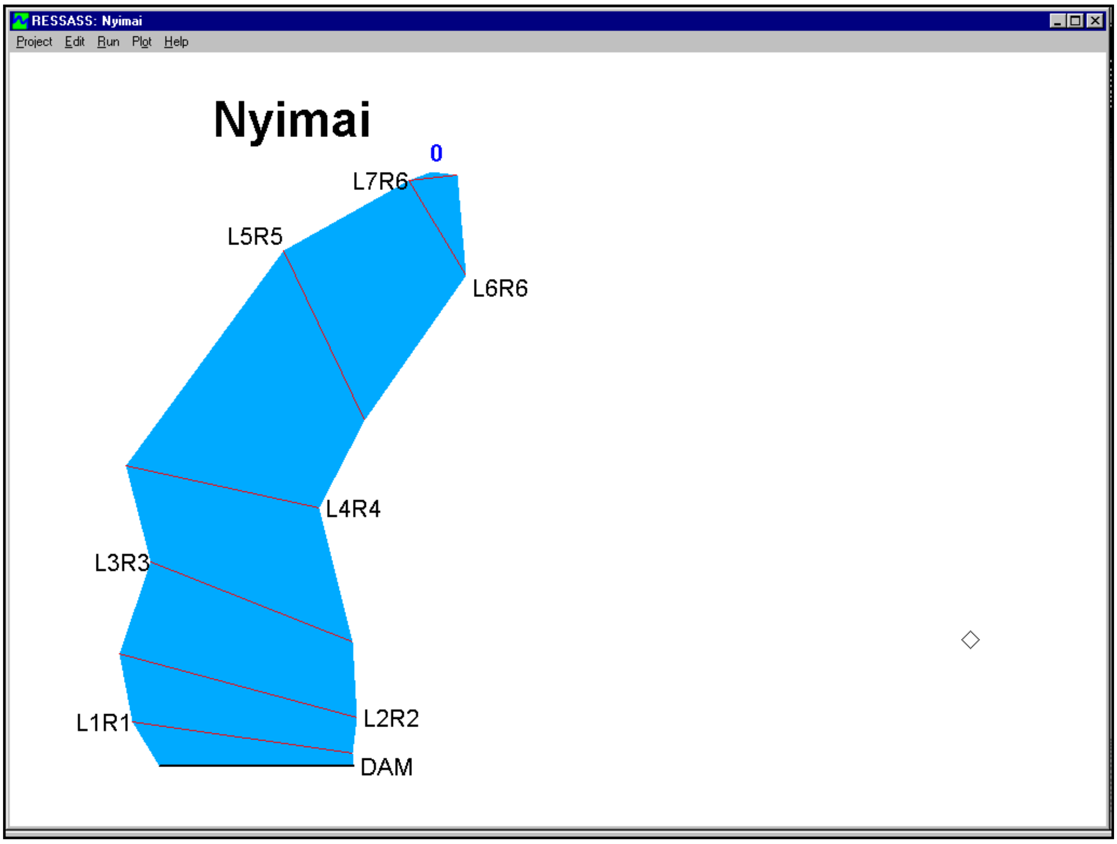
Cross-sections Survey 2002							
L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	101.18	0	101.28	0	101.09	0	101.22
5	99.21	5	99.14	5.1	98.83	5.1	99.35
10	98.66	10	98.42	10.2	97.82	10.2	98.44
14.9	98.63	15	98.34	15.3	97.72	15.3	98.17
19.9	98.63	20	98.22	20.4	97.73	20.4	97.95
24.9	98.63	24.9	98.32	25.5	97.9	25.5	97.72
29.9	98.66	29.9	98.39	30.6	98.06	30.6	97.58
34.8	98.64	34.9	98.34	35.7	98.17	35.7	97.55
39.8	98.59	39.9	98.39	40.8	98.22	40.8	97.55
44.8	98.72	44.9	98.4	45.9	98.26	45.9	97.55
49.8	98.76	49.9	98.45	51	98.27	51	97.55
54.7	98.87	54.9	98.4	56.1	98.21	56.1	97.55
59.7	98.99	59.9	98.46	61.2	98.32	61.2	97.56
64.7	99.07	64.9	98.53	66.3	98.28	66.3	97.56
69.7	99.11	69.8	98.59	71.4	98.34	71.4	97.53
74.6	99.27	74.8	98.66	76.5	98.42	76.5	97.52
79.6	99.25	79.8	98.79	81.6	98.46	81.6	97.56
84.6	99.3	84.8	98.89	86.7	98.44	86.7	97.59
89.6	99.65	89.8	99.01	91.8	98.51	91.8	97.58
99.5	100.35	94.8	99.12	96.9	98.61	96.9	97.54
		99.8	99.21	102	98.73	102	97.54
		104.8	99.31	107.1	98.85	107	97.52
		109.8	99.37	112.2	98.98	112.1	97.45
		114.7	99.43	117.3	99.08	117.2	97.46
		119.7	99.49	122.4	99.14	122.3	97.51
		129.7	99.77	127.5	99.22	127.4	97.62
		133.6	100.1	132.6	99.31	132.5	97.65
				137.7	99.35	137.6	97.73
				142.7	99.4	142.7	97.75
				147.8	99.4	147.8	97.76
				152.9	99.5	152.9	97.79
				163.1	99.54	158	97.9
				168.2	99.66	163.1	97.95
				173.3	99.96	168.2	98.09
				178.4	100.06	173.3	98.22
				184.3	100.48	178.4	98.33
						183.5	98.39
						188.6	98.45
						193.7	98.55
						198.8	98.71
						203.9	98.93
						209	99.12
						214.1	99.32
						219.2	99.53
						224.3	99.7
						229.4	99.87
						234.5	99.97
						239.6	100.04
						244.7	100.12
						245.7	100.06

Cross-sections Survey 2002 continued

L5R5		L6R5		L6R6		L7R6	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100.07	0	99.93	0	99.93	0	100.5
3.3	99.97	5.1	99.57	5	99.65	11.61	100.22
8.5	99.49	10.2	99.43	10	99.49	16.61	100.1
16.75	98.99	15.3	99.31	15	99.32	21.71	99.93
21.95	98.87	20.4	99.19	20	99.24	26.71	99.86
27.25	98.78	25.5	99.06	25	99.22	31.71	99.75
32.45	98.7	30.6	98.96	30	99.19	36.71	99.93
37.75	98.55	35.7	98.84	35	99.12	41.71	99.88
42.95	98.46	40.8	98.74	40	99.08	46.71	99.76
48.25	98.3	45.9	98.61	45	99.05	56.81	99.72
53.55	98.26	50.9	98.5	50	99.01	61.81	99.94
58.75	98.1	56	98.39	55	98.97	66.81	99.83
64.05	97.88	61.1	98.22	60	98.97	71.81	99.82
69.25	97.93	66.2	98.24	65	99.03	76.81	99.68
74.55	98.03	71.3	98.24	70	99.1	80.3	99.56
79.75	97.78	76.4	98.21	75	99.22	85.3	99.67
85.05	97.78	81.5	98.24	80	99.27	88.88	99.97
90.35	97.85	86.6	98.29	85	99.27	93.88	99.89
95.55	97.86	91.7	98.32	90	99.38	98.98	99.92
100.85	97.87	96.8	98.27	95	99.41	103.98	99.88
106.05	97.92	101.9	98.3	100	99.34	108.98	99.71
111.35	97.96	107	98.28	105	99.3	113.98	99.65
116.55	98.01	112.1	98.27	110	99.24	118.98	99.62
121.85	98.03	117.2	98.28	115	99.19	123.98	99.43
127.05	98.03	122.3	98.23	120	99.23	129.08	99.39
132.35	98.05	127.4	98.14	125	99.32	134.08	99.47
137.65	98.06	132.5	98.18	130	99.41	139.08	99.53
142.85	98.1	137.6	98.14	135	99.42	144.08	99.5
148.15	98.13	142.7	98.17	140	99.53	149.08	99.36
153.35	98.17	147.8	98.19	145	99.51	154.08	99.51
158.65	98.31	152.8	98.23	150	99.35	159.18	99.67
163.85	98.38	157.9	98.24	155	99.32	164.18	99.83
169.15	98.41	163	98.31	160	99.47	169.66	100.21
174.35	98.49	168.1	98.38	165	99.44		
179.65	98.51	173.2	98.44	170	99.3		
184.95	98.55	178.3	98.52	175	99.4		
190.15	98.65	183.4	98.64	180	99.59		
195.45	98.71	193.6	98.86	185	99.77		
205.95	98.9	198.7	98.98	190	100.02		
211.15	99.04	203.8	99.15	191.5	100.17		
221.65	99.29	224.33	100.12				
226.95	99.4						
232.25	99.54						
245.09	100.17						

Name: Nymai
Location: Chivi (Zimbabwe)
Full Supply Water Level: 100.13m (1999) and 98.75m (2001)

