CRANFIELD UNIVERSITY

School of Applied Sciences

Environmental Water Management

MSc THESIS
Academic Year: 2009 to 2010

GIS & GPS Capacity-building for Development Organisations working with the Urban Poor

M. C. Waterkeyn

September 2010

Supervisor: T. Brewer

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Water Management

ABSTRACT

Geospatial technology can benefit development organisations by giving them the ability to map their own projects; while also providing a graphic communication platform between professions, other organisations, donors, government ministries, and the populations that they serve – improving overall efficiency and effectiveness.

While the use of maps to share information has the potential to become the *lingua franca* across the development sector; small organisations that simply do not have the resources to dedicate staff time to capacity-building – using commonly available guidelines – become isolated from this growing *geospatial community*.

This study investigated the challenges and successes of a GIS & GPS capacity-building programme carried out in July 2010, designed for technical and managerial staff working on water and sanitation projects in the informal settlements of Kibera (Nairobi).

Assessment of the training programme revealed that basic mapping skills could be successfully transferred to the project staff; giving them the capacity to use geospatial technology to better plan, design, implement and evaluate their projects. Key to successful skill-transfer was attributed to the fact that the training materials were specifically developed around a project they were all working on, and was therefore of direct relevance and benefit to their work.

While the in-country phase of this research did not last long enough to assess the long term impact of this capacity building, there was however evidence that the capacity building was likely to have a lasting and positive impact. Skill sharing between trainees during the course suggested that further in-house training was possible, while the use of different versions of GIS software suggested that the training material could be adapted to other versions or brands of software. Some trainees also produced maps beyond the scope of the syllabus, suggesting successful knowledge transfer and the potential application of geospatial technology to other projects in the future.

ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude *Water and Sanitation for the Urban Poor* [WSUP] – the director Sam Parker, and all of the staff in London and Nairobi – for initiating and sponsoring the capacity building project, and for providing invaluable advice throughout the project.

I would like to especially thank WSUP's Project Manager for Nairobi, Peter Murigi, for his encouragement and help in facilitating the training workshop – without his support the capacity-building would not have taken place. I would like to thank all of the trainees who attended the course, for their constant enthusiasm and hard work – and their organisations, for sparing them the time out of their very busy work schedules. I dearly hope that you found that your time was well spent and that the knowledge and skills you learned in GIS and GPS will help you with your excellent work.

I would like to thank the *Umande Trust* for spending time showing me around the project areas in Kibera, and the *Nairobi City Water and Sanitation Company* [NCWSC] for providing the geographic data files on which the training materials were based.

I am grateful to *Cranfield University*'s MSc Student, Philip Shea, who carried out the feasibility study into integrating GIS and GPS into WSUP's operations last year, that led on to the capacity-building that I followed up with this year.

I would like to acknowledge the very good work of *MapKibera* and their partner organisations, in mapping out the Kibera townships and for publishing their files online. I hope that this training material will in-turn assist your organisation, as well as other individuals and organisations working in the informal settlements of Kibera.

Finally, I would like to thank my thesis supervisor, Tim Brewer, and my project coordinator, Alison Parker, (both at *Cranfield University*) for their training, advice and encouragement.

Contents

1. INTRODUCTION 7
  1.1. Rationale 7
    1.1.1. Update on global water and sanitation 7
    1.1.2. Why focus on the Urban Poor? 8
2. LITERATURE REVIEW 10
  2.1. Building *Common-Unity* with Maps 10
  2.2. Better Project Management through Mapping 11
  2.3. Geospatial Technology: Guidelines and Case Studies 12
  2.4. Applying Geospatial Technology to WSUP projects 15
  2.5. Capacity building for WSUP in GIS and GPS 16
  2.6. Summary of Literature Review 16
3. METHODOLOGY 18
  3.1. Initial Consultation & Observations 19
    3.1.1. Capacity building ethos of WSUP and their partners 19
    3.1.2. Current Projects of WSUP and their partners 19
    3.1.3. Assessment of current mapping capacity and use 22
  3.2. Assessment of the need for and nature of any capacity building 25
  3.3. Design of capacity building programme 27
    3.3.1. Target mapping capacity 27
    3.3.2. Approach 28
4. RESULTS 31
5. DISCUSSION 36
  5.1. Challenges 36
  5.2. Successes 38
6. CONCLUSIONS 42
7. RECOMMENDATIONS 44
  7.1. Practice: 44
  7.2. Evaluation: 44
  7.3. Extension: 44
8. REFERENCES 46
APPENDICIES 52

List of Figures

Figure 1: Kibera, Nairobi one of the largest slums in Africa and infamous for its 'flying toilets'. ________ 9

Figure 2: A Biocentre built by WSUP and their partners in Gatwekera (Kibera, Nairobi) ____________ 15

Figure 3: A typical backstreet in Kibera ____________ 15

Figure 4: Flow diagram of Research Methodology ____________ ***Error! Bookmark not defined.***

Figure 5: Map used in a community consultation meeting ____________ 21

Figure 6: Capacity Building Structure ____________ 29

Figure 7: GPS capacity building: Navigation and Data Collection in Kibera ____________ 35

Figure 8: Group work made in the training workshop ____________ 40

List of Tables

Table 1: Programme for Capacity Building Course ____________ 32

Table 2: GIS & GPS Capacity Building Syllabus and Course Activities ____________ 33

List of Abbreviations

ADWEA	–	Abu Dhabi Water and Electricity Authority
ASWB	–	Athi Services Water Board
CAD	–	Computer Aided Design
CB	–	Capacity Building
CBO	–	Community Based Organisation
CFK	–	Carolina For Kibera
CHC	–	Community Health Club
EA	–	East(ern) Africa
GIM	–	Geographical Information Management
GIS	–	Geographical Information System
GPS	–	Global Positioning System
.KML	–	Keyhole Mark-up Language
PEP	–	Poverty Environmental Partnership
MDG	–	Millennium Development Goals
NCC	–	Nairobi City Council
NGO	–	Non-Governmental Organisation
NPO	–	Not for Profit Organisation
NCWSC	–	Nairobi City Water and Sewerage Company
ODA	–	Overseas Development Institute
PHAST	–	Participatory Hygiene And Sanitation Transfer
RS	–	Remote Sensing
.SCP	–	Social Connection Policy
SHP	–	Shapefile
UN	–	United Nations
UNDP	–	United Nations Development Programme
UNFPA	–	United Nations Population Fund

1. INTRODUCTION

1.1. Rationale

1.1.1. Update on global water and sanitation

It is estimated that nearly one billion people in the world currently live without reliable access to safe drinking water; 2.4 billion people still lack access to hygienic sanitation facilities, while half of these people have no sanitation facilities at all. This global shortage of water and sanitation accounts for an average of 5,000 children dying daily due to illnesses related to poor access to water and hygienic sanitation [UNDP, 2010a].

In 2000, the United Nations Development Programme (UNDP), as part of a suite of eight Millennium Development Goals (MDGs) – signed up to by 189 nations, set a global target to "*reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation, by 2015*" [UNDP, 2010b – MDG 7].

According to the UNDP, "*The world is on track to meet the water target, but there are major gaps in many regions and countries, particularly in Sub-Saharan Africa. On current trends, the world will miss the sanitation target by a staggering 700 million people.*" [UNDP, 2010a]

In a comprehensive report on the state of the world's progress with respect to the achieving the MDGs, the UN Secretary General added the following words of encouragement:

*"The world possesses the **resources** and **knowledge** to ensure that even the poorest countries, and others held back by disease, geographic isolation or civil strife can be empowered to achieve the MDGs."* [Ban Ki Moon – UN, 2010]

Whilst the two targets for water and sanitation were not granted their own dedicated MDGs, it is becoming increasingly recognised that meeting these two targets underpin all the other MDGs [PEP, 2006]. If for no other reason, investment into this sector can be justified purely on economic terms; it is estimated that for every $1 spent on improving access to clean water, there is an average economic return of $4.4, while every $1 spent on sanitation gives a return of $9.1 [UNDP, 2010a].

1.1.2. Why focus on the Urban Poor?

By 2007, for the first time in history, half of the world's population inhabited urban areas. Over one billion people currently live in urban slums, 300 million of which do not have access to a clean water supply, while 400 million people do not have access to improved sanitation [World Bank, 2010].

By 2030, the number of people living in urban areas is predicted to increase by a further 4.9 billion over 2007 figures, equivalent to roughly 70% of the world's current population – while the number of people living in rural areas is expected to drop by 28 million [UNFPA, 2007; WSUP, 2010a].

Census data relating to global trends must be collated from a vast network of sources, and relies upon synchronising a complex array of models and sampling techniques, each with their own contribution of uncertainty (which is especially true when forecasting trends over long timescales). There will clearly be a significant level of uncertainty associated to the actual numbers presented, and analysis of such error is beyond the scope of this study, however, there are a few clear conclusions that can be drawn from this data that provide the underlying rationale for this research into capacity-building for development organisations, particularly those that work for urban poor:

- There are already unacceptable levels of poverty; billions of people do not have access to even the most fundamental of human needs – safe water and hygienic sanitation.
- The world's population is increasing at an alarming rate.
- The near-doubling of the world's human population in the next two decades is going to take place predominantly in urban areas.
- If development of these areas does not keep up with the population growth, the standard of living – already below the level of abject poverty for a large proportion of this urban population – is going to fall even further.
- In order to develop these urban areas, and to meet the targets set out by the MDGs, organisations working at a grass-roots level in urban slums level need to

build their operational capacity so that they are better equipped keep up with the rapid growth of slum populations.

- At every level, the coordination and evaluation of water, sanitation and hygiene promotion (WASH) projects is vital for effective implementation.

These last two points are especially relevant to this research project, which investigates the value of building the mapping capacity of development organisations, specifically those operating in urban slums, so that they can better coordinate and evaluate their work. In doing so, this study will also investigate the need and nature of any dedicated training in the use of GIS and GPS for project-level staff working for such organisations.

This research revolves around a case-study on a capacity building project that was carried out in June and July of this year for project staff from WSUP and their partner organisations who are implementing a range of WASH projects in the slums of Kibera, Nairobi. Figure 1 shows a typical scene from Kibera.

Figure 1: Kibera, Nairobi one of the largest slums in Africa and infamous for its 'flying toilets'. The severe lack of basic water and sanitation facilities mean that dysentery, cholera and other waterborne diseases are still a daily threat to the estimated 700,000 people who are crowded into an area of just 2.5km^2 [CFK, 2010].

Photo by M.C. Waterkeyn, 2010

2. LITERATURE REVIEW

2.1.Building *Common-Unity* with Maps

Any assumption of there being a functional *community* – a unified group people living together with whom an external organisation can liaise – within a given urban slum can lead to serious problems. Slums are generally made up by the informal settlements of a plethora of peoples; they are a melting pot of local residents and migrants with an amorphous demographic profile that comprises a wide range of ages, incomes, religions, and ethnic and cultural backgrounds.

