A Participatory Approach to Data Collection for GIS for Flood Risk Management in Informal Settlements of Cape Town

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Abstract.

A by-product of the apartheid era in South Africa is that most informal settlements in Cape Town are situated on marginal and often poorly drained land. Consequently, most of these settlements are prone to flooding after prolonged rainfall. Informal settlements are often characterised by high population growth and poor infrastructure. Current flood risk management techniques implemented by the authorities of the City of Cape Town (CC) are ideal for formally planned settlements but are not designed to support informal settlements. In fact, owing to a lack of information about the levels of flood risk within the individual settlements, the CC has often either been uninvolved or it has implemented inappropriate remedies within such settlements. Various authors purport that the inadequate flow of information between all stakeholders has hampered development of sustainable flood risk management strategies. Using a case study of a flood prone informal settlement in Cape Town, this paper demonstrates a methodology for the collection and integration of community based information into a Geographic Information System (GIS) that can be used by the CC for risk assessment. In addition, this paper shows how data collected from communities can demonstrate micro levels of vulnerability and guide risk management strategies. This work contributes to the body of Participatory GIS (PGIS). The overall contribution of this work lies in demonstrating a practical participatory approach to data collection for GIS that is used for development of sustainable flood risk management strategies in informal settlements.

Key words: Informal settlements. Flood risk management. Participatory GIS.

1 Introduction

1.1 Background

The policies that govern development in Cape Town are typically structured to mitigate hazards such as flooding. However, rapid urbanisation in Cape Town has led to the birth and spread of informal settlements and high density townships, which do not subscribe to typical town planning norms. As of 2007, there were approximately 109,000 families living in informal settlements (City of Cape Town, 2008).

Table 1. Occurrence of informal settlements in flood prone areas (City of Cape Town, 2009)

Flood hazard locality	Affected informal settlements	Estimated no. of dwellings affected
Storm water ponds	7	457
Environmentally sensitive wetlands	2	927
Trapped low-lying areas	33	3885
Flood plain or within 25m of water course	18	1848

In addition, much of this development has been along the 307 kilometres of coastline and on inland areas prone to flooding, such as natural drains and flood plains (See Table 1). A number of reports point out the extensive effect of flooding in these informal settlements. The City of Cape Town (CC) conducted a study in three informal settlements, namely Joe Slovo, Sweet Home and Nonqubela K-Section in Khayelitsha. That study reported that 83% of the residents had been affected by flooding (City of Cape Town, 2005). Bouchard *et al.* (2007) report that, during the winter month of July 2007, 120mm of rainfall had been recorded over a period of five days in Cape Town. This led to flooding that affected 8,000 households, comprising 38,000 residents, primarily in the informal settlements of Khayelitsha and Philippi. Slum Dwellers International (SDI) published the findings of their 2009 enumeration survey in Joe Slovo, another informal settlement in Cape Town, and reported that the predominant disaster experienced was flooding (SDI, 2009). Of the 2,748 families surveyed by SDI, 1708 had experienced flooding more than once during their stay in that settlement. A study was conducted in 2009 by the Department of Environmental and Geographical Science (EGS) at the University of Cape Town (UCT) in Sweet Home Farm, an informal settlement in Philippi. This study indicated that, because of a depression in the land on which the settlement is located, 50% of the settlement was prone to flooding during the winter months. A survey carried out in Masiphumulele, another informal settlement, in 2010 indicated that, of the 70 households interviewed, 92% had experienced flooding in that settlement. All the aforementioned studies demonstrate the significant impact of flooding on informal settlements across Cape Town and the consequent need for an efficient flood management policy in such areas. The next section examines the current flood risk management policy in Cape Town.

