

**Department of Water and
Environmental Affairs**

Chief Directorate: Integrated Water Resource Planning
Directorate: Options Analysis



**MOKOLO AND CROCODILE RIVER
(WEST) WATER AUGMENTATION
PROJECT (MCWAP) FEASIBILITY
STUDY: TECHNICAL MODULE**

Project No. WP9528



**SUPPORTING REPORT NO. 9
TOPOGRAPHICAL SURVEYS**

FINAL

Lead Consultant:

In association with:



LIST OF REPORTS

| REPORT NO | DESCRIPTION | REPORT NAME |
|------------------------------|----------------------------|---|
| FEASIBILITY STAGE | | |
| P RSA A000/00/8109 | Main Report | MCWAP FEASIBILITY STUDY TECHNICAL MODULE SUMMARY REPORT |
| P RSA A000/00/8409 | Supporting Report 8A | GEOTECHNICAL INVESTIGATIONS PHASE 1 |
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REPORT DETAILS PAGE

Project name: **Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP)**

Report Title: **Feasibility Study Report 9 – Topographical Survey**

Author: **J H Badenhorst**

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PREFACE

The Mokolo (Mogol) River catchment is part of the Limpopo Water Management Area (WMA). The Mokolo River originates close to Modimolle (Nylstroom) and then drains to the north into the Limpopo River. The Mokolo Dam (formerly known as the Hans Strijdom Dam) is the largest dam in the catchment. The dam was constructed in the late 1970s and completed in July 1980, to supply water to Mathimba Power Station, Grootegeluk Mine, Lephalale (Ellisras) Municipality and for irrigation downstream of the dam. Based on the water infrastructure, the current water availability and water use allows only limited spare yield existing for future allocations for the anticipated surge in economic development in the area.

There are a number of planned and anticipated consequential developments in the Lephalale area associated with the rich coal reserves in the Waterberg coal field for which additional water will be required. These developments include inter alia the development of further power stations by Eskom, the potential development of coal to liquid fuel facilities by Sasol and the associated growth in mining activities and residential development.

