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Annex 2: Topographic Surveys and Mapping

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## ANNEX 2

### TOPOGRAPHIC SURVEYS AND MAPPING

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# 1. TOPOGRAPHIC SURVEYS AND MAPPING

## 1.1 INTRODUCTION

In January 2009 ENTRO has awarded the preparation of Wed Meskin Project complementary surveys (CS) to BRLi, with Shoraconsult as subcontracted firm. Conducting the topographic survey of the project was among the principal components of the complementary survey assignments to provide the basic data and working documents for the feasibility study (FS) that would be carried out subsequently. Shoraconsult awarded the preparation of the project topographic surveys and mapping to Mierag Space Tech. Co. as a subcontracted firm. This chapter presents the approach and methodology used to produce topographic maps of the project command area, link canal alignment, barrage sites and the major crossing structures.

## 1.2 TOPOGRAPHIC SURVEY PROGRAM

The topographic survey works were programmed to be carried out by four survey crews using two 4WD cars in forty eight days. The survey team was stationed in Al Hawata town and the survey activities were programmed to be carried out in the early mornings and the late afternoons to avoid problems which may be posed by hot temperatures in the project area during the execution of the assignment. All the required survey works were executed in 31 days plus two days during which one survey crew revisited Wed Meskin barrage site for resurveying. The survey was carried out in four subsequent phases, office preparation and delineation of the project area boundaries, mobilization, establishment of benchmarks, and levels collection and maps preparation.

## 1.3 WEATHER CONDITIONS

The Wed Meskin Project area, named after Wed Meskin village is found in Rahad II area, Gadarif state, eastern region of Sudan. It is located east of river Rahad and south of Rahad irrigation scheme. In general terms the climate of the area is very hot, particularly from April to June. The average daily temperature during the hot season around 33<sup>0</sup>c. The average rainfall goes up 600 mm, and it concentrates during the periods of July to September. The dry period normally extends from November to early June.

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The topographic survey was carried out during the dry season, when the climate was characterized by very hot temperatures during the day. Generally, weather conditions in the project area did not affect the progress of work significantly until it was completed at the end of May. The weather conditions negative impacts on the survey activities were compensated for by increasing the working hours per day and working through the week ends.

Figure 1, shows the locations of the Project area and specific sites.