1.2 Flood risk management in Cape Town

There are several municipal organisations involved in flood risk management, including the Departments of Housing; Sports and Recreation; Water and Sanitation; Roads, Transport and Storm Water; Solid Water; City Health and the Call Centre 107 (City of Cape Town, 2009). In the formal settlements of Cape Town, there is sufficient infrastructure in the form of storm water drains, channels, canalized rivers, culverts etc to offset any potential floods. Such infrastructure is typically nonexistent in informal settlements. Consequently, current responses from the CC to flooding in informal settlements are focused on post flood events. Interviews with the CC winter preparedness 2010 committee on 23rd June 2010 confirmed that the CC was responsive rather than preventative in the management of flood risks in informal settlements Responses included the provision of blankets, sand, plastic, meals and temporary accommodation to victims of flooding in informal settlements. According to the 2009 winter preparedness strategy (City of Cape Town, 2009), a 7.5% increase from 8000 to 8600 households in July 2007 and July 2008 respectively was recorded in the number of households for which such provision was being made. Other long-term solutions discussed by the winter preparedness team included the prevention of further encroachment on flood prone land and relocation of affected households. It is noteworthy that with increasing populations in informal areas, the current response to flooding by the CC will become increasingly unsustainable.

In order to facilitate a sustainable flood risk management strategy, information on the existing situation must be sourced from all stakeholders. Interviews with the risk management committee have revealed that the partnership of the aforementioned CC departments has proven to be efficient in formal settlements because of the pool of information they hold collectively. That pool of information allows the risk management team to estimate and prepare sufficiently for potential flood risk. In informal settlements, in contrast, there is a lack of sufficient information to estimate flood risks accurately and thus to implement flood prevention strategies. This is largely because the current flood risk management platform does not support the sourcing of information from the afflicted communities. Consequently, the aforementioned solutions enacted by the CC are generic solutions and do not take into account the differing extent and sources of flood risk in the individual settlements. Instead, strategies are simply replicated across all informal settlements, implying that each settlement and each individual household within a settlement is equally at risk and prone to suffering the same type of flooding. As a result, solutions that are appropriate in some settlement are sometimes inappropriate in others.

It is also worth noting that the communities and CC officials often have different perceptions of what the solutions to the problems are and that this creates various limitations, especially with regard to the implementation of proposed solutions. For instance, interviews conducted with inhabitants of Masiphumelele indicated that several shacks were being flooded because of rising ground water. Current remedies provided by the CC, such as the provision of blankets for warmth and plastic to patch leaking roofs, did not address the problem. Instead, the inhabitants used the blankets on the floors of the shacks in a bid to stem the rising water. Additionally, a number of shacks do not have electricity and the owners are themselves often illiterate; hence, efforts by the CC, such as television broadcasted announcements and flyers often do not serve as viable warnings of impending floods. Similar situations have been identified by Satterthwaite *et al.* (2007) and Meyer *et al.* (2009) who point out that the major shortcoming of most flood risk management policies is that there is insufficient contemplation of the varying spatial allocation of risk as well as the critical analysis of the benefits of flood mitigation measures. Both studies confirm that a lack of shared information on the part of all stakeholders in solving the flooding problem has hampered the development of appropriate and sustainable flood risk management policies. Geographic Information Systems (GIS) are currently being used as an option for sharing of information between the various departments of the CC. The next section examines how the existing GIS can be extended to allow for the participation of hitherto excluded flood prone communities.

1.3 Participatory GIS

GIS may be defined as a computer based tool for mapping and analysing spatially referenced data (Quan *et al*., 2001). Several GIS scholars have identified the capacity of GIS to be used as a platform for the collection of various forms of spatially referenced data that can be used for planning. Quan *et al.* (2001) also define Participatory GIS (PGIS) as the integration of local knowledge as well as stakeholders' perspectives in a GIS. Similarly, Laituri (2003) describes PGIS in the context of planning as a confluence of social activity, such as the integration of input from grassroots organizations with government decision making and technology in specific places or grounded geographies. It is worth noting that the research of the various scholars with regard to PGIS can be split into two broad themes, namely, more inclusive access of the various stakeholders to information in the GIS and the inclusion of information from various stakeholders in a GIS. A more focused area of PGIS is what is now referred to as Public Participation Geographic Information Systems (PPGIS). The primary aim of this is to use GIS to provide information that can strengthen involvement of communities or marginalized groups in decision making (Ghose & Elwood, 2003; Sieber, 2006). This paper does not focus on empowerment, however, but rather on data integration. Since GIS is already being used for flood risk management in the CC, the task is to find a means of integrating local community information into the existing GIS.

