NATURAL RESOURCES SYSTEMS PROGRAMME

PROJECT REPORT[1]

DFID Project Number

R7330

Report Title

Peri-urban natural resources management at the watershed level, Kumasi, Ghana. Scientific Report.

Annex A (Part 1) of the Final Technical Report of project R7330.

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Date

2002

NRSP Production System

Peri Urban Interface

[1] This document is an output from projects funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

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Executive Summary

This Project has taken forward research on the Kumasi PUI under the NRSP, building upon the foundations laid by projects R6448 and R6799, in particular, by focusing attention on a more holistic approach to natural resource management at the watershed scale. This has entailed working with a wide range of stakeholders, from villagers and peri-urban micro-enterprise operators to the respective local and regional authorities, parastatal corporations, official agencies and urban industries with activities affecting, or responsibilities pertaining to, the PUI.

New primary research was to be minimised. The most substantive issues on which such work proved necessary were:

- the extent and precise nature of water pollution in peri-urban areas, to provide a baseline water quality database
- the natural resource-based and other activities of urban industries and peri-urban micro-enterprises that might impact upon peri-urban environmental quality
- current natural resource use and environmental management practices by peri-urban communities
- the perceptions and priorities of peri-urban villagers in relation to current NR use and environmental conditions, and potential improvements thereto
- the extent to which the KMA and four surrounding District Assemblies were engaging with Local Agenda 21 processes, either autonomously or through linkages with ICLEI, and what impact these might have on sustainable development in the PUI.

Given the size, shifting boundaries and rapidly changing nature of the PUI, the methodology adopted was to concentrate our attention on a representative sample of watersheds and village communities within them. Accordingly, we identified that part of the Owabi catchment feeding the Owabi Dam, and the Sisa-Oda catchment as appropriate examples of the 'inner zone' of the PUI where the impacts of rapid urbanisation are most pronounced. These watersheds were used for water quality monitoring along transects that covered the changes in stream/river conditions as the water approaches, then flows through and out of the urban area. The water sampling points were selected in close proximity to a sample of eight study villages chosen to represent the spectrum of conditions in the PUI, from predominantly rural, in the cases of Adagya and Asago to essentially urban in the cases of Abrepo and Sepetinpom. Duase, Esereso, Atafua and Maase represented intermediate situations. Only two of these villages (Duase and Asago) had been included in previous projects. Accordingly, we undertook baseline surveys in them all in order to ensure a common database and to update earlier material where it was available. Indeed, on the basis of the range of conditions we encountered, we found it most useful to conceptualise the inner part of the PUI as part of the functional urban area rather than as an entirely separate zone.

The principal subsequent research and monitoring activities were:

- raising awareness of existing environmental problems, particularly but not exclusively with respect to water quality and pollution, through participatory methods such as the use of basic water testing kits by junior secondary school pupils and through local radio broadcasts and the production of widely distributed leaflets
- bringing the various stakeholders together to discuss these problems and to explore ways forward through a succession of round table discussions, workshops and field visits to contentious areas
- facilitating self-help and mutual help, through the compilation of resources such as a Directory of Development and Environmental Organisations, and an annotated Bibliography of relevant materials
- using participatory methods, formulating and testing guidelines for community-based diagnosis of environmental problems and appropriate actions to address them, i.e. the Water Management Framework
- In view of a strongly expressed need by these long-studied communities to obtain some tangible benefit from all the research undertaken there by successive NRSP projects, we extended the research in what was an innovative direction in this region. This involved studying the communities' responses to, and adoption of, a series of experimental interventions designed as participatory demonstration microprojects in line with the priorities

previously expressed in each village. These small and inexpensive interventions had the objective of showing what each household and community could do themselves to address problems and ameliorate conditions at little or no financial cost. We focused on water harvesting as a supplementary source of additional water, and the next highest priorities expressed by villagers, namely provision of trees and bushes to screen refuse tips, provide shade and fruit; and erosion control measures.

Levels of participation and enthusiasm regarding the demonstration projects varied greatly, and results therefore ranged from excellent to disappointing. In the final months of the project, we were able to draw on the Community Level Facilitators (CLFs) identified and trained by Project R7995. Responsiveness throughout the Project, and the uptake of Project interventions, was generally most pronounced in the more rural villages, namely Adagya, Asago and Maase, where communal spirit and identity, and the role of traditional leaders were still most evident. Conversely, the most urban, i.e. Abrepo and Sepetinpom, had lost much of that ethos, and people were more concerned for their own families and households. Hence most communal activities were far harder to organise or sustain, although there was some variation among particular groups within these villages. Even getting a reasonable attendance at research or awareness-raising meetings was difficult, with Project staff having to make repeated and often frustrating visits. However, the specific activity of water testing through the JSS in Sepetinpom worked very well under the leadership of committed teachers. In the intermediate villages of Atafua, Esereso and Duase, circumstances varied, in some cases resembling more urban responses and in others more rural. This experience is entirely consistent with the notion of the PUI elaborated above, and where increasing urbanisation is quite rapidly reflected in more urban lifestyles and behaviour, even if the village retains traditional leadership and aspects of its identity and territory.

It is very difficult to attempt to measure changes in public awareness, let alone behaviour, from single actions and interventions. These are longer term and complex processes often with cumulative effects. Even seeking to measure such changes at the end of the project might be premature. Indeed, it would be instructive to conduct a follow-up evaluation a year or two later in order to see whether the participatory activities and the role of the CLFs have actually become sustainable once financial and support inputs by Project staff have ended.

Following the adoption by DFID and the NRSP of poverty reduction as primary objective during the life of this project, it became necessary to adapt our research programme accordingly. However, since our project was focused on sustainable natural resource utilisation at the watershed scale, rather than on identifying poor people per se, it was not appropriate to devote the time and resources to undertaking detailed research that accords fully with the asset-vulnerability framework or livelihoods strategy, even though this has now been adopted an 'official' DFID methodology. We sought to meet the challenge by including a wide spectrum of people in focus groups and participatory appraisals, by ensuring that poor villagers benefited from awareness-raising activities, and that the micro-interventions we demonstrated would be affordable. We also found that some of the poor were too preoccupied with day-to-day survival to attend and participate in Project demonstration activities. The participatory Watershed Management Framework developed and tested with community and other stakeholder participation, also forms a mechanism for linking the individual villages with the wider PU zone and urban context.

Our research leads us to the clear conclusion that the PUI is most appropriately conceived of as something of a continuum (although not necessarily with a simple linear form) between the poles of 'true' urban and rural. The width and nature, and even particular boundaries, of the PUI are dynamic and subject to rapid change according to the pace of urban growth and related processes.

The implications of this for natural resource use, environmental quality and NR-based livelihoods emerged from our research:

- we found no evidence of unique or distinctive NR uses and livelihood activities that we might associate with the PUI
- rather, as villages begin to experience urban influences – in terms of improved access, changing pressures on land-use and natural resources, increasing pollution, arrival of outsiders seeking affordable accommodation, reduced prices for manufactured goods etc – their rural character starts to change, with a progressive shift towards combinations of rural and urban

features, activities and facilities. It is these combinations and their rapidly changing complexion, that seem best to characterise the PUI

- in terms of natural resources, there is a progressive shift from agriculture and pastoral land-use towards residential and then commercial or industrial use, with associated increases in land values but losses of entitlement on the part of some farmers if appropriate compensation is not forthcoming, and hence a sometimes dramatic impact on their livelihoods. Similarly, pressure on woody biomass for fuelwood or through land clearance intensifies and sandwinning commonly also increases in areas of appropriate soil. Water pollution from the city commonly increases downstream over time, while intensive agriculture or livestock/poultry rearing for urban markets, along with inappropriate disposal of the growing volumes of human waste and refuse, may contaminate the groundwater and rivers
- In terms of livelihood strategies, the increase of urban pressures therefore leads to adaptation and diversification for most people, particularly the relatively and absolutely poor. Where possible, this may result in a combination of rural and urban livelihood activities, e.g. wage labour and cultivation. Otherwise, different non-urban activities may become necessary, using traditional skills (e.g. craft production for urban or tourist markets) or new ones (e.g. motor car repair). Certain environmentally harmful activities that use natural resources do tend to concentrate in peri-urban areas, where the land or other resources are still available. Examples include car washing adjacent to rivers or streams, and stone crushing for the roadbuilding and construction industries. However, even these are not distinctively peri-urban, and not all those who carry them out are peri-urban residents
- Awareness of these processes and problems was surprising low among peri-urban villagers and other stakeholders. In some cases, an apparent lack of awareness might have been used as a strategy for avoiding having to take responsibility or to initiate mitigatory actions which could prove costly and for which there was as yet no strong pressure
- Awareness-raising and the taking of appropriate actions are therefore important priorities among all stakeholders. This project has developed and piloted an innovative, participatory and sustainable mechanism for doing this within a collaborative and co-management context, the Water Management Framework This holds considerable promise in taking forward the Project purpose and that of the NRSP in the Kumasi context.

Abbreviations

ADP	Aerial Digital Photography
BIRD	Bureau of Integrated Rural Development, KNUST
CEDEP	Centre for the Development of People
CLF	Community Level Facilitator
DFID	Department for International Development, UK
EPA	Environmental Protection Agency, Ghana
GIS	Geographical Information System
GOAN	Ghana Organic Agriculture Network
GWC	Ghana Water Company
IRNR	Institute of Renewable Natural Resources, KNUST
IWMI	International Water Management Institute
KMA	Kumasi Metropolitan Assembly
KNUST	Kwame Nkrumah Institute of Science and Technology
KUMINFO	Kumasi Information System
NRI	Natural Resources Institute, University of Greenwich
NRSP	Natural Resources Systems Programme
PRA	Participatory Rural Appraisal
PUI	Peri-Urban Interface
RHUL	Royal Holloway, University of London
VCS	Village Characterisation Survey
WMF	Watershed Management Framework

1 Introduction

This three-year Project (February 1999 – March 2002) was designed as an important element in the progressive research programme under the NRSP's peri-urban interface (PUI) production system in Kumasi, Ghana. Whereas earlier projects had been concerned essentially with baseline studies and characterisation of Kumasi's peri-urban environment, this Project has focused on water resources issues in particular and environmental management in general. To that end, the Project has formulated and piloted a framework for sustainable natural resource management at the watershed scale. A parallel research stream has been undertaken in Hubli-Dharwad, India; comparisons and contrasts between these respective endeavours have been examined in Dávila and Brook (2000).

This Project has been more integrative in that it has sought to consolidate existing data from previous NRSP and other DFID projects and undertaking only limited new primary research where clear knowledge gaps could be identified. Particular lacunae thus researched have been water and related NR issues; questions regarding levels of community awareness of water and environmental issues; and the development of participatory local environmental co-management structures and tools appropriate for poor and under-resourced peri-urban villages. To this end, the Project was undertaken by a North-South partnership comprising the grantholders at Royal Holloway, University of London together with subcontractors at the Natural Resources Institute, University of Greenwich in the UK, and a diverse set of Ghanaian partners in Kumasi, namely the Institute of Renewable Natural Resources, Bureau for Integrated Rural Development, Sunyani Polytechnic, the Ghana Water Company, Environmental Protection Agency, Centre for the Development of People, and Ghana Organic Agricultural Network.

Following intensive reconnaissance, the PUI was characterised (Simon *et al.* 2001 - Research Paper 1) and a contribution made to conceptual refinement of the concept as constituting more or less a continuum from essentially rural to urban, but without a necessarily linear relationship between physical distance and the degree of 'urbanness' or 'rurality'. Key features of the PUI include the rapidity of change as urban pressures increase, the changing locations which are 'peri-urban' and hence also the changing identity and diversity of people within the PUIA cross-section of water quality sampling points was chosen to characterise a transect of streams and rivers from peri-urban through urban and back into the peri-urban zone downstream. Schools were selected close to water quality sampling points in order to pilot a method of environmental awareness-raising. A representative sample of eight villages experiencing different degrees of urbanisation and urban influence was selected for supplementary research and the piloting of participatory environmental co-management practices. Practical lessons from this research were subsequently incorporated within the Watershed Management Framework (WMF) formulated by the Project. The WMF represents the principal of a set of outputs designed to promote and facilitate sustainable natural resource utilisation and environmental co-management between peri-urban village communities, local authorities, official agencies and line ministries, and other relevant stakeholders.

Related outputs designed to serve as local resources to facilitate attainment of the project purpose include an annotated *Directory of Development and Environmental Organisations and Institutions in and around Kumasi* and an annotated Bibliography of relevant literature, covering academic, official, NGO and technical sources. An important element of the Project was to assess the level of awareness among all stakeholders of the extent and nature of environmental problems in the Kumasi PUI, and the necessity of preventative and remedial action. Since we found a disappointingly low awareness of these issues, or at least priority attached to them where people did have some knowledge, the Project undertook a series of awareness-raising activities, especially among the PUI communities and those industries and authorities with direct responsibilities for the PUI environment. These included:

- involvement of Junior Secondary School pupils in participatory water testing in and around their villages as part of their science classes
- ongoing group discussions and other activities in villages, culminating in the demonstration and piloting of micro-interventions through which villagers can improve

their immediate environment and quality of life, and which have now been incorporated within the WMF

- annual Project workshops with associated field visits, which attracted an excellent range of participants from most stakeholder groups and gained local press coverage
- production and distribution of a cartoon leaflet in both English and Twi editions
- two Twi broadcasts on local FM radio stations, and
- meetings with industrialists and officials

In keeping with the research nature of this project, all these activities formed part of the overall research strategy, in terms of which their implementation, take-up and at least short-term effects were monitored and evaluated. Considerable new knowledge has been generated through this process about the diversity of conditions in a representative cross-section of PUI villages, the rapidity of change in some conditions as urban influences intensify, and how different groups of villagers (in what are quite differentiated communities) perceive and respond to problems of natural resource and environmental degradation, and to urban encroachment.

Modifications to the work programme were made during the Project's life to accommodate as far as possible at that stage the new DFID and hence NRSP commitment to poverty reduction as its central objective. Accordingly, particular efforts were made to elicit views and perceptions from poor members of the communities, and to involve them in the demonstration micro-projects linked to the WMF. This poverty focus is now being taken forward by Projects R7995 and R8090 through the formulation and implementation of sustainable natural resource-based peri-urban livelihoods with particular reference to the poorest groups within the communities. The Community Level Facilitators identified and trained for these latter projects proved a helpful resource for community mobilisation on microproject activities in the final few months of this Project.

Despite many problems and challenges, this Project has largely fulfilled its purpose, in that a framework for sustainable and participatory natural resource and environmental co-management has been formulated and tested. This framework is underpinned by a secure database on water quality in the PUI, by surveys of polluting and degrading activities, and by a varied programme of environmental awareness-raising. Progress has also been made towards securing the sustainability of the important NRSP-funded KUMINFO GIS system at the Institute of Renewable Natural Resources of the University of Science and Technology in Kumasi. It is clearly beyond the ability of the Project to ensure take-up and implementation by the stakeholders, although prospects for this to happen have improved since the current government came to power at the beginning of 2001, removing the previous tensions between the Ashanti Region, and Kumasi in particular, and the central government in Accra.

This Report is divided into eight principal sections, with a series of appendices containing the logframes, technical reports and data, and some of the ancillary outputs such as the Directory and Bibliography. This Introduction constitutes **Section 1**. The remainder is structured as follows:

Section 2: Background to Project Purpose and Approach, explains the origin and context of this Project, its objectives and the impact of changing DFID and NRSP mission statements, and how the Project's philosophy and methodologies evolved.

Section 3: Research Background, Scoping Exercises and Research Design, starts by summarising the most pertinent literature, especially that emanating from related DFID projects and other recent materials not covered in earlier reviews. Thereafter details of the research team and our methodology are provided, with particular reference to characterisation of the PUI, water quality issues, assessment of the adequacy of existing data and the need for supplementary research, the selection of two representative watersheds for study and the identification within them of water testing sites and the representative sample of villages for detailed participatory work, and how the KUMINFO GIS system would be utilised as an integrative database and research tool.

Section 4: The Main Research Phase and Activities, is the largest section, presenting the detailed research results and analysis of the eight principal activities, namely

- the stakeholder analysis, including findings on the nature and extent of natural resource-based micro-enterprises and villagers' perceptions of them
- the communications strategy adopted by the Project, including workshops and associated field visits for stakeholders
- the village characterisation study to obtain baseline socio-economic and stated behavioural and perceptual information in the selected sample of villages, along with subsequent and more detailed watershed village characterisation study to explore selected priority themes pertaining to water and land allocation and use, and institutional structures
- water sources, use and their management
- existing farming systems and associated environmental issues
- the water quality research, including extensive and sustained datasets and information on the extent of heavy metal contamination at a downstream peri-urban site
- the experimental participatory water testing and awareness-raising programme undertaken in a sample of Junior Secondary Schools, and
- the extent to which the Kumasi Metropolitan Assembly (KMA) and the four district assemblies covering the relevant parts of the PUI are engaging with and promoting Local Agenda 21 issues that should facilitate and promote sustainable local environmental initiatives.

Section 5: KUMINFO, explains the use made of this GIS system that was originally developed under NRSP Project R6799 and for the maintenance and development of which we obtained a supplementary grant during the life of this Project. Progress towards the goal of making the GIS self-financing as the basis for longer term sustainability is also outlined.

Section 6: the Watershed Management Framework, presents the full WMF, which, as explained above, forms the principal output and proposed mechanism for participatory and sustainable co-management of the environment and natural resources by the relevant stakeholders at the watershed scale. A shorter version for use in peri-urban communities has been produced and is attached as Appendix D.

Section 7: Evaluations: In this section we report on the set of formal evaluations undertaken to assess the appropriateness, implementation/adoption and impact of the various outputs, products and awareness-raising activities, especially the cartoon leaflet, the schools' water test experiment, and the demonstration micro-projects and other WMF activities in the sample of villages.

Section 8: Conclusions: This final section draws together the principal findings, challenges and conclusions for the project as a whole and in the context of the ongoing Kumasi PUI research funded by the NRSP.

2 Background to Project Purpose and Approach

2.1 INTRODUCTION

This Project was derived in concept from work carried out under DFID-funded Projects R6448 *Peri-Urban Baseline Studies, Kumasi* (Holland *et al.* 1996) and R6799 *Kumasi Natural Resources Management Project: Inception Report* (Blake *et al.* 1997). In particular, R6799 Project staff at the Natural Resources Institute, University of Greenwich, first proposed the idea of looking at holistic watershed management as a template for integrated natural resources management in the rapidly-changing peri-urban zone around Kumasi.

Although the R6799 Project was generating significant bodies of information on natural resource use, there was little on water-related issues. Accordingly, this Project focused far more on an investigation of water resources, water use and quality, and the types and relative importance of water resource pollution; and the development of local environmental management structures and tools appropriate to communities with little financial capital. A complicating natural factor locally is that, as Kumasi lies across a local drainage divide, pollution generated within the city is frequently carried downstream from the city into the peri-urban zone.

The remit of the Project was to use, as far as practicable, existing data, rather than to generate more or larger data sets. In this respect, it was anticipated that the major data requirements would be derived from prior or on-going DFID-funded projects. With respect to R6799, it was agreed that both projects would benefit from the development of stakeholder surveys specifically focussing on water-related issues. This had been covered in general terms by the R6799 Village Characterisation Study, but in-depth supplementation and updating were required, including the development of PRA techniques to investigate water resources, water use and quality, the types and relative importance of pollution. Where practical, joint sites were chosen for study, and data sharing included baseline land use/farming systems data and soils data. The regional spread of data from R6799 was anticipated to be of importance in supplementing watershed-based data to verify generic diagnostic frameworks for watershed management within a Geographical Information System.

Further, it was envisaged that the research would also link to the DFID-established KUMINFO GIS database (available both in the Institute of Renewable Natural Resources, Kumasi and in the UK at Natural Resources Institute, University of Greenwich (NRI)), in using and refining the baseline data already present, and in providing appropriate additional datasets, and linking through to the work being undertaken by Project R6880 *Development of Methods of Peri-Urban Natural Resource Information Collection, Storage, Access and Management*.

The functional definition of *peri-urban* used by Blake *et al.* (1997) of an area approximately 47 km from the urban centre was originally used during our Inception Studies, but it became apparent that the major changes were taking place close to the urban edge and that the characteristic changes in the wider peri-urban area (as defined by Blake *et al.* (1997)) were also found close to the present urban boundary. Accordingly, the NRSP definition (Phillips *et al.* 1999: 5-6) seemed more useful. This distinguishes between an inner zone of direct impact (experiencing land pressure, pollution, increasing population, etc.) and a wider zone of influence, in which the handling of agricultural and natural resource products becomes increasingly market-related.

The principal focus in this research thus became the inner zone of the peri-urban area, within a radius of approximately 20 km of the city centre. This is consistent with emerging conceptual ideas about the nature of the peri-urban zone (Simon *et al*. 2001a: Research Paper 1). Little importance is now placed by researchers on attempting to measure the precise width of this zone. Indeed, this would be a futile exercise in the context of rapid expansion of the peri-urban zone, as in Kumasi. As a generalisation, there is a gradient between more urban and more rural segments within the zone. This gradient slopes away from the city, but is not spatially uniform, and it is possible (as in peri-urban Kumasi) to find relatively rural communities close to the city limits (often but not always a function of poor transport links). Also, urban 'outliers' are the consequence of the incorporation of formerly distinctive towns within the growing peri-urban zone. We have found that, for many (but not all) purposes, it is important to consider the inner PUI as an extension of the city rather than as an entirely separate area or zone. This is because the city region functions as an integrated whole in terms not only of its ecological footprint but also of its economic and demographic processes (Simon *et al*. 2001a: 11). (Conversely, however, in political and administrative terms, a large city like Kumasi and even its inner peri-urban hinterland is fragmented, exacerbating many of the well-known problems regarding a lack of integrated planning, service delivery and management.)

The significant consequence of this integrated approach in practical research terms is to shift attention away from attempting to study or verify peri-urban natural resources management and livelihood strategies as somehow distinct (or unique), and towards a more nuanced and holistic understanding of peri-urban resource use and management as part of the livelihoods/survival strategies, and the perceptions and priorities, of peri-urban residents. These strategies may well involve urban and perhaps even rural areas in addition to the peri-urban zone. Stated differently, the approach reorients the principal focus away from a spatially defined zone (the PUI) *per se* towards a more holistic focus on livelihoods and natural resource use and management of/by peri-urban residents on the one hand, and on the peri-urban consequences of actions by peri-urban, urban and perhaps also rural actors on the other. A key dimension of the research within this Project then became to examine the scope for meaningful action at the village and watershed levels to address the natural resource and environmental problems and improve the quality of life, especially for poor and marginalised groups.

In so doing, we have also sought to avoid the pitfalls in participatory watershed projects identified by Rhoades (1997). Thus, particular attention has been devoted to:

- local 'ownership' by working through and with community leaders and village committees
- acknowledging, understanding and seeking to accommodate the diversity of stakeholders and their respective positions and priorities, even at the village level
- genuine interdisciplinary collaboration in all aspects of the Project, rather than following traditional disciplinary divisions in a manner inimical to holistic integration
- integrating research, perceptions and awareness raising at different geographical scales

The importance of such a focus is underscored by the relatively poor access of Ghanaians to improved water sources and sanitation facilities. The most recent available national data suggest that only 49% of rural dwellers had access to an improved water source in 2000, compared with 87% of urban dwellers. The respective figures for access to improved sanitation facilities were 64% and 62% (World Bank 2001, cited in PHNIP 2002: 1). These variables are defined in terms of

- reasonable access to adequate water (at least 20 litres/person/day from a source within 1km of the dwelling) from an improved source such as household connection, public standpipe, borehole, protected well or spring, or rainwater harvesting; and
- access to at least adequate excreta disposal facilities (private or shared but not public) that can effectively prevent human, animal and insect contact with excreta (PHNIP 2002: 9).