Slums are characterised by their deplorable living conditions, with widespread malnutrition, disease and exposure to violence. Despite great efforts being made to achieve the MDGs for urban populations, the concentration of health and social hazards, and disorder of physical infrastructure and census data, all combine to create a complex challenge for organisations operating in urban slums. These challenges are felt at every stage in their operations; in their efforts to identify the causes of high rates of mortality and morbidity to design the most appropriate course of action to reduce these figures; in their attempts to liaise with the target population they are seeking to serve; and in their evaluation of the impacts of their work [Butala et al. 2010].

Some slums may have strong communities and have their own vibrant sub-economy, but such slums would be exceptional; slums are generally deeply fragmented, often divided along ethnic and religious lines, while the pressure of congested living conditions, combined with widespread and abject poverty mean that operating in slums can be a political minefield. Unless a rigorous effort is made to engage openly with the 'community' prior to any intervention, there is a real risk for such organisations being accused of favouritism towards one particular group of people.

Before a development organisation can successfully implement a project that has the support of the target population, *community-building* is likely to be a prerequisite activity in all but the most tightly bound and well formed communities. By focussing on development issues, such as, water and sanitation implementation, health promotion, or any other problem faced by the target population, a population is encouraged to consider the issues that they share, rather than concentrate on their differences [Waterkeyn & Cairncross, 2005; Waterkeyn, 2007].

Maps provide a visual tool to demonstrate to the target population the rationale behind a given project; this helps to bring an otherwise fragmented population together to achieve common goals that can benefit them all. Maps also provide visual feedback to the community of their progress, which is an important element of project sustainability in that the community is encouraged to be proud and take ownership of its own development. The benefits of using maps for project management and community liaison are now well established and are a key element of the now mainstream Participatory Hygiene And Sanitation Transfer (PHAST) methodology [Srinavasan, 1990]. Project mapping, even by hand, by the community themselves, helps development organisations to foster *Common-Unity* within the target population they are trying to help, whilst also helping to structure and evaluate the project around community-set objectives [Waterkeyn, 2010].

It is the process of community-building, followed by community consultation, and the subsequent earning the local stakeholder trust and support that is crucial for any sustainable development, that provides the strongest argument for development organisations to invest in building their own mapping capacity: geospatial technology is to mapping what personal computers and the internet are to typewriters and the postal service. Even when applied at the most basic level for mapping, geospatial technology can provide organisations with the ability to efficiently produce and disseminate clear *graphic* illustrations of the current situation on the ground, the proposed work, and the intended impacts.

2.2. Better Project Management through Mapping

Beyond community-building and community consultation, maps can also assist organisations to assess the situation on the ground at a project management level – and to adapt a project accordingly. In-house mapping can also be used by development and emergency-relief organisations and for collating project results and coordinating operations between different project areas, their partner organisations, and other organisations working in the same area[1].

Regular maps showing the same variables that are changing in the same area, for example, weekly occurrence of cholera in households in a village, allow development organisations to evaluate the impact of their programme over time [WHO, 2010a,b]. Spatial and temporal analysis and presentation of projects is another use to which maps, and in particular the digital processing power offered by geospatial technology, can be put. This technology is especially valuable when summarising and clearly presenting project proposals, progress, and key findings to donors, government and the development community at large.

Spatial and temporal analysis of maps can help to identify trends that would otherwise be hidden in spreadsheets or lengthy documents. A famous example of how the spatial analysis of health data can lead to crucially important understanding was when Dr John Snow (1849) made the vital connection between the locations of household cases of cholera and a contaminated well in Soho, London. The geographical representation of health data not only helped provide the inspiration to cordon off the contaminated well, but also led to the fundamental discovery that cholera was a waterborne disease[2].

2.3.Geospatial Technology: Guidelines and Case Studies

Everything that happens – happens *somewhere*.

Geospatial technology refers to a suite hardware and software that can be used to produce and use maps in a digital format. It can be broadly split into three parts [Longley et al., 2001]:

- Geographical Information Systems (GIS) is the central, software-based element of geospatial technology. It allows the user(s) to produce, illustrate and edit digital geographic data in the form of maps.

[1] For example, in post-earthquake Port au Prince (Haiti) emergency response operations were coordinated through online mapping [Washington Post, 2010].
[2] This hypothesis was initially rejected by medical journals at the time [John Snow Society, 2010].

- Global Positioning Systems (GPS) is the hardware-based element of geospatial technology that allows users to record or find the coordinates of points in the field.
- Remote Sensing (RS) is a hardware-based monitoring component of geospatial technology and serves the purpose of collecting descriptive information (attribute data) about a remote point in the field (entities).

RS covers a broad area of applications, that could range from gathering hydraulic data at a point in a pipe and feeding it automatically back into a GIS (for example, georeferenced water meters and telemetry), to satellite and aerial imagery or sensing of the earth's surface that provides information on anything from landuse, to weather, to surface temperature. The widely used and freely available satellite imagery published online by Google has made the integration of geospatial technology accessible to even the smallest development organisations. These images are available both through an internet browser [Google Maps, 2010] and through its own dedicated software [Google Earth, 2010]. The simple and intuitive workings of both, and the fact that they are freely available, are largely responsible for the popular uptake and use of these two open-source programmes by development organisations. In Kibera (Nairobi, Kenya), an initiative to coordinate and build upon existing mapping infrastructure has recently been established; where the locations of schools, roads, clinics, restaurants and other surface features and infrastructure is being mapped using handheld GPS and uploaded onto Google Earth for public use [Map Kibera, 2010]. Free online satellite imagery has made expenditure on the capturing and processing of dedicated aerial photographs by small development organisations largely unnecessary. As such, the focus of this research will be on building the capacity of small development organisations in the use of GIS software and GPS hardware, with a view that such capacity building could still complement the growing use of Google Earth.

There are a range of online guidelines and tutorials available to individuals and/or organisations wishing to use GIS to map their projects. Beyond the standard help menus and online user forums available from individual software manufactures on the use of their programmes, [DevInfo, 2010; ESRI, 2010; Map Window, 2010; Google Earth and Google Maps, 2010], there are also numerous studies and guidelines available to help users from development organisations to design and implement their intended mapping activities – particularly for Google Earth [Marks et al. (2009) – Google Outreach and Techsoup; Morris et al. (2009); Woof et al. (2008), Crossley (2008)]. Software producers also offer regionally available structured training in GIS, such as the series of courses in ArcGIS that take place around the annual ESRI Eastern Africa User Conference.

In a series of case studies carried out in Malawi, Tanzania, Pakistan, Nepal, Nigeria and Ghana, WaterAid [2004] and Welle [2005, 2006a,b, 2007a,b,c] investigate the use of mapping, and in most cases, the application of GIS and GPS technologies, as an advocacy tool to build arguments for the implementation of water and sanitation. Mapping – especially with the use of GIS and GPS – was found to be in its nascent stages in most of the countries studied, and there is little attention given to how these organisations had or were building their mapping capacity. However, the reports do offer valuable guidance to both WaterAid and other development organisations who wish to gain an overview of the range of different approaches, applications and limitations of applying mapping to water and sanitation projects. Summaries of mapping costs in each of the countries[3] are also provided, which serve to guide other organisations who wish to carry out similar mapping projects.

In South Africa, a relatively new version of RS called Mobile Researcher Platform[4] has been successfully applied to gathering social data within an Integrated Water Resource Management project [Rosenfeld et al., 2009]. This mobile phone application is especially relevant to development organisations that want to monitor social and health patterns and to keep track of behaviour change – and as such, has a similar relevance as GIS and GPS do to development organisations. Key to the success of the technology was its combination with a health promotion methodology that requires health practitioners to gather large amounts of social and environmental data at

[3] Excluding costs of training, but indicating level expertise of mapping staff, equipment used and scope of the mapping carried out (for example – range of social or physical data collected).

[4] Mobile Researcher is a form of RS that allows organisations to georeference the mobile telephone numbers of field workers to a point or area on a map. The mobile phone is loaded with dedicated surveying software that enables them to fill in and transmit results from questionnaires. This application allows for multiple-choice census data to be collected in the field without the need for network coverage, and then send back the data as a text message to a central database – potentially linked a GIS – when the field worker is within range of a mobile phone network.

regular intervals. Mobile Researcher was found to be a very effective and efficient tool for assessing community activity and household health [AfricaAHEAD, 2010]. This application could be put to even greater use if the data collected through the Mobile Researcher Platform were to be tied into a GIS so that the data could be clearly represented spatially[5]. A similar programme to Mobile Researcher Platform that is specifically focussed to creating maps from mobile phone data is called Ushahidi (meaning 'testimony' in Swahili) [Ushahidi, 2010]. If the same variables and mapping area are monitored periodically temporal analysis is also possible – providing a powerful tool for creating baseline surveys and evaluating change.

2.4.Applying Geospatial Technology to WSUP projects

Appendix A gives an overview of WSUP and their partners in Nairobi, and summarises the general scope of the WASH projects that they implement in the slums of Kibera (Figures 2 and 3).

Figure 2: A Biocentre (left) built by WSUP and their partners in Gatwekera (a village in central Kibera, Nairobi).

Figure 3: A typical backstreet in Kibera (right) – 'spaghetti pipes' of illegal water connections that are prone to breakages run through streets with open drains, meaning localised flooding occurs and raw sewerage mixes with treated water.

Photos by M.C. Waterkeyn, 2010

In 2009, Shea investigated a wide range of open-source and proprietary GIS software, GPS equipment, guidelines and case-studies on the use of GIS and GPS in the development sector, and concluded that while each variation of GIS software and GPS equipment had their own individual strengths and weaknesses, geospatial technology

[5] Africa AHEAD did collect the GPS coordinates of each household survey, but due to not having sufficient GIS capacity, this data was not represented in map form.

could generally be put to good use on WSUP's projects in Kibera [Shea, 2009]. A critique of the various versions of GIS and GPS technology that could be used by WSUP is also given in Appendix A.

2.5. Capacity building for WSUP in GIS and GPS

Through Shea's investigations (2009), the installation and demonstration of various GIS software on WSUP and Umande Trust computers, and the use of GPS hardware in the field, some informal GIS & GPS capacity building took place. Capacity building also involved encouraging WSUP and their partners to work with other local organisations in the acquisition and sharing of secondary datasets, against which primary GPS data collected in the field could be plotted. Recognising the potential that capacity in the use of GIS and GPS for mapping WSUP projects, he recommended that further dedicated training was carried out for staff from these organisations. In his report, he also referred to some of the above guidelines and case-studies that could assist project staff from WSUP and their partners to build their own capacity, as well as drawing on previous Cranfield University studies on mapping and the carrying out baseline studies on the WSUP projects in Naivasha, Kenya [Younis et al., 2006] and Bangalore, India [Taillandier et al., 2007].

2.6. Summary of Literature Review

Globally, it appears that there is an urgent need to build the capacity of local organisations to increase their operational efficiency, if the MDG targets for water and sanitation are to be met. Trends in rapid urban growth, combined with the complex nature, poor living conditions and predicted proliferation of slums worldwide, suggest that there is a sound rationale behind focussing on improving safe water and hygienic sanitation access in slums.

The use of mapping for community liaison, advocacy and project management is now well established in the development sector; while the integration of geospatial technology into project work has the potential to improve the efficiency, flexibility, accuracy and coordination of the mapping process within, and between development organisations.