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	0.00	0.00	100.13	97.70	0.00	100.13
'L1R1'	-14.10	22.70	100.10	97.00	6.80	100.08
'L2R2'	-20.60	56.90	100.29	99.50	24.70	99.97
'L3R3'	-4.70	103.30	99.83	97.50	63.10	99.75
'L4R4'	-17.10	151.40	100.23	80.10	130.40	99.80
'L5R5'	62.60	259.90	99.95	103.00	174.80	99.60
'L6R6'	125.60	295.50	100.97	154.20	247.30	100.12
'L7R6'	125.60	295.50	99.61	150.20	298.40	99.43
'UPST'	137.00	300.00	100.13	137.00	300.00	100.13

Note:
Elevation refers to local datum of 100.13 m at the spillway for the 1999 and 2000 survey and a datum of 98.75 m for the survey 2001.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.10	0.00	100.29	-10.00	100.42	0.00	100.23
1.40	99.48	6.10	99.58	0.00	99.83	10.10	99.85
6.00	98.41	13.40	98.41	24.00	98.41	28.30	98.41
16.00	95.80	23.90	96.23	34.00	96.03	37.50	97.56
26.00	92.29	34.40	92.42	44.00	93.87	46.70	96.81
36.00	91.97	44.90	93.69	54.00	93.23	55.80	96.14
46.00	92.63	55.50	94.24	64.00	93.19	65.00	95.53
56.00	94.11	66.00	95.35	74.00	93.64	74.20	94.65
66.00	95.77	76.50	96.07	85.62	96.35	83.40	94.31
76.00	96.89	87.00	96.92	94.00	96.47	97.40	98.41
86.00	97.80	97.50	97.89	102.00	98.41	99.44	99.83
92.10	98.41	105.00	98.41	107.20	99.66		
96.20	98.96	124.40	99.99	110.00	99.74		
108.60	100.09	125.30	99.97				

L5R5		L6R6		L7R6	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
-10.00	100.72	0.00	100.97	-10.00	100.60
0.00	99.95	11.60	99.90	0.00	99.59
11.90	99.04	21.90	98.40	5.40	99.05
17.60	98.41	26.40	97.81	8.50	98.40
27.60	97.09	30.90	97.52	10.40	99.09
37.60	96.11	34.90	97.99	11.70	98.41
47.60	95.32	43.50	98.41	11.90	98.13
57.60	96.13	58.10	99.43	16.70	98.13
67.60	97.39	65.18	99.66	17.10	98.41
75.70	98.41	68.10	100.13	19.90	99.32
93.60	99.61			24.50	99.43
				54.50	100.17

Cross-sections Survey 2000

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.10	0.00	100.29	0.00	99.83	0.00	100.23
3.90	99.57	15.00	99.57	4.00	99.57	10.70	99.57
14.33	97.27	25.43	98.23	14.43	99.14	21.01	98.70
24.26	93.98	35.86	94.77	24.86	98.16	31.32	98.14
35.19	93.20	46.29	92.53	35.29	95.56	41.63	97.46
45.62	93.20	56.72	93.59	45.72	93.82	51.94	96.55
56.05	93.87	67.15	94.36	56.15	93.21	62.25	95.94
66.48	94.81	77.58	95.68	66.58	93.21	72.56	95.33
76.91	96.32	88.01	97.27	77.01	93.65	82.87	94.21
87.34	97.27	98.44	97.17	87.44	96.55	93.18	97.52
97.77	98.47	108.87	98.00	97.87	97.30	97.50	99.57
108.20	99.53	119.30	98.62	107.00	99.57	98.80	99.81
108.70	99.57	120.90	99.57	110.00	99.74		
112.90	100.08	125.30	99.97				

L5R5		L6R6		L7R6			
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.95	0.00	100.97	-0.40	99.57		
4.50	99.57	13.90	99.57	0.00	99.60		
14.68	98.23	26.72	98.87	4.09	99.17		
24.86	97.49	39.54	98.20	8.19	99.19		
35.04	96.54	58.40	99.43	12.28	99.37		
45.22	95.44	65.18	99.11	16.38	99.30		
55.40	95.84	71.60	99.57	20.47	99.47		
65.58	97.19			24.57	99.25		
75.76	98.50			24.60	99.43		
85.94	99.07			27.70	99.57		
93.10	99.57						
93.15	99.60						

Cross-sections Survey 2001

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.10	0.00	100.29	0.00	99.83	0.00	100.23
4.86	98.75	10.99	99.13	10.00	99.43	10.00	99.67
6.36	98.40	14.29	98.74	20.00	98.77	20.00	98.78
16.33	95.75	21.99	98.00	30.00	97.45	30.00	98.19
26.31	92.40	34.60	92.55	36.00	95.58	40.00	97.41
36.28	92.22	43.97	93.00	40.00	94.68	50.00	96.68
46.26	92.65	54.97	94.00	50.00	93.83	60.00	96.08
56.24	94.27	65.96	94.75	60.00	93.38	70.00	95.60
74.24	96.70	76.96	96.40	64.48	93.20	72.00	94.89
86.16	97.72	87.95	97.35	80.00	94.70	80.00	94.39
96.14	98.77	98.94	98.11	90.00	95.58	84.20	94.54
106.12	99.92	109.94	98.76	100.00	98.20	99.44	99.80
108.61	100.08	120.93	99.62	109.80	99.42		
		124.34	99.97	109.82	99.75		

L5R5		L6R6		L7R6			
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.95	0.00	100.97	0.00	99.61		
10.00	99.12	13.90	99.57	5.00	99.46		
20.00	98.10	26.72	98.86	10.00	98.81		
30.00	96.78	39.54	98.19	15.00	98.08		
40.00	96.43	58.40	99.43	20.00	99.42		
50.00	95.92	65.18	99.66	24.77	99.43		
60.00	96.81	68.01	100.12				
70.00	97.88						
80.00	98.95						
90.00	99.43						
94.20	99.60						

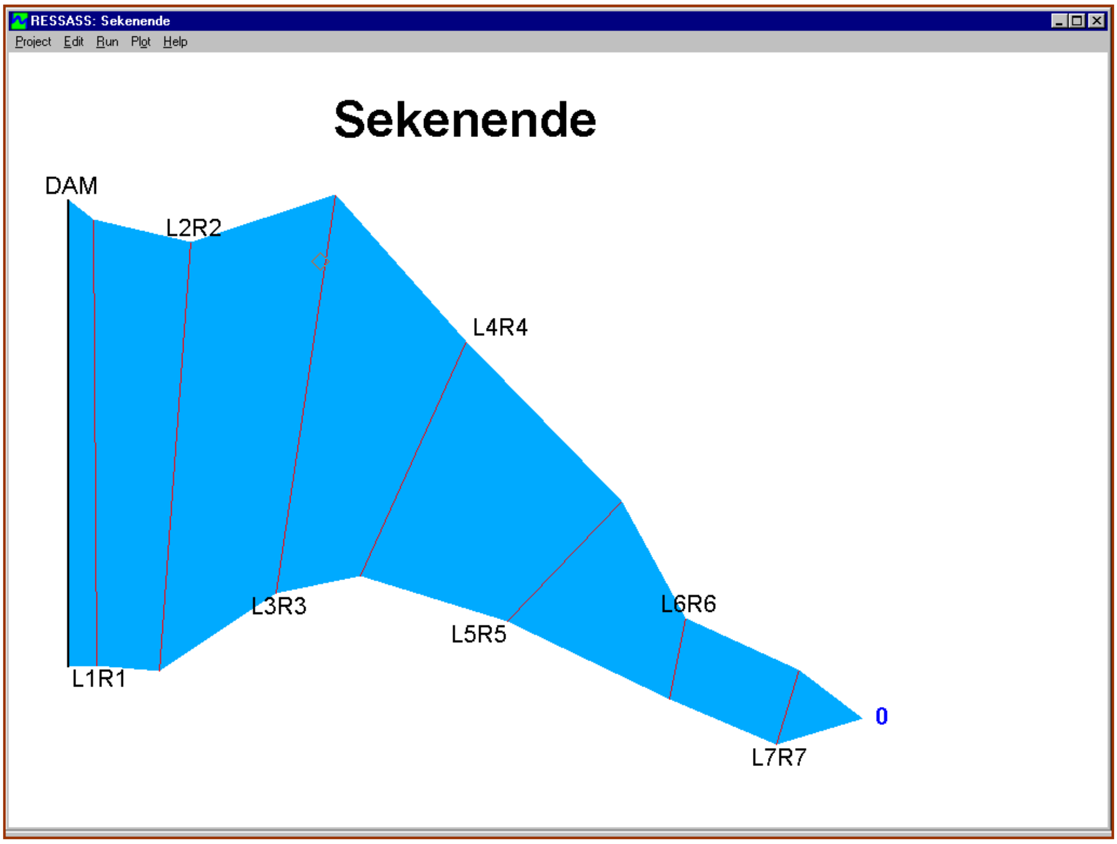
Cross-sections Survey 2002

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100.1	0	100.29	0	99.83	0	100.23
0.88	99.6	13	98.78	20.3	98.77	22.9	98.66
3.97	98.87	24.4	97.3	30.2	97.3	36.4	97.77
6.87	98.23	25	97	34.2	95.71	42.02	97.3
11.17	97.3	29.4	93.08	35.1	94.47	43.55	97.16
11.77	97.24	34.4	92.64	39.9	94.1	47.35	96.71
16.87	95.93	39.5	93.05	44.8	93.82	52.55	96.4
22.17	94.11	44.5	93.58	49.7	93.5	57.65	96.15
27.57	92.66	49.5	94.08	54.5	93.43	62.85	95.93
32.87	92.35	54.6	94.33	59.4	93.42	68.05	95.69
38.27	92.38	59.6	94.68	64.3	93.46	73.15	95.36
43.57	93.01	64.6	95.21	69.2	93.72	78.35	94.74
48.97	93.81	69.7	95.74	74	94.21	83.55	94.27
54.27	94.32	74.7	96.02	78.9	96.64	88.65	94.91
59.67	94.78	79.8	96.41	83.8	96.8	90.85	97.3
64.97	95.62	84.8	96.79	88.6	96.42	95.97	98.74
70.37	96.3	89.8	97.3	89.8	97.3	99.17	99.83
75.67	96.72	103	98.26	101.6	98.51		
81.07	97.14	111.7	98.67	109.8	99.66		
82.77	97.3	124.4	99.99				
92.87	98.65						
107.47	100.08						