Even allowing for data inaccuracies and definitional uncertainties such as whether a village communal ventilated improved pit latrine is deemed to be shared or public, these figures provide broad orders of magnitude. Although no statistics for the PUI as such exist, our knowledge of these communities suggests that conditions vary widely, according to each village's particular history, especially its recent rate and scale of growth and population increase, the extent of functional urbanisation, and whether it falls within the KMA or a district council area.

2.2 THE EFFECTS OF CHANGING DFID, NRSP AND PROJECT PURPOSES

Following a change in UK Government policy, DFID produced the White Paper *Eliminating World Poverty: A Challenge for the 21st Century* in 1997. Following the thrust of the White Paper, the overall aim of DFID is the elimination of world poverty, DFID's stated commitment being to the internationally agreed target to halve the percentage of people living in extreme poverty by 2015. The remit of DFID's separate research programmes is to assist in the delivery of this objective.

The ten year NRSP started in 1995, and is being implemented through contracted research projects, split into six major groupings, of which the Peri-Urban Interface is one. The 1997 commitment to poverty reduction led to a revision, in 1998, of DFID's strategy for research on natural resources. The principal focus of NRSP-related research changed then from one of focus primarily on NR-related production increases, to one where the emphasis was on the delivery of new knowledge that enables poor and marginalised people who are largely dependent on the NR base to improve their livelihoods sustainably.

This process was assisted by a series of commissioned reviews and 'position papers', such as Phillips *et al*. (1999), Budds and Minaya (1999) and Rakodi (1999), and through a major Workshop attended by NRSP project leaders: *Improving the Poverty Focus of NRSP's Research on Natural Resources* held in November 2000 (NRSP, 2001).

The latter stages of this research Project have been carried out against a more strongly stated NRSP Purpose, promulgated in 1999, namely*: benefits for poor people in targeted countries generated by application of new knowledge to natural resources management in peri-urban production systems*.

The government's second White Paper on international development, produced in 2000, *Eliminating World Poverty: Making Globalisation Work for the Poor*, places development targets in an international context where globalisation is seen as a force for positive change. This was followed in 2001 by an overview of DFID's approach to poverty reduction. *Poverty: Bridging the Gap* (2001) provides an introduction and guidance notes to help DFID staff and others to implement DFID strategy on poverty reduction. Particularly relevant to the present Research Project is Section 14 of the Guidelines, on poverty reduction and environmental management. The linkages between poverty and environmental degradation are made, and the central role of water management in reducing poverty through better health and more secure agricultural livelihoods is stressed.

This Project was commissioned by, and its logframe (see Appendix A) agreed with, the former NRSP management at NRI. During precontract negotiations, however, additional tasks had been requested by NRI, making the project rather ambitious, not least in relation to the budget. Within a few months of its commencement in February 1999, management of the NRSP passed to HTS Development. The new Programme Manager, Dr. Margaret Quin, and her Programme Advisory Committee commenced a review of the NRSP's remit and activities (see above). This resulted in an amendment to the programme logframe in line with identified knowledge gaps, evolving priorities and especially DFID's post-1997 White Paper commitment to poverty reduction and elimination. Accordingly, we were requested in turn to modify our objectives and activities as far as possible to bring poverty reduction centre stage. Although we had already formulated our research agenda and made considerable progress on the ground, we were able to underscore a commitment to poverty reduction quite effectively, especially in terms of

- the planned micro-interventions and analysis of how these were implemented and sustained by the different village communities
- focusing attention particularly on the poor and marginalised groups within each village and how to encourage and facilitate their empowerment through engagement with local institutions and the Project implementation process.

Further modifications to the logframe were effected following the *Project*'s Mid-Term Review (MTR) in November 2000 and ensuing discussions with the NRSP Management in early 2001. These took account of progress to date, the problems encountered and especially the evolution of the Project team's thinking in the light of local circumstances and the outputs of other concurrent research projects. In particular, this Project's research outputs were clarified, the content of specific activities was amended, and a new output 3 was included, with associated OVIs and MOVs. The previous outputs 3 and 4 have become 4 and 5 respectively. These seek to underscore the nature of this as a research project rather than a form of technical assistance. The final logframe is provided in Appendix B.

In particular, micro-interventions and projects have been conceived and implemented in the 8 study villages in line with villagers' expressed priorities, subject to financial constraints. The implementation of these projects, their short-term success, and the degree of 'sustainability' achieved, have been studied and analysed comparatively in order to document dispassionately the key lessons learned and the potential for wider replicability in the promotion of sustainable development and poverty reduction.

Overall, however, the modifications that we could effect were limited by the relatively late stage in the Project and hence the substantial extent to which research activities were under way or completed, and hence funds had already been disbursed and committed.

In summary, the philosophy adopted during this Project has been one of research to:

- consolidate existing knowledge from previous NRSP and other research projects relating to village-based and watershed-scale environmental and natural resource use and management in the Kumasi PUI, particularly with respect to water issues;
- update the database and fill any relevant gaps identified in this process;
- examine how communities – and different social groups within them, especially the poor – in a representative sample of PUI villages perceive their current situation, the problems and remedial priorities they identify, and their degree of awareness of – and ability or willingness to use – existing institutional channels and NGOs to address these;
- examine community responses to, and adoption/maintenance of, appropriate micro-scale interventions, demonstrations of good practice and the provisions of information resources to facilitate improvements in day-to-day activities affecting environmental quality and poverty within the lands of this sample of villages;
- use these results to formulate best-practice guidelines for sustainable community-level action on environmental and NRM to enhance quality of life and sustainable natural resource-based livelihoods, particularly for poor residents. This should include provision of resources and information to empower the communities to mobilise NGOs, local authorities and official agencies for assistance within a collaborative or co-management framework.

This approach can be summarised as targeted research into the existing situation and villagers' responses to interventions in line with their expressed priorities. This has been undertaken in order to foster empowerment for self-help and to formulate best-practice guidelines for the replicability of such activities through a Watershed Management Framework (WMF). This is quite distinct from the provision of technical assistance *per se*, and is consistent with the research orientation and purpose of the NRSP.

2.3 ROLE OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

The Project inherited from R6799 an integrated geographical information system for peri-urban natural resources research based on a PC-mounted GIS and dubbed KUMINFO. During the life of the present Project R7330, attention was focused on extending KUMINFO to become a broader information system, on taking steps to promote the longer-term sustainability of the system, and investigating ways of making this an interactive tool for natural resource planning purposes.

2.4 PROJECT APPROACH

The principal approach adopted throughout the Project has been one of research into methods of 'self-help', not technical co-operation. Means to achieve this objective have been wide-ranging, but have notably centred on education through the use of simple water quality test kits in the Junior Secondary Schools associated with most of the Project communities. Pupils and teachers have been encouraged to disseminate this simple form of environmental self-monitoring through their communities as a means of raising environmental awareness in general, and water quality issues in particular. The development and testing of a major Project output, the Watershed Management Framework, encapsulates the approach of self-help and raising environmental awareness.

3 Research Background, Scoping Exercises and Research Design

This section of the Report focuses on the background to the research, the scoping exercises and reviews carried out to inform research design, and the research design itself. It is set out broadly in line with the amended logframe headings consequent on the Mid-Term Review of the Project, and references to specific logframe outputs of activities are given in square brackets [ ] where appropriate.

3.1 LITERATURE REVIEW [1.F]

During the grant application process and Project inception phase, the relevant literature on the physical and socio-economic environment of peri-urban Kumasi, as well as the broader comparative literature on peri-urban areas, the rural-urban interface and rapid urbanisation was consulted. Particularly useful have been:

• the report of the Kumasi Baseline Study (Project No. R6448) (Holland *et al*. 1996); and the inception report (Blake *et al*. 1997) and various subsequent reports of the Kumasi Natural Resources Management Project (No. R6799), to which the present Project is closely linked. In particular, the Village Characterisation Study (VCS) undertaken as part of this latter project, provided quite detailed recent data on the range of settlements and of residents' perceptions of natural resource issues within the Kumasi urban and peri-urban area.

• the Literature Review on Peri-Urban Natural Resource Conceptualisation and Management Approaches produced in 1999 under DFID's Natural Resources Systems Programme, Project No. R6949 (Phillips *et al*. 1999). Given its comprehensiveness and recency, it served well as a literature review for this Project, thereby also illustrating the synergy between projects within the NRSP;

During the currency of this Project, further outputs of DFID-sponsored research relevant to this Project included:

- R6880: *Development of Methods of Peri-Urban Resource Information, Collection, Storage, Access and Management*. The principal thrust of this project was to investigate which scales of remotely-sensed imagery were most appropriate for deriving information on the PUI. The project was also required to test how best such information could be used to involve local people in participatory natural resource use planning, and to develop user-friendly information systems to support such participation.

- R7549: *Consolidation of Existing Knowledge in the Peri-Urban Interface System*. This project was commissioned to review the reports and other outputs of PUI projects previously funded through the NRSP. The principal terms of reference were to consolidate the knowledge generated by these earlier projects and outputs, to assess whether or not this knowledge was adequate to inform NRSP in formulating new research projects, and to identify any significant gaps in knowledge which required to be addressed with reference to the implementation of the changed focus of the NRSP PUI logframe.

- Brook and Dávila (2000) is an edited version of the final report for R7549, focusing specifically on Hubli-Dharwad and Kumasi.

- R7854*: Further Knowledge of Livelihoods Affected by Urban Transition, Kumasi, Ghana*. This project aimed to identify the gaps in existing knowledge of natural resource management in peri-urban Kumasi, with particular reference to the situation of the poor. It was noted in the FTR that there were limitations on the use of existing data, as these had been collected under the earlier NRSP remit of increasing productivity, but that many people still depended on natural resources for a major part of their livelihood. Among the conclusions was that land was the most contested asset in the peri-urban area, and that this significantly disadvantaged the poor, who had little power to contest land allocation issues.

- KAR Project R7132*: Water Quality and Peri-Urban Irrigation: An assessment of surface water quality for irrigation and its implications for human health in the peri-urban zone of Kumasi,* *Ghana*. This project carried out a review of waste water re-use, and undertook a review of water quality data from past studies on Kumasi's rivers. It supplemented these data with a targeted sampling programme of river water quality to provide physical, chemical and microbiological data on waters used for irrigation.

- DFID Project CNTR 98 5755: *Engineering and Planning Studies in Kumasi Region*. This project was carries out by Gibb Ltd as part of the Water Sector Improvement Programme (WSIP) funded by DFID. As well as providing useful background material on the water supply system, Gibb Ltd carried out limited sampling of the rivers draining into the Owabi Reservoir, and the reservoir water itself

- R7995: *Implementation Plans for Natural Resource Management Strategies for the Kumasi Peri-Urban Interface*. This project ran parallel to the latter stages of R7330 during 2001/2 and was commissioned from CEDEP in Kumasi in order to initiate progress from situation or problem-oriented research towards action research within the NRSP PUI programme. Participatory processes were established in 12 PU villages, including those being studied within R7330, to formulate NR-based livelihood plans for villagers, especially the poor. Its findings came too late for the present Project except that we were able to utilise the community level facilitators (CLFs) identified and trained in each village, in order to facilitate progress with our final WMF activities at the end of the Project.

Other relevant literature includes the following:

- Frantzen & Post (2001) provide the most detailed analysis to date of the history and management of different types of public toilet facilities in Kumasi city, and how they are perceived by the public. However, its relevance to this study is relatively slight, as they do not address the process of emptying latrines, holding tanks and nightsoil buckets, or how and where the sewage has been disposed of at different points in time. As explained below, dumping of untreated sewage in watercourses has had deleterious downstream impacts in the PUI.

- Mbiba & Huchzermeyer (2002) review the DFID approach to PUI research, and note that in their judgement the 'logframe' mechanism has tended to stifle objective theoretical research, and the development of an independent critical position. Further, the general approach of 'rural to urban transition' contrasts with the approach of USAID, UNICEF and the World Bank, which have tended to have an urban focus.

- ISODEC (1999) Kumasi Social Mapping Exercise. This study was undertaken in support of the Kumasi Water Sector Improvement Project, in order to pursue earlier reconnaissance that showed widespread and sever poverty in the KMA area. Thereby policy options would be enhanced in an effort to ensure that poor and vulnerable people will not be excluded from the benefits of the investment in improving the availability and quality of water within Kumasi.

- NRSP (2001) *Improving the Poverty Focus of NRSP's Research on the Management of Natural Resources* (Workshop Proceedings). This Workshop, held at Rothamsted in November 2000, provided a significant opportunity to network with other NRSP researchers, and to obtainm a better perspective on how to assess the effects of poverty on natural resource use and management.

- Corubolo with Mattingly (1999) *Peri-Urban Profiles Kumasi (Ghana).* This discussion paper provided a suitable summative focus on relevant issues in the early stages of Project research.

- Ministry of Works and Housing (1997 and 1998) *Water Resources Management Study: Information Building Block*. This extensive study provided regional-scale key information on geology, soils, water and erosion hazard, and other aspects of the physical environment of Ghana's regions.

3.2 ESTABLISHMENT OF A NETWORK OF RESEARCH PARTNERS AND INVESTIGATION OF SOURCES OF INFORMATION [1.A]

3.2.1 The Research Partnership

Great importance has been placed from the outset of this Project on the assembly of a viable and robust network of research partners, both in the UK and in Kumasi, through a process of

- collection and evaluation of the reports and associated outputs of related DFID-funded projects in and around Kumasi;
- intensive consultations with our original research partners at NRI (see below), with the leaders of other relevant DFID-funded projects and with a range of potential local collaborators; and
- field reconnaissance in urban and peri-urban Kumasi to appraise ourselves of the field sites of related projects (especially R6799, Kumasi Natural Resources Management Projects) and to plan our own field research.

In addition, RHUL employed Dr. Michael Campbell as a post-doctoral research assistant for 8 months during 2000; his time was split between RHUL and Kumasi.

The Project's network of partners and collaborators is shown in Table 3.2.1.

Table 3.2.1 Research partners and collaborators

Agency	Collaborator	Role/responsibilities
Natural Resources Institute (NRI), University of Greenwich	1. Mr. Martin G. Adam, agriculturalist 2. Ms Judith Pender, GIS specialist 3. Ms Hilary J. Warburton, socio-economist 4. Mr Richard J. Pole GIS programming specialist	Initial facilitation in Kumasi; introductory work on agronomy and agricultural systems (MGA), integration of data collection with KUMINFO (JP/RP), undertaking and interpretation of baseline village surveys in a manner compatible with the Village Characterisation Study undertaken as part of R6799 (HJW), liaison with PRA and environmental self-monitoring activities (DA)
Institute of Renewable Natural Resources (IRNR), KNUST	1. Dr. James Quashie-Sam 2. Mr Kingsley Boateng/ Veronica Nana Ama Asare	1. Overall Kumasi local co-ordinator and facilitator 2. GIS data manager
Bureau for Integrated Rural Development (BIRD), KNUST	1. Dr Kwasi Nsiah-Gyabaah; currently Principal, Sunyani Polytechnic 2. Dr. Sampson E. Edusah 3. Mrs Vesta Adu-Gyamfi (School of Art)	1. Joint local co-ordinator, with responsibility for socio-economic aspects and inputs to workshops 2. Community liaison and activities coordinator 3. Community activities and surveys
Environmental Protection Agency	1. Mrs Philomena Boakye-Appiah (Director) 2. Mr Kwame Omane Poku 3. Mr Daniel Benefor	2 & 3. Field officers responsible for water quality sampling and schools liaison
Ghana Water Company	1. Mr Nii Okai Kotei 2. Mrs Diana Ampofo 3. Mr Richard Johnson	1. Formerly Assistant Director, Water Quality Assurance 2 & 3. regular water quality

		sampling and analysis
Centre for the Development of People (CEDEP	Mr Bright Asare Boade	Field officer: community liaison and surveys. Preparation and dissemination of leaflets in Twi and English to villagers; running local focus groups and related Dissemination activities, including media coverage
Ghana Organic Agriculture Network (GOAN)	Mr. Emanuel Antwi; then Mrs. Ivy Otuboah Ahun	Dissemination activities among villagers and monitoring of feedback; promotion of organic agricultural development as part of sustainable watershed management strategies

The importance of these partners to achieving the objectives of the research cannot be understated. Firstly, the local knowledge of peri-urban Kumasi provided by the NRI team through their work on DFID Project R6799 proved essential in enabling us to gain access to data sources, in building up a sound network of local contacts, and in carrying out research on the ground. Local management and facilitation provided by Dr Quashie-Sam and Dr Nsiah-Gyabaah was necessary not only to provide local logistical support and guidance, but also to facilitate our interactions with local villagers, landusers and officials.

We were particularly fortunate in obtaining the enthusiastic support of GWC and the EPA in Kumasi, in support of water quality sampling in particular, and also in support of the Project objective of fostering community awareness of environmental issues. EPA became centrally involved in this exercise, and also assisted in the interface with industries and communities.

CEDEP and GOAN are major forces locally and nationally in dissemination of 'best practice', and have wide experience of participatory surveys and dissemination activities. CEDEP's help in setting up PRA exercises and disseminating the outputs of the research locally was invaluable. GOAN organised organic farming demonstrations in some of our study villages, with some follow-up extension work. However, due to internal problems, GOAN did not complete the task fully nor submit a final report on their activities within the Project.

It should be noted, however, that the anticipated involvement of a PhD candidate from the University of Greenwich, did not materialise. The student's principal interface with the Project was to have been to take forward action research within the communities attached to the schools involved in the water quality test kit sub-project. This work was to focus, with particular reference to the Project, on the ways in which the new knowledge generated by the test kits was taken up by pupils, and how this information did (or did not) disseminate within the relevant communities. The student's decision, some months into doctoral field period in Kumasi, to change tack away from the work of this Project left a gap that we found difficult to fill.

3.2.2 Liaison with other national and local government departments and parastatals

The *Water Resources Commission (Accra):* liaison with WRC was necessary, as they have the responsibility to oversee all research projects on water-related issues in Ghana, and have the remit to comment on proposals which they consider to be inappropriate. Their 1995-1998 'Building Blocks' study represents the formal Government view of water resources management throughout Ghana, and is the underpinning statement for the enabling Water Resources Commission Act of Parliament.

The *Water Resources Institute (Accra)* is responsible for hydrogeological mapping, and act as an archive for borehole data and reports. Their library contains borehole information relevant to the research area. They are also responsible for the production of regional-scale hydrogeological and water quality maps, and have archive data relating to these activities. DANIDA is supporting WRI (to undertake scientific analyses) as part of an overall support for water-related activities in Ghana.

The *Community Water and Sanitation Agency*, recently separated from the Ghana Water Company, has responsibility for supply of water to rural areas. Their Kumasi office contains a significant archive of borehole data and reports, presently uncatalogued, some of which proved to be relevant to the research area. DANIDA are actively supporting capacity building in CWSA, as well as assisting WRC in setting up its Master Plan. Mr Mike Adjei (Regional Director) and Mrs Beatrice Sakyi Amoanin (Health Education Officer) were particularly helpful.

The *Kumasi Metropolitan Assembly (KMA)* has overall planning authority in the Kumasi urban area. The World Bank-funded Urban Environmental Sanitation Project ('Urban 4' Phase) is active in Kumasi under the authority of the KMA. At present, major drainage works (especially canalisation) are taking place within the metropolitan area (see Section 3.5 below), an 'emergency' sewage treatment plant is in operation on the banks of the Subin River at Kaase, and two permanent settlement ponds were scheduled for completion by December 1999 and March 2000. However, both of these (though both of these are delayed. The one at Buobai near Duase, has been completed for some time but commissioning is being held up over a dispute with the EPA over its environmental approval process. The second, at Dompoase, is currently under construction.

District Assembly staff and representatives: Contacts were pursued during the main research and dissemination phases, as they are a vital link in the information exchange and action chain from community level upwards. This included the town planners responsible for the respective Districts, who are based in the regional Town Planning Section at the RCC. Several District Assemblymen were active participants in PRA and focus group discussions.

Regional Co-ordinating Council (RCC): Discussions were held throughout the research with various relevant staff of the RCC, and RCC was represented at all Project workshops.

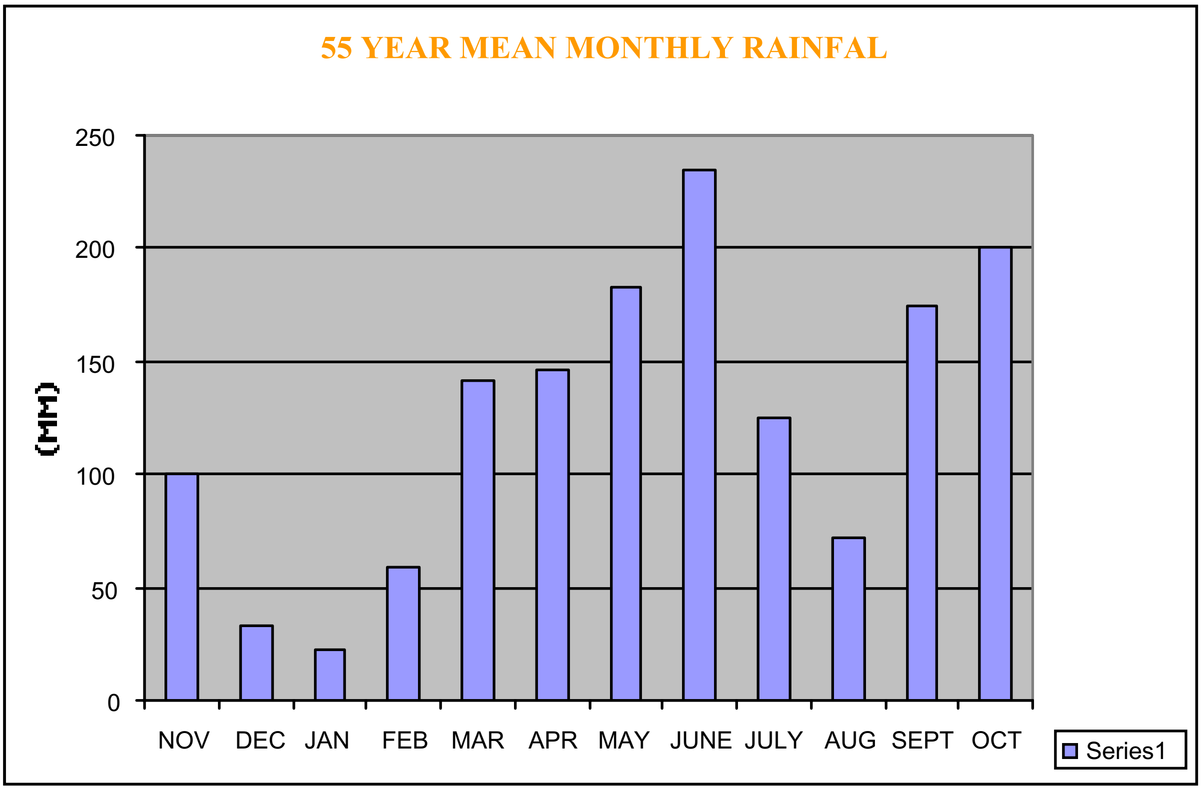
3.2.3 Liaison with local stakeholders

The Project had close contacts with range of local stakeholders, many of whom contributed by discussion or by action to the progress of the Project. The Project was particularly honoured by the presence of the Asantehene's representative, Nana Agyempenhene, at the Final Workshop. Village chiefs and elders, schoolteachers and headmasters, pupils of JSSs, and individuals from the communities gave of their time and knowledge to help frame the research. Their assistance is gratefully acknowledged and much appreciated.