A number of approaches have been used to solicit community based data for integration with GIS. Depending on the availability of data, researchers either engage directly with the community or use already existing information on the community. In an international context, for instance, Meyer *et al.* (2009) assessed flood risk in the Mulde River using official statistics on the risk-prone community as well as land use and flood data held by the local authorities. The official statistics included data, such as insurance data, taxation data and environmental studies collected within the area of study. Using a different approach, Tran *et al.* (2009) used GIS and local knowledge to contribute to proper planning and resource allocation for disaster preparedness in Thua Thien Hue, Central Vietnam. Community information included existing infrastructure, demographic and socio-economic conditions as well as information on the damage and loss caused by previous flood disasters. Participatory Rural Appraisal (PRA) techniques, such as focus groups, were used to highlight the most flood prone residential units as well as factors that contribute to flood vulnerability. Other studies point to different methods of community involvement, such as the use of interviews by Iuliana & Eugen (2009) in Romania; a review of the the use of questionnaires by Bird (2009) and the actual use of questionnaires by Abbot *et al.* (1998), Abbot (2000) and Bouchard *et al.* (2007) in South Africa and Raaijmakers *et al.* (2008) in Spain; and the general use of ephemeral mapping, sketch mapping and scale mapping by Rambaldi *et al.* (2006). Similar methods are highlighted by Tripathi & Bhattarya (2004) who carried out an elaborate study, looking at various authors with regard to the relevance of indigenous knowledge (IK) and the trends in integration of IK into GIS. Studies on the sourcing of community data in formal urban areas generally allow for less interaction with the actual households compared to rural and informal settlements. This is because, in the case of formal areas, data is readily available from various sources, such as health facilities, flood reports as well as land use and insurance registers. Abbott (2000) and Bouchard *et al.* (2007) conducted research on informal settlements, but apart from that, there has been limited research on practical sourcing of community information in informal settlements for GIS. Nonetheless, comparisons can be drawn with methods used in rural settings by Weiner, D. & Harris (2003) and Tripathi & Bhattarya (2004). The studies above therefore provide potential approaches for use in soliciting community information from informal settlements in Cape Town. The next section of this paper focuses on developing a methodology for facilitating the collection of such information from various stakeholders for flood risk management in an informal settlement. It also identifies a method of distinguishing between the different spatial allocations of flood risk within an informal settlement. The approach used here has been based on work by Abbot (2000) and Bouchard *et al.* (2007) because they worked with informal settlements in Cape Town.

2 Approach

2.1 Site Selection

Bouchard *et al.* (2007) identified the suburbs of Philippi and Khayelitsha as significantly flood prone areas. SDI was approached for their help in identifying a flood prone informal settlement that could be used as a pilot study. Consequently, Graveyard Pond in Philippi was selected. Graveyard Pond is an informal settlement located in a storm water catchment area. It is low-lying and contains approximately 300 households. CC aerial photographs of the area in September 2007 show the catchment pond with some surrounding structures, and aerial photographs taken in March 2009 show that the area has been almost completely inhabited (see Figures 1 and 2). A large portion of the settlement is continuously covered in water throughout the year.

Figure 1. Graveyard Pond, September 2007 (Source: City of Cape Town, 2008)

2.2 Data Collection

2.2.1 Spatial and Physical Data

The physical environment in which the community resides had to be analysed in order to comprehend the physical factors that were contributing to flooding in that area as well as the physical factors that would either increase or mitigate the impact of such flooding.