Shea (2009) established that WSUP and their partners in Nairobi could benefit from integrating geospatial technology into their projects, while case-studies carried out by other development organisations operating in Africa and Asia support this conclusion. Some informal capacity building took place in the process of carrying out his research; of most relevance to this current research project was the sourcing and dissemination of online and feely-available field guides and case-studies that could assist project staff in learning how to use and apply GIS and GPS to projects, and the encouragement to share geospatial data between local development organisations. It was recommended that further dedicated capacity-building in GIS and GPS took place for WSUP and their partners.

However, with online guidelines, case-studies and user help forums so readily available, the principle questions that this research project needs to address are as follows:

Is dedicated capacity building in GIS and GPS necessary? – And if so, Why?

Learning the answers to these initial questions is a prerequisite to designing, implementing and evaluating any capacity building programme.

3. METHODOLOGY

Figure 4 illustrates the methodology that was used for assessing the need and nature of dedicated capacity building in geospatial technology.

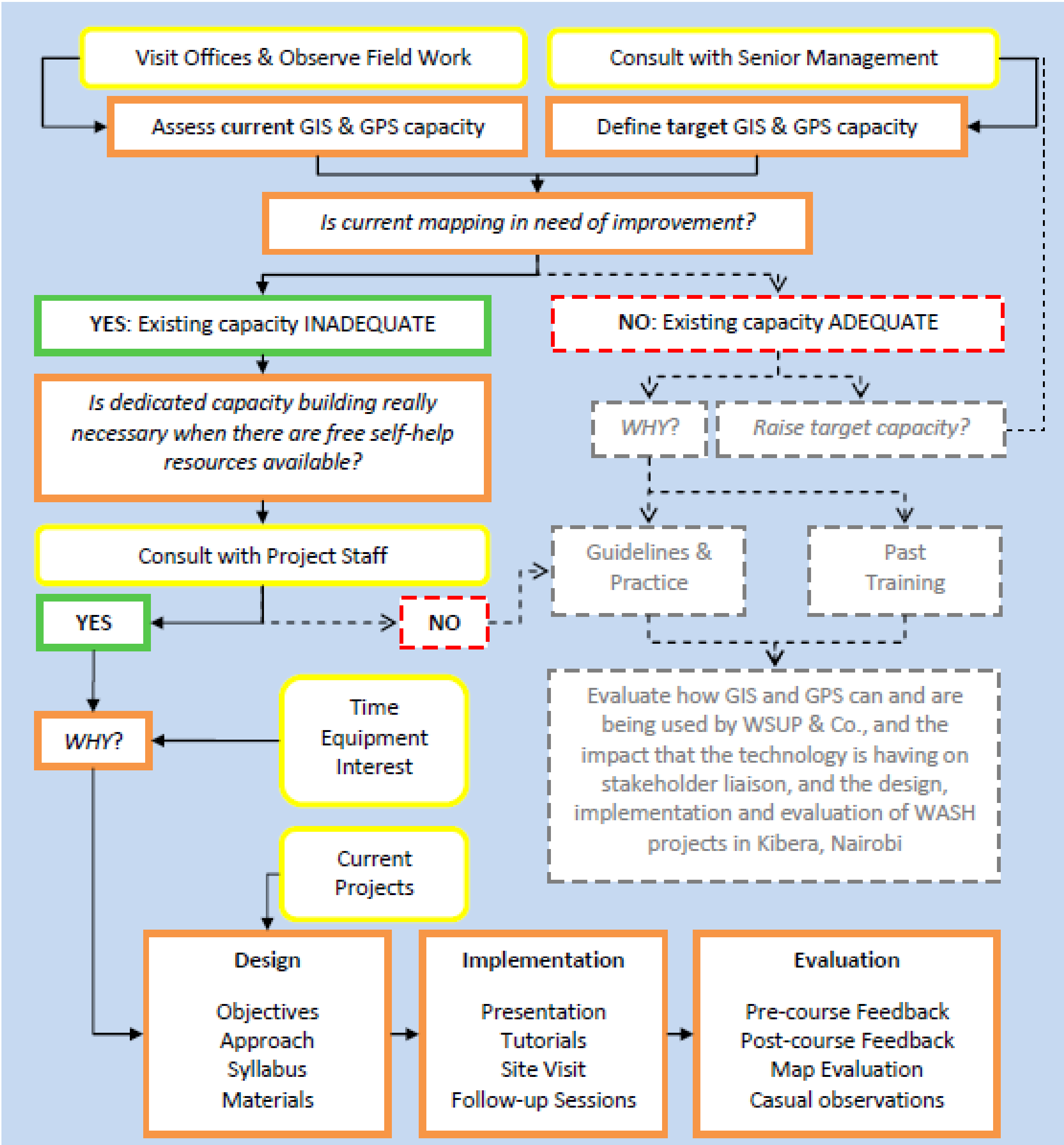

Figure 4: Flow diagram of Research Methodology – solid lines depict the research process undertaken to the design, implementation and evaluation of an appropriate and dedicated capacity building programme; dashed lines represent contingency research, if required.

3.1. Initial Consultation & Observations

3.1.1. Capacity building ethos of WSUP and their partners

To improve the sustainability of any development project that WSUP is involved in, there is a strong emphasis within WSUP on the capacity building of local organisations who play the leading role in implementation and maintenance.

In January 2009, a report on capacity building of NCWSC to improve the ability of local implementing partners' to manage their water and sanitation services was submitted to WSUP [Waite, M., 2009]. This report, while focussing on improving the general management structure of NCWSC, and not specifically on GIS and GPS, split the proposed capacity building into three separate areas: Policy, Education and Operations. In doing so, the report set out a framework for the capacity building developed in this study. Training in GIS and GPS should be of practical use to project level staff; in deciding how to engage with stakeholders (policy), raise public awareness, improve community liaison, train staff and/or create behaviour change (education), and in the design and implementation of the technical aspects of their projects (operations).

Transparency International and Maji Na Ufanisi (2009) called for the Kenyan government to encourage all NPOs involved in water and sanitation to engage in mapping to help coordinate sector development, to avoid 'exclusion' and to allocate resources effectively.

3.1.2. Current Projects of WSUP and their partners

The in-country phase of this research (June-July 2010) coincided with three separate but related water and sanitation initiatives that were in their initial stages of preliminary design:

Firstly, WSUP and their partners (NCWSC & Umande) were planning to implement a proposed Water Reticulation Network (WRN) in the village of Gatwekera (Central Kibera). This new network would deliver piped water into areas of Kibera that are currently reliant on either water vendors selling water to households by the jerry can, or by illegal connections to the water main (known as spaghetti pipes), that are generally made from flimsy electrical conduit pipe that was prone to breakages, leading to localised flooding and/or loss of pressure, and the contamination of the treated water supply as surface sewage enters the municipal system.

Linked to this project, an initiative named ‘Social Connection Policy (SCP) for Nairobi’s Informal Settlements’ was also being formed [WSUP, 2010b]. The SCP proposed that households within a 50m radius of the new WRN would be connected free of charge to the water mains, while households beyond this 50m threshold would be required to supplement the cost of laying pipes to be connected to the mains. It was proposed that the surveying and setting out of the WRN, and by implication, the zoning of free and user-subsidised household connections, would be carried out using GPS equipment.

At the time of this research, the Terms Of Reference were also being drawn up between WSUP and NCWSC for comprehensive mapping of all water and sanitation related infrastructure in the four Kibera villages of Gatwekera, Soweto West, Kisumu Ndogo and Kambi Muru since “there is currently no single comprehensive record of water, sanitation and solid waste infrastructure in the project area” [WSUP, 2010c]. It was intended that mapping of the existing and proposed water and sanitation infrastructure was to be carried out primarily through the collection of primary GPS data that would then be combined with existing secondary data to produce up to date maps that could then be used on related projects in the area.

Figure 5 shows a copy of the map used in a recent consultation meeting held with the local water vendors to explain the proposed works and to discuss how the problem of illegal connections could be addressed [WSUP, 2010d].

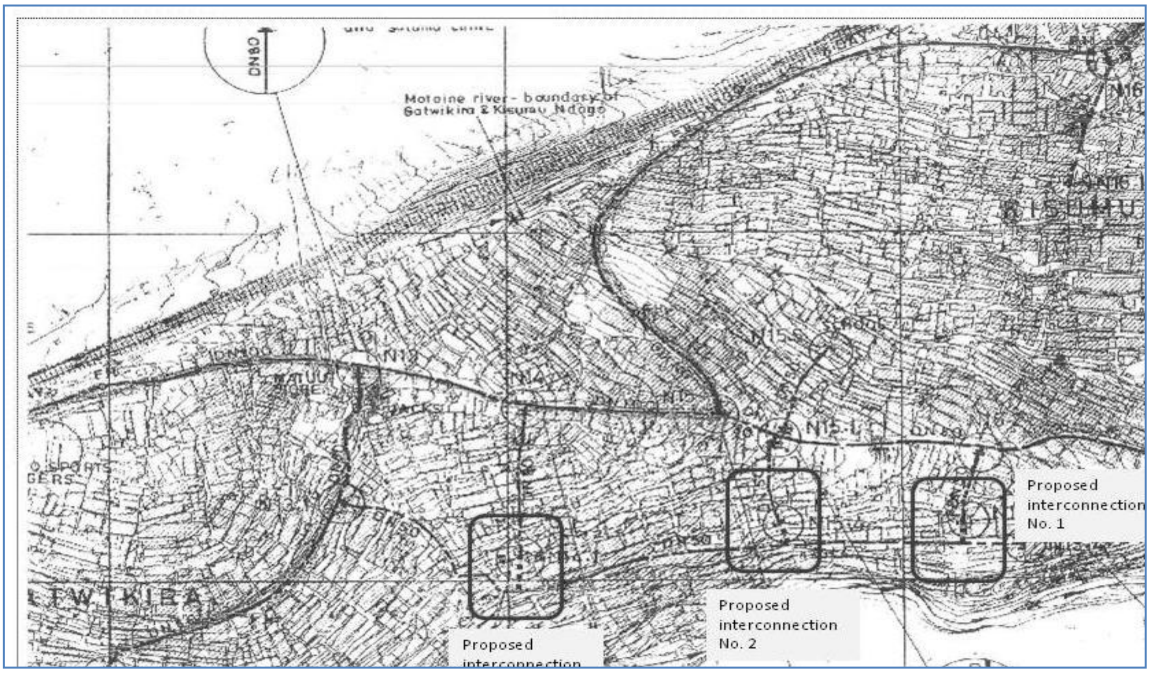

Figure 5: Map used in a community consultation meeting showing the proposed water reticulation network

Surveying and setting out using GPS has clear advantages over more conventional methods in that the technology is *potentially*[6] more accurate than using tape measures and/or simply pacing out the locations of proposed infrastructure relative to *known*[7] locations of other infrastructure, for example, water mains and buildings. It is also both quicker and potentially cheaper than carrying out a detailed topographical survey using a theodolite/total station, levels and ranging posts. Data collected by GPS is also readily transferred into a GIS that allows more flexibility in designing any proposed work, and is easily stored, displayed and shared in electronic format. However, of significant concern in this study was that if GPS was used for the surveying and setting out of the proposed WRN (and in determining which households are included and excluded from the SCP), the staff who design and implement the policy and infrastructure must be aware of both the limitations and correct use of the technology. If standard hand-held GPS was used with its potential error of +/- 15m (equivalent to +/- 30% of the proposed 50m radial distance measured from the proposed water mains), tens, if not hundreds of households, some of which are shacks only a couple of

[6] GPS is potentially more accurate – provided it is used correctly.
[7] Unless the locations of such structures are accurately measured from a precisely located control point, such as an ordinance survey datum, their stated location can be only be a relative and approximate estimate.

meters across, could be incorrectly classified[8]. Equally, even if specialist GPS equipment were to be purchased/rented for the task, it would be essential that the surveyors knew how to correctly set up and operate the equipment, otherwise the advantages of differential correction and carrier phase data collection would be lost and the accuracy of the surveying would be similar to the more basic and far cheaper GPS units.