L5R5		L6R6		L7R6	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	99.95	0	100.97	0	99.61
15.3	98.67	22.3	98.58	5	99.46
27.8	97.3	42.35	98.42	10	98.81
29.6	96.96	47.85	98.9	15	98.08
33.1	96.56	58.15	99.46	20	99.42
38.4	96.68			24.77	99.43
43.7	96.16				
48.9	96.03				
54.2	96.2				
59.5	96.84				
64.8	97.16				
66.9	97.3				
77.7	98.67				
94.2	99.61				

Name: Sekenende
Location: Masvingo (Zimbabwe)
Full Supply Water Level: 100.00m

Location of survey beacons



Section	Left bank point			Right bank point		
Name	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	0.00	0.00	100.00	0.00	148.00	100.00
'L1R1'	9.00	0.10	101.26	8.00	141.80	101.06
'L2R2'	28.80	-1.40	101.92	38.90	134.50	100.24
'L3R3'	66.10	23.10	101.05	84.80	149.70	100.10
'L4R4'	92.60	28.80	100.34	126.20	103.20	100.08
'L5R5'	139.30	14.30	99.99	175.60	52.40	100.35
'L6R6'	190.70	-10.30	100.19	195.90	15.40	100.26
'L7R7'	224.70	-24.90	100.26	232.00	-1.00	100.46
'UPST'	252.10	-16.60	100.00	252.10	-16.60	100.00

Note:
Elevation refers to local datum of 100.00 m at the spillway.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.28	0.00	101.89	0.00	101.07	0.00	100.36
21.00	99.83	20.60	100.54	24.00	99.92	13.80	99.11
40.20	98.96	57.60	99.11	27.40	99.11	19.10	98.15
45.20	98.86	62.03	98.74	32.70	98.09	24.40	97.96
50.20	98.64	67.37	98.05	38.00	97.61	29.70	96.72
55.20	98.45	72.70	98.14	43.20	97.56	35.00	97.44
60.30	98.30	78.03	97.86	48.50	96.24	41.10	99.19
65.30	98.04	83.37	97.46	53.80	97.01	45.60	98.94
70.30	97.84	88.70	95.84	59.10	97.83	55.60	99.11
75.30	97.52	94.03	95.76	64.30	98.09	64.10	99.55
80.30	97.08	99.37	97.75	69.60	98.19	81.64	100.08
85.30	97.09	104.70	97.90	74.90	98.35		
90.30	96.81	110.03	97.95	80.20	98.60		
95.30	97.17	115.37	98.11	85.50	98.97		
100.40	97.28	120.70	98.31	90.70	98.54		
105.40	97.41	126.03	98.64	99.00	97.30		
110.40	97.62	128.70	99.11	101.30	98.31		
115.40	98.09	129.30	99.69	104.10	99.11		
120.40	98.30	136.10	100.16	105.70	99.59		
125.40	98.76			127.30	100.10		
130.40	99.10						
131.60	99.11						
137.20	99.93						
142.20	101.07						

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.99	0.00	100.19	0.00	100.26
1.50	99.86	6.00	99.11	6.70	99.11
11.85	98.53	9.80	97.86	9.00	98.53
23.80	97.35	11.70	97.88	11.40	98.25
28.70	97.95	13.60	98.26	13.70	98.42
30.10	99.11	15.50	99.11	16.00	98.72
36.00	99.58	26.20	100.26	18.40	98.82
42.90	99.55			20.70	98.61
52.80	100.36			21.40	99.11
				24.90	100.46

Cross-sections Survey 2000

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.27	0.00	101.89	0.00	101.06	0.00	100.35
19.50	99.86	34.70	99.86	25.00	99.86	6.50	99.86
30.05	99.41	45.11	99.33	35.41	97.86	16.87	98.82
40.59	98.96	55.52	99.03	45.82	96.60	27.24	97.93
51.14	98.36	65.93	98.51	56.23	97.36	37.61	98.36
61.68	98.11	76.34	97.86	66.64	98.10	47.98	99.10
72.23	97.64	86.75	96.06	77.05	98.36	58.35	99.06
82.78	97.13	97.16	97.26	87.46	98.86	68.72	99.76
93.33	96.80	107.57	97.86	97.87	97.26	79.09	99.81
103.87	97.35	117.98	98.06	108.28	99.83	79.90	99.86
114.42	97.82	128.39	99.64	111.60	99.86	81.40	100.08
124.97	98.66	129.80	99.86	126.60	100.10		
135.51	99.29	134.50	100.17				
138.10	99.86						
141.20	101.07						

L5R5		L6R6		L7R7			
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	99.99	0.00	100.20	0.00	100.27		
1.50	99.86	3.60	99.86	3.70	99.86		
11.85	98.53	8.48	98.18	8.93	98.78		
22.20	97.39	13.36	98.19	14.16	98.56		
32.55	99.63	18.24	99.59	19.39	98.83		
42.90	99.57	21.60	99.86	23.60	99.86		
44.90	99.86	26.20	100.26	24.90	100.46		
52.50	100.36						

Cross-sections Survey 2001

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	101.26	0.00	101.92	0.00	101.05	0.00	100.34
10.74	100.44	10.46	100.92	10.00	100.58	10.39	99.52
21.49	99.81	20.92	100.56	20.00	100.11	12.46	99.26
32.23	99.34	31.38	100.08	23.92	99.93	16.46	98.60
34.38	99.26	41.83	99.63	26.30	99.26	20.01	98.11
42.97	98.99	52.29	99.37	30.00	98.22	29.98	96.72
53.72	98.53	54.59	99.34	40.00	97.54	40.84	99.17
64.46	98.24	62.75	98.85	43.07	97.59	50.76	99.12
75.20	97.67	73.21	98.30	44.69	97.08	59.06	99.33
85.94	97.04	83.67	97.50	50.00	96.58	61.14	99.66
96.69	97.19	88.50	96.01	60.00	98.06	71.53	99.70
107.43	97.54	94.12	96.00	70.00	98.14	81.40	100.08
118.17	98.27	100.04	97.78	77.40	98.44		
128.92	98.89	115.04	98.33	85.78	99.03		
134.29	99.35	125.50	99.00	99.35	97.26		
142.08	101.06	127.59	99.40	104.90	99.28		
		136.27	100.24	105.38	99.60		
				110.00	99.72		
				120.00	99.95		
				127.90	100.10		

L5R5		L6R6		L7R7			
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.14	99.99	0.00	100.19	0.00	100.26		
7.38	99.29	5.72	99.31	8.27	99.31		
10.48	98.56	10.40	97.94	10.33	98.54		
23.79	97.39	13.73	98.63	20.66	99.00		
31.00	99.29	15.21	98.97	20.87	99.30		
41.34	99.35	15.57	99.13	24.90	100.46		
51.67	100.21	17.16	99.31				
52.60	100.35	20.79	99.78				
		26.20	100.26				