Figure 2. Graveyard Pond, March 2009 (Source: City of Cape Town, 2010)

Aerial photographs of Graveyard Pond taken in March 2009 were acquired from the CC. In addition, GIS maps depicting geographical data in the same area, such as roads, storm water drains, contours, sewer lines, direction of flow of ground water and cadastral data were also acquired from the CC. An overlay of the cadastral data on the aerial image revealed that there was no cadastral information within Graveyard Pond. This is typical of informal settlements that have not been zoned as residential areas. Abbott (2000) showed that, in informal settlements without cadastral information, the piece of land that is the most vital to individual households is that on which the accommodation structure is situated. The individual shacks were therefore adopted as the basic spatial unit to which the social and demographic information could be linked in the GIS.

2.2.2 Social and Demographic Data

A participatory approach to flood risk management required the collection of information from the communities actually affected by the flooding. The information in the social database included a basic profile of the inhabitants' education levels, employment and skills, coping mechanisms, health, and frequency of exposure to flooding. It also included any other factors that might assist in assessing the vulnerability of these shack dwellers to flooding. The collection of this data involved a number of steps.

Firstly, the community leaders within the settlement were identified with the help of surveyors working with SDI. Meetings were held with these community leaders, during which the various types of flooding experienced in the community were discussed. It was noted that flooding occurred from rising underground water, from the combination of leaking roofs and depressed floors, and from poor drainage during rainfall, which the leaders described as 'real flooding'. The types of waterborne diseases, employment and welfare grants were also noted.

Secondly, because questionnaires had been used by Abbott (2000) and Bouchard *et al.* (2007) in their studies of informal settlements, a questionnaire was designed with the help of SDI that included all the factors discussed. It included questions on income, employment, length of stay in the settlement, gender, health, methods of adaptation, types of flooding, and proposed mitigation measures. In order to link the questionnaire to a household, each questionnaire was also designed to include a section to mark the respective shack number of the interviewee.

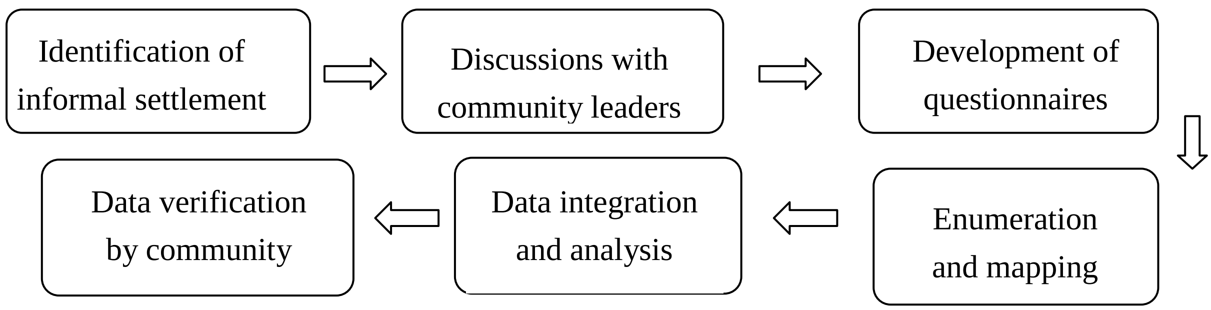

Figure 3. Social and demographic data collection steps

Subsequently, six experienced surveyors from within and around the settlement were selected to carry out the survey. The site was divided into six sections, each of which was allocated to a surveyor. They were required to mark the shack number of each visited shack on a print-out of the aerial photographs. In addition, any differences between the actual appearance of the shacks on the ground and on the image were marked on the printed aerial photographs. The questionnaires also contained the name of the enumerator so that, if two shacks in different sections had the same number, the individual questionnaires could be distinguished by the names of the enumerators. A workshop was then held to train each enumerator in map reading so that they could accurately mark the shack numbers on the aerial photographs. The survey itself took three days and approximately 270 households were interviewed. The questionnaires were then captured into a spreadsheet, using the shack number as the primary identifier for each questionnaire.

