Photorealistic Visualisation of Urban Greening in a Low-Cost High-Density Housing Settlement

by

Gavin Hugh Donaldson-Selby

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University of KwaZulu–Natal, Pietermaritzburg.

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Abstract

Apartheid housing policies of the pre-1994 South African government, and the low-cost high-density housing programmes of the post-1994 government, has given rise to numerous urban environmental problems, some of which could be addressed in a cost-effective and sustainable manner through urban greening, while simultaneously promoting biodiversity. Public participation in the planning of urban greening has been identified as being of vital importance, without which urban greening projects run a high, and expensive, risk of failure. Previous studies indicate that the greening priorities of residents in low-cost high-density housing settlements may differ considerably from those of managers and experts tasked with the protection and extension of the natural environment resource base. A system of participatory decision support is therefore required to reconcile the greening requirements of the community, and the ecological benefits of biodiversity. If language, literacy, map literacy and numeracy difficulties are to be avoided, and a sense of place or belonging is to be invoked, such a participatory decision support system should, ideally, be visually based, and capable of generating realistic eye-level depictions of the urban landscape. New computer-based landscape visualisation applications, which can directly utilise GIS, CAD and DEM data to produce detailed photo-realistic viewsheds, were deemed better suited to the task of visualising urban greening than existing GIS based mapping systems, CAD and traditional landscape visualisation methods. This dissertation examines the process of constructing a 3D computer model of the Mount Royal low-cost high-density housing settlement, situated in the eThekwini Municipality, KwaZulu-Natal, South Africa. Visualisations including terrain, natural features, indigenous vegetation, houses and roads were produced and submitted, with a questionnaire, to experts from different disciplines, Mount Royal residents and neighbors. Results from the expert survey indicate moderate support for visualisation in professional decision-making. However, both experts and residents expressed strong support for the accuracy and credibility of the visualisations, as well as for their potential in a participatory decision support system.

Preface

The research described in this dissertation was carried out in the Centre for Environment, Agriculture and Development, University of KwaZulu - Natal, Pietermaritzburg, from July 2004 to December 2005, under the supervision of Dr. Trevor Hill and Mr. Jan Korrubel.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any other University. Where use has been made of the work of others, it is duly acknowledged in the text.

Signed:
(Gavin Donaldson-Selby)

Signed:
(Dr. Trevor Hill – Supervisor)

Signed:
(Mr. Jan Korrubel – Co-Supervisor)

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Table of Contents
Component A

Component B

Page

List of Figures
Component A

Component B

Chapter One
Introduction

The global phenomenon of urbanisation is evident in many developing countries including South Africa, where the relatively high level of urbanisation, 55.5 percent in 2000 compared with an average of 40.5 percent for other developing countries (United Nations Department of Economic and Social Affairs: Population Division 2005), coupled with previous apartheid policies, has given rise to housing shortages (Boyle and Philp 2004; Knight 2004) and associated urban environmental problems (cf. 1.2.1) (Mutume 1998; Bullard 2002; Paton 2002; Department of Housing 2004a). Extensive post-apartheid housing programs, while ostensibly complying with environmental regulations, have done little to protect, rehabilitate or restore natural vegetation on the completion of low-cost high-density housing settlements (Adebayo 2001); thereby creating or exacerbating environmental problems that impact, both directly and indirectly, on the new inhabitants (Giyose and Bedford 2001) and further downstream.

Local and international advocates of urban greening (Sorensen, Smit, Barzetti and Williams 1997; Sowman and Urquhart 1998; Grobbelaar and Croucamp 1999; Park 2000) contend that many of these environmental problems could be addressed, or ameliorated, by means of urban greening. Section 1.3 (Benefits of Urban Greening) lists some of the potential benefits of urban greening, and Section 2.1 (International Case Studies) provides examples of urban greening in water supply catchment protection, wastewater treatment, air quality improvement, climate amelioration and energy savings, flood control, wildlife habitat and biodiversity, and urban agriculture. However, Sorensen *et al.* (1997), Sowman and Urquhart (1998), Grobbelaar and Croucamp (1999) and Giyose and Bedford (2001) note that local community[1] participation is essential to the success of urban greening, and that 'top-down' non-participatory approaches to urban greening are likely to fail. National and international institutional support for the principles of public participation in environmental decision-making (which would include urban greening) can be found in the *'Reconstruction and Development Programme: A Policy Framework'* (African National Congress 1994), the National Environmental Management Act (1998), and Local Agenda 21 Section 8.4 (f) *'Integrating Environment and Development in Decision-Making'* and Section 23.2 *'Strengthening The Role Of Major Groups: Preamble'* (United Nations Department of Economic and Social Affairs 2003).

[1] The term 'local community' in this dissertation refers to the inhabitants of a housing settlement, who would be immediately impacted by a proposed development or urban greening initiative.

Unfortunately, a local community's perception of the value of green open spaces, and the benefits of urban greening (as evidenced in Giyose and Bedford's 2001 study), may not necessarily be in accordance with those of the city managers and technical experts responsible for the protection / enhancement of a city's natural resources and biodiversity. Potential for a conflict of opinions and approaches with regards to open spaces and urban greening exists, necessitating a process of dialog, consultation, coordination, participatory decision-making and education if an undesirable, and possibly expensive, outcome is to be avoided. It is proposed[2] that such a process include visual components in order to transcend language, literacy, and numeracy difficulties, and should ideally incorporate realistic depictions of the proposed local (urban) landscape. Further desirable attributes are listed in Section 1.4 (Participatory Decision Support).

Three potentially suitable methods and technologies for the visual representation of urban greening and urban landscapes are presently employed in landscape planning and design. Traditional landscape visualisation methods, Geographic Information Systems (GIS) and Computer Aided Design (CAD) - are briefly discussed in Sections 1.4.1, 1.4.2 and 1.4.3 of this chapter, and in greater detail in Chapter 3, Sections 3.2, 3.4.1 and 3.4.2. All three methods / technologies are valuable decision support tools in a wide range of disciplines, including natural resource / environmental management and urban greening, but, for various reasons discussed in the cited sections, fail to meet the criteria set for a participatory decision support process - principally that of a visualisation system which is fast, realistic, geographically based, scientifically defensible, extensible, and of low-cost. However, software applications recently developed specifically for landscape visualisation, which are capable of directly utilising GIS and CAD data in the generation of detailed and realistic images, may potentially meet or exceed the above criteria.

It is the position of this dissertation that physically-based realistic landscape imagery could serve two important roles in urban greening. First, the geographically based (and therefore scientifically defensible) imagery could provide decision support and visual data verification to experts from a number of disciplines. Second, the broad accessibility of the images empowers all stakeholders (expert and non-expert) to participate more fully in environmental decision-making processes. Local Agenda 21 Section 40.22 *'Information for Decision-Making'* notes that "special emphasis should be placed on the transformation of existing information into forms more useful for decision-making and on targeting information at different user groups. Mechanisms should be strengthened or established for transforming scientific and socio-economic assessments into information suitable

[2] Proposed by this author.

for both planning and public information. Electronic and non-electronic formats should be used" (United Nations Department of Economic and Social Affairs 2003:336). Local Agenda 21 Section 40.25 notes that "where necessary, new technology should be developed and its use encouraged to permit participation of those not served at present by existing infrastructure and methods. Mechanisms should also be established to carry out the necessary transfer of information to and from non-electronic systems to ensure the involvement of those not able to participate in this way" (United Nations Department of Economic and Social Affairs 2003:337).

Sorensen *et al.* (1997:56) note that urban greening is "not just another project implemented in a metropolitan environment" but rather "is part of a much larger natural system. Cities are situated within a general ecosystem and as such are a part of a larger bioregion... to preserve natural systems then, we need to integrate nature into our cities". The considerable ecological, economic and social benefits derived by all from integrating **planned**[3] urban greening projects into a city's open space system, which in turn is linked to external sources of biodiversity, are often not understood, quantifiable or appreciated. Unplanned urban greening with no clear, plan, goal, vision or broad participatory support could well result in expensive failure; and might even be contrary to the best interests of a community and the city – e.g. biodiversity, food / water security and public health. Planned urban greening exercises must therefore investigate and consider all relevant knowledge, experience, opinions and options; and clearly and truthfully convey (as far as possible) both the underlying information, and the proposals / recommendations arising therefrom, to all participants. Visual media and new technology, such as photographs and defensible computer visualisations of urban greening, could assist in the unambiguous conveyance of such information, thereby circumventing misunderstandings, and may, in turn, act as a starting point toward further discussion, planning, environmental education (if necessary) and finally community endorsement and support. Mattson (2004 *pers. comm.*) suggests that landscape visualisation offers an opportunity to "deploy an unprecedented palette of plant diversity so as to deliver the broadest possible spectrum of environmental, cultural, nutritional and social benefits" and ... "that a system of viewable landscape elements ...raises the possibility, perhaps for the first time, of using plants in a truly integral planning tool".

Chapter One outlines the enormous pressures on housing in South Africa arising from the legacy of apartheid legislation; and the consequential environmental problems resulting from both apartheid housing policies and post-apartheid Reconstruction and Development Programme (RDP) housing

[3] Emphasis by this author.

programmes. The potential benefits of urban greening for RDP housing settlements; the importance of local community participation in the planning and implementation of urban greening; community awareness of the benefits of urban greening and open spaces; biological diversity in urban greening projects, and the requirements of a participatory decision making process that may resolve both the demands of the local community as well as the broader city-wide demands of biodiversity are also considered.

Chapter Two reviews South African environmental legislation and policy, and its support for urban greening. The important role local government plays in implementing urban greening; the development of the Durban Metropolitan Open Space System / eThekwini Environmental Services Management Plan which forms the ecological and biodiversity setting in the eThekwini Municipal Area (EMA) within which urban greening (ideally) should be integrated; various urban greening agencies in the EMA and key factors required to strengthen and support urban greening initiatives are also examined in Chapter Two. Landscape visualisation and quality assessment, traditional methods of landscape visualisation, the development of computer visualisation technology, and realism and ethics in landscape visualisation are discussed in Chapter Three. Chapter Four details the location, nature, topography and biological environment of the study area - the Mount Royal Reconstruction and Development Housing Project; as well as the data collection, preparation and processing phases of the study methodology.

1.1 Global Urbanisation

The initial process of urbanisation began between five and six thousand years ago in Mesopotamia, Egypt, India and China (van der Veen 2002). These ancient cities were small and dependent on agriculture and access to water, without which they could not survive. The late 18^{th} and 19^{th} centuries saw a second expansion of urbanisation, particularly in Britain and Western Europe, as a result of the Industrial Revolution, resulting in severe social and environmental problems. In 1800 only one city, London, had a population of one million, while the population of Paris was 500 000, and Vienna and St. Petersburg 200 000. By 1900 the populations of London, Paris, Vienna, St. Petersburg, Berlin, Tokyo, Manchester, New York, Chicago and Philadelphia all exceeded one million (Chandler 1987 cited in Worldwatch Institute 2003). The third and most rapid phase of urban growth, which began after 1945 and continues today, is apparent in many countries, particularly those classified as developing. Of the twenty most-populous cities in the world (Appendix 1: Table 1) sixteen are in developing countries (Infoplease 2004). Currently there are four hundred and eleven cities with populations exceeding one million inhabitants (Population Reference Bureau 2004a) of which nearly three hundred are in developing countries (Cepulkauskaite 1998). Expressed as a percentage, in 1800 some three percent (thirty million people) of the total world population were urbanised, rising to fourteen percent (two hundred and thirty one million people) by 1900, and 47.1 percent (2.86 billion people) by 2000 (Table 1.1) (United Nations Department of Economic and Social Affairs: Population Division 1999; United Nations Chronicle 2001; Population Reference Bureau 2004a; 2004b; United Nations Department of Economic and Social Affairs: Population Division 2005). It is estimated that by 2030 60.8 percent (4.98 billion people) of the world's population will be urbanised, with most of the population increase (1.98 billion people, or 93.4 percent) occurring in the urban areas of developing countries (United Nations Department of Economic and Social Affairs: Population Division 2005).

Table 1.1. Global trends in urbanisation. Adapted from United Nations Department of Economic and Social Affairs: Population Division (2005)

Percentage of Total Population	**Year**				**Percentage Urbanised**
	1980	**2000**	**2020**	**2030**	
World	39.2	47.1	55.9	60.8	
Africa	27.5	37.1	47.8	53.5	
Europe	68.6	72.7	76.6	79.6	
North America	73.9	79.1	84.8	86.9	
Central America	60.4	68.4	74.2	77.5	
South America	67.8	79.7	86.8	88.6	
Asia	26.3	37.1	48.5	54.5	
Oceania	71.1	72.7	74.2	74.9	
Less developed countries	29.5	40.5	51.4	57.1	
More developed countries	69.2	73.9	78.7	81.7	

1.2 Urbanisation in South Africa

In 1960 46.6 percent of the South African population was urbanised. By 2000 urbanisation had risen to 55.5 percent, and (allowing for HIV / AIDS mortalities) is estimated to reach approximately 60.3, 65.2 and 70.1 percent in 2010, 2020 and 2030 respectively (United Nations Department of Economic and Social Affairs: Population Division 2005). In the province of KwaZulu-Natal projected urbanisation for 2010 and 2020 is expected to be 59 percent and 62 percent respectively (Metropolitan Durban 1999b).

The process of urbanisation in South Africa, which is higher than the (2000) average of 40.5 percent for developing countries (United Nations Department of Economic and Social Affairs: Population Division 2005), has been substantially distorted by the legacy of apartheid. Legislation dating back to 1913 severely restricted where black South Africans could live, work or own property. Within the 'white' cities black people were viewed by the authorities as temporary migrant workers who were required to have permits to live or work there, and who were expected to eventually return to their 'homelands' (Tomlinson 2002). Consequentially, legislation based on this premise deliberately limited access to, or land for, housing and basic municipal services (Department of Housing 2004a). As the majority of employment opportunities were to be found in the 'white' urban areas many rural black workers (mostly male) moved to the cities and, because of their illegal status, were forced to reside in the overcrowded shacklands that mushroomed within the surrounding 'black' dormitory townships. The lifting of the racially based restrictions in the early 1990s, coupled with the shortage of affordable accommodation, saw the creation of numerous informal settlements on open lands. Statistics indicate that whereas there was one formal house per 3.5 whites, there was only one formal house per 43 blacks (Knight 2004). In order to address the severe housing shortage the post-1994 African National Congress (ANC) government embarked on a mass low-cost housing exercise as part of their Reconstruction and Development Programme (RDP); a policy that ostensibly incorporates sustainable development (Aliber 2002), and which requires government to ensure equitable access to natural resources, safe and healthy living / working environments, as well as the empowerment of communities to manage their natural environment through participatory decision-making (African National Congress 1994).

Since 1994, 1.6 million RDP houses for approximately six million people have been built at a cost of 24.22 billion Rand (Appendix 1: Table 2) (Department of Housing 2004b), but the backlog has since grown from 1.5 million (1994) to 2.4 million houses today (Boyle and Philp 2004). 2001 census figures (Appendix 1: Table 3) indicate that there are approximately 3 560 383 people living in informal settlements, of which 1 016 596 are in KwaZulu-Natal (Department of Housing 2004a). Housing Director-General Mpumi Nxumalo has indicated that government intends to address the informal settlement issue within ten years primarily through increased subsidies and high-density accommodation (Boyle and Philp 2004). In Durban, the Metro Housing unit has stated that it plans to deliver at least 17 000 housing units over the next ten years (Durban Metro Housing Unit 2004).

1.2.1 Environmental Impacts

The environmental impacts of Apartheid planning and legislation in respect of the pre-1994 formal townships include (African National Congress 1994; Department of Environmental Affairs and Tourism 1996; Mutume 1998; Bullard 2002; Paton 2002; Department of Housing 2004a):

- Air pollution as a result of proximity to industry, and the burning of fuel wood / coal for domestic heating and cooking.
- High levels of dust from unpaved roads, particulates generated by industry and wind blown mine tailings.
- Pollution of rivers and contamination of ground water by sewerage, waste dumps / land fills and mining / industrial leachates.
- Pollution of rivers by dumping of refuse either in the rivers or in storm water drains.
- Unsustainable and environmentally damaging patterns of resource use including illegal dumping on public open spaces - e.g. there are some five hundred and fifty illegal dumps in Soweto (Paton 2002).
- Health problems related to the close proximity of the townships to industrial areas and waste dumps / land fills.
- Health problems related to extreme overcrowding.
- Loss of access to agriculturally productive land and other natural assets for food production and livelihoods.

Informal settlements suffer environmental problems equal to, if not worse, than those of formal townships as a consequence of the complete lack of planning or municipal services in many settlements; as well as inappropriate location – often situated on steep inclines (leading to erosion), in ecologically sensitive areas such as river floodplains, estuaries or indigenous forests (Department of Housing 2000), in close proximity to heavy industry and landfills, or on degraded / undesirable land.

Aliber (2002) suggests that, while it is difficult to evaluate the direct environmental impacts of the RDP housing programme, the replacement of informal settlements with planned and serviced RDP housing benefits (in principle) both the environment and public health. Furthermore, developers of housing projects are required to comply with national, provincial and local environmental / housing legislation, including the conducting of environmental impact assessments (Department of Housing 2000). A Record of Decision or municipal contract may attach conditions such as an environmental management plan / protection of specific fauna / flora, or revegetation specifications - e.g. Ethekwini Municipality's *'Standard Environmental Management Plan and Revegetation Specification for Civil Engineering Construction Projects. Implementation Guideline Document'* (Wray and Boast 2002), which should be complied with by the developer.

Unfortunately, the pressure to meet mass low-cost housing targets, coupled with the high cost of implementing services (water, sanitation, roads, electricity) within limited budgets, has relegated environmental impact concerns to a low order of priority (Mathiane 2001). In order to minimise construction costs, sites are usually scraped clear of vegetation and topsoil (including the seed bank) prior to construction (Sowman and Urquhart 1998; Mattson and Dalzell 2002), and little or no effort is made to rehabilitate the area by way of landscaping or revegetation on completion. Adebayo (2001:15) observes that "the existing natural environment has in many cases been destroyed beyond repair" and that "new housing, especially in the state low-cost projects, has turned areas of natural vegetation to desert, with construction activity causing removal of all the trees on site rather than integrating them into the built environment". Adebayo (2001) contrasts this situation with that of informal settlements in Durban where trees (and other indigenous vegetation) are well preserved. Examples of this (Figures 1.1 and 1.2) can be found in Durban's Cato Manor suburb where informal and low-cost formal housing exist in close proximity *(pers. obs.)*.

Figure 1.1. Informal housing in Cato Manor. January 21, 2005.

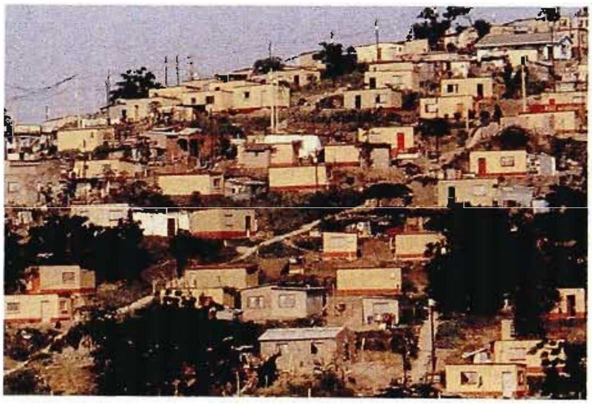


Figure 1.2. Formal housing in Cato Manor. January 21, 2005.

In their study *'Understanding The Greening Requirements Of New Low Income Settlements In The Ethekwini Metropolitan Area'* Giyose and Bedford (2001) noted the following consequences arising from the pre-construction clearance of vegetation in four low-cost housing developments:

- Rain caused considerable erosion and flood damage, particularly where there were high embankments and steep slopes. Soil would be washed into the streets and block storm water channels and drains, causing flooding of public and private spaces. Occasionally houses would be flooded causing damage to furniture, as well as social discord as people attempted to divert the water elsewhere – usually towards their neighbors.
- In the case of one low-income housing settlement erosion had caused considerable change in the topography.

- Focus group participants claimed that soil erosion had 'damaged' existing gardens, and rendered other sites unsuitable for the establishment of new gardens. In some cases residents were considering removing trees that had been undercut and were threatening to fall over.
- Technical assessments of the remaining soil, carried out by horticulturalists from the Parks and Recreation Department, showed it to be of 'poor quality' and unsuitable for food gardens. Residents complained that it was too hard and too stony for planting.

Other consequences arising from the pre-construction clearance of vegetation included a lack of windbreaks (resulting in windborne dust), heat, and poor aesthetic appeal (Giyose and Bedford 2001).

1.3 Benefits of Urban Greening

The Department of Water Affairs and Forestry defines urban greening as "an integrated approach to the planting, care and management of vegetation in cities, towns, townships and informal settlements in urban and peri-urban areas" (Mathiane 2001:2). Urban greening includes urban forestry, urban agriculture / permaculture and urban agroforestry (Grobbelaar and Croucamp 1999). Historically, urban greening has been generally utilised in the 'white' city areas for the provision of aesthetic, recreational and educational requirements (Park 2000); and in the context of post-apartheid reconstruction and development is seen in some quarters as a luxury. Park (2000), however, restating Miller (1988), contends that the purpose of urban greening is "to secure multiple environmental, economic and social benefits for urban dwellers" (Miller 1988 in Park 2000:2). Those potential benefits include (Sorensen *et al.* 1997; Kuchelmeister 1998; Sowman and Urquhart 1998; Spies 1998; Grobbelaar and Croucamp 1999; Addo, Breen and Jaganyi 2000a; Park 2000; Giyose and Bedford 2001):

- Climate amelioration and energy saving through the shade and evapotranspiration provided by trees.
- Air pollution reduction, including particulates, carbon monoxide, carbon dioxide, sulpher dioxide, nitrogen dioxide and ground level ozone.
- Flood control and storm water detention through the use of parks and wetlands.
- Catchment protection and improved quality of water supply through the interception of pollution, nutrients and sedimentation.
- Wastewater treatment through retention ponds, wetlands or settling ponds. Products could include water for agriculture, fertiliser, and fibers for craft production.

- Slope stabilisation and erosion control.
- Noise attenuation through absorption, deflection and masking.
- Food and agricultural production including fruit, vegetables, stock feed and forage, as well as other high-value items such as nuts, cut flowers and nursery products.
- Traditional medicinal plant production.
- Wood products including poles, timber and firewood.
- The creation of open green spaces appropriate for recreation i.e. parks and playing fields.
- Environmental educational opportunities.
- Reclamation of unused and degraded lands.
- Wildlife habitat and biodiversity including corridors linking other open spaces.
- Aesthetic benefits and increased property prices.
- Sustainable employment opportunities generated by all of the above activities.

Thus, far from being a luxury, urban greening constitutes an immediate, cost-effective and sustainable means of reducing poverty, enhancing social welfare, improving nutrition (i.e. a means of primary health care in the context of HIV / AIDS), and promoting environmental restoration (Mattson 2004 *pers. comm.*).

1.3.1 Community Participation in Urban Greening Projects

Sorensen *et al.* (1997), Kuchelmeister (1998), Sowman and Urquhart (1998), Grobbelaar and Croucamp (1999), Addo *et al.* (2000a) and Giyose and Bedford (2001) emphasise the importance of local community participation in urban greening, including:

- The identification and prioritisation of the community's needs.
- Understanding and appreciation of the value of the trees and vegetation planted.
- Participation in the planning, design and implementation.
- Agreement on the nature and scale of the project.
- Empowerment to manage the trees and vegetation.
- Monitoring, and evaluation of the usefulness and success of the project.

It is also necessary that urban greening agencies understand how people relate to the land and utilise its resources. Barzetti (1992) notes that stakeholders are frequently viewed as conservation or education targets, rather than as partners; and are only included towards the end of the project, often resulting in conflict and project failure (Barzetti 1992 cited in Sorensen *et al.* 1997). Mattson (2004 *pers. comm.*) observes that when promoting urban greening "one needs to meet people where they are at, and work with the value systems their life conditions have imposed on them" - e.g. mothers are likely to focus on child health care / nutrition, and entrepreneurs on business opportunities. Clearly dialogue, consultation and coordination should be an integral part of any urban greening project.

The advantages of a community-centred approach include (Grobbelaar and Croucamp 1999):

- The assurance that the community are the primary beneficiaries of the project.
- The promotion of direct involvement by the community, thereby:
    - Increasing self-esteem.
    - Increasing local responsibility for the environment.
    - Increasing pride in the local environment.
    - Increasing aesthetic appreciation of the environment.
- The linkage of rights with responsibilities.
- The integration of local, traditional and modern knowledge.
- The integration of land-use and resource-use sectors.
- The reduction or elimination of dependency on the state.
- Increased access to funding.
- The development of skills.
- A sense of ownership.

1.3.2 Community Awareness of the Benefits of Urban Greening

In their study of the greening requirements for new low-income settlements in the Ethekwini Municipal Area (EMA) Giyose and Bedford (2001) observed the following:

- The main priorities of the surveyed communities were schools, community halls, street names, playgrounds, water, public and private telephones, and improved roads. Urban greening was not seen as a high priority.
- Thirty seven percent of the sampled residents did not identify any environmental problems, despite the high prevalence of soil erosion in the selected areas.
- Thirty four percent of the focus group participants were unaware of the benefits of urban greening.
- Sixty nine percent of the focus group participants[4] were unaware of the importance of open spaces (Figure 1.3).

[4] Multiple responses were allowed, thus the total of percentages may exceed 100 %.

- Fifty percent of the focus group participants were unaware of the value of medicinal plants.
- Forty percent of the focus group participants were unaware of the benefits of grassing.

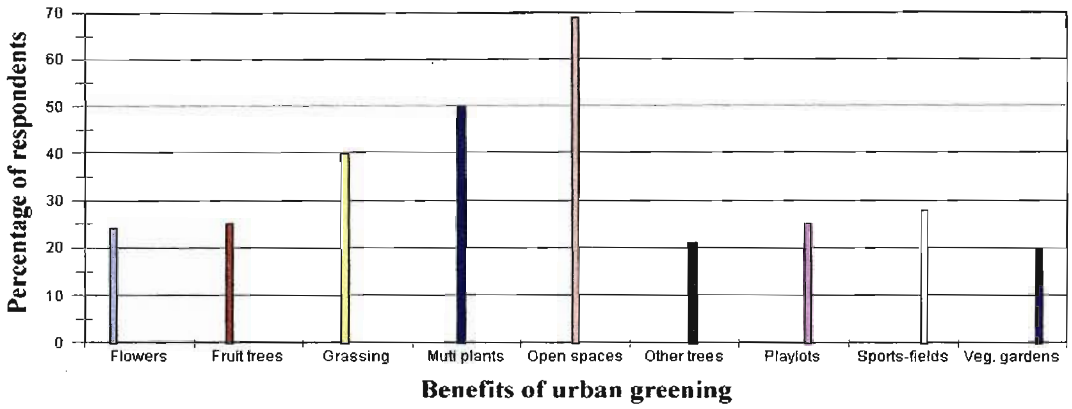


Figure 1.3. Percentage of respondents unaware of benefits of urban greening. Sourced from Giyose and Bedford (2001).

- Socio-economic benefits of greening (Figure 1.4) were identified[5] (in order of priority) as:
    1. Play lots (67 %).
    2. Sports fields (64 %).
    3. Flowers (55 %).
- Material (food production) benefits of greening were identified (in order of priority) as:
    1. Vegetables (53 %).
    2. Fruit trees (45 %).
- Environmental benefits of greening were identified (in order of priority) as:
    1. Other (shade) trees (47 %).
    2. Grassing (38 %).

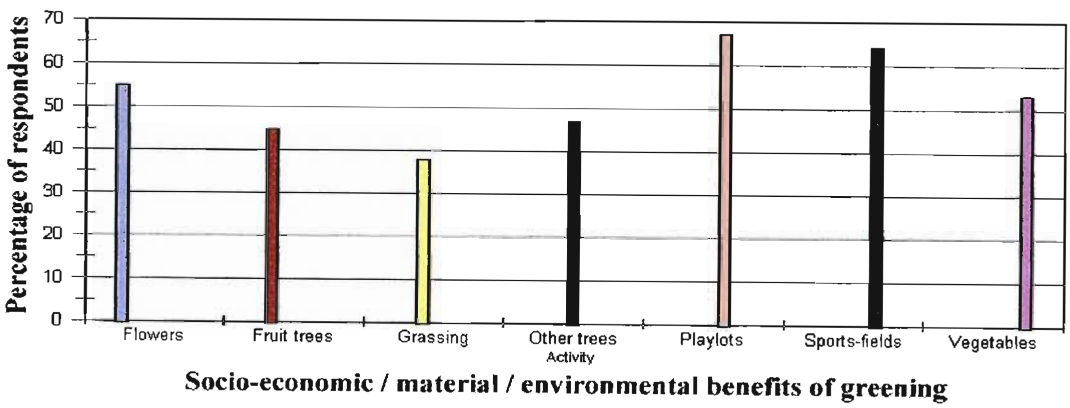


Figure 1.4. Percentage of identified socio-economic / material / environmental benefits of greening. Sourced from Giyose and Bedford (2001).

[5] Multiple responses were allowed, thus the total of percentages may exceed 100 %.

- The three most desirable greening activities were identified (in order of priority) as:
    1. The establishment of (private) vegetable gardens with a view to communal sharing.
    2. The planting of other (shade) trees. Focus group participants were uncertain of names.
    3. The planning of fruit trees and establishment of play lots.
- Fifty two percent of respondents were either not specific or did not know which species of vegetation should be avoided. A further twelve percent did not want thorn trees, and seven percent were happy with anything that provided beauty and shade. Reasons advanced for preference of vegetation included public safety, criminal activities, and superstition.
- At least one community indicated that it would have liked to have been consulted prior to commencement of construction.

It may be concluded from Giyose and Bedford's (2001) report that a high percentage of respondents and focus group participants were unknowledgeable of environmental problems in their communities, or the wide-ranging benefits of urban greening. Where the benefits were acknowledged emphasis was placed on food production (vegetable gardens and fruit trees), shade and beauty (shade trees and flowers), and the establishment of play-lots and sport fields. Giyose and Bedford (2001) also noted that:

- Participants were "generally unaware of the purposes of open spaces" and that they "did not see a need for open spaces for environmental or natural purposes. Everyone maintained that open spaces should be utilised for other development purposes, especially considering that their areas lacked in facilities" (Giyose and Bedford 2001:19).
- Some eighty six percent of respondents were willing to assist in the planting of vegetation in public spaces, as well as the establishment and maintenance of community gardens.
- "The beauty of an area was associated with a **sense of belonging**"[6] (Giyose and Bedford 2001:18).
- "The advantages of public participation and consultation cannot be over-emphasized, whereby communities develop a **sense of ownership** and **involvement**, consequently protecting and preserving the green environment" (Giyose and Bedford 2001:44).

Giyose and Bedford (2001) suggest that the survey indicates a general lack of understanding of greening issues, and cite Sowman and Urquhart (1998) in suggesting that environmental education (in addition to information and training workshops on greening) is necessary. Environmental education and greening workshops would foster a positive proactive attitude towards greening,

[6] Emphasis by this author.

equip the residents with skills and knowledge necessary to plan and manage their trees and vegetation, and inform the community in respect of the sustainable use of natural resources.

1.3.3 Biological Diversity in Urban Greening Projects

It has been estimated by Roberts and Boon (2002) that, in 2002, Durban's natural resource-base supplied essential environmental goods and services worth 3.1 billion Rand. The importance of these goods and services is recognised in the eThekwini Integrated Development Plan: 2003-2007 (IDP) stated intention to realise "plans and policies that will ... ensure that the natural environment asset base is protected and, where possible, extended" (eThekwini Municipality 2003:20). Environmental goods and services are largely derived from open spaces which the *'Durban Environmental Services Management Plan'* (Roberts and Boon 2002) groups into two categories:

- Urban open spaces, which may include industrial areas, recreational areas, utility areas, privately owned areas and urban agroforestry areas.
- Natural open spaces, which may include marine and coastal reserves, rivers and wetland areas, and undisturbed indigenous biomes.

Natural open spaces, which contain the most functional and productive ecosystems, tend to become 'islands' within urban areas, requiring connectivity (physical corridors) to link the open spaces / river catchments to each other as well as important external sources of biological diversity in order to ensure a flow of genetic material, energy, water and nutrition, thereby preventing local species extinction (Towle 1996; Roberts and Boon 2002; Bennet 2003). In the case of the eThekwini Municipal Area, the external sources of biological diversity (or bioregions) are the Pondoland and Maputaland centres of plant diversity, and the Eastern Cape marine biodiversity centre (Roberts and Boon 2002). Open space planning and policy to ensure the continued supply of environmental goods and services in the eThekwini Municipal Area has been developed and formalised in the eThekwini Environmental Services Management Plan (EESMP) - formerly known as the Durban Metropolitan Open Space System (D'MOSS) (cf. 2.4.4 – 2.4.5).

If urban greening is to promote, and extend, biodiversity within urban areas it is important that the selection process of trees and vegetation for urban greening take into consideration the ecological nature of the natural open spaces with which they connect, as well as the number of species utilised, in order to avoid either low biodiversity value or low ecological functionality (Nichols, Boon, Jayes, Martens and Hoare 2000). Mattson (2004 *pers. comm.*), however, argues that within the overall ecological context further consideration should be given to plants of ethno-botanical /

medicinal importance, cultural significance, economic value, primary health care importance and environmental restoration potential; as well as those grown for fencing, erosion control, soil fertility enhancement, seed storage and composting.

1.4 Participatory Decision Support

Clearly, the potential exists for a conflict of opinions, values, and approaches to urban greening between residents of low-cost housing projects, and the city managers / technical experts (ecology, hydrology, etc) tasked with the protection and extension of the natural environment resource base; which, if not anticipated and pre-empted, could result in one of the following scenarios:

- A 'top-down' non-participatory approach to urban greening that is likely to alienate the beneficiary community, thereby causing them to neglect their planting and maintenance responsibilities, resulting in the failure of the greening project.
- 'Ad-hoc' greening with little or no expert input or guidance that may at best meet some of the needs of the community, and at worst exacerbate local and city-wide environmental and ecological problems.
- Concern for the perceived high risk of failure resulting in no action being taken, thereby addressing neither the needs of the community, nor the requirements of biodiversity.

A participatory decision support process is, therefore, required to reconcile the tangible socio-economic and welfare benefits of urban greening (and development) as demanded by resource-poor communities, and the less tangible ecological benefits and services accrued to the city by biodiversity. This process should ideally have the following attributes:

- It should be visually based in order to circumvent language, literacy, and numeracy difficulties.
- It should clearly and unambiguously present proposals in a way that all parties can understand; and should, therefore, have the capacity to realistically depict urban landscapes.
- It should allow analysis and evaluation of three-dimensional spatial and visual relationships from different viewpoints, particularly eye-level perspectives.
- It should invoke community co-development and a sense of ownership.
- It should allow for easy implementation / consideration of design alternatives.
- It should be scientifically defensible.
- It should allow for data feedback for expert analysis and evaluation.

- It should be able to integrate a wide range of data, including that from outside the study area, in order that the broader impacts of a greening process can be analysed and evaluated.
- It should not be time consuming or expensive to implement.

Landscape visualisation methods and technologies that may (partially) meet the above criteria include:

- Traditional methods of landscape visualisation.
- Geographic Information Systems.
- Computer Aided Design.

1.4.1 Traditional Landscape Visualisation Methods

Traditional eye-level perspective landscape visualisation methods (cf. 3.2) include perspective drawings, physical models and photomontages (Lange 2002). All of these methods tend to suffer from the following limitations. First, they are time consuming (and therefore expensive) to produce. Second, they are not linked to real-world geographically based data (Appleton, Lovett, Sünnenberg and Dockerty 2001), and cannot effectively generate data feedback for expert analysis and evaluation. Third, they are not easily modified at short notice to reflect design changes. Perspective drawings and photomontages do not allow the observer to dynamically change their viewpoint. Unaltered photographs can only show what presently exists and require manual modification, usually through a process of overlays (photomontages), to provide an approximation of future impacts. Consequently the credibility of photomontages can be questionable (Bergen 1993; Berry, Buckley and Ulbricht 1998).

1.4.2 Geographic Information Systems in Landscape Visualisation

Over the past three decades Geographic Information Systems (GIS) have become an important mapping and database analysis tool for a number of disciplines including cartography, forestry, land use planning and management, natural resource management, urban planning, civil engineering, hydrology, geology, mining, archeology, and environmental science / management (cf. 3.4.2). Maps, showing features such as existing parks, open spaces, rivers and wetlands, utilities (electrical, water and sanitation), transportation routes (road and rail), topography, soil profiles and man-made structures (including housing) are essential to the design and implementation of urban greening projects (Sorensen *et al.* 1997). In the eThekwini Municipal Area (EMA) such maps are available through the extensive eThekwini Municipality GIS database, as well as the Chief Directorate:

Surveys and Mapping. However, most Geographic Information Systems are only capable of producing two-dimensional (2D) images and, through a process of 'draping' images over a Digital Elevation Model (DEM), limited three-dimensional (3D) images (Appleton *et al.* 2001). The usefulness of images produced by a Geographic Information System is constrained in at least three respects. First, the data represented can be extremely complex, making it difficult for people without GIS or mapping experience to understand. This may diminish their value in respect of public participation and decision support in environmental decision-making processes. Second, the limited (or non-existent) three-dimensional nature of GIS generated images can make it difficult for experts and non-experts alike to understand and objectively evaluate complex three-dimensional spatial relationships. Third, the lack of realistic visual detail in GIS generated images can hinder or limit understanding and evaluation of visual relationships between proposed developments, restorations or reclamations and existing buildings, vegetation, water bodies and landforms; thus reducing their usefulness in visual impact studies.