In light of these potential benefits and risks of using GIS and GPS for the current projects underway in Kibera, the following capacity building design brief was defined:

"To design, implement & evaluate a GIS capacity-building project for project staff from WSUP, NCWSC and the Umande Trust in Nairobi."

3.1.3. Assessment of current mapping capacity and use

An assessment of the current GIS & GPS mapping capacity of WSUP and their partners in Nairobi was made based on conversations and observations in the field and at their offices; this assessment of capacity was what was used for the development of further capacity building. Further assessment was made through the use of pre-course questionnaires [Appendix G] filled out by trainees at the start of the training workshop.

Details of the initial assessment of capacity of WSUP and their partner are given in Appendix A. It was found that NCWSC had a server licence of proprietary GIS software (ESRI ArcGIS 9.2) – which meant that training in this specialist GIS software was both feasible and worthwhile[9]. Their relevant skill base comprised predominantly of a senior surveyor who had a working knowledge of GIS and GPS, and several staff in both the Informal Settlements Department and the Surveying Department who had a basic understanding of some of the workings of hand-held GPS, ArcGIS and Google Earth.

[8] Radial error has greater influence on the area than standard linear error; for illustration – a 9" pizza has more than twice the surface area of a 6" pizza, even though the radius of the larger pizza is only 1.5 times that of the smaller pizza. This means that the influence of GPS error when applied to the social connection policy is particularly significant, since the radial error could have a great impact on the number of households that could be mistakenly included or excluded by the scheme.

[9] See paragraph on the choice of software given in the 'Approach' section of this methodology (section 3.3.2): The TOR for this research project was to focus primarily on building the mapping capacity of NCWSC, since this coincided with the proposed 'Mapping Exercise' [WSUP, 2010d]. If NCWSC had not already had access to proprietary software, capacity building would likely to have been developed for free and open-source software; unless the technical advantages offered by specialist software could justify the purchase of ArcGIS or similar proprietary software.

The rest of the staff at these departments had little or no exposure to using GIS or GPS. The Umande Trust had one member of staff with formal training in the use of GIS and GPS, but was not putting her training to its full use in her work as the evaluation officer. The Umande Trust had its own hand-held GPS and a copy of ArcView 3.2 (an old version of ArcGIS). The rest of the staff at Umande had little or no experience or training in GIS or GPS. The WSUP project manager for Nairobi had gained some informal exposure to GIS and GPS through assisting Shea with his research (2009), and had ArcView 3.2 installed on his laptop.

NCWSC have access to extensive hard-copy map archives of Nairobi, including water and sanitation infrastructure, other civil infrastructure, for example, roads and railways, buildings, topography and natural and social features such as surface water, land use and civic administration boundaries [NCWSC, 2010b]. The process of digitising this information into basic shapefiles (files that hold geospatial entity and attribute data about one particular type of feature) is underway. However, having viewed the basic shapefiles of each layer for the project areas in Kibera, the generally poor attention to detail with numerous errors, lack of metadata and somewhat peculiar approaches to labelling (setting up and labelling new line shapefiles instead of adjusting the labelling options in each layer) provided evidence that the process of digitising was being carried out with only a very basic understanding of tools available in the ArcGIS software, and with little understanding of the importance of error checking and map verification.

According to the senior surveyor, topographic layers including the digitising of building outlines, was carried out by means of photogrammetric methods by Geomaps International (using 2002 aerial photographs), while water and sewerage infrastructure was digitised from archive hard copy maps surveyed in the 1980s-1990s and have not been verified on site. NCWSC do not have any aerial photographs themselves, all that was procured was the vector data. The datum used in the NCWSC shapefiles is Arc 1960, while the projection is UTM.

Despite NCWSC’s considerable but relatively recent procurement of GIS software, specialist and standard GPS hardware, as well as substantial access to existing data;

and to a lesser extent, that of WSUP-Nairobi and the Umande Trust, it was observed that the partnership were still reliant on maps of very poor quality for their project work [WSUP, 2010d]. The map shown in Figure 5 shows appears to have been produced by marking-up an old scanned map from the NCWSC archives using Microsoft Word/Paint/PowerPoint. The map was printed in poor, black and white, *pixellated* and blurred quality over about 75% of the space available (on A3 sheet of tracing paper) with the edges cropped so as to remove some of the map and the title [Figure A in Appendix C shows the full extent of the map as it was intended to be printed]. No legend, north arrow, graticule or grid (with useful divisions and/or labels), scale bar or scale text to orientate the reader or give an indication as to its purpose were included, nor was there any information about what data was used and when it was collected, or who produced and/or was presenting the map. There was also very little indication of what the lines were that formed an irregular type of shading across much of the map were. These lines may have been due to poor scan or print quality, or may have indicated contours, or building and street layouts.

This map provides the evidence behind to two important observations:

1. WSUP and their partners are already using maps for project work; in this case, for community liaison.
2. An attempt has been made to use software to edit an existing map to show a proposed project; which indicates that while the level of editing is very basic, they are likely to be receptive to capacity building in GIS.

From observing the community liaison process (in a poorly lit room, using cell phones to illuminate the printouts), it was obvious that far from serving as visual aids, the two printouts of the *map* shared between roughly 15 people each caused more confusion than they served to avoid. Additional effort by the coordinators was required to explain not only the proposed projects, but also the maps themselves. A clearer visual demonstration could have been made (outside) by sketching the proposed water reticulation network and its proposed impacts, in the sand or on a blackboard with chalk.

A recent grass-roots initiative (started within the last year) to produce and disseminate maps of Kibera has been set up and is orchestrated by Map Kibera (2010). Shapefiles (.shp) and Keyhole Markup Language files (.kml) of the whole Kibera are available free to the general public online. The evaluation officer for Umande was already aware of Map Kibera's operations; however the senior surveyor from NCWSC and the project manager from WSUP were not aware of the organisations existence until it was brought to their attention through this research. The existence and work of Map Kibera provides an excellent opportunity to coordinate their research and mapping of the project areas and so close liaison with the organisation was encouraged since sharing of primary and secondary geospatial and social data could be of mutual benefit.

3.2.Assessment of the need for and nature of any capacity building

When asked why, with the apparent capability to produce clear maps for project management and/or community liaison, especially at NCWSC, maps such as the one used at the recent community liaison meeting were being used, the WSUP project manager said that that map was generally typical of what was used, and that even though NCWSC, and to some extent WSUP and Umande, were increasing the GPS and GIS capacity in terms of equipment, the project staff generally did not yet have the skills to incorporate geospatial technology into their work. Beyond evidence of trying to manipulate old maps of Kibera in order to illustrate proposed projects, there was clearly an intention to build capacity in this area, with keen interest shown by the staff, as well as a financial commitment made in buying specialist equipment. However, the only two people who had formal training in GIS and GPS were the senior surveyor from NCWSC and the evaluation officer from Umande, while the rest of the staff 'looked on and observed the magic' [WSUP, 2010e].

The project manager's response, and the observations made of the current mapping capacity, suggested that at least some capacity building, in the form of training, was required for project staff from NCWSC, WSUP and the Umande Trust, in the fundamental processes and limitations of GIS and GPS, and their basic application to water and sanitation projects, so that these staff could take advantage of the geospatial technology and data they had available.

When asked if (and why) a *dedicated* training course was necessary, when there were freely available guidelines available, he responded that staff simply did not have the time to search for relevant training materials and help forums, and did not want to read through long documents that may or may not be of particular use to their work. This was clearly demonstrated in the first week of preliminary testing of existing training materials when the WSUP project manager struggled tried to find time to complete three tutorials used by Cranfield University [Brewer, 2010a, b] to give students a basic understanding of ArcGIS. It was observed throughout the in-country phase that the project manager worked on average 12hr days, 6 or 7 days a week. Emails received at midnight from staff from the other partner organisations suggested that they have a similar demand for their time.

The Cranfield University introductory tutorials, combined with additional guidance and presentations, were successful in clearly demonstrating how to use the basic features of ArcGIS. They were of an appropriate level for training and the step-by-step approach reduced confusion and time wasted in going off course or getting stuck. They were however based on using ward census data from the county of Avon (England) to produce maps. While the content was found to be of interest, and the skills learned could be adapted to a development context (such as mapping health data in Kibera), the Avon study was still not entirely relevant to the projects at hand. Therefore:

If any training were to take place, it would have to be based around a project that was currently taking place. Time spent adapting existing training materials to be of direct relevance to the work of project staff, would not only build capacity, but would also be of direct benefit to the projects themselves and could therefore be justified.

When it was realised by senior management that the course would be focussed on the work currently being undertaken by their staff, and that the skills gained and exercises carried out in the training would be of direct benefit to their projects, interest in the capacity building project grew and staff time and a provision for hiring conference facilities was subsequently allocated towards a dedicated training course. Initially a target of training 15 project level staff from WSUP, NCWSC and the Umande Trust was set for the course. If possible, the attendance of senior management was also desired.

3.3.Design of capacity building programme

3.3.1. Target mapping capacity

Consultation with WSUP's senior management [WSUP, 2010f] further emphasised the importance of applying a pragmatic approach to capacity building with respect to staff time, training facilities, course materials and the target capacity for GIS and GPS use.

It was reconfirmed that project staff would benefit greatly from capacity building, but the level of training and the approach taken must be appropriate to their work: Simply gaining the ability to take a satellite image (from Google Maps) or existing scanned maps (from NCWSC archives) and use them as a back drop for a new map to mark on the existing and proposed infrastructure, and where available, combine it with other digital map data, and then publish clear maps (in PDF format) would be appropriate. It was noted however that it was essential that such maps must have all the basic cartographic features of a standard map to use them easily for surveying and setting out services in the field (Title, Scale, Legend, North Arrow etc.). An understanding of the underlying principles of GIS and GPS was clearly required if equipment was to be used correctly and if errors in existing or new data were to be routinely checked and corrected.