After the completion of the survey, the printed aerial photographs were used to digitise the shacks in the GIS. The shacks were digitised from the raster aerial photographs provided by the CC, taking into account any amendments by the enumerators. Also, the shack numbers marked by the enumerators in the printed satellite images were used as identifiers of the digitised shacks in the GIS. Since both the spreadsheet and the GIS had corresponding shack numbers as database identifiers, a spatial join could be carried out in the GIS software to link the questionnaires as attribute data for the corresponding shacks. The spreadsheets and digitized maps were then presented to the community at the local community hall to verify that the captured data was indeed accurate. The verified data was then analysed to tease out any spatial correlations in factors regarding flood risk in the settlement. A major setback in the data collection process was that not all respondents answered all the questions. Sometimes the heads of household were absent and the respondents did not have sufficient knowledge of the answers to the questions posed.

3 Results

During analysis, it was particularly important to find out if this participatory approach to GIS could inform the disparities in levels of vulnerability to flood risk as well as suggest potential solutions to mitigate flood vulnerability. The questions on types of flooding and incidence of disease from the questionnaire showed spatial disparities in risk within the settlement.

3.1 Type of Flooding

Based on the statistical report generated from the questionnaires, 94% of the people interviewed reported that they experienced flooding every winter. In addition, 70% of the respondents stated that an upsurge of underground water was responsible for the flooding. A map was created to show the types of flooding relative to the positions of the shacks (Figure 4).

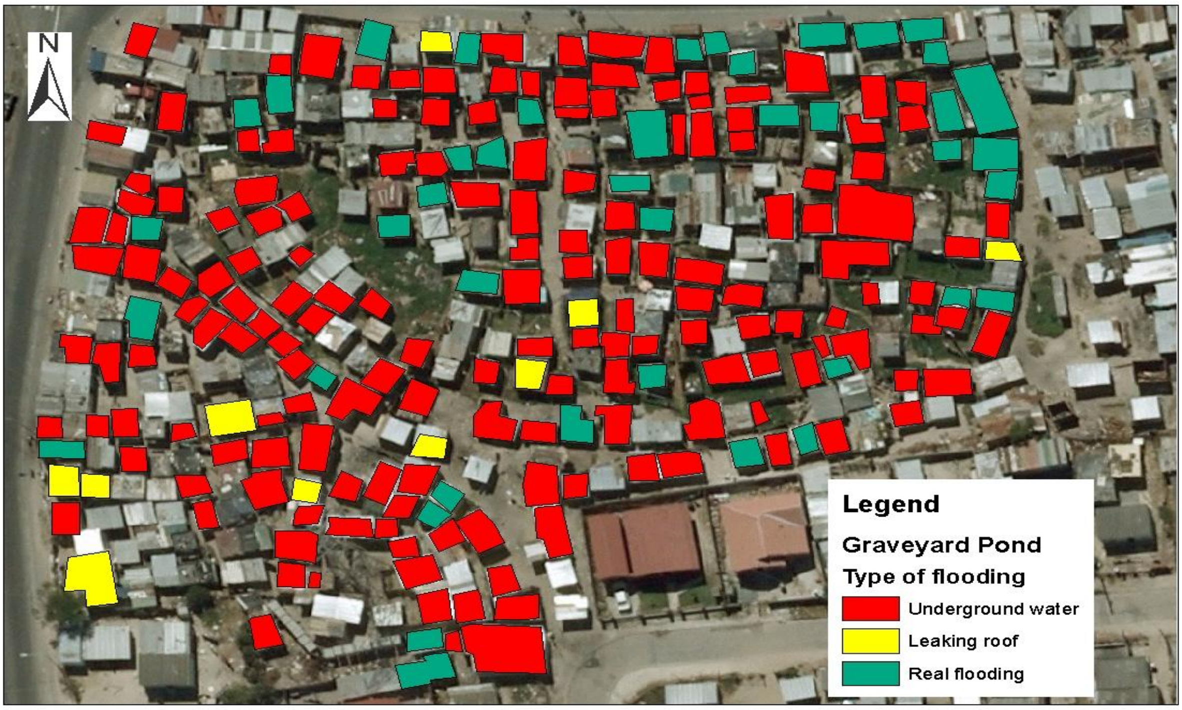

Figure 4. Types of flooding experienced in Graveyard Pond

Three main causes of flooding were mapped, namely, flooding from underground water, flooding from leaking roofs, and flooding by run-off water, which respondents referred to as 'real flooding'. From the map, it was noted that the majority of the shacks prone to flooding from run-off water were located on the periphery of the settlement, close to the roads and adjacent to formalised developments. From the questionnaires, it was also found that most respondents on the periphery often dug trenches to divert water away from their shacks as a means of mitigating the flooding (Figure 5).