1.4.3 Computer Aided Design in Landscape Visualisation

Computer Aided Design (CAD) is widely used in the design, testing and manufacture of buildings, industrial plants, motor vehicles, airplanes, ships, railways, roads, bridges, electronic and network design (Foley, van Dam, Feiner and Hughes 1992). Some CAD systems, particularly those with strong 3D modelling capabilities, can utilise high-level 3D geometrical surfaces to model complex organic shapes; while specialised modellers and renderers - i.e. those used in the entertainment industry (films and computer games) and the aviation industry (flight simulators), offer advanced computer graphic techniques capable of generating realistic and scientifically defensible images (cf. 3.4.1). However, most CAD databases (and consequently their database query / analysis tools) tend to be rudimentary (Maguire 1991) and do not readily facilitate:

- The selection, interrogation and manipulation of objects based on data attributes.
- The integration of data from outside the study area.
- Dynamic interaction with underlying data (Thurston, Moore, Parkinson and Poiker 2001).
- Undertaking complex spatial analyses (Bohnenstiehl 1999).

Most CAD systems are incapable of importing real-world (geographic) and projected data in any coordinate system other than their local Cartesian system. This limits their ability to integrate a wide range of data.

1.5 Problem Statement

As useful as GIS maps are to the design and implementation of urban greening, they are unable to provide the observer with realistic eye-level perspectives of the proposed vegetation relative to the site and surrounding space in general, and individual houses in particular. The lack of depth perception inherent in 2D maps limits understanding and communication of three-dimensional spatial / visual relationships between buildings, vegetation and terrain. GIS maps are therefore unlikely to inculcate a sense of place, belonging, vision or ownership in the local community. Furthermore, GIS mapping is not a suitable method for presenting complex data to non-experts, particularly where public participation, opinion or support is being sought, and where design alternatives need to be considered. Advanced 3D CAD and modelling / rendering systems can address the visualisation shortcomings of GIS; but their application in urban greening is otherwise constrained as a result of their limited database and query / analysis capabilities, restricted capacity for dynamic 'change on the fly' interaction with underlying data, as well as an inability to utilise projected data and georeferenced images from other (GIS) systems.

Eye-level perspectives could be generated by traditional visualisation methods, but their production and usefulness would be inhibited by factors mentioned above – specifically time and cost of production, a lack of association with real-world geographically based data, data feedback for expert analysis and evaluation, difficulty of modification to reflect design changes, fixed viewpoints in respect of perspective drawings and photomontages, and the credibility of both perspective drawings and photomontages.

1.6 Three-Dimensional Photorealistic Visualisation Tools

A potential solution to the respective visualisation and database limitations of GIS and CAD may be found in three-dimensional photorealistic visualisation tools which, historically, have been utilised in urban environmental design (Appleton *et al.* 2001), military simulations (Pérez, Poveda, Sevilla and Gould 1998), the entertainment industry (Ervin and Hasbrouck 2001), and in forestry for the purpose of mitigating the visual impact of tree harvesting (McGaughey 1997) and the visualisation of "alternative forest management practices and the results of growth model projections" (McGaughey 2004 *pers. comm.*). The development of computer technology and expansion of GIS into many disciplines has recently engendered new software applications and techniques capable of directly utilising GIS, CAD and DEM data to generate detailed and realistic viewsheds, largely eliminating the need for time-consuming pre-processing of data on (expensive) customised workstations prior to image generation. Ecological, geomorphological and hydrological parameters may also be dynamically controlled by GIS data attributes (cf. 3.5).

1.7 Research Aim

This dissertation will investigate the potential application of computer generated photorealistic visualisation as a participatory decision support tool for planned urban greening in a RDP housing project.

1.8 Research Objectives

The research objectives of this dissertation are as follows:

1. To create a three-dimensional photorealistic computer model of a low-cost high-density housing settlement including terrain, natural features and indigenous vegetation.
2. To determine the accuracy and credibility of the computer generated photorealistic visualisations.
3. To ascertain the efficacy with which photorealistic visualisations of urban greening could be produced.
4. To assess the potential of computer generated photorealistic visualisation as a participatory decision support tool in urban greening projects.

1.9 Conceptual Framework

This dissertation could be described as creative applied research, and shall directly address computer graphics with respect to the credibility, efficiency and usefulness of the modelling and rendering of three-dimensional photorealistic visualisations for the purpose of urban greening studies. The computer based modelling shall be as physically based as possible, and will incorporate ecological data, digital survey data and eThekwini municipal planning data (Figure 1.5).

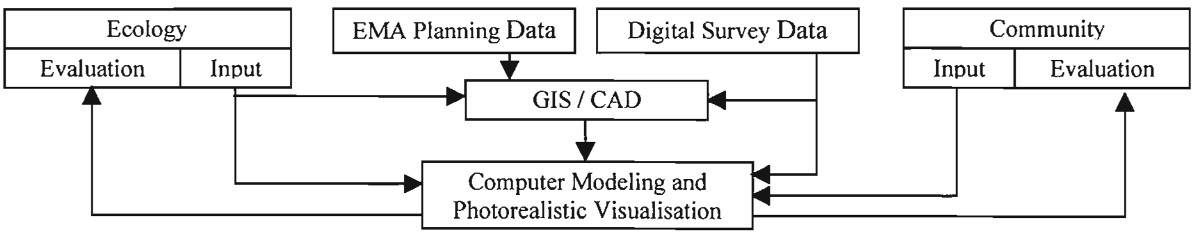


Figure 1.5. Diagrammatic representation of the conceptual framework for the dissertation.

Chapter Two
Urban Greening

The term 'urban greening' derives from Miller's (1988) definition as meaning "an integrated, city-wide approach to the planting, care and management of all vegetation in a city to secure multiple environmental and social benefits for urban dwellers" (Miller 1988 cited in Sorensen *et al.* 1997:1). Sorensen *et al.* (1997) note that urban parks and other vegetated city areas are perceived as being primarily recreational amenities, and suggests that "urban green areas can and should be used in an integrated, holistic manner for many other environmental and social benefits beyond recreational use and aesthetics" (Sorensen *et al.* 1997:1). Sorensen *et al.* (1997) argue that the preservation / restoration of vegetated areas and green spaces can generate numerous social, nutritional, health, economic and ecological benefits (cf. 1.3); and, noting that these benefits are not accidental, suggest that the following considerations are of key importance in the planning, creation / restoration and maintenance of healthy natural resources:

- Setting quantitative targets, and monitoring and evaluation systems. City planners should prioritise projects, establish criteria and set quantitative targets in order to evaluate progress and judge the degree of success. Quantitative targets might include (Sorensen *et al.* 1997):
    - The World Health Organisation's (WHO) recommendation of nine square metres of undeveloped open space for every city inhabitant.
    - The WHO's recommendation that all residents should live within a fifteen minute walk of an open space.
    - Developing a biodiversity index to rank open spaces by the number and percentage composition of indigenous species.
    - An on-going and permanent record of changes in air and water quality.
    - Determining improvements in cost-effectiveness from project to project.
    - Measuring public use and appreciation of open space,
- Maximising use and benefits, and minimising costs. Urban green areas should be designed in order to maximise potential uses – i.e. potential benefits of green spaces (other than recreational and aesthetic) such as improved air and water quality, protection of biodiversity, reduced erosion and flood risks, and agricultural output must also be considered. Sorensen *et al.* (1997) note that this entails a cross-sectoral communication and planning approach that would include water, sewage and transportation engineers, agronomists, businesses, and local communities. There may also be cost benefits as:

    - Urban greening is cheaper to implement in undeveloped areas, and should therefore be planned prior to development.
    - Greening costs may be absorbed into other infrastructure budgets e.g. stormwater retention.
- Maintenance, protection and monitoring of green areas. Sorensen *et al.* (1997) note that maintenance, protection and monitoring of green areas is required throughout the lifespan of the project. Funding and public participation are required to preserve the ecological, social and economic viability of greened areas from soil / vegetation degradation, crime and illegal settlements. A sense of ownership by citizens and local businesses, stemming from participation and consultation in the planning and implementation process (cf. 1.3.1), will assist in the provision of effective maintenance and protection. Local investment is often essential to the maintenance of greened areas and will, in turn, depend on perceptions of legitimate stakeholdership and land tenure security.

2.1 International Case Studies

Discussed within this section are a number of case studies in urban greening, some of which display innovative and multi-purpose usage - thereby exemplifying maximisation of use and benefits, and minimisation of costs, as advocated by Sorensen *et al.* (1997). Other case studies (cf. 2.1.6) demonstrate the negative impacts (flooding, pollution and declining fish stocks) resulting from the degradation or destruction of natural ecosystems. All of the case studies have relevance to cities and communities in developing countries – e.g. water supply catchment protection, wastewater treatment, air quality improvement, climate amelioration and energy savings, flood control and urban agriculture.

2.1.1 Water Supply Catchment Protection

Contaminated water sources and water-borne diseases are a major cause of illness and infant mortality throughout the developing world, including Africa (World Health Organisation 2004). Water catchments in many cities are to be found in the suburban and peri-urban areas surrounding cities, placing water supplies at risk to pollution and siltation. Sorensen *et al.* (1997) note that one of the primary functions of urban forestry has been to control erosion and protect urban watersheds, thereby ensuring clean, regular water supplies. Examples of catchment area protection and erosion control through aforestation include Hong Kong in the 1870s and 1950s (Sorensen *et al.* 1997), Kathmandu, Lima, Panama City, Kingston and Sao Paulo (Braatz 1993 cited in Sorensen *et al.* 1997).

2.1.2 Wastewater Treatment

Sorensen *et al.* (1997) and Sowman and Urquhart (1998) note that there are several safe alternatives to conventional wastewater treatment and disposal including irrigation of urban agriculture and forests, horticultural projects (e.g. export flowers), city landscapes, parks, woodlots and tree farms. Wastewater in Lima, Peru, is partially treated in stabilisation ponds before re-use for crop, fruit tree and woodlot irrigation, as well as drinking water for livestock (Smit, Ratta and Nasr 1996). Bangladeshi farmers harvest approximately one ton of duckweed *(Lemna minor)* per hectare per day, worth US $2,000 a year, from wastewater stabilisation ponds. Duckweed can completely purify wastewater in twenty days, doubles it weight in two to four days, and can yield more protein than soy beans. The Lemna Corporation (USA), which utilises duckweed in its nine wastewater processing facilities, estimates that duckweed processing is 50 to 75 percent cheaper than competing technologies (Smit *et al.* 1996; Sorensen *et al.* 1997).

2.1.3 Air Quality Improvement

Air pollution is removed by trees through interception of particulates and absorption of gaseous pollutants (McPherson 1994). A study by Nowak (1994) shows that in 1991 trees in the city of Chicago removed an estimated 15 metric tons of carbon monoxide, 84 tons of sulpher dioxide, 89 tons of nitrogen dioxide, 191 tons of ozone and 212 tons of particulate matter less than ten microns (PM10). Across a study area of two counties, in-leaf trees removed a daily average of 1.2 metric tons of carbon monoxide, 3.7 tons of sodium dioxide, 4.2 tons of nitrogen dioxide, 10.8 tons of ozone and 8.9 tons of PM10 particulates (Nowak 1994). Studies undertaken in Frankfurt revealed that streets with trees had an air pollution count of 3 000 dirt particles per litre, whereas streets without trees in the same neighborhood had air pollution counts between 10 000 and 20 000 dirt particles per litre (Overtveld 1990 cited in Peck, Callaghan, Kuhn and Bass 1999).

In a 1993 study of air pollution mitigation in a 212 Ha section of Lincoln Park, Chicago, McPherson and Nowak (1993), using the costs of traditional air pollution control measures, estimated the air cleansing value of the trees against two scenarios – the National Ambient Air Quality Standard (NAAQS), and average conditions (Table 2.1). Tree cover was estimated to be 23.2 percent, covering 491.84 m^2. In average conditions the annual air pollution mitigation value was estimated to be approximately $25 000 for the 180 day in-leaf season (mid-April to mid-

October). The study did not include implied values for ozone and carbon dioxide absorption, mitigating effects on hydrology (crown interception) or climate amelioration (McPherson and Nowak 1993).

	NAAQS			Average Conditions	
Pollutants	Unit Value[1] $/lb	Rate Lb/day	Implied Value $/day	Rate lb/day	Implied Value $/day
Particulates	2.09	170	355.30	48	100.32
Nitrogen dioxide	3.40	24	81.60	9	30.60
Sulpher dioxide	0.78	127	99.06	6	4.68
Carbon monoxide	0.45	5.4	2.43	0.5	0.23
Total Implied Value			**538.39**		**135.83**
[1]1990 estimates by the Tellus Institute (California Energy Commission 1992)					

Table 2.1. Estimated implied values for air pollution mitigation by trees in the Lincoln Park study area. Sourced from McPherson and Nowak (1993)

Both Mexico City and Santiago have serious air pollution problems that are, in part, exacerbated by their topographical features. Air pollution levels in Mexico City exceed Mexican safety standards approximately 250 days of the year. These problems are being addressed through an aggressive, multifaceted approach including urban parks programs and reforesting of the city and suburban areas (Sorensen *et al.* 1997).

2.1.4 Climate Amelioration and Energy Savings

Sorensen *et al.* (1997) observe that vegetation can have two distinct benefits on the urban climate, namely:

- Human comfort. Urban centres with large areas of paved surfaces can create what is known as an 'urban heat island' effect, where temperatures at the city centre are consistently several degrees higher than outlying vegetated areas (Sorensen *et al.* 1997). Higher temperatures can also exacerbate airborne pollutants and smog (Akbari 1995; Sorensen *et al.* 1997). Akbari, Davis, Dorsano, Huang and Winnett (1992) have found that tree shade can reduce average air temperatures in buildings by as much as five degrees Celsius. Heisler (1990) has shown that wind speeds, two metres above ground, can decrease by sixty percent in areas of moderate (67 percent) tree cover, which, in turn, can reduce wind chill on buildings in cold environments (McPherson 1994; Peck *et al.* 1999).
- Energy savings. Lowering temperatures in city centres can reduce the need for air conditioning in buildings, leading to energy savings and a reduction in 'brown-outs'. McPherson, Nowak and Rowntree (1994) have shown that increasing the tree cover in

Chicago by ten percent could reduce the energy used for cooling and heating between five and ten percent.

2.1.5 Flood Control

Nowak and Dwyer (2000) note that interception of precipitation by trees, in conjunction with permeable soils, can play an important role in reducing the rate and volume of stormwater runoff, flood damage, erosion, the cost of stormwater drainage and other related water quality problems. Estimated runoff for a severe storm in Dayton, Ohio, indicated that the existing tree canopy (22 percent) reduced runoff by 7 percent, and that an increase in canopy cover to 29 percent would reduce runoff by approximately twelve percent (Sanders 1986 cited in Nowak and Dwyer 2000). A study in the Gwynns Falls watershed in Baltimore indicated that runoff in heavily forested areas could be reduced by 26 percent, and low-flow runoff increased by 13 percent. Total runoff could be reduced by a much as 40 percent where tree cover was over permeable surfaces (Neville 1996 cited in Nowak and Dwyer 2000).

The Director: Parks, Recreation and Beaches Department: Durban (1989) and Sorensen *et al.* (1997) note that the use of wetlands and parks as a part of a city's storm water system is preferable to the traditional engineering approach of canalising and hardening watercourses with concrete. Hardened watercourses, which are expensive to construct, deliver high flow rates downstream, necessitating further engineering intervention. They are also visually and ecologically unacceptable. The location of parks and open green spaces along the floodplain of the watercourse allows for the storage of excess water until such time as the channel is able to cope with the flow. Porous soils help to absorb some of the excess water, and vegetation slows the rate of flow and traps silt. An example of this (Tlaiye and Biller 1994) can be found in Curitiba, Brazil, where the Iguaçu River and a number of its smaller tributaries run through the city. Prior to the 1950s, flooding of the river during the rainy season was uneventful as there was a wide floodplain on which to store the water. Development, however, led to encroachment on the floodplain with consequent flooding threats to life and property. Traditional engineering solutions utilising canalisation simply transferred the problem to other inhabited areas. City authorities resolved to recover the floodplain, and in a cross-sectoral effort expropriated areas along the watercourses and built small dams, leading to the creation of large parks and lakes. New zoning laws were created prohibiting the construction of buildings and streets in areas subject to flooding. These measures, together with interventions on other rivers, have resulted in Curitiba having a high ratio (50 m^2) of green area per city inhabitant, considerable recreational and cultural sites, 140 kilometres of bicycle paths, and in-city forest reserves (Tlaiye and Biller 1994).

2.1.6 Wetlands, Wildlife Habitat and Biodiversity

Bernstein (1994) observes that wetlands, which account for approximately six percent of the global land area, act as "transitional areas between terrestrial and aquatic environments, and are one of the world's most productive natural ecosystems" (Bernstein 1994:12). Services provided by wetlands include flood protection, ground-water recharge, pollution control, wildlife habitat, food-chain support, shoreline stabilisation, food production, natural resources, recreational opportunities and climate amelioration. Wetlands are, however, amongst the most threatened of environmental resources, many having been converted to agriculture / aquaculture, or drained and filled for urban residential / industrial use (Bernstein 1994). The destruction of wetlands threatens biodiversity and diminishes or destroys services such as flood protection, pollution control and food production. Bernstein (1994) cites the following case studies as examples thereof:

- Drainage of wetlands and marshes in the Colombo urban area (Sri Lanka) for development purposes has resulted in serious drainage problems (World Bank 1990 cited in Bernstein 1994).
- Filling of wetlands and fish ponds in Salt Lake City (Calcutta) for housing development has resulted in stormwater flooding in the eastern fringe areas, and threatens the ability of the wetlands to provide wastewater treatment and fish production (Sarkar 1990 cited in Bernstein 1994).
- Filling of swamps in Lagos and Manila has blocked extensive river systems, resulting in periodic flooding of the cities. (Kreimer, Munasinghe and Preece 1992 cited in Bernstein 1994).
- Filling of mangrove swamps and other coastal reclamation activities in Singapore has all but eliminated the coastal prawn ponds and fish traps that once provided good harvests (Chia 1979 cited in Bernstein 1994).
- Drainage of wetlands in the Mediterranean region for land reclamation and malaria prevention has resulted in reduced wildlife habitat, diminished pollution / sedimentation / flooding control, and declining fish stocks (World Bank and European Investment Bank 1990 cited in Bernstein 1994).
- Dumping of waste and sewerage into Lobito's wetlands (Angola) has affected species diversity and reduced the ability of the wetlands to replenish fish stocks. Consequently, food

production for the poorer sections of the population in the Lobito-Benguela metropolitan area, as well as the activities of the local fishing industry, is threatened (Bernstein 1994).

Sorensen *et al.* (1997) observe that wetlands that are integrated into urban greening projects, including those designed for wastewater treatment / floodwater control, can provide habitats necessary for the maintenance and enhancement of biodiversity. An example of preserving and enhancing a wetland for both human use and biological diversity can be found in the 170 acre Arcata Marsh and Wildlife Sanctuary, established in 1981 by the city of Arcata (California) as an alternative to an expensive, and environmentally questionable, state-sponsored regional wastewater treatment plant (City of Arcata 2002; Harvard University Kennedy School of Government 2005). Instead of treating the wastewater as a disposal problem, it is utilised as a resource to revive a nearby degraded wetland area. The nutrient-laden wastewater is conveyed through the wetland over a five-month period, resulting in water of a quality that meets federal water standards. The wetlands have been transformed by the wastewater nutrients into a recreation, education, and research centre that is used by 80 000 visitors per year for picnicking, bird-watching, hiking, jogging, biking, and boating. Sport and commercial fisheries have benefited from the improved water quality, with salmon counts matching those of non-wastewater commercial salmon culture facilities. The wetlands are also utilised for stormwater run-off, which conventional sewerage treatment plants cannot process. The innovative wastewater process which, through the integration of wetland treatment technology, water reuse, urban stream rehabilitation, and freshwater marsh habitat restoration, exemplifies appropriate wastewater reuse and wetlands restoration technology, was awarded the 1987 Ford Foundation's award for 'Innovations in Government' (City of Arcata 2002; Harvard University Kennedy School of Government 2005).

2.1.7 Food and Agricultural Products

The 1996 United Nations Development Programme report *'Urban Agriculture: Food, Jobs and Sustainable Cities'* estimates that approximately 800 million people worldwide are presently engaged in urban agriculture, of which 200 million are producing for market and 150 million are in full time employment (Smit *et al.* 1996). Table 2.2 shows global estimates of household participation, food production and land usage in urban agriculture (Smit 1996b; Smit *et al.* 1996).

Table 2.2. Global estimates of the level of urban agricultural activity (based on 1993 data). Sourced from Smit (1996b); Smit *et al.* (1996)

	Preponderant range of data	Global general significance
Participants:	15% to 70% of families (share of urban families)	About one third of urban families
Production:	10% to 90% of consumption (vegetables, eggs, meat/fish)	About one third of consumption
Land Use:	20% to 60% of urban area (land in agricultural use)	Over one third of urban regions

Agricultural activities may include "beekeeping, fish farming, market gardening, micro-livestock (rabbits, guinea pigs, etc.) and poultry production, flower beds, woodlots for fuel, orchards, harvesting medicinal plants and fodder, managing tree nurseries, field crops and irrigation projects, among others" (Sorensen *et al.* 1997:47). Smit (1996a; 1996b; 1996c) and Smit *et al.* (1996), citing studies by the United Nations University, the United States Department of Agriculture, the International Development Research Centre (IDRC) (Canada), the Council for Tropical and Subtropical Agricultural Research (ATSAF) (Germany), the Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP) (Bangladesh), and the World Vegetable Centre (AVRDC) (Taiwan), note that urban agriculture is a globally expanding phenomenon, growing more rapidly than urban populations and, in some counties, more rapidly than their economies. The 1980 US census found that 30 percent of the dollar value of agricultural production in the United States was produced in urban areas, rising to 40 percent by 1990. In Chinese cities 40 percent of jobs can be categorised as agricultural, and 30 percent of jobs in Maputo, Mozambique, can be similarly classified. Approximately 50 000 Berliners rent land for community gardening, with 14 000 on a waiting list. The number of food producing families in Dar es Salaam rose from 18 percent (in 1968) to 68 percent in 1988; while the number of Moscow families participating in food production rose from 20 percent (in 1970) to 65 percent in 1996. Participation in the Pro Huerta (community agriculture) program in Argentina rose from 50 000 (in 1990) to 550 000 in 1994, and the number of supporting institutions from 100 to 1 100. Many cities, including Shanghai and Bamako, are self-sufficient in vegetable production; and Singapore, which produces approximately 25 percent of its vegetable requirements, is fully self-sufficient in meat production. Hong Kong produces nearly 50 percent of the vegetables, 68 percent of the poultry and 15 percent of the pigs consumed by its population.

Smit *et al.* (1996) and Bakker, Dubbeling, Guendel, Sabel-Koschella and de Zeeuw (1999) observe that the proximity of urban farmers to their markets, coupled with poor transport infrastructure in many developing countries, provides them with a competitive advantage through lower transportation, packaging and storage costs. Farmers are also able to adapt their production for highly perishable items such as meat, milk and vegetables.

Environmental benefits of urban agriculture may include (Smit 1996a; Sorensen *et al.* 1997; Deelstra and Girardet 1999; Quon 1999):

- A reduction in the city's 'ecological footprint', thereby helping to conserve the environment of rural areas.
- Reduced energy and infrastructure required for the transportation of food to cities.
- A reduction of solid waste as some of this may be used for feeding livestock.
- The reclamation of unused and degraded lands – particularly derelict industrial 'brownlands'.
- Any number of the urban greening benefits discussed in this section and in Section 1.3 (Benefits of Urban Greening) - i.e. climate amelioration, air pollution reduction, flood control, slope stabilisation and erosion control, wastewater treatment, wildlife and biodiversity and aesthetics.

2.2 Urban Greening in South Africa: National Legislation and Policy

Grobbelaar and Croucamp (1999) observe that urban greening programmes, including urban agriculture and urban forestry, must consider (and comply with) the legislation and policies of the institutions they have to work through and with. Strong institutional support (national, regional and municipal) is essential to the provision of useful and sustainable urban greening. At the time of their inception many laws, regulations and city ordinances, particularly those pertaining to zoning, did not consider the creation / preservation of open green areas, or the protection of sensitive areas such as flood plains, steep slopes, watersheds or wetlands (Grobbelaar and Croucamp 1999; Quon 1999). Similarly health regulations, which may have been written decades ago, are not necessarily appropriate to food crop irrigation with wastewater. Certain aspects of urban greening, such as urban agriculture, cultivated medicinal plant production and urban forestry are relatively new in South Africa, and may require changes in zoning and land tenure policies if they are not to be discouraged by the absence of regulatory support. Institutional capacity and support in the form of budgets and technical expertise will also need to be considered. Key features of South African legislation and policy pertaining to urban greening in particular, and the environment in general, are listed in Table 2.3 (Sowman and Urquhart 1998; Spies 1998; Grobbelaar and Croucamp 1999; Mathiane 2001; Verster, Du Plessis, Schloms and Fuggle 2003).

Table 2.3. South African legislation and policy pertaining to urban greening. Adapted from Sowman and Urquhart (1998), Spies (1998), Grobbelaar and Croucamp (1999), Mathiane (2001), Verster *et al.* (2003).

Policy / Legislation	Key Features
Conservation Of Agricultural Resources Act, 1983 (Conservation of Agricultural Resources Act (43 of 1983) 1983)	• Provides for the conservation of natural agricultural resources through: o The maintenance of production potential. o The prevention of erosion. o The prevention of destruction of water resources. o The protection of indigenous vegetation. o The combating of weeds and invasive plants. • The minister may establish, and appoint members to, national and regional conservation committees. • The minister may prescribe control measures relation to: o The cultivation of virgin soil. o The utilisation and protection of cultivated land. o The prevention of waterlogging or salinisation of land. o The grazing capacity of grasslands. o The prevention and control of grassland fires, and protection of burned grasslands. o The restoration of eroded, disturbed or denuded land. • Obliges landowners and land users to maintain soil conservation works. • Provides for penalties in the event of non-compliance with regulations.
Environment Conservation Act, 1989 (Environment Conservation Act (73 of 1989) 1989)	• Defines 'environment' as "the aggregate of surrounding objects, conditions and influences that influence the life and habits of man or any other organism or collection of organisms". • Empowers the minister to determine policy in respect of: o The protection of ecological processes, natural systems, natural beauty as well as the preservation of biotic diversity. o The promotion of sustainable utilisation of species and ecosystems, and the effective application and re-use of natural resources. o The protection of the environment against disturbance, deterioration, defacement, poisoning, pollution or destruction as a result of man-made structures, installations, processes or products or human activities. o The establishment and maintenance of acceptable human living environments in accordance with the environmental values and environmental needs of communities. o The promotion of the effective management of cultural resources in order to ensure the protection and responsible use thereof. o The promotion of environmental education in order to establish an environmentally literate community with a sustainable way of life. o The execution and coordination of integrated environmental monitoring programmes. • Empowers the minister to identify activities that will probably have a detrimental effect on the environment, and prohibits their undertaking without written authorisation. • Empowers the minister or a competent authority to make regulations in regard to environmental impact reports. • Empowers a competent authority to declare areas of limited development. • Promotes opportunities for public participation, and appeals against decisions. • Provides for penalties in the event of non-compliance with regulations.

Policy / Legislation	Key Features
The Reconstruction and Development Programme: A Policy Framework, 1994. (African National Congress 1994)	• Government must work towards: o Safe and healthy living and working environments. o Equitable access to natural resources. o A participatory decision-making process in respect of environmental issues, thereby empowering communities to manage their natural environment.
White Paper on Housing Policy and Strategy for South Africa, 1994. (Department of Housing 1994)	• Policies, administrative practices and laws should uphold sustainable land delivery through the promotion of environmental sustainability, and deal sensitively and responsibly with the impact of land development on the environment. • Recognises that the environment within which a house is situated is as important as the house itself in satisfying the needs and requirements of the occupants. • Supports a people-centred development process that encourages community initiatives in respect of the development of their physical environment.
Development Facilitation Act, 1995. (Development Facilitation Act (67 of 1995) 1995)	• Establishes general principles for development planning, including environmentally sustainable land development practices and processes. • Policy, administrative practice and laws relating to land development should promote sustained protection of the environment. • Holds environmental consultants responsible and liable for the accuracy of the prescribed facts in land development applications. • Authorises development tribunals to impose conditions in respect of the environment or environmental evaluations.
Urban Development Strategy, 1995. (Ministry in the Office of the President 1995)	• Urban settlements must foster the long-term sustainability of the urban environment. • Explicitly supports Agenda 21, open space planning, research and environmental education, pollution control and waste management. • Monitoring and management of the environmental impacts of new developments is required. Corridors and open spaces necessary for biodiversity and human mental health must form an integral part of environmental planning • Promotes balance between built environment and open space, and consumption needs / renewable resources. • The Department of Environmental Affairs and Tourism is tasked with the promotion of integrated open space planning and the productive use of open space; including the compilation of guidelines and policy on the role of urban agriculture in improving nutrition, creating jobs, and recycling waste. • The overall quality of the urban environment may be improved by integrating environmental concerns within development planning and urban management practices. Environmental management should be integrated into local authority functions.
White Paper on Agriculture, 1995. (Department of Agriculture 1995)	• Urban agriculture broadens the economic and social options of rural and urban people. Improvement in food safety standards, as well as the variety and quantity of agricultural products, leads to an improvement in consumer satisfaction and encourages the processing of products within the urban environment. • Government should support a wide range of production systems and practices, including urban food gardens, in order to improve household food security.

Policy / Legislation	Key Features

Constitution of the Republic of South Africa, 1996. (Constitution of the Republic of South Africa 1996)	• Everyone has a right to:
	  o An environment that is not harmful to their health or well-being.
	  o Environmental protection that secures ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.
	• Local government is responsible for promoting a safe and healthy environment.

White Paper on Sustainable Forest Development in South Africa, 1996. (Ministry of Water Affairs and Forestry 1996)	• Notes the severe degradation of woodlands and destruction of natural forests as a result of the demand for fuelwood. • Recognises that natural forests and woodlands play a vital role in the household economies of many disadvantaged communities. • Notes that community forestry can contribute to improving the environment, enriching the resources, and creating income opportunities. • Encourages people to plant trees indigenous trees in rural and urban areas so as to build the local resource base and improve the living environment. • Government will support community forestry with relevant information, research and technologies. The Department of Water Affairs and Forestry will, where necessary and within its means, financially support community forestry. • A community forestry strategy will form part of the national forestry strategy as well as local development plans. • Local communities will determine the provision of services in their areas, investment in infrastructure, and local economic development. Government will follow the principle of people-driven development in community forestry.
Local Government Transition Act, Second Amendment, 1996. (Local Government Transition Act Second Amendment Act (97 of 1996) 1996)	• District Councils are responsible for the preparation of Integrated Development Plans (IDP) subject to the approval of local and rural councils. • Confers powers and duties in respect of the management, control and coordination of environmental affairs to metropolitan councils.
Urban Development Framework, 1997. (Department of Housing 1997)	• Environmental management must form an integral part of the urban planning and development process. • Green belts, open spaces and parks must form an integral part of environmental planning. • Environmental impacts of new developments must be monitored and managed according to the legal requirements of Integrated Environmental Management (IEM).
White Paper on Local Government, 1998. (Department of Provincial Affairs and Constitutional Development 1998)	• Sustainable and livable settlements depend on a number of coordinated services and regulations, including environmental management. • Metropolitan Councils are responsible for ensuring that their Integrated Development Plans facilitate the kind of urban environment in which citizens wish to live. • District Councils are responsible for developing IDPs, subject to the approval of municipalities within the district. • Municipalities can enhance environmental sustainability by including environmental issues in their planning processes.

Policy / Legislation	Key Features

National Environmental Management Act, 1998.
(National Environmental Management Act (107 of 1998) 1998)
	• Everyone has a right to an environment not harmful to health or well-being.
	• The State must respect, protect, promote and fulfill the social, economic and environmental rights of everyone.
	• Ensure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.
	• Notes that sustainable development requires:
	   o The integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions.
	   o That the disturbance of ecosystems and loss of biological diversity is avoided, or, where they cannot be altogether avoided, is minimised and remedied.
	   o That pollution and degradation of the environment is avoided, or, where they cannot be altogether avoided, is minimised and remedied.
	   o That the disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimised and remedied.
	   o That negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, is minimised and remedied.
	• Requires adequate and appropriate opportunity for public participation in decisions that may affect the environment.
	• Promotes the integration of the principles of environmental management
	• Municipalities and provincial government must ensure that environmental management and implementation is part of their IDP / Land Development Objectives (LDO).

National Water Act, 1998.
(National Water Act (36 of 1998) 1998)
	• Recognises the necessity for the protection of the quality of water resources, and mandates:
	   o The regulation or prohibition of any activity in order to protect a water resource or instream or riparian habitat.
	   o The conservation and protection of water resources including instream and riparian habitats, aquatic and associated ecosystems and their biological diversity.
	   o Catchment management agencies to recover the costs of rehabilitation from the responsible landowner / user in the case of pollution or watercourse disturbance.
	   o The establishment of national water resources monitoring systems. Monitoring includes:
	      ▪ The quality of water resources, including the character and condition of instream and riparian habitats, and the characteristics, condition and distribution of aquatic biota.
	      ▪ The use of water resources.
	      ▪ The health of aquatic ecosystems.
	      ▪ The rehabilitation of water resources.

Department Of Water Affairs and Forestry. Environmental Implementation and Management Plan, 2001. (Department of Water Affairs and Forestry 2001)	• Recognises a responsibility for urban environments and facilitating the incorporation of urban forestry / greening principles and practices in local government planning. • Provides for a community forestry service to facilitate development and thereby: o Contribute to social and economic upliftment by promoting the responsible and sustainable utilisation of South Africa's natural resources, and encouraging tree centred development in the country.

<table>
<tr><th>Policy / Legislation</th><th>Key Features</th></tr>
<tr><td></td><td>
<ul style="list-style-type:circle">
Address social deprivation, impoverishment, deforestation and land degradation in rural and urban communities through community forestry development.

Acknowledges the need for assistance and support of local government in the development of the urban forestry aspects of urban greening; including the co-development of urban greening strategies with municipalities, and the provision of trees and seedlings to urban communities through local government. The intention is to support the development of sustainable livelihoods in urban areas, and to improve the urban environment.
Commits the Department Of Water Affairs and Forestry to the establishment of a national Urban Greening Strategy.
</td></tr>
<tr><td>National Environment Management: Air Quality Act, 2004.
(National Environment Management: Air Quality Act (39 of 2004) 2004)</td><td>

Recognises that air pollution, ozone-depleting substances and greenhouse gases have deleterious effects on the environment, and mandates:

Greenhouse gas emission measurement and reporting.
The prevention of air pollution and ecological degradation.
The State to protect and enhance the quality of air.

Mining management must, within a period of five years prior to cessation of mining operations, submit a plan for:

The rehabilitation of the mining area.
The prevention of pollution of the atmosphere by dust.

</td></tr>
<tr><td>National Environmental Management: Biodiversity Act, 2004.
(National Environmental Management: Biodiversity Act (10 of 2004) 2004)</td><td>

Requires that the state manage, conserve and sustain South Africa's biodiversity and genetic resources.
Provides, within the framework of the National Environmental Management Act, for:

The management and conservation of biological diversity.
The sustainable use of indigenous biological resources.
Fair and equitable sharing of benefits arising from bioprospecting.
The implementation of ratified international agreements relating to biodiversity.
The provision of co-operative governance in biodiversity management.
The establishment of a South African National Biodiversity Institute.

Duties of the South African National Biodiversity Institute include:

Monitoring and reporting on:

The status of biodiversity in South Africa.
The conservation status of all listed threatened or protected species and ecosystems.
The status of all listed invasive species.

The collection, generation, processing, coordination and dissemination of information about biodiversity, the sustainable use of indigenous biological resources, and the establishment and maintenance of relevant databases.

The South African National Biodiversity Institute may:

Undertake and promote research on indigenous biodiversity and the sustainable use of indigenous biological resources.
Coordinate and implement programmes for:

The rehabilitation of ecosystems.
The prevention, control or eradication of listed invasive species.

Coordinate programmes to involve civil society in:

The conservation and sustainable use of indigenous biological resources.
The rehabilitation of ecosystems.

</td></tr>
</table>

Policy / Legislation	Key Features
	• Requires the minister to prepare, publish, adopt, monitor and review a national biodiversity framework. The framework must provide for an integrated, coordinated and uniform approach to biodiversity management by the state, NGOs, private sector, local communities, other stakeholders and the public. • Empowers the minister to determine a geographic region as a bioregion, and publish a plan for the management of biodiversity in that region. • Requires the minister to list ecosystems and species that are threatened and require protection. • Allows any person, organisation or state department to submit a biodiversity management plan for ecosystems or indigenous species. • Seeks to prevent the unauthorized introduction and spread of alien and invasive species to ecosystems and habitats where they do not naturally occur; and to eradicate alien and invasive species where they may harm ecosystems. • Requires the minister to publish a list of invasive species. • Requires landowners to take steps to control and eradicate listed invasive species.
National Environmental Management Second Amendment Act, 2004. (National Environmental Management Second Amendment Act (56B of 2003) 2004)	• Empowers the minister to identify: o Activities that may not commence without environmental authorisation. o Geographical areas, based on environmental attributes, within which specified activities may not commence without environmental authorisation. o Existing activities (individual or generic) for which environmental authorisation must be applied. • Procedures for the investigation, assessment and communication of the potential impacts of activities must ensure: o An investigation of the environment likely to be significantly affected by the proposed activity. o An investigation of the potential impact of the proposed activity and its alternatives, and an assessment of the significance thereof. o An investigation of measures to mitigate adverse impacts, including the 'no go' option. o The provision of public information and reasonable opportunity for public participation. o That gaps in knowledge, adequacy of predictive methods and underlying assumptions, and other uncertainties are reported. o Investigation and formulation of arrangements for the monitoring and management of impacts, and assessment of their effectiveness after implementation. • Every environmental authorisation must ensure that provision is made for the ongoing monitoring and management of the environmental impacts of the proposed activity throughout that activity's life cycle.

From the above legislation and policy it would seem that there is a level of regulatory commitment and support for:

- Ecologically sustainable land development practices and processes.
- Corridors, green belts, open spaces and parks as an integral part of environmental planning.

- Ecologically sustainable development and use of natural resources.
- Protection of natural resources, including air, water, soil and natural vegetation.
- Building the local resource base and improving the living environment.
- Monitoring and management of the environmental impacts of new developments.
- Avoidance of disturbance of ecosystems and loss of biological diversity or, where disturbance cannot be avoided, minimisation and remediation thereof.
- Sustainable and livable settlements.
- Improved household food security through urban food gardens.
- The development of urban greening strategies between national government departments and municipalities.