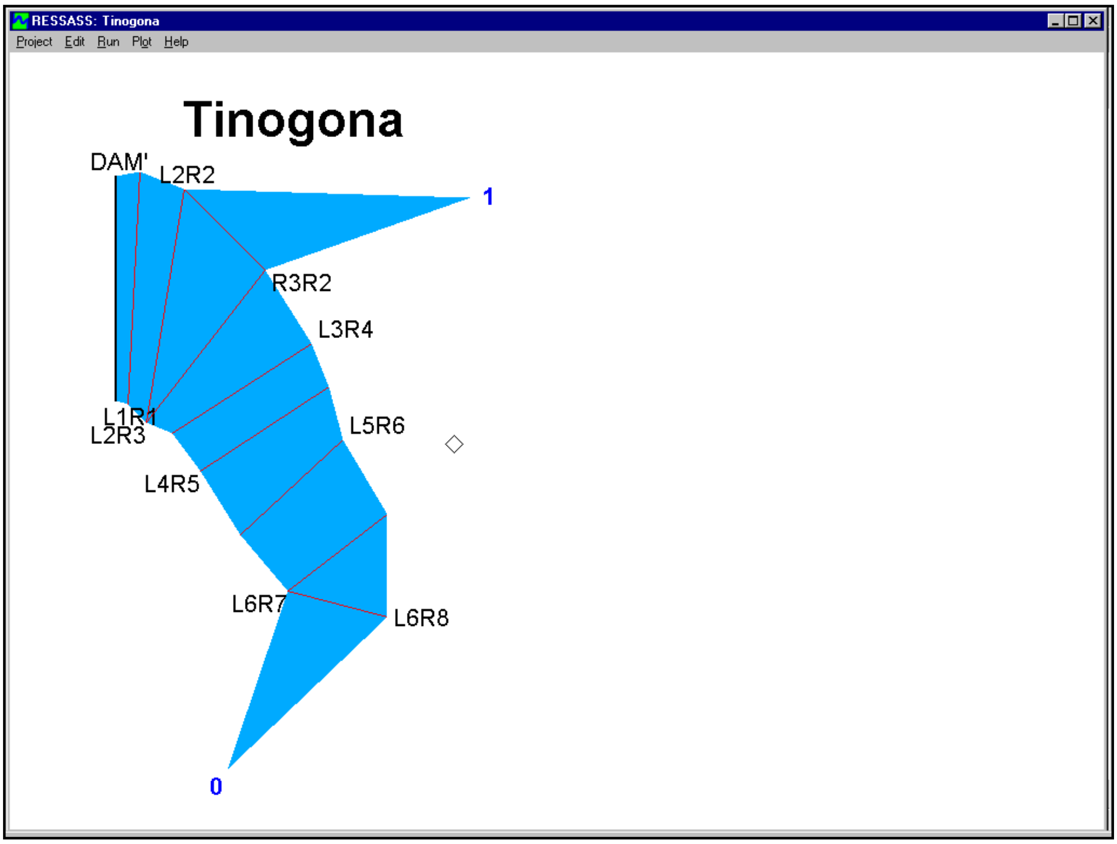
Cross-sections Survey 2002

L1R1		L2R2		L3R3		L4R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
18.14	100	39.59	100	0	101.08	2.83	100
20.24	99.85	44.59	99.7	23.92	99.91	5.23	99.85
25.24	99.62	49.59	99.6	28.69	98.9	10.23	99.51
30.24	99.5	54.59	99.41	33.69	97.95	15.23	98.81
35.24	99.28	59.59	99.21	38.69	97.46	20.23	98.01
40.24	99.13	64.59	98.95	43.69	97.77	25.23	97.87
45.24	98.93	69.59	98.45	48.69	96.52	30.23	96.83
50.24	98.68	74.59	98.08	53.69	97.14	35.23	98.67
55.24	98.49	79.59	97.55	58.69	98.05	40.23	99.18
60.24	98.3	84.59	97.61	63.69	98.23	45.23	99.08
65.24	98.08	89.59	96.51	68.69	98.25	50.23	99.13
70.24	97.93	94.59	95.8	73.69	98.39	55.23	99.17
75.24	97.48	99.59	97.91	78.69	98.67	60.23	99.6
80.24	97.08	104.59	97.91	85.96	99.04	65.23	99.78
85.24	97.13	109.59	98.03	90.96	98.78	70.23	99.68
90.24	96.89	114.59	98.2	98.88	97.3	75.23	99.8
95.24	97.22	119.59	98.46	100.96	98.33	78.03	100
100.24	97.34	124.59	98.98	105.96	99.6		
105.24	97.49	128.79	100	110.96	99.75		
110.24	97.7			127.32	100.09		
115.24	98.1						
120.24	98.62						
125.24	98.78						
130.24	99.02						
135.24	99.79						
135.84	100						

L5R5		L6R6		L7R7	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100	0.21	100.16	0	100.26
5	99.58	3.93	99.7	3.51	99.81
10	98.81	6.36	98.98	8.51	98.87
15	98.38	8.93	98.09	13.51	98.73
20	97.69	13.93	98.45	18.51	99.23
25	97.8	18.93	99.66	23.37	100.04
29.43	98.5			24.8	100.44
29.58	99.09				
36.42	99.66				
42.83	99.53				
47.03	100.14				

Name: Tinogona
Location: Mwenezi (Zimbabwe)
Full Supply Water Level: 100.00m

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM'	0.00	0.00	100.00	0.00	222.00	100.00
'L1R1'	12.13	-3.02	100.39	23.68	225.76	100.43
'L2R2'	29.53	-21.11	100.15	66.98	208.51	100.29
'TR_R'	0.00	0.00	100.00	0.00	0.00	100.00
'L2R3'	29.53	-21.11	100.15	147.04	128.54	100.25
'L3R4'	55.26	-32.09	99.93	192.45	56.81	100.79
'L4R5'	82.60	-69.82	100.19	209.48	14.16	99.90
'L5R6'	122.48	-132.70	99.87	223.91	-38.93	100.00
'L6R7'	169.83	-187.49	99.67	267.85	-112.40	99.74
'L6R8'	169.83	-187.49	99.67	267.20	-213.40	99.80
'UPST'	109.33	-363.69	100.00	0.00	0.00	100.00
'R3R2'	147.04	128.54	100.26	66.98	208.51	100.29
'UPST'	350.00	200.00	100.1	350.00	200.00	100.00

Note:
Elevation refers to local datum of 100.00 m at the spillway.
Location refers to the left bank of the dam (0, 0).

Cross-sections Survey 1999

L1R1		L2R2		L2R3		L3R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.40	0.00	100.15	0.00	100.15	0.00	99.93
7.60	100.48	63.00	97.83	19.50	99.34	13.10	99.82
14.20	99.74	73.10	97.31	47.50	97.83	36.40	97.83
82.70	98.27	83.20	95.44	57.75	97.33	46.69	97.22
114.70	97.83	93.30	95.44	68.00	96.66	56.97	96.65
124.67	97.22	103.40	95.86	78.25	95.75	67.26	96.13
134.63	96.69	113.50	96.59	88.50	96.83	77.55	97.48
144.60	96.25	123.59	96.53	98.75	96.63	87.83	97.59
154.56	94.94	133.69	95.83	109.00	96.76	98.12	97.67
164.53	95.18	143.79	95.78	119.25	96.80	108.20	97.83
174.49	95.28	153.89	96.00	129.50	96.75	130.54	98.37
184.46	95.83	163.99	95.62	139.75	97.16	140.58	98.75
194.42	97.48	174.09	95.82	150.00	97.51	160.66	99.76
200.70	97.83	184.19	95.01	160.25	97.82	163.50	100.79
217.60	98.68	194.29	95.31	160.50	97.83		
220.70	100.43	204.39	97.25	190.50	100.25		
		209.00	97.83				
		224.90	100.29				

L4R5		L5R6		L6R7		L6R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.20	0.00	99.87	0.00	99.67	0.00	99.67
23.60	98.85	34.60	98.27	22.60	99.17	25.80	99.33
38.60	97.83	43.80	97.83	34.90	98.97	48.20	98.83
44.30	96.96	49.09	97.28	56.00	98.32	56.80	98.24
49.99	96.11	54.38	96.84	76.10	98.25	59.70	97.83
55.69	96.14	59.66	96.54	76.60	97.83	64.00	97.83
61.38	97.05	64.95	97.27	80.10	96.93	71.80	98.42
67.08	97.36	70.24	97.46	90.60	97.83	96.20	99.31
72.78	97.46	75.53	97.60	93.60	98.19	100.50	99.82
78.47	97.63	80.82	97.77	112.70	99.34		
84.17	97.72	81.80	97.83	124.60	99.77		
89.87	97.81	89.80	98.21				
93.10	97.83	108.80	98.81				
135.60	99.16	137.80	100.02				
153.10	99.90						

Cross-sections Survey 1999 continued	
R3R2	
Chainage (m)	Elevation (m)
0.00	100.26
10.00	98.96
32.40	97.83
42.84	96.58
48.06	96.34
58.50	95.70
63.71	95.71
74.15	95.74
84.59	96.33
95.03	97.25
102.00	97.83
105.80	98.46
110.50	100.29

Cross-sections Survey 2000							
L1R1		L2R2		L2R3		L3R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.39	0.00	100.15	0.00	100.15	0.00	99.93
28.50	99.19	24.00	99.19	23.00	99.19	11.98	99.86
38.67	99.14	34.29	98.90	33.73	98.58	20.50	99.19
48.84	98.80	44.58	98.87	44.46	98.09	30.86	98.24
59.01	98.71	54.87	98.94	55.19	97.27	41.22	97.54
69.18	98.71	65.16	98.09	65.92	96.67	51.58	96.81
79.35	98.30	75.45	98.30	76.65	95.85	61.94	95.99
89.52	98.23	85.74	95.84	87.38	96.83	72.30	97.26
99.69	98.11	96.03	97.09	98.11	96.63	82.66	97.50
109.86	98.03	106.32	97.07	108.84	96.52	93.02	97.59
120.03	97.29	116.61	96.70	114.12	96.78	103.38	97.70
130.20	97.07	126.90	96.58	124.85	96.68	113.74	97.88
140.37	96.42	137.19	95.91	135.58	96.95	124.10	98.22
150.54	96.03	147.48	95.91	146.31	97.24	134.46	98.54
160.71	95.14	157.77	96.32	157.04	97.64	144.82	99.05
170.88	95.29	168.06	95.49	167.77	98.29	148.00	99.19
181.05	95.39	174.78	96.43	174.55	99.19	163.50	100.79
191.22	96.49	180.60	94.99	190.00	100.25		
201.39	97.54	190.89	95.49				
211.56	98.36	201.18	97.08				
220.40	99.19	211.47	97.99				
221.07	100.43	219.96	99.19				
		224.96	100.29				

