Digital Map Revision – A Namibian Experience

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Key words: Capacity, methodology, lessons, digital, orthophoto.

ABSTRACT

Namibia has complete topographic coverage at the scale of 1:50000. These maps, however, as at 1996, were more than twenty years out of date. At independence, the skilled staff available for the mapping activities in Namibia left for South Africa. The digital map revision was therefore done in an environment with severe limited capacity.

The methodology used was PC based using a GIS package with use limited to the region. The scale of photography used was 1:80 000 as opposed to the conventional scale of 1:60 000 or 1:50 000 used worldwide.

The strategy for the implementation of this project was split into two, Administrative strategy and Execution strategy. The administrative Strategy includes, selection of consultant and contractor, identification of entities, sources and qualities, acquisition of hardware and software, the training of staff and organization of workshops with users. The execution strategy includes acquisition of aerial photographs and orthophotos, capture of old data from existing plates, application of changes by comparing old data and new digital orthophoto and quality control.

The use of a PC-based system is advised for an environment with limited capcity and resources. Standardising on a software package with limited international usage was found costly. It is possible to use raw personnel to achieve satisfactory result. However this demands considerable technical assistance to accomplish. Having qualified personnel is still the best.

The use of a twin camera as compromise between an aerail photography coverage at small or large scale is recommended. Quality control must be strictly applied and enforced at every phase of the production. It is also very important to document the quality within the data. Using external evaluation is necessary when parts of the work are outsourced, but normally, quality control should be done internally.

This paper further discusses the methodology used, the problems encountered and the lessons learnt with respect to selection of hardware and software, scale of photography, quality of personnel, selection of contractor/consultants and quality control. Recommendations were also made for application in similar environment.

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1. BACKGROUND

Namibia has the privilege to have a comprehensive topographic map coverage of the whole country at 1:50,000 scale. These maps were produced during the colonial era. Limited activities related to the production of these maps were done from the Surveyor General Office in Namibia with significant portion done in South Africa. At independence, many staff members returned to South Africa and investments in equipment fell behind. Consequently, the mapping activities at the Directorate of Survey and Mapping (DSM) in Namibia were reduced to cadastral activities.

The quality of these maps is indeed very good, but, by 1994, they were seriously outdated, especially in the northern regions, where very important development occurred in the last 20 years. Moreover, an important backlog existed in printed maps. This situation explains the recurrent request for updated topographic maps made by actors of regional development.

Therefore, in 1995, the Lux-Development in collaboration with the DSM started a pilot project for map updating in the Kavango region. This project had two main objectives:

1. Produce an updated topographic maps of the Kavango region at the scale, 1:50'000, to be used for development projects (among others) and;
2. Develop the internal capacity in the Directorate of Survey and Mapping to replicate the project in other regions of Namibia.

2. EXECUTION OF THE PROJECT

The strategy for the execution of this project can be split into two, Administrative Strategy and Production Strategy.

2.1 Administrative Strategy

2.1.1 Selection of a Consultant

As a young organization with little experience in data conversion, a Consultant was engaged early enough to help with initial tasks. His initial tasks included developing core data capture requirements, drafting a strategic implementation plan, draft hardware/software and data conversion specifications and advise on the selection of competent system and conversion vendor. The advantage of the same consultant preparing the system specification and conversion specification is that consistency between the two documents is enhanced (Hawkes, 1994). The main benefit of engaging a consultant at this stage is that the consultant has the requisite knowledge and experience in developing specifications and preparing system specifications. To obviate the common problem of the consultant offering off the shelf solution that may not suit a particular environment the consultant worked closely with the project manager in all his tasks. In this way the project manager gained an understanding of the specifications and was also able to impact on the final document.

2.1.2 Selection of a Contractor

A critical component in gaining the confidence and support of management is having visible outputs early enough within the life cycle of the data conversion project. For an organization like ours with little or no experience, engaging a contractor to work along with the in-house team was an attractive option. We were also under pressure to complete the project in two years since the donor agency was not keen on financing the project beyond two years.