3.3 CHARACTERISTICS OF THE PHYSICAL ENVIRONMENT [1.C]

Kumasi lies across a drainage divide at approximately 280m above mean sea level. Whilst much of the area of metropolitan Kumasi drains towards the south, into the Sisa-Oda system, the northwestern part of the built-up area drains westwards into the catchment of the Owabi dam and the River Ofin. The Kumasi area has a semi-humid tropical climate with an average annual rainfall of 1488mm (Adu, 1992). The rainfall distribution is weakly bimodal (Figure 3.3.1), with a principal wet season between March and June, and a subsidiary wet period in September-October.

Figure 3.3.1 Monthly rainfall distribution at Kumasi, 55 year period



Rainfall data derive from a meteorological station at Kumasi airport, but there are no readily available and reliable flow gauging data for any of the rivers in the immediate peri-urban area. This represented an unfortunate gap for the purposes of this Project. Flow gauge data were obtained from the River Oda at Bekwai, to the south of the city.

As a consequence of the semi-humid climate, water shortages (as opposed to access to water sources) have not been perceived as a problem, except during the relatively short dry season, when many tributary streams may dry up. However, the rainfall data from Kumasi Airport show a significantly declining trend over recent decades, and the implications of this for water supply are examined later (Section 4.7).

Little is known about the nature of groundwater storage in the Kumasi city and peri-urban areas, though a regional map has been produced as part of the 'Building Blocks' survey (Ministry of Works and Housing, 1998)

Soils in the immediate peri-urban area, developed over highly-weathered phyllites, greywackes, schists and gneiss, are predominantly reddish silty clays and silty clay loams, generally well-drained but with low chemical fertility below a thin organic topsoil, according to Adu (1992: 32). Adu (1992: 121-122) reports that these soils are deficient in phosphorus, and that their high acidity appears to reduce still further the availability to plants. The major source of available phosphorus is therefore organic. Nitrogen, in contrast, is readily available, though Adu notes that where cultivation has been carried out continuously for long periods, soil nitrogen levels are "very low". Heavy leaching has depleted the soil of elements such as calcium and magnesium, and has resulted in relative concentrations of compounds of iron and aluminium. Low organic matter below the litter layer renders these soils susceptible to erosion hazard.

The terrain is generally moderately dissected, with slopes of 5^{o} to 15^{o} and local amplitude of relief of up to 30m. Steeper slopes are prone to erosion, particularly on cleared land during the wet season.

Summits are often relatively flat-topped, and underlain by laterised concretionary gravels (as noted, for example, on a summit site west of Adagya, where these gravels were being quarried for road making materials).

Under these conditions of high rainfall, high temperatures and dissected topography, exposure of the soil by the removal of natural forest vegetation renders the soil susceptible to significant soil erosion risk. This will be compounded where mechanisation of agriculture supplants the present system of hand-operated rotation cultivation. Adu (1992: 131) asserts that improper cultivation practices, particularly on steep upper and middle slopes, have led to widespread accelerated erosion. This in turn, according to Adu, has led to the exposure of subsoil gravel and stones and to shallow soil depths.

3.4 IDENTIFICATION AND PRIORITISATION OF PROBLEMS AFFECTING WATER RESOURCES IN THE WATERSHED AREAS AND THE EFFECTS ON PERI-URBAN INHABITANTS [1.B]

Using background information, existing surveys and reconnaissance field investigations, identification of the problems affecting water resources was made during the Inception Phase of the research. The principal problems observed by the Project team and/or reported to us during the course of the research, are:

1. River water pollution especially within and downstream from urban Kumasi, attributed to
- untreated sewerage and other domestic waste
- hospital waste
- industrial waste, including an assortment of chemicals and possibly heavy metals; oils from informal motor repair businesses; sawmills; brewing; formal and informal abattoirs
- urban and rural runoff, including agricultural chemicals and residues
- leachate from groundwater into the river system of any of the above pollutants.

2. Contamination of boreholes and wells situated close to polluted watercourses by one or more of the pollutants listed under 1through seepage from the watercourse.

3. Contamination of boreholes and wells by leachate from pit latrines and refuse dumps located upslope from them.

4. Unplanned and unregulated waste tipping, both by villagers and by urban dwellers, with inadequate if any management and mitigation measures.

5. Localised heavy resource exploitation e.g. sand winning, deforestation for agriculture and wood use, and new urban and peri-urban housing and industrial/commercial premises.

In terms of the summary of views expressed by local people, during preliminary scoping surveys and community visits, and observations made by the investigators, these are approximately in descending priority order. It is recognised, however, that the particular problem or problems perceived as most important vary with particular site conditions, for example with proximity to a major point source of pollution such as a factory or workshop.

3.5 SELECTION OF STUDY WATERSHEDS [1.C]

The prime objective in selecting specific watershed areas for Project investigations was to characterise the range of physical conditions and environmental problems encountered in the Kumasi peri-urban area. An important consideration was to select areas where data already existed, in order to reduce the primary data collection effort in line with the original Project objectives. Accordingly, two watersheds were identified, the Owabi reservoir catchment and the Sisa-Oda catchment. Although these watersheds lie partly within the urban area of Kumasi, they are both largely peri-urban and between them contain the major types of environmental problems identified by Blake *et al*. (1997) as being present in peri-urban Kumasi. Further, the most significant environmental problems are focused on the urban area and near-urban fringe of Kumasi. The selection of study watersheds close to Kumasi was therefore deemed appropriate.

Investigations at the watershed scale are explicit in the Project's title and terms of reference. However, as these key areas, particularly the latter, are large in relation to the finances available for primary data collection, it was decided to sample sub-catchments in the case of the Owabi, and to sample upstream and downstream segments of the Sisa catchment, together with areas representative of the output from the predominantly rural catchment of the Oda.

***The Owabi reservoir catchment*:**
Two contrasting subcatchments were identified for study within the Owabi Reservoir catchment:
• subcatchment draining into the Owabi River from Suame Magazine
Rationale: manageable scale; clear delimitation, fringe of built-up area, encroachment on forest reserve
• subcatchment along Owabi River NE of Kronom
Rationale: manageable scale; clear delimitation; less pollution pressure, so provides good contrast with Suame Magazine runoff.

A further advantage of studying this catchment is that it affords the opportunity to utilise and build upon the studies undertaken by Gibb Ltd as part of the DFID-funded Water Sector Improvement Programme (Project CNTR 98 5755: Engineering and Planning Studies in Kumasi Region).

The Sisa-Oda catchment

The Sisa-Oda catchment is large and complex. The Sisa River passes to the east of Kumasi, through the UST campus, then southwards and eventually merges with Oda just outside Asago. The catchment is too extensive for this Project to have studied in detail as a whole; therefore the focus is on broad monitoring and characterisation, partly by extending the time-series of HRWallingford sample sites set up under DFID-KAR Project R7132.

Rationale

• as indicated by the analysis of water quality undertaken by DFID-KAR Project R7132, water quality was perceived as almost certain to decline progressively as it flows south through urban Kumasi, therefore the intention was to gauge this at key points along the catchment's watercourse.
• sites within Kumasi and downstream had been reported by villagers as being highly polluted, affecting their health. Although very keen for us to test and to intervene on their behalf, they had low expectations of official intervention in light of a political impasse with KMA. Asago, included in the R6799 Village Characterisation Study (VCS), is also said to be one of poorest villages in the area.
• it was hoped that this sample network would allow assessment to be made of the effects of different kinds of pollutants. For example, the Subin River in the KMA area has until relatively recently been the site of uncontrolled dumping of night soil and other domestic and industrial waste. Rehabilitation works are presently nearing completion as part of the World Bank-funded Urban Environmental Sanitation Project (UESP) in five of Ghana's major cities.

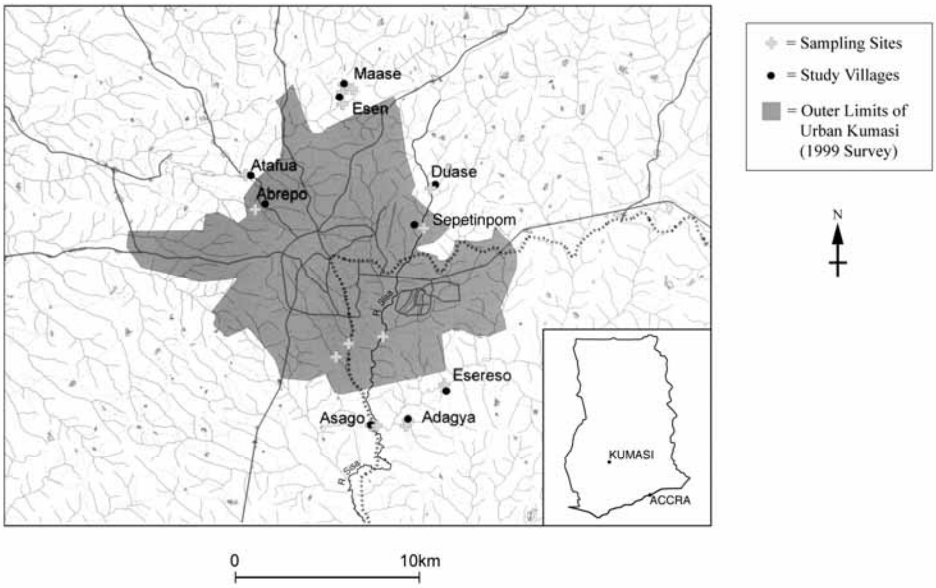
In addition, sites near the confluence of the Oda and Sisa rivers were chosen as representative of the output from the more rural Oda catchment.

3.6 SELECTION OF WATER QUALITY SAMPLING POINTS [1.E]

Following extensive vehicle and walking transects of the peri-urban zone in the two chosen watersheds (the Owabi and the Sisa/Oda), a set of 14 sample points was chosen to be representative of environmental conditions, including typical pollution problems, within the watersheds. As far as practicable, sites representative of fluvial source-area conditions as well as those in mid- and lower-catchment, were chosen. Further sampling points were added at Asago later in the research (the village borehole and a hand-dug well in the village) in order to investigate water quality problems there in more detail.

The water quality sampling points are set out in Table 3.6.1, together with a brief justification for their choice; their locations are shown on Figure 3.6.1.

Figure 3.6.1: Project villages and water quality sampling sites



Of these, points 4 and 5 are also sample points used by, or close to, those of Gibb Ltd (1999) (OWA 2 and SUK 1 respectively), and points 1 and 3 are a short distance upstream from OWA 1. Points 7, 9, 10 and 14 are at, or adjacent to, sample points reported in Cornish *et al*. (1999, 2000).

Table 3.6.1 Location of key water quality sample sites and brief justification

No.	Location	Approx. Grid reference	Brief directions	Brief justification
1	**Maase**	679000E 767000N	Spring at edge of floodplain, just into tree line on track to right off road to Mmedoma	Source area of Owabi River
2	**Maase**	677500E 765500N	Village centre	Borehole near Site 1
3	**Essen**	677000E 764000N	At the culvert c. 500m S of Essen on main road from Atimatem	Downstream of major sand-winning area
4	**Atafua**	659000E 752000N	River Owabi at foot of hill to W of Atafua just at corner of forest reserve. Bamboo thicket marks the culvert sampling point where Owabi crosses road	Mid-catchment of Owabi
5	**Chief's Palace Hotel**	662500E 744500N	Turn right at Hotel; c. 200m take turning to left; sampling point is c 100m down track. at bridge	River Suame. Downstream of major source of hydrocarbons pollution
6	**Duase**	693000E 748000N	Sample point on main road on bridge to SW of Duase	Upper catchment of River Sisa. Relatively rural. extensive floodplain cultivation
7	**Sepetinpom**	692000E 742000N	Bridge over Sisa River crossing, to east of village	Inner edge of peri-urban zone
8	**Atonsu**	684500E 722000N	Bridge on main road to Esereso crossing Sisa River	Urban pollution on Sisa River
9	**Kaase**	678000E 720000N	where road crosses Subin at railway line/ line of pylons. Culvert c. 50m downhill from railway line (river diversion).	Urban pollution on Subin River, a tributary of Sisa River
10	**Daban**	676000E 717500N	Where road crosses river between Ahodwo and Daban village	Urban pollution on Daban, tributary of Sisa River
11	**Esereso**	695000E 712500N	Sample point at bridge north of village	Output of River Oda catchment
12	**Adagya**	690000E 706000N	Borehole in village	Borehole adjacent to Oda River. Rural village
13	**Adagya**	690000E 705500N	River Ankoni crossing. Follow good track to left through Adagya village	Tributary of River Oda
14	**Asago**	683000E 706000N	Through village to river. Sample from Sisa River, c. 200m upstream	Combined output of urban streams

Grid References are taken from Ordnance Survey of Ghana 1:50,000 topographic map sheets 0602A2and 0602A4. Co-ordinates refer to origin of Ghana National Grid.

Budgetary and collection time constraints limited the Project to a monthly sampling interval, and to sites that were relatively close to suitable vehicle access. Additional samples were taken at Asago in order to investigate the nature of heavy metal uptake (see Section 4.8).

A consideration here was part of the Project's 'awareness-raising' intiatives. Five Junior Secondary Schools and one private school were selected close to some of the sampling points, in order to test the use of simple water quality test kits. This initiative will be described and analysed in Section 4.9.

3.7 SELECTION OF STUDY COMMUNITIES [1.E]

As with the selection of appropriate watersheds for study (see above), the research strategy demanded that a representative cross-section of settlements be identified within them as the basis for detailed study. It was initially hoped that a significant number of the villages included within the Kumasi Baseline Study (Project R6448) or the VCS (Project R6799) would lie within the watersheds concerned and prove suitable for inclusion in the sample set. This would have the considerable advantage of providing a comprehensive and recent baseline of data, against which short-term change could readily be measured. However, this did not prove to be practicable in most cases, and ultimately only two villages were common to these projects.

3.7.1 Rationale and objectives

The rationale for selecting a cross-section of settlements for further research was to include a representative sample of the range of prevailing socio-economic conditions within the scope of the present Project.

Our objectives in undertaking such detailed research were:
- to update the baseline data available from the Kumasi Baseline Study and VCS;
- to ensure compatibility with the VCS format as far as possible in order to maximise comparability and enable data entry into the KUMINFO GIS database;
- to identify the key issues and problems from the perspectives of villagers, the researchers and other stakeholders; and hence
- to provide a basis for ascertaining the more specialised/detailed socio-economic research needs during the remainder of this Project.

The two principal requirements were that:
- they should also all be compatible with the location and nature of environmental and hydrological research to be undertaken;
- the number selected should be the minimum required to provide a representative cross-section of conditions within peri-urban communities.

3.7.2 Village selection

The criteria utilised in the village selection process were:
- population size
- distance from the city
- quality and frequency of public transport links with central Kumasi
- degree of 'rurality' versus 'urbanity' in terms of linkages
- extent and importance of agricultural vs non-agricultural activities
- their relative location within the watersheds
- the nature and extent of water quality and other environmental problems as perceived by the study team and residents
- distance from rivers and the extent of reliance on these as opposed to other sources of potable water.

The selection procedure utilised a combination of methods, namely map inspection, analysis of the VCS and other reports from Project R6799, discussions with collaborators and key informants, and site visits.

One important shortcoming of the locally available ordinance survey maps (1:50,000 scale) is that they are very outdated. Dating from the early 1970s, they therefore fail to capture any of the extensive outward spread of urbanisation during the last 25 years. Accordingly, many locations indicated on them as separate peri-urban villages are now entirely built-up areas within Kumasi. This underlined the importance of field inspection. Utilising grid point references collected by the staff of the project on Engineering and Planning Studies in Kumasi, within the Water Sector Improvement Project funded by the DFID Engineering Division, we were able to plot the current outer perimeter of the built-up area of Kumasi (Figure 3.6.1).

Ultimately, a set of eight villages was identified, namely: Atafua, Abrepo, Maase, Duase, Sepetinpom, Esereso, Adagya and Asago (Table 3.7.1; Figure 3.6.1). The first three are situated in the watersheds draining into the Owabi Dam, while the remainder are in different parts of the Sisa-Oda catchment.

Table 3.7.1 Location of survey villages

Village	Catchment	Location
Maase	Owabi	Upstream of Kumasi, at top of watershed
Atafua	Owabi	On watershed between streams from Kumasi and from Maase area
Abrepo	Owabi	Downstream from Kumasi
Duase	Sisa	Upstream from Kumasi
Sepetinpom	Sisa	Upstream from Kumasi
Esereso	Oda	Downstream from rivers through rural/peri-urban zone
Adagya	Oda	Downstream from rivers through rural/peri-urban zone
Asago	Sisa/Oda	Downstream from Kumasi

Of these, Adagya, Asago and Maase have the most rural aspect, whereas Abrepo and Sepetinpom are the most urbanised. Esereso, Atafua and Duase represent an intermediate stage in this rural to urban transition.

3.7.3 Research methodology

Only Asago had been included in the R6799 Kumasi Baseline Study and Duase in the R6799 VCS. Accordingly, it became necessary to undertake detailed baseline surveys in all eight villages. For this purpose, the VCS questionnaire was adapted and extended to provide appropriate coverage of water quality and environmental issues (Appendix C).

Each village was visited by the study team in September 1999. Following an initial meeting with chiefs, elders and district assemblymen, detailed research discussions were conducted with different groups within each community: the chief and elders, teachers, and separate sample groups of women and men. One of the local researchers and one of the British-based team conducted each of these. The research method was a hybrid between a semi-structured interview and a focus group discussion, in terms of which the questionnaire served as the basis, but discussion among group members was encouraged and the sequence of topics was kept flexible. These group sessions were of 1.5 - 2.5 hours' duration. A walking reconnaissance of the village and its surrounding farmland was undertaken by one or more of the team members, accompanied by a local guide. This provided very valuable visual checks and an opportunity to substantiate or clarify issues raised during the interviews and group discussions. This hybrid methodology therefore also contained an element of participatory rural appraisal (PRA). In total, the team spent up to 3 hours in each village in this initial stage.

3.8 CHACTERISATION OF THE WATER RESOURCE ENVIRONMENT [1.D]

Characterisation of the water supply environment covers such issues as

- source of supply
- quality of water at source of supply
- range of uses to which water is put
- types and scales of water abstraction
- contamination sources, sinks and pathways
- nature and scale of sedimentation

The water resources of peri-urban Kumasi present significant problems for the authorities and the populace alike. Rainfall is sufficient to maintain an integrated stream network for most of the year.

Main streams exhibit reduced flow in the dry season, and low-order streams may dry up or suffer intermittent flow. Ground water resources appear to be plentiful at present, and springs are a significant point source of water in many parts of the area.

The principal problems are those of water supply and water quality. Ghana Water Company Ltd (GWC) has responsibility for the provision of piped water, mainly within the Kumasi Metropolitan Area, and operates the Barakese and Owabi treatment plants. Areas and villages at the extremities of the pipe network suffer frequent interruptions of supply due to inadequate water pressure within the pipes, though water quality is monitored regularly by GWC throughout the distribution system. River water is still used in some areas for washing, and drinking water is still abstracted from streams in the more rural areas in times of shortage.

Controls on the discharge of pollutants into rivers have been difficult to enforce. As a result, river water pollution is both reported and seen as being widespread, particularly within and downstream of Kumasi, and arises from a variety of sources including

- untreated sewage and other domestic waste
- hospital waste
- industrial waste, including an assortment of chemicals and possibly heavy metals; oils from informal motor repair businesses; sawmills; brewing; formal and informal abattoirs
- urban and rural runoff, including agricultural chemicals and residues
- leachate from groundwater into the river system of any of the above pollutants.

The Community Water and Sanitation Agency (CWSA) is now an autonomous authority responsible for provision of water beyond the GWC distribution network. Its remit is to manage water as a sustainable resource, primarily in rural areas (Mensah 1998), but active in peri-urban Kumasi. It is a relatively new agency, and as yet in peri-urban Kumasi appears to have acted as an enabling organisation for aid programmes rather than having the resources to implement borehole/well and latrine/sanitation construction projects. As a result, the majority of boreholes and wells in the peri-urban area appear to have been constructed privately or by aid agencies.

There appears to be no effective control on the siting of wells and boreholes, nor on their rates of abstraction. There are, however, unconfirmed reports of contamination of abstracted groundwater from polluted water courses and by leachate from pit latrines located upslope.

3.9 SOURCES OF WATER USED IN STUDY COMMUNITIES [1.D]

A preliminary survey of sources of water used in eight villages adjacent to water quality sampling points revealed that sources of drinking water varied between the villages depending on the sources of water available, its quality, the season and the ability to pay (Table 3.9.1).

Table 3.9.1 Water resources in surveyed villages (1999 survey)

Village	Piped water	Borehole	Well	Springs/ streams	Rainwater collected
Maase	No	1	2 abandoned	1 good 1 poor quality	Yes
Atafua	Yes	2 private	6 private	2 rivers used for washing	Yes
Abrepo	Yes	0	0 (old ones destroyed)	2 rivers used for washing	Yes
Duase	Yes	1 + 1 broken	2	Several streams and rivers	Yes
Sepetinpom	Yes	1 broken	6 private, 1 free	1 good (but polluted downstream)	Yes
Esereso	No	3 - 1 good, 2 broken or little water	Several, variable quality	Several springs	Yes
Adagya	No	1	4 private	1 good, but weedy	Yes
Asago	No	1 constructed 1999. Pump installed 2000	3 public but of variable quality. 2 private, good quality	2 rivers, polluted but used for washing	

Springs, streams and rivers are the traditional source of drinking water and still remain an important source in six of the villages as well as being used for washing in all of the villages. In villages that have streams arising within the village boundaries, people collect water from close to the source which they believe to be good quality (for example, in Esereso and Sepetinpom). These streams can become covered with weeds and difficult to access. In Adagya, for example, one spring was reported as producing good drinking water, but being very weedy and infested with snakes. Some streams have never been used for water, either because the stream is sacred (eg. Stream Angofera in Sepetinpom) or because the water is not considered good (eg. Stream Abenaa in Duase described as having a 'lustrous film' on the water). For villages with few springs, the larger streams and rivers had been an important source of drinking water, such as the Owabi and Ntikyei rivers at Atafua, and the Oda at Asago. However, the villagers were aware of the growing levels of pollution in the rivers and had stopped using these for drinking, although they were still used for washing.

In all villages, people were aware of the growing levels of pollution in the streams and rivers, and the health problems it could cause. Children were reported as suffering most, as they tended to more careless with hygiene, and as they swam in the rivers. Dysentery, cholera and bilharzia were among the diseases children were reported as being susceptible to.

Initial perceptions of the use of boreholes indicated that these were invariably very heavily used, with long queues for water at peak times, and with problems due to breakdown of individual boreholes exacerbated by lack of funds to effect a quick repair. In these circumstances, villagers reported reverting to nearby stream water for their supply.

3.10 LAND USE IN THE PERI-URBAN AREA [1.B; 2.A.3]

Although agriculture remains the prime land use in the peri-urban zone, major competition for land between agriculture and ever-increasing urbanisation is seen throughout.

Currently, the farming systems in peri-urban Kumasi consist of varying mixes of traditional and introduced elements (Nsiah-Gyabaah and Adam 2001), which can be summarised as shown in Table 3.10.1.