Furthermore, the above legislation and policy lends supports for:

- People-centred development processes that encourage and support community initiatives and participatory decision-making in respect of environmental issues and the development of their physical environment.
- The integration of environmental concerns within development planning and urban management practices, and the integration of environmental management into local authority functions.
- The inclusion of environmental management and implementation by municipalities and provincial government into their Integrated Development Plans and Land Development Objectives.
- Responsibility for the promotion of a safe and healthy environment resting with local government.
- Local Agenda 21.

Kidd (1997), however, notes that responsibility for administering environmental legislation is distributed amongst a large number of national and local government departments, leading to fragmented administration of legislation. The consequences of administrative fragmentation may include:

- Economic inefficiencies, as well as duplication of functions.
- A lack of clarity, or confusion, in respect of responsible authorities, leading to inaction.
- Discouraging a holistic view of the environment and environmental problems.

2.3 Local Government and Agenda 21

South Africa is a signatory to the *'Rio Declaration On Environment And Development'* (United Nations Department of Economic and Social Affairs 2000) in which the principles of global sustainable development are outlined; and which emphasises the need for cooperation between local government and communities in planning and implementing local sustainable development. Section 28.1 of Agenda 21 *'Local Authorities' Initiatives In Support Of Agenda 21'* is of relevance to local government - particularly municipalities - in that it states "because so many of the problems and solutions being addressed by Agenda 21 have their roots in local activities, the participation and cooperation of local authorities will be a determining factor in fulfilling its objectives. Local authorities construct, operate and maintain economic, social and environmental infrastructure, oversee planning processes, establish local environmental policies and regulations, and assist in implementing national and subnational environmental policies. As the level of governance closest to the people, they play a vital role in educating, mobilizing and responding to the public to promote sustainable development" (United Nations Department of Economic and Social Affairs 2003:273).

And in Section 23.2 of Agenda 21 *'Strengthening The Role Of Major Groups: Preamble'*...
"One of the fundamental prerequisites for the achievement of sustainable development is broad public participation in decision-making. Furthermore, in the more specific context of environment and development, the need for new forms of participation has emerged. This includes the need of individuals, groups and organizations to participate in environmental impact assessment procedures and to know about and participate in decisions, particularly those which potentially affect the communities in which they live and work. Individuals, groups and organizations should have access to information relevant to environment and development held by national authorities, including information on products and activities that have or are likely to have a significant impact on the environment, and information on environmental protection measures" (United Nations Department of Economic and Social Affairs 2003:259).

And in Section 28.3 of Agenda 21 *'Local Authorities' Initiatives In Support Of Agenda 21'* ...
"Each local authority should enter into a dialogue with its citizens, local organizations and private enterprises and adopt 'a local Agenda 21'. Through consultation and consensus-building, local authorities would learn from citizens and from local, civic, community, business and industrial organizations and acquire the information needed for formulating the best strategies" (United Nations Department of Economic and Social Affairs 2003:273). Section 28.3 of Agenda 21 proposes that by 1996 local authorities in each country should have consulted with communities

with a view to establishing their own Local Agenda 21 (United Nations Department of Economic and Social Affairs 2003).

Many of the environmental problems found in the pre and post-apartheid low-cost high-density housing settlements (cf. 1.2.1) have localised origins; and policy, planning and implementation of measures, including urban greening, to address these problems will require the cooperation and support of local government and municipalities. Local Agenda 21 would, therefore, seem to be an ideal forum to address public participation in the planning and implementation of urban greening, the importance of which has been stressed by Sorensen *et al.* (1997), Kuchelmeister (1998), Sowman and Urquhart (1998), Grobbelaar and Croucamp (1999), Addo *et al.* (2000a) and Giyose and Bedford (2001).

In 1994, Durban became the first South African city to adopt Local Agenda 21 (LA 21) (Roberts and Diederichs 2002). Achievements of Durban's LA 21 programme between 1994 and 2001 include the preparation of Durban's first State of the Environment and Development Report (SOE&DR); the Durban Metropolitan Environmental Policy Initiative (DMEPI); a Strategic Environmental Assessment (SEA) for the Durban South Basin; the design of the Durban Metropolitan Open Space System (D'MOSS) framework plan; community open space development projects, an environmental education and outreach initiative; Durban's submission to the Cities Environmental Reports on the Internet (CEROI) Project; a review of environmental performance in local government; and the preparation of a Unicity Environmental Services Management Plan (UESMP) (Roberts and Diederichs 2002).

Durban's LA 21 programme has encountered numerous obstacles including limited human and financial resources within the Environmental Management Branch (who are the sole custodians); marginalisation of the LA21 programme resulting from a perceived association with 'green' issues; opposition from other local government departments, line functions and political decision makers to the Environmental Management Branch in general, and D'MOSS in particular; the fragmented and *ad hoc* approach to public participation and conflict resolution prevalent in Durban; poor planning, communication and management in the community open space projects (cf. 2.6.2); a lack of environmental education within the general public resulting in difficulties in understanding environmental and sustainable development concepts; and the failure of the Awareness and Preparedness for Emergencies at the Local Level (APELL) project in the Durban South Basin, largely resulting from local politics and the non-cooperation of self-appointed 'gatekeeper' organisations (Roberts and Diederichs 2002).

Spies (1998) and Mathiane (2001) observe that local government, particularly municipalities, are the key agencies responsible for facilitating and implementing local Agenda 21 objectives, including urban greening, through their IDPs and LDOs. Kuchelmeister (1998), Sowman and Urquhart (1998), Spies (1998), Grobbelaar and Croucamp (1999) and Mathiane (2001) note the following constraints on local government and municipalities with respect to urban greening:

- Many local government departments lack the capacity to plan, coordinate, implement, manage and monitor urban greening programmes.
- Not all of the relevant legislation has been adopted in some provinces (Mathiane 2001).
- Urban greening is still perceived as being a 'green issue' and consequently receives a much lower priority from local government than 'brown issues' such as housing, sanitation, potable water, etc. Sorensen *et al.* (1997) and Kuchelmeister (1998) note that the socio-economic value of urban greening is not easy to measure and, given that little data exists for cities in developing countries, is often not factored into the budgetary process.
- There are a number of urban greening organisations that have yet to be drawn into the local government planning process.
- Some local government authorities use consultants to prepare their IDPs and LDOs, and the level of community participation therein is uncertain.
- There is a lack of coordination in respect of planning, defining of roles, and responsibilities amongst the various levels of government. Spies (1998) notes that where planning exists it is often not integrated with that of other urban greening organisations. This may have important implications – e.g. the Department of Water Affairs and Forestry will only provide support for urban greening where (Department of Water Affairs and Forestry Undated):
  - There is full community participation.
  - Local government has a clear and integrated strategy.
  - There is partnership with all urban greening agencies.
- National and local legislation / policy has yet to address:
  - Land security with respect to permanent / temporary tenure.
  - Gender issues, and the right of women to farm and provide for their families.

South African President, Thabo Mbeki, recently noted that the results from a government audit on municipalities revealed that 126 of the 284 municipalities in South Africa "had little or no capacity to service their areas" and that "they needed urgent support to improve their delivery mechanism" (Adams 2004:5). Mbeki also stated that "over the last ten years ... a very strong comprehensive policy base and legal base had been established and that the task we face is implementation of those policies and ensuring that those policies produce the outcomes visualised" (Adams 2004:5).

2.4 Open Space and Biodiversity in the eThekwini Municipal Area

Unless otherwise cited all information in this section is derived from the *'Durban Environmental Services Management Plan'* (Roberts and Boon 2002).

The city of Durban is located within the eThekwini Municipality, on the eastern seaboard of southern Africa, and covers an area of 2 297 km^2. The topography of the municipal area is diverse, ranging from steep escarpments and rolling hills in the west, to a relatively flat coastal plain in the east. The area contains eighteen major river catchments and ninety-eight kilometres of coastline. As a result of its location and varied landscape the biodiversity of eThekwini Municipal Area (EMA) comprises a wide variety of terrestrial, freshwater, estuarine and marine ecosystems, and associated flora, fauna and genetic resources, originating from:

- The northern Maputaland tropical complex.
- The warm temperate Pondoland complex to the southwest.
- A small indigenous transitional complex.

The 1989 report *'D'MOSS. Durban Metropolitan Open Space System'* (Director: Parks, Recreation and Beaches Department: Durban 1989) describes the area presently occupied by the city of Durban, in 1839, as a large and beautiful tropical lagoon, bordered with mangrove forests. Extensive wetlands in the low-lying areas around the bay were inhabited by a wide variety of bird and aquatic life. Large freshwater lakes, populated by hippopotamus and crocodiles, were to be found north of the Umgeni River, as well as to the south at the Umlaas River mouth (Director: Parks, Recreation and Beaches Department: Durban 1989). The surrounding hills were dominated by grasslands and coastal forest (Acocks 1988).

Wood from local trees was utilised for building, wagons, coaches, furniture, ships and railway sleepers; resulting, in time, in the disappearance of many of the forests. The post World War I and Great Depression years saw the eastern wetland (Kingsmead) and the Umlaas River mouth wetlands destroyed by levelling the natural sand dunes into the wetlands. The western wetland (Warwick Avenue and Greyville Racecourse) was filled with town waste, and the freshwater lakes north of the Umgeni River were drained and turned into farmland. By 1932 intensive market gardening had denuded many of the areas around the city boundary as far as Westville (Appendix 2: Figure 1). The post-World War II economic boom resulted in the abandonment of many of the farms and the recovery of forests and grasslands, of which Virginia Bush is the best known example. The Group Areas Act (36 of 1966) resulted in further areas such as Newlands, Durban North and Cato Manor being largely vacated. Newlands and (until the 1970s) Durban North made good progress towards a recovery of the indigenous vegetation, but Cato Manor, which had been cut off from its genetic material sources, was invaded by alien plants, and was largely unable to recover (Director: Parks, Recreation and Beaches Department: Durban 1989; Pillay and Webster 1997).

2.4.1 Benefits of Open Spaces

Urban dwellers benefit from a range of environmental services and benefits derived from open spaces, and the fauna / flora that they support (Table 2.4). These benefits may be categorised as:

- **Direct Benefits.** Resources that are directly utilised or consumed - e.g. water, fuelwood.
- **Indirect Benefits.** Resources that provide benefits or cost savings - e.g. wetlands reduce flooding, trees provide shade.
- **Option Benefits.** Resources to be protected for future use - e.g. attractive landscapes or coastlines for tourism.
- **Existence Benefits**. Resources that invoke well-being, sense of place, mental health.

Table 2.4. Environmental services and benefits that can be derived from open spaces. Adapted from Roberts and Boon (2002)

Service	Benefits
Gas Regulation	Carbon sequestration; oxygen production;
Climatic Regulation	Urban heat amelioration; noise and wind reduction.
Disturbance Regulation	Flood control; drought recovery; refuge from severe environmental events.
Water Regulation	Capture and gradual release of water by vegetation
Water Supply	Water storage – rivers, watersheds, reservoirs.
Erosion Control	Prevention of soil loss by vegetation cover; soil entrapment in wetlands.
Soil Formation	Accumulation of organic materials.
Nutrient Cycling	Capture, storage and processing of nutrients.
Waste Treatment	Removal and breakdown of excess nutrients and air pollution.
Pollination	Pollination of plants by insects enables plant reproduction.
Biological Control	Predator control of rodents and insects.
Refugia	Resident and migratory habitats – e.g. fish nurseries.
Food Production	Primary food production – e.g. fish; crops; fruit.
Raw Materials	Fuel; building materials; craftwork materials.
Genetic Resources	Unique biological materials – e.g. genes; medicinal plants.
Recreation	Eco-tourism; fishing; swimming; bird watching; relaxation.
Cultural	Aesthetic; environmental education; research opportunities; sense of place.

There is clearly considerable commonality between the environmental services and benefits derived from open spaces, as listed above in Table 2.4, and those derived from urban greening (cf. 1.3).

2.4.2 Design and Planning of Open Space Systems

Roberts and Boon (2002) observe that a sustainable supply of environmental services and benefits is dependent on a functional open space system, which is best achieved by ensuring:

- As many functional ecosystems as possible.
- The widest range of open space types (urban and natural).
- Physical links (corridors) between open spaces / river catchments and important external sources of biological diversity (e.g. the Pondoland / Maputaland centres of plant diversity and the Eastern Cape marine biodiversity centre), in order to ensure a flow of genetic material, energy, water and nutrition; and thereby prevent local species extinction.

Roberts and Boon (2002) note that key elements of eThekwini's open space system comprise:

- Large relatively undisturbed areas and reserves.
- River corridors, and the land / vegetation adjacent to the riparian zones.
- Coastal areas, including estuaries and the seashore.

Open spaces in the eThekwini Municipal Area (EMA) are planned and managed according to the river catchment within which they fall (Appendix 2: Figure 2). Catchment planning provides a means to understand and quantify both the lateral and longitudinal impacts of urban development on the adjacent natural environment. Catchments have different environmental service and benefit capacities, and require targeted management strategies in order to balance the supply and demand of services and benefits. Therefore it is important that the selection process of trees and vegetation for any urban greening project which intends to promote and strengthen open space, and associated flora, fauna and genetic resources, in the EMA, must take into consideration the ecological nature of the natural spaces with which they connect, as well as the number of species utilised, in order to avoid either low biodiversity value or low ecological functionality (Nichols *et al.* 2000).

2.4.3 Valuation of Open Spaces

Roberts and Boon (2002) suggest that the services and benefits derived from open spaces are often intangible, and not usually valued in monetary terms. Consequently, the value of urban open spaces is often not well understood by urban dwellers. Freund (2001) notes that following the post 1994 democratisation of the Durban City Council 'green' issues, such as the preservation of natural open spaces, have given way to basic health, housing and sanitation concerns ('brown issues') of the newly enfranchised, and largely poor, constituents. Roberts and Boon (2002) observe that in the course of the 1990s, natural open spaces, which had previously been valued from an ecological and conservation perspective, have had to be re-conceptualised as assets with social, economic and ecological worth; and argue that protection of the open space system ensures the supply of environmental services and benefits critical to meeting the needs of the city's communities. The services and benefits provided by Durban's open spaces have therefore been quantified using resource economics (Appendix 2: Figure 3) (Roberts and Boon 2002; Roberts, Boon, Croucamp and Mander 2005). Roberts and Boon (2002) state that the replacement value of services and benefits supplied by Durban's open spaces in 2002 was worth 3.1 billion Rand per annum, which excludes the value of tourism to Durban, estimated to be worth 3.3 billion Rand in 2001. Roberts and Diederichs (2002:ix) however sound a note of caution "regarding the use of resource economics as a decision-support tool", noting that many of the services and benefits derived from open spaces are intangible, difficult to quantify in economic terms, and considered by many to be irreplaceable or priceless.

2.4.4 Development of the Durban Metropolitan Open Space System (D'MOSS)

2.4.4.1 Phase 1. The Metropolitan Open Space System (MOSS). 1981.

The first attempt at planning a city-wide open space system was made by the Metropolitan Open Space System committee of the Wildlife Society. It was essentially a conservation based system, consisting of conservation areas and trails across the then Durban metropolitan area (Director: Parks, Recreation and Beaches Department: Durban 1989); and was authorised by the Durban City Council in 1982. The plan was further detailed and developed in the 1987 report *'Towards A Plan For the Durban Metropolitan Open Space System'* (Nicolson 1987), which was commissioned by the Natal Town and Regional Planning Commission.

2.4.4.2 Phase 2. The Durban Metropolitan Open Space System. 1989

The Durban Metropolitan Open Space System (D'MOSS) report was produced by the Director: Parks, Recreation and Beaches Department: Durban (1989) in conjunction with the University of Natal. The report, which built holistically on the earlier work of the Wildlife Society, included:

- A network of nine parks linked by corridors – particularly along river valleys (Figure 2.1).
- Active and passive recreational areas, sporting facilities and picnic sites.
- Stormwater management and flood control through the use of natural river features.

- Recognition of the importance of environmental education.
- Recognition of the importance of community involvement in open space systems.
- Recognition of the benefits of open space systems including climatic moderation and air, water and noise pollution control.

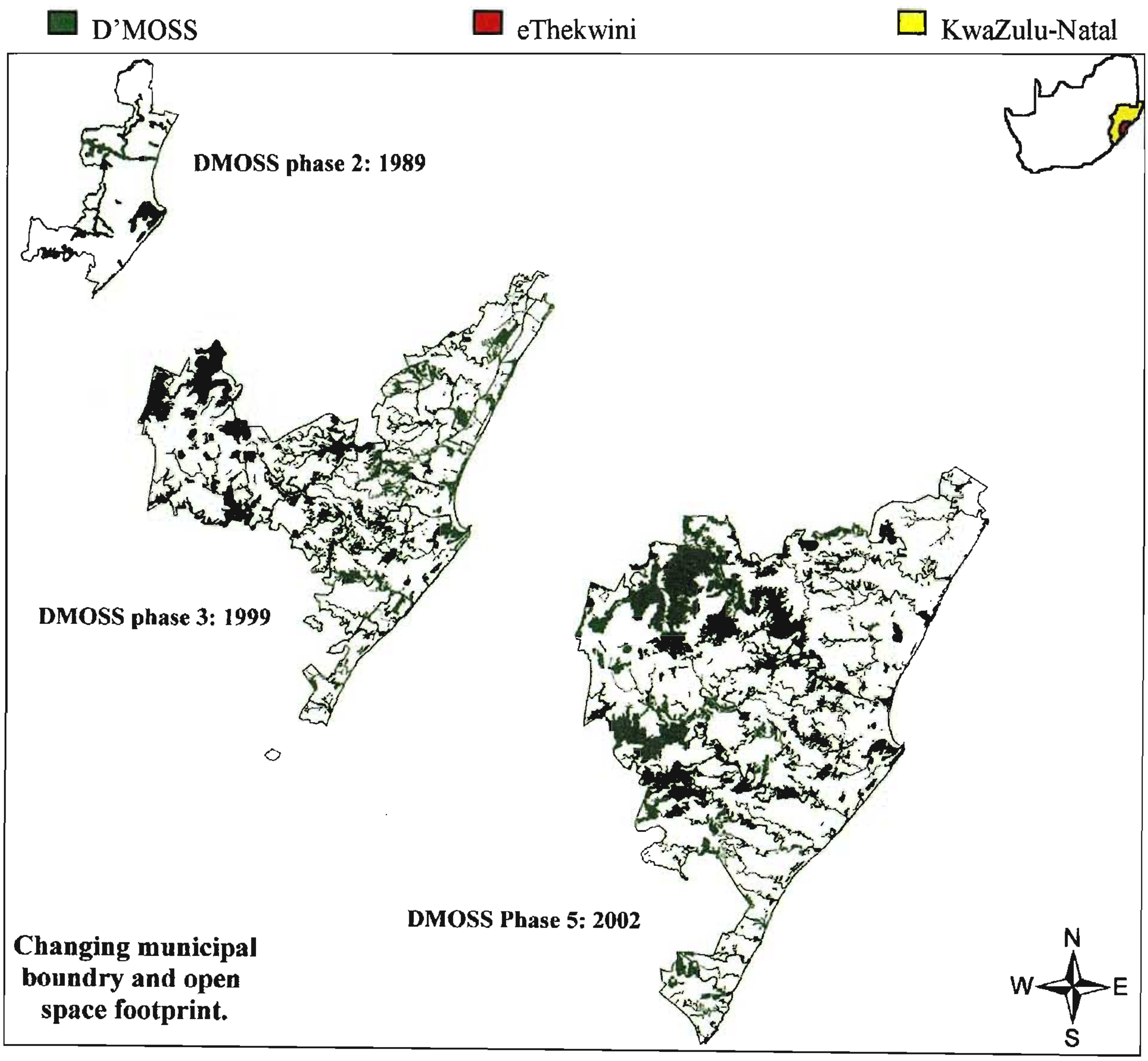


Figure 2.1. Changing eThekwini municipal boundary, and open space footprint. Scale = 1:1 000 000. Adapted from Roberts and Boon (2002).

2.4.4.3 Phase 3. D'MOSS Reloaded. 1999

Changing municipal boundaries, coupled with the need to respond to the democratisation process of the 1990s as well as Local Agenda 21, required that D'MOSS be re-conceptualised as an asset with social, economic and ecological worth (cf. 2.4.3). In order to facilitate the necessary data collection and management D'MOSS was digitally mapped using GIS (Figure 2.1). The calculated spatial footprint of D'MOSS at 45 090 Ha included some thirty three percent of the metropolitan area, of which fifty two percent was considered undevelopable because of steepness, flooding, instability, or other legal constraints (Roberts and Boon 2002).

2.4.4.4 Phase 4. The eThekwini Environmental Services Management Plan. 2001

Completion of the municipal demarcation process in 2000 resulted in a sixty seven percent increase in the size of the municipal area, necessitating the re-mapping of the open space system. This process resulted in a footprint of 123 000 Ha, which comprised some fifty four percent of the EMA. Development pressures required that this be reduced which, through the exclusion of agricultural land and rural settlements, resulted in a footprint of 76 000 Ha. Sixty two thousand hectares of this land is considered critical to the ecological viability of the open space system, and 14 000 Ha provides added value. Parallel to the mapping process was a review of national and international best management practices, which resulted in a range of potential management tools e.g. land development rights transfer, property rates rebates, environmental charges, zoning regulations, incentivising landowners, and land acquisition. The eThekwini Environmental Services Management Plan (EESMP) was approved by the eThekwini City Council in March 2003 as the official open space planning and management policy (Roberts and Boon 2002).

2.4.4.5 Phase 5. EESMP – Securing the Open Space Asset. 2002

In the course of phase 4 it became clear that improved aerial photography, as well as the changed ecological status of many areas, would require the remapping of the open space system. In order to accommodate land development needs the spatial footprint was reduced from 76 000 Ha to 63 000 Ha (Figure 2.1). In the course of remapping the open space system forty-four key areas were identified and ranked in respect of developmental threats. It was also discovered that only six of the thirty-six nature reserves within the EMA were protected by provincial legislation, and specific recommendations were developed for each reserve.

2.4.5 Open Space Management

Roberts and Boon (2002) observe that the eThekwini municipality is unable to effectively manage the open space system on its own as a result of the size, distribution, ownership (largely non-municipal) and maintenance costs of open space assets. They note that many open spaces in the EMA are already managed by individuals, private corporates, public institutions, non-governmental and community based organisations; and argue that there needs to be collaboration by all stakeholders if effective open space management is to be achieved. Partnerships will need to be established between open space managers in order to facilitate:

- Capacity building.
- Information sharing.
- Efficient use of resources.

Roberts and Boon (2002) also argue that open space management should focus on maintaining functional ecosystems, and propose the following open space management principles:

- The establishment of measurable goals.
- Investment in on-going monitoring and research.
- The maintenance of biological diversity.
- The management of open space systems within a wide range of timescales.
- The acknowledgement of human activities within open space ecosystem performance.

2.5 Open Space Planning in Johannesburg and Cape Town

The development and implementation of open space planning in two other major South African centres is briefly discussed below.

2.5.1 Johannesburg

The 2000 State of the Environment Report for the Greater Johannesburg Metropolitan Council notes that the state of open space over the whole of Greater Johannesburg is regarded as being generally poor (Greater Johannesburg Metropolitan Council 2000). The ratio of open space per person varies from an average of 21 m^2 per person in the north, to less than 10 m^2 per person in the south. Greater Johannesburg is mostly fully developed, with suburban gardens constituting a large proportion of the existing open space. Serobatse (2005) observes that only 1.8% of the greater Johannesburg is formally conserved; and although there are areas of unutilised land to the north and south, they are often either degraded, or subject to commercial cultivation (Greater Johannesburg Metropolitan Council 2000). Consequently conservation potential in Greater Johannesburg is generally rated at low. A SWOT analysis by Walmsley Environmental Consultants (1997) identified the following threats and weaknesses to existing open space in the Greater Johannesburg:

- Many planned parks are situated in middle to high-income areas.
- Many open spaces in lower income areas comprise land leftover after development.
- Many open spaces are utilised for illegal dumping.

- Open spaces have become increasingly dangerous as a result of crime.
- Many of the planned parks are populated with exotic species.
- There is little or no maintenance of open spaces in many areas, which could lead to their complete degeneration, and use for alternative developments.
- There is insufficient budgeting for the maintenance and management of open spaces.
- Many open spaces are inaccessible as a result of private ownership, or transport limitations.
- Air and water pollution will eventually result in the destruction of biodiversity in many open spaces.

Phase one of the Metropolitan Open space system for Johannesburg (JMOSS), essentially a desktop study which was completed in 2002, identified 74 238 ha of potential open space (Strategic Environmental Focus 2002). Serobatse (2005) notes that the city requires funds to 'groundtruth' the identified open space and refine JMOSS prior to phase two (public participation).

2.5.2 Cape Town

The City of Cape town is located within the Cape Floral Kingdom, one of six floral kingdoms in the world. The Cape Floral Kingdom includes approximately 9600 indigenous species, of which 70 percent are endemic and 1406 are listed in the Red Data Book (Katzschner, Oelofse, Wiseman, Kackson and Ferreira 2004). The City of Cape Town (2003) and Katzschner *et al.* (2004) note that the Cape Town Lowlands, which supports more than 1466 plant species, is under-conserved and highly threatened. The City of Cape Town (2003) seeks to explain this situation by pointing out that:

- Under the apartheid dispensation nine government organisations, including seven local authorities, were responsible for the protection of biodiversity in the City of Cape Town. The lack of coordination or integration of efforts and approaches by these organisations resulted in a fragmented approach to biodiversity.
- Historically, the Peninsula Mountain Chain has received more attention than the Lowlands, which were largely ignored under apartheid planning. The few lowland nature reserves that were proclaimed were never identified or prioritised for their potential contribution to the city as a whole.

A number of conservation and recreation open space initiatives arose from the Cape Town city council's *'Greening the City'* report' (City of Cape Town 1982), which was adopted by the city council in 1984 (City of Cape Town 2003). However, the recommendations of further reports that identified and mapped important conservation-worthy areas were either never acknowledged, or never implemented; and many of these areas were 'lost' as a result of substantial urban expansion on the Cape Flats during the mid 1980s, and the political pressure for housing rather than conservation. By the mid 1990s even local and provincial nature reserves were slowly degrading owing to a lack of 'on-the-ground' management (City of Cape Town 2003). Between 1994 and 1997, conservation focus was on the consolidation of conservation areas and management of the Peninsula Mountain Chain, resulting in the Cape Peninsula National Park in 1998. The City of Cape Town (2003) suggests that city authorities now have an opportunity to address conservation on the Cape Town Lowlands, while engaging poor and marginalised communities.

The City of Cape Town (2005) acknowledges the need for a planning, management, implementation and maintenance framework for open space in Cape Town, and notes that a study of the Cape Metropolitan Open Space System (CMOSS) is currently being undertaken in three phases. Phase one, which was completed in 2000, determined a definition and vision of CMOSS, and the criteria / methodology to be used in identifying and mapping CMOSS. Phase two - the identification and mapping phase - has yet to be completed; although a pilot project to test the nature and extents of the data-sets, as well as the methodology, was completed in 2001. Katzschner *et al.* (2004), citing the City of Cape Town report '*Identification of a Biodiversity Network for the City of Cape Town*' (City of Cape Town 2002), notes that a conservation-planning analysis has identified 261 sites totaling 32 262 ha which, together with linking corridors, form the proposed Biodiversity Network for the city (City of Cape Town 2002 cited in Katzschner *et al.* 2004). Phase three - the development of Management Guidelines for CMOSS - was due to commence in 2002 (City of Cape Town 2005).

Open space planning in both Johannesburg and Cape Town appears to suffer from a lack of political will, and possibly resources. The planning, creation and consolidation of open spaces has largely had to make way for pressing 'brown' issues, resulting in the loss of many conservation-worthy areas. Furthermore, a high level of development, coupled with the limited quality natural open space available, raises questions with regard to the viability of a city-wide open space system in Johannesburg. By comparison, the implementation of open space planning in eThekwini is considerably further advanced. While this is probably in part due to the establishment of D'MOSS prior to democratisation of city councils (and the consequent elevation of 'brown' issues over 'green' issues), the continued success of the EESMP can also be ascribed to the re-conceptualisation of open space as an asset (cf. 2.4.3), national legislation - e.g. The National

Environmental Management Biodiversity Act (10 of 2004), as well as the use of alternative management tools. eThekwini's *'State of the Environment Report 2004'* notes that the EESMP, which was adopted by the eThekwini City Council in March 2003, underpins the city's Sustainable Development Strategy and Integrated Development Plan, and is "used in all levels of spatial development planning conducted by the Municipality" (Environmental Management Department of eThekwini Municipality 2005:23).

2.6 Urban Greening Initiatives in the eThekwini Municipality

In their report *'Greening Durban Metropolitan Area. Volume II: Current Greening Initiatives, Institutional Arrangements, Support and Funding'* Addo, Breen and Jaganyi (2000b) observe that there are approximately thirty institutions and organisations engaged in urban greening within the eThekwini Municipality[7] (Appendix 2: Table 1). The greening activities of these institutions and organisations, which range from eThekwini municipal departments to local conservancies, may be broadly categorised as:

- Tree planting, medicinal plants, food production (urban agriculture) and horticulture.
- Cleaning of the environment, and waste removal / waste management.
- Education, training and facilitation.

2.6.1 Benefits and Services of Urban Greening Institutions and Organisations

Benefits and services provided by, and / or accrued to, urban greening institutions and organisations in the EMA (broadly) include (Addo *et al.* 2000b):

- The provision of educational, facilitation and technical skills.
- The promotion of indigenous plants and nursery production.
- Access to, and sourcing of, private funding.
- Training in food production.
- Strategic planning - i.e. The Durban Metropolitan Open Space System (D'MOSS) and the Intathakusa-Etafuleni Integrated Development Plan.
- Job creation and income generation.
- Improved quality of life resulting from clean and healthy environments.
- Improved property values resulting from clean and healthy environments.

[7] Addo *et al.* (2000b) acknowledge that time and financial constraints may have resulted in the omission of some urban greening organisations and projects from their report.

- Community driven projects.
- Manufacturing of goods from recycled materials, thereby keeping collection, sorting, transport and infrastructure costs down.

Addo *et al.* (2000b) identify three immediate greening activities that currently supply, or could potentially supply, economic opportunities for local communities in the EMA - waste recycling (metal, glass, paper and cardboard), the Silverglen Medicinal Plant Initiative, and urban agriculture.

2.6.1.1 Waste Recycling

A 2003 eThekwini council survey estimates that some 450 people in the eThekwini city centre 'eke out' a living by collecting cardboard for recycling, and that in the greater eThekwini area the number of cardboard collectors was probably greater than 1 000 (Broughton 2003 cited in Allebone 2003). Durban Solid Waste currently operates six collection points for waste paper, glass, scrap-metal, plastic and cans (Mgingqizana 2005 *pers. comm.*). South Africa's recovery rate for paper (52 percent) compares well with that of Britain (47 percent) and the USA (48 percent) (Allebone 2003). A 1990 survey in 80 cities and towns by the 'Keep South Africa Beautiful' organisation indicated that beverage cans contributed eight percent of the country's litter (Keep South Africa Beautiful cited in Collect-A-Can 2003a). The Collect-A-Can initiative, a joint recycling venture established in 1993 by Iscor and Nampak (Dhliwayo 2003), has helped to reduce this percentage to under one percent (Collect-A-Can 2003a). Collect-a-Can estimates that nationally there are more than 37 000 people collecting cans for recycling, of whom 82 percent would be otherwise unemployed. These collectors are self-employed, and in some cases can earn as much as R30 000 per month (Collect-A-Can 2003c). Over the past ten years some 270 million Rand have been paid out to can collectors (Dhliwayo 2003). South Africa's recovery rate for steel beverage cans, which was approximately 66 percent in 2003, compares favorably with other first world countries (Collect-A-Can 2003b).

2.6.1.2 Silverglen Medicinal Plant Initiative

Mander (1998) estimates the 1998 value of medicinal plants traded in KwaZulu–Natal was worth some 60 million Rand, and that the annual value of medicinal plant material traded nationally was approximately 270 million Rand (Mander 1998 cited in Metropolitan Durban 1999a). There are an estimated 6 million traditional medicine consumers in KwaZulu-Natal, and 27 million in South Africa. Between 20 000 and 30 000 people in KwaZulu-Natal, mostly black rural women, derive an income from the trade of indigenous medicinal plants. The total number of jobs created from the medicinal plant trade in the EMA is estimated at 14 000. The high demand for medicinal plant material (4 000 tons in KwaZulu-Natal, 20 000 tons nationally), coupled with a lack of resource management, destructive harvesting techniques, and little or no cultivation, has resulted in a decline in the supply of many of the approximately 700 plant species traded. The intensive harvesting of wild plants poses a threat to biodiversity in the EMA as well as KwaZulu-Natal, with some species such as wild ginger (*Siphonochilus aethiopicus*) and the pepper-bark tree (*Warburgia salutaris*) having become extinct outside of protected areas. As a result some plant products, such as wild ginger, regularly trade at prices as high as R450 per kilogram (Mander 1998 cited in Metropolitan Durban 1999a).

The Silverglen Medicinal Plant Initiative is a project of the eThekwini Parks Department, Mkhuluwe Cele (an Umlazi herbalist), the National Botanical Institute and Ezemvelo KZN Wildlife to conserve, and provide education concerning the cultivation of, rare and threatened plants used in traditional healing (Mteshane Undated). Ezemvelo KZN Wildlife is also working with the KwaZulu-Natal Department of Agriculture in setting up cultivation trials for the purposes of advising small scale and commercial farmers, as well as traditional healers, on medicinal plant cultivation (Ezemvelo KZN Wildlife Undated).

2.6.1.3 Urban Agriculture

Addo *et al.* (2000b) suggest that a 'significant' number of jobs could be provided through community vegetable gardens, crops and high value agricultural products. This view is consistent with that of Smit (1996a; 1996b; 1996c) and Smit *et al.* (1996) who note that urban agriculture is a rapidly expanding global phenomenon which provides competitive advantages to local farmers, as well as environmental benefits (cf. 2.1.7). In 1998, the Inner West Council of eThekwini Municipality agreed to make urban agriculture a function of the eThekwini Parks Department. Thereafter the council approved, subject to certain rules and agreements, the use of large sections of unused / undeveloped land on the western fringes of the municipality for the purposes of community gardens. Council initially provided funding for earthworks, fencing, water connections, secure storage facilities and composting, but owing to the considerable increase in the number of gardens has been unable to fully fund the initiative (Leech Undated). Gordon (2002) notes that at present the initiative is dependent on those individuals and groups who contact the Parks Department, and consequently the process is one of 'piece-meal response' rather than integrated strategic planning. Gordon (2002) argues that successful urban agriculture in the EMA will require integrated structures, planning policies and management systems at local government level, and implementation / monitoring at individual project level – a position consistent with Spies (1998) (cf. 2.6.3) and Sorensen *et al.* (1997).

2.6.2 Identified Limitations Within Institutions and Organisations

Limitations identified within these institutions and organisations include (Addo *et al.* 2000b):

- A lack of long-term strategies.
- A lack of marketing skills.
- A lack of skilled staff and leadership.
- A lack of funding.
- High staff turnover as a result of low pay.
- Staff and projects have to be supervised over considerable distances. In the case of the eThekwini Parks Department responsibility for urban greening has been delegated to area managers, resulting in a lack of central record keeping (Naidoo 2004 *pers. comm.*).
- A lack of transport and communication.
- Economic upliftment is not equitably shared with smaller non-government organisations (NGOs) and Community Based Organisations (CBOs).
- Urban greening projects are often not sustainable and require local government / municipal support.
- A lack of institutional support.
- A lack of cooperation between urban greening agencies.
- A lack of community ownership.
- Unrealistic community expectations.
- A lack of transparency.
- Local community members are often not employed in the projects.
- Goods produced from urban greening activities produce little income.
- Violence and criminal activities.

Examples of problems arising from the above limitations can be found in three community urban greening projects undertaken in Ntuzuma, Kenville / Avoca and KwaMashu between April 1997 and July 1998 by the eThekwini Parks Department, who were acting as implementing agents for the eThekwini Environmental Management Branch, in the course of Phase Two (1997 - 1999) of the implementation of eThekwini's Local Agenda 21 (Roberts and Diederichs 2002).

2.6.2.1 Ntuzuma

The Ntuzuma Project consisted of the development of a park on the Goboghobo River, the building of an access bridge for community members living on the other side of the river, the leveling of a platform for a sports and playing field (in a riverine area), the creation of picnic sites and placement of benches. There was a misunderstanding between the Environmental Management Branch and the Parks Department with regard to operating budgets, resulting in there being insufficient funds for plants and labour. As a result of the delay in grassing, there was considerable erosion of the platform and its slopes during periods of high rainfall. The steep gravel access road also eroded, and eventually subsided. Timber from both the bridge and the park benches was stolen; and Parks Department maintenance staff were threatened by members of the local community who believed that community members should have been employed to maintain the area.

2.6.2.2 Kenville / Avoca

The Kenville / Avoca Project consisted of the development of a playground and picnic spot in a park area, and a trail and picnic sites along the Umhlangane River canal. Considerable capital was spent on clearing alien vegetation along the Umhlangane River, but neglectful maintenance, resulting from insufficient supervisory staff, led to re-establishment of the alien vegetation as well as illegal dumping of rubbish and waste. Further resources had to be utilised in order to clear the re-established alien vegetation and remove dumped materials. The anticipated participation of the Umhlangane Conservancy in the Umhlangane River Trail did not materialise as a result of a misunderstanding with regard to responsibility for its maintenance and management on completion of the project.

2.6.2.3 KwaMashu

The KwaMashu Project consisted of the construction of two wooden walkways across a small river, and the development of a small picnic site with gazebo, braai facilities and seating. Ownership of the land was not verified prior to commencement of the project, resulting in considerable delays of the project. As with the Ntuzuma Project there was theft of trees and plants; and Parks Department maintenance staff were threatened by local community members who believed that community members should have been employed to maintain the area. The park, which was intended for adults, is largely utilised by children for whom there are few recreational facilities in the area, thus raising the question whether money might have been better prioritised on playground equipment.