In this project, the contractor was both the system vendor and the conversion vendor. This we found very helpful. It reduced the number of organizations to deal with and system related problems were solved with minimum disruption to the project. Usually the selection process involves (Briggs, 1998) issuing of Requests for Information, Invitation to tender, Pre-contract conferences and Pilot Projects. The criteria to select a suitable contractor might include (quoted in Briggs, 1998) capitation and track record of the contractor; experience of the client's industry; experience of the GIS software which is to be adopted; technological competence; and price. This process was not followed in this project principally because of the dearth of suitable companies in Namibia. Teething problems we had mid stream within the project may be attributable to not following a proper procedure for the selection of a conversion contractor.

An important objective of the project was capacity building. In order to address this objective and at the same time meet the deadline, the contractor and the project staff worked in the same premises and substantial part of the work were carried out jointly thereby complimenting his staff with ours. In this way our staff was able to gather the required experience in a productive environment. This arrangement had the added advantage of providing additional skilled capacity to the project without increasing the permanent employee head count. This is very pertinent in our case where the Government is determined to downsize the civil service.

2.1.3 Selection of Suitable Working Space:

We realised early enough within the project and as confirmed in William T. Bersson (1994) that a stand alone project office including personnel and equipment were important for the success of this project. The emphasis by the donor agency on adequate working space was also very helpful in securing the right type of space.

The hardware and software identified by the consultant and discussed with the project manager and the contractor were acquired and installed at the premises identified for this project.

2.1.4 Identification of Entities/Features, Sources and Their Qualities

The main source of the entities to be captured is the plates from which the maps were printed. The entities were mainly derived from the legend of the map. The entities and their sources were presented in a form of source data matrix. The attributes of the data was given as an appendix. The scales and projections were determined by the original maps and there were no multiple scales and projections. Other source records were databases of schools and boreholes.

2.1.5 Aerial Photography and orthophotos

The updating was done from digital orthophotos derived from 1;80 000 small-scale aerial photography. The orthophotos were produced as 1:50’000 hard-copies with the same spatial definition than the 1:50’000 topographic maps, and as digital files (geo-referenced TIFF format).

This scale of the aerial photography is quite unusual, compared to the usual standard used for map updating at 1:50’000 in most countries (aerial photos at scale 1:60’000). The choice of this smaller scale has of course an incidence on the cost of data acquisition and processing. The reduction of cost can be evaluated to 25% of one of the most expensive part of the budget (aerial photography + orthoproduction = 25% of the budget). On the other hand, reducing the scale of the photos also means reducing the ground resolution, and accordingly reducing the potential for interpretation, hence requiring more field survey.

This aspect was especially critical in the Kavango project, because one of the most important features to be extracted from the images were the individual settlements, often impossible to detect on the 1:80 000 photos (small size of the huts, poor contrast of tatched roofs). Moreover, the quality of some photos were below normal expectation (low contrast), but due to important delay in the production, the project was obliged to accept these photos.

The production of the orthophotos was outsourced. The scanning of the photos was done using a 15µm spot size (actually, positive copies of the original negatives were used, allowing some improvement of the poor contrast of the original negatives). The aerial triangulation was also done using the latest and most efficient technologies (Leica Helava DPW 770 digital photogrammetric workstation in combination with Helava automated triangulation system).

The resolution of the orthophoto was downgraded from a (theoretical) 1.2m to 2.5m. This option was mainly dictated (in 1996) by the volume of image data to process on DSM’s 70MHz PCs equipped with 24Mb RAM and 0.5Gb hard-disk (at 2.5m resolution, the digital orthoimage corresponding to 1 map sheet is more than 250Mb).

This was probably not a good decision, and dividing the orthophotos in sub-sheets would be better. The processing power and storage capacity improved dramatically in a few years, and handling 500MB images from CD-ROM is no more a problem. It is quite obvious that the resolution of the orthophotos should now be set at the maximum possible. However, the actual value should not be determined from theoretical values only, but rather from comparative tests, because the optimal resolution also depends on external factors (quality of the film process, optical quality of the atmosphere during the flight mission, etc.) From good quality 1:80’000 aerial photos, it should be possible to produce orthos with 1.5m pixels. Practically, such images could be enlarged up to 1:10’000 on the display.