Table 3.10.1 Farming systems in and around Kumasi

No.	Farming system	Practitioners
1	Temporary inter-cropped bush fallow food crop, rainfed – the traditional food staple system	Predominantly women
2	Permanent inter-cropping, mainly rainfed, which without renewal of fertility becomes soil mining	Predominantly women
3	Sole crop vegetables, with irrigation in the dry season	Predominantly men, often younger men
4	Specialised valley-bottom cropping e.g. sugarcane, taro, green maize	Predominantly men, often non-Ashanti
5	Tree crops	Predominantly men
6	Backyard farms - mostly banana, plantain, cassava and vegetables	Both men and women
7	Livestock (little integration with crop farming)	Nearly all men, often non-Ashanti
8	Fish farming	Nearly all men

The Kumasi Natural Resources Management Project studies (Blake 1997) have shown that as villages around Kumasi become more urbanised, fewer people come to depend principally on agriculture for their livelihoods. As more and more land is taken up for urban development, the traditional farming practice of allowing the land to recover fertility under bush fallows (farming system 1 in Table 3.10.1) is rendered ineffective or impossible. The logical economic solution is to intensify inputs and thereby gain greater outputs per unit area. However, those remaining in farming are generally poor in financial assets and are unable to do so. Most give up farming. Those who remain are often specialist farmers. In the peri-urban fringes there is a concentration of poultry farms and in the partially waterlogged low-lying areas right up to the city centre sugarcane, taro (water cocoyam, *Colocasia esculenta*), maize and vegetables are grown, as well as cassava and other traditional staple food crops. Crops grown in backyards of both peri-urban and urban dwellings are most likely to be the traditional cassava, cocoyam (*Xanthosoma saggitifolium*) and plantains, even in the low-density housing areas (NRI 1999a).

Sand winning is a major (and only partly regulated) activity in many floodplain areas, and appears to intensify in areas of greatest urbanisation. Thus, for example, on the new road between Ahwiaa and Maase, to the north-west of Kumasi, where several large areas were in the process of conversion to housing, extensive alluvial sand winning operations were noted.

3.11 WATER REQUIREMENTS AND AGRICULTURE [1.B; 2.A.3]

The water requirements of the common farming systems around Kumasi are not regarded as large-scale (see Table 3.11.1). By far the greater proportion of agricultural production depends on normal annual precipitation, which is currently judged to be nearly always adequate to supply the needs of the current farming systems.

Table 3.11.1 Common water management practices by farmers around Kumasi

Farming system	Water use		
	Diversion of surface flow	**Impounding of surface flow**	**Abstraction from water table**
1. Bush-fallow food-crop	Very occasional drainage ditches	No	No
2. Permanent inter-cropping	Occasional drainage ditches	No	No
3. Sole-crop vegetables	In raised-bed systems on waterlogging sites, to remove excess water from soil surface and provide abstraction source.	Very occasionally, in conjunction with fish farming	Frequent. Usually shallow wells, less often deeper wells, occasionally boreholes or piped supplies. In half of the sampled villages one farmer has a pump.
4. Specialised valley-bottom cropping	In rice, water cocoyam and sugarcane systems, to retain water.	To maintain wet conditions in the dry season.	No
5. Tree crops	Occasional flood irrigation. Also drainage ditches.	Very occasional basin irrigation.	Sometimes, for establishment and dry season irrigation.
6. Backyard farms	No	No	Often wells, roof collection or piped supplies.
7. Livestock	Only by livestock directly drinking.	Very occasional small dams.	For housed stock, principally poultry and pigs.
8. Fish farming	Yes	Yes	No

However, as well as a significant reliance on raid-fed agriculture, a number of farmers in the peri-urban area use forms of irrigation to a greater or lesser extent. A major questionnaire survey conducted by DFID KAR Project R7132 in 1998/1999 indicated that dry-season irrigation practices are extensive in the peri-urban area (Cornish 2001). The survey indicated that there had been a significant recent expansion of the numbers of farmers moving into irrigation since around 1990, almost certainly related to an increase in commercial opportunities for sale in Kumasi or to traders. However, the recent trend of declining rainfall (see Section 3.3) may also be a significant stimulus.

The most widely source of water for irrigation reported by Cornish (2001) is the shallow dugout well, though around 24 percent of the respondents claim to make at least occasional use of motorised pumps.

It is notable that at least 80 percent of respondents claim that inadequate water supply limits their production, though “ …73% referred to the effort or cost involved in bringing water to the plot with only 27% referring to water scarcity” (Cornish 2001: 33).

3.12 GEOGRAPHICAL INFORMATION SYSTEMS INTERFACE [1.E]

3.12.1 Rationale and Objectives

The aims of the GIS element of this Project were to develop means of visualising water related issues and data, to model some of the dynamic aspects of surface water and groundwater quality, and to produce relevant Graphical User Interfaces (GUIs) to facilitate effective watershed management. The Kumasi Natural Resources Management Research Project (R6799) developed the GIS for the Kumasi peri-urban zone (KUMINFO), which formed the basis of the watershed GIS. KUMINFO was installed at Royal Holloway.

Surface water quality data has been collected by other projects (Cornish et al. 2000, Gibb Ltd 1999), and are available within KUMINFO. Water quality samples collected by this Project at monthly intervals between September 1999 and September 2001 are available. Further secondary data have been located, from student dissertations, the Water Resources Research Institute and the Water Resources Commission. Additional primary data have been collected, under the supervision of EPA, by three students of Royal Holloway; and a Masters project was designed around the Project framework (Omane Poku of EPA).

Groundwater data samples and regional-scale maps have been obtained from WRI (Accra) showing static water levels, depth to water table, borehole location, geology, pH and other water quality indicators. This material has been digitised as separate coverages for the watershed GUIs. Borehole data including water transmissivity, depth to water table and soil variables were also obtained from the Community Water and Sanitation Agency in Kumasi.

Corrected ADP images with KUMINFO overlays were assessed for scale and usefulness during the pilot water sampling exercise. The images were accurate for locating the water sampling sites and also provided an overview of the sampling sites which was difficult to obtain on the ground due to vegetation densities. Where detailed coverage exists, this will be an invaluable aid to interpretation of terrain characteristics, land use and hydrological behaviour. Unfortunately, there are gaps in the coverage within the area nominally covered by the flight, which reduces the effectiveness of the ADP for continuous analysis and general use.

3.12.2 Design of Data Structures

The NRI team assessed at an early stage the data structures for design of the 'watersheds' database.

Critical variables for the local aquifers are the depth to the water table, hydraulic conductivity and transmissivity. A digitial elevation model (DEM), stream ordering and basin identification outputs have been developed in Arc-View from existing topographic and stream network maps. These form the basis for simple hydrological modelling. A tool for displaying water quality data is already available in KUMINFO. The following variables were scheduled to be derived by the NRI team from the GIS for development of a watershed model and graphical user interface (GUI).

- area increment functions for surface drainage network and coding of channels on the basis of contributing area.
- use of the ADPs to quantify the size of devegetated areas around the eight village sampling sites where wet season runoff will rapidly disperse surface pollutants and sediment.
- direction and gradients from the DEM which will allow direction of surface water pollution dispersion to be inferred.
- drainage densities and 'overland flow distances' for the sample catchments. This coverage will indicate those areas sensitive to pollution production in the sense that pollutants would be quickly dispersed by drainage.
- coverages on village water use derived from the Village Characterisation Study, e.g. the extent of cultivation of river banks.

Access to further satellite imagery would be required to get some idea of temporal changes in vegetation cover around villages.

3.13 IDENTIFICATION AND DESIGN OF DATA REQUIREMENTS AND METHODS [1.E]

The original idea for the present Project developed out of early experiences by the research team engaged on Project R6799. Accordingly, in order to ensure compatibility and continuity, to maximise complementarity and avoid overlap, and to draw on the relevant local experience of that team, the three principal British researchers on R6799, Mr. M.G. Adam, Ms. H. Warburton and Ms J. Pender, were invited to join the Project team as collaborators. Similarly, some of the key local collaborators on R6799 in Kumasi were approached, along with other relevant persons.

Pursuant to our terms of reference and an agreement reached during discussions with the NRSP-PUI management team formerly established by NRIL, this Project was constrained to minimise new primary data collection and to focus as far as possible on the collation and integration of primary and secondary data already garnered by the suite of DFID-funded projects on Kumasi and its peri-urban interface.

3.13.1 Primary Research

The principal research objectives at the Inception stage effectively set the agenda for the bulk of the data collection activities in the main research phase of the Project, and were:

- the identification and nature of relevant data sets
- liaison with other DFID-funded programmes with respect to data complementarity
- identifying data access protocols
- identifying data supplementation requirement
- identifying and setting up study sites
- identification of schools willing to participate in environmental self-monitoring activities.

Successful liaison with other DFID-funded programmes was largely, if not entirely, achieved. In particular, the results of various surveys carried out by the *Kumasi Natural Resource Management Project* (R6799) were available to this Project (R7330). Some of the villages focused on in that Project proved to be suitable suitable for further activities within R7330, and the database of that Project proved to be invaluable. Data-sharing was agreed with the WSIP *Engineering and Planning Studies in Kumasi Region* (CNTR 98 5755 – i.e. Gibb Ltd) and with the *Water Quality and Peri-Urban Irrigation* study (KAR Project R7132); and some of these Projects' sampling sites were utilized by R7330.

Discussions took place with Project R6880 *Development of Methods of Peri-Urban Natural Resource Information Collection, Storage and Management* on possibilities for the development of GIS tools and products suitable for commercial development in the Kumasi region. The literature review carried out under R6949 *Literature Review on Peri-Urban Natural Resource Conceptualisation and Management Approaches* proved to be most useful in defining terms of reference and in identifying key literature from analogous areas elsewhere.

3.13.2 Rationale and Objectives

The original rationale of the data collection exercise was to minimise primary data collection, as far as is consistent with achieving high-quality output, by relying as far as possible on available data sets. The principal objective, to identify and access the physical data to underpin watershed management plans and strategies, was partially driven by the need to input information into KUMINFO in a form that is suitable for input and which is susceptible to GIS format manipulation.

The focus was on collection of data, archive and contemporary, which enabled the Project to characterise, in peri-urban Kumasi,

- continued pressures on land due to urban expansion
- water quality and sources/types of contamination
- water supply problems related to increasing abstraction
- progressive land quality deterioration through agricultural intensification, land degradation, and increasing pollution (solid and liquid waste disposal)

This must be set against a socio-economic background of uncertain and changing land tenure arrangements which encourage short-term advantage over longer-term security and husbandry; of conflicts between traditional and state controls on land allocation and land use; of in-migration to peri-urban areas; and of the highly gendered nature of many agricultural and domestic activities relating to the use of water resources.

3.13.3 Socio-Economic Data

For the baseline research in the sample of eight villages, three local interviewers were recruited, regarded as essential to achieve maximum levels of dialogue with community members and other stakeholders. They were Mrs. Vesta Adu-Gyafi, Mr. Eric Nsiah-Gyabaah, and Mr. Aaron Boateng. They all had extensive experience undertaking comparable social research surveys, but received extensive briefings from the team leaders prior to commencing the research. Mrs Adu-Gyamfi subsequently continued to participate in community activities to the end of the Project. Mr Bright Asare Boadi (CEDEP) joined the team at the end of this phase as preparation for his subsequent involvement as key PRA practitioner.

For the remaining duration of the research, the majority of visits to communities were undertaken by local collaborators, and focused on specific issues, participatory processes or evaluations of Project activities. The outcome of these visits is detailed in Section 4 of this Report.

3.14 ENDNOTE

This Section of the Report has presented the background to the research, the scoping studies and issues of research design, much of it during the Inception Phase. In Section 4, subsequent research and the results and analysis thereof, are set out in detail.

4. Main Research Phase and Activities

4.1 INTRODUCTION

This Section of the report presents the substantive primary research findings of the Project.

It is divided into thematic sections, and relevant Outputs are denoted by square brackets [….] where appropriate.

These sections present the detailed research results and analysis of the principal research activities, namely

- 4.2 the stakeholder analysis, including findings on the nature and extent of natural resource-based micro-enterprises and villagers' perceptions of them
- 4.3 the communications strategy adopted by the Project, including workshops and associated field visits for stakeholders
- 4.4 the village characterisation study to obtain baseline socio-economic and stated behavioural and perceptual information in the selected sample of villages, along with subsequent and more detailed watershed village characterisation study to explore selected priority themes pertaining to water and land allocation and use, and institutional structures
- 4.5 water sources, use and their management
- 4.6 existing farming systems and associated environmental issues
- 4.7 the water quality research, including extensive and sustained datasets and
- 4.8 information on the extent of heavy metal contamination at a downstream peri-urban site
- 4.9 the experimental participatory water testing and awareness-raising programme undertaken in a sample of Junior Secondary Schools, and
- 4.10 the extent to which the Kumasi Metropolitan Assembly (KMA) and the four District Assemblies covering the relevant parts of the PUI are engaging with and promoting Local Agenda 21 issues that should facilitate and promote sustainable local environmental initiatives.

4.2 <u>Stakeholder Analysis</u> [2.A1]

This subsection reports on the methodology of the overall analysis undertaken in order to understand the perceptions and priorities of the different stakeholder groups utilising the study watersheds and of those potentially polluting the watersheds. It also involved an analysis of existing institutional capacities, policies and practices respect of watershed and associated NR regulation, control and enforcement, and an assessment of the effectiveness of environmental controls.

These research activities spanned the Inception Phase and part of the Main Research Phase, and generated substantial new knowledge that extended the results of R6799 in respect of the villages. Because of the volume of material generated in some of the activities, it is not all reported in detail in this subsection. The locations of the material presented elsewhere are identified below.

4.2.1 SURVEY OF GOVERNMENT BODIES

This is reported in Section 3, where we summarise the nature and degree of involvement of, and engagement by, the various official bodies with a role in relation to the PUI.

4.2.2 SURVEY OF STAKEHOLDERS USING WATERSHEDS [A2 Socio-Economic Surveys and Activities, first two bullet points and sub-points]

Rapid village surveys during the Inception Phase, as reported above, enabled us to gain an appreciation of the situation in the sample of eight villages and of the different perceptions of, and problems facing, different social groups within each community. However, it became essential to undertake more detailed village characterisation surveys for the following reasons:

- only two of these villages – Duase and Asago – had been surveyed by previous NRSP PUI projects, and the data were by now somewhat out of date;
- this Project's greater focus on water and other natural resource-related aspects of environmental use and management meant that new information relating directly to these issues was required;
- formulation of an appropriate and sustainable co-management framework at the watershed scale necessitated a clear understanding of how different stakeholders use the watersheds and their natural resources, as well as of their respective problems, perceptions and priorities.

This Watershed Village Characterisation Study was undertaken in late 1999 and early 2000, using a format consistent with that previously used by R6799 (Blake *et al.* 1997; Adam *et al.* 1999) in order to maximise comparability. Our research team utilised the hybrid method outlined above, which combined aspects of rapid rural appraisal (RRA), PRA and focus group discussions. Each team member concentrated on a particular category of villagers that we had identified as likely to provide us with the diversity of perspectives that we sought, namely chiefs, queen mothers and elders; teachers; women; and farmers. Where possible (in terms of their presence during the research visits), a youth group was also consulted. The respective sets of responses were then triangulated by the team in order to reveal areas of agreement or disagreement over aspects of village resources, water supply, institutional structures, farming activities and waste disposal. A consolidated report on each village was then produced.

These results still revealed gaps or insufficiently detailed knowledge and understanding of particular issues of direct concern to the Project, namely land tenure and allocation processes, institutional issues, and land-use and environmental concerns. Accordingly, checklists on these themes were developed into semi-structured questionnaires that were used during interviews in May-July 2000 with relevant key informants, especially chiefs, Unit Committee chairs and others as appropriate, e.g. WATSAN Committee secretaries. Such individuals and the different groups identified above were again consulted at length, using the same hybrid method. Where the researchers felt it necessary or appropriate, follow-up discussions with the communities were sometimes held to air and discuss different responses and to obtain inputs from other villagers, including poor people. This material is reported in Section 4.4 and Research Paper 9 (Edusah and Simon 2001).

4.2.3 SURVEYS OF POTENTIALLY POLLUTING STAKEHOLDERS [2A1 bullet 3]

Surveys were undertaken of both large urban industries that could be potential contributors to downstream water pollution in the peri-urban areas, and of (mostly informal) micro-enterprises operating in and immediately around the study villages. The former involved interviews with senior management of twelve large industrial firms during May- September 2000, using a semi-structured questionnaire, in order to examine the nature of their production processes, their use of natural resources, and marketing and waste disposal activities. Most of these firms are concentrated in and around the Kaase, Ahensan and Asokwa industrial areas, which straddle the Subin-Sisa river drainage basins. These in turn form part of the Oda-Sisa catchment, our Project's main focus of research. The sampling procedure was purposive and cross-sectional, in order to include at least one representative of each major category of industries identified from field reconnaissance and existing knowledge on the following criteria:

- type and scope of activity
- volume of water consumption
- waste generation and management
- geographical location, including proximity to river banks
- assumed potential to cause river or other water pollution

A survey of micro-enterprises in the villages was undertaken in mid-2001 by a Royal Holloway student, John Eames. This adopted a similar methodology, combining field observation and a semi-structured questionnaire used with a dozen natural resource-using enterprises in different categories identified in the villages. In addition, the perceptions of a sample of villagers regarding the activities and environmental impacts of these enterprises were ascertained. His work forms the bulk of sub-subsection 4.2.5 below.

4.2.4 ANALYSIS OF EXISTING INSTITUTIONAL CAPACITIES; ASSESSMENT OF THE EFFECTIVENESS OF ENVIRONMENTAL CONTROL; IDENTIFICATION OF RECENT/PROJECTED OWNERSHIP CHANGES [2A1 Bullets 4, 5 & 6]

These tasks were undertaken at appropriate junctures at different stages of the Project's life through a combination of

- key informant interviews with appropriate officials of the respective bodies,
- analysis of relevant policy and regulatory documentation and press reports,
- personal field observation by Project team members, and
- ascertaining the experience and perceptions of informants during our village research and industrial surveys.

Frank discussions with staff of the GWC and EPA Ashanti Region, access to their relevant documentation, and joint field visits and industrial interviews were facilitated by virtue of these being members of the Project team. Other key informants included the Deputy Director and planning staff of the Regional Co-ordinating Council; KMA Chief Executive and senior staff of its Waste Management Division; District Assembly staff and town planners; the Deputy Regional Director of the CWSA; the Agyempenhene as senior representative of the Asantehene's traditional authority; Chiefs, elders and chairs or secretaries of the Unit Committee (UC) and Water and Sanitation Committee (WATSAN) in the Project's eight study villages; and the Executive Directors and Staff of development-environment NGOs, especially CEDEP and GOAN, which are also partners in the Project team.

The principal changes in ownership and institutional structure of relevance to environmental management are:

- the gradual national programme of commercialisation and privatisation in the state sector. In particular, as our project commenced in early 1999, the Ghana Water and Sewerage Corporation (GWSC) was split into the commercialised Ghana Water Company, with responsibility for bulk and domestic water supply within those parts of urban and rural areas served by a pipe network, and the Community Water and Sanitation Agency (CWSA), with responsibility for water provision and related issues in urban, peri-urban and rural communities not served by the GWC. The planned partial privatisation of the GWC has been delayed, in part due to the huge controversy the intention has generated;

- the government's enhancement of environmental legislation and enforcement powers via the relaunched Environmental Protection Agency (EPA) in the late 1990s, with new but understaffed regional offices.
- The former NDC government's policy of establishing a UC and WATSAN in every village had the potential to yield positive results but our research found that the process was incomplete and that there is great variation in the extent and effectiveness of their operation even where they exist (See Table 4.4.1 Institutions in Villages).
- At a broader level, the NPP's assumption of power in the December 2000 general election also greatly increased prospects for coherent environmental policy and management in our study area. This had previously been hamstrung by virtue of the oppositional politics between the central government and the predominantly NPP-supporting KMA and surrounding District Assemblies.

4.2.5 MICRO-ENTERPRISE INDUSTRIES IN PERI-URBAN KUMASI AND THEIR ENVIRONMENTAL IMPACT

This subsection gives a brief overview of the main micro-enterprises found in the peri-urban zone. Where these are found in most or all peri-urban communities, a general description will be given, with examples as necessary. Boapeah (1997) provides a more general discussion of the importance of small-scale or micro-enterprises to sustainable rural (and, by extension, peri-urban) development. Material was also provided by Eames (2002).

Sand Winning

Sand winning was the most controversial peri-urban industry encountered because of its detrimental environmental consequences and possible illegality. Many exhausted sites have not been rehabilitated, leading to erosion and land degradation, while pools of water accumulating in borrow pits provide mosquito and other insect breeding grounds. In the past, rehabilitation was rare; but nowadays a permit from the EPA is required for sandwinning, which includes a requirement for rehabilitation. Nevertheless, some illegal winning still occurs, while rehabilitation regulations are often ignored to cut costs or to avoid limitations on quantities that can be extracted. Sand winning often occurs either late at night or at dawn. It was claimed that this occurred to avoid the heat of the day, but in some, if not many, cases, this seemed to be a subterfuge to avoid drawing attention to the activity.

Sand is usually taken from the designated 'family land' of the village for a set fee, and is supposed to be managed according to EPA regulations. These regulations include a prohibition on excavation within 200 feet of a watercourse. However, since most sand encountered is on floodplains, this presents a significant dilemma! In fact, many excavations occur in floodplain areas, and many of these are close to, or impinge upon, the local stream. Nevertheless, the Chairman of the Esereso and Adagya Sand Winning Association claimed that his members comply with the relevant regulations.

Before a site is excavated, woody vegetation is taken as fuelwood by local women. All of the excavated sand is used in the building industry and the access roads have a subsequent use when the site is abandoned, in providing access to more remote land that can then either be farmed or built on.

Block Making

The small-scale manufacture of bricks and blocks is commonly encountered in peri-urban villages. Locally mined sand is used, and the cement is bought in Kumasi.

A number of environmental problems are evident on most block-making sites. The sand and cement are invariably loosely heaped in unsheltered piles across the site, rendering them vulnerable to being wind blown and washed away. This is particularly problematic in the case of the cement because, through groundwater, it could reach the river and would reduce water quality. This problem is exacerbated as blocks are often made at the building sites to cut down on transportation costs. Leachate was therefore discharged close to the river, increasing the potential for pollution.

In addition to cement blocks, some blocks are made from mud taken from suitable sites adjacent to villages, as in Adagya. The mud has sufficient clay in it to give an adhesive property when wet and is easily baked by the sun into a rough brick. These are cut by hand and are of a poor quality, when compared in the case of Adagya to those made from cement in Esereso. The environmental effects of the Adagya enterprise are less significant due to its small size and the use of relatively little cement. Even the cement that is used as mortar is kept in piles protected by a wall of blocks, so is not vulnerable to weather damage.

Carpentry

Many small enterprises process lumber produced by the local large-scale sawmilling industry; and these are located throughout Kumasi and its peri-urban areas. The largest cluster of carpentry enterprises is concentrated in Anloga Junction near the centre of Kumasi. This area provides an interesting case study as it comprises several thousand micro- and small-scale enterprises that had clustered together in order to overcome growth constraints and in order to gain collective efficiency and ease of response in times of crisis or opportunity (McCormick 1999; Ward and Gilbert 2001). The Anloga community comprises some 20,000 people crowded into 90ha of land. Carpentry is the largest single economic activity, involving approximately 1,100 master carpenters and 5,000 apprentices. The downside to such dense clustering is not just an increase in competition from neighbouring enterprises, but more profoundly an increase in the potential environmental damage caused by the carpentry industries.

The most evident pollutant in and adjacent to the Abuabo River (a tributary of the Sisa) that forms the western boundary of Anloga is clearly the huge quantity of sawdust produced by the carpentry workshops. The high raised banks of the river comprise largely accumulated sawdust and are therefore prone to collapse in times of elevated flow. This constitutes a potential fire and flood hazard for the riverside enterprises, especially if the river's flow is choked. The sawdust and shavings also pollute the river, causing a serious problem for downstream residents, including in peri-urban villages such as Asago. A large, uncontrolled refuse dump on the site also represents a health hazard; nearby carpenters claimed that it was never cleared or levelled but only burnt. A small watercourse flows alongside the dump and is clearly polluted. This feeds into the Abuabo River and therefore adds to the pollution caused by sawdust. A third major source of pollution at the Anloga site is the direct result of poor sanitation. The site is served by a row of latrines overhanging the river, hence raw human excrement is added to the pollutants. The carpentry enterprises in the peri-urban sites are not on this scale, but still have the potential to cause similar, localised problems.