2.6.2.4 Lessons Learnt

Important issues highlighted by the Ntuzuma, Kenville / Avoca and KwaMashu greening projects include (Roberts and Diederichs 2002):

- The need for operational / maintenance budgets to be addressed in the planning phase, and to be linked to capital budgets.
- The need for project management throughout the lifespan of the project.
- The need for improved inter-departmental and inter-agency communication.
- The need for project responsibilities to be formalised.
- Stakeholders, particularly local residents, must be afforded the opportunity to participate in all phases of the project cycle – planning, implementation, management, operation and maintenance.
- 'Cheaper' solutions are not necessarily sustainable or cost-effective.
- Limited staff / financial resources cannot be stretched beyond their capacity without increasing the risk of project failure and, consequently, wasted capital / diminished confidence in urban greening.

2.6.3 Key Factors Required to Strengthen and Sustain Urban Greening Initiatives

Key factors identified by Addo *et al.* (2000b) necessary to strengthen and sustain urban greening initiatives / organisations in the EMA include:

- Funding.
- Business, planning, and development skills.
- Institutional structures.
- Capacity building i.e. technical skills, project management, financial management and marketing.
- Physical resources.
- Community participation in urban greening initiatives, leading to full ownership thereof.
- Municipal support for new and upcoming initiatives, while allowing them to operate in their own manner.
- Sharing of knowledge, expertise, experience and information by all urban greening agencies.

Many of these 'key factors' have been previously noted and discussed in both national and international contexts - e.g. Sorensen *et al.* (1997), Sowman and Urquhart (1998) and Grobbelaar and Croucamp (1999). Spies (1998) suggests three requirements of local / provincial government necessary for the development of effective and integrated urban greening include:

- A supportive policy framework that integrates the roles, responsibilities and strategies of all urban greening agencies.
- Institutional capacity building for municipalities in disadvantaged areas in order to address issues such as seed money, training and education, participative planning, and management and maintenance of projects.
- The establishment of enabling conditions to support urban greening e.g. land zoning, community ownership, information and education.

2.6.4 Current and Potential Institutional Support

Current and potential institutional support for urban greening initiatives and organisations in eThekwini include (Addo *et al.* 2000b):

- **Public Institutions.** Metropolitan and local government.
- **Parastatal Organisations.** KZN Wildlife, Umgeni Water, Eskom, Durban Airport, Transnet, CSIR, National Botanic Institute, Human Science Research Council and the Natal Sharks Board.
- **Institutions.** Tertiary educational institutions, private schools, missions, churches, professional institutes, National Monument Council.
- **Private Organisations.** Business, consultants, industry, property developers, landowners, Tolcon.
- **NGOs.** Wildlife and Environment Society of South Africa (WESSA), Institute of Natural Resources (INR), Farmers Support Group, Botanical Society of South Africa, Earthlife, Environmental Justice Networking Forum, Valley Trust, Coast Watch, Birdlife Africa, Keep Durban Beautiful Association.
- **CBOs.** Conservancies, development forums, residents associations, neighborhood watch and vigilante groups, community trusts, Simunye Environmental Association.

Further potential institutional support for urban greening may come from national government's recently announced Expanded Public Works Program (EPWM) (Expanded Public Works Programme 2004). The environmental sector of the EPWM, for which 249 million Rand have been budgeted for the 2004 - 2009 period, will undertake a number of projects including alien vegetation clearance, wetland rehabilitation, coast clearance, land rehabilitation and waste management. It is anticipated that new projects may include integrated urban greening and housing programmes.

2.7 Urban Greening Agencies in the eThekwini Municipality

Due to limited time and resources it was not possible to investigate all the urban greening initiatives in the eThekwini Municipality. Urban greening initiatives by the eThekwini Parks Department - the largest institutional urban greening agency in the EMA, two active NGOs - the Botanical Society of South Africa and the Wildlife and Environment Society of South Africa (WESSA), and those of several conservancies are discussed below.

2.7.1 eThekwini Parks Department

The eThekwini Parks Department provides an important service to local councils with regard to the development and maintenance of over six thousand hectares of parks, recreational and open space systems (eThekwini Parks Department 2004b), including:

- Nine major natural system parks.
- Several small nature reserves.
- The 14.5 Ha Durban Botanical Gardens.
- Sixty other parks of horticultural and floral attraction.
- One hundred and sixty recreational playing fields.
- Numerous children's playgrounds.
- Beaches and public lawn areas.

Many of the above open spaces fall within D'MOSS. The Parks Department also plays a role in advising, planning and implementing urban greening requests from other municipal departments - i.e. housing, environment, as well as the Mayor's Office (which is currently managing an urban greening initiative).

2.7.1.1 Tree Planting

Tree planting in low-cost housing high-density projects such as the Cato Manor Development Project, where a wide variety of fruit trees were planted by the Parks Department, has proved unsuccessful as residents neglected to care for the trees. The Parks Department is presently directing its community-based urban greening efforts towards urban agriculture (Mbadla 2004 *pers. comm.*).

2.7.1.2 Urban Agriculture

There are currently approximately three hundred urban agriculture projects in the eThekwini Municipality; of which thirty-six are funded by the Department of Agriculture, ten are funded by eThekwini Rural Area Based Management, and two are funded by the eThekwini Small Business and Community Economic Development Unit (Naidoo 2004 *pers. comm.*). The average size of these projects is approximately one hectare. The Parks Department supplies technical expertise and, where funding is available, materials and equipment. In the Cato Manor Development Project gardening clubs, each consisting of approximately ten residents, have been set up to facilitate training in, and implementation of, urban agriculture on steep open (denuded) areas (Figure 2.2) that will generate income while stabilizing the ground (Mbadla 2004 *pers. comm.*).

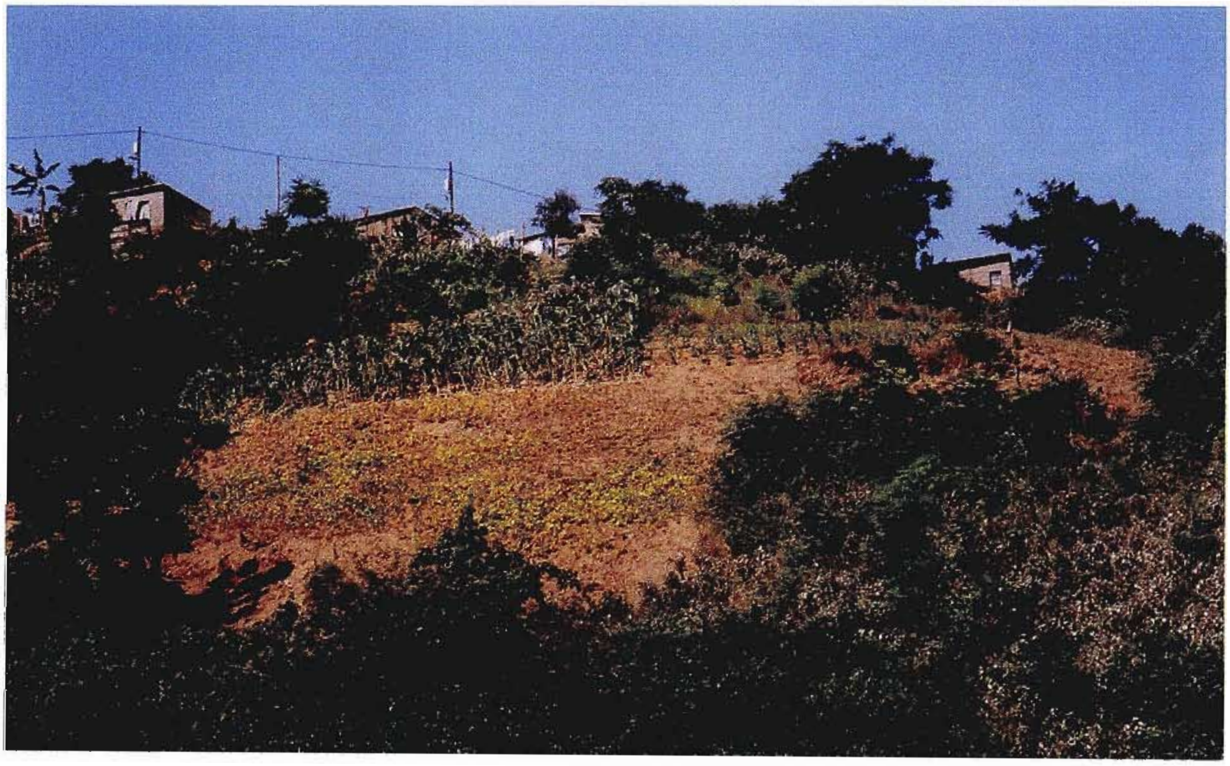


Figure 2.2. Urban agriculture on steep slopes in Cato Manor. July 21, 2005.

Recently the Durban Botanic Gardens, which is administered by the Parks Department, purchased land for the purposes of establishing an urban agriculture / greening, medicinal plant conservation and demonstration centre. Mattson (2004:8) states that purpose of the centre will be "to visibly demonstrate to large numbers of people the environmental and socio-economic benefits of wise plant use"; and to focus public attention on:

- The medicinal plant trade in KwaZulu-Natal.
- The need for urban organic food gardening projects.

- The need for greening projects in low-cost housing developments in Durban.

The aim of the project would seem to be consistent with one of the stated aims of the Botanical Gardens' Mission Statement, namely "to demonstrate the role plants can play in social upliftment through our involvement in urban greening, organic gardening and medicinal plant conservation projects" (eThekwini Parks Department 2004a:1). Mattson (2004:8) notes that "in developing this site, the Gardens are aiming for a consultative, community-driven, social welfare-based approach that will emphasize the balancing of social, economic, environmental and aesthetic needs."

2.7.2 The Wildlife and Environment Society of South Africa (WESSA)

WESSA was instrumental in the initial planning for a number of city-wide open space systems, including Johannesburg, East London, Bloemfontein, Cape Town and Durban (cf. 2.4.4), of which D'MOSS has been the most successful. WESSA's continued participation in, and support of, the open space system, now known as the eThekwini Environmental Services Management Plan (EESMP), includes (Dold 2004 *pers. comm.*):

- Alien vegetation clearance in designated open space areas - e.g. Burman Bush and Steinbank Nature Reserve.
- Input into the development of the EESMP – e.g. phases four (2001) and five (2002).
- Input into many of the EIAs conducted within, and outside of, the EMA, including the Hawaan Forest, Umhlanga and various Outer West developments.

Indirect support for D'MOSS / EESMP includes (Dold 2004 *pers. comm.*):

- Growing and distributing indigenous plants to schools.
- Environmental education excursions for adults.
- Environmental education centres at Umgeni, Bluff and Mtunzini.
- Bergwatch and Coastwatch, which respectively monitor developments in the Drakensberg and on the coast.

2.7.3 The Botanical Society of South Africa

The Botanical Society of South Africa promotes education and awareness of indigenous trees / plants through (Newmarch 2004 *pers. comm.*):

- Newsletters, excursions and lectures for its members.
- The society's annual indigenous public plant sale, which has created a growing public demand for indigenous trees. Dell (2004 *pers. comm.*) estimates that 30 000 plants were sold

in the 2004 sale. Consequently many wholesale nurseries in KwaZulu-Natal have substantially increased their indigenous stock.

- Joint publication with WESSA, eThekwini Municipality and the Durban Botanic Gardens, of three freely available posters that provide information on both alien and indigenous plants; with a view to encouraging indigenous gardens, and thereby enhancing D'MOSS.
- Highly successful indigenous gardening workshops.

The Botanical Society, in conjunction with WESSA, eThekwini Municipality and Ezemvelo KZN Wildlife, have also launched a project to clear coastal grasslands of invasive alien and indigenous woody plants (Boon 2004).

2.7.4 Conservancies

Lindsay (2004) notes that eighty percent of land in South Africa is privately owned, and argues that any conservation plans must include private landowners. Conservancies are a useful means by which to involve communities, land owners, and the general public in actions that could confer conservation benefits to a region including rural, urban, marine and industrial areas (Cape Nature Conservation 2001); with resultant empowerment and educational benefits (Lindsay 2004). The National Coordinating Committee For Conservancies (1994:3) defines a conservancy as the "voluntary, co-operative, environmental management of an area by its owners, communities and user groups and is registered with the relevant provincial conservation authority". There are some eight hundred conservancies in South Africa, covering 4 000 000 Hectares (KZN Conservancies Association 2004). Within the EMA there are fifty registered conservancies between Umdloti in the north, to Umkomaas in the south, and Cato Ridge in the west (Lindsay 2004). An urban conservancy's objectives may include (Lindsay 2004):

- Promotion of conservation of flora, fauna and natural ecosystems.
- Monitoring, reporting and limiting of all forms of pollution.
- Monitoring of injudicious and environmentally unfriendly construction and development e.g. houses built within the 50 to 100 year flood line, excessively steep banks which lead to erosion, and poor river engineering practices.
- Informing, advising and educating landowners and residents.
- Encouraging waste minimisation.
- Removal / control of alien invasive vegetation.

- Lindsay (2004) observes that all of the conservancies in the EMA are involved in alien vegetation clearance, re-introduction of indigenous plants, and environmental education / awareness.

2.8 Conclusion

The case studies discussed in Section 2.1 (International Case Studies) demonstrate the wide range of environmental, social, health and economic benefits that urban greening could potentially accrue to a city and its inhabitants. A planned approach to urban greening that incorporates the principles of 'maximisation of use and benefits, and minimisation of cost' (Sorensen *et al.* 1997), could, arguably, provide returns that exceed Miller's (1988) definition of urban greening. On the other hand, ignoring the environmental consequences of uncontrolled development brings with it consequences of a nature as documented in Section 2.1.5 (Flood Control) by Tlaiye and Biller (1994) and Section 2.1.6 (Wetlands, Wildlife Habitat and Biodiversity) by Bernstein (1994). Urban greening should, therefore, not be seen as a 'luxury' or 'green issue', but rather as an immediate, cost-effective and sustainable means of providing social, health, economic and environmental goods and services essential to all city inhabitants.

South African environmental legislation and policy would appear to offer broad support for the protection of natural resources, sustainable land development practices, and certain aspects of urban greening (open spaces, green belts, parks and urban agriculture). National legislation cannot, however, effectively intervene at every level of every local community, and, in accordance with Agenda 21, it is therefore necessary to seek the cooperation and participation of local authorities and municipalities in addressing local social, economic and environmental issues. Devolvement of environmental management and implementation to local authorities and municipalities does, however, raise new questions with regard to technical / financial capacity, inter-governmental planning and coordination, defining of roles and responsibilities, prioritisation of resources, levels of community participation and administrative fragmentation. Key issues that must yet be addressed through local policy and legislation include zoning, local community participation, land security / tenure and the right to harvest, and female participation in urban greening. Sorensen *et al.* (1997:29) note that women "typically assume a disproportionate share of the responsibility for the 'green' elements of a family's welfare" yet are rarely consulted in the planning phases of urban greening projects.

The Durban Metropolitan Open Space System (D'MOSS) / eThekwini Environmental Services Management Plan (EESMP), which currently incorporates 63 000 Ha of land considered to be vital to the ecological viability of the open space system (Roberts and Boon 2002), has proved to be one of the most successful city-wide open space systems in South Africa (Dold 2004 *pers. comm.*). Yet, despite its apparent success, the open space system has come under strong criticism from pro-development factions within the city management (e.g. housing), and outside political forces, as being (variously): of a low priority, anti-development, or even perpetuating pre-1994 apartheid urban boundaries, thereby earning it the moniker 'DEMON' (Dold 2004 *pers. comm.*; Bedford 2005 *pers. comm.*). In order to justify the continued existence and protection of the open space system the city's Environmental Management Branch resorted to resource economics, quantifying open space as an asset of considerable social, economic and ecological value (3.1 billion Rand), supplying vital environmental services and benefits to the city's communities (Roberts and Boon 2002). This value represents an annual replacement value, and does not necessarily include potential social / economic assets such as urban agriculture or niche / ethnobotanical / craftwork / medicinal plants, or the income derived from tourism. Roberts and Boon (2002), noting that much of the open space is not owned by the municipality, acknowledge the need for partnerships in open space planning in order to facilitate capacity building, information sharing and efficient use of resources (cf. 2.4.5).

The limitations and constraints identified by Addo *et al.* (2000b) (cf. 2.6.2) on urban greening organisations in the EMA, and lessons learnt in the Ntuzuma, Kenville / Avoca and KwaMashu greening projects (Roberts and Diederichs 2002), reflect issues similar to those documented by Sorensen *et al.* (1997) in international case studies (cf. 2.1), namely: insufficient funding; an absence of institutional support; poor cooperation between urban greening agencies and institutions; insignificant community ownership; the need for on-going project management, and violence / criminal activities. The lack of central record keeping by a number of eThekwini departments, including the Parks Department (Naidoo 2004 *pers. comm.*), renders ongoing monitoring and evaluation difficult, and mitigates against the development of an 'institutional memory' (Bedford 2005 *pers. comm.*). A shortage of expertise also appears to be a problem, as evidenced by the planting of alien vegetation at the Mount Royal Housing Project handing-over ceremony (*pers. obs.*), and the on-going audits of the Park's department nurseries by WESSA for alien plants (Dold 2004 *pers. comm.*). Successful urban greening projects undertaken in recent years by some NGOs and urban conservancies are, however, noteworthy.

In order to generate broad support for planned urban greening, and improve the prospects for success, it is important to deploy a participatory decision support system that: (A) conveys the necessary information in a clear and unambiguous manner, thereby facilitating understanding of the project and its environmental impacts without the need for specialist knowledge; and (B) enables dialogic participation of all stakeholders (cf. 1.3.1; 2.3). Ideally such a system should be scientifically defensible, capable of showing design alternatives, provide multiple viewpoints, allow for changes and be practical and efficient to use (cf. 1.4). It is proposed[8] that technologies from the discipline of landscape visualisation may be well suited to this task. Chapter Three discusses the process of landscape visualisation and quality assessment; and examines three established landscape visualisation technologies, as well as new technologies 'borrowed' from other disciplines. However, the high degree of photorealism that can be achieved by some of these technologies, coupled with their potential to mislead viewers, necessitates a discussion of ethical guidelines and existing gaps-in knowledge in their application within a participatory decision support system.

[8] Proposed by this author.

Chapter Three
Landscape Visualisation

Landscape visualisation is a process whereby alphanumeric landscape data is transformed into a graphical representation that conveys information on existing and / or proposed landscapes in an universally comprehensible manner; and is an important element of visual impact assessment and environmental decision making (Oh 1994; Macaulay Land Use Research Institute 2004c). The term 'landscape' comprises both the natural world as well as the built environment – roads, settlements, towns and cities (Hull and Revell 1989; Ervin and Hasbrouck 2001). The process of visualisation, which includes modelling and simulation, is employed to simulate, depict and comprehend the landscape and the underlying processes - including soil erosion, hydrology and vegetative succession - and is considerably swifter, safer and more prudent than experimenting with the 'real thing' (Ervin and Hasbrouck 2001). The intended recipients could include the general public (the majority of whom lack mapping and GIS expertise) as well as experts, planners and local authorities; and as such visualisation offers an opportunity for greater transparency and broader participation in environmental planning and decision making.

3.1 Landscape Quality Assessment

Daniel (2001) observes that landscape quality assessment over the past fifty years has been dominated by two approaches which he terms the (objective) expert / design approach, and the (subjective) public perception approach. The expert / design approach as encapsulated in *'Design With Nature'* (McHarg 1969), *'National Forest Landscape Management, Vol. 2, The Visual Management System'* (US Department of Agriculture, Forest Service 1974), *'Landscape Aesthetics: A Handbook for Scenery Management'* (US Department of Agriculture, Forest Service 1995), *'Visual Resource Management Program'* (US Department of Interior, Bureau of Land Management 1980) and *'Visual Impact Assessment for Highway Projects'* (US Department of Transportation 1981) was developed and formalised within the practice of public land management. Biophysical features of the landscape (mountains, trees, rivers and lakes) are translated into standardised attributes (e.g. form, line, texture and colour) and relationships (e.g. variety, unity, vividness and harmony), and evaluated against set guidelines. The premise of this process is that objective and quantitative methods should produce consistent results. Daniel (2001) notes that criticism by Daniel and Vining (1983) of the expert / design approach highlights the lack of precision, reliability of the expert assessments and the criteria on which the assessments are made.

The public perception approach, which has been developed and applied within environmental perception and landscape assessment research, utilises survey research and psychological scaling to quantify the perceived aesthetic qualities of the landscape (Daniel 2001). Visual landscape qualities are ranked on the basis of individual preference utilising indices such as perceptual factors (visual penetration, focality, complexity), emotional responses (security, relaxation, warmth, cheerfulness, stress, fear, insecurity, constraint, gloom) and cognitive constructs (complexity, mystery, legibility, coherence, prospect / refuge) by observers drawn from the general public. Daniel (2001) notes that perception based studies, particularly those based on small to medium sized groups, have achieved very high levels of statistical reliability; while Bishop and Hull (1991) observe that the results of numerous psychophysical modelling and assessment studies have been shown to be dependable, predictive and broadly applicable. Palmer and Hoffman (2001) have, however, raised several concerns regarding overconfidence in the results of some previous landscape visualisation studies, suggesting that the thirteen pre-1995 studies that they reviewed were 'ecologically fallacious' as:

- Reliability of the landscape assessments was derived from the mean ratings of two or more groups, and not from individuals.
- Validity of the photographic representations used was averaged over a group of views, rather than individual views.

Palmer and Hoffman (2001:159) note that many previous studies were limited to "scenic preference", and that confidence derived therefrom had been extended to all "visible landscape qualities" without question or sufficient research.

Daniel (2001) observes that in recent years there has been a tendency towards a convergence of the two approaches. In what the Macaulay Land Use Research Institute terms 'quantitative holistic methods' biological, physical and social features are systematically related using multiple regression analysis (Macaulay Land Use Research Institute 2004a). The US Department of Agriculture: Forest Service's Scenic Management System (US Department of Agriculture, Forest Service 1995), while still leaning strongly towards the expert / design approach, now explicitly includes provision for constituent surveys; and variants of perception-based methods such as the psychophysical and surrogate component models acknowledge the biophysical features of the landscape – e.g. Daniel and Boster's (1976) Scenic Beauty Estimation Method. Palmer (2003) notes the existence and utilisation of other 'professional' methods of landscape appraisal including economic benefits (hunting, bird watching), functional services (food, amenities, recreation, education) and resource quality (land form, water, vegetation, structures). The Macaulay Land Use Research Institute (Macaulay Land Use Research Institute 2004a) includes ecological models in the expert / design approach - a key assumption being a positive relationship between undisturbed natural areas (ecosystem integrity) and landscape quality. Daniel (2001) while noting the difficulty of defining and measuring ecological goals such as biodiversity, resilience and sustainability, proposes that using 'naturalness' as a yardstick may facilitate ecological quality assessment through visual landscape aesthetic quality appraisal. McLure and Griffiths (2002) suggest that evidence connecting landscape structure to plant and animal health / diversity is sufficiently advanced for ecologists to contemplate designing and visualising ecologically optimised landscapes for specific species. Figure 3.1 shows a synthesis of landscape quality assessment approaches and professional methods of landscape appraisal, as abstracted from Daniel (2001), Macaulay Land Use Research Institute (2004a), and adapted from Palmer (2003).

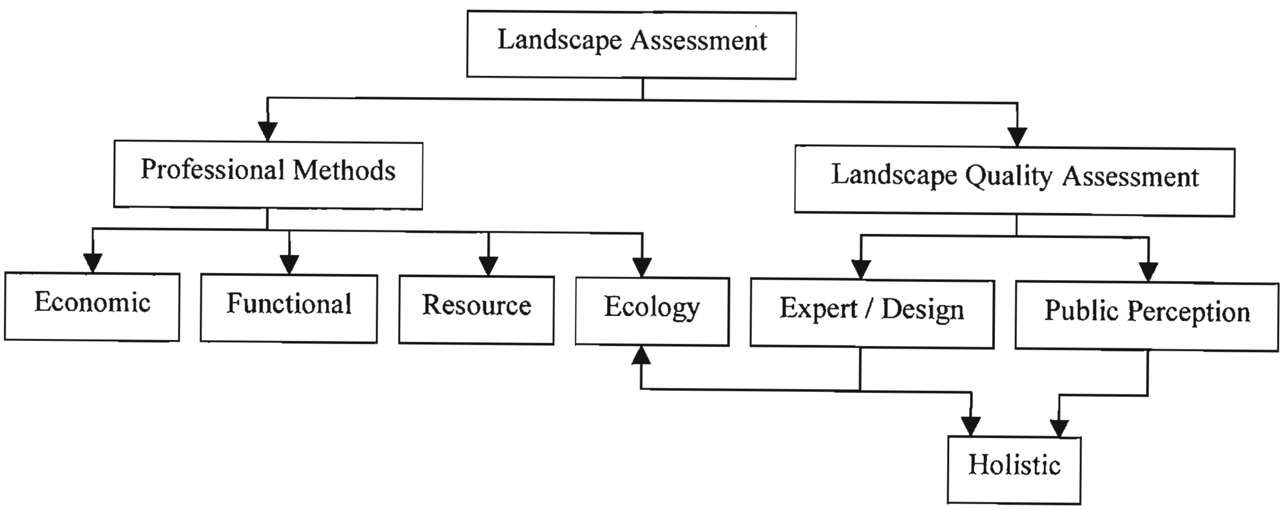


Figure 3.1. Synthesis of landscape quality assessment and professional methods of landscape appraisal. Adapted from Daniel (2001), Palmer (2003) and Macaulay Land Use Research Institute (2004a).

3.2 Traditional Methods of Landscape Visualisation

Traditional analog (non-computerised) methods of landscape visualisation which have been used to supplement two-dimensional maps include perspective drawings (artists' impressions), physical models and photomontages (Oh 1994; Landscape Institute and Institute of Environmental Management and Assessment 1995; Lange 2002). The last decade has however seen the development of modern computer technology capable of assisting or even duplicating these conventional methods - particularly those of photomontaging.

3.2.1 Perspective Drawings and Paintings

The techniques of perspective drawing and painting, which were invented in ancient Greece (approximately 465 BC) and reinvented during the Renaissance, have become commonly used tools for architectural and landscape design presentation (Lange 2002) and are still widely used. The advantages of perspective drawing and painting (over other techniques) include the following (Appleton 2003):

- Freedom of content.
- A minimum of required resources - they do not necessarily require photographic and computer equipment.

The disadvantages of perspective drawing and painting include the following:

- A tendency to impose a certain 'artistic style' (as opposed to 'neutrality').
- No linkage to real-world geographically based data, which may:
    - Undermine viewer's trust in the presentation.
    - Negate data feedback for expert analysis and evaluation.
- They do not allow dynamic changes of viewpoint.

Available computer software for sketching and painting includes *'Paint Shop Pro'* (JASC Software 2004), *'Corel Painter'* (formerly Fractal Design Painter) (Corel Corporation 2004a) and *'Corel Draw'* (Corel Corporation 2004b).

3.2.2 Physical Models

Physical models are also used for architectural and landscape design presentation (Ervin 2003), although for reasons listed below possibly not as widely as other traditional techniques. The advantages of physical models (over other techniques) include the following (Lange 2002; Piper, Ratti and Ishii 2002):

- They allow dynamic change of viewpoints by the viewer.
- Their three-dimensional nature facilitates understanding of complex geometry and spatial relationships.

Some disadvantages of physical models are:

- They are time consuming (and therefore expensive) to produce.
- At reasonably useful scales, physical models of landscapes are likely to be large (*pers. obs.*).
- They are not easily modified at short notice to reflect design changes.
- Verifiable linkage to real-world geographically based data may (at best) be tenuous.
- With the exception of very sophisticated modelling / laser scanning / data processing and projection system such as MIT's *'Illuminating Clay'* - a 3D interface for landscape analysis (Piper *et al.* 2002) - physical models cannot effectively generate data feedback for expert analysis and evaluation.

Available computer software for the production of physical models include a wide range of CAD software such as *'AutoCAD'* (Autodesk 2004) and *'Rhinoceros'* (Robert McNeel & Associates 2004). Digital models can be exported to a stereolithography machine for the manufacture of the model.

3.2.3 Photographs and Photomontages

Photography, which was invented in the 19th century, has long been used to document landscapes, the natural environment and ecology (Library of Congress 1999; New York Institute of Photography 1999); and remains a widely used technique for the presentation of landscape / development proposals as well as psychophysical studies (Bergen, Ulbricht, Fridley and Ganter 1995; Lange 2001; Macaulay Land Use Research Institute 2004b). The advantages of photographs (over other techniques) include the following:

- They can show proposals utilising the real landscape from real viewpoints (Landscape Institute and Institute of Environmental Management and Assessment 1995).
- They can produce images with a high degree of realism (Wherrett 2000; Macaulay Land Use Research Institute 2004b).

Some disadvantages of photographs are:

- They can only show what presently exists and require modification, usually through a process of overlays (photomontages), to simulate proposed developments and landscape changes (Bergen *et al.* 1995). Appleton (2003) notes that this introduces an artistic element into the visualisation, resulting in what Berry, Buckley and Ulbricht (1998) describe as 'pseudo-realistic abstractions' which are not scientifically defensible. Consequently, the credibility of photomontages can be questionable.

- Verifiable linkage of photomontages to geographically based data may be tenuous.
- The nature of photographs restricts queries and data feedback for analysis and evaluation.
- Accurate and successful photomontages are by no means trivial exercises to undertake, and can be time consuming to prepare. In order to correctly place proposed developments within the photographic background the following data must be factored in (Landscape Institute and Institute of Environmental Management and Assessment 1995):
    - Accurate location and height at the point at which photograph was taken.
    - Focal length of the lens used.
    - Direction of view of the camera.
    - Location and dimensions of proposed development.
    - Suitable registration points.
    - Lighting and shadows.

  Fortunately the advent of desktop computer technology and digital photomontaging software has, to a certain extent, simplified this process. (Macaulay Land Use Research Institute 2004b).
- Photographs and photomontages do not allow dynamic changes of viewpoint. Every visualisation generated would require re-computation of the above-mentioned data.

Figure 3.2 shows a juxtaposed panoramic photograph of an undeveloped landscape (top), and a photomontage of a proposed development (bottom) (Kretzler 2002).

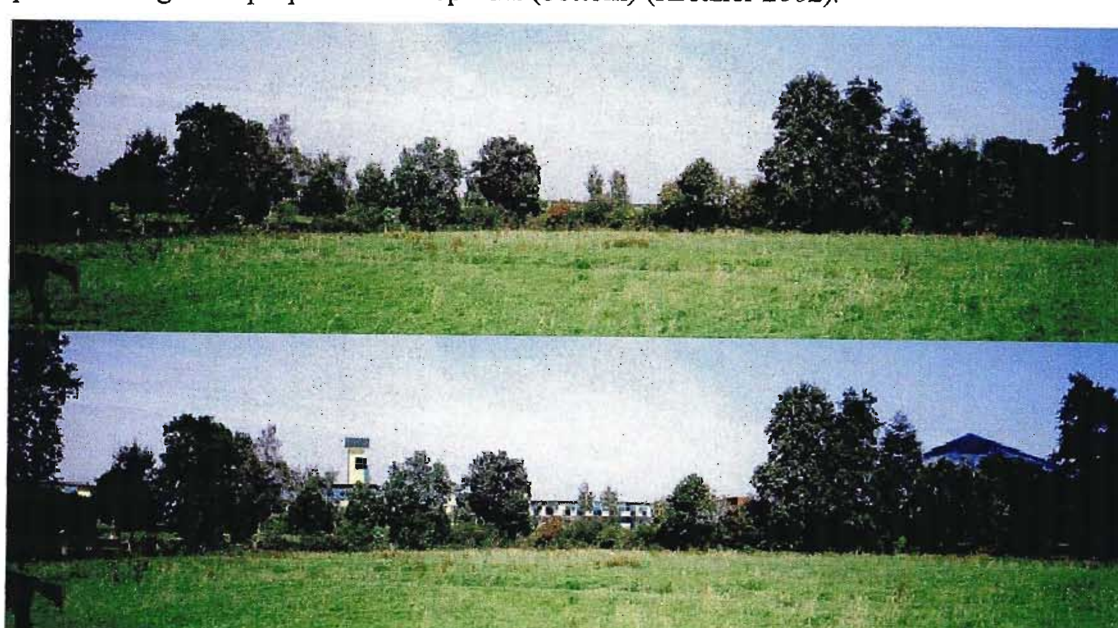


Figure 3.2. Panoramic photograph of existing landscape (top) and photomontage of proposed development (bottom). Sourced from Kretzler (2002).

Available computer software for the production of digital photomontages include a wide range of CAD software (cf. 3.2.2) and photo editing software such as *'Adobe Photoshop'* (Adobe Systems Incorporated 2004).

3.3 Computerised Methods of Landscape Visualisation

3.3.1 Key Developments

The development of digital landscape modelling and visualisation owes much to the parallel research and development of computer-graphic techniques in other fields including the military, aviation, science, engineering, entertainment industry (film and games), as well as architecture and landscape architecture (Ervin and Hasbrouck 2001; Ghadirian and Bishop 2002). Key developments over the last four decades in computer graphic techniques, hardware and software applications for landscape visualisation include (Kerlow 2000; Ervin and Hasbrouck 2001):

1960s

- Pioneering research by Ivan Sutherland at the Massachusetts Institute of Technology (MIT) that demonstrated the use and application of a graphical user interface (GUI) in CAD.
- Development of Computer Aided Design and Manufacturing (CADAM) systems for design and manufacturing by General Motors, Boeing Aerospace, IBM, McDonnell Douglas, General Electric and Lockheed. Flight simulators, Computer Aided Tomography (CAT) scanners and CADAM were amongst the first graphical systems developed.
- The Canada Geographic Information System (CGIS), lead by Roger Tomlinson, commenced development. Its purpose was to analyse the Canada Land Inventory (CLI) and produce statistics for developing land management plans (Centre for Advanced Spatial Analysis 2000).
- The establishment of the Harvard Laboratory for Computer Graphics and Spatial Analysis at Harvard University by Howard Fisher. Important pioneering research in spatial data processing undertaken there was widely disseminated and incorporated into later GIS applications (Centre for Advanced Spatial Analysis 2000).
- The founding of Evans and Sutherland, a manufacturer of high-end graphics hardware and landscape visualisation software for flight simulators, by David Evans (University of Utah) and Ivan Sutherland in 1968 (Evans and Sutherland 2004).

1970s

During the 1970s much of the research and design in computer graphics moved away from large, expensive and proprietary mainframe computers systems to minicomputers such as Digital Equipment Corporation's PDP and VAX models. Microcomputers such as the Apple and the Radio Shack TRS-80, which popularised video and computer games, were introduced towards the end of the decade, but initially did not have the necessary computing power or data storage for intensive graphics processing. Key developments in the 1970s include:

- The University of Utah, and later Cornell University and the New York Institute of Technology, became important centres of computer graphic research. Staff and Ph.D. students developed algorithms and techniques that are widely used in computer graphics such as hidden line removal, Gouraud and Phong shading, z-buffering, texture and bump mapping, reflectance and environment mapping, surface simulation, antialiasing and radiosity (Catmull in Upstill 1990; Kerlow 2000).
- The first Landsat remote sensing satellite was launched in 1972.
- The first conference of the Association of Computing Machinery's (ACM) Special Interest Group on Computer Graphics (SIGGRAPH) was held in 1973. The annual SIGGRAPH conferences have become an important industry forum at which researchers report on their work in computer graphics including, the modelling and visualisation of terrain, vegetation, water and atmospheric effects.
- Mandelbrot (1975) published his work on fractal geometry, followed with *'The Fractal Geometry of Nature'* (Mandelbrot 1982), in which he explained how fractal principles could describe and create realistic simulations of natural occurrences such as coastlines, vegetation and mountains.
- The United States Department of Agriculture: Forest Service developed techniques for landscape and forestry visualisation that are still utilised (US Department of Agriculture, Forest Service 1974).
- George Lucas' Lucasfilm established a computer division in 1979, attracting many of the top graduates from the University of Utah, Cornell University and the New York Institute of Technology. The computer division, which later (1986) became Pixar, developed the *'Renderman Interface'* and *'Renderman'* photorealistic rendering software.