Cross-sections Survey 2000

L4R5		L5R6		L6R7		L6R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.19	0.00	99.87	0.00	99.67	0.00	99.67
22.40	99.19	12.60	99.19	20.30	99.19	36.50	99.19
32.77	98.42	23.12	98.71	30.94	98.98	46.94	98.91
45.17	96.78	33.64	98.29	41.58	98.83	57.38	98.53
53.51	96.44	44.16	97.82	52.22	98.38	67.82	98.06
63.88	97.30	54.68	96.96	62.86	98.32	78.26	98.64
74.25	97.52	65.20	97.14	73.50	98.20	88.70	99.02
84.62	97.71	75.72	97.56	84.14	97.44	95.50	99.19
94.99	97.85	86.24	97.99	94.78	98.35	102.00	99.80
105.36	98.08	96.76	98.38	105.42	99.08		
115.73	98.35	107.28	98.60	108.00	99.19		
126.10	98.56	117.80	99.08	124.00	99.74		
136.47	98.99	120.90	99.19				
139.40	99.19	137.60	100.00				
153.00	99.90						

R3R2	
Chainage (m)	Elevation (m)
0.00	100.26
12.80	99.19
13.33	98.54
23.96	98.08
34.59	97.28
45.22	96.19
55.85	94.89
66.48	95.45
77.11	95.59
87.74	96.35
98.37	97.36
107.71	99.19
110.44	100.29

Cross-sections Survey 2001

L1R1		L2R2		L2R3		L3R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.39	0.00	100.15	0.00	100.15	0.00	99.93
10.38	100.18	10.60	99.88	9.89	99.78	10.04	99.92
20.76	99.40	21.20	99.40	19.79	99.43	20.08	99.23
31.14	99.06	31.80	98.96	28.99	98.95	22.69	98.94
41.52	99.07	33.07	98.95	29.68	98.89	30.12	98.04
45.98	98.95	42.46	98.85	39.58	98.34	40.16	97.47
51.98	98.75	53.00	99.02	49.47	97.54	50.21	97.16
62.28	98.69	63.59	98.59	59.37	96.75	60.25	96.07
72.65	98.62	74.19	98.57	69.26	96.57	70.29	95.93
83.03	98.24	84.79	97.77	79.16	95.79	80.33	97.41
93.41	98.29	95.39	97.39	89.05	96.74	90.37	97.52
103.79	98.21	105.99	97.38	98.95	96.70	100.41	97.62
114.17	97.88	116.59	97.04	108.84	96.69	110.45	97.81
124.55	97.17	127.19	96.64	118.74	96.41	120.98	98.04
134.93	96.72	137.79	96.04	138.53	96.73	130.54	98.37
145.31	96.19	148.39	95.64	148.42	97.24	140.58	98.75
155.69	95.56	158.99	95.89	158.32	97.49	143.79	98.94
166.07	94.84	169.59	95.36	168.21	97.95	150.62	99.32
176.45	95.21	180.18	95.47	178.11	98.95	160.66	99.76
186.83	95.45	190.78	94.63	188.00	100.05	163.47	100.79
197.21	97.08	201.38	95.64	190.28	100.25		
207.58	97.89	211.98	97.24				
217.96	98.82	222.58	98.24				
218.90	98.93	226.29	98.93				
221.07	100.43	232.65	100.29				

L4R5		L5R6		L6R7		L6R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	100.19	0.00	99.87	0.00	99.67	0.00	99.67
10.39	99.65	10.80	99.28	10.33	99.37	10.28	99.45
20.77	99.04	18.68	98.87	20.67	99.24	20.57	99.39
22.74	98.93	21.60	98.90	31.00	98.98	30.85	99.28
31.16	98.27	32.40	98.36	35.75	98.91	41.13	99.05
41.54	97.55	43.20	97.95	41.33	98.66	46.27	98.90
51.93	95.93	54.00	97.11	51.67	98.38	51.41	98.72
62.31	97.11	64.80	97.32	62.00	98.39	61.70	97.81
72.70	97.49	75.60	97.60	72.33	98.34	71.98	98.48
83.09	97.71	86.40	98.06	82.66	97.48	82.26	98.90
93.47	97.85	97.20	98.34	93.00	98.23	92.54	99.14
103.86	98.13	108.00	98.75	102.30	98.91	100.77	99.80
114.24	98.32	111.02	98.87	103.33	98.99		
124.63	98.62	118.80	99.11	113.66	99.47		
131.17	98.93	129.60	99.51	123.48	99.74		
135.01	99.09	138.13	100.00				
145.40	99.57						
152.15	99.90						

Cross-sections Survey 2001 continued

R3R2	
Chainage (m)	Elevation (m)
0.00	100.26
10.09	99.99
10.89	98.93
20.17	98.31
30.26	97.89
40.34	96.86
50.43	96.00
60.51	95.51
70.60	95.61
80.68	95.91
90.77	96.86
100.86	97.79
105.90	98.94
113.16	100.29

Cross-sections Survey 2002

L1R1		L2R2		L2R3		L3R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100.39	0	100.15	0	100.15	0	99.93
20	99.41	20	99.42	20	99.33	20	99.29
40	99.1	39.82	98.93	40	98.42	32	98.23
60	98.73	64.92	98.31	45.3	98.23	35.7	97.92
80	98.33	70.8	98.14	48.1	97.83	40.7	97.63
100	98.13	81.59	96.8	53.1	97.56	45.7	97.28
108	98.23	86.59	96.67	58.1	97.37	50.7	96.95
111.4	97.98	91.59	97.55	63.1	96.86	55.7	96.78
116.4	97.7	96.59	97.69	68.1	96.77	60.7	96.15
121.4	97.35	101.59	97.41	73.1	96.57	65.7	96.06
126.4	97.17	106.59	97.27	78.1	95.84	70.7	97.23
131.4	97.62	111.59	97.04	83.1	96.59	75.7	97.43
136.4	96.68	116.59	96.85	88.1	96.9	80.7	97.55
141.4	96.43	121.59	96.74	93.1	96.84	85.7	97.59
146.4	96.15	126.59	96.56	98.1	96.78	90.7	97.62
151.4	95.84	131.59	96.16	103.1	96.83	95.7	97.68
156.4	94.98	136.59	96.06	108.1	96.8	100.7	97.72
161.4	94.98	141.59	95.93	113.1	96.84	105.7	97.82
166.4	95.3	146.59	95.97	118.1	96.87	110.7	97.93
171.4	95.36	151.59	95.9	123.1	96.58	115.7	98.08
176.4	95.36	156.59	95.75	128.1	96.85	120.7	98.15
181.4	95.45	161.59	95.6	133.1	96.88	124.1	98.23
186.4	96.01	166.59	95.58	138.1	97.17	163.5	99.96
191.4	96.99	171.59	96.01	143.1	97.24		
196.4	97.42	176.59	95.62	148.1	97.88		
201.4	97.8	181.59	98.26	153.1	98.26		
206.4	98.16	186.59	98.5	158.1	98.5		
207.1	98.23	191.59	98.6	163.1	98.6		
229.1	100.47	196.59	98.84	166.9	99.71		

Cross-sections Survey 2002 continued

L1R1		L2R2		L2R3		L3R4	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
		201.59	99.16	190.3	100.26		
		206.59	99.34				
		216.59	99.62				
		263.99	100.29				