Because of the interest of many users for orthophotos, it is recommended to consider the orthophotos as a commercial product and to produce more copies for sale.

2.1.6 Acquisition of Hardware and software

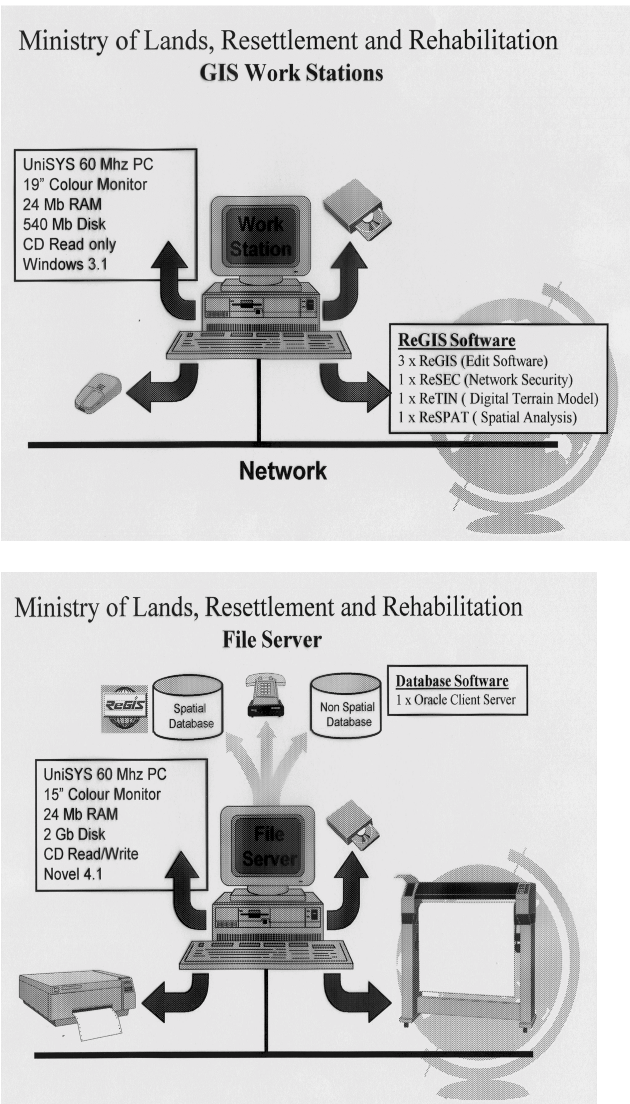

Figure 1: hardware and software Configurations

When the project started, in 1995, it was decided to base all the production done locally in Namibia on PC computers, because of the cost, but mainly because of the difficulty to maintain UNIX-based workstation in this technical environment. The 5 computers provided to the project conformed to the standards prevalent at the time: Pentium 70 MHz, with 510 MB hard disk, 32 MB RAM, etc. Three A0 digitising tables and one A0 colour plotter were also installed in the DSM office, in Windhoek. A file server was added to the system, configured as a LAN. During a mid-term review of the project, it became obvious that these PCs were not sufficient to efficiently process the huge volume of data requested by the project (some 20 GB of digital orthophotos), and another 5 PCs, with up-to-date specifications were added to the project (Pentium II 350 MHz, 128 MB RAM, 1.6 GB to 7.5 GB hard disk). The operating system was also upgraded from Windows 3.11 to Windows NT 4.

The option to use only PC computers for an important mapping project was not so obvious in 1995. From the experience gained, this choice can be recommended for the future, even if the cost aspect is not taken into account.

2.1.7 GIS Software

Another important decision taken at the beginning of the project was to base most of the activities on the usage of GIS software. Again, this seems quite obvious now, but in 1995, many mapping projects were still based on CAD and/or dedicated solutions.
The software used for this project was ReGIS, developed by Computer Foundation (South Africa). This GIS was a *de-facto* standard in Southern Africa when the project started. In many aspects, this software is very different than the most commonly used GIS software . One of the most interesting aspects of this software (with its additional modules) was its performance for heads-up digitising using large images, a feature that was not so common a few years ago. In 1998, the development of ReGIS was stopped, and it won't be supported anymore. For future map updating activities, the DSM decided to switch to a more widely used package.