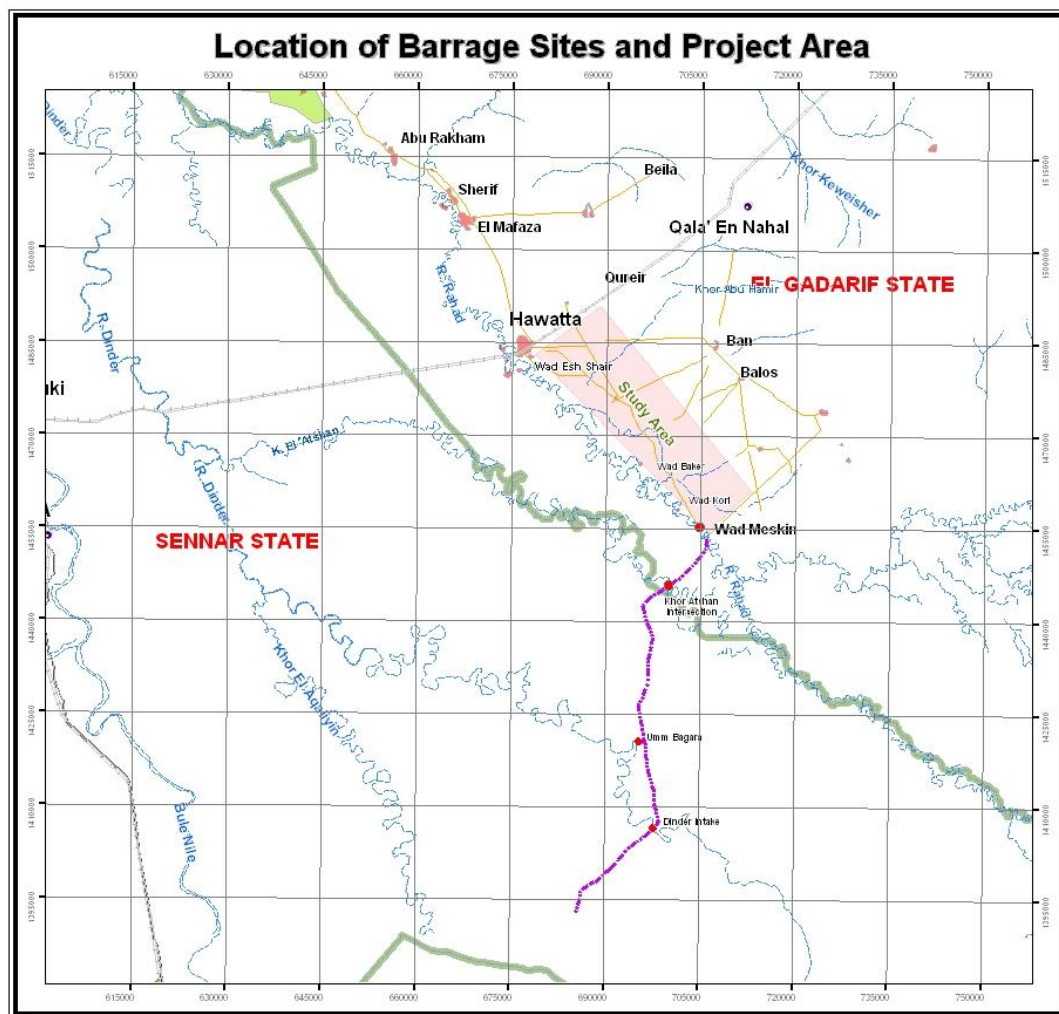


Figure 1: Location of the project area and the specific sites

## 1.4 SCOPE OF THE STUDY

The topographic survey team was briefed about the objectives, methodologies and planning of the survey works before mobilization to site. The team includes highly qualified and well experienced staff in their fields in different levels. Senior surveyors were included in the team to ensure the quality of the topographic surveys. All the survey works were carried out conform to the requirements of the TOR and the Inception Report. The topographic survey of the command area was executed in order to prepare for the feasibility design of the irrigation scheme, including selection of irrigation methods, preparation of irrigation layouts, preparation of bill of quantities and cost estimates, design of irrigation infrastructure, etc.

The project area and the command area boundaries were delineated. Horizontal and vertical control points with known x,y,z co-ordinates were established in the project area. These control points were tied to the National grids using existing National geodetic reference stations (Trig. Stations) in the area and static differential GPS of dual accuracy under long period observation. Traverse surveying using digital and automatic levels was used to tie these established control points to the M.S.L. These BMs were established by installing a 1.5 inch iron pipe of about 70 cm long into the ground, where the upper part of the pipe is prepared in a 25x25x25 cm cube of concrete. They were clearly marked with identification numbers and painted with visible colors. Figure 2, shows a sample of the BMs established in the project area.

A topographic survey covering a gross area of about 8,369 ha was carried out, following the topographic survey methods stipulated in the TOR and the Inception Report. Topographic maps at scale 1:25,000 and 0.25 meter interval were prepared for current use. These maps can be prepared latter at a larger scale, up to 1:2,500 as required. Also, a detailed topographic survey was carried out at the project diversion sites (Dinder and Rahad barrages) and one major canal structure site (Khor Al Atshan crossing). Topographic maps at scale of 1:500 and 1:750 according to the size of the area, and 0.25 meter contour interval were prepared for these sites. Finally, A topographic map at scale 1:50,000 covering the whole project area was prepared for general use. These prepared topographic maps show every major feature in the area, including rivers, roads, springs, hills, forests, water bodies, settlements, etc.





*Figure 2: Sample of the BMs established in the project area*



## 2. Study Methodology

### 2.1 DELINEATION OF THE IRRIGABLE AREA FOR SURVEY

At the commencement of the study, a review of all the data and documents provided by the National Coordinator of the project was made in order to determine the project planned topographic survey area. As mentioned before, the project area lies in the eastern bank of the Rahad River. The western extent of the area was delineated by the Rahad River and the eastern extent was delineated by contour + 447.5 meter above M.S.L, this is due to the water level at Wed Meskin barrage. The exact project area is located south of Al Hawata town and extended south to cover an approximate area of 32,000 ha north of Wed Meskin village. The delineation of the area was carried out using ArcGIS software and a digital georeferenced map of the project area.

Considering the exclusion of areas for villages, roads, buffer zones along streams, water bonds, forests, and topographically unsuitable areas, the approximate net command area was assumed to be 30% of the gross delineated area between contour +447.5m and Al Rahad River. After the delineation of the command area, coordinates were delivered to the survey team to carry out the survey as planned.