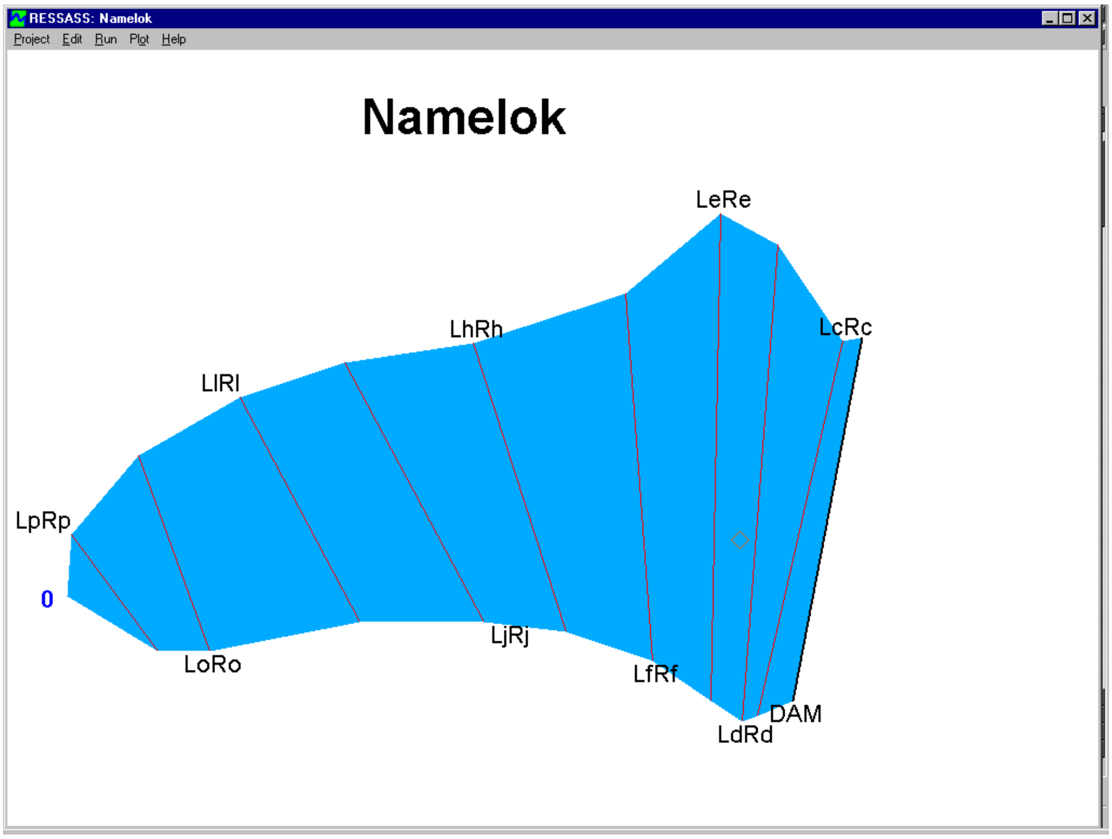
L4R5		L5R6		L6R7		L6R8	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0	100.19	0	99.87	0	99.67	0	99.67
10.39	99.65	20	98.83	20	99.21	10	99.46
20.77	99.04	36.4	98.23	40	98.73	20	99.4
22.74	98.93	41.4	98	64.8	98.23	30	99.3
31.16	98.27	46.4	97.74	66.1	98	40	99.08
41.54	97.55	51.4	97.2	71.1	97.76	50	98.81
51.93	95.93	59.38	96.56	76.1	97.38	55	98.64
62.31	97.11	61.4	96.85	81.1	97.54	60	97.91
72.7	97.49	66.4	97.39	86.1	97.95	65	98.02
83.09	97.71	71.4	97.58	88.3	98.23	70	98.36
93.47	97.85	76.4	97.69	123.5	99.76	80	98.81
103.86	98.13	81.4	97.87			90	99.02
114.24	98.32	86.4	98.13			100.8	99.82
124.63	98.62	88.9	98.23				
131.17	98.93	138.1	100.02				
135.01	99.09						
145.4	99.57						
152.15	99.9						

R3R2	
Chainage (m)	Elevation (m)
0	100.26
19	98.23
20.8	97.94
25.8	97.57
30.8	97.12
35.8	96.57
40.8	96.18
45.8	95.92
50.8	95.84
55.8	95.79
60.8	95.78
65.8	95.63
70.8	96.11
75.8	96.49
80.8	96.84
85.8	97.48
90.8	97.85
95.8	98.15
98.8	98.23
113.2	100.26

Annex 2b Kiteto Dams Survey Results

Name: Namelok
Location: Kiteto (Tanzania)
Full Supply Water Level: 1488.50 masl

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	229020	9399465	1448.50	228950	9399100	1448.50
'LcRc'	229000	9399462	1448.50	228915	9399085	1448.50
'LdRd'	228935	9399559	1448.50	228899	9399080	1448.50
'LeRe'	228878	9399590	1448.50	228868	9399100	1448.50
'LfRf'	228782	9399510	1448.50	228809	9399140	1448.50
'LhRh'	228629	9399460	1448.50	228722	9399170	1448.50
'LjRj'	228500	9399440	1448.50	228640	9399180	1448.50
'LlRl'	228394	9399405	1448.50	228515	9399180	1448.50
'LoRo'	228292	9399347	1448.50	228364	9399150	1448.50
'LpRp'	228225	9399268	1448.50	228311	9399150	1448.50
'UPST'	228220	9399205	1448.50	228220	9399205	1448.50

Note: Elevation refers to sea level.
Location refers to UTM grid zone 37.

Cross-sections Survey 1954

LcRc		LdRd		LeRe		LfRf	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
36.00	1484.50	36.00	1486.30	6.00	1486.00	28.00	1487.00
43.00	1484.90	38.00	1486.00	28.00	1484.90	35.00	1486.80
66.00	1483.70	63.00	1484.30	58.00	1483.00	69.00	1485.00
96.00	1482.00	96.00	1482.20	82.00	1481.90	91.00	1483.20
116.00	1480.80	123.00	1480.90	105.00	1481.30	142.00	1481.80
140.00	1480.20	163.00	1480.40	160.00	1481.20	178.00	1481.80
190.00	1480.30	210.00	1481.20	184.00	1481.70	234.00	1482.80
236.00	1481.80	236.00	1482.00	220.00	1482.30	272.00	1483.90
290.00	1483.50	276.00	1482.90	286.00	1484.40	318.00	1485.70
346.00	1485.50	316.00	1483.90	340.00	1485.70		
384.00	1486.80	350.00	1485.00	370.00	1486.80		
		392.00	1486.20				
		416.00	1486.80				

LhRh		LjRj		LlRl		LoRo	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
28.00	1486.80	12.00	1486.90	12.00	1487.70	28.00	1488.20
40.00	1486.00	33.00	1486.10	40.00	1486.10	37.50	1487.80
64.00	1484.50	59.00	1484.80	59.00	1485.40	53.00	1487.20
91.00	1483.30	85.00	1483.70	91.00	1484.70	73.00	1486.50
124.00	1482.80	114.00	1483.60	134.00	1484.60	96.00	1485.90
158.00	1482.90	152.00	1483.60	165.00	1484.80	145.00	1486.30
214.00	1484.20	202.00	1484.70	209.00	1485.90	194.00	1486.80
254.00	1485.80	229.00	1485.80			210.00	1487.50
268.00	1486.30						

LpRp	
Chainage (m)	Elevation (m)
36.00	1488.00
65.00	1487.20
72.00	1487.20
80.00	1487.10
100.00	1487.10
111.00	1487.20
127.00	1487.30
147.00	1487.50
201.00	1488.20

Cross-sections Survey 2001

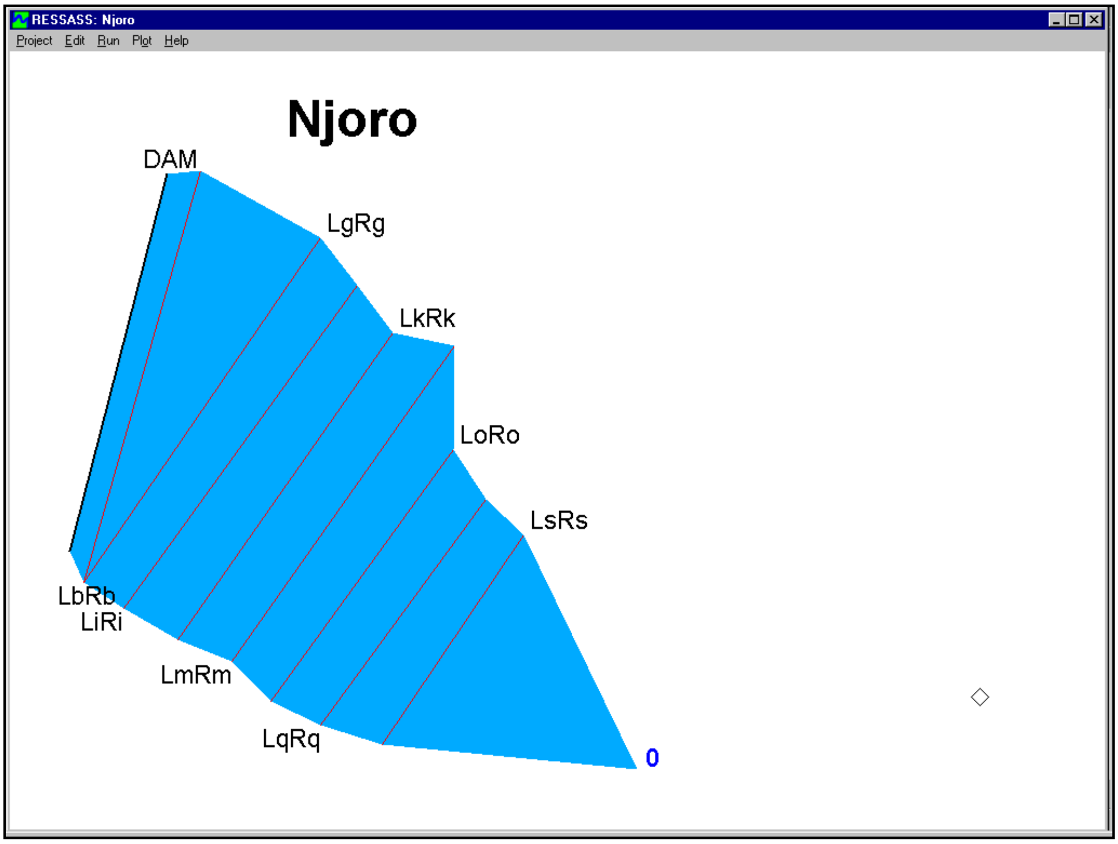
LcRc		LdRd		LeRe		LfRf	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	1488.50	0.00	1488.50	0.00	1488.50	0.00	1488.50
20.00	1488.00	20.00	1488.00	16.00	1488.00	12.00	1488.00
36.00	1487.24	36.00	1486.94	28.00	1485.23	28.00	1487.36
43.00	1486.76	38.00	1486.76	58.00	1483.47	35.00	1486.77
66.00	1485.42	63.00	1485.07	82.00	1482.81	69.00	1485.02
96.00	1484.16	96.00	1483.30	105.00	1482.52	91.00	1483.87
116.00	1484.46	123.00	1482.41	160.00	1482.51	142.00	1482.76
140.00	1484.06	163.00	1482.21	184.00	1482.29	178.00	1482.76
190.00	1485.14	210.00	1482.41	220.00	1482.69	234.00	1483.93
236.00	1485.24	236.00	1482.41	286.00	1484.29	272.00	1484.77
290.00	1485.08	276.00	1482.76	340.00	1486.06	318.00	1486.76
346.00	1485.58	316.00	1483.22	370.00	1486.75	350.00	1488.00
384.00	1486.73	350.00	1483.51	418.00	1488.00	366.00	1488.50
435.00	1488.50	392.00	1485.07	446.00	1488.50		
		416.00	1486.71				
		432.00	1488.50				