During heavy rainfall, water channelled along the roads and built surfaces of the neighbouring formal developments flows into the settlement, first flooding the shacks on the periphery and then flowing along the trenches into the centre of the settlement. Since the centre of the settlement lies at a lower altitude than the periphery, the run-off water collects in the valley, hence the rising underground water. In the valley, responses include the use of sandbags and covering the floors using blankets and concrete, as well as raising shacks on wood and stones. The type of flooding affecting the shacks determines the type of response required by the respective shack dwellers. It therefore makes sense that the responses required to flooding in the shacks on the periphery of the settlement and those in the centre are appreciably different.

Figure 5. Methods of flood mitigation

3.2 Incidence of Waterborne Diseases

Part of the questionnaire investigated the incidence of waterborne disease in the settlement. During the survey, more than 10% of the respondents mentioned the occurrence of rashes in the winter. Subsequently, it was found that the shacks with respondents suffering from rashes in the winter lay within a 5m buffer of the underground storm water drain in the settlement (Figure 6). On further enquiry into community sanitation, it was also found that there was a shortage of toilets in Graveyard Pond.

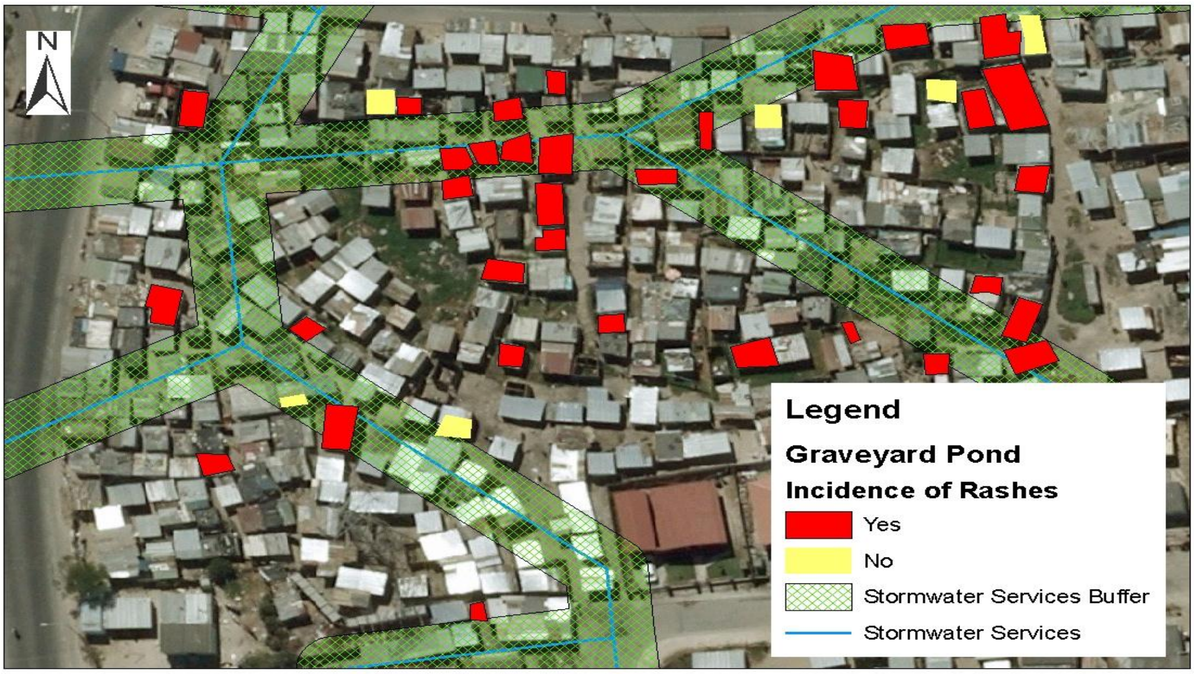

Figure 6. Incidence of rashes

There were 15 public toilets located in the South West of Graveyard Pond, which were for the use of the entire settlement of approximately 270 households. Incidentally, statistics from the questionnaires also showed that there was an average of three people per household. Interviews with the community leaders revealed that a number of residents either used toilets in the neighbouring settlements or buckets as makeshift toilets (Figure 7).

Figure 7. Types of toilets used in Graveyard Pond

The residents with access to flush toilets were either located close to the public toilets or on the periphery of the settlement, making it convenient for them to access toilets in neighbouring settlements. The shortage of toilets was confirmed during the survey, when a number of residents were observed using buckets as temporary toilets, dumping their excrement into an open storm water drain in the settlement. Any leakage in the storm water drains would allow the contaminated water to seep to the surface, which could be a plausible cause of the rashes in households located around the storm water drains.

The results from these two questions showed how participatory GIS could contribute to developing strategies to mitigate flood risk and vulnerability. The GIS on its own, however, would not be able to provide sufficient information to infer different levels of risk within the settlement. However, with the addition of the information from the questionnaires, the GIS became a more versatile tool for understanding the existing situation and identifying appropriate decisions.