High resolution satellite images (Quick Bird 60 cm) were acquired, and loaded on the computers of the surveyors and used at field level for orientation and verification of the survey activities. The topographic survey was carried out for the planned study area, excluding the topographically unsuitable areas and covered a gross area of 8,369 ha. The network of BMs established in the project area was used to control the topographic survey. Ground levels were then collected at maximum grids of 200x100 meter depending on the topography of the land using automatic and digital levels. Topographic maps were prepared at different scales and contour intervals for the project area.

## 2.2 MOBILIZATION

A survey team consists of five surveyors, equipped with the appropriate survey equipments, including a set of differential GPS, with one base and two rovers, one automatic levels, and two digital levels were stationed at site on 18 April 2009. Two 4WD cars were joining the team. Before mobilization the topographic survey team was briefed about the objectives, methodologies and planning of the survey works. The survey team rented a house in Al Hawata town that accommodated all the survey team including the drivers. In addition to the staff mobilized, rod men were recruited from the localities and trained for providing assistance for the survey works. The team stayed on site until all the survey works were completed. The list of the equipments used in the project is presented in table 4.1 and that of the personnel mobilized to the project area is presented in table 4.2. This chapter therefore, presents a brief description of the approaches and methodologies used to conduct these topographic surveys and mapping activities, more details are presented in the attached subcontractors report.

Table 1: List of Survey equipments used in the project

S. No.	Description	No. available on site
1	Digital Levels, LEICA, DNA03 with accuracy of 1 mm Double running 1 km, SD not exceeds 0.5 mm.	2
2	Automatic Levels,	1
3	Communication devices	7
4	Office Equipment, ArcGIS 9.2- ERDAS- AutoCAD Software, PC Workstations,	5
5	Lap top computers	3
6	Dual frequency Differential GPS Horizontal $\pm 10$ mm + 1 ppm RMS Vertical $\pm 20$ mm + 1 ppm RMS	1 set (2 GPS)
7	Normal GPS	2
8	4WD, vehicles,	2

Table 2: Personnel mobilized to the Project site

Sr. No.	List of Manpower	No. on site	Remarks
1	Team leader	1	
2	Chief surveyors	4	
3	Technical Labors	3	
4	Level man	8	

## 2.3 ESTABLISHMENT OF BENCHMARKS AND CONNECTION WITH THE NATIONAL GRIDS

The project area was delineated by establishing concrete poles of 0.6 m long steel bar (40 cm inside ground and 20 cm above). A network of permanent benchmarks with X,Y,Z values was established in the project area. All BMs were clearly marked with identification numbers on the site and on the produced topographic maps with list of coordinates. Differential GPS dual accuracy under long observation was used to tie the project area to the National grids from existing National geodetic reference stations (Trig. Stations). Traverse surveying using digital and automatic levels was used to tie the project area with M.S.L height from the existing National reference BMs in the area.

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In addition, a group of site reference points were established at each of the project specific sites using differential GPS with the GPS site calibration model established for the project area.

The benchmarks established in the project area are listed in table 3 and the GPS site reference points established at Wed Meskin barrage, Dinder (Salsal) barrage and Al Atshan stream crossing sites are presented in table 4.

*Table 3: List of Benchmarks established in the project area*

Name	Northing	Easting	Elevation	Code
BM01	1484263.026	678395.181	444.0063	BM
BM010	1467674.774	696013.532	446.306	BM
BM011	1465306.078	698057.236	448.7971	BM
BM012	1463644.528	700128.925	450.0173	BM
BM013	1461633.768	700889.212	449.8844	BM
BM014	1459073.246	702552.767	450.0949	BM
BM015	1457324.831	703421.41	450.8768	BM
BM016	1454645.45	705916.576	451.9612	BM
BM017	1477974.375	685385.88	443.0736	BM
BM018	1475517.651	683434.306	442.4705	BM
BM019	1474982.74	686842.298	442.7095	BM
BM02	1485437.885	681032.729	447.0615	BM
BM020	1473466.389	690019.45	442.639	BM
BM021	1471013.426	688301.041	443.981	BM
BM022	1469031.449	690879.811	445.2179	BM
BM023	1465686.693	693701.283	444.9433	BM
BM03	1481022.328	679644.028	442.5353	BM
BM04	1482314.71	682338.449	445.4862	BM
BM05	1479684.803	682713.412	443.2001	BM
BM06	1479604.805	686822.859	445.9784	BM
BM07	1477807.419	689225.14	444.4763	BM
BM08	1475870.774	691925.459	445.0128	BM
BM09	1470627.921	693466.282	445.3675	BM
BM32837	1485691.445	683718.848	449.616	Ref. BM
BM32838	1481698.463	679715.015	443.072	Ref. BM
BM32839	1481693.427	683714.423	445.979	Ref. BM
BM32851	1465688.817	695702.811	447.844	Ref. BM
BM32852	1465690.64	699699.752	451.57	Ref. BM
BM32955	1455729.157	704371.735	452.186	Ref. BM