LhRh		LjRj		LlRl		LoRo	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	1488.50	0.00	1488.50	0.00	1488.50	0.00	1488.50
12.00	1488.00	12.00	1488.03	12.00	1488.33	16.00	1488.00
28.00	1487.38	33.00	1486.85	40.00	1486.82	28.00	1487.22
40.00	1486.79	59.00	1485.51	59.00	1486.18	37.50	1486.79
64.00	1485.49	85.00	1484.56	91.00	1485.43	53.00	1486.44
91.00	1484.23	114.00	1484.56	134.00	1485.38	73.00	1486.75
124.00	1483.61	152.00	1484.45	165.00	1485.75	96.00	1487.20
158.00	1483.97	202.00	1485.94	209.00	1486.84	145.00	1487.33
214.00	1484.73	229.00	1486.87	237.00	1488.00	194.00	1488.02
254.00	1486.16	257.00	1488.00	253.00	1488.50	210.00	1488.82
268.00	1486.75	277.00	1488.50				
292.00	1488.00						
304.00	1488.50						

LpRp	
Chainage (m)	Elevation (m)
0.00	1488.50
36.00	1487.92
65.00	1487.34
72.00	1486.76
80.00	1487.09
100.00	1487.54
111.00	1487.24
127.00	1487.69
147.00	1488.27
201.00	1488.90

Name: Njoro
Location: Kiteto (Tanzania)
Full Supply Water Level: 1501.14 masl

Location of survey beacons



Section Name	Left bank point			Right bank point		
	East (m)	North (m)	Elevation (m)	East (m)	North (m)	Elevation (m)
'DAM	217550	9421350	1501.14	217618	9421613	1501.14
'LbRb'	217560	9421328	1501.24	217641	9421615	1501.14
'LgRg'	217560	9421328	1502.13	217725	9421568	1501.14
'LiRi'	217588	9421310	1501.14	217750	9421535	1501.14
'LkRk'	217625	9421288	1501.16	217775	9421502	1501.14
'LmRm'	217663	9421273	1501.70	217818	9421493	1501.14
'LoRo'	217690	9421245	1501.14	217817	9421421	1501.14
'LqRq'	217725	9421229	1501.19	217840	9421386	1501.14
'LsRs'	217768	9421215	1501.31	217866	9421361	1501.53
'UPST'	217945	9421198	1501.14	217945	9421198	1501.14

Note:
Elevation refers to sea level.
Location refers to UTM grid zone 37.

Cross-sections Survey 1976

LbRb		LgRg		LiRi		LkRk	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	1501.24	0.00	1502.13	0.00	1501.14	0.00	1501.16
20.00	1499.91	20.00	1499.88	94.00	1495.37	80.00	1496.72
40.00	1498.58	40.00	1498.32	104.00	1495.25	90.00	1496.15
110.00	1495.38	80.00	1496.01	114.00	1494.75	100.00	1495.66
120.00	1495.26	90.00	1495.59	124.00	1494.74	110.00	1495.83
130.00	1494.42	100.00	1495.20	134.00	1495.25	225.00	1501.14
140.00	1493.70	110.00	1494.78	144.00	1495.84		
150.00	1493.89	120.00	1493.81	214.00	1500.25		
160.00	1494.31	130.00	1493.91	229.00	1501.14		
170.00	1494.68	140.00	1493.95				
180.00	1495.88	150.00	1494.82				
190.00	1496.32	160.00	1495.56				
280.00	1501.14	170.00	1496.45				
		240.00	1501.14				

LmRm		LoRo		LqRq		LsRs	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	1501.70	0.00	1501.14	0.00	1501.19	0.00	1501.31
65.00	1497.15	2.00	1500.99	10.00	1500.48	26.00	1499.44
75.00	1496.79	22.00	1499.74	30.00	1499.05	31.00	1498.84
85.00	1497.48	34.00	1498.26	36.00	1498.61	33.00	1499.05
95.00	1497.28	42.00	1497.97	45.00	1498.77	57.00	1499.17
105.00	1497.25	52.00	1498.20	69.00	1499.34	80.00	1499.91
115.00	1497.23	112.00	1498.93	84.00	1499.63	106.00	1500.26
120.00	1497.32	132.00	1499.31	108.00	1499.69	133.00	1500.63
135.00	1498.01	152.00	1499.74	143.00	1500.12	163.00	1501.53
155.00	1498.52	172.00	1500.06	163.00	1500.76		
175.00	1499.55	192.00	1501.00	175.00	1501.14		
195.00	1501.05	194.00	1501.14				
215.00	1500.38						
230.00	1501.14						

Cross-sections Survey 2001

LbRb		LgRg		LiRi		LkRk	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	1501.24	0.00	1502.13	0.00	1501.14	0.00	1501.16
20.00	1499.91	20.00	1499.88	4.00	1500.96	20.00	1500.16
40.00	1498.58	40.00	1498.32	24.00	1500.04	40.00	1499.14
60.00	1497.86	60.00	1497.31	44.00	1499.16	60.00	1498.04
80.00	1497.31	80.00	1496.51	64.00	1497.69	80.00	1497.22
100.00	1496.92	90.00	1496.39	84.00	1496.73	90.00	1497.15
120.00	1496.66	100.00	1496.45	88.00	1496.52	100.00	1496.96
140.00	1496.66	110.00	1496.41	94.00	1496.37	110.00	1497.03
160.00	1497.16	120.00	1496.41	104.00	1496.55	120.00	1497.19
180.00	1497.92	130.00	1496.41	114.00	1496.55	130.00	1497.40
200.00	1498.29	140.00	1496.39	124.00	1496.54	150.00	1498.24
220.00	1498.79	150.00	1496.42	134.00	1496.55	170.00	1499.07
240.00	1499.35	160.00	1496.36	144.00	1496.44	190.00	1499.95
260.00	1500.11	170.00	1496.53	148.00	1496.51	210.00	1500.68
280.00	1501.14	180.00	1497.08	154.00	1496.84	225.00	1501.14
		200.00	1498.43	174.00	1498.11		
		240.00	1501.14	194.00	1499.40		
				214.00	1500.25		
				229.00	1501.14		

LmRm		LoRo		LqRq		LsRs	
Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)	Chainage (m)	Elevation (m)
0.00	1501.70	0.00	1501.14	0.00	1501.19	0.00	1501.31
15.00	1500.65	2.00	1500.99	10.00	1500.48	26.00	1499.44
35.00	1499.38	22.00	1499.74	30.00	1499.05	31.00	1498.84
55.00	1497.90	34.00	1498.26	36.00	1498.61	33.00	1499.05
65.00	1497.85	42.00	1498.27	45.00	1498.77	57.00	1499.17
75.00	1497.59	52.00	1498.50	69.00	1499.34	80.00	1499.91
79.00	1497.83	62.00	1498.76	84.00	1499.63	106.00	1500.26
85.00	1497.98	72.00	1499.08	108.00	1499.69	133.00	1500.63
95.00	1497.78	92.00	1499.22	143.00	1500.12	163.00	1501.53
105.00	1497.75	112.00	1498.93	163.00	1500.76		
115.00	1497.73	132.00	1499.31	175.00	1501.14		
120.00	1497.82	152.00	1499.74				
135.00	1498.51	172.00	1500.06				
155.00	1499.02	192.00	1501.00				
175.00	1499.55	194.00	1501.14				
195.00	1501.05						
215.00	1500.38						
230.00	1501.14						

Annex 3 Catchment Characterisation

A3.1 Introduction

As part of the procedure to estimate sediment yields, a catchment characterisation procedure was developed for small dam sites, appropriate for application in Southern Africa. The system was developed with collaborators in Masvingo Province, Zimbabwe, and on the Masai Steppe in Tanzania. It allows an assessment of the erosion hazard in a catchment, based on a visual inspection.