A typical small carpentry enterprise manufacturing products such as chairs, tables, doors and window frames for local inhabitants and schools – and thus similar in character to many at Anloga – was situated in Maase. When interviewed, the owner claimed that his only waste product was sawdust because machinery was not used as he made only limited amounts of basic furniture. Most of the sawdust that he did produce is stored and sold to a local woman who uses it as fuel for her fire, so it is therefore not wasted. Some sawdust was nevertheless evident in the surrounding area but the carpenter claimed to be careful about leaving it lying around as the Town Council took people to court and fined them if they were found to be causing pollution. This deterrent seemed to have a positive effect on the Maase carpentry enterprise as it resulted in very little pollution and an extra sense of care.

The sawmilling industry is overwhelmingly large-scale and commercial. A handful of small-scale enterprises exists but none operated around the villages covered by this survey in mid-2001.

Metalwork

A metalworking business shares an area of land in Esereso with a carpentry enterprise. The merchandise produced is relatively basic due to a lack of sophisticated machinery and expertise, but includes gates, fences, containers and reservoir tanks. The only waste that the enterprise produces is a small amount of unusable scrap metal and empty paint cans which are taken to the village's refuse site and dumped when necessary. This may well add small amounts of toxic material to the already visually polluted groundwater that emanates from the refuse site. Polychlorinated Biphenols (PCBs) are used to manufacture paints and, although biodegradable over time, they are difficult to break down unless incinerated to over 1200 degrees Celsius. In an aquatic environment the chemicals can be bio-accumulated along the food chain and may reach dangerously high levels before causing problems such as reduced growth and infertility amongst mammals. The actual metal used therefore causes few problems, but the careless disposal of paint could have future environmental implications.

Motor Repairs

Motor repair is a prominent industry in Kumasi due to the volume of traffic and predominance of second-hand vehicles on the roads. Although Esereso did have a vehicle repair enterprise on the river bank adjacent to its main road, it has remained closed and appeared derelict throughout the life of this Project. The site is used for car washing, with the result that waste water, contaminated by oil and detergents, enters the river.

However, Ghana's (and reputedly Africa's) largest motor repair agglomeration lies at Suame Magazine to the north of the Kumasi ring road. The Suame Magazine is renowned throughout Ghana and has been known to draw customers from neighbouring countries (McCormick 1999). It extends into its own village community with a network of well-surfaced roads and workshop areas. Most of these are electrified and piped water is common. Air pollution is high due to the extensive use of old cars and heavy lorries that emit excess exhaust fumes. This is combined with smoke from the practice of burning tyres and refuse which could be seen in five different sites in the area. Water pollution is also high since most of the workshop floors were covered in oil and guttering systems were full of water with a petrol film floating on top. Each individual mechanic's workshop had a significant environmental impact due to the 'dirty' nature of the processes involved.

Crucially, the streams which issue from the Suame Magazine area flow into the peri-urban zone, and articulate with the River Owabi.

Food Processing

Small enterprises milling grain for flour are found in many peri-urban communities, particularly those such as Esereso which are supplied by mains electricity. This is relatively environmentally friendly as electricity is the only source of power used, while any waste products are sold to poultry farmers as chicken feed. The only significant pollution appears to be the noise from the grinding machines.

Seedling Nursery

A private nursery is situated to one side of the main road through Esereso. The business involved growing seedlings such as mango, orange, teak and pepper on raised beds or in plastic bags and then selling them to local residents who would use them on their farmland. A tributary of the river Oda runs across the plot of land, but had an oily film on it at the time of the research visit. The workers interviewed claimed that this came from larger industries upstream, but this was uncertain as the car washing point referred to above was situated on the opposite bank of the river and this could not have caused the oil pollution. Discarded plastic bags from the nursery site did reach the river, constituting a separate form of pollution. Even though this seemed to go unnoticed by the nursery workers, they did appear to be environmentally conscious. Instead of using chemical fertilisers or pesticides, they made their own fertiliser by crushing long grass and allowing it to decompose naturally into a kind of mulch. Overall, the nursery therefore had a mixed environmental impact.

Kente Weaving

Kente cloth is one product unique to Ghana and hence is now produced for the tourist trade as well as catering for the home market. Maase has a significant group of producers. The cloth is woven in strips on a simple, hand-built loom; these are then sewn together to form a wider fabric. The only waste and environmental damage in the weaving process is excess thread, but there is a potential for water pollution in the dyeing process. Kente cloth is brightly coloured, the fabric consisting of greens, yellows, reds and blues, so therefore involves a large quantity of dyes. This could either be spilt or disposed of inappropriately and may therefore cause pollution. However, the actual dyeing is not done in Maase as the thread is purchased pre-dyed in Kumasi and the local environmental effect of Kente weaving in Maase is therefore very limited.

Palm Oil Processing

Although our initial reconnaissance early in this Project revealed a few small enterprises processing palm kernels into oil, the only direct evidence of this activity in our study communities came from Sepetinpom (see below). By far the largest palm oil processing centre we encountered is situated adjacent to a river between the southern fringe of Atonsu and Dompoase, south of Kumasi. This involved over 50 possibly self-employed women, working in difficult conditions. Although some contamination of the river and its adjacent banks with crushed kernels and oily residues is likely, it was well-nigh impossible to detect visually on account of the black dye contamination from the nearby kente cloth factory.

The inhabitants of Adagya, Esereso and Maase had differing views regarding their immediate environments and the impact on them of the micro-enterprise industries. The carpentry industries in Maase and Esereso had different environmental impacts. In Maase the owner claimed that he had to avoid causing pollution, as otherwise the village committee would fine him. This was not the case in Esereso and therefore no attention was paid to where the sawdust was disposed of. Minimal pollution is caused by the Kente enterprises in Maase because of the essentially clean nature of the processes involved. The people of Maase had formed a committee with local jurisdiction over issues of pollution and this had the effect of limiting pollution in the area. Esereso and Adagya's economies are based around a much wider spectrum of livelihoods, including more polluting industries, and people therefore turned a blind eye to environmental degradation. The interviews carried out in Adagya revealed that the micro-enterprises with environmentally damaging effects – such as sand winning – were tolerated due to their local importance and because they promoted economic development. The environment was seen as a resource for farming and land, but was also expendable in order to make money. This view was mirrored in Esereso, where the environment was ignored in order to cut down on the costs of waste disposal. However, some residents in Sepetinpom expressed concern at water contamination by small-scale palm oil processing operations (see Section 4.7).

4.3 Communications Strategy [2.A1 Bullet 7]

Throughout the Inception and main phases, discussions with villagers during the participatory research exercises, the industrial surveys and key informant interviews explored perceptions regarding the forms of information and good practice dissemination and communication most likely to be appropriate to different constituencies.The outcome was the decision to provide a diverse suit of outputs and to disseminate these via different media. Evaluation of initial activities also enabled us to diversify the subsequent forms of dissemination. The range of outputs comprised:

- A cartoon-based leaflet (with both English and Twi editions) raising awareness about water and sanitation issues in villages. This was produced by CEDEP in 2000 and distributed to the eight study villages; to participants in our annual Project workshops in 2000, 2001 and 2002; to organic farmers countrywide via GOAN, and to other groups where CEDEP was working;
- A series of three annual Project workshops, with associated fieldtrips to relevant sites in and around some of the study villages in the PUI. These provided an important vehicle for dissemination of project outputs and environmental messages, the obtaining of feedback during consultations on ideas for the WMF and demonstration micro-projects, and so forth.
- Two radio phone-in broadcasts on local FM stations. These were led by Dr. Nsiah-Gyabaah, predominantly in Twi, and were also recorded;
- a Directory of organisations, institutions and companies with activities and expertise in the development-environment field, for use by villagers and other interested parties to enable them to ascertain the most appropriate source of advice or assistance in pursuit of more appropriate and sustainable local environmental utilisation and management. This is attached as Appendix G;
- laminated posters illustrating key aspects of good environmental practice in relation to village water use and sanitation, for display in village schools and clinics;
- laminated display posters illustrating different development-environment and natural resource problems in peri-urban Kumasi, and how the Project was seeking to address the relevant ones, for display in the KMA offices and those of Project partner organisations;
- an illustrated handbook of good practice in relation to water and sanitation issues, and more general aspects of village and watershed-scale sustainable environmental management, known as the Watershed Management Framework (WMF), for use by Chiefs, UCs and WATSANs, and DA, KMA and NGO staff (See Section 6);
- demonstrations of good practice and how to improve the village environment, by means of micro-projects (tree planting, erosion control, water harvesting, mulching and other organic farming methods) relating to natural resource utilisation and associated livelihoods, the subsequent maintenance and utilisation (degree of 'ownership') of which by villagers was studied and assessed (see Sections 6 and 7);
- an annotated Bibliography of books, journal articles, official publications and reports, and grey literature on relevant aspects of natural resources, environmental issues and development in Kumasi and relevant parts of the country, as a resource for researchers. This is attached as Appendix H.
- A consolidated list of Project outputs, which is attached as Appendix I.

4.4 Village Characterisation Survey [A2]

4.4.1 VILLAGE POPULATION AND STRUCTURE

Estimates of village populations ranged from around 500 in the small villages of Adagya and Atafua to around 8,000 in Abrepo, which is more or less a suburb of Kumasi. However, estimates varied widely between the different groups and should be treated as a very rough guide only. There has been no official census since 1984.

The Traditional Authorities (chiefly hierarchy) still continue to play a major role in all the villages, particularly with regard to land allocation and land sales. All villages came under the control of a chief, and each village has a Queen Mother. In most cases the Queen Mother has no direct control over allocation of village lands, but in Sepetinpom the Queen Mother does control land allocation and land sales.

Government representation of the villages is maintained through the Assembly man appointed to represent each village, and the Unit Committees which usually consist of 15 members of which 5 are appointed by the government and 10 are elected. Responsibilities are: organising communal labour, maintaining village facilities such as toilets and refuse dumps, organising village projects such as school buildings. However, several of the UCs were newly formed and had yet to establish what they did. In Duase there were two UCs due to the factional infighting and both were yet to be inaugurated.

Four villages had Water and Sanitation Committees (WATSANs) and one had a Sanitation Committee (Esereso). The roles of this group appeared to overlap with that of the UCs with regard to maintaining water sources such as boreholes and collecting water fees, but they also had a role in educating the villagers on hygiene matters.

4.4.2 LAND OWNERSHIP AND USE

The underlying ownership of land in these peri-urban villages is divided between the original settler families and the Stool (symbol of authority of the chief). Under the traditional land tenure system indigenous inhabitants are allocated land to farm by their family head. They have usufructory rights to land rather than individual ownership rights, and cannot sell the land outright. Strangers can also gain access to land through approaching the chief and arranging with him to lease land for farming or to buy land for housing.

An increase in residential development has occurred in all the villages over the last 20 years, especially in the villages with electricity close to Kumasi. However, even in Maase, which still has the appearance of a rural village, about half the land was reported to be zoned for housing development. Village lands (both Stool and family lands) have been sold by the chiefs to individuals for housing plots. The pattern of development was similar in all the villages, with the new residential areas comprising a mix of individual villa-type houses and incomplete or undeveloped plots which were often being farmed on a temporary basis until building work started. Intensive backyard farming is carried out around many of the new houses.

Abrepo had the largest area of residential development, with very little farmland left other than the lands in the Owabi reservoir reserve. Farming was mostly confined to backyards and river banks. This was also true in Sepetinpom where there were few farm lands left (other than airport lands). Esereso had lost large areas of land to residential development but still had farmland some distance from the village. In the other villages, farmland currently accounted for the majority of village lands.

Table 4.4.1 Institutions in the villages

Village	Chief	Queen Mother	Assembly man	Community-based organisations
Maase	Yes	Yes (lives outside village)	Lives outside, visits often	UC (3W, 11M) WATSAN 13 churches Youth mobilisation
Atafua	Yes – lives in Kumasi, subchief acts as regent	Yes, lives outside; has sandwinning business in village	Lives outside, does not visit	UC (2W, 8M) 2 churches
Abrepo	Yes – unsure of status	Yes	Yes	UC (3W, 12M) WATSAN based in Suame 11 churches Trade & market associations Youth mobilisation
Duase	Yes – major chieftaincy disputes	Yes	Lives outside, does not visit	UC divided into two 9 churches
Sepetinpom	Yes	Yes- controls land	Yes	UC (2-4W, 11-13M) About 15 churches EU microprojects clinic
Esereso	Yes	Yes	Lives outside, but visits	UC (4W 11M) Sanitation committee 15 churches Trade & market associations 31st December Women's Movement
Adagya	Caretaker under Esereso	Yes	Lives outside	UC (3W, 12M) WATSAN 7 churches 31st December Women's Movement (newly formed)
Asago	Caretaker – dispute over chieftaincy	Yes	Lives outside	UC (2W, 13M) WATSAN About 7 churches

4.4.3 VILLAGE FACILITIES

The range of facilities in the villages is shown in Table 4.4.2. Electricity was regarded as a very important part of the development of the village and was a top priority project in the villages where it had not yet been installed or required further extension to all the houses. Schools and clinics were also high priority areas, followed by markets, commercial areas and community centres.

Table 4.4.2 Facilities in villages

Village	Electri-city installed	Piped Water	School	Market	Trotro cost to Kumasi	Other facilities
Maase	No	No	JSS	No	500	Few
Atafua	No	Yes	Close by	No	300	4 poultry farms, tile factory
Abrepo	1968	Yes	SSS	No	300	Many – phones, small enterprises
Duase	1992	Yes	JSS	No	300	Few – Quarry nearby
Sepetinpom	1971	Yes	JSS	Yes	300	Many – phones, small enterprises
Esereso	1991	No	JSS	Yes	350	Some – phones, small enterprises
Adagya	1997	No	PS	No	450	Few – 4 poultry farms
Asago	1999	No	PS	No	400	Few

4.4.4 OCCUPATIONS

Main occupations are shown in Table 4.4.3. Although overall the majority of inhabitants still retain some connection with farming, this declines with the urbanisation of the village. There is a marked difference between the older and younger generations. In particular, there is a higher proportion of older women remaining in farming, but a low proportion of young women. Some of the young men go into vegetable farming. Many people have more than one job, and unemployment was also said to be a problem especially amongst the young women.

4.4.5 WASTE MANAGEMENT AND SANITATION

In all the villages, refuse is dumped onto communal tips. Glass bottles and tin cans are reused and only thrown away when broken. Old newspapers are also reused before being thrown away. For villages within the Kumasi Metropolitan Area (KMA) the refuse may be collected by KMA and taken to a landfill site. However, in two KMA villages, Abrepo and Duase, collection was very irregular.

Maintenance of refuse dumps is one of the responsibilities of the Unit Committees. (However, it was noted that Duase had well-maintained refuse dumps despite the absence of a functioning UC). They organise communal labour to clear and weed round the refuse area and burn in the dry season. The bulk of the maintenance is done by women with the younger men sometimes helping with clearing.

The refuse dumps were a cause of concern in almost all the villages. They were often poorly sited, upstream and close to rivers so that rubbish was washed into the streams, especially in the rainy season. As villages have grown, dumps that were previously on the edge of the village have become surrounded with houses.

All the villages had communal latrines. In addition some of the larger and more modern houses had their own private toilets. The private toilets were either pit, Kumasi Ventilated Improved Pit (KVIP) or (only in villages with piped water) flush toilets with septic tanks. It is not known what proportion of houses had their own toilets.

Table 4.4.3 Main occupations reported

Village	Older Men	Older women	Young men	Young women	Job location
Maase	Almost all farmers Weaving, trading	Most are farmers. Petty trade, cooked foods	Majority farmers Weaving, trades	Less than half farmers. Petty trade, construction labour	Most in village
Atafua	Few farmers Trades, construction, trading	Majority farmers Trading, cooked foods, construction labour	About a third farmers. Trades, construction labour	Very few farmers. Petty trading, hairdressing, sewing	Most in Kumasi
Abrepo	Some farmers. Trades, construction	Some farmers. Trading, sewing, teaching	Few farmers. Trades, construction	Very few farmers. Petty trade, construction labour	Most in Kumasi
Duase	Some farmers. Trades, cocoa, steel works	Majority farmers. Trading	Some farmers. Trades	Very few farmers. Trading, hairdressing, sewing, construction labour	Most in Kumasi
Sepetinpom	About half farmers. Trades, trading	About half farmers. Trading, cooked foods, fish smoking	Few farmers (mainly outside village). Trades, steel works, trading	Few farmers. Trading	Most in Kumasi
Esereso	Some farmers. Trades, saw mills, trading	About half farmers. Trading, cooked food, teachers	Few farmers. Trades, saw mills, construction	Some farmers. Trading, hairdressing, sewing	About half in Kumasi
Adagya	Almost all farmers. Trading, palm wine	Almost all farmers. Petty trade, cooked foods	Most are farmers. Trades, steel workers	Most are farmers. Petty trade	Most in village
Asago	Almost all farmers. Fishing, saw mills	Almost all farmers. Trading, fish trading	Most are farmers. Trades, saw mills, fishing	Majority farmers. Petty trade	Most in village

The communal toilets were either pit or KVIP. For villages within the KMA area, the toilets are maintained by KMA. An attendent collects a fee of C50 a visit which is used to pay for the maintenance and emptying of the latrines. KMA trucks collect the nightsoil when the latrines are full. This was done in five villages. However, villagers complained that the use charge deterred some from using the latrines. Also the collection was not always frequent enough: in Abrepo the latrines had overflowed on several occasions, and nightsoil had been washed into the streams. The communal toilets were generally inadequate for the size of the villages. In villages where there is no attendant, children are usually responsible for cleaning the latrines.

Waste water from houses was thrown into open channels and drains. There was no drainage system in any of the villages other than gutters built along some the roads which channelled the water down into the streams. Some of the modern houses had plastic guttering and pipes to carry the waste water away from the house, but these also fed into open gutters in the village.

Table 4.4.4 Maintenance of refuse dumps and communal latrines

Village	Responsibility for sanitation	Refuse dumps maintained by	Communal latrines Type	Maintained by
Maase	UC / WATSAN	Women	2 pit ,1 VIP not yet in use	Children No attendant yet
Atafua	UC	Women	1 pit	Private co. collects nightsoil
Abrepo	KMA / UC	KMA attendant	1 pit 1 VIP	KMA collects nightsoil C50 charge
Duase	UC?	Women	1 VIP, 1 VIP under construction	KMA collects nightsoil C50 charge
Sepetinpom	UC	Women	1 pit 3 VIP – only 1 usable	KMA collects nightsoil C50 charge
Esereso	UC	Women	1 pit (school) 1 VIP	KMA collects nightsoil C50 charge
Adagya	UC	Women	2 pit	Young girls
Asago	WATSAN	Women, young men help clear	Pit	Children

4.4.6 RESULTS OF THE WATERSHED VILLAGE CHARACTERISATION SURVEY (WVCS)

As explained in Section 3.13, this study formed an important part of the baseline participatory research and data collection activities. It also served to determine the nature and orientation of subsequent socio-economic research in terms of filling remaining gaps and deepening our understanding in relation to the perceptions and priorities of different groups within each community.

The wealth of qualitative and quantitative information collected during the WVCS precludes easy display and discussion in disaggregated form. However, this entire database is being lodged with the NRSP management and is available within the KUMINFO Version 3 in both Kumasi and RHUL. Moreover, since the study was not intended as an end in itself but as a means to an end, relevant elements of the material have been utilised in a range of tables and textual discussion in different parts of this report. Accordingly, here we present and discuss only a few pertinent aspects with a twofold purpose, namely to exemplify the format and richness of the database, and to present some of the baseline information on the basis of which we formulated the subsequent follow-up research and ultimately the micro-interventions within the eight study villages.

Tables 4.4.5-4.4.9 reveal the responses from the four or five different groups of people participating in the research in each village, in respect of changes since 1983 and environmental issues; landuse change; drinking water, waste water, sanitation and refuse disposal. It should be borne in mind that the response recorded for each group reflects the outcome of discussion within the group during interviews, focus group meetings and participatory appraisal activities. Views were rarely unanimous to start with; even at the end there may not have been consensus. In such cases, the researcher recorded a majority response. Where a group is labelled ‘unassigned’, the field researcher omitted to insert the information at the time of interview and our subsequent efforts to identify the group were inconclusive.

For some variables, such as the principal changes observed since the major drought of 1983, and planned developments within their village (Table 4.4.5), there is consistency of responses across the different groups within each village. However, in other cases, people’s perceptions or rankings differ, no doubt as a reflection of the importance of each to the livelihood activities and daily routines of each category of participant and respondent in a particular village. This is well exemplified by environmental or pollution problems 1, 2 and 3 in Table 4.4.5. Naturally, the location, size, history and degree of urbanisation of, and level of infrastructural and service provision in, each village also influences the responses. Hence the responses in Abrepo and arguably Sepetinpom are more typically urban, those from Asago and Adagya are more typically rural, while others like Duase and Esereso are intermediate. Thus, as explained earlier, one of the characteristics of the PUI is that it spans a spectrum of rapidly changing conditions and challenges, from rural to essentially urban, with 'urbanness' increasing over time, albeit unevenly across space. However, it is noteworthy that none of the Abrepo respondents apparently perceived rainwater runoff from the metal roofs and many sloping tarred roads to be problematic, despite the conspicuous evidence of damage to unsurfaced pathways and even the foundations of some buildings (Plate 4.4.4).

In Table 4.4.6, the perceptions of landuse change since 1983 held by different groups are remarkably consistent, both within and between the study villages. This provides strong evidence of the widespread and consistent nature of farming land loss through conversion to residential and industrial uses. Again, Abrepo and Sepetinpom represent the most highly urbanised end of the spectrum, with none or only a few people still farming, and the bulk of the land now used for residential and other non-agricultural purposes.

Table 4.4.7 shows the extent of reliance on different sources of drinking water by village, along with the reported quality and unit cost (i.e. bucket or container) where applicable. Again, the responses from different groups within a village were remarkably consistent. Many households rely on more than one source of water, according to seasonal availability, quality and/or price and affordability. Although not reflected in the table, such multi-sourcing is widespread in villages lacking piped water supply. In such cases, water for livestock, agriculture and washing is usually of lower quality and therefore price than that used for human consumption. The perceptions reported here influenced our decision-making in terms of where and what water sources to test scientifically, as reported in Section 4.7 below.

From Table 4.4.8, it is evident that most domestic waste water is disposed of through open drainage in the village, although a certain proportion of homes in Abrepo, Esereso, Sepetinpom, Duase and (according to one group) Maase, have disposal pipes or drains. Abrepo also has a stormwater gutter system, into which at least some domestic waste water, not to mention leachate from the refuse dump, flows. In this sense, too, Abrepo is more urban in character than most others.

Refuse disposal is clearly problematic in all villages (Table 4.4.9). Within the KMA area, the WMD provides skips into which people are supposed to tip their waste. However, as explained below, the frequency and coverage of this service is inadequate, and large dumps frequently build up adjacent to the skip. Even so, this service is available only in Abrepo and Duase. Elsewhere it is the responsibility of the village – at least in theory usually through the Unit Committee or WATSAN – to organise disposal facilities in the form of a dump and to maintain it. Maintenance may be undertaken by a paid member of the village, by communal labour, or by a particular age/gender group. Most refuse dumps are inappropriately situated relative to water sources and dwellings. Households themselves, often through children, are responsible for carrying refuse to the dump. There is some recovery and recycling of saleable materials like metal and glass, but nowhere is the separation of waste types, the use of organic waste for composting, or any similar strategy reported. The potential for waste reduction and productive recycling is thus evident, and the Watershed Management Framework that we have formulated (Section 6) includes guidelines on how to do these, and on appropriate siting and maintenance of dumps.