Table 4: GPS Points established at the project specific sites

Description	Easting (m)	Northing (m)	Elevation (m)	Site of installation
wmkn1	704663.423	1455153.135	449.954	Wed Meskin Barrage
wmkn2	704686.711	1454998.101	451.264	
wmkn3	705014.545	1455018.995	451.748	
wmkn4	704973.706	1455195.848	451.697	
Atshan1	700215.423	1446350.793	451.312	Khor Al Atshan Crossing
Atshan2	700353.017	1446071.563	451.524	
Atshan3	699910.359	1445818.427	450.120	
Atshan4	699701.001	1446105.546	449.564	
Salsal1	696482.798	1408185.373	454.253	Salsal Barrage (Dinder)
Salsal2	696636.447	1408273.294	454.500	
Salsal3	696774.000	1408004.000	453.824	
Salsal4	696620.351	1407916.079	453.935	

## 2.4 ESTABLISHING THE NETWORK OF BENCHMARKS

In order to facilitate the detailed design and the construction of the project works during the implementation phase an adequate number of benchmarks were established for horizontal and vertical control. These benchmarks were based on the existing National geodetic reference stations (Trig. Stations) and reference benchmarks in the area. Six reference stations were used to traverse these BMs within the project area as dense as possible. These reference stations are attached at the bottom of table 4.3. Overall 23 BMs were evenly distributed and installed at locations determined according to the shape of the area.

These BMs were established by installing a 1.5 inch iron pipe about 70 cm long, supported by an iron base into the ground at selected locations, with the top 200 mm protruding above the ground. After the construction and curing of each BM an identification number was clearly marked on it. In addition a number of site reference points were established at each of the project specific sites, using differential GPS with dual accuracy under long observations. Overall, 12 GPS reference points were established in the project area, four points at each of Wed Meskin, Dinder barrages and Khor Al Atshan crossing site.

## 3. Field Level Topographic Survey

### 3.1 GENERAL

The network of BMs was connected to the Sudan National grids using the static differential GPS dual accuracy under long observation and the National geodetic reference stations (Trig. Stations) available in the area. The network was connected to M.S.L height, using digital and automatic levels traversing and the existing National reference BMs in the area. Thus all BMs in the area were given x,y,z values and used to control the topographic survey in the project area.

### 3.2 COMMAND AREA SURVEY

A detailed topographic survey of the project area was carried out using a grid network of spot heights 200x100 meters. The spacing between the grid points was decreased to show features when required. The spot heights were collected using digital or automatic levels and were based on the network of benchmarks established in the project area. Significant features in the project area were located using Real Time Kinematic (RTK) with the GPS site calibration model. A digital topographic map with a high resolution satellite images (as back ground) was produced at scale of 1:25,000 and contour interval of 0.25 m and can be latter produced at a larger scale, up to 1:2,500 as required, using ArcGIS and Surfer application programs. These maps include all the significant features in the project area, such as, rivers, water bodies, forests, roads, villages, tracks, gullies, hills and footpaths etc. The main features in the project area were extracted from the rectified satellite images.

A general use map at scale 1:50,000 was produced for the whole project area (see volume Maps). This topographic survey covered a gross irrigable area of 8,369 ha out of the 32,000 ha planned area, demarcated using land characteristics observed from satellite images and digitized topographic maps of the area.

### 3.3 TRAVERSING OF BENCHMARKS

The new benchmarks established in the project area were traversed using digital and automatic levels and connected to the M.S.L height using the existing National benchmarks in the area. A total of 23 BMs evenly distributed in the project area were established and used to control the topographic survey of the command area and will be used later to control the design and implementation of the project.

### 3.4 DIVERSION SITES SURVEY

In line with the topographic survey of the command area, two barrage sites (Dinder and Wad Meskin barrages) were surveyed. This survey was carried out using GPS, Real Time Kinematic (RTK), based on the site reference points established at these locations. A grid network of spot heights 10x10 meters was collected for each site. A digital topographic map at scale 1:500 and 1:750 according to site and contour interval 0.25m, supported by a digital terrain model and profiles for two cross section lines was produced for each site (VOLUME Maps).