A3.2 Catchment Characterisation

The ability to carry out a qualitative assessment of the erosion status of a catchment using visual indicators can provide a powerful assessment tool. Advantages of the approach include:

It is based on readily observable features;

It is straight-forward and simple to apply by non-specialist staff;

It does not require specialist skills or equipment;

It requires minimal time and resource input – a typical catchment can be characterised in a day.

However there are some disadvantages. Results from a catchment characterisation procedure provide an assessment of the erosion status of a catchment at a specific time. Catchment conditions vary over time, and the results cannot in theory be used to predict either past or future rates of soil erosion. Soil erosion rates tend to vary in response to climatic variations and changes in land use. For example an assessment may be carried out following a series of wet years when vegetation will be better established and erosion rates are smaller than the long-term average. Conversely after a series of dry years the catchment may be badly degraded from overgrazing and soil erosion rates will be much larger than the long-term average. It is thus necessary to be aware of temporal variations in conditions, and bear these in mind whilst carrying out assessments.

Initially the assessments were based on evaluating the seven key catchment characteristics listed in table A3.1. Four classes were identified for each characteristic: extreme, high, normal and low, with a text description and numerical value assigned to each class. When a catchment falls between two classes, or needs to be split into two or more representative areas due to distinct changes in topography or land use, intermediate values are assigned. These are derived by weighting each factor by the proportion of the catchment area that they represent.

All the catchments included in the study were characterised using the form shown in table A3.1. It was realised that there is an element of double counting in the factors listed in the table. Most will for example contribute to “signs of active erosion”. The significance of individual factors was evaluated later during the development of the predictive equation, when measured sediment yields were available. This resulted in some factors being discarded and others being replaced with quantitative information that could be readily obtained from 1:50000 mapping.

The qualitative factors adopted for the final form of the characterisation procedure are:

Soil Type and Surface Drainage (STD)
Although the assessment is carried out at the driest time of the year, surface infiltration can be gauged by noting soil surface texture (coarse, medium or fine) together with information from local farmers on whether there is extensive ponding on the soil surface after heavy rains.

Vegetation Cover over the Whole Catchment (VC)
The extent of annual cropping and the nature and quality of the grassland and any woodland/forests in the catchment should be assessed separately. For example, although less than 20% of a catchment may be cultivated with annual crops giving excellent cover, at the same time less than 30% may be under good grass or protected forest cover giving only fair cover.

Signs of Active Soil Erosion (SASE)
Obvious signs of active erosion should be recorded, particularly the presence or absence of actively eroding gullies (dongas) draining directly into the dam and/or watercourses, and/or active undercutting of riverbanks along main watercourses.

The qualitative factor for relief in table A3.1 was replaced with the slope of the main stem river form the catchment boundary to the location of the dam. This is derived from a map and is not evaluated during the catchment scoring exercise. None of the other factors provided significant correlations with observed sediment yields, and their inclusion in the equation described in chapter 4 did not improve its predictive ability. They were thus not included in the recommended version of the characterisation procedure, which is summarised in table A3.2. The scoring system for erosion status was revised during the calibration described in chapter 4 so that: Low = 5, Normal; = 10, High = 20, Extreme = 40.

The results of the catchment characterisations and the quantitative factors used in the development of the sediment yield predictor are listed in table A3.3.

Table A.3.1 Preliminary catchment characterisation form

Dam Site: Date:

Observer:

Factor	Extreme		High		Normal		Low	
Relief	Steep: average slope >30%	40	Hilly (10-30%), hills cover >50% of catchment	30	Rolling (5-10%), hills cover <50% of catchment	20	Relatively flat land (0-5%)	10
Soil Type & Drainage	No effective soil cover; either rock or thin shallow soils	40	Poorly drained compacted soils; much ponding on soil surface after heavy rains	30	Moderately well drained medium-textured soils; some ponding on soil surface after heavy rain	20	Well drained coarse-texture d soils; little ponding on soil surface after heavy rain	10
Vegetation Condition over Whole Catchment	Little effective plant cover, ground bare or very sparse cover over 80% of catchment	40	Fair cover: >50% of catchment is cultivated with annual crops;	15	Good cover: 20-50% of catchment is cultivated with annual crops;	10	Excellent cover: <20% of catchment is cultivated with annual crops;	5
			<30% of catchment is under good grass cover or protected forest cover	15	30-60% of catchment is under good grassland or protected forest cover	10	>60% of catchment is under well-maintaine d grassland and/or protected forest cover	5
Signs of Active Soil Erosion	Many actively eroding gullies (dongas) draining directly into dam and/or watercourses; active undercutting of riverbanks along main watercourses	80	Some actively eroding gullies (dongas) draining directly into dam and/or watercourses; moderate undercutting of riverbanks along main watercourses	60	Few actively eroding gullies (dongas) draining directly into dam and/or watercourses; little undercutting of riverbanks along main watercourses	20	No actively eroding gullies (dongas) draining directly into dam and/or watercourses; no undercutting of riverbanks along main watercourses	0
Vegetation Condition Along Watercourses	Bare soil; very little vegetation cover	40	Poor grassland along riverbank	15	Moderately well protected grassland along riverbank	10	Well protected grassland along riverbank	5
			Very few or no trees along riverbank	15	Some trees along riverbank	10	Many trees along riverbank	5
Surface Water Storage in Catchment (trapping sediment)	Negligible; no pools in watercourses, no marshes or dambos (vleis)	40	Low; few pools in watercourses, few marshes or dambos (vleis)	30	Medium; some pools in watercourses, some marshes or dambos (vleis)	20	High; extensive pools in watercourses, extensive marshes or dambos (vleis)	10
Village Population Density	Densely populated	40	Moderately densely populated	30	Normal/average population density	20	Sparsely populated	10

Table A.3.2 Revised catchment characterisation form

Dam Site: Date:

Observer:

Factor	Extreme		High		Normal		Low	
Soil Type & Drainage	No effective soil cover; either rock or thin shallow soils	40	Poorly drained compacted soils; much ponding on soil surface after heavy rains	30	Moderately well drained medium-textured soils; some ponding on soil surface after heavy rain	20	Well drained coarse-textured soils; little ponding on soil surface after heavy rain	10
Vegetation Condition over Whole Catchment	Little effective plant cover, ground bare or very sparse cover over 80% of catchment	40	Fair cover: >50% of catchment is cultivated with annual crops;	15	Good cover: 20-50% of catchment is cultivated with annual crops;	10	Excellent cover: <20% of catchment is cultivated with annual crops;	5
			<30% of catchment is under good grass cover or protected forest cover	15	30-60% of catchment is under good grassland or protected forest cover	10	>60% of catchment is under well-maintained grassland and/or protected forest cover	5
Signs of Active Soil Erosion	Many actively eroding gullies (dongas) draining directly into dam and/or watercourses; active undercutting of riverbanks along main watercourses	40	Some actively eroding gullies (dongas) draining directly into dam and/or watercourses; moderate undercutting of riverbanks along main watercourses	20	Few actively eroding gullies (dongas) draining directly into dam and/or watercourses; little undercutting of riverbanks along main watercourses	10	No actively eroding gullies (dongas) draining directly into dam and/or watercourses; no undercutting of riverbanks along main watercourses	5

Table A3.3 Catchment characterisations of study sites in Zimbabwe and Tanzania

Catchment name	Area km^2	Mean Annual Rainfall mm	Slope	Erosion status Score [1]	Soil type and drainage Score	Veg. Cover Score	Observed Sediment yield (t/km^2/y)
Chengwe	1.6	655	0.017	5	20	20	269
Murambi	1.7	747	0.016	10	20	30	370
Chihava [2]	2.8	614	0.091	40	20	20	1823
Gari	3.5	568	0.051	10	20	30	243
Tinogona	5.3	568	0.013	20	20	30	858
Mutangi	6.6	568	0.011	20	30	25	406
Msalatu	8.5	600	0.030	29	20	20	736
Ngondo	8.8	614	0.093	20	20	30	657
Sekenende	9.1	655	0.013	5	20	20	123
Nyimai	10.5	630	0.017	10	20	20	212
Jechera	17.0	747	0.012	20	20	30	154
Matumbulu	18.0	500	0.013	23	20	25	588
Njoro	27.0	550	0.006	10	24	23.7	157
Namelok	40.0	550	0.006	9	21.3	10	122
Dove	55.1	625	0.018	15	20	31.25	152
Takavarasha	541.0	650	0.009	33	20	27.7	330
Mwisanga	18.0	891	0.090	38	30	35	3392

Notes:
1 The scores for this factor were converted from the original scoring system to a revised ranking based on a geometric progression: low = 5, Normal; = 10, High = 20, Extreme = 40 during the calibration exercise described in chapter 4.
2 In this catchment, erosion and sedimentation rates appear to have been much higher in the past than when the characterisation was carried out. Much of the agricultural land has now been abandoned, and left to grazing. At the same time the stocking density appears also to have declined. Many of the previously actively eroding gullies have largely stabilised either naturally or by placing brushwood and stones within the gullies. Scores from the original characterisation were adjusted to reflect this.