It was not initially deemed necessary to attempt to raise the capacity of project staff beyond this basic level in GIS & GPS. Until an understanding of the fundamental concepts, applications and limitations of geospatial technology had been entrenched, and the careful collection of coordinates using hand-held GPS, and the production of simple but usable maps using GIS software was practiced, it was considered premature to consider using the more powerful analytical or data management tools available in GIS software. Similarly, the level of training in GPS was targeted at achieving the comfortable use of standard hand-held GPS by a greater number of project staff, rather than training a select few in the use of the more specialist equipment (with carrier phase signal and differential correction capabilities). As such, the training programme was designed to bring technical and managerial level project staff, from all disciplines, up to the following GIS & GPS capacity:

1. *To understand the fundamental principles, processes, features and limitations of Geospatial Technology (Geographical Information Systems, Global Positioning Systems & Remote Sensing)*
2. *To have a basic mapping capacity using existing shapefiles*
3. *To be able to produce new map layers through georeferencing, digitising & editing*
4. *To be able to use hand-held GPS for navigation & data-collection*
5. *To have the ability to share skills with others, and to apply geospatial technology to other projects.*

3.3.2. Approach

To ensure that the trainees had the best chance of learning the target theory and skills, the approach had to be such that not only were the training materials of direct relevance to their work but training itself should be interactive, allowing trainees to put the theory and skills that they were learning into practice, within a supportive environment. The approach needed was such that trainees gained a balance between being *taught the theory*, being shown *how to apply the theory* to practical project related mapping tasks, and getting the *chance to apply, explore and practice the theory themselves*.

The course and materials were developed with a mind to the long-term impact of the training, allowing for continued capacity building beyond the duration of the course itself, and as such, the training materials needed to be able to be used for both revision and dissemination in the form of further in-house training of other staff who were unable to attend, or by those who struggled with the course and needed more time. This stand-alone nature and therefore potential future use of the training materials was especially important given the relatively short period available for training during the in-country phase of this research project, and due to the wide range of GIS & GPS skills and experience that were expected to be brought to the course by trainees. The course materials should have the flexibility to serve as a training tool for staff who have more GIS & GPS experience and who wish to help other staff. This cyclical, hands-on and long-term approach followed a mantra of

‘*Demonstration – Replication – Extension – Practice & Dissemination*’ that was embedded into every aspect of the training course and materials [Figure 6].

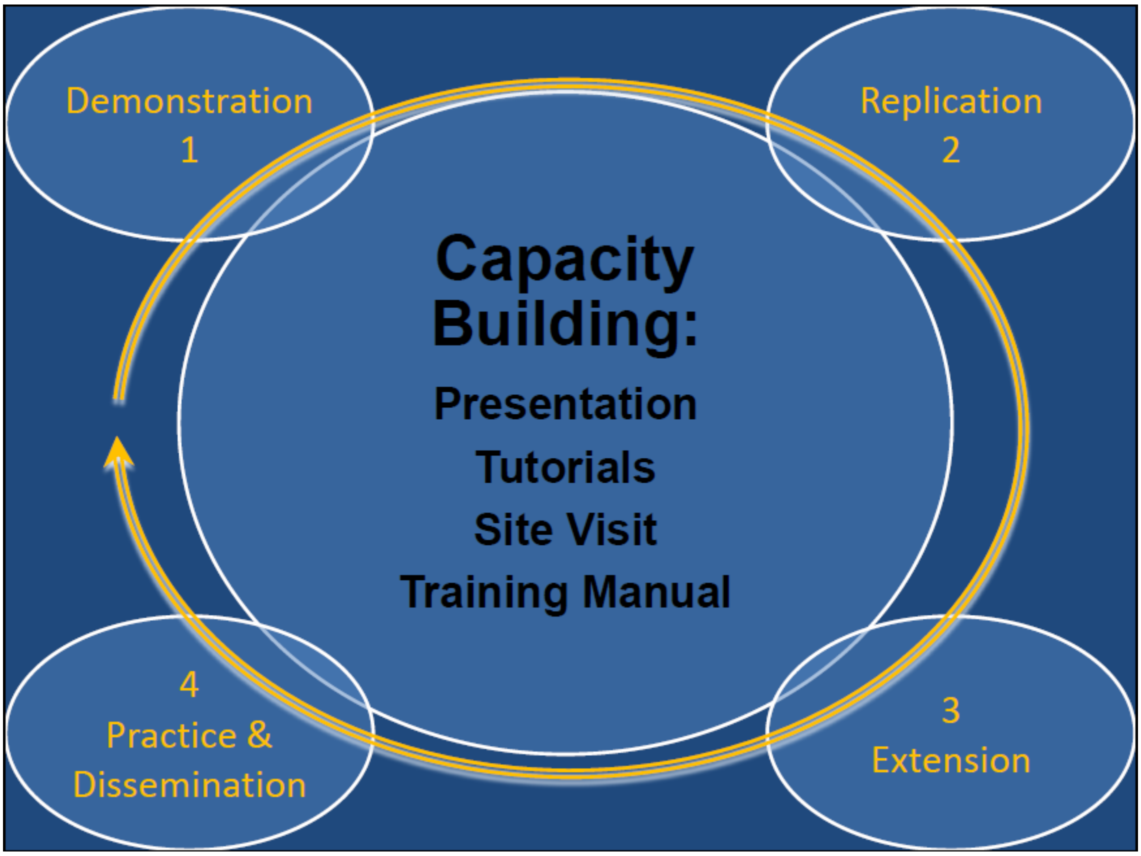

Figure 6: Capacity Building Structure: The presentation, tutorials, site visit and training were designed to balance theory with hands on application to relavant project work, and followed ciclical pattern of *Demonstration - Replication - Extension - Practice and Dissemination*.

Conference facilities were booked for three full days (Monday, Tuesday and Thursday) for the GIS aspects of the course and a half day (Wednesday) was allocated to a visit to the project areas (Kibera) to learn how to navigate and collect coordinate data using hand-held GPS. This mid-week half-day gave staff the opportunity to either revise some of the material they had just covered, prepare for the rest of the course, or to follow up with any office work. The final day (Friday) was set aside for further practice and extension sessions at the staff offices (half a day each at the NCWSC and the Umande Trust offices).

In order to be able to produce coherent training materials – with illustrations of the step-by-step guidance that matched what was being shown on the trainees’ screens – the tutorials needed to be developed around a single version of GIS software. Given that the three organisations had various versions of the specialist proprietary ESRI GIS software installed, it was appropriate to develop the training materials for this programme. With various versions of ESRI ArcGIS having slightly different features, it was requested that all trainees arrived at the course prepared with individual laptops (if possible) loaded with ESRI ArcGIS version 9.3.2. Free (3 month) evaluation licences of this current version was available from the ESRI Eastern Africa office in Nairobi, and after this software had been successfully procured and installed on the WSUP project manager's laptop in, detailed instructions were given to the partner organisations as to how they could also this software from the ESRI Eastern Africa two weeks prior to the start of the course.

The site visit was intended to gave trainees the opportunity to learn how to use standard hand-held GPS for navigating to predetermined points of interest in the field (proposed water pipe connection points and water kiosks), and then collect several pairs of GPS coordinates at each of these locations so that they could observe the variability in GPS readings, and so they could update their maps with the primary data they collected in the field. The projections of the GPS units were set, and ten points of interest were manually uploaded into the GPS units[10]. The key features of each GPS unit were explored, with time allowed for trainees to find their way through the different menus and settings of each GPS. In addition to manually setting target waypoints, trainees were shown how to set the projection and datum of each GPS.

[10] It was thought that trainees should learn how to manually upload and download data from the GPS units, since every brand of GPS has its own proprietary software, and having the ability to work out how to use a range of recreational GPS units, and then manually input data via MS Excel → .CSV → shapefile also gave them the capacity to also add other data – such as social data held in spreadsheets, while encouraging them to check through the data, and variability of the data they were collecting.

4. RESULTS

During the design of the capacity building programme, regular consultation was made with senior management from WSUP, NCWSC and the Umande Trust as to what facilities and equipment were available for the training course, the number of delegates that would be able to attend (including a brief description of their technical skills and job roles), and the scope of subjects that the training material needed to cover.

19 project and senior management staff from WSUP, the Umande Trust, NCWSC and Frame Consultants[11] attended the course[12], up from the target attendance of 15. A full register of attendance, including details of trainee job titles and their respective organisations, is provided in Appendix B, which included engineers, surveyors, draftsmen, technical advisors, sociologists and managers. Table 1 gives the course timetable for the training week. The week following the training course was also set aside for further informal staff training and evaluation if required (and if staff were available), since the programme and syllabus [Table 2] set an ambitious target for capacity building[13].

[11] Civil Engineer from Frame Consultants was seconded to NCWSC.

[12] 17 project and senior management staff attended the whole course, 2 senior management staff were only able to attend the introduction presentation.

[13] The Cranfield course required five full days for only the GIS side of the course and it was unknown as to how the level and range of experience of the attending staff, and therefore how long the trainees would take to successfully complete the activities.

Table 1: Programme for Capacity Building Course

<table>
<tr><th colspan="7">GIS Capacity Building Workshop Timetable</th></tr>
<tr><td colspan="2">Location:</td><td>Conference Centre [Hotel]</td><td>Conference Centre [Hotel]</td><td>Site [Kibera]</td><td>Conference Centre [Hotel]</td><td>NCWSC and Umande Offices</td></tr>
<tr><td>Start-Finish</td><td>Day:</td><td>Monday</td><td>Tuesday</td><td>Wednesday</td><td>Thursday</td><td>Friday</td></tr>
<tr><td>09.00hrs-10.30hrs</td><td>Session 1</td><td>Intro Presentation: Fundamentals of GIS and GPS</td><td rowspan="2">Tutorial 3: Georeferencing Images & Error Checking</td><td>[Site Visit] GPS Navigation</td><td rowspan="2">Workshop: Site Data Input & Consolidation and Extension Exercise</td><td rowspan="2">Trouble-shooting Session [Umande Office]</td></tr>
<tr><td>10.30hrs-12.30hrs</td><td>Session 2</td><td>Tutorial 1: Data Management in ArcCatalogue</td><td>[Site Visit]: GPS Surveying</td></tr>
<tr><td>Lunch</td><td></td><td></td><td></td><td rowspan="3">Private study/ office work</td><td></td><td></td></tr>
<tr><td>13.30hrs-15.00hrs</td><td>Session 3</td><td rowspan="2">Tutorial 2: Map Making in ArcMap</td><td rowspan="2">Tutorial 4: Adding Data Layers, Digitizing Images & Buffer Zones</td><td>Individual map preparations</td><td rowspan="2">Trouble-shooting Session [NCWSC Office]</td></tr>
<tr><td>15.00hrs-17.30hrs</td><td>Session 4</td><td>Group feedback session</td></tr>
</table>