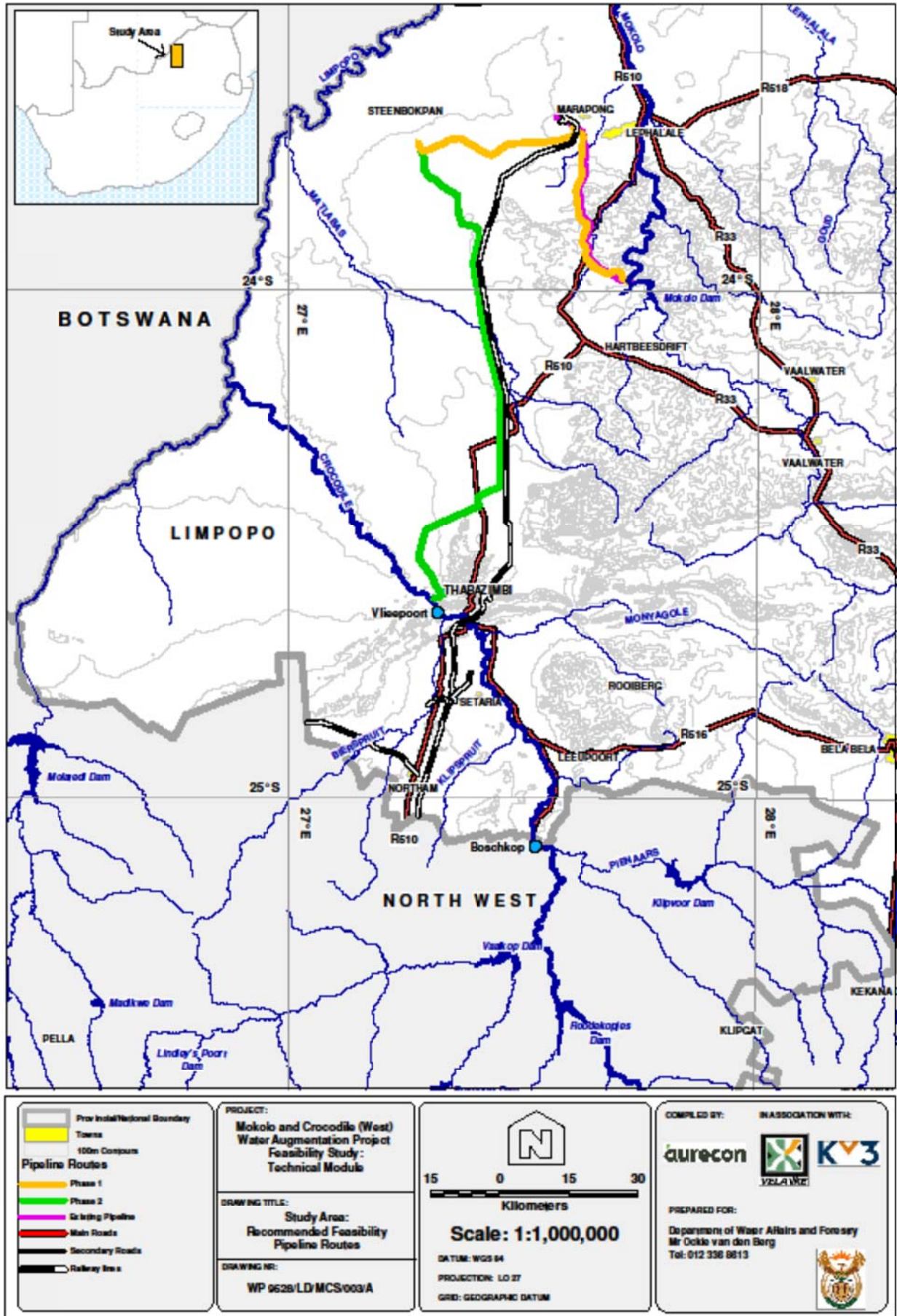
The development of new power stations is of high strategic importance with tight timeframes. Commissioning of the first generation unit will start in September 2010 and additional water needs to be available by mid-2011 according to the expected water requirements. A solution addressing the water needs of the Lephalale area must be pursued. The options to augment existing water supplies include transferring surplus effluent return flows from the Crocodile River (West) / Marico WMA to Lephalale and the area around Steenbokpan shown on the map indicating the study area on the following page.

The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) to analyse the options for transferring water from the Crocodile River (West). In April 2008, the Technical Module of this study was awarded to Africon in association with Kwezi V3, Vela VKE and specialists. The focus of the Technical Module is to investigate the feasibility of options to:

- Phase 1: Augment the supply from Mokolo Dam to supply in the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) can be implemented. The solution must, over the long term, optimally utilise the full yield from Mokolo Dam.
- Phase 2: Transfer water from the Crocodile River (West) to the Lephalale area. Options to phase the capacity of the transfer pipeline (Phase 2A and 2B) must be investigated.

The Technical Module has been programmed to be executed at a Pre-feasibility level of investigation to identify different options and recommend the preferred schemes, which was followed by a Feasibility level investigation of the preferred water schemes. Recommendation on the preferred options for Phase 1 and Phase 2 Schemes were presented to DWA during October 2008 and draft reports were submitted during December 2008. The Feasibility Stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted a draft Feasibility report during October 2009 to the MCWAP Main Report in November 2009.

This report (Report 9 – Topographical Surveys, P RSA A000/00/8509) covers the procurement, methodology, receipt of deliverables and costs for Phases 1 and 2, and the River Conveyances.