### 3.5 THE LINK CANAL SURVEY

The link canal survey was based on the data and documents provided by the National Coordinator of the project (maps, profiles, and cross sections, SIRM. MCDONALD & PARTNERS CONSULTING ENGINEERING, 1965) (VOLUME Maps).

### 3.6 DETAIL SURVEY OF MAJOR CANAL STRUCTURE

In line with the topographic survey of the command area a detailed topographic survey of the major canal crossing at Khor Al Atshan along the route of the proposed canal between Dinder and Wed Meskin barrages was carried out. This detailed survey was made using GPS Real Time Kinematic (RTK), based on the site reference points established at this location. A grid network of spot heights 10x10 meters was collected for the site and a digital topographic map at scale 1:750 and contour interval 0.25m was produced, supported by a digital terrain model and profiles for two cross section lines. (Volume Maps).



### 3.7 GENERATION OF TOPOGRAPHIC MAPS

The daily collected survey data were downloaded after working hours and checked for consistency and errors. The terrain model was then prepared to compare the land features generated with the actual features of the land. Powerful computers with the latest versions of the survey application programs (ArcGIS, Erdas Imagine, Surfer, AutoCAD, etc) were used for data processing and the production of topographic maps. The contour maps with contour intervals of 0.25 meter and 1 meter were prepared at office level from the collected field survey data. Digital topographic map with high resolution satellite images (as background) were prepared and printed at a scale of 1:25,000 for current use and can be latter produced at larger scales, up 1:2,500 as required. These maps show all the significant features in the area, such as, rivers, forests, waters bodies, villages, tracks, hills, roads, etc. A general use map at a scale of 1:50,000 was also prepared. All these maps are presented in VOLUME Maps.

### 3.8 PROBLEMS ENCOUNTERED

The first problem encountered by the survey team was the inaccessibility of most of the project area with motorized vehicles, particularly in Dinder and Rahad barrage sites, which are densely forested and can only be crossed on foot. Also, there were no access roads evenly distributed in the project area. This forced the team to travel on foot to cover the whole project area to conduct the survey and install the benchmarks.

The rough nature of the terrain coupled with the very hot temperatures in the project area during the conduction of the topographic survey works were also some of the constraints that hindered the team activities to some extent. However, though these faced problems created a negative impact on the survey activities in general, all the survey works were completed in a period of 31 days plus two days during which one survey crew revisited Wed Meskin site for resurveying. The farmer's communities residing within the project area were so cooperative and no problems were encountered by the survey team in this regard. Most of the people in the project area were aware of the planned development program and this created a positive impact on the team activities in the area.

## 4. CONCLUSIONS

This topographic survey was performed according to the TOR and the Inception Report of the Additional Surveys. It was carried out by highly qualified and well experienced personnel in the specializations required for topographic survey digital data, collection, management, presentation and documentation. All the services required were made in accordance with the industries accepted standards and practices for survey works in support of topographic survey for proposed irrigation schemes.

The field survey data was collected using modern digital survey equipments. Data processing and mapping were carried out by well experienced personnel in the fields of computer graphics, data processing and presentation using powerful computers. Specialized software programs were used for data plotting and presentation.

The topographic surveys and mapping assignment of the project area was completed within the planned period. The topographic survey has covered a gross area of 8,369 ha or 26% out of the planned 32,000 ha area demarcated using land characteristics observed from satellite images and digitized topographic maps of the project area. As the area surveyed from the project demarcated area is more than the amount to be surveyed and agreed with the client (7,500 ha), it is assumed that the command area topographic survey is completed.

The digital topographic maps produced for the project command area, barrage sites, the major crossing at Al Atshan stream and the canal alignment form an excellent basis for the preparation of the detail design of the proposed irrigation development scheme. These maps provide the required data and documents for the selection of irrigation methods, preparation of irrigation layouts, estimation of land levelling requirements and design of irrigation infrastructure etc.

The horizontal and vertical control network established in the project area and the site reference points at the project specific sites form a very good reference frame for the future setting out activities in the project area, the expansion of the project area and an excellent addition to the National horizontal and vertical control networks in the area.

The problems faced during the execution of the assignment were insignificant and mainly related to hot temperature and the inaccessibility of most of the project area with motorized vehicles.

The hot temperature did not pose major problems as the works were programmed to be carried out in the early mornings and late afternoons. The inaccessibility problem forced the survey team to travel all the time on foot to cover the whole project area. The communities residing within the project area were cooperative and aware of the planned development program and no major problems were encountered by the survey crews from them. However, the negative impacts on the survey activities posed by the inaccessibility of the project area and hot temperature problems were compensated for by increasing the working hours during the day and working through the week ends.