2.1.8 Workshop with Users

The need to involve users of our product early enough in the lifecycle of the project was emphasized in the project document. Instead of having individual discussions it was decided to have a workshop where the intended project methodology, entities to be captured, accuracy, sources and other details were presented and the views solicited from end users. After the presentation, the audience broke into groups determined by interest in the different themes to be captured. This approach proved very helpful. At the end each group presented their findings and suggestions for resolutions to be taken.

The resolutions taken at this workshop were incorporated in the conversion specifications, work plans and the prototype data model.
A second workshop was held with users after carrying out a pilot project.

2.2 Production Strategy

2.2.1 Conversion Specifications, Procedures and Design of Data model

The data model was essentially driven by the conversion specifications. The consultant in close cooperation with the project manager designed the data model. An adequate conversion specification is very essential for a successful conversion project. A conversion specification (Hawkes, 1994) is a technical document containing all the information necessary for the conversion team to develop and implement procedures for the delivery of the data in a format, a time period and at a quality level acceptable to the user. The contents of a conversion specification includes, scope of work, system specifications, data specifications, accuracy specifications, acceptance criteria, schedule and delivery.

Our initial specification document, although reflecting the above content, was found very deficient with respect to schedule ad acceptance criteria. This was modified later in the project. The data base design was also found to be too theoretical and difficult to implement. Some modifications were also made here.

We gave very little attention to data scrubbing. Fortunately, problems arising from this were very minimal. We had no proper workflows and movement of documents was not properly documented.

2.2.2 Training of Staff

Capacity building was very central to this project. Being a new organization with very little experience, training was of utmost importance. Training on the data capture and GIS software were carried out very early within the project. Short learning curves were very critical in choosing the packages for this project. The option selected was to use only PC-based equipment and to intensively use GIS solutions

Training related to the software used for the project, as well as training on GIS, photo-interpretation, mapping and quality control were provided to project staff in 1996. The most important part of the training was however organised as on-the-job training, where the DSM carried out about 25% of the map production. A consultant from the contracting firm was engaged specially to oversee the data capture by the project staff. A detailed data capture manual was also produced and used extensively for the project. This was a time consuming process, as some operators had to redo several times the same activities before achieving expected results. However, this approach proved satisfactory, and at the end of the project, most operators were able to perform in a satisfactory way, even if not fully self-supported.
In its initial definition, the project expected to train 3 to 6 persons, having an academic background and some professional experience, to become GIS/mapping experts, with the risk of having them resign at the end of the project, preferring to work for private company. At the end of the actual project, 6 persons starting with nearly no background and experience were trained to be operational for technical tasks related to mapping, and they are still very motivated to continue working and learning with the DSM. With some technical assistance and some supervision, they can be considered to be nearly operational, at least for the data capture, map updating, field completion and map editing. Other more technical tasks like aerial photography, the orthophoto production and offset printing will still be outsourced.

2.2.3 Pilot Project

A small area sufficient enough to test a considerable number of the specification components was chosen. The pilot was also used to determine the capture scheme. For example, does one operator capture all the themes within a map sheet or should operators specialize in themes? We were also able to determine a more realistic data capture rate and some limitations of the software.

The findings from the pilot were then used to fine-tune the workflow, revise the specifications, work plan and methodology. The results of the pilot project together with the revised documents were again presented to the users before the conversion started in earnest.

2.2.4 Capturing data from old maps

A preliminary activity was the duplication of original plates

All information from the old maps were captured and stored in a GIS database. A sub-contractor did the capture of 75% of the maps, while the DSM, as part of the training achieved the remaining.

The decision to capture all elements from the previous maps has its pros and cons. For the aim of map updating, many elements were simply not usable for the new map: for instance, the amount of change in the cultivated areas was so significant that it was nearly impossible to modify existing polygons, and new polygons had to be created instead. Digitising contour lines and spot heights, river network and roads were certainly useful, while other themes, corresponding to less-permanent man-made features were less interesting. On the other hand, this exercise was very useful to train the new staff of DSM in mapping and to become familiar with the GIS. Moreover, having this GIS version of the complete old situation proved invaluable for further regional management (but this is not really related to the map updating project).