MOKOLO AND CROCODILE (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY

TECHNICAL MODULE

TOPOGRAPHICAL SURVEYS

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LIST OF ABBREVIATIONS

| | |
|-------|--|
| DWA | Department of Water Affairs |
| DTM | Digital Terrain Model |
| ECW | Enhanced Compression Wavelet |
| ER | Earth Resource |
| MCWAP | Mokolo and Crocodile River (West) Water Augmentation Project |
| RWR | Raw Water Reservoir |

1. BACKGROUND AND INTRODUCTION

1.1 Scope of the Investigations of this Report

The project entails two separate phases, Phase 1 and Phase 2A, plus the River Conveyance System.

Phase 1 comprises expansion of the existing pumping station at the Mokolo Dam, a pipeline to the delivery area at Mathimba Raw Water Reservoir (RWR), near Lephalale, and a pipeline extending west from a point approximately 2 km south-east of the delivery area to Steenbokpan.

Phase 2A which describes abstraction from the Crocodile River at the Vlieëpoort site, and transfer via a pipeline to link up with the western leg of the Phase 1 pipeline near Steenbokpan, the flow of which will be reversed to accommodate transfer to the delivery area near Lephalale.

The River Conveyance System which comprises the Crocodile River from Hartebeespoort Dam to the Dwaalboom Bridge, including Roodekopjes Dam and the tributaries from the Vaalkop and Klipvoor Dams.

This report describes:

- The procurement process in brief;
- The methodology;
- The deliverables received; and
- Costs.

The layout of the scheme is shown on Figure 1-1. It must be noted that, since the time that the topographical surveys were carried out and compilation of this report, the alignment of the pipelines has changed (but not yet necessarily finalised). This report thus deals with the alignment as it was at the time of the investigation, as shown in Figure 1.1.

1.2 Topographical Surveys Introduction

Telephonic queries directed to the Department of Water Affairs and the Chief Directorate: Surveys and Mapping indicated and confirmed that there is very little detail reliable survey and mapping data available for the project area.

A detail survey (still in Cape Datum), of the Mokolo Dam done for DWA, was the only recent survey that could be obtained.

It was therefore decided that new up to date survey and mapping information would be procured for the project.

LIDAR mapping was the preferred method at the start of the project due to the quick turnaround time compared to that of conventional photogrammetric means.