Finally, Table 4.4.10 summarises in qualitative terms the principal similarities and differences – including some of the aspects just discussed – among the eight villages. The approximate correlation of rapid growth; population change and diversity; infrastructural provision (even if inadequate); and landuse and occupational change with relative proximity and ease of access to Kumasi, is evident. Conversely, poor sanitation and drainage, and inadequate or continuous access to good quality drinking water, are universal problems.

Local Changes, Environmental and Land Issues

Table 4.4.5

ABREPO	Chiefs/Elders	Men	Teachers/Men	Unassigned	Women
Main Changes	Residential areas have replaced farmland	Hospital, sawmill, drug shops, increased population	Street lighting	Farmland losses to the government, or lost to residential houses. Saw mill, communication centres, drug and pharmacy shops, population increase	More houses, churches
Developments planned		Market, post office, police station	Market	Market, post office, police station	Market, road (bridge), toilet
Enviro/polln problems 1	Bad smell from the refuse	Toilet/refuse dump problem	Sanitation	Disease, cholera, malaria	Pollution
Enviro/polln problems 2	Refuse and toilet overflow found their way into the river	Health		Toilet problems – overflow	No street lighting
Enviro/polln problems 3	General sanitation	Air, water pollution		Air and water pollution	Water shortages, leaking toilet drains
Current land issues		Yes			
What current land issues		Fight between government and people			
Other changes since 1983	New developments have beautified the town	Land erosion, street lighting, hospital		Land use competition for land, population increase	In-migration on the increase, accommodation

ADAGYA	Chiefs/Elders	Men	Unassigned	Women
Main Changes	Farmland replaced by residential land	Loss of farmland to building land use. Increase in sand winning	Farmland replaced by residential lands. Sand winning, borehole construction, establishment of primary school. Increased population, small businesses surfacing, e.g. hair dressing, salons and sewing	Road, electricity, borehole, transport, school, new houses, more people, small businesses
Developments planned	Building of toilet, school, road	School, health centre, KVIP, community centre	KVIP, school block, more boreholes, tarred road, community centre, bridge, culvert, market	KVIP, school blocks, tarred roads, more boreholes, market, bridge over Oda
Enviro/polln problems 1	Water pollution	Water pollution	Poor toilet facilities, refuse dump, air pollution	Poor toilet facilities, refuse dump
Enviro/polln problems 2	Increased erosion	Soil, air pollution	Deforestation, new weeds	No jobs
Enviro/polln problems 3	Deforestation, new weeds	Toilet problems	Soil erosion, poor drainage and pollution	Overgrazing by sheep
Current land issues		Yes		
What current land issues		Dispute between the chiefs of Esereso and Adagya		
Other changes since 1983	Electricity, borehole, building of houses, population	Electricity, borehole, school, water pollution, erosion, road	Borehole, electricity, school, increased population. Water/air pollution, bad drainage and road	Borehole, lights and school, poor drainage

Local Changes, Environmental and Land Issues (Cont.)

Table 4.4.5 (Cont.)

ASAGO	Chiefs/Elders	Men	Teachers/Men	Unassigned	Mixed
Main Changes	Decline in soil fertility and increase in population	Light, road deterioration, residential expansion, smaller farms, more farms, rice, beans, groundnuts, guinea corn not common; cabbage increased		Increased area under farming, soil degradation, reduced fallow periods, deforestation, expansion of residential, increased bush fires, changes in cropping pattern, introduction of irrigation	Change from cultivation of peppers to tomatoes, garden eggs and carrots.
Developments planned	Water, JSS and road construction		Committee farm, class room construction	Construction of JSS block, rehabilitation of school block, extension of electricity, borehole, road construction	Electricity, schools and wells
Enviro/polln problems 1	Water pollution		Sanitation	Water pollution	Water pollution
Enviro/polln problems 2	Soil fertility loss			Air pollution	Air pollution
Enviro/polln problems 3	Deforestation			Poor sanitation	
Current land issues	Yes	Yes	Yes	Yes	Yes
What current land issues	Tribal land dispute	Individual disputes		Major land dispute in royal family	Land disputes within chief's family
Other changes since 1983	New grasses	Water pollution	Water		Electricity

ATAFUA	Chiefs/Elders	Men	Unassigned	Women
Main Changes	Increased population, Farming on residential plots	Piped water, construction, electricity	Increased population, education facilities, piped water, reduced farmlands, land scarcity, shortened or no fallow periods and soil degradation. More sand winning, unemployment, competition for land and cost of plots.	More farmers, more residential houses, piped water
Developments planned	Electrification project, building of Chief's palace, Improvement of the drainage systems (gutters)	Electricity project, school	Electrification, schools, construction of chief's palace, improved drainage system, clinic	Electrification, schools
Enviro/polln problems 1	Sanitation problems (refuse)	Land and soil erosion	Air., water pollution	Refuse dump
Enviro/polln problems 2	Refuse dumping in river	Water pollution	Refuse dumps	Poor siting of toilet
Enviro/polln problems 3		Poor refuse dump and drainage channels		Air pollution
Current land issues	Yes	Yes		Yes
What current land issues	Government take over of land	Chieftaincy and other disputes		
Other changes since 1983		Piped water, water pollution, soil erosion		Sandwinning, lack of electricity

Local Changes, Environmental and Land Issues (Cont.) Table 4.4.5 (Cont.)

DUASE	Men	Men	Unassigned	Unassigned	Women
Main Changes	Farmlands being used for building, decline in numbers of farmers, farm intensification and soil degradation	Soil degradation, loss of farmland to residential land	KVIP toilet, electricity, borehole, piped water, tarred road, reduced farm sizes, soil degradation and increased numbers of females. More use of poultry manure and composting	Loss of farmland to developers	Not much change, due to land litigation
Developments planned	Clinic or hospital, more schools especially JSS and SSS, community centre, KVIP, Industrial centre, relaying of pipelines	School, toilet	Clinic, SSS, vocational school, industrial area, eradication of pests, connection of pipes, community centre	School, community centre, KVIP	Hospital, school, KVIP, reconstruction of pipelines, industrial area
Enviro/polln problems 1	Ants	Water pollution	Pets, water pollution	Water pollution	Pests (ants, mosquitoes)
Enviro/polln problems 2	Water pollution, soil erosion, dynamite	Air pollution	Vibrations from construction machinery	Air pollution	Air and water pollution
Enviro/polln problems 3	Poor drainage	Soil erosion, poor drainage, pests	Soil erosion	Land erosion (sand winning)	Refuse
Current land issues	Yes	Yes	Yes	Yes	Yes
What current land issues	Fighting over land, illegal land sales		Conflicts over access for individuals. Litigation	Dispute between early settlers and fetish priest	Family fight over land
Other changes since 1983	Electricity, piped water, tarred road, increased population, KVIP, sandwinning	Road construction reducing dust, piped water, increased population		Electricity, piped water and borehole, KVIP	Electricity, piped water, tarred road, illegal land sales, water pollution, quarrying

ESERESO	Chiefs/Elders	Men	Women
Main Changes	New buildings, construction of roads and streets, turning of farmlands into residential areas, demarcation of farmlands into church and school lands	More construction, sand winning	Expansion of village, more houses, factories, more jobs, construction works, food sellers
Developments planned	Residential and commercial size, clinic, piped water, toilet project (KVIP) under construction, quarters/accommodation for teachers	Piped water, toilet facilities, community center, clinic, teachers	Library, SSS vocational, more boreholes, community center, more toilets, hospital, credit facilities and inputs to farmers
Enviro/polln problems 1	Refuse causing air pollution in the town	Water pollution	Poor siting of KVIP/refuse dumps
Enviro/polln problems 2	Defecation along (into the) river	Air pollution from refuse dump	Erosion
Enviro/polln problems 3	Water pollution as a result of washing of cars	Toileting, soil erosion	Presence of termites and ants
Current land issues		Yes	

Local Changes, Environmental and Land Issues (Cont.)

Table 4.4.5 (Cont.)

ESERESO (continued)	Chiefs/Elders	Men	Women
What current land issues		Family disputes	
Other changes since 1983	Pollution increases-Positive, Advent of new churches-positive, building of schools-positive, building of new houses-positive	Electricity, schools, roads, water pollution, KVIP	Electricity, more brick and block houses. Rapid development, good road

Local Changes, Environmental and Land Issues (Cont.)

Table 4.4.5 (Cont.)

MAASE	Chiefs/Elders	Men	Teachers	Women
Main Changes	Farmlands in the past are now changed into residential settlement	Decline in drinking water quality, decline in soil fertility, KVIP/electricity	Electricity poles, areal expansion, improved road network	Toilets, KVIP borehole, electricity
Developments planned	School rehabilitation, clinic, commercial area, police station	Electricity, house for doctor, renovation of school, borehole construction	Health post	Clinic, schools
Enviro/polln problems 1	Water pollution	Water pollution	Land scarcity	Sanitation
Enviro/polln problems 2	Air pollution	Sanitation	Decline in land productivity	No attendant for toilet
Enviro/polln problems 3	Sand winning	Health	Water resources decline/forestation	
Current land issues			Yes	
What current land issues			Competition for land	
Other changes since 1983	New houses. Increased population	Increase in population	Population increase, more transport	Increase in food production, decline in weaving

SEPETINPOM	Chiefs/Elders	Men	Women
Main Changes	Residential land has taken over from farmland	Construction landuse has replaced farming landuse	Market, new residential area, piped water
Developments planned	Piped water and boreholes, toilets, new electricity, sanitary site	Construction of school wall, new transformer, toilet	Fencing of school land, more communal labour, sanitation, pay more attention to water bodies
Enviro/polln problems 1	Deforestation	Land erosion	Water pollution
Enviro/polln problems 2	Water pollution	Water pollution	Market structures
Enviro/polln problems 3		Air pollution	Drainage problems, sand winning
Current land issues		Yes	
What current land issues			
Other changes since 1983		Increased population, increase in land for construction, population, water pollution	More housing projects

Land Use Change

Table 4.4.6

ABREPO	**Chiefs/Elders**	**Men**	**Teachers/Men**	**Unassigned**	**Women**
Land Use – Residential	Most >75%	Most >75%	Most >75%	Most >75%	Most >75%
Residential since 1983	Increase		Increase	Increase	
Land use – Farming	None	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Farmland since 1983				Decrease	
Land use – Forest reserves	None	None	None		None
Forest Change since 1983					
Land use – Flooded	Few/some<25%	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Floods change since 1983					
Land use – Factory/Commercial	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Factory/Commercial change since 1983				Increase	
Land use – sand winning	None	None	None	Few/some <25%	None
Sand winning change since 1983					
Land use other					
Land use other proportion					

Land Use Change (Cont.)

Table 4.4.6 (Cont.)

ADAGYA	**Chiefs/Elders**	**Men**	**Unassigned**	**Women**
Land Use – Residential	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Residential since 1983	Increase	Increase	Increase	Increase
Land use – Farming	About half 50%	Most >75%	Most >75%	Few/some <25%
Farmland since 1983	Decrease	Decrease	No change	No change
Land use – Forest reserves	None	Few/some <25%		None
Forest Change since 1983		Decrease		
Land use – Flooded	Few/some <25%	Few/some <25%	Few/some <5%	Few/some <25%
Floods change since 1983	Decrease		Increase	Increase
Land use – Factory/Commercial	Few/some <25%			None
Factory/Commercial change since 1983	Increase			
Land use – sand winning	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Sand winning change since 1983	Decrease	Increase	Increase	No change
Land use other				
Land use other proportion				

Land Use Change (Cont.)

Table 4.4.6 (Cont.)

ASAGO	Chiefs/Elders	Men	Mixed	Teachers/Men	*Unassigned*
Land Use – Residential	Few/Some <25%	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Residential since 1983			Increase		Increase
Land use – Farming	Most >75%	Most >75%	Most >75%	Most >75%	Most >75%
Farmland since 1983	Decrease		Decrease		Increase
Land use – Forest reserves	None	None	None		
Forest Change since 1983					
Land use – Flooded	Few/some <25%	Few/some <25%	Few/some >25%	Few/some >25%	Few/some <25%
Floods change since 1983					
Land use – Factory/Commercial	None	None	None		
Factory/Commercial change since 1983					
Land use – sand winning	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Sand winning change since 1983					
Land use other	School land				Stone quarrying
Land use other proportion	Few/some <25%				Few/some <25%

Land Use Change (Cont.)

Table 4.4.6 (Cont.)

ATAFUA	Chiefs/Elders	Men	Unassigned	Women
Land Use – Residential	Most >75%	Few/some <25%	Few/some <25%	Few/some <25%
Residential since 1983		Increase	Increase	Increase
Land use – Farming		Most >75%	About half 50%	Most >75%
Farmland since 1983		Decrease	Decrease	Decrease
Land use – Forest reserves	Few/some <25%	Few/some <25%		Few/some <25%
Forest Change since 1983				No change
Land use – Flooded		Few/some <25%		Few/some <25%
Floods change since 1983				
Land use – Factory/Commercial	Few/some <25%	None		None
Factory/Commercial change since 1983				
Land use – sand winning	About half 50%	Few/some <25%	Few/some <25%	Few/some <25%
Sand winning change since 1983		Decrease	Increase	Increase
Land use other				
Land use other proportion				

Land Use Change (Cont.)

Table 4.4.6 (Cont.)

DUASE	Men	Men	Unassigned	Women
Land Use – Residential	Few/some <25%	Few/some <25%	Few/some <25%	Few/some <25%
Residential since 1983	Increase		Increase	
Land use – Farming	Most >75%	About half 50%	Most >75%	Most >75%
Farmland since 1983	Decrease		Decrease	
Land use – Forest reserves		Few/some <25%		None
Forest Change since 1983				
Land use – Flooded		Few/some <25%		Few/some <25%
Floods change since 1983				Increase
Land use – Factory/Commercial		Few/some <25%		None
Factory/Commercial change since 1983				
Land use – sand winning		Few/some <25%		None
Sand winning change since 1983				
Land use other				
Land use other proportion				

Land Use Change (Cont.)

Table 4.4.6(Cont.)

ESERESO	Chiefs/Elders	Men	Women
Land Use – Residential	About half 50%	Most >75%	About half 50%
Residential since 1983	Increase	Increase	Increase
Land use – Farming	About half 50%	Few/some <25%	Few/some <25%
Farmland since 1983	Decrease	Decrease	Decrease
Land use – Forest reserves	None	None	None
Forest Change since 1983			
Land use – Flooded	Few/some <25%	Few/some <25%	Few/some <25%
Floods change since 1983		Decrease	No change
Land use – Factory/Commercial	Few/some <25%	Few/some <25%	Few/some <25%
Factory/Commercial change since 1983	Increase		Increase
Land use – sand winning	Few/some <25%	About half 50%	None
Sand winning change since 1983	Decrease	Decrease	
Land use other	Reserve land		
Land use other proportion	Few/some <25%		None

Land Use Change (Cont.)

Table 4.4.6 (Cont.)

MAASE	Chiefs/Elders	Men	Teachers	Women
Land Use – Residential	Few/some <25%	Most >75%	Few/some <25%	About half 50%
Residential since 1983	Increase	Increase		Increase
Land use – Farming	Most >75%	Few/some <25%	About half 50%	Most >75%
Farmland since 1983	Decrease	Decrease		Decrease
Land use – Forest reserves	None	None	Most >75%	None
Forest Change since 1983				
Land use – Flooded	Few/some <25%		Few/some <25%	None
Floods change since 1983	Increase			
Land use – Factory/Commercial	Few/some <25%	Few/some <25%		Few/some <25%
Factory/Commercial change since 1983	Increase			
Land use – sand winning	Few/some <25%	Few/some <25%	Few/some <25%	Almost all/all >90%
Sand winning change since 1983	Increase	Decrease		Increase
Land use other				
Land use other proportion				

Table 4.4.6 (Cont.)

SEPETINPOM	**Chiefs/Elders**	**Men**	***Women***
Land Use – Residential	Most >75%	Most 75%	Most >75%
Residential since 1983	Increase	Increase	Increase
Land use – Farming	None	None	None
Farmland since 1983		Decrease	Decrease
Land use – Forest reserves	None	None	None
Forest Change since 1983			
Land use – Flooded	Few/some <25%	Few/some <25%	Few/some < 25%
Floods change since 1983	Decrease		
Land use – Factory/Commercial	Few/some <25%	None	Few/some <25%
Factory/Commercial change since 1983	Increase		
Land use – sand winning	None	None	Few/some <25%
Sand winning change since 1983			
Land use other			
Land use other proportion			

Drinking Water

Table 4.4.7

ABREPO	Chiefs/Elders	Men	Teachers/Men	Unassigned	Women
Piped – number using	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%	Few/some <25%	About half 50%
Piped – supply consistency	Constant	Constant	Constant		Constant
Piped – quality	Poor	Good	Good		Good
Piped cost	40	40	80	40	0
Bore – number using					
Bore – supply consistency					
Bore hole – quality					
Bore hole cost	0	0	0	0	0
Well – number using				Almost all/all >90%	Few/some <25%
Well – supply consistency					Constant
Well – quality					Good
Well cost	0	0	0	0	0
Stream etc – number using	Few/some <25%			Almost all/all >90%	
Stream etc – supply consistency	Constant				
Stream etc – quality	Good			Poor	
Stream etc – cost	0	0	0	0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ABREPO (CONTINUED)	Chiefs/Elders	Men	Teachers/Men	Unassigned	Women
Tanker – number using					
Tanker – supply consistency					
Tanker – quality					
Tanker cost					
Other source	Rain water	Rain water	Rain water	Rain water	Rain water
Other – number using	About half 50%	Almost all/all >90%	Few/some <25%		Almost all/all >90%
Other – supply consistency	Intermittent	Intermittent	Intermittent		Intermittent
Other – quality	Good				Good
Other cost	0				0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ADAGYA	Chiefs/Elders	Men	Unassigned	Women
Piped – number using				
Piped – supply consistency				
Piped – quality				
Piped cost				
Bore hole – number using	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%
Bore hole – supply consistency	Constant	Constant	Constant	Constant
Bore hole – quality	Good	Good	Good	Good
Bore hole cost	20	20	20	50
Well – number using	Almost all/all >90%	Few/some <25%	Almost all/all >90%	Almost all/all >90%
Well – supply consistency	Intermittent	Intermittent	Constant	Constant
Well – quality	Poor	Good	Good	Good
Well cost	0	50	0	0
Stream etc – number using			Almost all/all >90%	Most >75%
Stream etc – supply consistency			Constant	Intermittent
Stream etc – quality			Poor	Poor
Stream etc – cost	0	0	0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ADAGYA (CONTINUED)	Chiefs/Elders	Men	Unassigned	Women
Tanker – number using				
Tanker – supply consistency				
Tanker – quality				
Tanker cost				
Other source	Rain water	Rain water	Rain water	Rain water
Other – number using	Almost all/all >90%		Almost all/all >90%	Almost all/all >90%
Other – supply consistency	Intermittent		Intermittent	Intermittent
Other – quality	Good		Good	Good
Other cost	0	0	0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ASAGO	Men	Mixed	Teachers/Men	Unassigned	Women
Piped – number using	None	None			None
Piped – supply consistency					
Piped – quality					
Piped cost					
Bore hole – number using		None		Few/some <25%	None
Bore hole – supply consistency				Constant	
Bore hole – quality				Good	
Bore hole cost				0	
Well – number using	Few/some <25%	Most >75%	Few/some <25%	Almost all/all >90%	Almost all/all >90%
Well – supply consistency	Constant	Intermittent		Constant	Constant
Well – quality	Poor	Poor		Good	
Well cost	50	50	0	0	0
Stream etc – number using	Few/some <25%	Almost all/all >90%			Almost all/all >90%
Stream etc – supply consistency		Intermittent			Constant
Stream etc – quality		Poor			
Stream etc – cost		0			0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ASAGO (CONTINUED)	**Chiefs/Elders**	**Mixed**	**Teachers/Men**	**Unassigned**	**Women**
Tanker – number using	Few/some <25%	None			
Tanker – supply consistency	Intermittent				
Tanker – quality	Good				
Tanker cost	0				
Other source		Rain Water		Rain water	Rain water
Other – number using		Almost all/all >90%		Almost all/all >90%	Almost all/all >90%
Other – supply consistency		Intermittent		Intermittent	Intermittent
Other – quality		Good		Good	Good
Other cost		0		0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ATAFUA	**Chiefs/Elders**	**Men**	**Unassigned**	**Women**
Piped – number using	Almost all/all >90%	Almost all/all >90%	Most >75%	Almost all/all >90%
Piped – supply consistency	Constant	Constant	Constant	constant
Piped – quality	Good	Good	Good	Good
Piped cost	50	50	50	50
Bore hole – number using	None	Most >75%	Most >75%	
Bore hole – supply consistency		Constant	Constant	
Bore hole – quality		Good	Good	
Bore hole cost		0	0	
Well – number using	Few/some <25%	Few/some <25%	Most >75%	Almost all/all >90%
Well – supply consistency	Constant	Constant	Constant	Constant
Well – quality	Good	Good	Good	Good
Well cost	0	0	0	0
Stream etc – number using	Few/some <25%	Most >75%		Few/some <25%
Stream etc – supply consistency	Constant	Constant		Constant
Stream etc – quality	Good			Poor
Stream etc – cost	0			0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ATAFUA (CONTINUED)	Chiefs/Elders	Men	Unassigned	Women
Tanker – number using				
Tanker – supply consistency				
Tanker – quality				
Tanker cost				
Other source	Rain Water	Rain water		Rain water
Other – number using	Few/some <25%	Almost all/all >90%		Almost all/all >90%
Other – supply consistency	Intermittent	Intermittent		Intermittent
Other – quality	Good	Good		Good
Other cost	0	0		0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

DUASE	**Men**	**Men**	**Unassigned**	**Unassigned**	**Women**
Piped – number using	Almost all/all >90%	Almost all/all >90%	Most >75%	Almost all/all >90%	Almost all/all >90%
Piped – supply consistency	Constant	Constant	Intermittent	Constant	Intermittent
Piped – quality	Good	Good	Good	Good	Good
Piped cost	20	20	20	20	20
Bore hole – number using	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%
Bore hole – supply consistency	Constant	Constant	Constant	Constant	Constant
Bore hole – quality	Good	Good	Good	Good	Good
Bore hole cost	0	0	0	20	20
Well – number using	About half 50%	Almost all/all>90%		Almost all/all 90%	Few/some >25%
Well – supply consistency	Constant	Constant		Constant	Constant
Well – quality	Good	Good		Good	Good
Well cost	0	0		0	0
Stream etc – number using			Few/some <25%		Almost all/all >90%
Stream etc – supply consistency			Intermittent		Constant
Stream etc – quality			Good		Good
Stream etc – cost			0		0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

DUASE (CONTINUED)	Men	Men	Unassigned	Unassigned	Women
Tanker – number using					
Tanker – supply consistency					
Tanker – quality					
Tanker cost					
Other source	Rain water	Rain water	Rain water	Rain water	Rain water
Other – number using	Almost all/all >90%		Almost all/all >90%	Almost all/all >90%	Almost all/all >90%
Other – supply consistency	Intermittent		Intermittent	Intermittent	Intermittent
Other – quality	Good		Good	Good	Good
Other cost	0		0	0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ESERESO	Chiefs/Elders	Women
Piped – number using	None	
Piped – supply consistency		
Piped – quality		
Piped cost		
Bore hole – number using	Almost all/all >90%	Most >75%
Bore hole – supply consistency	Intermittent	Constant
Bore hole – quality	Good	Good
Bore hole cost	0	0
Well – number using	Most >75%	Most >75%
Well – supply consistency	Constant	Intermittent
Well – quality	Good	Poor
Well cost	0	0
Stream etc – number using	About half 50%	
Stream etc – supply consistency	Intermittent	
Stream etc – quality	Good	
Stream etc – cost	0	

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

ESERESO (CONTINUED)	Chiefs/Elders	Women
Tanker – number using	Most >75%	
Tanker – supply consistency	Intermittent	
Tanker – quality	Good	
Tanker cost	0	
Other source	No	
Other – number using		
Other – supply consistency		
Other – quality		
Other cost		

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

MAASE	Chiefs/Elders	Teachers	Women
Piped – number using	None		
Piped – supply consistency			
Piped – quality			
Piped cost			
Bore hole – number using	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%
Bore hole – supply consistency	Constant	Constant	Constant
Bore hole – quality	Good	Good	Good
Bore hole cost			1000
Well – number using	None		Few/some <25%
Well – supply consistency			Intermittent
Well – quality			Good
Well cost			0
Stream etc – number using		None	Most >75%
Stream etc – supply consistency		Constant	Intermittent
Stream etc – quality		Poor	Good
Stream etc – cost		0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

MAASE (CONTINUED)	Chiefs/Elders	Teachers/Men	Women
Tanker – number using			
Tanker – supply consistency			
Tanker – quality			
Tanker cost			
Other source	Rain water	Rain water	Rain water
Other – number using	Almost all/all>90%	Almost all/all >90%	Almost all/all >90%
Other – supply consistency	Intermittent	Intermittent	Intermittent
Other – quality	Poor	Good	Good
Other cost	0	0	0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

SEPETINPOM	**Chiefs/Elders**	**Men**	**Women**
Piped – number using	Most >75%	Most >75%	Almost all/all >90%
Piped – supply consistency	Intermittent	Intermittent	Constant
Piped – quality	Good	Good	Good
Piped cost	50	50	70
Bore hole – number using	Few/some >25%		
Bore hole – supply consistency			
Bore hole – quality			
Bore hole cost			
Well – number using	Few/some <25%	Few/some <25%	Few/some <25%
Well – supply consistency	Intermittent	Intermittent	Constant
Well – quality	Poor	Good	Good
Well cost	0	50	0
Stream etc – number using			Few/some <25%
Stream etc – supply consistency			Constant
Stream etc – quality			Poor
Stream etc – cost			0

Drinking Water (Cont.)