Table 2: GIS & GPS Capacity Building Syllabus and Course Activities

Course Activity	Syllabus
Intro. Presentation Hotel Conference Centre	**Fundamental principles and processes of Geospatial Technology** **Applications and limitations of GIS & GPS** **Course overview**
Tutorial 1 (GIS Training Manual) Hotel Conference Centre	**Data Management** Using ESRI ArcGIS 9.3 (ArcCatalogue) and Microsoft Windows Explorer to organise and view existing NCWSC shapefiles (secondary data) of the project areas in Kibera – including setting their projection and datum.
Tutorial 2 (GIS Training Manual) Hotel Conference Centre	**Cartography** Using ESRI ArcGIS 9.3 (ArcMap) to view and edit the basic cartographic properties of existing NCWSC shapefiles – including their *Symbology*, in the *Data View*. To create and publish an A4 map of exiting layers (existing water and sanitation infrastructure against general geographic and infrastructure features in Kibera) with a title, scale, north arrow, pertinent metadata and company information, suitable grid/graticule, labels and legend, in the *Layout View*.
Tutorial 3 (GIS Training Manual) Hotel Conference Centre	**Georeferencing** Viewing and georeferencing archive maps and satellite images in ArcMap, so that these images align with the existing NCWSC shapefiles, and discrepancies between difference sources of data can be identified. Tutorial covered the georeferencing of a .JPG image of the same map used in a recent community liaison meeting which 'showed' the proposed Water Reticulation Network for Kibera. The tutorial also explained how to copy a screenshot of a Google Maps satellite image of any project area and save it as a .jpg file so that it can be used offline.
Tutorial 4 (GIS Training Manual) Hotel Conference Centre	**Digitising and Editing** Using the Editor Tool in ArcMap to modify existing geospatial data so that it correlates with the georeferenced archive map (e.g. changing the locations of water and sewerage networks in the NCWSC shapefiles). Creating new line shapefiles of proposed water pipes by digitising the archive map. Creating new point shapefiles of connection points and water kiosks that can be verified on site. Creating new fields and editing the attributes of shapefiles so that additional data could be assigned to individual entities, and the symbology and labelling of layers can be set up to illustrate the target information geographically (e.g. pipes coloured and labelled according to project, or buildings coloured according to social data). Creating a buffer to represent the 50m radial coverage of the proposed social connection policy.
Site Visit Site Visit to Kibera	**GPS Navigation & Data Collection** Manual input of coordinates into recreational GPS units (several makes and models). Navigation to pre-determined points of interest (verification of the proposed locations of proposed water pipe connections and water kiosks). Collecting GPS several sets of coordinates for each point of interest (demonstration of GPS error and the importance of map verification). Manual input of coordinate data from GPS units into a GIS (creating a spreadsheet in MS Excel, exporting to a .CSV file and creating a point shapefile).
Follow-up Sessions NCWSC & Umande Offices	**Practice and Extension** Additional time (if required) to finish tutorial exercises. Revision and practice sessions for trainees who struggled with particular areas of the course. Opportunity to explore other applications of geospatial technology.

The introduction presentation [Appendix H] covered the fundamental principles, applications, workings and limitations, of GIS and GPS as set out in the capacity building target 1. The training manual [Appendix I] worked through a series of tutorials that were aimed at translating the theory learned in the presentation into skills in GIS that could be applied to project work. Tutorials 1 and 2 covered training target 2, while tutorials 3 and 4 covered target 3. The site visit addressed target 4; the navigation and data collection using hand-held GPS, with raw data and subsequent error analysis that was carried out following the site visit is given in Appendix D. Group work, a constant emphasis throughout the course placed on the importance of sharing skills and geospatial data, and evidence of further exploration showed that target 5 had also been met.

The map in Figure B [Appendix C] illustrates the overall target capacity for mapping with GIS and GPS, while the remaining maps in this appendix [Figures C to H] were submitted by the trainees themselves and show that trainees had by and large reached or exceeded the intended target capacity. Evidence of surpassing the target capacity of the course are provided by the last two maps [Figures G and H] submitted by staff from the Umande Trust and NCWSC. These two maps show that they considered applications for GIS and GPS beyond what was covered by the course. One map showed that trainees had considered the impact that a 15m of GPS error could have on the 50m Social Connection Policy (NCWSC), while the other mapped out a hypothetical cholera outbreak in Kibera (Umande Trust).

For the site visit, the trainees then split into three groups of five or six each, with each group allocated three to four target points. Each group successfully navigated to, and collected multiple GPS readings from three to four points of interest per group [Figure 7]. The affects of overhead or adjacent obstructions on GPS signals – such as in tight alleyways with overhanging roofs, were also demonstrated. The primary data collected on-site was collated into a single MS Excel spreadsheet [Table 2, Appendix D] and represented as a scatter chart [Figure I, Appendix D] so that trainees could quickly check to identify human error (in manually transferring coordinates). Another scatter chart [Figure J, Appendix D] was created to show the off-set of each pair of coordinates from the centroids of each set (these centroids were super-imposed to show a distribution of GPS readings around an origin). This activity showed that the mean error was only 1.63m for the 42 readings taken, and that 90% of the readings fell within 2.89m of their centroids.

Figure 7: GPS capacity building: Trainees worked in groups to successfully navigate to, and collect primary data from predefined points of interest in Kibera

Photo by M.C. Waterkeyn, 2010

5. DISCUSSION

5.1.Challenges

The staff from Umande did arrive with their own individual laptops; however ArcGIS 9.3.1 had not been installed prior to the course (still only having ArcView 3.2). The installation of the software was done prior to starting the introduction presentation – setting the training programme back by one hour. The staff from NCWSC, who made up the majority of trainees, only arrived with a few laptops, some of which were loaded with ArcGIS 9.2 (none with ArcGIS 9.3.1). To overcome this technical challenge, it was decided at the start of the course that trainees would split into groups of up to three per laptop, while the laptops that loaded with ArcGIS 9.2 were *not* updated with the more recent v9.3.1 since v9.2 was deemed to be similar enough to allow trainees to progress through the training manual since the features were virtually the same and setting up v.9.3.1 on these additional laptops would have take even more time, possibly more than simply working round the differences during the tutorials. To avoid a repeat of these software problems, any future course should not only give guidelines on how to procure and set up the appropriate software, but to also check each individual computer prior to the training; or, if such facilities are available, hire out a computer lab with server access to the relevant licence and training data.

While it was observed that trainees could easily follow the step-by-step guidance in the tutorials, particularly the earlier and simpler activities of data management and cartography, the students with prior experience tended to rush ahead without carefully following each step, resulting in later difficulties that were otherwise avoided by less experienced but more methodical trainees. The comprehensive nature of the course meant that if trainees did skip steps in the tutorials, such as not setting the projections on all of the shapefiles in ArcCatalog, these errors would generally be picked up in latter activities – such as when they try to import these shapefiles that do not have set projections into ArcMap (the software flags up a reminder). The visual nature of maps (compared for instance to modelling software) meant that other errors or missed steps were generally also easy to spot simply by glancing at the trainee maps as they worked through the tutorials (as opposed, for instance, to reading through programming code).

The two topic areas that caused the greatest difficulty was georeferencing and digitising [Table 3, Appendix E] – which required some practice before trainees were able to select appropriate control points to avoid severely distorting the image when georeferencing, or use the editing tools and snapping settings correctly when digitising. It is thought that little can be done about these areas of difficulty, other than offering guidance (further justification for dedicated training) and dedicating time to practicing these skills (as was highlighted in several feedback forms).

It became apparent – especially as people started work on the georeferencing, digitising and editing activities – that the course programme was too ambitious. By Tuesday afternoon, most of the trainees were still in the process of georeferencing the old archive map or only just starting the digitising of the existing network; when they should have completed the digitising of the proposed water network, created a 50m buffer around the network, as well as produced new shapefiles for the verification points that would be used on-site the following day. To allow the trainees to complete the GIS tutorials and site activities by the end of the week, the session allocated to presenting maps was dropped and the demonstration coordinate data given in the tutorials was used for GPS navigation and map verification. Despite this extra time made available, basic errors in map layout and cartographic details were still made and give evidence of a rushed effort. Any future course with a similar syllabus and group of trainees should have more time allocated for dedicated workshop sessions – a minimum of five full days for the presentation and tutorials is recommended.

Assessment of the trainees overall progress [Appendix F] was based largely on post-course questionnaires[14] [Appendix G], that could be compared against the feedback received at the start of the week; as well as casual observations of individual progress, feedback and involvement that were made during the week, and the maps that they were asked to submit at the end of each tutorial[15]. The trainee assessment marks stated in Appendix F, while too approximate to constitute thorough quantitative

[14] All 19 of the pre-course feedback forms were completed, while 15 of the 17 staff that attended the full week completed the post-course questionnaires.

[15] Because there were not enough computers for everyone, trainees worked in groups, making assessment of individual progress based on their maps alone more of a challenge. The same applied to field exercise where trainees split into three groups for the GPS navigation and data collection activities.

analysis of capacity building, served merely to coordinate the various methods of qualitative (and subjective) assessment of individual trainee progress. The marks did however indicate that while some trainees had reached a higher standard than others, when comparing final capacity against initial capacity, there was a relatively even and positive step in GIS and GPS capacity made by the class as a whole.

The main challenge to evaluating individual trainee progress, and the overall impact of the course, came from the difficulty faced in getting hold of completed maps and feedback forms. Trainees were reluctant to submit unfinished maps at the end of each day/tutorial during the course for fear of being seen as not having made enough progress. Since trainees struggled to complete the tutorial activities on time, the submission of maps by some groups crept into the follow-up sessions at the organisations' offices (timetabled for Friday). Once back at the offices it was very difficult to coordinate follow-up training since only a few of the staff were around/available at any one time, which also made it difficult to collect each groups' tutorial maps and completed feedback forms. Maps were also not saved as different files at the end of each tutorial (as requested in the manual), so interim progress was difficult to assess and record beyond the causal observations made during the training. Besides offering more time to complete the tutorials, offering trainees a certificate of formal GIS and GPS training in return for a complete set of tutorial maps being submitted for assessment, may be one way to resolve this problem in the future.

5.2. Successes

When compared with the map produced and used for the community liaison meeting only one month previously, the maps produced at the end of the course provide clear evidence of successful skill transfer in GIS and GPS. While the maps that were submitted showed evidence that the target capacity had been met (at least by each group[16]), two trainee maps in particular [Appendix C, Figures G and H] showed exploration beyond the scope of the syllabus and are crucial in demonstrating that trainees had the imagination, and had gained the relevant skills, that they needed to re-apply what they had learned to other projects successfully. Feedback (both informal

[16] Maps not submitted were at least observed during the training week.

and in the questionnaires) suggested that the adaptability of the skills learned was largely thanks to the training materials being both specific and relevant enough to allow trainees to see how they can be applied to their own work, yet broad enough to illustrate how they could also use their skills in GIS and GPS elsewhere. This suggested that the capacity building in GIS and GPS will have a lasting impact on future development work carried out by these organisations.

The in-country phase of this research meant that it was not possible to conclusively assess whether the skills transferred in the course had been (or will be) integrated successfully into day-to-day project work. However, an email received from the Umande Trust Evaluation Officer, several weeks after the end of the course, mentioned that she was about to start mapping an entirely new project (a flood prone area in western Kenya). This email demonstrated that there was at least some lasting impact from the course.

The overall success of the course (in terms of skills transfer, not long term impact) was further emphasised by the very positive post-course feedback that was received, as is summarised in Appendix E. Initial scepticism as to the genuine satisfaction of trainees, through the potential influence that trainee 'willingness to please' could play in distorting the responses in to the post-course questionnaires, was countered when very positive feedback was also received indirectly in the week that followed the course. This indirect feedback was received via the NCWSC Senior Manager for the Informal Settlement Department who expressed his surprise at the spontaneous and very positive feedback that he had received from NCWSC staff who completed the course, and who forwarded on this feedback to the Capacity Building Consultant for WSUP in the week that followed the course [Waite, 2010b].