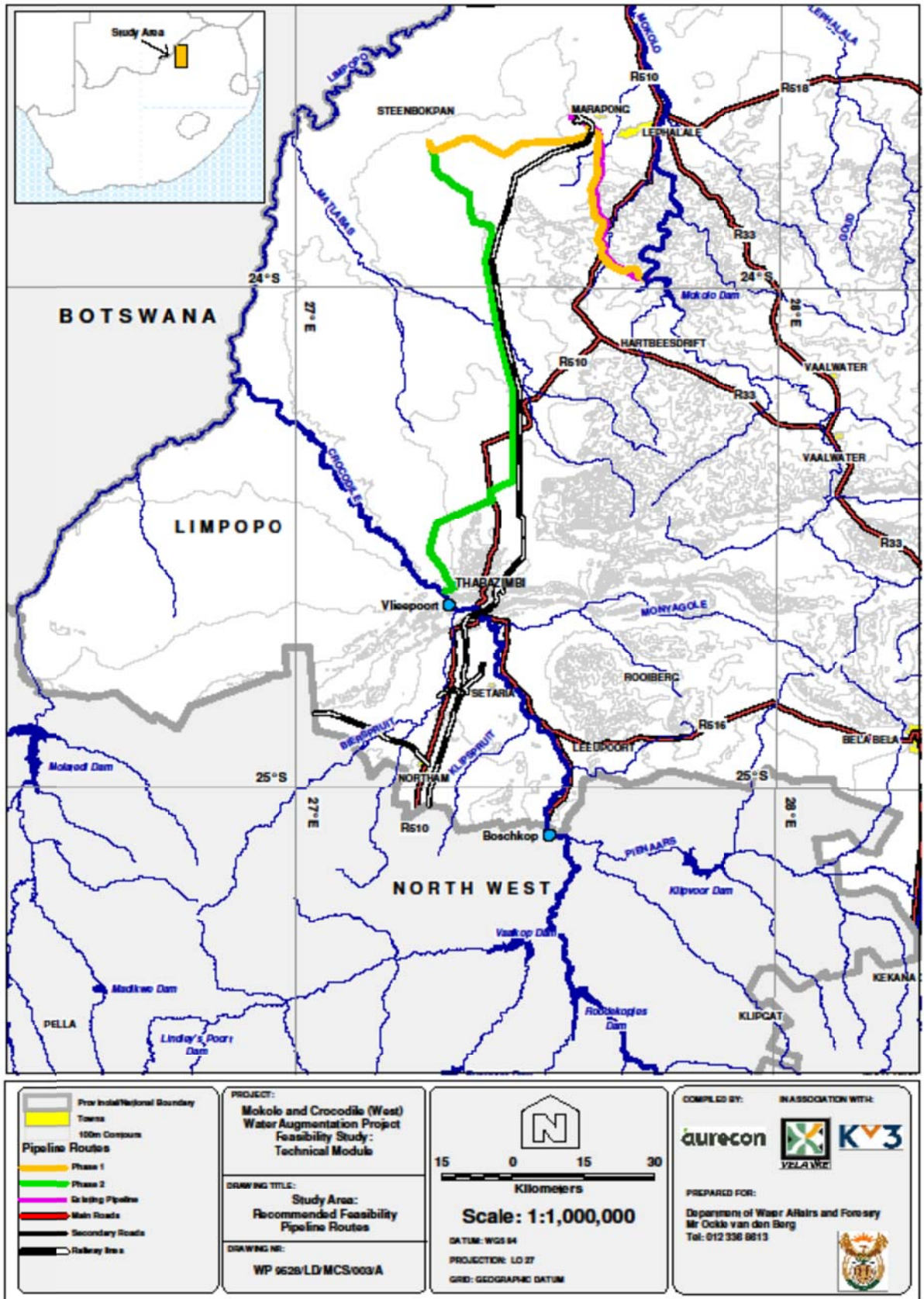


Figure 1-1: Pipeline Alignments

2. PROCUREMENT

2.1 Tenders Invited

Six South African companies, offering aerial surveys and mapping, were invited to tender to supply the required aerial surveys and mapping as required by the technical consultancy team of the MCWAP Project. These companies were:

- CK Aerial Survey;
- AOC Geomatics;
- Fugro Maps South Africa;
- Southern Mapping Company;
- Kwena Air; and
- Fotogramensura.

Fotogramensura was invited to tender, even though their mapping is based on conventional photogrammetric mapping and not LIDAR technology, based on the reasoning that they should be given an opportunity to offer an alternative competitive product.

Rob Wooding & Associates, a KwaZulu Natal based survey and mapping company, was contacted electronically via e-mail, but did not respond.

During the first working week of January 2009, AOC Geomatics, Southern Mapping Company and Fotogramensura requested a week's extension of the tender submission, based on the unavailability of sub-consultants for the control survey and the cadastral mapping due to these companies being closed over the Christmas break.

This extension was duly granted by the Project Leader with the authorization of the Project Coordinator.

2.2 Tenders Received

Five tenders were received on the submission date as valid tenders. Kwena Air declined to submit a tender.

The Tender Submissions were opened at VelaVKE's Randburg offices on 16 January 2009 at 13:45 in the presence of the following people:

- Johan Badenhorst (VelaVKE); and
- Peter Varndell (VelaVKE).

The companies who submitted tenders and their tendered amounts are shown in Table 2-1 below.

Table 2-1: List of Tenderers and Tendered Amounts

| Tender No. | Company | Amount (excl. VAT) |
|-------------------|------------------------------|---------------------------|
| 1 | CK Aerial Surveys | R 6 320 229.10 |
| 2 | AOC* ¹ | R 5 447 906.16 |
| 3 | Fugro | R 4 521 402.00 |
| 4 | Southern Mapping Company | R 3 470 187.00 |
| 5 | Fotogramensura* ² | R 7 893 475.00 |

*¹ The AOC tender contained alternative pricing for control surveys and was not totalled. The amount reflects the total excluding the alternative prices.