The quality of the data capture was not sufficient: many errors were found later in the attributes, and both the internal and inter-layers consistency was questionable (unclosed polygons, badly correlated rivers and contours, etc.). Of course, these errors, judged minor during this phase, had important effects in the later stages.

2.2.5 Map Revision Principles

The first phase of the updating is done in the office, by visual comparison of the existing situation (the vector data captured on the old maps) with the recent situation (synthesised by the orthoimages). This is done in the GIS, bringing the vector data as overlay on the image data. The software used has an efficient module to prepare orthoimages for faster display, and to handle these images in the GIS.

A lot of interesting "service" data are as well available in different government ministries and were included in the new topographic maps. These include administrative limits, roads network, telephone and powerlines. List of schools and list of boreholes were also provided, with co-ordinates. In most cases, these external sources were only used as complementary information, because of their inadequate scale and/or accuracy. For instance, the new classification of the roads, provided by the Ministry of Works was very useful to give the proper attribute to road segments, but the precise location of the roads was captured from the orthoimages.

Map updating is a much more difficult task than data capturing, as it requires excellent capabilities for photo-interpretation (including of course a good knowledge of the region of interest), and the ability to work in a very systematic and replicable way. Accordingly, for the DSM, this part of the production required a considerable amount of training and technical assistance.

2.2.6 Field Completion

With all topographic mapping, a thorough and comprehensive field completion is an absolute necessity to ensure the completeness and quality of the information contained in the final maps. A part of this activity was also outsourced (to the company who also carried out the updating), and the DSM was in charge of 20 map sheets.

Usage of GPS for field work is an invaluable help, both to reach the areas to work, and to integrate new observations in the database. However, the amount of work requested for field completion was largely underestimated, partly due to the very poor accessibility of some areas. To some extent, field completion is also needed to correct errors and shortcomings done in the previous phase. The poor quality of the updating done by interpretation of the aerial photos has to be balanced here.

Normally field completion is undertaken by the most experienced and skilled topographers or topographic surveyors employed within the mapping organisation. Usually these personnel have undergone a formal education and training in land surveying, supplemented by extensive field surveying experience. This was very far from being the case with the Kavango Project, both at the DSM and at the sub-contractor's side.

The experience gained in Kavango project will certainly be very helpful in future field validation exercies.

2.2.7 Quality Control

The saying "garbage in garbage out" is very relevant in any map revision project. Data quality assessment is a very important task in the process of building a geographical database, because the quality of the used data will influence any further operation. It is now generally recognized that error, inaccuracy, and imprecision can "make or break" many types of GIS project. In deciding on the quality of the captured data, we were also conscious of the following facts:

- The trade-off between data quality and costs
- Variability of data quality with respect to applications.

The guiding rule **" fitness for purpose"** was applied but unfortunately not complemented by **"truth of labelling"**: in the sense suggested by US National Committee for Digital Cartographic Data Standard (NCDCDS). Including the truth (quality) about each data set in the report, would enable the user to make his/her own judgement.

The basic concept of the quality control of digitizing is to compare the content of the digital database with the original printed maps (or films). The plots were overlaid on the films and checked using a light table. In our own case, where the final product includes a GIS database, the assessment of quality encompasses the following:

- Positional Accuracy (Mapped location with respect to the true location in real the world).

- Attribute Accuracy (degree of compliance of observations found in the database compared to values found on the ground).
- Completeness (the number of missing entries)
- Logical Consistency (for example crossing contours, interruptions in hygrographic network, roads crossing rivers without a bridge, valid range of values, etc.)

3 CONCLUSION/LESSONS LEARNT

3.1 Hardware and software

The option to use only PC computers for an important mapping project was not so obvious in 1995. From the experience gained, this choice can be recommended for the future, even if the cost aspect is not taken into account.