Table 4.4.7 (Cont.)

SEPETINPOM (CONTINUED)	**Chiefs/Elders**	**Men**	**Women**
Tanker – number using			
Tanker – supply consistency			
Tanker – quality			
Tanker cost			
Other source	Rain Water	Rain water	Rain water
Other – number using	About half 50%	Almost all/all >90%	Almost all/all >90%
Other – supply consistency		Intermittent	Intermittent
Other – quality	Good	Good	Good
Other cost	0	0	0

Wastewater

Table 4.4.8

ABREPO	Chiefs/Elders	Men	Unassigned		Women
Waste water open			Almost all/all >90%		Most >75%
Waste water pipes	About half 50%	Most >75%			
Waste water irrigate					
Waste water other					Few/some <25%
ADAGYA	**Chiefs/Elders**	**Men**	**Unassigned**		**Women**
Waste water open	Most >75%	Almost all/all >90%	Few/some <25%		Almost all/all >90%
Waste water pipes					
Waste water irrigate					
Waste water other			Almost all/all >90%		
ASAGO	**Chiefs/Elders**	**Mixed**	**Teachers/Men**	**Unassigned**	**Women**
Waste water open	Most >75%	Most >75%	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%
Waste water pipes		None			
Waste water irrigate		None			
Waste water other					

Wastewater (Cont.)

Table 4.4.8 (Cont.)

ATAFUA	Chiefs/Elders	Men	Unassigned	Women
Waste water open	Most >75%	Most >75%	Almost all/all >90%	Almost all/all >90%
Waste water pipes		Few/some <25%		
Waste water irrigate				
Waste water other				

DUASE	Men	Men	Unassigned	Women
Waste water open	Most >75%	Almost all/all >90%	Almost all/all >90%	Almost all/all >90%
Waste water pipes		Few/some <25%		Few/some <25%
Waste water irrigate				
Waste water other				

ESERESO	Chiefs/Elders	Men	Women
Waste water open		Most >75%	Almost all/all >90%
Waste water pipes	About half 50%	Few/some <25%	
Waste water irrigate	About half 50%		
Waste water other			

Wastewater (Cont.)

Table 4.4.8 (Cont.)

MAASE	Chiefs/Elders	Men	Teachers	Women
Waste water open	Almost all/all >90%	Almost all/all >90%	About half 50%	
Waste water pipes		None	About half 50%	
Waste water irrigate		None		
Waste water other				Almost all/all >90%
SEPETINPOM	**Chiefs/Elders**	**Men**		**Women**
Waste water open	Most >75%	Most >75%		Almost all/all >90%
Waste water pipes	Few/some <25%	Few/some <25%		
Waste water irrigate	None	None		
Waste water other				Gutters

Refuse

Table 4.4.9

ABREPO	**Chiefs/Elders**	**Men**	**Teachers/Men**	**Unassigned**	**Women**
Refuse collection	No	No	Yes	No	No
Who collects refuse			KMA	None	
How often refuse collection					
Who refuse dump maintenance	Unit committee/KMA	KMA	None		KMA
Refuse maintenance tasks		Refuse taken away	Nothing		
Site of dump 1	Adjacent to water course	Adjacent to water course	Upstream	Upstream	Adjacent to water course
Site of dump 2	Near houses	Upstream	Near houses		Upstream
Site of dump 3					Near houses
Disposal of bottles	Reused	Reused	Sold	Refuse	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump, sold
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump
Disposal of paper	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump

Refuse (Cont.)

Table 4.4.9 (Cont.)

ADAGYA	Chiefs/Elders	Men	Unassigned	Women
Refuse collection	No	No	No	No
Who collects refuse				
How often refuse collection				
Who refuse dump maintenance	Unit Committee	Communal labour	Communal labour	Communal labour
Refuse maintenance tasks	Burning	Cleaning, burning, weeding		Cleaning, burning, weeding
Site of dump 1	Upstream	Upstream	Upstream	Upstream
Site of dump 2	New houses	Near houses		
Site of dump 3				
Disposal of bottles	Sold	Refuse dump, reused, resold	Refuse dump, reused or sold	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump, sold	Refuse dump	Refuse dump	Refuse dump
Disposal of plastic bags		Refuse dump	Refuse dump	Refuse dump, reused
Disposal of paper		Refuse dump	Refuse dump	Refuse dump

Refuse (Cont.)

Table 4.4.9 (Cont.)

ASAGO	Chiefs/Elders	Mixed	Teachers/Men	Unassigned	Women
Refuse collection	No	No	Yes	Yes	No
Who collects refuse			School children	Children	
How often refuse collection			2		
Who refuse dump maintenance	Unit Committee	Unit Committee		Children	Villagers
Refuse maintenance tasks	Burning	Burning		Burning, cleaning, sweeping	Burning, weeding and sweeping
Site of dump 1	Near houses	Upstream		Near houses	Adjacent to water course
Site of dump 2		Near houses			Near houses
Site of dump 3					
Disposal of bottles	Sold/Reused	Reused	Reused	Reused	Refuse dump, sold
Disposal of tin cans	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump
Disposal of paper		Refuse dump		Refuse dump	Refuse dump

Refuse (Cont.)

Table 4.4.9 (Cont.)

ATAFUA	Chiefs/Elders	Men	Unassigned	Women
Refuse collection	No	No	Yes	No
Who collects refuse			Unit committee	
How often refuse collection				
Who refuse dump maintenance	Unit committee	People	Unit committee	Unit committee/communal
Refuse maintenance tasks	Cleaning	Weeding and gathering	Burning, cleaning	Cleaning, weeding and burning
Site of dump 1	Upstream	Upstream	Upstream	Upstream
Site of dump 2	Near houses	Near houses		Near houses
Site of dump 3				
Disposal of bottles	Sold	Refuse dump, reused, sold	Refuse dump	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump	Refuse dump	Refuse dump	
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump	
Disposal of paper	|Refuse dump	Refuse dump, reused	Refuse dump	

Refuse (Cont.)

Table 4.4.9 (Cont.)

DUASE	Men	Men	Unassigned	Unassigned	Women
Refuse collection	Yes	Yes	No	Yes	Yes
Who collects refuse	KMA	KMA	Children	KMA	KMA
How often refuse collection	1	1	2	0	1
Who refuse dump maintenance	Assembly woman's appointee	Communal labour	KMA/Community	Communal labour	Communal labour
Refuse maintenance tasks	Cleaning and weeding	Cleaning, weeding, burning	Cleaning, collection		Clean, weed and burn
Site of dump 1	Adjacent to water course/ near houses		Upstream	Near houses	Adjacent to water course
Site of dump 2	Adjacent to water course/near houses		Near houses		Upstream
Site of dump 3	Near houses				
Disposal of bottles	Sold	Refuse dump, reused, sold	Refuse dump, reused, sold	Refuse dump, reused	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump	Refuse dump	Refuse dump
Disposal of paper	Refuse dump	Refuse dump	Refuse dump, reused	Refuse dump	Refuse dump

Refuse (Cont.)

Table 4.4.9 (Cont.)

ESERESO	Chiefs/Elders	Men	Women
Refuse collection	No	No	No
Who collects refuse			
How often refuse collection			
Who refuse dump maintenance	Unit Committee	Unit committee/command labour	Unit committees, chief and elders
Refuse maintenance tasks	They hire bulldozer to clear them during the dry season	Clearing dumps	Clean, weed around dumps, burn
Site of dump 1	Upstream	Upstream	Downstream, close to houses
Site of dump 2			
Site of dump 3			
Disposal of bottles	Reused or sold	Refuse dump, reused, sold	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump/reused	Refuse dump	Refuse dump
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump
Disposal of paper	Refuse dump	Refuse dump, reused	Refuse dump

Refuse (Cont.)

Table 4.4.9 (Cont.)

MAASE	Chiefs/Elders	Men	Teachers	Women
Refuse collection	Yes	No	Yes	No
Who collects refuse	Whole village		Women and children	
How often refuse collection			2	
Who refuse dump maintenance	Unit committee/WATSAN		Old men	Women
Refuse maintenance tasks	Burning		Sweeping and burning	Burning
Site of dump 1	Upstream	Upstream, close to houses	Adjacent to water course	
Site of dump 2			Upstream	
Site of dump 3			Near houses	
Disposal of bottles	Sold	Reused	Sold	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump	Refuse dump	Refuse dump	Refuse dump/sold
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump	Refuse dump
Disposal of paper		Reused	Reused	Refuse dump

Refuse (Cont.)

Table 4.4.9 (Cont.)

SEPETINPOM	Chiefs/Elders	Men	Women
Refuse collection	No	No	Yes
Who collects refuse			Children/adults
How often refuse collection			
Who refuse dump maintenance	Unit committee	KMA, communal labour	Unit committee
Refuse maintenance tasks	Burning	Cleaning, weeding, sweeping	Cleaning, weeding, burning
Site of dump 1	Upstream	Upstream	Adjacent to water course
Site of dump 2			Upstream
Site of dump 3			
Disposal of bottles	Reused, sold	Refuse dump, reused, sold	Refuse dump, reused, sold
Disposal of tin cans	Refuse dump	Refuse dump	Refuse dump
Disposal of plastic bags	Refuse dump	Refuse dump	Refuse dump
Disposal of paper		Refuse dump	Refuse dump

Table 4.4.10: Major Differences among the Eight Kumasi Peri-Urban Villages, ordered from most rural to most urban

Village	Similarities and Major Differences
Adagya	• slow growth • moderate influence of Kumasi Metropolis • farming is the major occupation • loss of some farmlands to housing and sand winning • strong communal spirit • easy access to Kumasi • poor level of infrastructure • poor sanitation and drainage system
Asago	• slow growth • moderate influence of Kumasi Metropolis • farming is the major occupation • loss of some farmlands to housing and sand winning • strong communal spirit • poor access to Kumasi • poor level of infrastructure • poor sanitation and drainage system
Maase	• moderate growth • moderate influence from Kumasi Metropolis • farming is the major occupation • loss of some farmlands to housing • strong communal spirit • moderate access to Kumasi • appreciable level of infrastructure • poor sanitation and drainage system
Duase	• moderate growth • moderate influence of Kumasi Metropolis • major occupation is still farming • nevertheless, farming is on the decline • increasing loss of some farmlands to housing • easy access to Kumasi • strong communal spirit • appreciable level of infrastructure • poor sanitation and drainage system
Esereso	• moderate growth • strong influence of Kumasi Metropolis • farming on the decline • most people still engaged in farming • loss of some farmlands to housing • strong communal spirit • easy access to Kumasi • appreciable level of infrastructure • poor sanitation and drainage system
Atafua	• increasingly rapid growth • easy access to Kumasi • strong influence from Kumasi Metropolis • farming on the decline • farming is still important

	• increasing loss of farmlands to housing • strong communal spirit • appreciable level of infrastructure • poor sanitation and drainage system
Sepetinpom	• strong influence of Kumasi Metropolis • easy access to Kumasi • growing rapidly • loss of almost all farmlands to housing • most people now engaged in non-agricultural occupations • large population of strangers • appreciable level of infrastructure • poor sanitation and drainage system
Abrepo	• engulfed by Kumasi • growing rapidly • farming on the decline • most people thus now engaged in secondary occupations • rapid loss of farmlands to housing • large population of strangers • easy access to Kumasi • appreciable level of infrastructure • poor sanitation and drainage system

Source: Field Surveys, 1999- 2000

4.5 <u>Communities and Water Resources</u>

4.5.1 WATER SOURCES, USE AND MANAGEMENT

Sources of drinking water varied between the villages depending on the sources of water available, its quality, the season and the ability to pay.

Table 4.5.1: Sources of water

Village	Piped water	Borehole	Well	Springs/ streams	Rainwater collected
Maase	No	1	2 abandoned	1 good 1 poor quality	Yes
Atafua	Yes	2 private	6 private	2 rivers used for washing	Yes
Abrepo	Yes	0	0 (old ones destroyed)	2 rivers used for washing	Yes
Duase	Yes	1 + 1 broken	2	Several streams & rivers	Yes
Sepetimpom	Yes	1 broken	6 private, 1 free	1 good (but polluted downstream)	Yes
Esereso	No	3 – 1 good, 2 broken or little water	Several, variable quality	Several springs	Yes
Adagya	No	1	4 private	1 good, but weedy	Yes
Asago	No	1 (opened during project)	3 public, variable quality 2 private good quality	-	Yes

Four of the villages closest to Kumasi had piped water, provided and maintained by the Ghana Water Company (GWC). The water was available from public standpipes which were money was collected per bucket or container. (Price C20-C50 a bucket). Houses that could afford their own connections had water piped to them and metered. In several cases the households with their own supply would sell their water to others at the same rates as GWC. For example, in Abrepo there were 2 public standpipes and at least 4 private standpipes. The water quality was reported to be good in all four villages. However there were occasional breaks in the service, for a few days at a time when people would have to turn to alternative sources of water.

Piped water was the most popular source for drinking and washing where it was available. However, those with little money would use alternative sources for washing, especially the streams and rivers. For drinking water, there was little alternative to piped water in Abrebo (apart from rain water), other than the rivers, as the old wells had been destroyed. Therefore the respondents thought even the poorest members of the village would pay for drinking water. In the 3 other villages there were alternative sources – wells, springs and boreholes.

Rain water was collected as run-off from the roofs of houses in all villages by most people. This was usually into buckets and small containers for individual use. Only a few houses had large barrels or plastic tanks to collect the water. No extensive guttering or other methods to collect the water efficiently were observed or mentioned by respondents[1]. After the early rains had washed the dust from the roofs, the rain water was considered as good quality for drinking and washing. It was used for iced water. In Asago, where good quality water was in short supply, respondents reported that they kept collected rain water inside to prevent it being stolen by others.

Boreholes were installed in four of the villages and under construction in one (Asago). They provided the main source of drinking water in three villages which had no piped water. However, because there was only one working or reliable borehole in each of these villages there were long queues to fetch water, and minor disputes often broke out between those waiting for water. Respondents said that one borehole was not sufficient for the needs of the village and that many villagers also used alternative sources – springs and wells – to avoid the long queues. The water quality was said to be good. In two villages an attendant was employed to collect a fee of C20 per bucket and to maintain the pump. In Maase, each household paid C1000 a month for use of the pump, and in Esereso the water was free (although the pump frequently broke).

There were wells in all the villages except Abrepo (where the old wells have been destroyed by the new road). Many of these were privately owned and used. However, some owners would sell water especially in the dry season, when other sources were in short supply (reported in four villages). Wells were the most important sources of drinking water in Asago, where there were three public and two private wells. The quality of the water was reported as variable. Some wells, such as the public wells in Asago become flooded in the rainy season with polluted water from the rivers, others have a salty or unpleasant taste at certain times of the year. Water from the public wells was free but there were sales of water from private wells. Particularly in Asago where there is no other source of good quality drinking water, water from the two private wells was sold at C50 a bucket, sometimes rising to C100 during the dry season. Sales were also reported in three other villages.

Springs, streams and rivers are the traditional source of drinking water and still remain an important source in six of the villages as well as being used for washing in all of the villages. In villages which have streams arising within the village boundaries, people collect water from close to the source which they believe to be good quality (for example, in Esereso and Sepetinpon). These streams can become covered with weeds and difficult to access. In Adagya, for example, one spring was reported as good drinking water, but very weedy and infested with snakes. Some streams have never been used for water, either because the stream is sacred (eg. Stream Angofera in Sepetinpon) or because the water is not considered good (eg. Stream Abenaa in Duase described as having a “lustrous film” on the water). For villages with few springs, the larger streams and rivers had been an important source of drinking water, such as the Owabi and Ntikyei rivers at Atafua, and the Oda at Asago. However, the villagers were aware of the growing levels of pollution in the rivers and had stopped using these for drinking, although they were still used for washing.

Women and children were responsible for collecting water for household use. In all villages men would rarely fetch water, other than for their own personal use.

4.5.2 POLLUTION OF WATER COURSES

In all the villages people were aware of the growing levels of pollution in the streams and rivers, and the health problems it could cause. The children were said to suffer most as they tended to be more careless with hygiene and to swim in the rivers. They were susceptible to water-borne diseases such as dysentery, cholera and bilhazia. All villages, both upstream and downstream from Kumasi suffered from forms of pollution, some generated from within the village itself, and some from outside. The main types of pollution identified by respondents were as follows:

[1] A few of the modern houses may have underground tanks.

Pollution from within the village

Drainage from rubbish dumps and toilet areas
These areas were often sited alongside water courses or in valley areas which drained into the streams and rivers. In the villages where the rubbish and nightsoil was collected by KMA, the collection was not frequent enough to prevent overflowing rubbish. In Sepetimpom it was noted that some householders with bucket latrines would empty the nightsoil directly into the streams. Villagers noted the increase in plastics and other rubbish, plus worms in the water as evidence of the growing pollution. Pollution from rubbish dumps and nightsoil was generated within the villages themselves, in addition to pollution from areas upstream. Even in Maase, at the top of the watershed, rubbish flooded down and into the springs and streams in the rainy season from the village rubbish dump.

Washing vehicles
In three villages, respondents complained that vehicles were driven to the river banks and washed, leaving a film of oil in the water. In two villages, there were local rules to prevent this which included fines, but these were often difficult to enforce.

Waste waste

Clothes are not usually washed directly in the river, but on the river banks. The waste water drains back straight into the rivers. Waste water from houses is thrown into open drainage canals or straight on to the ground, and this also drains back into the streams.

Pollution from enterprises in the village

There were no heavy industries within the villages, but residues from small industries were mentioned: residues from gin distilling in 2 villages; palm kernel processing in one village.

Pollution from agriculture

The only form of pollution that was mentioned directly by respondents was sugarcane growing in Duase. The crop is grown directly alongside the river, and growers make small canals to irrigate the crop. Villagers disliked the fact that growers were wading in the river and effectively blocking and diverting the flow of water.

Apart from sugarcane and water cocoyam, vegetables are often grown on river banks, and the farmers often use pesticides[2] and chemical fertilisers on these. The chemicals would be mixed with water from the streams, and could run-off into the streams. However, this was not mentioned by any of the respondents as a major cause of pollution.

Pollution from upstream peri-urban villages
Respondents were aware of where their rivers came from, and the pollution from upstream villages. Villages which are not affected directly by pollution from Kumasi city still suffer from pollution from upstream. For example, those in Adagya complained about pollution from Esereso; those in Sepetimpom about pollution from Duase and Kenyase villages. In Atafua, villagers complained that they could no longer use the Owabi and Ntikyei rivers because of the levels of pollution.

Pollution from Kumasi city
The villages that suffer most from pollution from the city are Duase, Abrebo and Asago. Although Duase is upstream from Kuamsi, there is a large KMA rubbish dump situated upstream on the borders of the village. The inhabitants have complained about it, but it is still used.

Abrebo is situated downstream from the largest area of mechanics and car maintenance enterprises (Suame Magazine). Villagers are aware of the run-off of oils and other rubbish into the Akuosu stream. The stream is not generally used for drinking (as there is piped water), but is used for washing. It is also used for growing crops such as sugarcane and water cocoyam.

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[2] These may still include DDT.

Asago suffers most from pollution from the city, because it is directly downstream from two rivers that flow through the heart of the city (Subin and Sisa). The main dumping area for nightsoil from Kumasi is situated about 2km upstream (at Kaase). Untreated nightsoil is dumped by and in the Sisa river causing major pollution of the river, and also water flows back into the Oda, which joins the Sisa at Asago. Large quantities of sawdust are also washed down the rivers from the sawmilling industries and this blocks the flow of water and increases flooding problems. Villagers said that the sawdust affects the fish in the river. Residues from other industries such as the abattoir and brewing industries add to the pollution in the river. The result is that the river is littered with plastics and other rubbish and a bad odour pervades the area. The villagers are extremely concerned and have written a letter to the Chief Executive of KMA to complain (but to no effect). Asago is particularly badly affected by this because the village does not have a good source of water other than the Oda. It has no piped water or working borehole. Many of the farms are situated on the other side of the Oda, so villagers have to wade through dirty water to reach them. Also the pollution is said to affect the taste and size of fish, which provide a secondary income for some of the villages.

Water Treatment

Water from pipes and boreholes is not treated by villagers before use. The GWC does monitor the quality, and provide chemicals for water treatment for the boreholes. The only water treatment methods reported by villagers were leaving the water so the sediment settled out, and (in Asago) filtering the water through a cloth. Respondents in Asago knew that water could be boiled in order to purify it, but said that no one did this.

4.5.3 MANAGEMENT OF WATER SOURCES

Management of water and sanitation was said to be the responsibility of the Unit Committees in all the villages, as part of their general responsibility for village development and communal labour. Their main role was in contacting GWC (sometimes through the Assembly man) to fix and maintain the piped water supply and boreholes; organising communal labour to clean the toilet areas, maintain the rubbish dumps and collect fees. They do have a role in enforcing local rules, for example, about washing vehicles in the river or cultivating on river banks. However, this role seems to be limited. Only in one village (Sepetimpom) did respondents say that the Unit Committee protected rivers and in other villages people said it was difficult to enforce local rules. In Maase, there were regulations over use of the spring during the dry season, to prevent it drying up. One village had a Sanitation committee who organised communal labour for waste management, and four villages had WATSAN committees. The split of responsibilities between the Unit Committee and WATSAN was unclear and varied between villages. One specific role that the WATSAN committee had was to educate the villagers about water and hygiene.

Although the Unit Committees have taken over many of the functions of the Traditional Authorities, some old rules and taboos connected with water still remain. In four villages, respondents said there were taboo days once a week when certain rivers could not be visited. In one village there was a sacred stream where no water could be used for cooking.