*² Fotogramensura submitted a tender for conventional aerial survey as an alternative to LIDAR in response to our invitation.

The amounts above reflect the total amounts, excluding any increase or reductions in costs for possible variations in the aerial survey areas.

2.3 Tender Evaluation

From the Tender Evaluation Scores, it was clear that Southern Mapping Company consistently has the highest combined technical and financial scores. Fugro is second on all counts except where only Modules 1 - 5 are considered; here CKAS has the second highest score.

All four companies offering LIDAR surveys were close on the technical rating, but varied greatly on price.

The conventional photogrammetric alternative offered by Fotogramensura was by far the highest priced (more than double the lowest tender) and also suffered in the technical scoring due to not having submitted a working programme.

As Southern Mapping Company has submitted the lowest price on all scenarios and their personnel has demonstrably extensive experience of LIDAR surveys in South Africa and other African countries, it was recommended that Southern Mapping Company be contacted for further discussions and negotiation with the intention to award them the aerial survey contract.

2.4 Tender Award

Southern Mapping Company was appointed to carry out the survey and mapping contract following several meetings and discussions during which the following changes were made to the scope of works:

- The River Conveyance Survey would be extended to the Hartebeespoort Dam wall;
- Spirit levelling of the ground control stations would not be required along the River Conveyances; and
- The ground control stations for the River Conveyances would be not be required to be located at a 2 000 m spacing, as no construction was envisaged along the river conveyance .

3. METHODOLOGY

3.1 Aerial Mapping

The topographical survey was carried out using an aircraft mounted LIDAR system that scanned the ground below with a 70 kHz laser resulting in a dense Digital Terrain Model (DTM) of the ground surface and objects above the ground. Digital colour images were also taken from the aircraft to produce colour orthophotos of the area.

The proposed Phase 1 and Phase 2 pipeline routes, plus the River Conveyance areas, were handed to Southern Mapping Company in CAD format prior to them flying the project area.

3.2 Ground Control Survey

Southern Mapping Company sub-contracted the ground control survey to MHP Geomatics of Durban. The survey manager of MHP Geomatics is a registered professional land surveyor.

The ground control survey was required to act as control for the aerial survey and to act as a basis for future surveys and setting out. The ground control was done to cover the whole project area.

Prior to the flying of the area, marks were made on the ground at distributed intervals to be visible on the aerial photos. These marks were then used to compare their results and to calibrate the aerial mapping as required.

Survey stations were installed approximately 2 000 m apart, surveyed and spirit levelled. The horizontal surveying was done using GPS methods and no attempt was made to ensure direct line of sight between stations as this would have increased the duration and cost of the ground survey. This means that future surveys will have to be done using GPS.

Photographs of each station were taken and submitted, which will aid in the location of the stations.

4. DELIVERABLES

Southern Mapping Company delivered the Phase 1 mapping on two (2) DVDs (5 copies). The final delivery was on three portable hard disk drives, containing the following:

4.1 ASCII Point Files

The surveyed points were submitted as ASCII point files. The survey was split into separate blocks of information for ground points and non-ground points, respectively.

The LIDAR points were first evaluated with proprietary software and the points were filtered into ground and non-ground points. A preliminary DTM was then built from the ground points. This was manually evaluated further by the LIDAR process operator and points that do not fit into the DTM were removed.

The ASCII points are arranged in three columns representing Y and X coordinates and levels, referenced to the Lo27 Hartebeesthoek Datum. The mathematical signs have been swapped for CAD purposes.

4.2 CAD Files

Contours plotted to 0.5 m intervals were submitted in both 'dgn' (Microstation) and 'dwg' (AutoCAD) drawing format files.

A drawing file of each format is included in a key plan for both the data block and the image tiles.