1980s

In the 1980s (and 1990s) research and design in computer graphics and visualisation primarily continued on minicomputers as well as powerful new proprietary super microcomputers, known as workstations, from companies such as Sun Microsystems and Silicon Graphics Inc. (SGI). However, the 1980s also saw the rapid growth in popularity of personal microcomputers (PC) including: IBM's personal computer (IBM PC), the Apple Macintosh and the Commodore Amiga, as well as a growing range of applications to operate on the increasingly more powerful machines. The new PCs, which were considerably cheaper than minicomputers, provided affordable computer access to researchers, programmers and users, and thereby spurred the further development of new applications, Graphic User Interface (GUI) based applications and operating systems, and more powerful hardware. Early GUI applications included CAD, desktop editors, image editors, GIS and the ubiquitous games. Key developments in the 1980s include:

- Carpenter (1980) demonstrated the application of Mandelbrot's fractal geometry to generate realistic terrains at the 1980 SIGGRAPH conference. Fractal geometry is widely used in computer visualisation applications for the generation of realistic vegetation and terrains.
- Environmental Systems Research Institute (ESRI) headed by Jack Dangermond, a graduate of the Harvard Laboratory for Computer Graphics and Spatial Analysis, released the first major commercial GIS application – *'ARC/INFO'* - for minicomputers in 1981 (Longley, Goodchild, Maguire and Rhind 2001; ESRI 2004).
- Silicon Graphics Inc. (SGI) was founded in 1982. SGI focused its research and design on high performance graphics computers utilising multiple Reduced Instruction Set Chip (RISC) processors and integrated three-dimensional graphic capabilities. Amongst SGI's many contributions to visualisation has been *'OpenGL'* – a widely used application programming interface (API) for 2D and 3D graphics (SGI 2004).
- Autodesk released the first commercial CAD application for the PC, *'AutoCAD'* version 1, at the 1982 Computer Dealers Exposition (COMDEX).
- The first 32-bit Intel microprocessor (the 80386) was released in 1986. However, it took another seven years before Microsoft Corporation released a 32-bit multi-tasking operating system *'Windows NT'* (Microsoft Corporation 2006) that could take full advantage of the processor, thereby delaying the development of high-end modelling and visualisation applications for the Intel computing platform.
- ESRI released *'PC ARC/INFO'*, one of the first PC based GIS workstations, in 1986. (ESRI 2004)

1990 – 2000s

Through the 1990s and 2000s super microcomputers, or workstations, gained popularity amongst research groups and companies undertaking research in computer graphics, or utilising computer aided visualisation. Personal computers such as the Amiga and the Apple Macintosh, which were highly regarded for their integrated graphics support and GUI operating systems, became the preferred visualisation and graphics computing platforms by individuals and small companies. Key developments in the 1990s through the present include:

- Autodesk released *'3D Studio'*, their first three-dimensional modelling and animation application, in 1990. *'3D Studio'* marked an important transition from Autodesk's conventional 2.5D CAD systems in that it emphasised three-dimensional modelling, and incorporated computer graphic techniques developed in the 1970s and 1980s such as texture, bump and reflection mapping, Phong shading, camera, lighting and atmospheric controls as well as high quality rendering output (Autodesk 1992).
- *'ArcCAD'*, a GIS add-on for *'AutoCAD'*, was released by ESRI in 1992 (ESRI 2004), and offered engineers and architects GIS capabilities in a CAD system they were familiar with - e.g. support for Autodesk's DWG format, excellent integration with *'ARC/INFO'* datasets, and strong query and thematic mapping tools that were not previously available in *'AutoCAD'* (Edgetech America, Inc. 2004). *'ArcCAD'*, however, suffered from weak image integration as well as single-precision accuracy (Henry and Pugh 1997); and was discontinued when Autodesk developed their own GIS application.
- Questar Productions (later renamed to 3D Nature) released *'World Construction Set 1'* (WCS), a powerful three-dimensional landscape modelling, rendering and animation application for the Amiga in 1994 (3D Nature 2003a). With the maturation of *'Windows NT'* development of WCS was moved to the Intel platform. In 2001 3D Nature released *'Visual Nature Studio 1'* (VNS) – essentially WCS with added GIS capability.
- The increase in processing capacity of PCs, coupled with the release of 32-bit multitasking operating systems such as *'Windows 95'* (1995) and *'Windows NT4'* (1996) (Microsoft Corporation 2006), and their subsequent maturation, facilitated the development of computationally intensive modelling and rendering applications as well as the 'porting' of a number of high-end applications from Unix based workstations (e.g. *'ArcINFO 7.1'*, *'Pixar's Renderman'*), and other platforms such as the Amiga (e.g. *'LightWave 3D'*, WCS) and the Apple Macintosh, to the Intel platform. (Longley *et al.* 2001; 3D Nature 2003a; Newtek 2004; Pixar 2004).

3.4 Computer Applications for Landscape Visualisation

There are a number of high quality computer-based image creation and editing applications currently available that can potentially be utilised for landscape visualisation. If, however, the intended purpose of the visualisation software is to produce realistic images that meet the criteria for a landscape visualisation and participatory decision support process (cf. 1.4), then the underlying process should be based on scientifically defensible real-world data - i.e. be physically based; integrate a wide range of data, including that from outside the area under investigation; facilitate data storage, processing and feedback; and enable analysis and evaluation of three-dimensional spatial and visual relationships from different viewpoints. Two recognised technologies that would seem appropriate are CAD and GIS.

3.4.1 Computer Aided Design

Computer Aided Design (CAD) and Manufacturing (CADAM) has been developed for the design, testing and manufacturing of mechanical, electrical, electromechanical and electronic systems / components (Foley *et al.* 1992) including buildings, industrial plants, motor vehicles, airplanes, ships, railways, roads, bridges, electronic and network design. The diverse range of disciplines in which CAD is utilised has engendered a wide variety of software applications ranging from general two-dimensional (2D) and three-dimensional (3D) products, to specialised modelling tools employed in areas such as materials testing, hydrology, entertainment, terrain and vegetation generation (Figure 3.3). Output from CAD programs may include two-dimensional plans or assembly diagrams as used in the construction industry; three-dimensional models used for visualisation of complex geometries; and data feedback – i.e. structural, thermal or hydrological data – as generated by the interrogation of sophisticated three-dimensional models.

	2D CAD	2.5D CAD	3D CAD	Modelers
Nature of Output	2D site plans. Electronic circuit board design	Essentially 2D plans, with height (z) to assist visualisation e.g. House design	3D output, where height (z) is essential e.g. Mechanical design	Visualisation e.g. Industrial design, Terrain generation. Data feedback
Example software	***'EasyCad'*** ←	***'AutoCAD'***	→ ←	***'Rhinoceros'*** → ***'Maya'*** ***'Bryce'*** ***'Xfrog'***

Figure 3.3. Proposed continuum from 2D CAD to Modellers, and their output (Alias Systems Corp 2004; Autodesk 2004; DAZ Productions Inc 2004; Evolution Computing 2004; Greenworks Organic-Software 2004; Robert McNeel & Associates 2004).

Some three-dimensional CAD and modelling programs partially meet the criteria required for a landscape visualisation and participatory decision support process in that:

- They are capable, through the application of advanced computer graphic techniques (cf. 3.3.1), of generating highly realistic images.
- They may, through the use of real-world data such as Digital Elevation Models (DEM) and accurate geometry, be physically based, and therefore scientifically defensible.
- The three-dimensional nature of a computer model enables the generation of viewsheds from different static viewpoints, thereby facilitating analysis and evaluation of three-dimensional spatial and visual relationships. Dynamic changes of viewpoint, either through animation or through technology such as *'Virtual Reality Modelling Language'* (VRML) are also feasible; although in the case of VRML there may be restrictions on the level of detail as a result of the large amounts of data that needs to be refreshed as the viewpoint changes (Appleton *et al.* 2001).

However, most three-dimensional CAD and modelling programs fail to meet the remaining criteria required for a landscape visualisation and participatory decision support process in that:

- Their attribute databases, which are typically file-based and designed to hold inventory listings, tend to be rudimentary (Maguire 1991). They do not provide the integrated geographical databases and powerful query / analysis tools generally associated with GIS, and are therefore particularly limited in respect of their ability to:
    - Interact dynamically with underlying data (Thurston *et al.* 2001).
    - Undertake complex spatial analyses (Bohnenstiehl 1999).
- Data feedback is limited to predefined attributes, thus making it difficult to integrate data from outside the study area / model.
- They are usually limited to their local Cartesian coordinate system, and consequently real-world (geographic) data and georeferenced data / images from other GIS have to be re-projected before they can be imported. Unless the required tools are available this limits their ability to integrate a wide range of data.

3.4.2 Geographic Information Systems

The term 'Geographic Information Systems' broadly encompasses information technologies or systems used "for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the earth" (Department of the Environment 1987:132 cited in Maguire 1991:10). Data in GIS has two components – the geographical (or locational / positional) element and the attribute (or statistical / non-locational) element (Maguire 1991). Ervin and Hasbrouck (2001) note that the GIS databases are typically structured so as to clearly separate the geometrical (geographical) data from the attribute data. It is the discreet, but linked, nature of the data elements that underpin the capacity of GIS to apply spatial and statistical analysis of attribute and geographic information (Zeiler 1999; GIS Lounge 2004). Maguire (1991) observes that GIS could (in part) be considered a subset of four predating systems, namely: CAD, Database Management Systems (DBMS), Computer Cartography and Remote Sensing (Figure 3.4). A key aspect of GIS, not usually included in the above four systems, is the importance placed on analytical functions; and Maguire (1991) notes Goodchild's (1988) observation that the capacity for spatial analysis is often seen as a defining element of GIS and that which differentiates GIS from other mapping systems (Goodchild 1988:67 cited in Maguire 1991:13).

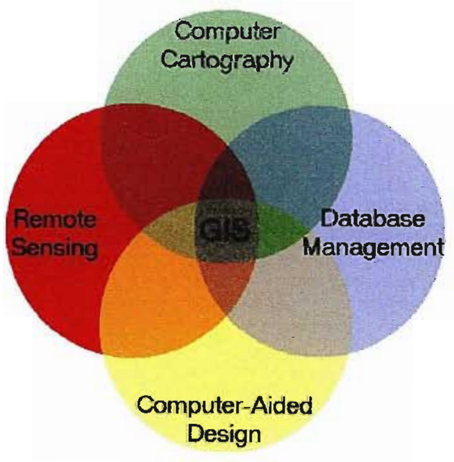


Figure 3.4. Relationship between GIS, CAD, Computer Cartography, DBMS and Remote Sensing Information Systems. Adapted from Maguire (1991).

As with CAD, there are a large number of GIS applications (of differing complexity, sophistication, ability and cost) catering for a wide range of disciplines including cartography, agriculture, forestry, land planning and management, natural resource management, urban planning, civil engineering, surveying, hydrology, geology, geography, mining, archeology, and environmental science / management. A GIS could therefore be classified (or customised) according to the intended application (Maguire 1991) e.g.

Cadastral Information Systems	Image Based Information System
Land Data Systems	Geographically Referenced Information Systems
Natural Resource Management Systems	Market Analysis Information Systems
Multipurpose Cadastres	Planning Information Systems

Soil Information Systems	Spatial Information Systems
Spatial Decision Support Systems	Urban Information Systems

Some GIS programs partially meet the criteria required for a landscape visualisation and participatory decision support process in that:

- They are inherently physically based, as they are founded on real-world geographic data, and accordingly can be considered to be scientifically defensible.
- Most GIS utilise database technology that is accessible, well understood (if not standardised), programmable and modifiable. They are, therefore, well suited to the storage, processing, analysis and feedback of data, as well as the integration of external data.
- Although the output of most GIS is two-dimensional in nature, some GIS can, through a process of 'draping' images over a DEM, generate limited three-dimensional terrain models, thereby enabling the generation of viewsheds from different static viewpoints. Dynamic changes of viewpoint, usually through technology such as VRML, are also feasible, although restrictions on the level of detail may apply in the case of large and / or complex models.

However, most GIS programs fail to meet one of the most important criteria required for a landscape visualisation and participatory decision support process – that of realistic image generation; as the process of 'image draping', which can produce good results in large-scale perspective views, is limited in its ability to generate realistic low-level localised perspective views as a result of:

- A tendency to generate coarse pixelisation in the foreground (Berry *et al.* 1998), in addition to revealing the coarseness of the underlying geometry at high levels of magnification (McLure and Griffiths 2002).
- An inability to convey height detail in the absence of underlying geometry – buildings and trees are mapped onto the ground surface (McGaughey 1997).

The limited three-dimensional nature of GIS-generated 'draped' images, and the complexity of data represented, can make it difficult for experts and non-experts alike to understand and objectively evaluate complex three-dimensional spatial relationships. Furthermore, the lack of realistic visual detail can hinder or limit understanding and evaluation of visual relationships between proposed developments, restorations or reclamations and existing buildings, vegetation, water bodies and landforms. Consequently, the value of GIS generated images for visual impact studies, public participation and stakeholder consultation within environmental decision-making may be limited. Mayall and Hall (1994) observe that GIS derived landscape models are of little use in visual resource planning; and Faust (1995) suggests that the usefulness of draped images is limited to 'show and tell'. Figures 3.5 and 3.6 demonstrate the coarse pixelisation and flattening of three-dimensional details when the camera viewpoint in a 'draped' image is moved from overhead to a low-level perspective.

Figure 3.5. Aerial photograph showing factory buildings 'draped' over a DEM. Sourced from Photogrammetry Branch of eThekwini Municipality (2004).

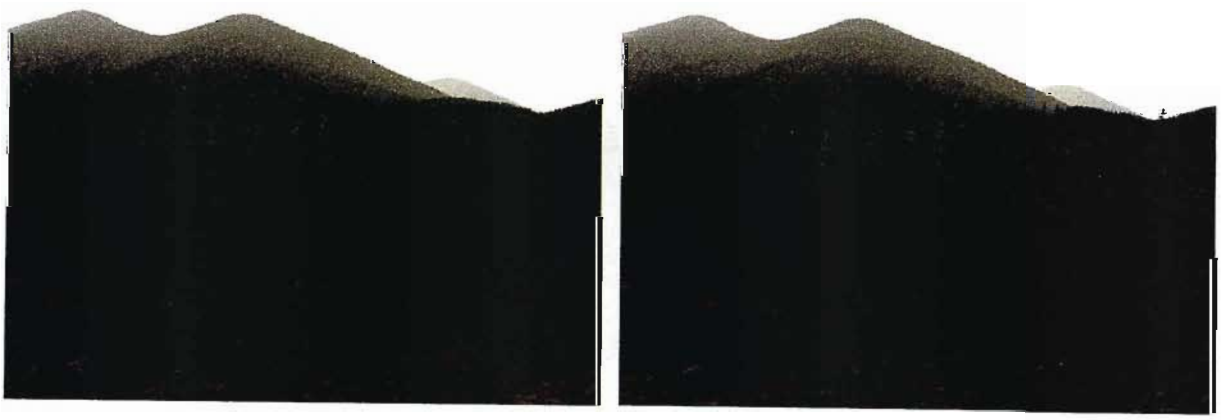
Figure 3.6. Coarse pixelisation of foreground and flattening of the factory buildings arising from a change of viewpoint to a low - level perspective.

3.5 Synthesis and Convergence

Ervin (1995) observes that the underlying theoretical basis and practical applications of CAD and GIS have, in the course of their evolution, diverged over the past three decades. CAD is often perceived as a 2D / 3D drawing and design tool for architects and engineers, while GIS is viewed as a mapping, planning and spatial analysis technology (Ervin 1995; Bohnenstiehl 1999). However, such generalisations fail to acknowledge the strengths and opportunities offered by both software categories in landscape visualisation. GIS offer geographical databases and comprehensive data capture, query, analysis and manipulation tools. Some CAD systems, particularly those with strong 3D modelling capability, can provide higher-level 3D geometrical capabilities such as surfaces-of-revolution and non-rational uniform b-splines (NURBS); while specialised modelers and renderers offer advanced computer graphic techniques such as fractal geometry, particle dispersion, advanced lighting, texture, bump, environment and reflection mapping, Phong shading, procedural surface simulation, z-buffering, camera and atmospheric controls, ray-tracing and radiosity. The potential for photorealistic landscape visualisations derived from GIS data has been noted by researchers (Berry *et al.* 1998; Doyle, Dodge and Smith 1998; Bohnenstiehl 1999; Thurston *et al.* 2001); and a number of studies have explored and documented the technical processes required to transfer GIS data to terrain modeling / visualisation applications in order to model and generate realistic images. Many of the earlier studies required a number of intermediate steps, usually facilitated by custom software, to process the GIS data - e.g. Mayall and Hall (1994), Berger, Meysembourg, Sales and Johnston (1996); while modelling and final rendering were usually undertaken on powerful (and expensive) Unix based workstations – e.g. Bishop and Karadaglis (1997), Bishop, Wherrett and Miller (2001). The focus of these studies was on generating photorealistic images and, in Bishop and Karadaglis's (1997) study, the evaluation of interaction between viewers and virtual landscapes. Dynamic interaction between visualisation and underlying GIS data was however precluded by the number of steps required to transfer the GIS data, as well as the computer processing capacity of the relatively slow modelling process.

3.5.1 Three-Dimensional Photorealistic Visualisation Tools

Appleton *et al.* (2001) and Ghadirian and Bishop (2002) observe that three-dimensional photorealistic visualisation tools have historically been utilised in urban environments, military simulations (Pérez *et al.* 1998), the entertainment industry (Ervin and Hasbrouck 2001) and in forestry for the purpose of mitigating the visual impact of tree harvests (McGaughey 1997) and the visualisation of "alternative forest management practices and the results of growth model projections" (McGaughey 2004 *pers. comm.*). Figures 3.7 and 3.8 show visual impact studies of tree harvesting modeled with Vantage Point (Cooperative for Forest-Systems Engineering 1996).



Figures 3.7 and 3.8. Harvest treatment proposal for Plum Creek Carbon River Project. Modeled with Vantage Point (Cooperative for Forest-Systems Engineering 1996). Sourced from Ulbricht (1994).

Recently there has been a trend towards a convergence of GIS and 3D visualisation software (Sheppard 1999; Limp 2000; Lovett, Sünnenberg, Appleton, Dockerty, Dolman, Cobb and O'Riordan 2002), which is exemplified by new software applications capable of direct utilisation of GIS, CAD and DEM data to generate detailed photorealistic viewsheds; thereby reducing the number of steps, and the amount of time-consuming work, necessary to generate photorealistic images that would otherwise be required by processing GIS data through conventional CAD and modelling software. Available software for PCs - which varies in complexity, features, quality and realism of output, and price - includes *'Visual Nature Studio'* (3D Nature 2004), *'Genesis II'* (Geomantics Software 2004) and *'Natural Scene Designer Pro'* (Natural Graphics 2004). The most sophisticated of these (*Visual Nature Studio*) allows for the importation of GIS data in most projections and datums, and supports a range of commonly used CAD, multi-resolution DEM and geo-referenced raster formats. Ecological, geomorphological and hydrological parameters such as foliage height, density, and colour, terrain colour and lake elevation can be dynamically controlled by GIS data attributes. Boolean search-queries allow selection and interrogation of objects based on attributes. Complex overstory and understory ecosystem combinations can be simulated; and the 'Rules of Nature' ™ feature allows variables such as sun and wind directions, water drainage and altitude to simulate vegetation growth and placement as it occurs in nature (3D Nature 2004).

3.5.2 Elements of Photorealistic Landscape Visualisation

Key elements of landscape visualisation, as abstracted from Wooley (2000), Ervin (2001), Muhar (2001), Ervin and Hasbrouck (2001) and Lange (2002) include landform, vegetation, water, lighting and atmosphere, buildings and people.

3.5.2.1 Landform

Landform (or terrain) data is usually sourced as a DEM, and may be converted and stored as a mesh, triangulated irregular network (TIN), patch, parametric surface e.g. NURB, or as a solid. The resolution of the DEM is an important consideration in order to avoid coarseness and / or artifacts if the grid size is too large, or increased file size, computer memory requirements and rendering time if the grid size is too small. *'Visual Nature Studio'* allows for the merging of DEMs of different resolutions, thereby facilitating varying level of detail (LOD) with high-resolution data in the foreground and low-resolution data in the background (3D Nature 2003b). Features such as rivers, roads, lakes, and berms are parametrically created through a process known as terraforming. Methods of texturing the landform may include:

- Multi-channel textures.

- Procedural textures
- High-resolution geo-referenced textures.
- Variable fractalisation displacement.
- Bump mapping.

3.5.2.2 Vegetation

Realistic vegetation is probably the most difficult and time-consuming element to model in a landscape visualisation. Real vegetation is both complex, consisting of trunks, branches, leaves and flowers, and diverse in respect of age and species (Muhar 2001); and whereas a building may be adequately represented by a few thousand polygons an individual tree may require hundreds of thousands (if not millions) of polygons to achieve realism (Ervin 2001). Two commonly used methods of modelling vegetation include:

- The mapping of textures onto vertical intersecting planes – known as 'billboards'. This technique has the advantages of simplicity and photorealism, but cannot be utilised for aerial views. 'Billboarding' is best used for mid-ground and background vegetation.
- The use of specialised vegetation modelling software (Figure 3.9) which utilise algorithms - e.g. L-systems (Prusinkiewicz and Lindenmayer 1990) and the Atelier de Modelisation et d'Architecture des Plantes (AMAP) system (Jaeger and deReffye 1992) - to describe and generate vegetation. Examples of vegetation modelling software include L-systems based *'Xfrog'* (Greenworks Organic-Software 2004) and *'Onyx Tree-Pro'* (Onyx Computing 2004); and AMAP based *'Orchestra'* (Bionatics 2004).

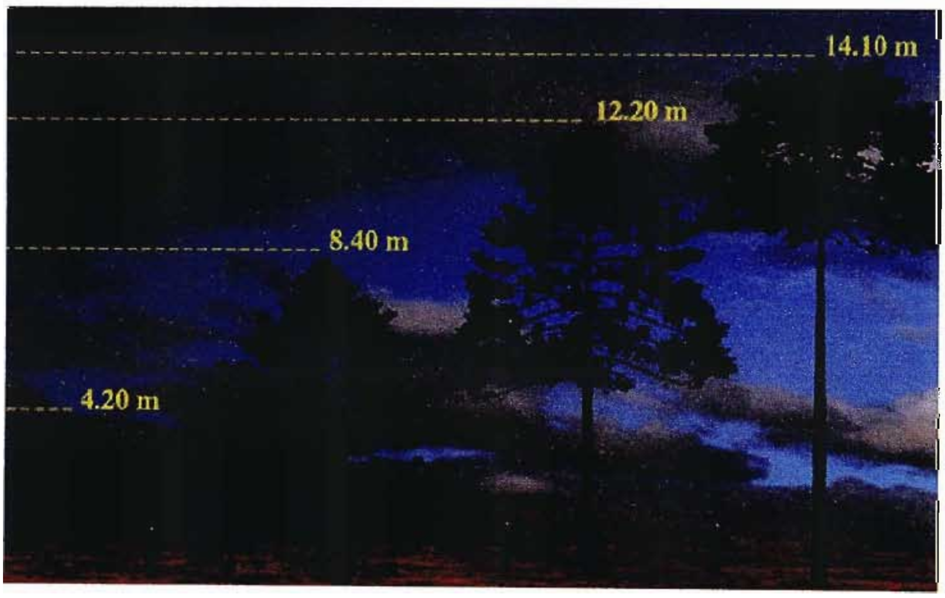


Figure 3.9. Stages in Pine Tree growth modeled with AMAP based software. Adapted from Stephane Gourgot (Ervin and Hasbrouck 2001).

Vegetation models generated by the above-mentioned software have the advantage of being fully three-dimensional, and can be viewed from any angle. Disadvantages include:

- High polygon counts. Deussen, Hanrahan, Lintermann, Radomír, Pharr and Prusinkiewicz (1998) have, however, described how the techniques of 'instancing' and selective geometrical simplification can substantially reduce file size; and were able to reduce their 'mountain meadow' ecosystem example, which consisted of eight herbaceous species represented by 102 522 plants, from an estimated file size of 200 Gigabytes to 151 Megabytes – a compression ratio of approximately 1300:1.
- The necessity to learn a new modelling system.

A potential limitation of both 'billboarding' and algorithm driven modelling systems is the necessity (with some visualisation programs) to import the vegetation data. Modern CAD / modelling data formats make this a relatively simple task; however, unless a variety of species of different ages are modelled and imported, dynamic interaction with vegetation data will be limited. Visual Nature Studio does allow vegetation (and other) parameters to be dynamically controlled by GIS data attributes.

3.5.2.3 Water

The realistic rendition of water may require a variety of applied effects. Still water, as in a slow moving river or lake, will require layered transparency, reflection, reflectivity and refractivity texture maps. Mist and spray respectively may be created by procedural textures and particle systems. Dynamic water movement such as ripples, waves, waterfalls are best achieved with physics-based models (Ervin and Hasbrouck 2001) such as the plug-in effect generators sold by Areté (Areté Entertainment Inc. 2002).

3.5.2.4 Lighting and Atmosphere

Lighting and atmosphere respectively play an important role in determining how the landscape is perceived, and the emotive qualities invoked (Ervin and Hasbrouck 2001). Most landscape visualisation software, including *'Visual Nature Studio'*, provide the necessary tools to implement and control lighting / atmospheric effects. Four sources of landscape lighting include sunlight, ambient (diffuse) light, moonlight and artificial light.

- Sunlight, which is the primary light source for most landscape visualisation, is a distant light source with parallel rays. The sun's position, and consequently the size and direction of cast shadows, varies according to latitude, longitude, season and time of day. Photorealistic visualisation requires that the sun's position be accurately calculated, either within the software, or by external means. Colour temperature can also vary from approximately 6500 Kelvin at midday to 2200 Kelvin at dawn / sunset.

- Ambient (or diffuse) lighting is light that has been reflected or scattered by the atmosphere or landscape; and provides the illumination for those parts of a three-dimensional object which are not directly lit by the sun - i.e. the shadowed areas.
- Moonlight is similar in nature to sunlight, except that it is at a much lower intensity. Colour muting may be necessary to simulate scotopic vision.
- Artificial lighting may be simulated either by using self-illuminating materials, or by placing spotlights / floodlights within the scene.

Shadows are important as they assist understanding of the shape of three-dimensional objects, and relationships between objects. Visualised objects rendered without shadows often appear to 'float' (*pers. obs.*). Shadows are computationally expensive to generate, and techniques such as shadow mapping may be used to reduce rendering time. Clouds contribute towards realism in the scene, and may be generated either by texture maps or by procedural textures. Haze and fog may be created either by particle systems or by procedural textures.

3.5.2.5 Buildings and Structures

Buildings are often an important part of the landscape and their placement, together with other structures such as lampposts, bridges and cars, provides information and context (Scheepers 2001). Models of new buildings are often available in a CAD data format, and their importation into a visualisation program is usually without difficulty. However, the commonly used Autodesk Data Exchange Format (DXF) is both limited and unreliable, and more versatile modelling formats such as *'3D Studio'* (.3ds); *'LightWave'* (.lwo) or *'Wavefront'* (.obj) should be used in preference (*pers. obs.*). Existing and older buildings, for which there are no CAD models, will either have to be modeled within the visualisation program or a CAD program.

3.5.2.6 People

Lange (2002) notes that people and animals are often left out of landscape visualisations, an important omission as:

- Both play a role in shaping the landscape (Ervin and Hasbrouck 2001).
- Their presence (or absence) affects human perception of the landscape.
- Use of the human figure provides a visual sense of scale (Figure 3.9).

Modelling of people and animals may, in a manner similar to that of vegetation, be undertaken by means of 'billboards' or specialised modelling programs such as *'Poser'* (Curious Labs Incorporated 2004).

3.6 Realism and Ethics

Improved processing capacity, storage and graphical output of computers (particularly PCs); research, development and application of computer graphic techniques in visualisation; and increased access to an extensive variety of data (including DEMs and digital satellite / ground imagery) over the past three decades has made it possible for researchers, land planners, natural resource managers, landscape designers and environmental consultants to generate increasingly more realistic visualisations (Sheppard 2001; Appleton and Lovett 2003). Orland, Budthimedhee and Uusitalo (2001) observe that data-driven visualisation is fast replacing non-graphical / verbal information in public participation processes and environmental impact statements[9], and warn that the adoption and usage of computer-based visualisation may be outpacing the level of understanding required to implement and evaluate its application. Limp (2000) and Sheppard (2001) note the powerful influence of visualisation on perception and decision making; a point Sheppard (2001) suggests is well understood and appreciated by the entertainment business and advertising industries. Luymes (2000) observes that realism inculcates an assumption of accuracy, dependability and knowledgeableness in the preparer (Luymes 2000 cited in Sheppard 2001); and Orland *et al.* (2001) suggest that highly believable images may imbue confidence in the visualisations by planners and managers, thereby limiting critical discernment and possibly even the identification of errors. Sheppard (2001) observes that inherent in the powerful influence of visualisation is the potential to mislead viewers, and suggests several possible causes:

- Inadequate data.
- Mode of presentation.
- Budgetary constraints.
- A natural tendency by developers, and some professionals, to present their proposals in the best possible light.

[9] The National Environmental Policy Act (US) and the Development Control Process (UK) identify aesthetics, natural scenic beauty, and potential visual impacts of proposed developments as elements that must be considered in Environmental Impact Assessments. Major developments require that a Visual Impact Assessment be undertaken. (Macaulay Land Use Research Institute 2004b).

Sheppard (1999; 2001) argues that, given the risks of the expanding but unstructured application of computer-based landscape visualisations in public participation and decision making, there is a need for a guidance and support framework for landscape visualisation including best practices, training, standards, appropriate databases, networking, and a code of ethics. In his *'Proposed Interim code of Ethics for Landscape Visualization'* (Appendix 3: Figure 1) Sheppard (2003) proposes six general principles that all types of landscape visualisations (traditional and computer-based) should adhere to, namely:

- Accuracy – simulation of the actual or expected landscape appearance.
- Representativeness – representation of typical or important landscape views / conditions.
- Visual clarity – clear communication of detail, components and overall content.
- Interest – engagement and holding of audience interest.
- Legitimacy – defensible processes and demonstrable accuracy.
- Access to visual information – visualisations and associated data should be publicly accessible.

3.7 Areas for Further Research

Wherrett (2000), Daniel and Meitner (2001), Ervin (2001), Orland *et al.* (2001) and Sheppard (2001) acknowledge the need for more research into aspects of computer-based landscape visualisation. Ervin (2001) argues that in the course of landscape modelling, a balance must be found between 'looks like' image generating models and 'acts like' physically based inferential models; and suggests nine areas of further research:

1. **Physical laws and systems.** Landscape modelling is heavily dependent on a number of sciences including: geography, geology, botany, silviculture, hydrology, architecture, engineering, zoology, sociology, psychology, surveying and remote sensing. The challenge will be to understand, determine, extract, model and incorporate that knowledge which is relevant.
2. **Sheer size and magnitude of models.** The size and magnitude of landscape models has been a challenge in all fields of computer-based visualisation including entertainment, aerospace and military simulations. No matter how powerful computers become, modelling the real landscape, for the foreseeable future, will require more resources than are available. Consequently a number of techniques, short cuts and work-arounds have been devised to

implement 'looks-like' solutions. The challenge will be to devise and incorporate similar solutions for 'works-like' models.

3. **Resolution and level of detail.** A considerable amount of computer processing time is spent rendering details that can barely be seen e.g. background elements in landscapes. The challenge will be to devise or improve algorithms / techniques that address levels of detail for different visualisation usages i.e. photorealism, virtual environments, etc.
4. **Complexity, interrelationship and interaction.** Landscapes tend to be very complex with many interrelationships and interactions between its various elements. Ervin (2001) notes that existing algorithmic and data-structuring techniques that support the organisation, construction and representation of complex interrelationships, as well as processing techniques such as 'cellular automata', are not yet integrated into landscape modelling.
5. **Dynamics.** Dynamics within the landscape can be categorized as:
    a. Movement through the landscape. Virtual reality technology - e.g. VRML - that facilitates movement though the landscape is available, although Ervin (2001) notes that it can be unconvincing.
    b. Movement of the landscape. The scale of landscape movement can range from the instantaneous, through seasonal, to the glacial. Apart from trees and leaves blowing in the wind this problem has not been addressed in landscape modelling.
    c. Interaction with the landscape. Ervin (2001) notes that the necessary theoretical, empirical and technical knowledgebase has yet to be understood and developed.
6. **Objects vs. fields.** Most available software programs are 'object-oriented', and few address the tedious, time-consuming and computationally expensive problem of placing large numbers of objects (fields) - e.g. individual trees vs. VNS's parametrically driven ecotypes (Hanson 2005 *pers. comm.*).
7. **Abstraction levels.** Digital models need to be able to generate images other than the purely photorealistic - i.e. they should facilitate abstraction of filtered data for inferential purposes.
8. **Knowledge of human perceptual systems.** Although there is a growing body of knowledge on this subject (cf. 3.1), there is a need for more research - e.g. Daniel and Meitner (2001:70) have shown that photorealistic visualisations can "provide precise and valid indications of human observers' responses to the environment represented"; but more studies are required to determine appropriate levels of realism for different purposes (i.e. emotive vs. cognitive studies) in other environments – e.g. urban, rural, etc.
9. **Computer science and algorithms.** Existing (and future) computer-based landscape visualisation is dependent on computer science, particularly algorithms and computer

graphic techniques. Ervin (2001) argues that it is incumbent upon digital landscape modelers to become more aware of the technical and scientific nature of their medium.

3.8 Conclusion

Orland *et al.* (2001) and the Macaulay Land Use Research Institute (2004c) describe visualisation as a universal form of communication or 'common currency' that utilises abstractions of the real world, within a decision support system, through which the impacts of a proposed development can be made comprehensible to experts and non-experts alike; and which offers opportunities for holistic, non-linear and dialogic participation. Orland *et al.* (2001) note that the 'essential currency' of participatory landscape planning is not the store of ecological, visual, recreational or economic benefits within and / or accrued by the environment; but rather comprises "access to and transfer of information that illuminates natural and social system interactions" (Orland *et al.* 2001:142). Although much research on the technical and human perceptual aspects of visualisation has been undertaken by academia and the military / aerospace / entertainment industries, the nature and manner of processing the data utilised in participatory landscape models requires further consideration and study. Ervin (2001) observes that landscape modeling is heavily dependent on input from a wide range of sciences; and Orland *et al.* (2001) argue that qualitative and quantitative decision aids must be integrated into decision support systems in order to facilitate voting, ranking and group interaction, thereby enabling citizens and general public to establish the levels and mixes of development activities compatible with their environmental goals.

Prior to the mid 1990s production of highly realistic computer generated landscape visualisations could only be seriously contemplated on expensive high-end workstations such as those used in flight / military simulations and the entertainment industry. Consequently simulations of the environmental impacts of development projects, and public input therein, were limited. The advent of powerful low-cost microcomputers, the development of sophisticated modeling and visualisation tools, and improved access to digital terrain data through mediums such as the Internet, has brought landscape visualisation within reach of a wide range of environmental professionals. Expansion of the user base will, in turn, broaden the range of application, thereby spurring the development of more powerful modeling and visualisation tools. The growth of communication mediums such as the Internet may, in time, facilitate fully interactive public participation and feedback in landscape planning.

Chapter Four discusses the application of landscape visualisation technology as a tool in a participatory decision support system, for an urban greening research project, in a low-cost high-density housing settlement. This section describes the study area, including the topography and biological environment, as well as data preparation, proposed data processing and image evaluation.

Chapter Four
Study Area and Methodology

The housing project used in this urban greening study is the low-cost high-density Mount Royal Reconstruction and Development Housing Project in the eThekwini Municipality. Unless otherwise cited all information on the study area is derived from the *'Environmental Impact Scoping Report for Mount Royal Redevelopment Project'* (SA Environet 2003).

4.1 The Study Area

4.1.1 Location

The study area is approximately ten kilometers north of Durban, at 29° 44' 13" S, 31° 00' 35" E. The area lies southeast of the Phoenix Industrial Park, and northwest of Mount Moriah, on the northern side of Main Road M25 to KwaMashu. The housing project is approximately sixty-four Hectares in size (Figures 4.1 and 4.2).

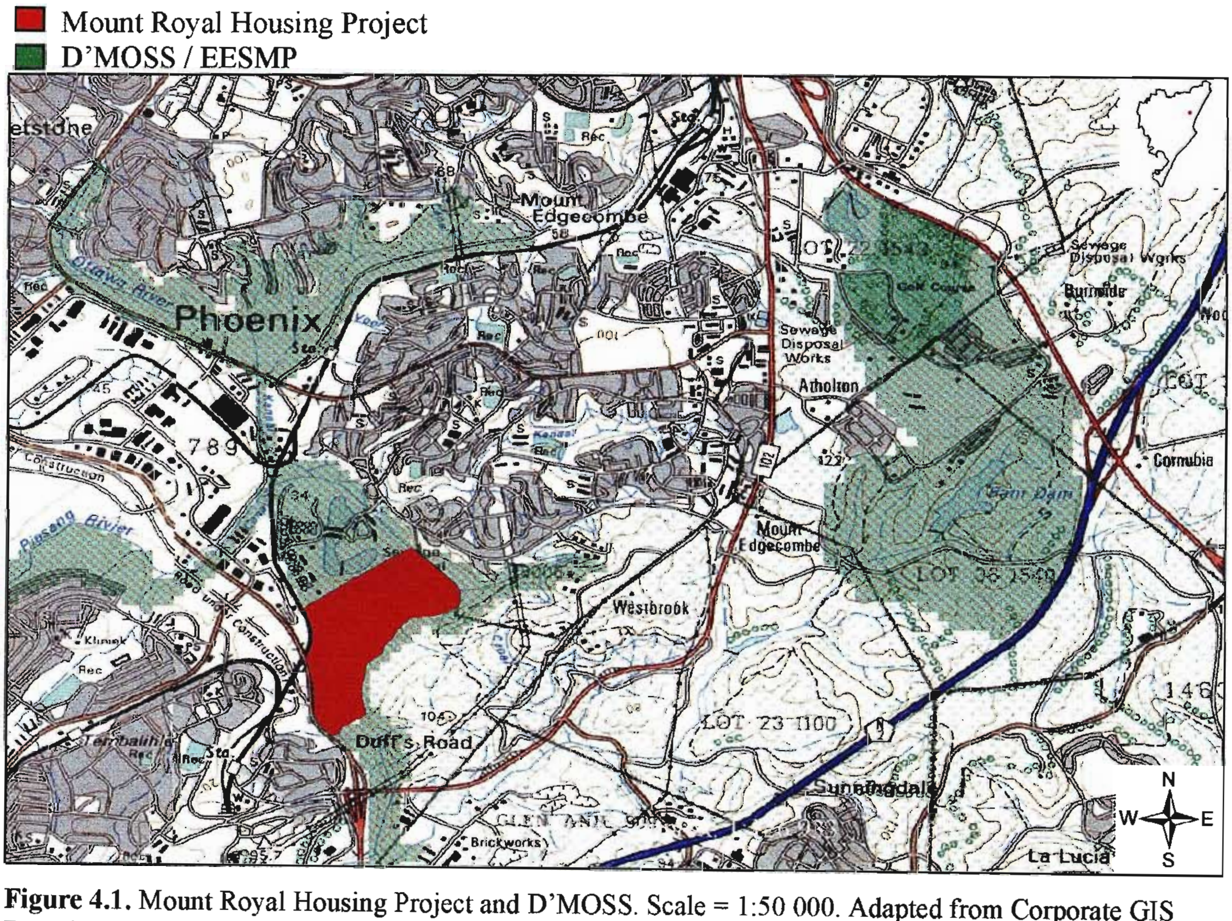


Figure 4.1. Mount Royal Housing Project and D'MOSS. Scale = 1:50 000. Adapted from Corporate GIS Branch of eThekwini Municipality (2005) and Chief Directorate : Surveys & Mapping (2002).