While the working through the tutorials on shared laptops and the submission of maps in groups made individual evaluation more difficult, it was however observed that trainees with prior skills in GIS and GPS did offer support to other less experienced students in their group [Figure 8]. This meant that the skill-sharing part of capacity building target 5 had already been demonstrated during the course, and suggested that similar in-house training was possible. The need to share skills is especially important if there were trainees who did not keep up with the faster students, but who's relatively slow progress was not picked up in either the group evaluation or individual self-assessment process (questionnaires); if there are trainees who scored higher marks than should have been allocated, these trainees will at least stand a chance of catching up with the rest of the group through further in-house training and practice.

Figure 8: Group work made it hard to assess individual progress; however it did demonstrate that skill sharing naturally took place - suggesting that future in-house training was possible.

Photo by M.C. Waterkeyn, 2010

The successful use of the training manual on laptops loaded with the older version of ArcGIS (v9.2) suggested that while the two versions were similar, the training material could be used on other versions of software. This suggesting that both the trainees and the manual were versatile enough to allow them to be used (and possible adapted) for future versions (and brands) of GIS software, which bodes well for the long term impact of the course. Having the training manual and map data (in bound hard-copy format and on CD) also allows for future reference for revision or in-house training purposes, improving the likelihood that the capacity building project will have a long-term and beneficial impact beyond the duration of the course.

The quick demonstration using the scatter charts to check the GPS data served to demonstrate two key points:

1. Variation did exist between GPS readings (demonstrating GPS error) – but this error was significantly less the 10 to 15m generally suggested as a safe limit for GPS use. It was demonstrated that the more readings that were taken for a point, the more certainty one could have with the location of the centroid of each set of readings; and while there was always the possibility of there being individual readings having high errors, the greater the error, the lower the probability of recording such a reading. Despite being able to increase confidence in primary GPS data by collecting more points, it was also pointed out that the actual GPS error (as opposed to the estimated error) could only be calculated by making a comparison with a known reference site.
2. There were also differences between the locations of the centroids of each set of GPS readings, and the coordinates extracted from the tutorial maps. This suggested map (or secondary data) error. The mean error was 4.36m, significantly more than the mean error of the individual GPS readings. Possible causes of this error were explored; given the apparent randomness of the off-set directions, incorrect setting of projection was discounted, with errors arising from digitising and reading coordinates off mildly distorted georeferenced images being the suspected main cause for the map error.

While there are many other factors that affect the accuracy of GPS readings, comparing and discussing the locations of each reading to the centroid of each group of readings helped demonstrate the limitations of GIS and GPS technology, and by implication, the danger of taking only one reading and assuming that it was accurate. By using only a selection of standard GPS units, the site activities demonstrated practically many of the key learning objectives covered in the presentation and the tutorials; including the principles behind more specialist equipment such as using rover units in parallel with base stations with differential and carrier phase GPS capacity.

6. CONCLUSIONS

The literature review established that the use of maps by development organisations, such as WSUP and their partners operating in the urban slums of Nairobi can help them with their stakeholder liaison, and in designing, implementing and evaluating their projects. It was found that WSUP and their partners were already using maps for this purpose, but despite having ready access to archive data, and the equipment to create maps using GIS and GPS, lack of technical skill among their project staff was holding them back from producing clear maps of their projects. In-house and informal training of staff had not significantly taken place, not for lack of interest, but because staff did not have the time explore freely available online guidelines and tutorials, and if any dedicated training were to take place, it had to be adapted specifically to a project that the trainees were currently working on, so that staff time and the hire of training facilities could be justified. In light of these restrictions, a dedicated capacity building programme – with specially developed training materials was designed for a target of 15 project level technical and managerial staff. The programme lasted for four days; three days to cover the fundamentals of GIS and GPS, including guided workshop sessions in using specialist GIS software, and a day spent on site to practice using GPS. Additional time was also allocated, and in some cases needed, for follow-up sessions at their offices.

Through a suite of evaluation methods, ranging from informal observations made during the training, critical analysis of the maps that trainees produced and the GPS data that they collected, to pre- and post-course questionnaires, were used to evaluate the individual progress of trainees, and the success of capacity building project as a whole. Capacity building in GIS and GPS – to an appropriate level that allowed for basic data management, surveying and map creation – was found to have successfully transferred the practical mapping skills to project staff, allowing the organisations to produce their own basic but clear maps of their projects for better stakeholder liaison and project management.

Key to trainee interest, the allocation of time and resources towards capacity building, and the success of the project as a whole, was the adaption of training materials to a project that they were currently working on, thereby clearly demonstrating the practical benefit and limitations of applying GIS and GPS to their work. Despite time and financial resources being allocated to training, the capacity building programme was found to be too ambitious in terms of covering the range of intended activities, that were required to bring staff up to the desired capacity, within the time available. Coupled with this was the challenge of not having enough computers available for every trainee; and that despite clear guidance given on how to make sure that every laptop came prepared with the correct software installed, installation of the software had to be carried out on most of the laptops at the start of the course.

Assessment of individual trainee progress was hindered by not having enough computers, meaning trainees had to share laptops and produce maps in groups. However, this challenge did give rise to an observation that suggested the positive long term impact that the course could have, in that skill sharing within and between groups, from trainees with more experience to those who were struggling, indicating that future in-house training and support while working on mapping projects was possible. Some of the laptops were not loaded with the same version of software that the training materials were designed around, yet the differences between what was being shown on screen to what appeared in the manual did not prevent groups using the different software from successfully completing the tutorials. This showed that the training manual and the trainees were adaptable enough to potentially apply the guidelines to other versions (and potentially other brands) of GIS software.

The in-country phase of this research was too short to allow for a full evaluation to be made on the application of the skills learnt to project work – and in doing so, making an accurate assessment of the long term impact of the training. However, there was some evidence of exploration beyond the scope of the syllabus, with one map being produced that illustrated the potential impact that GPS error could have on a current project, while another mapped out a hypothetical cholera outbreak. Several weeks after the course, one of the trainees requested advice on mapping an entirely different project to the ones used in the training. These maps, and the follow-up email did give some evidence that the skills learnt on the course could, and was being put to use on different project work, which suggests that the course will have a positive and long-term impact on WSUP and their partner organisations in Nairobi.

7. RECOMMENDATIONS

7.1. Practice:

This entire capacity building project, and indeed the potential to use geospatial technology to assist planning, design, implementation and evaluation of development projects, will be wasted if the project staff who attended the course are not given the time to practice and extend the skills that they have learnt. During the course, trainees showed their ability to help each other in areas of technical difficulty. The ability to train others not only shows confidence in a subject, but is also an excellent way to consolidate one's own understanding of the topic at hand, and demonstrates the potential for continued in-house training. It is therefore strongly recommended that trainees are given the time to practice, share and extend upon the skills they have learned. Just an hour or two dedicated to applying GIS and GPS to project work each week will ensure that the skills learned during the course are likely to have a lasting and positive impact on the work of their organisations.

7.2. Evaluation:

The long-term success of the capacity building was predicted, but it could not be conclusively assessed during the relatively short period available for in-country research. To assess if the organisations that sent trainers to the capacity building workshop genuinely benefited from the capacity building in GIS and GPS, it is recommended that a separate evaluation is made at least four months post-training to determine if and how project staff are applying GIS and GPS to their work. Evidence of the successful and appropriate application of GIS and GPS to projects other than the one used in the training materials, exploration of other GIS tools or even the use of different software, and training of other staff who did not attend the course or who struggled with the training workshop, would all suggest that the capacity-building has had a long term beneficial impact.

7.3. Extension:

Following on from an evaluation how GIS and GPS has (or hasn't) been put to use on day-to-day project work, topic areas that cause consistent difficulty, or those that are of particular interest can be identified, and further capacity building can be designed if appropriate and the resources are available. Further capacity building does not however need to wait for an external evaluation, if the organisations themselves deem such training to be necessary. Indeed, there were several calls from trainees that any further training would be both greatly appreciated and would be put to good use, while the post-course questionnaires have already provided some insight into the common areas of interest and difficulty.

It is strongly recommended that the organisations that sent trainees to the workshop also explore ways in which they can improve their own mapping capacity through working with other organisations, by sharing skills and data (particularly with other local organisations – such as Map Kibera), and by dedicating time to exploring other guidelines, methodologies and technologies that may assist them in their mapping operations. A good opportunity to do this would be to meet and share contacts and ideas with other similar organisations at local workshops and conferences, such as the upcoming ESRI Eastern Africa User Conference that will take place in Nairobi this November. The training materials were based on proprietary ESRI ArcGIS 9.3 software, specifically the ArcCatalog and ArcMap components; it would be worthwhile for the trainees to explore other elements of the ArcGIS package such as Spatial Analyst. Exploration and use of open source software such as Google Earth, with reference made to guidelines like the Google Outreach programme, is also encouraged since this is a very effective way to publicise the work of their organisations to the wider development community and to the public in general.

While evaluation of the current hygiene promotion activities carried out by WSUP and their partners was outside the scope of this research project, discussions with the Director of the Umande Trust and the Senior Surveyor at NCWSC revealed a keen interest to use the Community Health Club methodology in combination with the social data collection technology, such as the Mobile Researcher Platform (described in the literature review) to improve community liaison, the creation extensive baseline surveys, the evaluation (and implementation) of hygiene behavioural change, and the in-depth monitoring and mapping of the health impacts of their water and sanitation projects.

8. REFERENCES

AfricaAHEAD (2010); *"Association for Applied Health Education And Development (AHEAD): The Community Health Club Approach to Sustainable Development"*. Homepage available at:

http://www.africaahead.org/ – site accessed May – June 2010

Brewer, T. & Cranfield University (2010a), "*Fundamentals of GIS*", Abu Dhabi Water and Electricity Authority Training Course (Tutorials and Presentations), Cranfield University, UK.

Brewer, T. & Cranfield University (2010b), "*Satellite Navigation Systems: A1135 – Digital Photogrammetry*", Geographical Information Management Course (Presentation), Cranfield University, UK.

Butala, N. M., VanRooyen, M. J. & Patel, R. B. (2010), "Improved health outcomes in urban slums through infrastructure upgrading", *Social Science & Medicine*. 71. p935-940.

CFK, (2010), *"Carolina For Kibera (NGO) – About Kibera"*. Available at:

http://cfk.unc.edu/about-kibera.php – site accessed June 2010

Crossley, J. (2008), *"A Rough Google Earth Guide"*, Reproduced from the Mercury Corps supported dissertation of Janet Crossley, MSc in Geographical Information Science by Research Dissertation, University of Edinburgh: *"Google Earth as a geospatial tool for development organisations: Mapping climate change vulnerability"*, Mercury Corps, Edinburgh.