The contours drawings and key plans are referenced to the Lo27 Hartebeesthoek Datum. The mathematical signs have been swapped for CAD purposes.

4.3 ECW Image Files

The image background to the survey was submitted as 'ecw' format files, called tiles, for ease of handling in the CAD applications.

The ECW file is an Enhanced Compression Wavelet data format. It is an open standard wavelet compression image format developed by Earth Resource (ER) Mapping. It is currently the most efficient image format for use in CAD and GIS.

A key plan for the image tiles is included under the CAD files.

The image tiles have been ortho-rectified, i.e. each feature identified on an image is at the correct position on ground level (features above the ground, e.g. tops of high structures does not appear in the correct place due to stereographic distortion). The image tiles are geo-referenced to the Lo27 Hartebeesthoek Datum. The mathematical signs have been swapped for CAD purposes.

4.4 Reports

Southern Mapping Company submitted a report on the aerial mapping and methodology.

The MHP Ground Control Survey report, which includes field data files, calculation files, locations of the control stations and the working plans, is also included on the portable hard drives.

Both reports, including attachments were also submitted as hard copy.

4.5 Triangulation Files

Southern Mapping Company included CAD files containing the triangulated survey, i.e. the lines connecting the surveyed LIDAR ground points, on the first delivery of DVDs.

During the first evaluation on how the AutoCAD Civil 3D software would handle the submitted data, it was found that AutoCAD Civil 3D could handle the survey data without having to use the triangulation files.

The triangulation files were considered to be redundant to requirements or were therefore not requested to be included in any further submissions.

4.6 Outstanding Items

The following items are currently outstanding:

i) Cadastral Mapping

Cadastral mapping was requested. This cadastral mapping is considered to be of first order level, i.e. as available from the survey general's office database and not as surveyed, controlled and registered by a professional land surveyor. This data has to date not been delivered.

The cadastral mapping is to be delivered as CAD files, referenced to the Lo27 Hartebeesthoek Datum.

ii) Line Mapping

Line mapping of features was requested on the basis of identifying areas of importance. Once the deliverables have been compared with the pipe routes, areas will be identified where line mapping of features and structures such as wind pumps, reservoirs, bridges, houses and other buildings will be identified.

The line mapping will show the footprint of structures and other man-made feature as CAD objects on drawings.

As this interpretation is done by the mapping company, it is expected to be more accurate and less ambiguous than interpreted by the project draftspersons.

The line mapping is to be delivered as CAD files, referenced to the Lo27 Hartebeesthoek Datum.

4.7 Summary

The delivered files are summarised and quantified in Table 4-1 below.

Table 4-1: Number of Data Files

| Name and Phase | ASCII Blocks Ground and Non-Ground | ECW Images | CAD and Index Files | Horizontal and Vertical Resolution |
|----------------|------------------------------------|------------|---------------------|------------------------------------|
| Pipe 1 Phase 1 | 13 + All | 515 | 13 + 2 Index | 100mm Hor 100mm Ver |
| Pipe 2 Phase 2 | 7 + All | 620 | 7 + 2 Index | 100mm Hor 100mm Ver |

| Name and Phase | ASCII Blocks Ground and Non-Ground | ECW Images | CAD and Index Files | Horizontal and Vertical Resolution |
|-------------------|------------------------------------|------------|---------------------|------------------------------------|
| Pipe 3 Phase 2 | 16 + All | 548 | 16 + 2 Index | 100mm Hor 100mm Ver |
| River Conveyances | 62 | 4656 | 62 + 2 Index | 150mm Hor 150mm Ver |

4.8 Quality and Accuracy of the Data

It was endeavoured to ensure a high level of quality and accuracy of the data by specifying that the personnel employed by the survey and mapping service provider is experienced and competent.

It was further proposed to have independent checks carried out on the delivered data.

i) Personnel and Methods

Southern Mapping Company have in their employ and management the leaders in LIDAR survey in South Africa, with their core staff having more than 12 years' experience each.