Figure 4.2. Close-up of Mount Royal Housing Project Area. Scale = 1:10 000. Sourced from the Photogrammetry branch of eThekwini Municipality (2004).

4.1.2 Purpose and Nature of the Proposed Housing Project

The main aim of the housing project is to develop high-density low-cost residential accommodation and thereby reduce the number of inhabitants in the crowded L-Section of KwaMashu. Table 4.1 details the proposed number of units and Hectares utilised, and figure 4.3 shows the proposed layout of the Mount Royal Housing Project.

Table 4.1. Proposed number of units, purpose, and Hectares utilised for the Mount Royal Housing Project. Sourced from Environmental Management Branch of eThekwini Municipality (2003).

Purpose	No. of Units	Ha. Utilised	% of Total
Special Residential Sites	977	26.4906	41.28
Crèche	2	0.2623	0.41
Places of Worship	1	0.2584	0.40
Minor shopping	1	0.0995	0.16
General Shopping	2	0.6084	0.95
Municipal	1	0.1100	0.17
Cultural and Entertainment	1	0.3153	0.49
Education	2	2.8684	4.47
Public Open Space	11	26.0445	40.58
Roads		7.1158	11.09
		64.1732	**100**

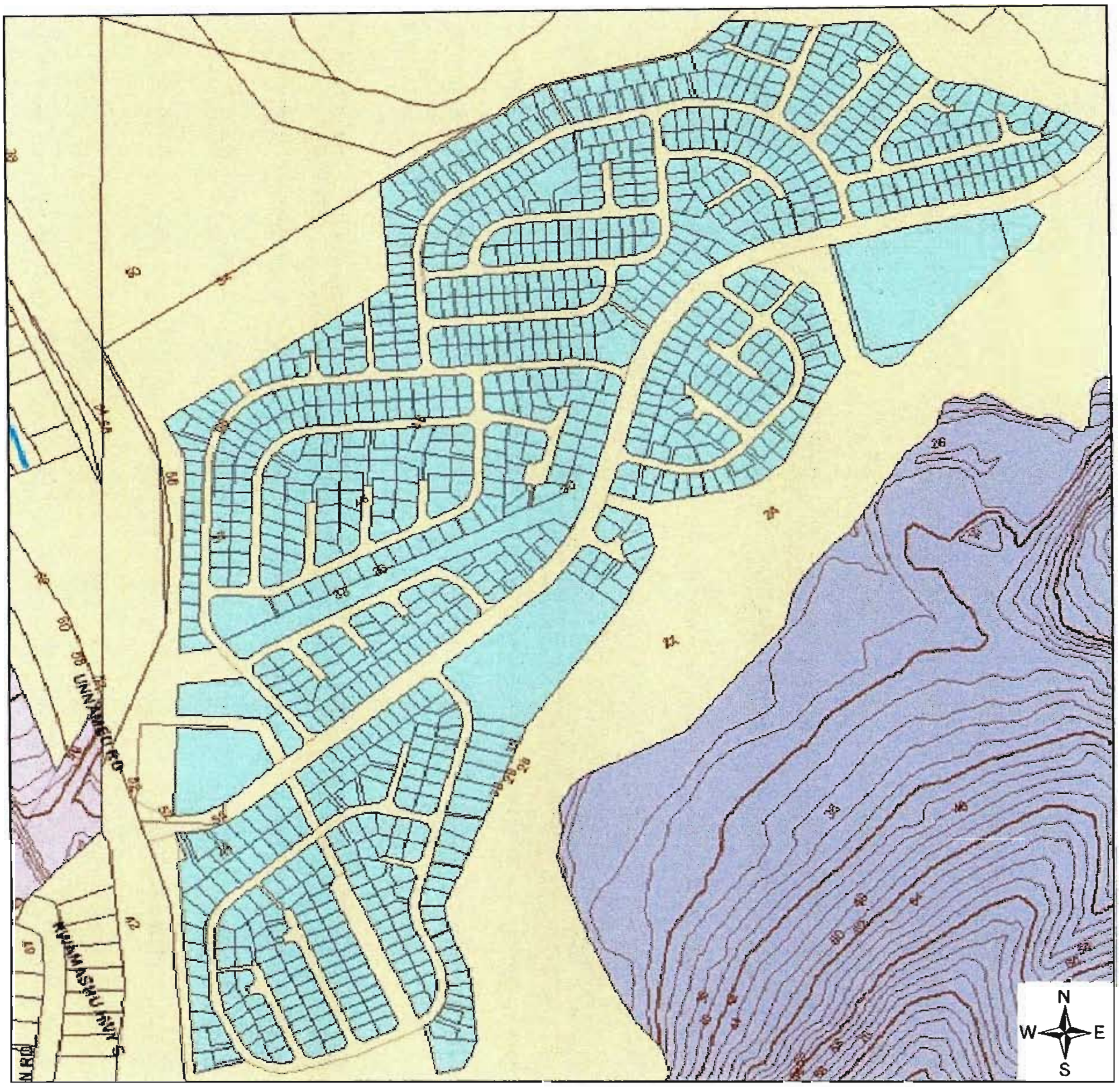


Figure 4.3. Proposed layout of the Mount Royal Housing Project. Scale = 1:6 000. Sourced from eThekwini Municipality (2004).

4.1.3 Topography

The topography of the area comprises of shallow slopes on the higher ground facing southeast towards the Little Umhlangane River. These slopes gently adjoin two floodplains at the upper and lower ends of the river section, whereas the gradient at the mid-section of the river is steeper. Properties on the opposite (southeastern) side of the river comprise of steep slopes that oppose the floodplains, and a shallow incline at the river mid-section.

4.1.4 Biological Environment

The high ground has been extensively grazed, and is dominated by contiguous cover of a limited number of grass and forb species. There are only a few small trees present on high ground. The river valley consists of intensively grazed floodplains, riverine scrub, reed beds and the river; and is dominated by alien invasive plant species (Mattson 2004 *pers. comm.*). On the opposite side of the river the steep slopes are covered with dense woodland and scrub. The river is approximately five metres wide, and fifty centimetres deep. Water quality is characterised as good with fish, tadpoles and macro-invertebrates present. An abundance of birds, monkeys, reptiles, rodents, mongoose and five species of butterfly inhabit the area. Some thirty bird species were observed in the course of the scoping exercise (Appendix 4: Table 1) and many more species are known to be present in the area. The Mount Royal Scoping Report observes that:

- The study area, particularly the river and riparian areas, constitutes a refuge for flora and fauna in an increasingly fragmented urban environment.
- The riverine habitat is comparatively rich in biodiversity, has high conservation value, and is irreplaceable.

The Record of Decision (ROD) (Provincial Department of Agriculture and Environmental Affairs 2003) notes the likely presence of three Red Data Species (International Union for Conservation of Nature and Natural Resources 2004) in the study area - namely Black-headed Dwarf Chameleon *(Bradypodion melanocephalum)*, Corn Crake *(Crex crex)* and Pickersgill's Reed Frog *(Hyperolius pickersgilli)*.

4.1.5 Environmental Impacts of the Construction Phase of the Proposed Housing Project

The Mount Royal Scoping Report (SA Environet 2003) notes the following potential impacts of the construction phase of the proposed housing project on the high ground (Figure 4.4) of the study area:

- Construction will negatively affect the local biophysical environment, leading to the local extinction of some species. The Mount Royal Scoping Report notes, however, that this area is already severely affected by grazing.
- Leveling and terracing will destroy vegetation and animal habitats. Soil will be exposed to wind / water erosion, and could lead to siltation down-slope and in the riverine area.

Figure 4.4. Housing and road construction on the high ground of the Mount Royal Housing Project. September 17, 2004.

Potential environmental impacts resulting from leveling, terracing and construction in areas close to the river (Figure 4.5) could include:

- Potential erosion of steep slopes near the river, resulting in siltation of the riverine area.
- Negative aesthetic impacts greater than those of construction on the higher ground.
- A loss of habitat, and further negative aesthetic impacts, if sand is extracted from the riverine area.

Figure 4.5. Leveling and terracing in an area close to the river. September 17, 2004.

4.1.6 Socio-Economic Impacts of the Proposed Housing Project

The Mount Royal Scoping Report (SA Environet 2003) notes that present usage of the area includes livestock farming, fire wood and reed harvesting, hunting, bathing and outdoors recreation. All of these activities rely on the biological resources of the area. The Scoping Report also records that the area has considerable potential for outdoor recreation including bird and wildlife watching, jogging, photography, relaxation and picnicking.

4.1.7 Recommendations of the Mount Royal Scoping Report

Recommendations of the Mount Royal Scoping Report include:

- That either an Environmental Impact Assessment (EIA) should be undertaken, or an Environmental Management Plan (EMP) be implemented for the area.
- That sand should not be extracted from the river.

4.1.8 Conditions of the Record of Decision

Noting the possible presence of Red Data Species in the area, a condition of the ROD was that the development footprint be kept twenty metres above the 1:100 year flood line (Provincial Department of Agriculture and Environmental Affairs 2003). This condition, which was appealed by the eThekwini Municipality, was later rescinded on the basis of a verbal agreement between Ezemvelo KZN Wildlife and eThekwini Municipality made in the course of a site visit (Roberts 2004. *pers. comm.*). This agreement undertook to:

1. Ensure the resilience of the open space system.
2. Ensure the viability of Red Data Species.

A further condition of the ROD was that an EMP be prepared and implemented by eThekwini Municipality.

4.1.9 The Need for Urban Greening in the Mount Royal Housing Project

The biodiversity and conservation value of the riverine habitat has been noted in the Mount Royal Scoping Report, as well as the Record of Decision (cf. 4.1.4). Roberts and Diederichs (2002:116) note that the Umhlangane River, which flows to the South East of the study area, forms "one of the major ecological corridors of D'MOSS". The relocation of 977 low-income households, many of whom will be reliant on local biophysical resources, to the Mount Royal Housing Project, will almost certainly have a negative impact on the limited vegetation, habitat and biodiversity of the area. In their report *'Environmental Management and Urban Greening-Agriculture of Housing Projects in eThekwini -The Mt. Royal Housing Development'* Mattson and Nichols (2003) restate Sorensen *et al.* (1997) when observing that "Durban is typical of large, rapidly growing cities in that the urban poor usually reside on marginal, environmentally sensitive land, and often face the greatest exposure to urban environmental hazards" (Sorensen *et al.* 1997:5 in Mattson and Nichols 2003:1). They also note "that efforts to protect the open space / D'MOSS components of Mt. Royal are unlikely to take root if residents are also not afforded opportunities to improve their own immediate environments. Should such approaches become common, then they will enhance the D'MOSS footprint in areas where this is needed most" (Mattson and Nichols 2003:1).

4.2 Methodology

4.2.1 Data Collection

A 2D cadastral file, geo-referenced aerial photography and a Digital Elevation Model (DEM) showing the Mount Royal Housing Project and surrounding area were obtained from the Photogrammetry Branch of eThekwini Municipality. The DEM, which is based on five metre contours (Transverse Mercator with a central meridian at 31 degrees East, WGS 84 datum), was supplied in DXF and XYZ format. A detailed site survey plan (Transverse Mercator with a central meridian at 31 degrees East, WGS 84 datum) showing half metre contours, fifty / one hundred year flood lines, location and elevation of houses, and location of roads and underground services was supplied in DXF format by JC Martin Surveys. CAD drawings of similar projection and datum showing the positions of electrical poles and pole-to-pole overhead mains connections were supplied by the eThekwini Municipality electricity department. The study area was visited and measurements / photographs of one of the existing houses were made for the purposes of modeling and texturing. Most of the houses in the Mount Royal Housing Project are identical in size and shape, and vary only in colour.

The Environmental Control Officer (ECO) provided a list of trees (Mattson 2004 *pers. comm.*) suitable to the location (coastal forest biome), which was cross-referenced against riverine vegetation recommended by Guthrie and Wyatt (2000) and Wyatt (1997) for stream bank stabilisation and riparian areas, as well as street trees recommended by the eThekwini Municipality Parks Department's *'Tree Planting and Removal Policy'* (Kloppenborg, Ngcobo, Skweyiya and Sutcliffe 2003). Table 4.2 details the location of tree species utilised, and their habitat support (Breedlove and Nichols 1998).

Table 4.2. Location and habitat support of tree species utilised. Adapted from Breedlove and Nichols (1998).

Scientific Name	Common Name	Zone	Guild Support	Life Requisite Support				Attracts
				F	B	N	R	
Acacia karoo	Sweet thorn	1,2,3	Canopy	4	3	5	3	Birds, Insects, Mammals
			Trunk	4	1	1	3	Birds, Insects, Mammals
			Ground	4	1	1	1	Birds, Insects, Mammals
Acacia robusta	Splendid thorn	1	Canopy	4	3	4	3	Birds, Insects, Mammals
			Trunk	2	3	3	2	Birds, Insects, Mammals
			Ground	2	2	2	2	Birds, Insects, Mammals
Albizia adianthifolia	Flat-crown	2,3	Canopy	5	3	4	4	Everything
			Trunk	3	2	5	4	Everything
			Ground	5	2	3	1	Everything
Barringtonia racemosa	Powder-puff tree	1	Canopy	3	2	2	2	Birds
Bridelia micrantha	Coastal gold leaf	1,2,3,4	Canopy	5	3	3	2	Everything
			Trunk	3	3	3	3	Everything
			Ground	5	3	2	1	Everything
Celtis africana	White stinkwood	2,3,5	Canopy	3	4	3	3	Everything
Combretum erythrophyllum	River bushwillow	1,4						
Cussonia spicata	Common cabbage tree	3,5	Canopy	5	3	3	3	Everything
Ficus lutea	Giant-leafed fig	1						
Ficus natalensis	Natal fig	1	Canopy	5	4	4	4	Everything
			Trunk	3	3	4	4	Everything
			Ground	5	3	3	3	Everything
Ficus sur	Broom cluster fig	1,4	Canopy	5	4	4	3	Everything
			Trunk	5	3	3	3	Everything
			Ground	5	3	3	3	Everything
Ficus thonningii	Common wild fig	1	Canopy	5	3	3	3	Everything
			Trunk	4	3	4	3	Everything
			Ground	5	2	2	2	Everything
Harpephyllum caffrum	Wild plum	1,2,3,5	Canopy	5	4	4	4	Everything
			Trunk	3	3	5	3	Everything
			Ground	5	3	3	3	Everything
Millettia grandis	Umzimbeet	5	Canopy	3	2	3	2	Everything
Phoenix reclinata	Wild date palm	1	Canopy	5	3	4	3	Everything
Rauvolfia caffra	Quinine tree	1,4	Canopy	3	3	2	3	Everything
Strelitzia nicolai	Natal wild banana	2,3	Canopy	5	3	4	3	Everything
Syzgium cordatum	Water berry	1,2,3,5	Canopy	5	3	4	3	Everything
			Ground	4	2	2	3	Everything
Trichelia emetica	Natal mahogany	2,3,4,5	Canopy	3	3	3	3	Everything

Zone: 1=Stream bank; 2=Riparian area; 3=General area; 4=Main Road; 5=Medium and small roads
F B N R = Feeding, Breeding, Nesting, Resting (On a scale of 0 – 5, 5 has the highest usefulness).

Grasses utilised were those specified in the Mount Royal environmental management plan (Environmental Management Branch of eThekwini Municipality 2003). Tables 4.3, 4.4 and 4.5

respectively indicate the species of grasses, water plants and vegetables utilised. Time and resource constraints precluded a wider range of vegetation – particularly understory.

Table 4.3. Grasses utilised in the study

Scientific Name	Common Name
Chloris gayana	Rhodes grass
Digitaria eriantha	Common finger grass
Eragrostis curvula	Weeping love grass
Eragrostis tef	Tef grass

Table 4.4. Water plants utilised in the study

Scientific Name	Common Name
Phragmites australis	Common reed
Typha capensis	Bulrush

Table 4.5. Vegetables and crops utilised in the study

Scientific Name	Common Name
Brassica oleracea capitata	Cabbage
Colocasia esculenta	Amadumbe
Cucurbita maxima	Pumpkin
Daucus carota	Carrot
Lycopersicon esculentum	Tomato
Plectranthus esculentis	Livingstone potato
Spinacia oleracea	Spinach
Vicia faba	Broad bean
Zea mays	Maize

Images of the vegetation for the purposes of 'billboarding' were either photographed or sourced from van Wyk and Gerike (2000), van Wyk, van Wyk and van Wyk (2000), Venter and Venter (2002) and van Oudtshoorn (2004).

4.2.2 Data Preparation

The DEM provided by the Photogrammetry Branch of eThekwini Municipality was imported into *'Rhino 3D'*, from which a file containing 3D points was extracted. The site plan provided by JC Martin Surveys was imported into *'Rhino 3D'* and relevant data separated into discrete files – contours, house locations / elevations, sewers and drains, roads, and flood lines. The contours were assigned the appropriate elevation, and a file containing 3D points was extracted. The 3D point file based on eThekwini data was then merged in *'Rhino 3D'* with the point data from the site survey. Overlapping points from the eThekwini data were deleted, and a merged XYZ control point data file was generated. The XYZ file was imported into *'Visual Nature Studio'* (VNS) and a terrain was gridded using seven by four tiles (EW, NS respectively) at 240 columns by 250 rows per tile. The resultant DEM (Figure 4.6) contains 28 tiles, each tile covering approximately 25.08 hectares, with a grid cell size of approximately 2.04 metres (NS) by 2.06 metres (EW). The number of tiles, rows and columns (and consequently grid cell size) was arrived at after limited experimentation, with the intention of balancing the demands of DEM resolution / smoothness against those of available computer memory (two Gigabytes) and rendering times.

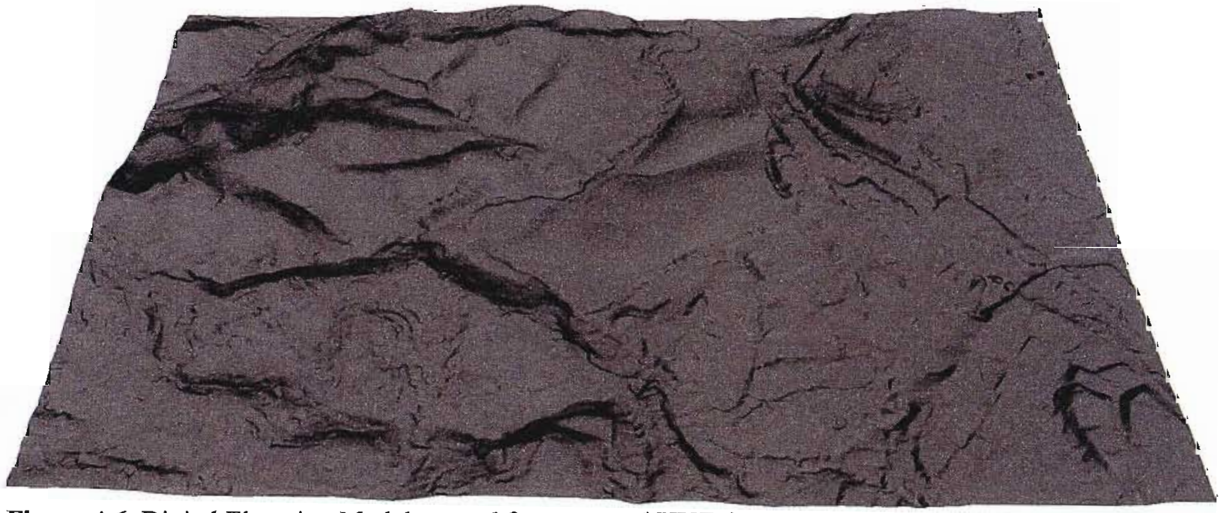


Figure 4.6. Digital Elevation Model created from merged XYZ data.

The geo-referenced aerial photography provided by the eThekwini Municipality Photogrammetry Branch was imported into VNS and 'draped' over the DEM for use as background textures (Figure 4.7).

Figure 4.7. Geo-referenced aerial photography draped over the DEM.

4.2.3 Proposed Modeling of the Housing Project

4.2.3.1 Houses, Roads, River and Electricity

Utilising the measurements and photographs taken on site one house will be modeled, textured and cloned in a CAD application with the purpose of creating three different coloured houses. Position and alignment vectors for the houses, and the house platforms, will be extracted from the site plan supplied by JC Martin Surveys, and imported into VNS. The houses will then be imported into VNS and cloned, positioned and aligned according to the above vectors. Area terraffectors leveling the terrain within a one and a half metre perimeter around each house will be produced in VNS from the house platform vectors. Vectors extracted from the site plan will also assist the creation of linear terraffectors for the roads and river, to which an asphalt ecosystem and stream effect will be applied respectively. Vectors indicating the position of electrical poles, and pole-to-pole / pole-to-house overhead mains connections, will be generated from the eThekwini Municipality electricity department plans, and imported into VNS in order to place electrical poles and overhead electrical main connections.

4.2.3.2 Ground, Ecosystem and Foliage

Aerial photography in the area encompassing the housing project, and a strip of ground on the far side of the Umhlangane River (Mount Moriah), will be replaced with a suitable fractal-based ground effect. Photographic textures of the vegetation listed in Tables 4.2 – 4.5 will require pre-processing prior to being imported into VNS. Polygons defining 'eco-zones' will be produced within Visual Nature Studio in order to facilitate the mass placement of in-stream, streambank, riparian and general overstory / understory vegetation. With the aid of a merged CAD drawing showing houses, roads, overhead electrical mains connections and underground services vectors will be generated in order to facilitate:

- The placement of private vegetable gardens and communal crops.
- The placement of street trees compliant with the eThekwini Municipality Parks Department's specifications for tree planting (Kloppenborg *et al.* 2003).

Species of street trees utilised shall, as far as possible, be the same as those used for the streambank and riparian areas. In order to introduce an element of incompletion or uncertainty some areas will be left clear of vegetation, thereby providing residents an opportunity to suggest how they might utilise the open space. A feature that is not part of the plans for the study area - e.g. a sports field - will also be included so as to encourage analysis and invite comment.

4.2.3.3 Sun, Shadows and Atmosphere

In order to generate accurate shadows the sun position shall be set to a date and time matching that of the general perspective photograph taken of the study area. Atmospheric haze will also be simulated to match that visible in Figures 4.4 and 4.5.

4.2.3.4 People

People will be modeled and imported into VNS so as to provide a sense of scale in the close-up renderings.

4.2.4 Proposed Data Processing and Image Evaluation

A variety of eye-level[10] and elevated[11] perspective renderings showing the housing settlement, open spaces and the river will be produced. A rendering matching the position and focal length of a photograph taken of the study area, from a suitable vantage point, will be generated to facilitate evaluation of the accuracy of the visualisations. Visualisations and questionnaires will be submitted to a selected number of experts from different disciplines and Mount Royal residents / neighbors for evaluation. The purpose of the expert survey shall be to assess the credibility and potential usefulness, to the experts, of photorealistic visualisation in decision support, and the communication of information to people inside and outside of their profession. Respondents will be asked to rate the level of confidence with which they could make decisions based on the computer generated imagery, their assessment of the long-term accuracy of the depicted urban greening, as well as the desirability of the depicted urban greening. They will also be offered the opportunity to make comments and / or suggested changes. Appendix 4: Table 2 lists the proposed experts, municipal departments and organisations to partake in the expert survey. The purpose of the resident survey shall be to evaluate the residents' perception of the potential of photorealistic visualisation as a participatory decision support tool in urban greening projects. Residents, and neighbors from overlooking suburbs, will be asked to rate:

- The desirability of the depicted urban greening in the river area and in the housing settlement.
- The extent to which the computer images provide sufficient information regarding the planting of trees and proposed use of open space.
- Their preferences for the utilisation of the open space between houses.
- The long-term accuracy of the depicted urban greening.
- The extent to which the computer imagery enables them to participate in the planning and discussion of urban greening.

Results of the surveys will be tabulated and, where appropriate, presented in a bar graph. Findings shall be discussed in context with the objectives stated in Section 1.8 of this dissertation.

[10] Camera elevation is approximately 2 metres.
[11] Camera elevation varies from approximately 50 to 90 metres.

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Personal Communications

Bedford, L.
Program Manager
Area Based Management and Development Program
City Engineers Building
166 Old Fort Road
Durban, 4001

Dell, S.
Secretary
The Botanical Society of South Africa
KZN Coastal Branch
PO Box 30544
Mayville, 4058

Dold, D.
Conservation Coordinator
WESSA
100 Brand Road
Glenwood
Durban, 4001

Hanson, C
3D Nature, LLC
13195 West Chenango Ave
Morrison, CO 80465
United States of America

Mattson, M.
PO box 393
St. Lucia, 3936

Mbadla, V.
eThekwini Parks Department
Mitchell Park
Morningside
Durban, 4001

McGaughey, B.
USDA Forest Service
University of Washington
PO Box 352100
Seattle, WA 98195-2100
United States of America

Mgingqizana, N.
Durban Solid Waste
188 Argyle Road
Durban, 4001

Naidoo, A.
eThekwini Parks Department
70 St Thomas Road
Durban, 4001

NewMarch, D.
197 Queen Elizabeth Avenue
Manor Gardens
Durban, 4001

Rich, J.
eThekwini Environmental Management Branch
City Engineers Building
166 Old Fort Road
Durban, 4001

Dr. Roberts, D.
Deputy Head:
eThekwini Environmental Management Branch
City Engineers Building
166 Old Fort Road
Durban, 4001

Appendix One

Table 1. The twenty most populous cities of the world: 2004. Sourced from Infoplease (2004)

Rank	City[1]	Population
1.	Shanghai, China	13,278,500
2.	Mumbai (Bombay), India	12,622,500
3.	Buenos Aires, Argentina	11,928,400
4.	Moscow, Russia	11,273,400
5.	Karachi, Pakistan	10,889,100
6.	Delhi, India	10,400,900
7.	Manila, Philippines	10,330,100
8.	Sao Paulo, Brazil	10,260,100
9.	Seoul, South Korea	10,165,400
10.	Istanbul, Turkey	9,631,700
11.	Jakarta, Indonesia	8,987,800
12.	Mexico City, Mexico	8,705,100
13.	Lagos, Nigeria	8,682,200
14.	Lima, Peru	8,380,600
15.	Tokyo, Japan	8,294,200
16.	New York City, U.S.	8,091,700
17.	Cairo, Egypt	7,609,700
18.	London, United Kingdom	7,593,300
19.	Teheran, Iran	7,317,200
20.	Beijing, China	7,209,900

1. Refers to the city proper, as opposed to an urban agglomeration, which would also count the surrounding urban areas in the total.

Table 2. Reconstruction and Development Project houses completed or under construction. Sourced From Department of Housing (2004b)

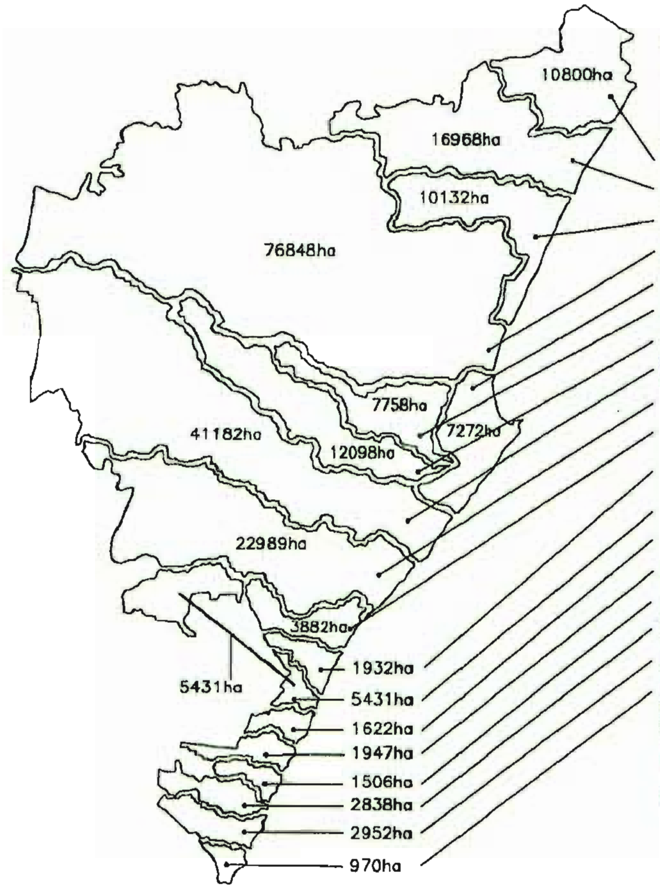
Houses Completed or Under Construction									
Province	Financial Years up to and Including March 2004								Total
	1994/95 to 96/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	
Eastern Cape	6,511	32,223	24,659	20,345	34,021	10,816	58,662	27,119	214,356
Free State	13,042	18,001	17,391	7,177	16,088	7,005	9,155	16,746	104,605
Gauteng	56,239	70,924	58,170	45,384	38,547	46,723	24,344	49,034	389,365
KwaZulu-Natal	17,553	78,468	53,105	28,997	28,547	14,379	24,485	33,668	279,202
Limpopo	11,108	15,743	22,899	12,401	20,996	16,667	14,953	15,810	130,577
Mpumalanga	19,884	10,873	16,838	4,808	16,457	14,584	21,649	21,232	126,325
Northern Cape	6,666	4,768	2,387	2,600	4,148	2,588	6,056	3,787	33,000
North West	21,287	20,977	18,367	12,944	14,109	13,885	23,784	10,484	135,837
Western Cape	25,321	43,834	34,575	26,916	17,730	16,634	20,500	12,301	197,811
Total Projects	177,611	295,811	248,391	161,572	190,643	143,281	203,588	190,181	1,611,078

Table 3. Total population living in informal settlements in relation to number of housing units planned per province. Sourced from Department of Housing (2004a).

Province	Informal Population	Planned Units
Eastern Cape	416,956	237,765
Free State	257,068	104,046
Gauteng Province	1,011,387	999,190
KwaZulu-Natal	1,016,596	303,081
Limpopo Province	70,415	146,908
Mpumalanga	190,782	155,434
Northern Cape	31,405	42,730
North West	212,443	149,690
Western Cape	353,331	228,789
TOTAL	**3,560,383**	**2,367,633**

Appendix Two

Figure 1. Aerial photograph *ca.* 1935 showing cultivation and development in the eastern section of Cato Manor (foreground). The last remnants of coastal forest can be seen in the mid-ground and on the far side of the harbour (bluff). Sourced from Chief Directorate : Surveys & Mapping (1935).



MOSS Classes per Catchment																	
Catchments	Alien Vegetation	Beaches and Rock Outcrops	Disturbed Woodlands	Dry Valley Thicket/Broad-leaved Woodland	Extractive	Field Crops	Forest	Grassland	Recreational	Settlements	Tree Crops	Utility	Water	Wetland (non woody)	Wetland Forests	Wooded Grasslands	Grand Total
Tongati	29	39				82	207		72		10	6	87	363			894
Umdloti	572	72		639	42	17	782	165	73	38		13	197	618	16	316	3562
Ohlange	10	100	8			74	644	64	83		4	17	26	336		65	1430
Mgeni	703	367	1084	13270	36	135	3123	736	663	627		99	1589	1650	45	4439	28566
Durban Bay	38	100					343	9	253	67		12	867	9	14		1712
Umbilo	590		16	3	41		570	131	146	1		44	20	120	2	94	1779
Umhlatuzana	555		129	9	71	64	644	159	101	7		20	23	248		714	2744
Umlaas	486	39	1013	3055	8	297	1678	868	113	33		64	109	957	20	2878	11616
Mbokodweni	407	57	349	1099	2	15	1224	483	76	68		1	14	544	43	2419	6802
Amanzimtoti		21	3				235		59			3	2	75	17	20	434
Little Amanzimtoti	41	59	10				135	2	4			6	4	29			289
Illovu	146	14	59				360	47	5	21			55	133	5	114	959
Umzimbazi	2	48	8				61	6					17	63	3	5	213
Umgababa	28	17	80			11	37	31	3				40	116		61	424
Ngane	15	35	2				63	29	2			4	2	34	2	4	192
Umkomazi	137	7	61	231	2	42	94	59	16	2			29	119	3	8	808
Mahlongwana	28	34				5	199	39	41	1			10	33	29	10	428
Mahlongwa		31					181	1	3	1			3	39	2		261
Grand Total	3787	1039	2823	18306	203	741	10581	2828	1712	865	14	289	3093	5485	201	11145	63115

- All areas listed are in Hectares
- Many catchments extend beyond the city boundary

Figure 2. Open space types / habitats / ecosystems per catchment in the EMA. Sourced from Roberts and Boon (2002).

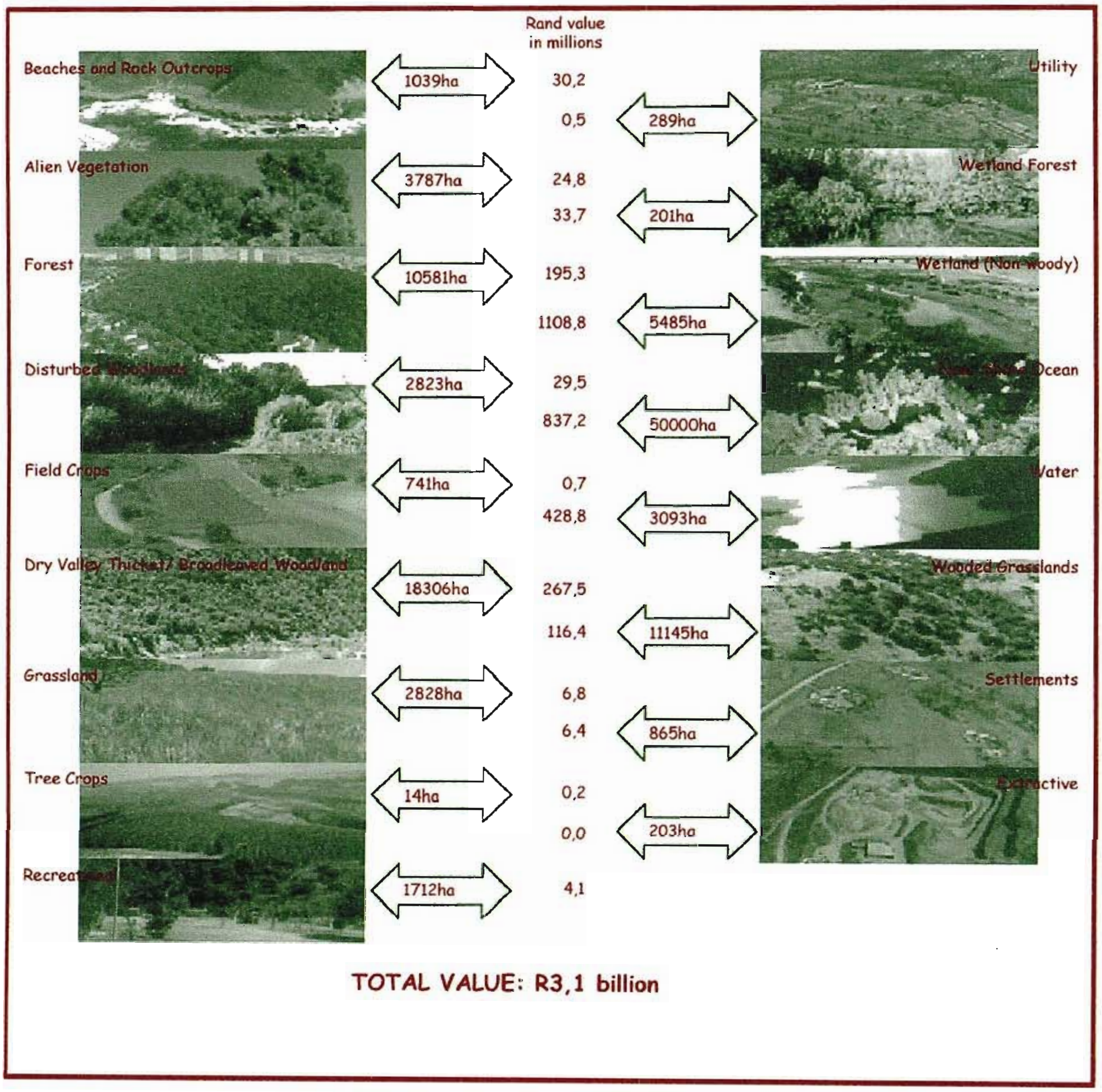


Figure 3. Replacement value of services and benefits supplied by Durban's open spaces in 2002. Sourced from Roberts and Boon (2002).