Considering the quality of staff used for the map revision and the fund available for the project, the choice of ReGIS for the project could be justified. This GIS was a *de-facto* standard in southern Africa when the project started and therefore had local support. With additional customization it proved efficient. In 1998, the development of ReGIS was stopped, and it won't be supported anymore. **A lesson from this is to be wary of standardising on a software package with limited international support. For this switch, we had to embark on another retraining programme with attendant loss in productivity. We also had to modify our methodology.**

3.2 Quality of Personnel

It is possible to use raw personnel to achieve satisfactory result. However this demands considerable technical assistance to accomplish. Having qualified personnel is still the best.

3.3 Data Capture

Recommendations for future projects will be to capture only the re-usable features of the old maps, and to use semi-automatic scanning/vectorisation as much as possible (the DSM is now equipped and trained to use an A0 scanner and vectorising software). Another recommendation is to develop a complete strategy for quality control and to implement it in all phases of the project. This is especially important when some activities are performed by sub-contractors.

3.4 Scale of Aerial Photography

The 1:80 000 scale proved cost effective and satisfactory results were obtained. The major problem was identifying small punctual elements like huts. However, there is still doubt if this deficiency can be cured by enlarging the scale to 1:50 000. One would rather recommend that a twin camera be used in the same mission, one shooting at 1:80 000 while another shoots selected areas at a scale of 1:20 000.

3.5 Satellite Imagery Versus Orthophoto

The usage of orthophotos is easier to understand for non educated operators, but the cost of producing the orthophotos is quite high, and this technology (production of orthophotos) cannot realistically be transferred in Namibia. It is nevertheless worth mentioning that the orthophotos are, in themselves, valuable by-products of the process of updating that can be used (either in digital or hard-copy format) for various applications in geology, forestry, agriculture and the environmental sciences. These can be sold especially if cost-recovery is concerned. This is not possible with satellite imagery since copyright would reside outside the DSM. The price differential between geometrically corrected and georeferenced satellite imagery(10m) is not significant especially with the disproportionate increase in the field validation task. The orthophotos approach is most demanding for computer power (to handle large digital images), especially if one tries to use only PC-based solutions. This aspect was critical when the project started, but thanks to the very fast evolution of PC hardware, it is no more a problem. The DSM would continue to use this approach.

3.6 Cost

Our map revision programme went relatively well. The cost remained within our budget and comparable with the cost elsewhere. The cost of the project so far is about US$1 million This amounts to US$20-00 per square kilometre considering that the total area is about 50 000km^2 Although we underestimated the cost of the data capture, we were lucky that the cost of hardware reduced drastically and thus compensated for the extra cost of the data capture.

3.7 Quality Control

During the project planning, the assumption was that our data was good so that post data conversion data validation and correction will mostly be concerned with errors introduced during the data conversion. This was found not to be correct. During data validation, we found significant number of logical inconsistencies, like contours crossing each other, rivers moving over high terrains, etc. During edge matching we also noticed that many features that were supposed to join on adjoining sheets did not do so. The quality control was organised sheet by sheet. Although this was helpful, we found it inadequate. We therefore had to supplement this with block checking.
Recommendations are very clear here: quality control must be strictly applied and enforced at every phase of the production. It is also very important to document the quality within the data. Using external evaluation is necessary when parts of the work are outsourced, but normally, quality control should be done internally.

3.8 Capacity Building

We currently have the capacity to complete the data conversion programme. This is a testimony to success of the training method employed during the project. Our need for external assistance has been reduced to about 20% and this is expected to reduce to about 10% within the next one year.

3.9 Consultant

The engagement of a consultant early in the project was found to be very helpful. He helped to design the project monitoring mechanism and assist in many technical areas before they got out of hand. We experienced, however that he was more inclined to pleasing the donor agency that engaged him on our behalf than serving our peculiar needs. For example, capacity building is an essential index of the successfulness of the project, but it was not for the consultant. A lesson from this is that, no matter the source of funding, our organization should be involved in the choice of a consultant.

3.10 Contractor

The choice of a contractor was not done through a Request for Proposal. We just took a gamble. We nearly paid for this gamble but for the timely intervention of the project management committee who engaged additional experienced hands to ensure we still delivered on schedule. The contractor was good on the software side but not sufficiently experienced in data capture involving topographic maps.

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BIOGRAPHICAL NOTES

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