DevInfo (2010), Development-orientated data representation software. Website available at

http://www.devinfo.org/ – site accessed May – August 2010

ESRI (2010), GIS software (specialist, proprietary). Website available at:

http://www.esri.com/ – site accessed June 2010

Google Earth (2010), Virtual earth software (free, open-source). Website available at:

http://earth.google.com – site accessed May – August 2010

Google Maps (2010), On-line (free) maps and satellite images. Website available at:

http://maps.google.com – site accessed May – August 2010

John Snow Society (2010), Website available at:

http://www.johnsnowsociety.org – site accessed August 2010

Longley, P. A., Goodchild, M. F., Maquire, D. J. 7 Rhind, D. W. (2001), "*Geographic Information Systems and Science"*, Wiley, Chichester, UK.

Map Kibera (2010), Secondary geospatial data for Kibera (Nairobi) available for download at:

http://www.mapkibera.org/download – site accessed June 2010

Map Window (2010), GIS software (free, open-source). Website available at:

http://www.mapwindow.org/ – site accessed June 2010

Marks, M. & Peters, C. (2009), *"Google Earth; Plan Your Project"*, Google Earth Outreach, and TechSoup guidelines available at:

http://earth.google.com/intl/en/outreach/create_maps_plan.html – site accessed June 2010

Mobile Researcher Platform (2010), *"A breakthrough in technology"*, Website available at

http://www.populi.net/mobileresearcher/ - site accessed June 2010

Morris, N. & Map Action (2009), "*New GIS Field Guide: Field Guide to Humanitarian Mapping"*. Field guide available at:

http://www.mapaction.org/more-news/183-new-gis-field-guide.html – site accessed June 2010

NCWSC (2010a), *Pers. Comm.* (Meeting) – Munene, E. (Senior Surveyor) & Muguna, N. M. (Senior Manager of Informal Settlements Department), Nairobi City Water and Sewerage Company, 14th & 16th June 2010, Nairobi, Kenya.

NCWSC (2010b), *Pers. Comm.* (Emails) – Munene, E. (Senior Surveyor), Nairobi City Water and Sewerage Company, 22nd – 23rd June 2010, Nairobi, Kenya.

PEP (2006), *"Linking Poverty Reduction and Water Management"*, Table 1, Poverty Environment Partnership. Article available at:

http://www.povertyenvironment.net/node/1009 – accessed July 2010

Rosenfeld, J. & Waterkeyn, J. (2009), "Using Cell Phones to Monitor and Evaluate Behaviour Change Through Community Health Clubs", in *Water Sanitation and Hygiene: Sustainable Development and Multisectoral Approaches*, WEDC International Conference, 2009, Addis Ababa, Ethiopia

Shea, P. (2009), "*Investigating geospatial technologies to assist a not-for-profit organisation, Water and Sanitation for the Urban Poor (WSUP), in the informal settlement of Kibera, Nairobi, Kenya*", (Unpublished MSc Thesis), Cranfield University, Bedfordshire, UK.

Snow, J. (1849), *"On the mode of communication of cholera"*, Pamphlet, Frith Street, Soho, London, 1849. Pamphlet (and later articles by same author) available at:

http://johnsnow.matrix.msu.edu/MCC1-PMCC-51MT.pdf – accessed July 2010

Srinavasan, L. (1990), *"Tools for Community Participation: A Manual for Training Trainers in Participatory Techniques"*, PROWESS/United Nations Development Programme Technical Series Involving Women in Water and Sanitation. New York.

Taillander, J., & Franceys, R. (2007), *"Quality assurance of WSUP common baseline survey methodology"*, School of Applied Sciences, Cranfield University, UK.

Transparency International and Maji Na Ufanisi (2009), *"Water Governance Study Summary Report*", Transparancy International and Maji Na Ufanisi, Nairobi, Kenya.

Ushahidi (2010), GIS software for integrating mobile phone data into a map. Software available at:

http://www.ushahidi.com/ – accessed August 2010

UN (2010), *"The Millennium Development Goals Report 2010"*, United Nations. New York – quote by Ban Ki Moon (UN Secretary General), taken from opening statement of report. Report available at:

http://unstats.un.org/unsd/mdg/Resources/Static/Products/Progress2010/MDG_Report_2010_En.pdf – accessed June 2010

UNDP (2010a), "*Environment and Energy: Water Supply and Sanitation"*. Website available at:

http://www.undp.org/water/priorityareas/supply.html – accessed June 2010

UNDP (2010b), *"Millennium Development Goals: Goal 7 – Ensure Environmental Sustainability*", Website available at:

http://www.undp.org/mdg/goal7.shtml – accessed June 2010

UNFPA (2007), "The Promise of Urban Growth", in: *State of the world population: Unleashing the potential of urban growth*, United Nations Population Fund, New York. p6. Publication available at:

http://www.unfpa.org/swp/2007/presskit/pdf/sowp2007_eng.pdf – site accessed July 2010

Umande Trust (2010), *Pers. Comm.* (Meetings) – Binale, A. (Evaluation Officer) & Omotto, J. (Director), Umande Trust, 15th June 2010, Kibera, Nairobi, Kenya.

Umande Trust (2010), *Pers. Comm.* (Meetings) – Binale, A. (Evaluation Officer), Umande Trust, 15th June 2010, Kibera, Nairobi, Kenya.

Waite, M. (2010a), *"WSUP Capacity Building Review for Nairobi City Water and Sewerage Company"*, (Internal Report), WSUP, Nairobi.

Waite, M. (2010b), Pers. Comm. (Meeting) – Waite, M. (Capacity Building Consultant), WSUP, 21st July 2010, Nairobi, Kenya.

Washington Post (2010), *"Crisis mapping brings online tool to Haitian disaster relief effort"*, News article available at:

http://www.washingtonpost.com/wp-dyn/content/article/2010/01/15/AR2010011502650.html – accessed August 2010

WaterAid (2004), *"WaterAid/APDO Water & Sanitation Mapping in the Afram Plains"*, (Briefing Paper), WaterAid, Ghana.

Waterkeyn, J. & Cairncross, S. (2005), "Creating demand for sanitation and hygiene through Community Health Clubs: a cost effective intervention in two districts of Zimbabwe", *Social Science and Medicine*. 61. 1958 – 1970.

Waterkeyn, J. (2007), *"Community Health Clubs in Informal Settlements: A Training Manual for Community Workers using Participatory Activities"*, AfricaAHEAD, Cape Town, South Africa.

Waterkeyn, J. (2010), *"Hygiene Behaviour Change through the Community Health Club Approach: A cost-effective strategy to achieve the Millennium Development Goals for improved sanitation in Africa"*, Lambert Academic Publishing, Saarbrucken, Germany.

Welle, K. (2005), "WaterAid learning for advocacy and good practice – WaterAid Water Point Mapping: Report of findings based on country visits to Malawi and Tanzania", WaterAid, London. Report available at:

http://www.wateraid.org/documents/plugin_documents/waterpointmappingmalawitanzaniaweb.pdf – accessed June 2010

Welle, K. (2006a); "WaterAid learning for advocacy and good practice – Water and sanitation mapping in Pakistan: Report of findings based on field visits to OPP-RTI and ASB, Pakistan", WaterAid, London. Report available at:

http://www.wateraid.org/documents/plugin_documents/pakistan.pdf – accessed June 2010

Welle, K. (2006b), *"WaterAid learning for advocacy and good practice – Water and sanitation mapping in Nepal: Report based on a field visit to WaterAid Nepal and its partners"*, *WaterAid*. London. Report available at:

http://www.wateraid.org/documents/plugin_documents/nepal.pdf – accessed June 2010

Welle, K. (2007a), *"WaterAid learning for advocacy and good practice – Water and sanitation mapping in West Africa: Report of findings based on visits to Ghana and Nigeria"*, WaterAid. London. Report available at:

http://www.wateraid.org/documents/plugin_documents/west_africa.pdf – accessed June 2010

Welle, K. (2007b), *"WaterAid learning for advocacy and good practice: Synthesis of findings"*, WaterAid, London. Report available at:

http://www.wateraid.org/documents/plugin_documents/synthesis.pdf – accessed June 2010

Welle, K. (2007c), *"Mapping for better accountability in service delivery"*, (Briefing Paper), Overseas Development Institute, London. Paper available at:

http://www.odi.org.uk/resources/download/44.pdf – accessed June 2010

Wernecke, J. (2008), *"The KML Handbook"*, 1st Edition, Addison-Wesley, US.

WHO (2010a), *"World Health Organisation: Interactive Map of Cholera Treatment Centres in Zimbabwe"- last updated on 22/12/2008*. Cholera map available at:

http://ochaonline.un.org/CholeraSituation/InteractiveCholeraTreatmentCentresMap/tabid/5151/language/en-US/Default.aspx – site accessed August 2010

WHO (2010b), *"World Health Organisation: Zimbabwe Daily Cholera updates"- last updated on 02/04/2009*. Cholera updates available at:

http://www.who.int/hac/crises/zmb/sitreps/cholera_daily_updates/en/index.html – site accessed August 2010

World Bank, 2010, *"World Development Indicators (WDI), Section 1 – World View"*; Document available at:

http://data.worldbank.org/sites/default/files/wdi/section1.pdf – site accessed July 2010

WSUP (2010a), *"Water and Sanitation for the Urban Poor – Homepage"*. Website available at:

http://www.wsup.com – site accessed February 2010

WSUP. (2010b), *"Mapping Exercise – WSUP: Soweto West, Gatwekera, Kisumu Ndogo, Kambi Muru"*, (Draft Terms Of Reference), WSUP. UK – *Pers. Comm.* (Email). Parker, S. (CEO WSUP), 4th April 2010, UK.

WSUP. (2010c), *"Social Connection Policy for Nairobi's Informal Settlements"*, (11th Draft), ASWB & NCWSC – *Pers. Comm.* (Email). Parker, S. (CEO WSUP), 4th April 2010, Nairobi, Kenya.

WSUP. (2010d), Map of the *"Proposed Water Reticulation Network"* and the *"Social Connection Policy"* used at a WSUP, Umande Trust, NCWSC and local water vendors meeting in Kibera on the 16th June 2010 – Site Observation (Meeting), WSUP, Nairobi, Kenya.

WSUP. (2010e), *Pers. Comm.* (Meeting) – Murigi, P. (WSUP Nairobi Project Manager). 18th to 23rd June 2010, Nairobi, Kenya.

WSUP. (2010f), *Pers. Comm.* (Meeting) – Wilson, R. (Country Director), Mugo, K. (Country Manager), Murigi, P. (Nairobi Project Manager), Waite, M. (Capacity Building Consultant – via email) & Parker, S. (CEO WSUP – via email), and further consultation with the Murigi, P. (in week following meetings and email contact). 15th June 2010, Nairobi, Kenya.

Woof, N & MapAction. (2008), *"Google Earth and its potential in the humanitarian sector"*, (Briefing Paper), MapAction, Buckinghamshire, UK. Paper available at:

http://www.humanitarian.info/wp-content/uploads/2008/04/google-earth-and-its-potential-in-the-humanitarian-sector.pdf – accessed June 2010

Younis, A. B., Bevan, J. Franceys, R. & Cranfield University (2006), *"An investigation into the feasibility of implementing a common WSUP baseline data collection methodology: A case study in Naivasha, Kenya"*, Cranfield University at Silsoe, UK.

APPENDICIES