Table 1. Current Greening Initiatives in the Durban Metropolitan Area. Adapted from Addo, Breen and Jaganyi (2000b)

eThekwini Parks Department	WESSA-PLANT
Durban Greening Trust (Parks and Electricity)	Valley Trust - (Permaculture and Urban Agriculture)
Botanical Society of South Africa	Institute of Natural Resources (INR)
GNHS	Environmental Management Branch - (D'MOSS)
Claremont conservancy	Dept. Civil Engineering (UKZN) – (NGO / Community based labour intensive projects)
KZN Dept. of Transport	Simunye Environment Awareness Group – CBO. (Recycling and River Rehabilitation)
Built Environment Support Group (BESG)	Department of Agriculture
Thuthuka Africa Community Gardens and Parks (KwaMashu)	Durban Youth Radio (Education)
Municipal Local Authority (Health / Solid waste, etc)	Local Conservancies
South Durban Community Environment Alliance (SDCEA)	Farmer Support Group (Umlaaz Valley)
Weerts, Butler and Bulman (WBB)	Integrated Urban Agriculture Project. Inthataguza-Etafuleni
Urban Econ / Zakhe Training (Food Gardens)	Metro Housing
WWMD (Sludge Composting)	EThekwini Mayoral Awards
Traditional Healers Association	Merebank Environment (Cleaning initiative)
African Heritage Services	Keep Durban Beautiful Association (KBDA)

Appendix Three

Proposed Interim Code of Ethics for Landscape Visualization - *Version 4 –July 4, 2003*
Purpose of Landscape Visualization Professional preparers and presenters of realistic landscape visualizations are responsible for promoting full understanding of proposed landscape changes; providing an honest and neutral visual representation of the expected landscape, by seeking to avoid bias in responses (as compared with responses to the actual project); and demonstrating the legitimacy of the visualization process.
General Principles Preparers and presenters of landscape visualizations should adhere to the following general principles: ▪ Accuracy: realistic visualizations should simulate the actual or expected appearance of the landscape as closely as possible (at least for those aspects of the landscape being considered); visualizations should be truthful to the data available at the time. ▪ Representativeness: visualizations should represent the typical or important range of views, conditions, and time-frames in the landscape which would be experienced with the actual project, and provide viewers with a range of viewing conditions (including typical worst-case conditions at a minimum). ▪ Visual clarity: the details, components, and overall content of the visualization should be clearly communicated. ▪ Interest: the visualization should engage and hold the interest of the audience, without seeking to entertain or "dazzle" the audience. ▪ Legitimacy: the visualization should be defensible by following a consistent and documented procedure, by making the simulation process and assumptions transparent to the viewer, by clearly describing the expected level of accuracy and uncertainty, and by avoiding obvious errors and omissions in the imagery. ▪ Access to visual information: visualizations (and associated information) which are consistent with the above principles should be made readily accessible to the public via a variety of formats and communication channels.
Code of Ethical Conduct The use of landscape visualizations should be appropriate to the stage of development of the project under consideration, to the landscape being shown, to the types of decisions being made or questions being addressed, to the audience observing the visualizations, to the setting in which the presentation is being made, and to the experience level of the preparer. In general, preparers and presenters of landscape visualization should:
▪ Demonstrate an appropriate level of qualifications and experience
▪ Use visualization tools and media (more than one if possible) that are appropriate for the purpose
▪ Choose the appropriate level(s) of realism
▪ Identify, collect, and document supporting visual data available for or used in the visualization process; conduct an on-site visual analysis to determine important issues and views
▪ Seek community input on viewpoints and landscape issues to address in the visualizations
▪ Provide the viewer with a reasonable choice of viewpoints, view directions, view angles, viewing conditions, and timeframes appropriate to the area being visualized
▪ Estimate and disclose the expected degree of error and uncertainty, indicating areas and possible visual consequences of the uncertainties
▪ Use more than one appropriate presentation mode and means of access for the affected public
▪ Present important non-visual information at the same time as the visual presentation, using a neutral delivery
▪ Avoid the use or the appearance of "sales" techniques or special effects
▪ Avoid seeking a particular response from the audience
▪ Provide information describing how the visualization process was conducted and key assumptions/decisions taken
▪ Record responses to visualizations as feedback for future efforts
▪ Conduct and document post-construction evaluations to assess accuracy of visualizations or changes in project design/construction/use

Figure 1. Proposed Interim Code of Ethics for Landscape Visualisation. Sourced from Sheppard (2003).

Appendix Four

Table 1. Bird Species observed in the course of the Mount Royal Scoping Exercise. Adapted from SA Environet (2003).

Common Name	Scientific Name
African Fish Eagle	*Haliaeetus vocifer*
African Goshawk	*Accipiter tachiro*
Black Egret	*Egretta ardesiaca*
Blacksmith Plover	*Vanellus armatus*
Brownthroated Martin	*Riparia paludicola*
Burchell's Coucal	*Centropus superciliosus*
Cape Reed Warbler	*Acrocephalus gracilirostris*
Cape Sparrow	*Passer melanurus*
Cape Turtle Dove	*Streptopelia capicola*
Cape Wagtail	*Motacilla capensis*
Cattle Egret	*Bubulcus ibis*
Egyptian Goose	*Alopochen aegyptiacus*
Fantailed Cisticola	*Cisticola juncidis*
Fiscal Shrike	*Lanius collaris*
Forktailed Drongo	*Dicrurus adsimilis*

Common Name	Scientific Name
Greenshank	*Tringa nebularia*
Grey Heron	*Ardea cinerea*
Hadeda Ibis	*Bostrychia hagedash*
Little Bee Eater	*Merops pusillus*
Malachite Kingfisher	*Alcedo cristata*
Reed Cormorant	*Phalacrocorax africanus*
Southern Masked Weaver	*Ploceus velatus*
Speckled Mousebird	*Colius striatus*
Stonechat	*Saxicola torquata*
Threebanded Plover	*Charadrius tricollaris*
Whitebellied Sunbird	*Nectarinia talatala*
Yellowbilled Duck	*Ana undulata*
Yellowbilled Kite	*Milvus migrans*
Yellowthroated Longclaw	*Macronyx croceus*
Yellowthroated Warbler	*Seicercus ruficapillus*

Table 2. Proposed experts, municipal departments and organisations to partake in the expert survey

Name	Discipline / Municipal Department / Organisation
Mr. M Byerley	Executive Acting Director: eThekwini Housing Department.
Ms. D Dold	The Wildlife and Environment Society of South Africa.
Mr. J Foley	HoD: Department of Environment and Recreation Technology. Durban Institute of Technology.
Mr. S Giyose	Social Researcher: eThekwini Housing Department.
Dr. E Granger	Programme Director: Wildlife Science. University of KwaZulu-Natal.
Mr. K Gould	eThekwini Photogrammetry Department.
	Institute for Natural Resources.
Mr. T Ireland	eThekwini Corporate GIS Department
Mr. R Kasserchun	Deputy Head: eThekwini Coastal Engineering, Stormwater and Catchment Management.
Mr. G Kloppenborg	Acting Director: eThekwini Parks Department .
Mr. J Martin	Civil Engineer: JC Martin Surveys.
Mr. K Moulder	Acting Head: eThekwini Electricity.
Mr. D Newmarch	The Botanical Society of South Africa.
Ms. J Park	Executive Director: Food and Trees for Africa.
Dr. D Roberts	Deputy Head: eThekwini Environmental Branch.
Mr. D Van Heerden	School of Architecture, Planning and Housing. University of KwaZulu-Natal.

Appendix Five
Glossary

Unless otherwise cited all information in this glossary is derived from Wikipedia (2006).

Antialiasing.

A process used to smooth diagonal lines.

Bump mapping.

A computer graphics technique where at each pixel a perturbation to the surface normal of the object being rendered is looked up in a texture map and applied.

Computer Aided Design (CAD).

A computer system capable of undertaking precise and detailed engineering, architectural or electronic design.

Datum.

A reference point on the earth's surface against which position measurements are made, and an associated model of the shape of the earth for computing positions. Horizontal datums are used for describing a point on the earth's surface, in latitude and longitude or another coordinate system. Vertical datums are used to measure elevations or underwater depths.

Digital Elevation Model (DEM).

A representation of the topography of the Earth in digital format.

Environment mapping.

A technique that uses cube mapping to make objects look like they reflect the environment around them.

Fractal.

A shape that is recursively constructed or self-similar, that is, a shape that appears similar at all scales of magnification.

Geographic Information System. (GIS).

A computer system capable of integrating, storing, editing, analyzing, and displaying geographically-referenced information.

Georeference.

Data that defines the position of an image file in 3D space.

Gouraud shading.

A method used in computer graphics to simulate the differing effects of light and colour across the surface of an object. Gouraud shading is much less processor intensive than Phong shading, but does not calculate all desirable lighting effects as accurately.

Map projection.

Any method used in cartography (mapmaking) to represent the two-dimensional curved surface of the earth or other body on a plane.

Non-Uniform, Rational B-Spline (NURBS).

A mathematical model commonly used in computer graphics for generating and representing curves and surfaces.

OpenGL (Open Graphics Library).

A specification defining a cross-language cross-platform API for writing applications that produce 2D and 3D computer graphics. OpenGL is widely used in CAD, virtual reality, scientific visualization, information visualization, and video game development.

Particle system.

A computer graphic technique to simulate certain fuzzy phenomena, which are otherwise very hard to reproduce with conventional rendering techniques – i.e. fire, explosions, smoke, flowing water, sparks, falling leaves, clouds, fog, snow, dust, meteor tails, or abstract visual effects like glowing trails, etc.

Phong shading.

Can be regarded as an improved version of Gouraud shading that provides a better approximation to reality

Radiosity.

A global illumination algorithm used in 3D computer graphics rendering. Radiosity simulate the many reflections of light around a scene, generally resulting in softer, more natural shadows and reflections.

Ray tracing.

In 3D computer graphics raytraced scenes are rendered by following rays from the eye to light sources.

Rendering.

The final process of creating the actual 2D image or animation from the prepared scene.

Rules-of-Nature.

A VNS feature that facilitates parametric rule-based control over ecosystems (Krutz, Huber and Hauldren 2005).

Terrafector.

A displacement effect feature in VNS that changes the shape of the terrain. Used to create roads, streams, mountains and lakes (Krutz *et al.* 2005).

Texture mapping.

A method of adding realism to a computer-generated graphic. An image (the texture) is added (mapped) to a simpler shape that is generated in the scene.

Viewshed.

An area of land, water or other environmental elements that is visible from a fixed vantage point.

VRML (Virtual Reality Modeling Language.

A standard file format for representing three-dimensional (3D) interactive vector graphics.

Z-Buffering.

The recording of distance (z) information from the camera of every pixel. Z-Buffered images can be composited together at a later stage, thereby ensuring correct foregrounds and backgrounds.

Component B

Prologue

Component B of this dissertation has been formatted in accordance with the requirements of the journal *'Urban Forestry & Urban Greening'*.

December 15, 2005.

Photorealistic Visualisation of Urban Greening in a Low-Cost High-Density Housing Settlement, Durban, South Africa

Gavin Donaldson-Selby [a], Trevor Hill [b*], Jan Korrubel [c]

[a] Centre for Environment, Agriculture and Development, University of KwaZulu-Natal, Pietermaritzburg, South Africa

[b] Discipline of Geography, School of Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa

[c] Centre for Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, Suffolk, NR33 OHT, United Kingdom

[*] Corresponding author.

Discipline of Geography

School of Environmental Sciences

University of KwaZulu-Natal

Private Bag X01

Scottsville 3209

South Africa

Telephone: +27 33 2605235

Facsimile: +27 33 2605344

E-Mail address: HillT@ukzn.ac.za

Abstract

Apartheid housing policies of the pre-1994 South African government, and the low-cost high-density housing programmes of the post-1994 government, has given rise to numerous urban environmental problems, some of which could be addressed in a cost-effective and sustainable manner through urban greening, while simultaneously promoting biodiversity. Public participation in the planning of urban greening has been identified as being of vital importance, without which urban greening projects run a high, and expensive, risk of failure. Previous studies indicate that the greening priorities of residents in low-cost high-density housing settlements may differ considerably from those of managers and experts tasked with the protection and extension of the natural environment resource base. A system of participatory decision support is therefore required to reconcile the greening requirements of the community, and the ecological benefits of biodiversity. If language, literacy, map literacy and numeracy difficulties are to be avoided, and a sense of place or belonging is to be invoked, such a participatory decision support system should, ideally, be visually based, and capable of generating realistic eye-level depictions of the urban landscape. New computer-based landscape visualisation applications, which can directly utilise GIS, CAD and DEM data to produce detailed photorealistic viewsheds, were deemed better suited to the task of visualising urban greening than existing GIS based mapping systems, CAD and traditional landscape visualisation methods. This paper examines the process of constructing a 3D computer model of the Mount Royal low-cost high-density housing settlement, situated in the eThekwini Municipality, KwaZulu-Natal, South Africa. Visualisations including terrain, natural features, indigenous vegetation, houses and roads were produced and submitted, with a questionnaire, to experts from different disciplines, Mount Royal residents and neighbors. Results from the expert survey indicate moderate support for visualisation in professional decision-making. However, both experts and residents expressed strong support for the accuracy and credibility of the visualisations, as well as for their potential in a participatory decision support system.

Keywords

Computer Decision Participatory Support Visualization

Introduction

Urbanisation in South Africa

In 2000 the level of urbanisation in South Africa was approximately 55 percent - considerably higher than the 40.5 percent average for developing countries; and is expected to reach 60.3 percent and 70.1 percent by 2010 and 2030 respectively (United Nations Department of Economic and Social Affairs: Population Division 2005). The rapid process of urbanisation in South Africa has, however, been substantially distorted by the legacy of apartheid, with legislation dating back to 1913 severely restricted where black South Africans could live, work or own property. Within the 'white' cities, black people were viewed by the authorities as temporary migrant workers who were required to have permits to live or work there, and who were expected to eventually return to their 'homelands' (Tomlinson 2002). Consequentially, legislation based on this premise deliberately limited access to, or land for, housing and basic municipal services (Department of Housing 2004a). As the majority of employment opportunities were to be found in the 'white' urban areas, many rural black workers moved to the cities and, because of their illegal status, were forced to reside in the overcrowded shacklands that mushroomed within the surrounding 'black' dormitory townships. The lifting of the racially based restrictions in the early 1990s, coupled with the shortage of affordable accommodation, saw the creation of numerous informal settlements on open urban lands. Knight (2004) notes that whereas there was one formal house per 3.5 whites, there was only one formal house per 43 blacks. In order to address the severe housing shortage, the post-1994 government embarked on a mass low-cost high-density housing exercise as part of the Reconstruction and Development Programme (RDP); a socio-economic policy framework that seeks to integrate growth, development, reconstruction, redistribution and reconciliation into a unified programme (African National Congress 1994). The Reconstruction and Development Programme ostensibly incorporates sustainable development (Aliber 2002), and requires government to ensure equitable access to natural resources, safe and healthy living / working environments, as well as the empowerment of communities to manage their natural environment through participatory decision-making (African National Congress 1994). Since 1994, 1.6 million RDP houses for approximately six million people have been built (Department of Housing 2004b), but the backlog has since grown from 1.5 million (in 1994) to 2.4 million houses (Boyle and Philp 2004). Within the eThekwini Municipal Area (EMA) the City of Durban, like many other South African metropolitan areas, is currently experiencing a burgeoning informal settlement problem, which the Metro Housing unit plans to address through the building of at least 17 000 housing units over the next ten years (Durban Metro Housing Unit 2004).

Environmental Impacts

The environmental impacts of apartheid planning and legislation in respect of the pre-1994 formal townships include: high levels of air pollution as a result of proximity to industry, and the burning of fuel wood / coal for domestic heating and cooking; high levels of dust from unpaved roads, particulates generated by industry and wind blown mine tailings; pollution of rivers and contamination of ground water by sewerage, waste dumps / land fills and mining / industrial leachates; unsustainable and environmentally damaging patterns of resource use including illegal dumping on public open spaces; health problems related to the close proximity of the townships to industrial areas and waste dumps / land fills; health problems related to extreme overcrowding; and loss of access to agriculturally productive land and other natural assets for food production and livelihoods (African National Congress 1994; Department of Environmental Affairs and Tourism 1996; Mutume 1998; Bullard 2002; Paton 2002; Department of Housing 2004a). Informal settlements suffer similar environmental problems, aggravated by a complete lack of planning or municipal services and inappropriate location - often situated on steep inclines (leading to erosion) or in ecologically sensitive areas such as river floodplains, estuaries or indigenous forests (Department of Housing 2000).

While it is difficult to evaluate the direct environmental impacts of the RDP housing programme, the replacement of informal settlements with planned and serviced housing should (in principle) benefit both the environment and public health (Aliber 2002). Developers of housing projects are required to comply with national, provincial and local environmental / housing legislation, including the conducting of environmental impact assessments (Department of Housing 2000). Unfortunately, the pressure to meet mass low-cost housing targets, coupled with the high cost of implementing services (water, sanitation, roads, electricity) within limited budgets, has relegated environmental impact concerns to a low order of priority (Mathiane 2001). In order to minimise construction costs, sites are usually scraped clear of vegetation and topsoil (including the seed bank) prior to construction (Sowman and Urquhart 1998; Mattson and Dalzell 2002), and little or no effort is made to rehabilitate the area by way of landscaping or revegetation on completion. Adebayo (2001:15) observes that "the existing natural environment has in many cases been destroyed beyond repair" and that "new housing, especially in the state low-cost projects, has turned areas of natural vegetation to desert, with construction activity causing removal of all the trees on site rather than integrating them into the built environment". Examples of this (Figs. 1 and 2) can be found in Durban's Cato Manor suburb where large low-cost housing projects and informal housing exist in close proximity *(pers. obs.)*.

Figs. 1 and 2

Giyose and Bedford (2001) note that environmental problems arising from the pre-construction clearance of vegetation in low-income settlements in the Ethekwini Municipal Area included: considerable erosion of private gardens and open spaces; flood damage to houses and property resulting from soil-blocked drains and storm water channels; insufficient topsoil to establish food gardens; a lack of windbreaks (resulting in windborne dust); heat; and poor aesthetic appeal.

Urban Greening

Urban greening, which includes urban forestry and urban agriculture / permaculture, could address some of the environmental problems experienced in low-cost high-density housing settlements in a cost-effective and sustainable manner. Interception of precipitation by trees, in conjunction with permeable soils, can play an important role in reducing the rate and volume of stormwater runoff, flood damage, erosion, the cost of stormwater drainage and other related water quality problems (Nowak and Dwyer 2000). Areas of moderate (67 percent) tree cover can reduce wind speeds, two metres above ground, by sixty percent (Heisler 1990); which, in turn, can reduce wind chill on buildings in cold environments (McPherson 1994; Peck *et al.* 1999). Akbari *et al.* (1992) have found that tree shade can reduce average air temperatures in buildings by as much as five degrees Celsius; and McPherson *et al.* (1994) have shown that increasing tree cover could lower the amount of energy used for cooling and heating. Urban trees remove air pollutants such as carbon monoxide, sulpher dioxide, nitrogen dioxide, ozone and particulates (Nowak 1994) and, in combination with reflective roof surfaces, can lessen the urban heat island effect; which, in turn, could curtail the formation of smog (Akbari 1995).

Sorensen *et al.* (1997:56), however, note that urban greening is "not just another project implemented in a metropolitan environment" but rather "is part of a much larger natural system. Cities are situated within a general ecosystem and as such are a part of a larger bioregion… to preserve natural systems then, we need to integrate nature into our cities". If urban greening is to promote, and extend, biodiversity within urban areas it is important that the selection process of trees and vegetation take into consideration the ecological nature of the natural open spaces with which they connect, as well as the number of species utilised, in order to avoid either low biodiversity value or low ecological functionality (Nichols *et al.* 2000). Natural open spaces, which contain the most functional and productive ecosystems, tend to become 'islands' within urban areas, requiring connectivity (physical corridors) to link the open spaces / river catchments to each other, as well as important external sources of biological diversity, in order to ensure a flow of genetic material, energy, water and nutrition, thereby preventing local species extinction (Towle 1996; Roberts and Boon 2002). In the case of the eThekwini Municipal Area, the external sources of biological diversity (or bioregions) are the Pondoland and Maputaland centres of plant diversity, and the Eastern Cape marine biodiversity centre (Roberts and Boon 2002). It has been estimated (Roberts and Boon 2002) that in 2002 Durban's natural resource-base supplied essential environmental goods and services to all communities - particularly the urban and rural poor - worth 3.1 billion Rand. Natural and urban open space planning / policy to ensure the continued supply of environmental goods and services in the eThekwini Municipal Area has been developed and formalised in the eThekwini Environmental Services Management Plan (EESMP) - formerly known as the Durban Metropolitan Open Space System (DMOSS). The Environmental Management Department of eThekwini Municipality (2005) note that there are 85 465 ha of undeveloped land within the EMA, much of which falls within the EESMP's 63 115 ha spatial footprint.

Community Participation in Urban Greening

National and international institutional support for the principles of public participation in environmental decision-making (which would include urban greening) can be found in the *'Reconstruction and Development Programme: A Policy Framework'* (African National Congress 1994), the National Environmental Management Act (1998), and Local Agenda 21 section 8.4 (f) *'Integrating Environment and Development in Decision-Making'* and section 23.2 *'Strengthening The Role Of Major Groups: Preamble'* (United Nations Department of Economic and Social Affairs 2003). Sorensen *et al.* (1997), Sowman and Urquhart (1998), Grobbelaar and Croucamp (1999), Addo *et al.* (2000) and Giyose and Bedford (2001) emphasize the importance of local community participation to the success of urban greening, and Barzetti (1992) observes that stakeholders are frequently viewed as conservation or education targets, rather than as partners; and are only included towards the end of the project, often resulting in conflict and project failure (Barzetti 1992 cited in Sorensen *et al.* 1997).

In their study of the greening requirements for new low-income settlements in the Ethekwini Municipal Area (EMA) Giyose and Bedford (2001) observed that the main priorities of the surveyed communities were schools, community halls, street names, playgrounds, water, public and private telephones, and improved roads. Thirty seven percent of the sampled residents did not identify any environmental problems, despite the high prevalence of soil erosion in the selected areas. Thirty four percent of the focus group participants were unaware of the benefits of urban greening, and sixty nine percent were unaware of the importance of open spaces. Giyose and Bedford (2001) note that most participants believed that open space should be used for development purposes, particularly as their areas lacked facilities.

Participatory Decision Support

Clearly potential exists for a conflict of opinions, values, and approaches to urban greening between residents of low-cost housing projects, and the city managers / technical experts (ecology, hydrology, etc) tasked with the protection and extension of the natural environment resource base. If not anticipated, and pre-empted, such a conflict could result in: (A) a 'top-down' non-participatory approach that risks project failure; or (B) 'ad-hoc' greening, with little or no expert input, that may exacerbate local and citywide environmental and ecological problems; or (C) no action being taken for the (perceived) fear of project failure, thereby addressing neither the needs of the community, nor the requirements of biodiversity. A participatory decision support process is therefore required to reconcile the tangible socio-economic and welfare benefits of urban greening (and development) as demanded by resource-poor communities, and the less tangible ecological benefits and services accrued to the city through the maintenance and strengthening of biodiversity. In order to preclude language, literacy, map literacy and numeracy difficulties, invoke a sense of place or belonging and timeously produce reliable results, such a process (ideally) should: (1) be visually based; (2) present proposals clearly and unambiguously, and ought, therefore, to have the capacity to realistically depict urban landscapes; (3) allow analysis and evaluation of three-dimensional spatial and visual relationships from different viewpoints, particularly eye-level perspectives; (4) invoke community co-development and a sense of ownership; (5) allow for easy implementation / consideration of design alternatives; (6) be scientifically defensible; (7) allow for data feedback for expert analysis and evaluation; (8) be able to integrate a wide range of data, including that from outside the study area; and (9) not be time consuming or expensive to implement.

Decision Support Systems

Three potentially suitable methods and technologies for the visual representation of urban greening and urban landscapes include traditional landscape visualisation methods, Geographic Information Systems (GIS) and Computer Aided Design (CAD). Traditional landscape visualisation methods, which include perspective drawings, physical models and photo-montages (Lange 2002), are time consuming (and therefore expensive) to produce; are not linked to real-world geographically based data (Appleton *et al.* 2001) - thereby diminishing both their scientific defensibility as well as their capacity to generate data feedback for expert analysis and evaluation; and are not easily modified at short notice to reflect design changes. Manual intervention is required in the production of photo-montages in order to provide an approximation of future impacts, which raises questions with regards their credibility (Bergen 1993; Berry *et al.* 1998).

Most GIS are only capable of producing two-dimensional (2D) images and, through a process of 'draping' images over a Digital Elevation Model (DEM), limited three-dimensional (3D) images (Appleton *et al.* 2001). The data represented in a GIS-generated map or image can be extremely complex, making it difficult for people without GIS or mapping experience to fully comprehend. This may diminish their value in respect of public participation and decision support in environmental decision-making processes; and is unlikely to inculcate a sense of place, belonging, vision or ownership in the local community. The limited three-dimensional nature of GIS-generated images can make it difficult for experts and non-experts alike to understand and objectively evaluate complex three-dimensional spatial and visual relationships between buildings, vegetation and terrain. Mayall and Hall (1994) observe that GIS derived landscape models are of little use in visual resource planning, and Faust (1995) suggests that the usefulness of draped images is limited to 'show and tell'. Advanced 3D CAD and modelling / rendering systems can address the visualisation shortcomings of GIS; but their application in urban greening is otherwise constrained as a result of their limited database (Maguire 1991) and query / analysis capabilities (Bohnenstiehl 1999), restricted capacity for dynamic 'change on the fly' interaction with underlying data (Thurston *et al.* 2001), and their inability to utilise projected data and georeferenced images from other (GIS) systems.

Recently there has been a trend towards a convergence of GIS and 3D visualisation software (Sheppard 1999; Limp 2000; Lovett *et al.* 2002), resulting in the synthesis of new software applications capable of direct utilisation of GIS, CAD and DEM data to generate detailed photorealistic viewsheds. Available software for PCs varies in complexity, quality and realism of output, features and price. One of the more sophisticated landscape visualisation applications, Visual Nature Studio (VNS), allows for the importation of GIS data in most projections and datums, and supports a range of commonly used CAD, multi-resolution DEM and geo-referenced raster formats. Ecological, geomorphological and hydrological parameters such as foliage height, density, and colour, terrain colour and lake elevation can be dynamically controlled by GIS data attributes. Boolean search queries allow selection and interrogation of objects based on attributes. Complex overstory and understory ecosystem combinations can be simulated; and variables such as sun and wind directions, water drainage and altitude can modify and control vegetation growth and placement as it occurs in nature (3D Nature 2004).

This paper investigates the potential application of computer generated photorealistic visualisation as a participatory decision-support tool for planned urban greening in a RDP housing project in KwaZulu-Natal, South Africa. Four objectives were: (1) to create, within VNS, a three-dimensional photorealistic computer model of the low-cost high-density housing settlement including terrain, natural features, indigenous vegetation, houses and roads; (2) to determine the accuracy and credibility of the computer generated photorealistic visualisations; (3) to ascertain the efficacy with which photorealistic visualisations of urban greening could be produced; and (4) to assess the potential of computer generated photorealistic visualisation as a participatory decision support tool in urban greening projects.

Material and Methods

Study Area

The housing project used in this urban greening study is the low-cost high-density Mount Royal RDP housing project, approximately ten kilometers north of the City of Durban at 29° 44' 13" S, 31° 00' 35" E, in the eThekwini Municipality, KwaZulu-Natal, South Africa; and is approximately sixty four Hectares in size (Fig. 3). Unless otherwise cited all information on the study area is derived from the *'Environmental Impact Scoping Report for Mount Royal Redevelopment Project'* (SA Environet 2003).

Fig 3

Table 1 details the proposed number of units and Hectares utilised.

Table 1

Biological Environment

The ground above the river valley has been extensively grazed, and is dominated by contiguous cover of a limited number of grass and forb species. The river valley consists of intensively grazed floodplains, riverine scrub, reed beds and the river; and is dominated by alien invasive plant species (Mattson 2004 *pers. comm.*). On the opposite side of the river the steep slopes are covered with dense woodland and scrub. The environmental scoping report for Mount Royal (SA Environet 2003) observes that the study area, particularly the river and riparian areas, constitutes a refuge for flora and fauna in an increasingly fragmented urban environment; and that the riverine habitat is comparatively rich in biodiversity, has high conservation value, and is irreplaceable. The Record of Decision (ROD) (Provincial Department of Agriculture and Environmental Affairs 2003) notes the likely presence of three Red Data Species

(International Union for Conservation of Nature and Natural Resources 2004) in the study area - namely *Bradypodion melanocephalum*, *Crex crex* and *Hyperolius pickersgilli*.

Data collection

A 2D cadastral file, a DEM based on five metre contours and geo-referenced aerial photography showing the Mount Royal Housing Project and surrounding area were obtained from the Photogrammetry Branch of eThekwini Municipality. A detailed site survey showing half metre contours, fifty / one hundred year flood lines, location and elevation of houses, and location of roads and underground services was supplied by the survey engineer. CAD drawings showing the positions of electrical poles and pole-to-pole overhead mains connections were supplied by the eThekwini Municipality electricity department. All of the data was supplied in DXF format (Transverse Mercator with a central meridian at 31 degrees East, WGS 84 datum). The study area was visited and measurements / photographs of one of the existing houses were made for the purposes of modelling and texturing. Most of the houses in the Mount Royal Housing Project plans are identical in size and shape, and vary only in colour.

The Environmental Control Officer (ECO) provided a list of trees (Mattson 2004 *pers. comm.*) suitable to the location (coastal forest biome), which was cross-referenced against riverine vegetation recommended by Guthrie and Wyatt (2000) and Wyatt (1997) for stream bank stabilisation and riparian areas, as well as street trees recommended by the eThekwini Municipality Parks Department's *'Tree Planting and Removal Policy'* (Kloppenborg *et al.* 2003). Grasses used were those specified in the

Mount Royal environmental management plan (Environmental Management Branch of eThekwini Municipality 2003). Images of the vegetation for the purposes of 'billboarding' were either photographed or sourced from van Wyk and Gerike (2000), van Wyk *et al.* (2000), Venter and Venter (2002) and van Oudtshoorn (2004).

Data Preparation

The DEM provided by the Photogrammetry Branch of eThekwini Municipality was imported into a CAD program, from which a file containing 3D points was extracted. The site plan provided by the survey engineer was imported into the CAD program and relevant data was separated into discrete files – contours, house locations / elevations, sewers and drains, roads, and flood lines. The contours were assigned the appropriate elevation, from which a file containing 3D points was extracted. The 3D point file based on eThekwini DEM was then merged in the CAD program with the point data from the site survey. Overlapping points from the eThekwini data were deleted, and a merged XYZ control point data file was generated. The XYZ file was imported into Visual Nature Studio (VNS) and a terrain was gridded using a North - South / East - West transect of four by seven tiles. The resultant DEM contained 28 tiles, each tile covering approximately 25.08 hectares, with a grid cell size of approximately 2.04 metres (NS) by 2.06 metres (EW). Grid cell size was arrived at after limited experimentation, with the intention of balancing the demands of DEM resolution / smoothness against those of available computer memory (two Gigabytes) and rendering times. The geo-referenced aerial photography was imported into VNS and 'draped' over the DEM for use as background textures (Fig. 4).

Fig. 4

Utilising the measurements and photographs taken on site, one house was modelled, textured and cloned in the CAD program in order to create three different coloured houses. With the aid of a LISP script, position and alignment vectors for the houses were generated in the CAD program from the site plan, and imported into VNS. The houses were then imported into VNS and cloned, positioned and aligned according to the above vectors. The site plan was also imported in order to verify accuracy of the placement and alignment of the houses. A fractal-based ground effect encompassing the housing project, and a strip of ground on the far side of the Umhlangane River, was created in VNS for the purpose of replacing the aerial photographs in the foreground of the study area (Fig. 5).

Fig. 5

Vectors were extracted from the site plan and imported into VNS for the purpose of creating area terraffectors, thereby leveling (cutting and filling) the terrain within a one and a half metre perimeter around each house (Figs. 6 and 7).

Figs. 6 and 7

Vectors were produced in the CAD program from the site plan, and in VNS from the DEM / aerial photography, to facilitate the creation of linear terraffectors for the roads and river respectively. A stream effect was applied to the river terraffector, and an asphalt ecosystem was applied to the road terraffector (Fig. 8). A site visit revealed that numerous minor poles, which were not indicated in the electricity department's plans, had been installed in order to route overhead electrical connections from the main electrical poles to the houses. Unfortunately, the eThekwini Municipality was unable to provide plans showing the position of these minor poles, or the routing of overhead electrical mains to the houses. The pole-to-house electrical connections were therefore approximated from visual observation made on site. Vectors indicating the position of electrical poles and pole-to-pole / pole-to-house overhead mains connections were generated in the CAD program, with the aid of LISP scripts, and imported into VNS in order to place electrical poles and overhead electrical main connections (Fig. 8).

Fig. 8

The photographic textures of the vegetation required pre-processing in a graphics program prior to being imported into VNS. Polygons representing 'eco-zones' were created within VNS in order to facilitate the mass placement of in-stream, streambank, riparian and general overstory / understory vegetation (Fig. 9). The width of the streambank and riparian vegetation is approximately 15 and 40 metres respectively.

Fig. 9

With the aid of a merged CAD drawing showing houses, roads, overhead electrical mains connections and underground services, vectors were generated in order to place private vegetable gardens, communal crops (maize), grass and street trees (Fig. 10). The placement of street trees is in compliance with the eThekwini Municipality Parks Department's specifications for tree planting - i.e. they should be one metre away from the face of the curb; one and a half metres from underground services; three metres from driveways; ten metres from streetlights; and fifteen metres from intersections (Kloppenborg *et al.* 2003). Street trees were placed on the opposite side of the road to overhead electrical mains connections in order to minimise maintenance. The species of street trees utilised were predominantly the same as those used for the streambank and riparian areas, thereby supporting biodiversity and ecological functionality. Areas between the houses were left clear of vegetation so as to introduce an element of incompletion or uncertainty, and thereby discourage a sense of *'fait accompli'*.

Appleton (2003:145) notes that high levels of realistic detail in a visualisation can influence "viewers' impressions of the level of certainty associated with the proposal and its design", and may encourage people to focus on minor details rather than the general impression. Furthermore, the lack of vegetation provided an opportunity for residents to suggest how they might utilise the open space.

Fig. 10

The sun position was set to September 30, 1.00 pm - S4°2'14.007" E16°0'58.458" - to match general perspective photographs taken of the study area. A light haze was also applied to simulate that observed during site visits. People were created in a character modelling program, and imported into VNS, so as to provide a sense of scale in the close-up renderings.

Questionnaires were prepared for a selected group of experts and Mount Royal residents / neighbors (Appendix One and Two respectively). The aim of the expert survey was to assess the credibility and potential usefulness, to the experts, of photorealistic visualisation in decision support, and the communication of visual information to people inside and outside of their profession. The aim of the resident survey was to assess the residents' responses to depicted urban greening, and to evaluate the residents' perception of the potential of photorealistic visualisation as a participatory decision support tool in urban greening projects. Sixteen professionals from different disciplines (environmental scientists, social researchers, architects, civil engineers and eThekwini managers of housing, parks, electricity, environment, coastal drainage, photogrammetry and GIS) and ten Mount Royal residents were requested to complete their respective surveys. Two copies of the survey form, and a letter briefly explaining the underlying methodology and purpose of the survey, were provided for each of the expert and resident / neighbor surveys.

Results and Discussion

A number of visualisations from different positions, headings and elevations were rendered of the study area. A photograph and six renderings, showing views of the general area, the riverine area and the housing settlement, were used for the study (Appendix One and Two). A football field (Appendix Two: Fig. 5), which is not part of the plans for the study area, was included as a discussion point in the resident survey. There were eight responses from the expert group and sixteen responses from Mount Royal residents. The responses are tabled in Appendix Three.

Expert Survey

Respondents in this group included environmental scientists, ecologists, a social researcher and an engineer responsible for stormwater and catchment management in the EMA. Although the focus of the study was on urban greening, the nature of the questions allowed for input from other professions; and it could therefore be assumed that non-respondents (which included GIS and photogrammetry experts, civil and electrical engineers, and an architect) did not find the visualisations to be of use in their professions. Expert respondents rated the potential usefulness of three visualisations showing the general area, riverine area and housing settlement, in decision making within their own professions. Possible values ranged from 1 (of no use), to 10 (of great use). Median values of 7, 6 and 6 (mean = 6.6, 6.6 and 6.1) for the three respective visualisations indicate a moderate assessment of the potentially usefulness of the visualisations in professional decision-making (Fig. 11). Evaluation of the same visualisations with respect to the communication of ideas and information to: (A) other people in their profession, and (B) people outside of their profession, generated higher median values of: (A) 8, 7.5 and 8 (mean = 7.5, 7.3 and 7.1), and (B) 8, 7 and 7.5 (mean = 7.6, 7.4 and 7) respectively (Figs. 12 and 13).

Figs. 11, 12 and 13

Confidence levels with which the experts felt they could make professional decisions based on the visualisations produced a median value of 6 (mean = 5.9), which corresponds with the (above) values assigned by the group to the potential usefulness of the three visualisations in their decision making. The group's opinion as to: (A) whether Mount Royal could, in time, resemble the visualisations if urban greening was implemented (predicted realism), and (B) the desirability of the urban greening depicted in the visualisations, generated high median scores of 8 and 9 (mean = 7.4 and 9) respectively.

Some summarised comments submitted by the expert group include: (1) concern for the proximity of dense vegetation close to the houses, and the possibility that residents may perceive this to be a threat or danger; (2) concern that the imagery was not based on real-world scientifically defensible data, and that the space between houses would, from their experience, be insufficient to grow anything significant; (3) a lack of realism with respect to grasses and understory utilised; (4) concern for the costs of this approach; and (5) the expressed opinion by several experts that visualisation held great potential for the prediction of future views, as well as the disciplines of archaeology, plant ecology, agriculture and forestry. In response to the above comments the authors note that: (1) it was anticipated that objections by the residents to dense vegetation along the river were likely (and did materialise in the resident survey), as such vegetation can provide concealment to criminal elements; (2) it is possible that the explanatory letter did not sufficiently explain to the expert respondents that the positioning of **all** imagery, including street trees and vegetable gardens, was undertaken in applications that utilised real-world geographically based data; (3) there is a need for a greater variety of understory species - although it must be pointed out that in some visualisations the foreground overstory had to be 'turned off' so as to make other elements (e.g. houses and mid-ground vegetation) visible; and (4) the costs of a visual participatory decision support system for urban greening are discussed in a later section.

Residents and Neighbors' Survey

In contrast to the expert survey, results from the residents' survey are characterised by opposite extremes. Residents' support for tree planting in the riverine area and housing settlement generated median scores of 1 and 9 (mean = 2.5 and 7.3) respectively; where possible values ranged from 1 (strongly opposed), to 10 (strongly supported). Support for a football field, and the positioning thereof, was strongly approved of by all respondents (median =10 and 10, mean = 10 and 10). The importance of the following use of open space - flower gardens, fruit trees, grass, shade trees, vegetable gardens and sport fields - scored median values of 2, 2, 10, 9, 3 and 10 (mean = 2, 2.5, 8.9, 9, 4.1 and 10) respectively (Fig. 14).

Fig. 14

Residents' opinions as to: (A) whether the images provided sufficient information to make decisions with respect to the planting of trees, and use of open space; (B) whether Mount Royal could, in time, resemble the visualisations if urban greening was implemented (predicted realism); and (C) the extent to which the images empowered them to participate more fully in the planning and discussion of urban greening, generated high median scores of 10, 10 and 10 (mean = 9.9, 9.8 and 9.8) respectively.