The results from the analysis above were shared with the community leaders in Graveyard Pomd. They have subsequently used it in discussions with the CC officials and reported that the CC found the thematic maps informative. Current CC efforts have now been directed towards identifying potential location of toilets. The actual GIS data will be provided to the CC at the request of the community leaders.

4 Conclusions and Future Work

The combination of increased population growth and poor infrastructure in flood prone informal settlements has made flood risk management particularly difficult in informal settlements. Based on the findings in Graveyard Pond, it is clear that solutions vary even within a settlement and that macro level solutions are inappropriate. In order to develop a sustainable flood risk management strategy, there is a need for efficient sharing of information between various stakeholders. This study has shown that, in spite of the difficulties faced, PGIS is a viable tool for enhancing the pooling of data for flood risk management in informal settlements. In addition, it also offers a means of analysing the various contributors to risk in order to enhance the formulation of sustainable strategies. Although several texts have highlighted the relevance of PGIS in planning, few have progressed to the stage of practically developing a PGIS model. In addition, although PGIS has been analysed in urban and rural contexts, few authors have analysed its potential use in informal settlements. This paper contributes to those two research gaps. This study has not looked at the aggregated risk borne by the individual households after considering all factors affecting vulnerability in the settlement. The next stage of research will look at developing a GIS and multicriteria analysis model for aggregating and mapping flood risk in informal settlements.

References

Abbot, J.R. 2000. 'An Integrated spatial information framework for informal settlement upgrading', *International Archives of Photogrammetry and Remote Sensing*, Vol. 33, Part B2, pp. 7-16.

Abbot, J., Chambers, R., Dunn, C., Harris, T., de Merode, E., Porter, G., Townsend, J., & Weiner, D. 1998. 'Participatory GIS: Opportunity or Oxymoron.' *PLA Notes*, Vol. 33, pp. 27–34.

Bird, D.K. 2009. 'The use of questionnaires for acquiring information on public perception of natural hazards and risk mitigation: A review of current knowledge and practice.' *Natural Hazards and Earth System Sciences*, Vol. 9, pp. 1307–1325.

Bouchard, B., Goncalo, A., Susienka, M., & Wilson, K. 2007. *Improving flood risk management in informal settlements of Cape Town.* E-project-121307-110919. Available at: http://www.wpi.edu/Pubs/E-project/Available/E-project-121307-110919/unrestricted/FinalReport.pdf. Accessed on 14 January 2011.