The ground control survey was carried out by MHP Geomatics and managed by a professionally registered land surveyor with over twenty years' experience.

ii) Inherent Checks

The LIDAR ground points were checked by the Southern Mapping Company processor by local comparisons to known points such the additional ground control survey points.

The results from the Southern Mapping Company LIDAR Survey report are shown in Table 4-3.

Table 4-2: Maximum Deviations between Ground Survey and Aerial Mapping

| Area | Ave Dz (m) | Min Dz (m) | Max Dz (m) | Ave-rage (m) | RMS (m) | Std Dev (m) |
|------------------|------------|------------|------------|--------------|---------|-------------|
| Pipe 1 | +0.008 | -0.144 | +0.193 | 0.070 | 0.084 | 0.080 |
| Pipe 2 | +0.000 | -0.153 | +0.165 | 0.053 | 0.062 | 0.066 |
| Pipe 3 | +0.006 | -0.144 | +0.193 | 0.077 | 0.092 | 0.093 |
| River Conveyance | -0.007 | -0.133 | +0.117 | 0.059 | 0.065 | 0.066 |

4.9 Hard Copy Attachments

The following information is attached as hard copy documents and drawings:

- i) The **Southern Mapping Company LIDAR Survey Report**, which provides details of the processing, methodology, transformations, and comparisons of results.

- ii) The **Ground Control Survey** report which comprises:
- The Survey Report
 - The GPS Control Geographical Coordinate List
 - Level Schedule
 - The GPS Control Grid Coordinate List
 - GPS Survey Point Information
 - Control Point Booking Sheets
 - Control Working Plan
 - Levelling Working Plan

5. COST

Three invoices have to date been submitted by Southern Mapping Company.

Table 5-1: Invoices Submitted by Southern Mapping Company

| Item No. | SOUTHERN MAPPING COMPANY Invoice | Date | Amount Excl VAT | VAT | Amount |
|----------|----------------------------------|------------|-----------------------|---------------------|-----------------------|
| 1 | INV050 | 16/07/2009 | R 1 014 118.27 | R 141 976.56 | R 1 156 094.83 |
| 2 | INV068 | 22/09/2009 | R 500 000.00 | R 70 000.00 | R 570 000.00 |
| 3 | INV080 | 28/08/2009 | R 1 202 585.33 | R 168 361.95 | R 1 370 947.28 |
| 4 | Total Amount | | R 2 716 703.60 | R 380 338.50 | R 3 097 042.10 |

ADDENDUM A

LIDAR SURVEY REPORT

ADDENDUM B
GROUND CONTROL SURVEY:
SURVEY REPORT

ADDENDUM C
GROUND CONTROL SURVEY:
GPS CONTROL GEOGRAPHICAL COORDINATE LIST

ADDENDUM D
GROUND CONTROL SURVEY:
LEVEL SCHEDULE

ADDENDUM E
GROUND CONTROL SURVEY:
GPS CONTROL GRID COORDINATE LIST

ADDENDUM F
GROUND CONTROL SURVEY:
GPS SURVEY POINT INFORMATION

ADDENDUM G
GROUND CONTROL SURVEY:
CONTROL POINT BOOKING SHEETS

ADDENDUM H
GROUND CONTROL SURVEY:
LEVELLING WORKING PLAN

ADDENDUM I
GROUND CONTROL SURVEY:
CONTROL WORKING PLAN

REPORT DETAILS PAGE

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Report Title: **Feasibility Study Report 9 – Topographical Survey**

Author: **J H Badenhorst**

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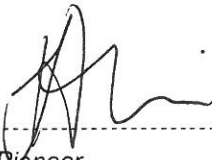
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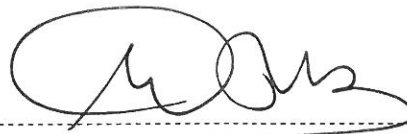
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