It is clear that while residents support certain aspects of urban greening (sports fields, shade trees and grass) within the housing settlement, they are strongly opposed to any dense vegetation along the river that may be perceived as a threat. The results raise questions regarding what is in the best interests of: (A) the residents; and (B) the immediate environment, and other natural open spaces connected by this riverine corridor. If streambank stabilisation and water quality is to be ensured, and local / citywide biodiversity is to be maintained and strengthened, either viable alternative proposals will need to be made (and visualised), and / or intervention in the form of mediation / environmental education may be required. The support for riverine vegetation by a few individuals, who could champion greening in the riverine area, is encouraging. The low scores for fruit trees and vegetable gardens are surprising, given the socio-economic nature of the housing settlement; but do go some way to explaining the failure of similar projects in the EMA. A better understanding of the needs and requirements of the residents would therefore be necessary prior to the introduction of urban agriculture in the area.

The Computer Modeling and Visualisation Process

VNS proved capable of importing a wide variety of data formats as generated by GIS and CAD applications. For the purpose of this study the generation and merging of 3D points from the supplied DEM and half metre contours, within the CAD program, proved adequate. The importation and gridding of the resultant XYZ control point data, and the importation / draping of the geo-referenced aerial photography, into VNS, was achieved without difficulty. VNS's ability to generate DEMs directly from digital contour maps, and to merge DEMs of different resolution, was not tested.

The geometry of the houses was kept as simple as possible in order to minimise the number of polygons. As low-cost high-density RDP housing projects tend to utilise a single house design of varying colours, only one house was required to be modeled; which was exported from the CAD program to VNS using the .obj format. Positioning and aligning the houses, however, proved to be a tedious and time-consuming task, as VNS does not support scripting. Each of the 953 houses had to be positioned and aligned according to vectors created in the CAD program from the site plan – a process that took several days. An alternative method would have been to utilise thematic mapping in conjunction with VNS's wall creation facility. Although this approach would have had several advantages, including speed of house creation and less computational overhead, it would have resulted in houses with flat roofs (characteristic of GIS 3D visualisations) thereby reducing realism.

Terraffectors, which were used to create the roads, river, football field and for levelling the terrain around the houses, are a powerful and easy to use feature in VNS. The computational overheads of the large number of area terraffectors applied to the terrain around the houses required that they be 'burnt' into the DEM, thereby reducing memory demands. VNS proved capable of depicting streams, rivers and lakes with a high level of realism.

The creation of vegetation, with a graphics editor, took several weeks to complete. Unlike North America or Europe there are no readily available libraries of indigenous Southern African vegetation available, so images of each species used had to be sourced and pre-processed. Where possible, more than one example of the vegetation type was used so as to reduce repetitive patterns. Through the application of parametric rules, including percentage of species, height, density, altitude, over and understory, wind direction, and drainage VNS enabled the creation of complex ecotypes, thereby making the process of inserting the imagery considerably simpler. VNS cannot, however, modify vegetation to suit density, and accurately recreating the 'look' of a forest with textures sourced from solitary trees proved difficult.

Previewing a large number of 3D objects did prove to be a limitation. Despite the use of a high quality video processor, VNS's 'OpenGL preview' was overwhelmed by the number of houses in the model, resulting in excessive delays in screen regeneration. In order to be able to navigate through the houses it was necessary to use simple vectors as 'stand-ins'. Hanson (2005 *pers. comm.*) notes that "WCS / VNS's 'OpenGL (pre)view' is not optimized for bulk preview of 3D objects"; and although these processing challenges will, in time, be solved through improved technology, Ervin (2001) observes that modelling the real landscape will, for the foreseeable future, require more resources than are available, no matter how powerful computers become. Given the ‘high-end’ computer resources required to process the considerable amounts of data necessary in a landscape visualisation, it seems unlikely that interactive three-dimensional landscape visualisations and ‘fly-through’s’ will become an internet resource, accessible by the general public, in the near future.

Modelling and rendering was undertaken on a 3GHz Pentium 4 with 2GB of RAM - currently the maximum amount of application memory space in a 32-bit operating system. There was sufficient memory for all operations except the rendering of shadows. The use of shadow maps significantly reduced rendering times, as they only had to be generated once. However, the loading of 953 shadow maps required approximately 1.4 GB of RAM which, together with the approximately 500 MB RAM used by the vegetation, left insufficient memory to undertake renderings – even with the use of image ‘tiling’. Shadows were therefore only utilised on ‘close-up’ images, for which separate renderings which recorded the distance (z) from the camera for every pixel were generated of (A) the houses, and (B) the terrain and vegetation. The renderings were later merged in VNS using a process, widely used in film and video production, called ‘z-compositing’. This process can, potentially, extend VNS’s capabilities considerably as a number of ‘high-end’ modelling and animation programs, used in professional film and video production, can similarly render their images with a recorded camera distance, to be merged later either in VNS or another application. It is expected that new 64 bit operating systems, which allow for 4GB of application memory space, will address the memory limitations experienced. VNS is capable of exporting data in a wide range of 2D formats and, through a newly released add-on

(Scene Express) a variety of widely used 3D formats (3D Nature 2005). Scene Express can also extract and export data from VNS indicating the position, age and species of vegetation utilised in a GIS format, a feature that could be useful in the planning and costing of urban greening.

Required expertise includes GIS and CAD proficiency, ecology and botany, civil and electrical engineering, social research and advanced computer graphics knowledge. As this study occurred within the eThekwini Municipality, a large municipality that has its own photogrammetry and GIS departments, detailed terrain data was easily accessible. Should the study have occurred outside of a well resourced municipality, (coarser) terrain data could have been resourced from: (A) the Chief Directorate: Surveys and Mapping; and / or (B) from a public source – i.e. Shuttle Radar Topography Mission (SRTM) DEM data; and / or (C) from a private company. Vegetation data appropriate to the location also needs to be sourced, although re-use in other projects could reduce the cost. The level of skills and knowledge required suggests that while this approach to urban greening is probably not cost effective for 'once off' low-budget urban greening projects, it should be well within the capabilities of a well-resourced municipality, where the necessary expertise and data already reside. Given: (A) the existence of a suitable vegetation library and available GIS / CAD data; and (B) access to the necessary expertise, the entire process of visualising urban greening in a housing settlement of this kind could be accomplished within a week by a single skilled operator.

Conclusion

Urban greening in South Africa is often perceived as being (variously): a luxury, elitist, anti-development or even perpetuating pre-1994 apartheid urban boundaries. Failed urban greening projects, often based on assumptions regarding what was in the best interests of local residents, or the environment, bear witness to the need for public participation in the planning of urban greening. The Mount Royal resident survey shows that while there is strong support for some forms of urban greening, that other forms - e.g. the dense river vegetation, flower and vegetable gardens - are either unwanted or unacceptable. Clearly there is a need to develop and deploy decision support tools, within a participatory decision support system, that can be easily understood and utilised by all participants. Results from the expert survey indicate strong support for the use of visualisations in communicating ideas and information to people inside and outside of their profession. Similarly the resident survey shows strong support for both the level of information provided by the visualisations, and the extent to which the residents felt that the visualisations empowered them to participate more fully in the planning and discussion of urban greening. The high return rate for the resident survey (80 % of all resident questionnaires), coupled with the strong endorsement of the depicted football field and its position, implies support by the residents for, and active use of, visualisations as a decision support tool. Further development of a broader and more inclusive participatory decision support system should incorporate public meetings and feedback – as envisaged in the National Environmental Management Act (1998).

The expert group's moderate support for visualisations in their own professional decision-making, and the moderate confidence levels with which they felt they could make professional decisions based on the visualisations, suggests, at this time, a limited endorsement of visualisation in decision making. Reasons for these results might include unfamiliarity with the technology, as well as it's advanced technical nature. Strong support from both the expert group and residents regarding the likelihood of the Mount Royal housing settlement resembling, in time, the visualisations if urban greening was implemented, suggests that the images are both accurate and credible. Strong support from the expert group regarding the desirability of the depicted urban greening, while possibly indicating a professional preference, implies accuracy and credibility.

The authors' experience of modelling the Mount Royal housing settlement indicates that the need for expert input from a number of disciplines, rather than data, is the most important consideration in visualising urban greening. Where expertise already exists, as in well-resourced municipalities, visualisation could be an efficient and cost effective participatory decision support tool. In order to provide future residents of planned housing settlements, and residents of neighboring suburbs, the opportunity to participate more fully in the planning of their environment, visualisations should, ideally, be undertaken prior to commencement of house construction. The costs of implementing a participatory decision support system, possibly within existing Local Agenda 21 structures, in the eThekwini Municipal Area, are outweighed by the potential visual, environmental and social impacts that will result from the large number of low-cost high-density houses planned in the area. The authors suggest that a participatory decision support system, incorporating realistic urban landscape visualisations, could provide all stakeholders a means by which they could participate and contribute towards the planning and greening of the physical, visual and social environment within which they live and work.

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Appendix One

Expert Survey

Dear respondent

Thank you for agreeing to participate in this survey. With the exception of one photograph (figure 1) all of the enclosed images were computer generated using real-world geographically based data including site survey plans, electrical plans, aerial photography and Digital Elevation Models. All of the vegetation utilised is indigenous to the area. Imagery based on real-world data (as opposed to artists' impressions) are increasingly being used in Europe and North America to undertake visual impact studies, and convey information to the general public regarding proposed landscape changes – e.g. housing and office block developments, cell phone masts and new roads. The aim of this survey is to evaluate the credibility and potential usefulness of photorealistic visualisations in urban greening projects from different disciplinary viewpoints. A separate survey will be undertaken of the Mount Royal residents. Please note that:

a. The Mount Royal housing project is still under construction, and it is therefore not possible to make direct comparisons with photographic images.
b. The study area was limited to Mount Royal, and does not include Mount Moriah (to the east).
c. A check box for 'not applicable' is provided if you feel that the question is not relevant to your profession.

1. Please list your profession – e.g. architect, electrical engineer, civil engineer, environmentalist, city manager, botanist, etc.

---

2. Please rate the potential usefulness of figures 2,3 and 4 to your own decision-making in your profession.

		Of no use									Of great use	
2A	Figure 2	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A
		Of no use									Of great use	
2B	Figure 3	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A
		Of no use									Of great use	
2C	Figure 4	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

---

3. Please rate the potential usefulness of figures 2, 3 and 4 in communicating ideas / information to other people in your profession.

		Of no use									Of great use	
3A	Figure 2	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A
		Of no use									Of great use	
3B	Figure 3	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A
		Of no use									Of great use	
3C	Figure 4	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

---

4. Please rate the potential usefulness of figures 2, 3 and 4 in communicating ideas / information to people **outside** of your profession.

		Of no use	Of great use	
4A	Figure 2	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10		☐N/A
4B	Figure 3	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10		☐N/A
4C	Figure 4	☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10		☐N/A

---

5. With what level of confidence could you make any professional decisions based on the computer-based imagery?

No confidence at all **With great confidence**

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

---

6. If urban greening were implemented in the Mount Royal housing settlement do you think the view in figure 1 could (in time) resemble figure 2?

Highly unlikely **Highly likely**

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

---

7. Is the urban greening depicted in the computer-based imagery desirable?

Highly undesirable **Highly desirable**

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

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8. What changes would you make based on the computer-based imagery?

9. Please list any other comments below.

Figure 1. Mount Royal: Stonebridge Drive. S29°43'48.393" E31°1'3.0496". Photograph.

Figure 2. Mount Royal: Same camera position as Figure 1. S29°43'48.393" E31°1'3.0496". Computer image.

Figure 3. Mount Royal: Southern section - looking southeast toward river. S29°44'17.959" E31°0'35.158". Computer image.

Figure 4. Mount Royal: Northern section - looking south down the river. S29°44'1.4474" E31°1'5.5732". Computer image.

Appendix Two

Residents and Neighbors' Survey

Dear respondent

Thank you for agreeing to participate in this survey. With the exception of one photograph (figure 1) all of the enclosed images were computer generated using real-world geographically-based data including site survey plans, electrical plans, aerial photography and Digital Elevation Models. All of the vegetation utilised is indigenous to the area. Imagery based on real-world data (as opposed to artists' impressions) are increasingly being used in Europe and North America to undertake visual impact studies, and convey information to the general public regarding proposed landscape changes – e.g. housing and office block developments, cell phone masts and new roads. The aim of this survey is to evaluate the potential of computer-based imagery as a participatory decision support tool in urban greening projects. Urban greening may include tree planting, vegetable gardens and urban agriculture, river rehabilitation and urban forestry.

Please note that:

a. The Mount Royal housing project is still under construction, and it is therefore not possible to make direct comparisons with photographic images.
b. The study area was limited to Mount Royal, and does not include Mount Moriah (to the east).
c. A check box for 'not applicable' is provided if you feel that the question is not relevant.

1. Please indicate whether you are a resident of Mount Royal, or of a neighboring suburb.

I am a resident of Mount Royal ☐

I am a resident of a neighboring suburb ☐

---

2. To what extent do you support the planting of trees as shown in figures 3 and 4?

		Strongly opposed									Strongly support	
2A	Figure 3	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

		Strongly opposed									Strongly support	
2B	Figure 4	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

---

3. Figure 5 shows a football field (which is **not** part of the plans for Mount Royal) on the boundary of the water treatment plant. Please indicate whether you approve of the football field and its position.

		Approve	**Disapprove**
3A	Approval of the football field	☐	☐
3B	Position of the football field	☐	☐

---

4. Figures 3 and 4 show that apart from grass, private vegetable gardens, and communal crop fields, little use has been made of the space between houses. Please indicate the importance of the following use of the open space.

		Least important									Most important	
4A	Flower gardens	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

		Least important									Most important	
4B	Fruit Trees	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

		Least important									Most important	
4C	Grass	☐1	☐2	☐3	☐4	☐5	☐6	☐7	☐8	☐9	☐10	☐N/A

Least important **Most important**

4D Shade trees ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

Least important **Most important**

4E Vegetable gardens ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

Least important **Most important**

4F Sports fields ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

---

5. Please indicate the extent to which these images provide sufficient information for you to make decisions regarding the planting of trees and use of open space.

Not enough information **Sufficient information**

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

---

6. If urban greening were implemented in the Mount Royal housing settlement do you think the view in figure 1 could (in time) resemble figure 2?

Highly unlikely **Highly likely**

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

---

7. To what extent do you think that these images empower you to participate more fully in the planning and discussion of urban greening?

No empowerment **Empowered**

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 ☐N/A

Figure 1. Mount Royal: Stonebridge Drive. S29°43'48.393" E31°1'3.0496". Photograph.

Figure 2. Mount Royal: Virtual Camera – same camera position as Figure 1. S29°43'48.393" E31°1'3.0496". Computer image.

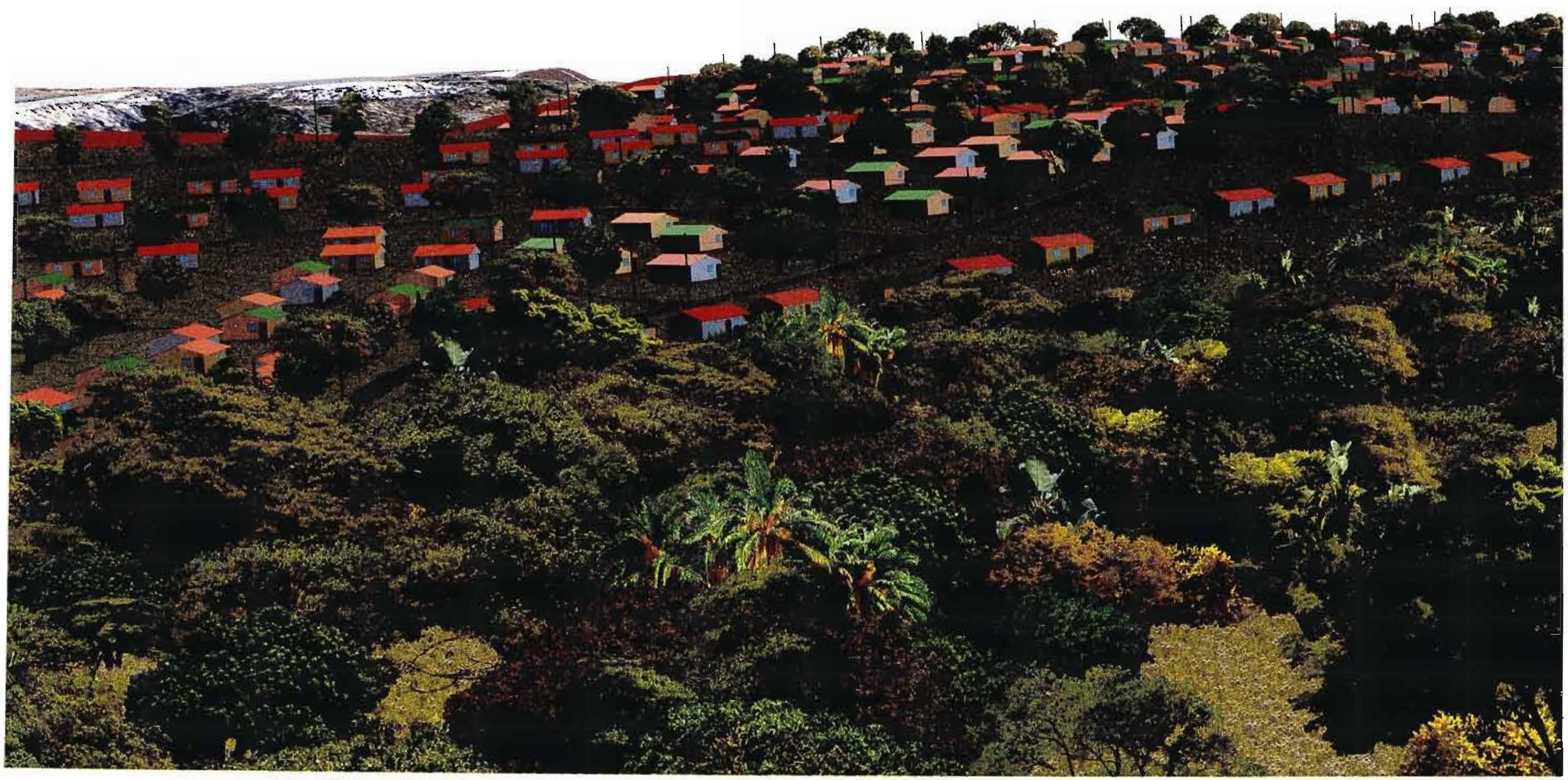

Figure 3. Mount Royal: Southeast to northwest over-river perspective. S29°44'26.071" E31°0'45.941". Computer image.

Figure 4. Mount Royal: Northern section – looking north. S29°44'0.070664" E31°0'47.348". Computer image.

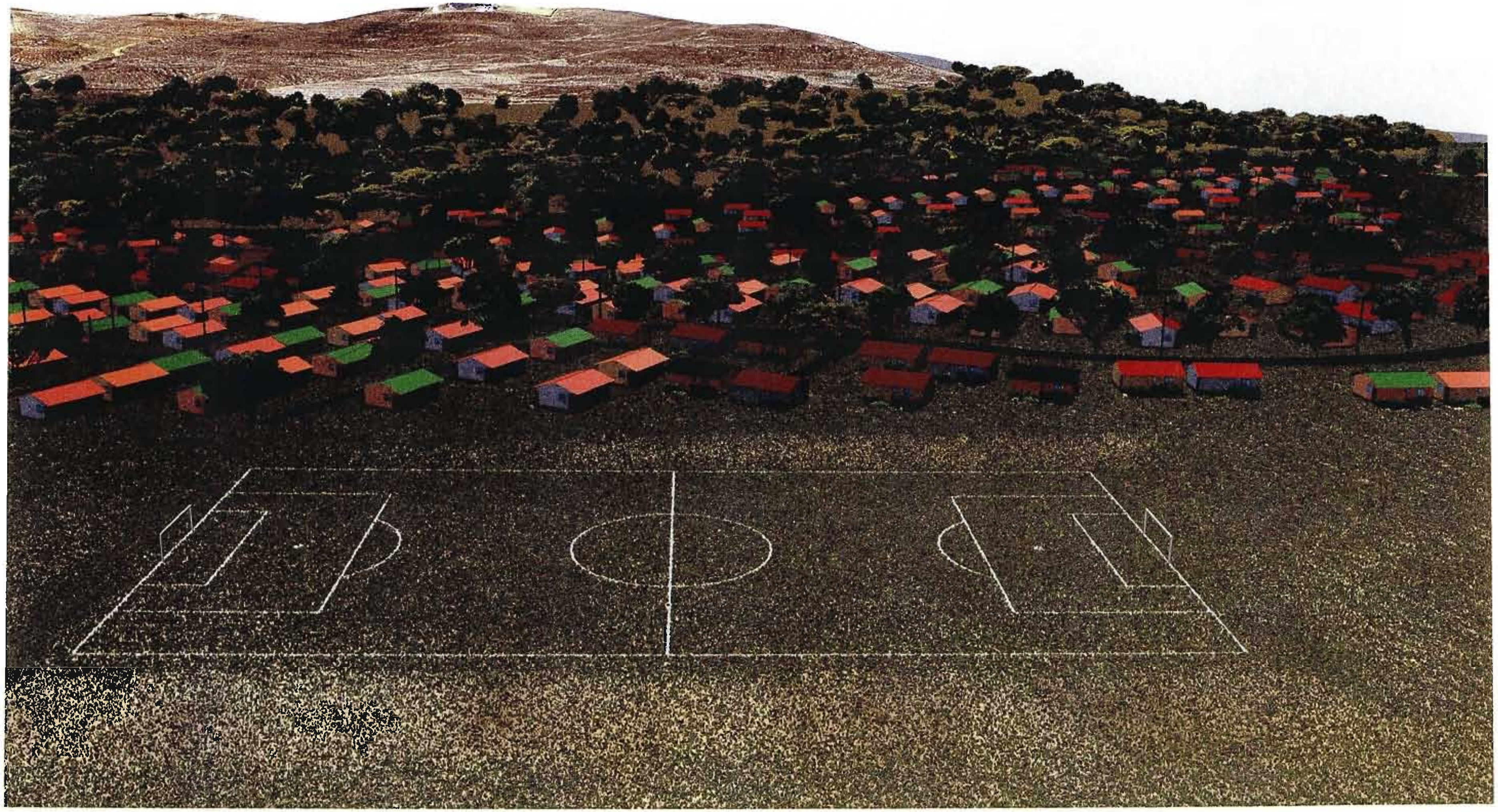

Figure 5. Mount Royal: West to east general perspective. S29°43'56.873" E31°0'33.096". Computer image.

Appendix Three

Survey Results

Table 1. Expert Survey Results

	Environmental Scientist	Civil Engineer	Social Researcher	Botanical Society	Grassland Scientist	Ecology Lecturer	Environ-mentalist	Horti-culturist	Median	Mean
Question 2A	8	5		7	10	5	3	8	7	6.6
Question 2B	8	5		6	10	4	3	8	6	6.6
Question 2C	8	6		7	6	5	3	8	6	6.1
Question 3A	7	6	8	8	10	8	5	8	8	7.5
Question 3B	7	7	8	6	10	8	4	8	7.5	7.3
Question 3C	7	7	8	8	8	8	3	8	8	7.1
Question 4A	6	6	8	8	10	9	6	8	8	7.6
Question 4B	6	6	8	6	10	9	6	8	7	7.4
Question 4C	6	6	8	7	9	9	3	8	7.5	7
Question 5	6	5		7	8	6	2	7	6	5.9
Question 6	5	9	10	8	9	8	2	8	8	7.4
Question 7	10	7	10	9	10	9	9	8	9	9

Table 2. Resident Survey Results

	Res. 1	Res. 2	Res. 3	Res. 4	Res. 5	Res. 6	Res. 7	Res. 8	Res. 9	Res. 10	Res. 11	Res. 12	Res. 13	Res. 14	Res. 15	Res. 16	Median	Mean
Question 2A	1	1	1	10	1	2	1	2	1	10	1	2	1	1	2		1	2.5
Question 2B	10	10	10	10	10	9	9	1	9	10	1	1	1	10	8		9	7.3
Question 3A	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Question 3B	10	10	10	10	10	10	10	10	10		10	10	10	10	10	10	10	10
Question 4A	2	1			1	2	2	2	1	2	2	2	3	2	3	3	2	2
Question 4B	2	2	2		1	1	2	3	8	3	1	3	3	2	3	1	2	2.5
Question 4C	9	9	2	10	10	10	9	10	8	10	10	10	9	7	10	10	10	8.9
Question 4D	9	10	9	9	10	10	9	9	8	9	10	9	9	7	8	9	9	9
Question 4E	10	1	2	10	1	3	2	3	4	3	7	3	9	3	3	1	3	4.1
Question 4F	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Question 5	10	10	10	9	10	10	10	10	10	10	10	10	10	10	10	10	10	9.9
Question 6	10	10	10	9	10	10	10	10	8	10	10	10	10	9	10	10	10	9.8
Question 7	10	10	10	9	10	10	10	10	8	10	10	10	10	9	10	10	10	9.8

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Personal Communications

Mattson, M.
Mount Royal Environmental Control Officer
PO box 393
St. Lucia, 3936
South Africa

Hanson, C
3D Nature, LLC
13195 West Chenango Ave
Morrison, CO 80465
United States of America

Figure Legend

Figure 1. Informal housing in Cato Manor.

Figure 2. Formal housing in Cato Manor.

Figure 3. Close-up of Mount Royal Housing Project Area. Scale = 1:10 000. Sourced from the Photogrammetry branch of eThekwini Municipality (2004).

Figure 4. Geo-referenced aerial photography draped over the DEM

Figure 5. 3D houses cloned, positioned and aligned in the VNS Mount Royal model. A fractal-based ground effect replaces aerial photography in the study area.

Figure 6. Terrain prior to application of terraffectors.

Figure 7. Area terraffectors level the terrain within a 1.5 metre perimeter of each house.

Figure 8. Roads and river created with linear terraffectors, and the respective application of an asphalt ecosystem and stream effect. Positioning of electrical poles and overhead electrical main connections.

Figure 9. Addition of in-stream, streambank, riparian and general vegetation.

Figure 10. Addition of vegetable gardens, communal crops, grass and street trees.

Figure 11. Potential usefulness of visualisations in professional decision making.

Figure 12. Potential usefulness of visualisations in communicating ideas and information to people within experts' profession.

Figure 13. Potential usefulness of visualisations in communicating ideas and information to people outside of experts' profession.

Figure 14. Preferred use of open space.

Appendix 1: Figure 1. Mount Royal housing project: View from Stone Bridge Drive.

Appendix 1: Figure 2. Mount Royal: Same camera position as Figure 1.

Appendix 1: Figure 3. Mount Royal: Southern Section – looking southeast toward river.

Appendix 1: Figure 4. Mount Royal: Northern section – looking south down the river.

Appendix 2: Figure 1. Mount Royal housing project: View from Stone Bridge Drive.

Appendix 2: Figure 2. Mount Royal: Same camera position as Figure 1.

Appendix 2: Figure 3. Mount Royal: Southeast to northwest over-river perspective.

Appendix 2: Figure 4. Mount Royal: Northern section – looking north.

Appendix 2: Figure 5. Mount Royal: West to East general perspective.

Figures

Fig. 1. GH Donaldson-Selby. January 21, 2005.

Fig. 2. GH Donaldson-Selby. January 21, 2005.

Fig. 3. GH Donaldson-Selby.

Fig. 4. GH Donaldson-Selby.

Fig. 5. GH Donaldson-Selby

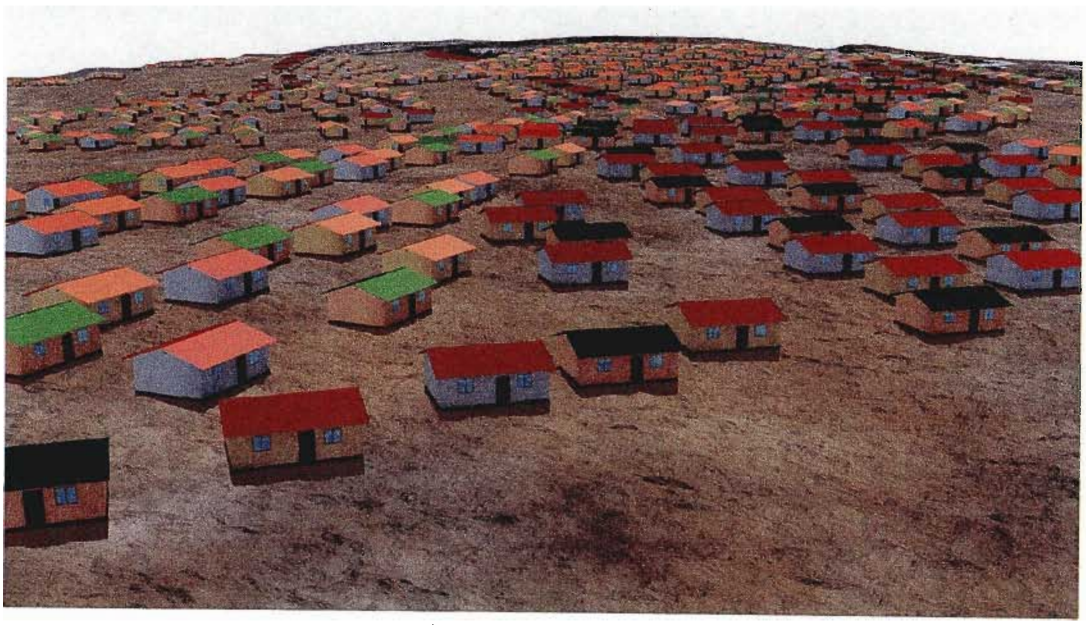

Fig. 6. GH Donaldson-Selby

Fig.7. GH Donaldson-Selby

Fig.8. GH Donaldson-Selby

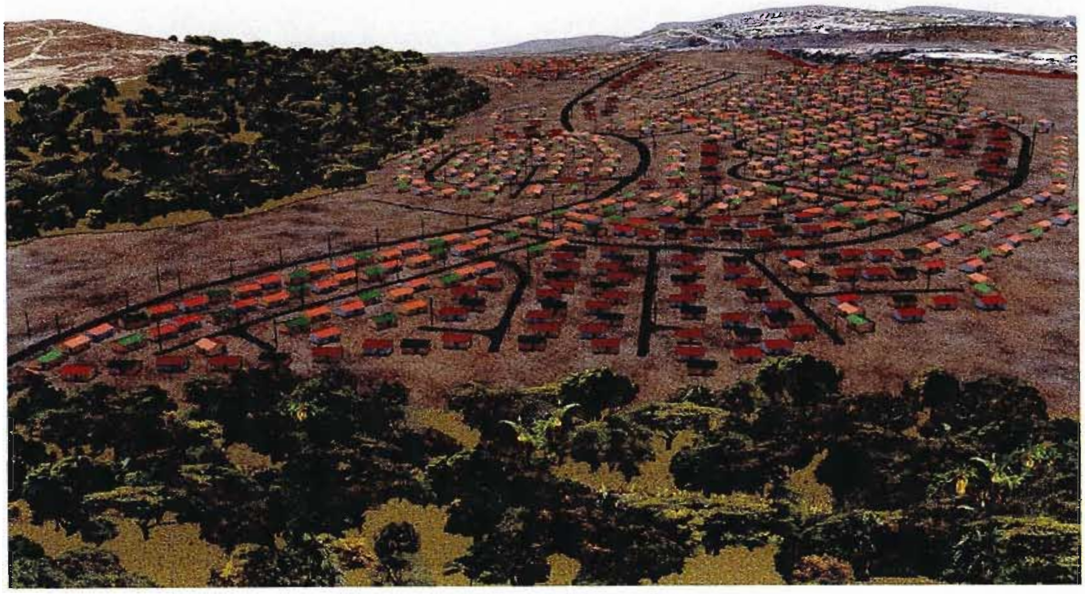

Fig.9. GH Donaldson-Selby

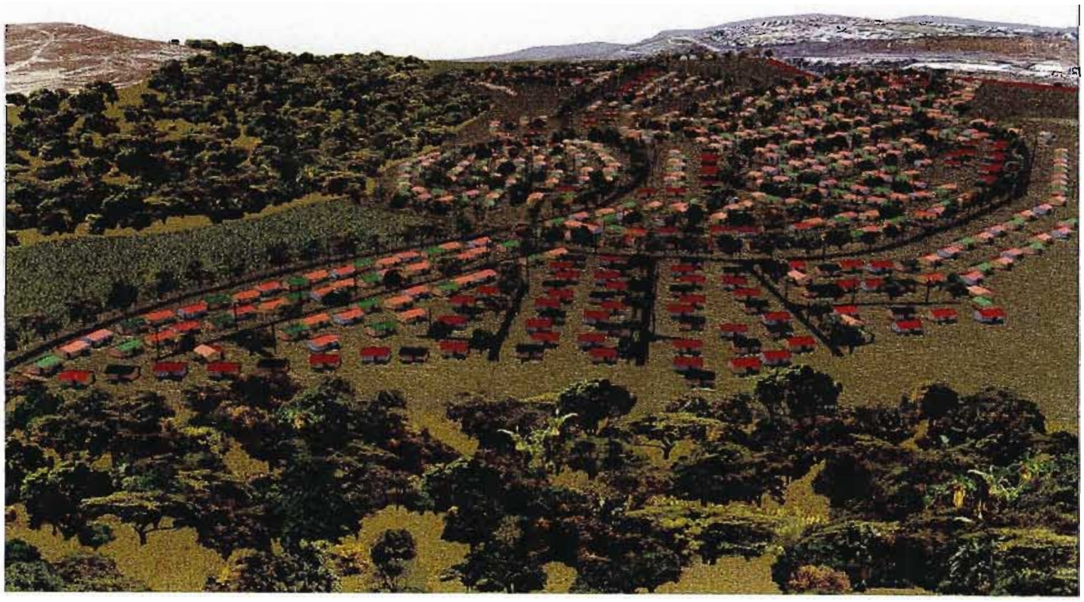

Fig.10. GH Donaldson-Selby

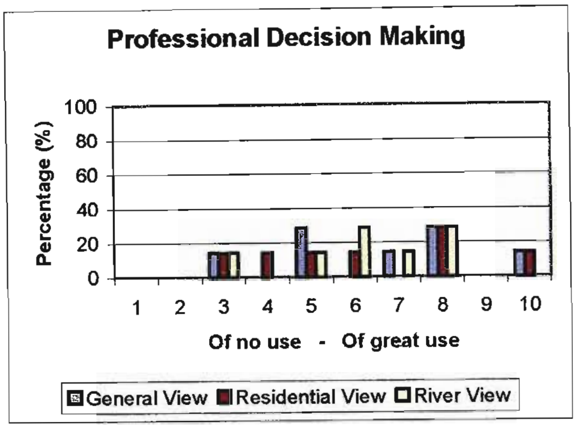

Fig.11. GH Donaldson-Selby

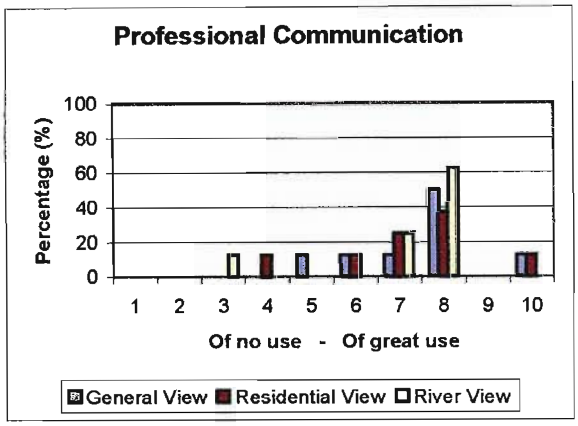

Fig.12. GH Donaldson-Selby

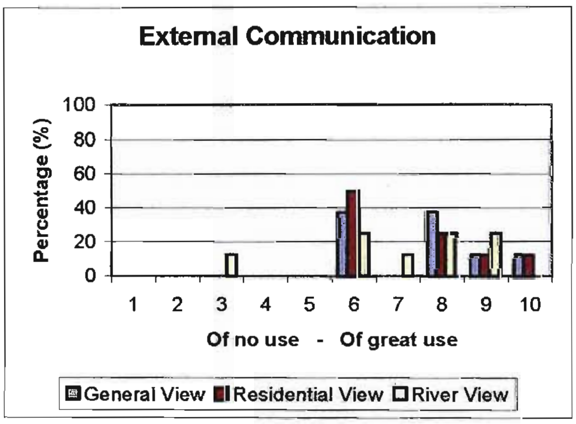

Fig.13. GH Donaldson-Selby

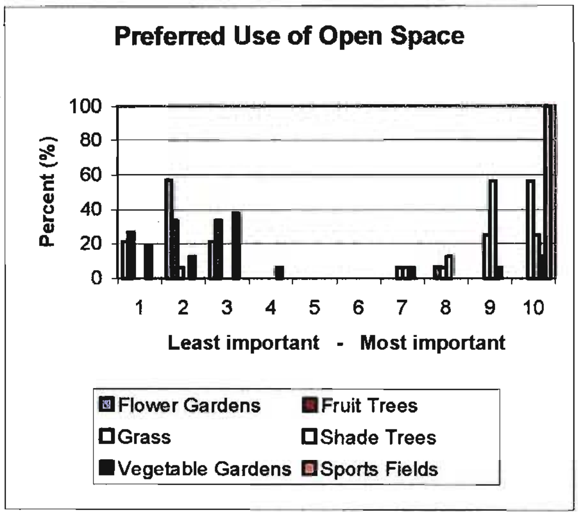

Fig.14. GH Donaldson-Selby

Table Legend

Table 1. Proposed number of units, purpose, and Hectares utilised for the Mount Royal Housing Project. Sourced from Environmental Management Branch of eThekwini Municipality (2003).

Appendix 3: Table 1. Expert Survey Results.

Appendix 3: Table 2. Resident Survey Results.

Tables

Table 1.

Purpose	No. of Units	Ha. Utilised	% of Total
Special Residential Sites	977	26.4906	41.28
Crèche	2	0.2623	0.41
Places of Worship	1	0.2584	0.40
Minor shopping	1	0.0995	0.16
General Shopping	2	0.6084	0.95
Municipal	1	0.1100	0.17
Cultural and Entertainment	1	0.3153	0.49
Education	2	2.8684	4.47
Public Open Space	11	26.0445	40.58
Roads		7.1158	11.09
		64.1732	**100**