City of Cape Town. 2005. *Study on the social profile of residents of three informal settlements in Cape Town*. Cape Town: City of Cape Town. Available at: http://www.capetown.gov.za/en/stats/CityReports/Documents/Informal%20Settlements/Informal_Settlements_Executive_Summary_272200611403_359.pdf. Accessed on 14January 2011

City of Cape Town. 2008. State of Cape Town (CCSCT) – *Development Issues in Cape Town*. Cape Town: City of Cape Town. Available at: http://www.capetown.gov.za/en/stats/CityReports/Pages/IDP.aspx. Accessed on 14January 2011.

City of Cape Town. 2009. *Winter Preparedness Strategy*. Document number SMC 05/03/09.

Ghose, R. & Elwood, S. 2003. 'Public Participation GIS and Local Political Context: Propositions and Research Directions.' *URISA Journal: Special Issue on Access and Participatory Issues*, Vol. 15, No. 2, pp. 17-24.

Iuliana, A. & Eugen, A. 2009. 'Perception of flood risk in Danube Delta, Romania.' *Natural Hazards*, Vol. 50, No. 2, pp. 269-287.

Laituri, M. 2003. 'The Issue of Access: An Assessment Guide for Evaluating Public Participation Geographic Information Science Case Studies.' *Journal of the Urban and Regional Information Systems Association*, Vol. 15, APA.II, pp. 25-31.

Meyer, V., Scheuer, S. & Haase, D. 2009. 'A multi-criteria approach for flood risk mapping exemplified at the Mulde river, Germany.' *Natural Hazards*, Vol. 48, No.1, pp. 17–39.

Quan, J., Oudwater,N., Pender, J. & Martin, A. 2001. 'GIS and Participatory approaches in natural Resources Research.' *Socio-Economic Methodologies for Natural Resources Research*. Best Practice Guidelines. Chatham, UK: Natural resources Institute. Available at: http://www.nri.org/publications/bpg/bpg09.pdf. Accessed on 12 December 2010.

Raaijmakers, R., Krywkow, J. & van der Veen, A. 2008. 'Flood risk perceptions and spatial multi-criteria analysis: An exploratory research for hazard mitigation.' *Natural Hazards*, Vol. 46, No.3, pp. 307–322.

Rambaldi, G., Kwaku Kyem, P., McCall, M. & Weiner, D. 2006. 'Participatory Spatial Information Management and Communication in Developing Countries.' *The Electronic Journal of Information Systems in Developing Countries*, Vol. 25, No. 1, pp. 1-9.

Satterthwaite, D., Huq, S., Pelling, M., Reid, H. & Lankao, P. 2007. 'Adapting to Climate Change in Urban Areas.' *International Institute for Environment and Development*, London. Available at: http://pubs.iied.org/pdfs/10549IIED.pdf. Accessed on 12 December 2010.

Sieber, R. 2006, 'Public participation geographic information systems: A literature review and framework.' *Annals of the American Association of Geography*, Vol. 96, No. 3, pp. 491–507.

Slum Dwellers International, 2009. *Joe Slovo Household enumeration report, Langa, Cape Town.* Available at: http://www.sdinet.org/static/upload/documents/JSEnumeration.pdf. Accessed on 20 December 2010.

Tran, P., Shaw, R., Chantry, G. & Norton, J. 2009. 'GIS and Local Knowledge in Disaster Management: A Case Study of Flood Risk Mapping in Vietnam.' *Disasters*, Vol. 33, No.1, pp. 152–169.

Tripathi, N. & Bhattarya, S. 2004. 'Integrating indigenous knowledge and GIS for participatory natural resource management: State-of-the-practice.' *The Electronic Journal on Information Systems in Developing Countries* Vol. 17, No. 3, pp. 1–13.

Weiner, D. & Harris, T.M. 2003. 'Community-Integrated GIS For land Reform in South Africa.' *URISA Journal: Special Issue on Access and Participatory Issues*, Vol. 15, No. 2, pp. 61-73.