Around the Owabi river on government land there are rules that no cultivation should take place within 200 metres of the river.

In Duase there was a reserved area where there had been a project organised by the Forestry Department to plant trees along the river banks, but this had now ended. In Esereso, the 31st December Women's Movement had a project to plant trees along the banks of the Oda river.

Land use around water courses

According to the villagers, cultivation and building close to the river banks and around springs was discouraged by local rules, however in most of the villages this was ignored. Sugarcane and water cocoyam were grown right up to the edge of streams and in flooded areas. Vegetable growers (mainly tomatoes, garden eggs, okro) rented land by the river to grow dry season vegetables. There were no special restrictions on access to this land, as long as the farmer could pay the rent. In three villages respondents said that farmers came from outside to rent land for vegetables. In the more urbanised villages (Abrebo, Atafua, Sepetimpom) there were houses built close to the river banks.

4.5.4 DISCUSSION

The following are some issues that arise from the survey results

Methodology

Interviewing three different groups within the village provided the survey team with a better understanding of the issues than if only one group had been interviewed. On several occasions, the groups gave different answers, and by comparing and discussing the answers the team gained more information about the situation in the villages.

The groups often found it difficult to give quantitative answers on, for example, population or number of houses. Therefore all such numbers should be treated with caution. However the numbers do reflect the perceptions of the groups and are useful because of this. For example, the population of women was often given as 1000 or more than men. The proportion of residential development compared with farm land was often stated to be much greater than it was observed to be by the survey team. This may reflect the fact that many villagers do not have a clear idea of the spatial extent of the village lands, but do realise that the residential area is growing fast.

Access to water

There are insufficient boreholes and piped water standpipes to provide sufficient water for drinking and washing in the villages so that streams and rivers continue to provide an important source of water, especially for washing. In villages where there were springs, some people continued to take water from these for drinking rather than queue and pay for piped or borehole water.

The market for water

Charging for water is common practice. This is not only done by GWC, who have a policy of metering houses or charging per container, but also by private individuals who own wells or have piped water to their houses. People are willing to pay for better quality water, especially when alternative sources are considered polluted (as in Asago or Abrebo). For the very poor, the alternatives to paying for water are using poorer quality water from public wells or streams, supplemented by rainwater collected in the rainy season.

Peri-urban pollution

It is clear that, apart from pollution originating in Kumasi itself, there is pollution arising within the peri-urban villages themselves. Even Maase, on the top of the watershed, had some pollution problems caused by the siting and run-off from the refuse tip into the springs. As the residential development continues in the villages, there is no provision for better waste management or drainage systems. These systems, which may have been adequate for a rural village, are no longer adequate for the growing village. Outside KMA the other Districts have no provision for waste collection. Whilst it is evident that the pollution problems are most severe for villages downstream of Kumasi (Abrebo and Asago), the locally-generated pollution should not be overlooked.

Perceptions of pollution and clean drinking water

Villagers were generally aware of an increase in pollution in the streams and rivers, and thought this increased the risks of water-borne diseases. Apart from obvious signs such as plastics in the water, they associated small brown/red worms in the water as a sign of pollution. It is not clear what these worms are or whether they are associated with some form of pollution. Villagers were less concerned about polluted rivers if they had alternative water sources. For example, villagers in Asago said that villages downstream from them were not concerned about pollution as they had good alternative sources of water.

There did not appear to be any concern in taking water from streams for drinking, as long as the streams were not obviously polluted by refuse tips or other factors upstream. There were one or two streams that were either taboo or considered bad for drinking, but these were the exceptions, not the rule.

This does raise the question over how people judge the quality of water for drinking and other uses, and whether local perceptions agree with scientific perceptions of water quality.

Polluted crops?

Sugarcane and water cocoyam are grown in polluted rivers and streams. Villagers did not mention this as an area of concern, but there is a question of whether these crops might be affected by pollution. Sugarcane, in particular, is sold as a snack food and eaten raw.

Land use along rivers and streams

Although most villages had local rules which forbade building, farming or other uses right up to the water courses, these rules were not strictly enforced. The reasons appear to be linked with changing economic incentives and a decline in observation of traditional rules and taboos. For example, the chiefs sold plots for houses along the river, thus flouting their own traditional rules in order to gain income. Community leaders found it harder to enforce local rules, for example, in Esereso people said they had difficulties in preventing young men washing their vehicles in the river. In Duase, villagers complained about the sugarcane cultivation along and in the river beds, but it continues to flourish as it provides a good income for farmers.

Water and waste management

Although water and waste management functions are vested in the Unit Committees, it is not clear how their functions will develop. The UCs are relatively new and some are yet to start functioning. Their role appears to take over some of the responsibilities previously under the Traditional Authorities (for example for communal labour). They are part of the government structure with associated political affiliations. In practice, it is the women who have the most direct role in day-to-day water and waste management. It is the women (and children) who are responsible for most of the household water collection and the maintenance of the refuse sites.

There is little evidence of inter-village or District-wide planning for water or waste management. The experience of Asago and Duase in trying to complain about pollution from KMA implies they received little support from other villages or District Authorities and were not successful in lobbying KMA.

4.6 Farming system impact on water resource use in selected watersheds [A3]

4.6.1 INTRODUCTION

Much of the material in this Section has been derived from a Project report (Adam, 2001). Reference should be made to that report for a fuller exposition of the topics covered.

From a combination of R6799 material, observations and the results of the present Project's questionnaire survey, the relative importance of farming systems in and around the study villages can be characterised (Table 4.6.1). It can been noted that traditional bush fallow remains in place in all but the most urbanised of villages, though under reported reduced fallow periods. Permanent intercropping, conversely, is more common in the more urbanised communities. Monocropping was not found to be common, although many farmers perceive the market advantages of concentrating their effort on cash crops such as tomatoes.

Common water management practices found in these systems have been tabulated earlier (Table 3.11.1).

An assessment of the principal environmental concerns associated with some of the common agricultural activities around Kumasi has also been made (Table 4.6.2) from a combination of generic information derived from R6799, and further observation and discussions with farmers, undertaken by M. Adam for this Project.

Very little is known about the environmental effects of the various pollutants produced by agriculture and other industries active in the peri-urban area around Kumasi. It is, however, a reasonable assumption that these effects will be analogous in nature, if perhaps not in absolute magnitude, to those in humid tropical areas of similar geology, topography and soils. The following account therefore points to areas of concern, based on survey information from R6799 and observation and community/farmer discussions carried out by this Project. The account is of necessity somewhat speculative in places, and indicates where further work is required for a fuller investigation of the areas of concern.

Of the effects of processing industries mentioned in Table 4.6.1, concern was expressed by villagers at Sepetinpom about pollution from small-scale oil-palm processing; and the clogging of watercourses by sawdust with resulting reduction of fish catches was mentioned during community discussions at Asago. The dumping of effluent from local gin (*akpetshie*) distilleries, often sited on watercourses and using the water in production, was mentioned as a cause for concern by villagers in Asago and Atafua.

The use of nitrogenous fertilisers leads not only to the export of nitrogen in crops, but the build-up of nitrate in groundwater. In farming systems more generally, fertiliser application rates seem to be the most important single factor in nitrate leaching from agricultural catchments. The maximum accumulation of nitrogen seems to occur in water-saturated landscapes, such as those valley bottoms in and around Kumasi where sugar-cane and water cocoyam are grown. The role of these areas in nitrogen cycling deserves further investigation; it may be expected that they are both nitrogen sinks and also the principal sites of the evolution of gaseous nitrogen through denitrification, thus affording a means of reducing the outflow of nitrates from these saturated areas.

Table 4.6.1: Occurrence of farming systems in study villages

Village	River system	Catchment position	Perceived degree of urbanisat-ion	Farming systems							
				Bush-fallow food crop	Permanent inter-cropping	Sole crop vegetables	Speciali-sed valley bottom cropping	Tree crops	Backyard farms	Livestock	Fish farming
Maase	Owabi	Upper	Mid	***	*	**	**	**	**	**	-
Atafua	Owabi	Mid	Mid	***	*	**	*	-	**	*	-
Abrepo	Owabi	Mid	High	-	***	*	*	-	**	*	-
Duase	Sisa	Upper	Low	***	**	**	**	*	*	*	-
Sepetinpom	Sisa	Mid	High	**	**	*	**	*	**	*	-
Esereso	Oda	Mid	Mid	***	*	*	*	**	*	**	1
Adagya	Oda	Mid	Low	***	*	*	-	*	*	*	-
Asago	Oda / Sisa	Lower	Low	***	*	**	*	*	*	*	-

*** All or most farmers ** Some farmers * Few farmer

Table 4.6.2: Principal environmental concerns associated with some agricultural activities around Kumasi. (Partly derived from NRI 1999a and 1999b, Goodland *et al* (1984)

Crop / livestock	**Occurrence**	**Production**	**Processing**
Rice	*Wetland: small riverine patches only* Upland: increasing, but more in rural areas	Wetland crop: few concerns – some health hazards Upland crop : forest loss, erosion hazard, weed invasion, chemical leaching.	No significant concerns
Maize	Universally grown	Bare soil for planting (but good cover thereafter in traditional mixed systems). Where fertiliser applied, danger of nutrient leaching.	No significant concerns, except that breweries in Kumasi dispose of some wastes into drainage.
Vegetables	Widely cultivated	Soil and water pollution by biocides. Possible residues of biocides and heavy metals in the crop.	Contamination of marketed produce by foul water.
Cassava & other root crops	Universally grown	Bare soil for planting (but good cover thereafter in traditional mixed systems). Where fertiliser applied, danger of nutrient leaching. Tolerant of drought and low fertility but low human nutritional value.	As there is no industrial processing, few concerns. *Fufu* (traditional staple food of the Ashanti) processing requires addition of cold, possibly foul water.
Cocoa	More in rural areas	Protects the soil. But can deplete nutrients. Biocides can disturb natural balances and pollute watercourses.	No significant concerns
Sugar cane	Common in low-lying areas	As grown in and around Kumasi, with few inputs, little concern. Water-borne disease risk. Transmission of trace metals?	As there is no industrial processing, no significant concerns.
Oil palm	Common – both cultivated and wild trees	Protects the soil. Where fertiliser used (not commonly at all or if so not at high rates), nutrient leaching.	Effluents harm fish populations and impair other water uses. But no large-scale processing plants in and around Kumasi.
Forestry	Less than formerly. Teak is now being planted by many.	Careful logging reduces damage. Depletion reduces watershed protection but increases water throughflow. Soil fertility regeneration disturbed.	Sawmills produce huge quantities of waste sawdust & wood shavings which interfere with stream flows & could exacerbate metal concentrations in streams
Ruminant livestock	Some, often insignificant	Few concerns - small numbers of stock reared in extensive systems, except in some urban communities, often non-Ashanti, where manure disposal could give rise to groundwater pollution & disease	Manure and blood from the abattoir is largely washed into surface drainage. Other by-products are used.
Non-ruminant livestock	Poultry mainly; large peri-urban farms	Manure disposal : about one-third is still dumped & could pollute groundwater. Contamination of manured vegetable crops with disease organisms & antibiotics not proven.	Manure and offal disposal, as for ruminants, a potential hazard.
Freshwater fisheries	Very few farms	Potential beneficial effects through recycling of manures. Species used are indigenous or present no threat to local natural fish stocks.	No significant concerns

It has also been found that high denitrification is associated with pools of organic matter such as dead *E. coli* cells (such as may be expected to be common where human and animal waste enters the watercourse) decaying under anaerobic conditions. Villagers at Duase said that the Sisa was "polluted by sugar cane" and this perception should be clarified; perhaps waste from the upstream KMA dump (active at the time of survey but now not in use) which might otherwise be carried away (and add to nitrogen and other pollutant levels downstream) may be held up in Duase by sugar cane cultivation. Studies of some parameters in such investigations would be most suitably carried out at plot level e.g. leaching, whilst some could be carried out at catchment level e.g. groundwater measurements (Moldan & Cerny 1994). The suggestion would be that such areas not only act as 'green lungs' for the city and its environs but reduce concentrations of nitrogen and possibly other pollutants downstream.

In fact, the majority of the farming systems described around Kumasi use low amounts of fertiliser inputs, and this was confirmed by this Project's village survey. If it is assumed that all the fertilisers distributed from Kumasi (c.5000t [per annum] according to NRI (1999b)) are applied in the Ashanti region (say 300,000 ha cropped land (estimated from figures supplied by the Ministry of Agriculture in Accra)), the average application rate may be estimated to be about 15-20kg/ha of any type of fertiliser. The amount of nitrogen in this fertiliser (c. 1000 tonnes) represents 3kg N per hectare and is a small amount compared to the estimated annual nitrogen deficit for Ghana as a whole, which is 30kg/ha (Stoorvogel & Smaling 1990). It supplies an even lower proportion of the potash deficit but perhaps half of the phosphate deficit. The main reasons for the low application figure are the continued reliance on bush fallows to restore fertility and the lack of cash resources to purchase fertiliser. This is not to say that all the supply will be taken up by the plants: much can be lost through leaching, volatilisation and denitrification, due in part to the supply of nutrients not synchronising with the demand for them by the crops (Bationo *et al.* 1998). Thus it is very likely that this low application estimate conceals possible "hot spots", for example intensive tomato production near Maase, where excess fertilisers may well be applied and result in losses into the surface and sub-surface water systems.

4.6.2 DEMANDS AND EFFECTS OF FARMING SYSTEMS ON WATER FLOWS AND AVAILABILITY

As more and more farmland is converted to housing, the bulk demands of farming systems on water flows and availability should theoretically reduce. However, this does not take into account the current trend towards declining rainfall (see Figure 3.3.1) nor does it consider potential intensification of agriculture on the lands protected from urban sprawl, either by chiefs with a social conscience or by the marginal status of the land.

Quite apart from the increased demands on water resources caused by increases in housing, further potential source of increased agricultural demand on water is increased use of irrigation, a distinct possibility in view of the increasing market, both in Kumasi and in Accra, for fresh vegetables.

Effects of possible changes in water quantity and quality at farm level

As there are few available data, it is difficult to estimate possible changes in water quantity and quality at farm level. However, considering the range of agriculturally related activities around Kumasi, the most likely water quality problems to occur are those of

- Sanitary quality
- erosion / sedimentation
- nutrient enrichment and
- pesticides.

Some of the causes of the problems are inter-related. For example, irrigation increases the likelihood that soil field capacity is reached at an earlier stage with precipitation, leading to greater leaching of nitrates and other nutrients. Other negative effects of irrigation on health may occur through the direct contamination of water supplies by toxic chemicals and pathogens and through the application of this water to crops.

Some of these problems, for example sanitary quality, are expected to be exacerbated by non-agricultural sources of pollution. Others, for example pesticides, were beyond the capacity and resources of this project to address. This was also the case in the study by Mensah (1997), for which samples of vegetables were collected, but analyses for pesticides could not be carried out for lack of funding. The measurement of sediment flows, however, is particularly relevant to the peri-urban situation, where the vegetation cover of the topsoil and even subsoil is prejudiced not only by agricultural but construction activities.

Some researchers have estimated that 80% of all diseases and 33% of deaths in developing countries are linked to poor water quality (FAO 1993). Water-borne diseases particularly liable to be transmitted by the practice of irrigation include malaria, bilharzia and onchocerciasis. Of these, malaria is most common around Kumasi, where the mosquito larvae found especially around the edges of taro (water cocoyam) farms and open-water areas are often malaria-transmitting. However, since these anopheline mosquitoes normally favour sun-exposed sites, the planting of taro in open sites may actually reduce larval populations by creation of shade. More likely sites for larval breeding are provided by the small shallow wells created for dry season vegetable irrigation, which should be covered by mosquito gauze to prevent their use for egg-laying by adult mosquitoes. Anopheline mosquitoes prefer clean water, rather than foul or turbid water, in which to breed and it has been found in urban Kumasi that, with more likelihood of foul standing water than in rural areas, the mosquito population consists mainly of non-malaria transmitting culicine (nuisance) mosquitoes (White 1998).

Diarrhoea, dysentery, cholera and bilharzia were also mentioned during community meetings with Project staff by people in all the villages surveyed as originating from the nearby polluted watercourses. The children and (in Esereso) pregnant women who bathe in the streams, were said to suffer the most. In three villages the presence of worms in the water was cited as evidence of the result of harmful pollution. It is probable that the species noticed (bloodworms and flatworms) are not themselves harmful but could indicate a generally high worm burden of pathogens such as threadworms and tapeworms.

It is established in this Report (Section 4.7) and reported by Cornish *et al.* (1999) that the mean level of bacteriological pollution in terms of the recommended measure of the microbiological suitability of Kumasi area water for irrigation, numbers of faecal coliforms per 100 ml, was highest at Asago and lowest in more rural upstream areas. There was a pattern of increasingly poor water quality moving from the main urban centre downstream towards Asago (9km south of the city) (see Section 4.7).

Cornish *et al.* (1999) conclude that irrigation practised on the Sisa and Wiwi rivers, upstream of Kumasi, may pose a minor threat to the health of consumers as the faecal coliform numbers are close to the recommended WHO limit. Around Kaase, Daban and as far south as Asago the rivers are highly polluted but "… there is no evidence of the river water being used extensively for irrigation". However, they state that there is greater cause for concern in the area between Asago and Adwaden, further to the south, where many farmers are irrigating with river water which is significantly above WHO guidelines for faecal coliforms.

Potential requirements for water conservation measures at farm level

Whilst agricultural intensification has not yet occurred to any great extent around Kumasi, the indications are, from wider-scale analyses, that globally mankind in the 21st century will not succeed in sustaining growing populations without increases in high-input agricultural practices (Greenland et al. 1998). Kumasi will surely not be an exception. Indeed, in peri-urban areas with their advantages of market access, the process may be expected to be accelerated compared to more rural areas. Intensively-farmed traditional food crop, vegetable and poultry production are likely to be the up-and-coming farming systems of the Kumasi area in the near future. Such intensification will create a need to give greater attention to soil and water conservation measures.

In the peri-urban situation, the principal need for mechanical measures for soil and water conservation concern the discharge of water and effluents from housing, industrial areas and roads. These discharges can directly affect areas of crop production and appropriate grades and drop structures, to slow down the flow rate and trap sediment, should be installed to minimise damage. Planning of watershed erosion control measures, such as tree planting or grass banking, should take place in conjunction with urban development.

However, Mugomba (2002) reports that few farmers she interviewed in Adagya, Esereso and Maase either practice soil and water conservation measures, or are aware of a need for them.

4.6.3 FARMERS' PERCEPTIONS OF, AND ATTITUDES TO, LAND MANAGEMENT IN PERI-URBAN KUMASI

A critical part of farming systems impact on water resource use in the Kumasi peri-urban area is the practices employed by farmers and their attitudes to the problems that confront them. The following discussion has been informed by the outputs of an undergraduate dissertation undertaken during July 2001 by Chiedza Mugomba (Department of Geography, University of London). (Mugomba, 2002).

A series of in-depth interviews held with 35 farmers in Adagya, Esereso and Maase indicated that farmers in peri-urban Kumasi have a sound indigenous knowledge of soil assessment, both for estimating soil fertility and for judging when a soil is declining in fertility. Perhaps most striking in this context is that the indicators used by farmers, such as soil colour, soil texture (particularly a change towards a more sandy texture) , declining yields, pest and weed invasion, change in soil colour) are very similar to those reported by Chokor and Odemerho (1994) in a similar investigation in southeast Nigeria.

What is also notable from Mugomba's survey is the imperfect perception of soil erosion as a problem. Only 29 percent of farmers surveyed agreed that soil erosion is a problem, while a further 14 percent recognised that soil erosion occurs, but did not regard it as a problem. Most farmers who recognised the problem declared that there was nothing they could do about it. Again, these figures closely parallel attitudes in Chokor and Odemehro's investigations, and agree with a similar survey carried out by McGregor and Barker (1991) on Jamaican hillside farmers.

It is clear from this that any attempts at soil and water conservation among Kumasi's peri-urban farmers will require a carefully thought-through 'educational' effort.

Mugomba (2002) also reports limited use of organic fertilisers (by 6 percent of those surveyed – mostly chicken manure), but relatively common use of chemical fertilisers (31 percent), almost exclusively on relatively high-value crops such as tomatoes, okra, 'garden eggs' (aubergines) and peppers. Finance was most often quoted as a constraint on the use of chemical fertilisers. There was also some use of herbicides (9 percent), incorrectly used as pesticides, and 26 percent of farmers admitted to the use of DDT. Mugomba also noted that in a GOAN organic farming scheme at Ofinso (some 23 km north of Kumasi, an infusion of ground neem seeds was being used as a low-cost but relatively effective pesticide.

Use of irrigation was not common in the sample obtained by Mugomba (2002). Most farmers rely on rains, and only irrigate high-value crops, such as tomatoes and garden eggs, when deemed necessary. Some farmers (17 percent) used their local knowledge to ensure that they could grow crops in areas that were most suited, for example, where there was a high water table or in close proximity to a stream.

Only one farmer in the sample used irrigation extensively. This farmer had reclaimed a floodplain site close to Maase village, which had had its topsoil permanently removed by sand winning. This farmer has utilised the high water table by digging a shallow well. He was producing market vegetables (reportedly for both Kumasi and Accra) which needed constant water supplies for optimum growth and freshness. He has also mixed sawdust with the soil to encourage water retention.

As elsewhere, a principal response to the progressive reduction in the amount of farm land available has been a reduction in, and even the elimination of, fallow periods. This may well prove to be a more critical variable in the future agricultural systems of peri-urban Kumasi than declining water quantity and quantity. It has to be noted, however, that declining total amounts of rainfall and increasing use of fertilisers are both factors which will need to be monitored to ensure a thriving peri-urban agriculture.

4.7 <u>Water Quality in Peri-Urban Kumasi</u> [2B]

4.7.1 INTRODUCTION

This Section presents a summary of the data obtained by the Project relating to water quality in the rivers and groundwater in the Kumasi peri-urban zone. Detailed analyses of these data are presented elsewhere (Thompson *et al.* 2002). A synopsis is presented here, highlighting the principal results, and commenting on their significance for water resources in the peri-urban zone.

It was deemed essential to the achievement of Project aims that a detailed examination of water quality in the streams and rivers around Kumasi be undertaken. This was

- to provide data on the nature and scale of pollution
- to use that data to inform stakeholders of the nature and scale of the problem
- to identify polluters and quantify the problems they cause
- to provide a secure database against which plans to ameliorate the problems can be formulated
- to obtain secure data which can be used by stakeholders to push for action against polluters and by the relevant decision makers
- to demonstrate that pollution of the water bodies is the integrative outcome of wider natural resource pollution and environmental degradation, which may otherwise be regarded as localised, site-specific, problems.

The identification and prioritisation of problems affecting water resources in watershed areas and the effects on peri-urban inhabitants are outlined in Section 3.4 of this Report.

The method of selection of study watersheds, the Owabi Reservoir and the Sisa-Oda catchments, is detailed in Section 3.5. It was decided to sample subcatchments in the case of the Owabi, and to sample upstream and downstream segments of the Sisa catchment, together with areas representative of the output from the predominantly rural catchment of the Oda.

The selection and location of water quality sampling points are set out in Section 3.6

The water resource and supply environment is explained in Section 3.8, while the results of a survey of sources of water used by communities linked to the Project are given in Section 3.9. Waste management and sanitation in the eight Project communities was investigated, and the results are reported in Section 4.4.

This Section therefore discusses the broad spatial and temporal trends within the two catchments selected for regular sampling. Due to the relatively coarse temporal sampling frame, intervals of one month between samples, it is not possible to comment on the detailed dynamics of pollution diffusion. However, the data set does allow us to define the effects of peri-urban Kumasi on its local river systems and to begin to resolve the temporal variations to the seasonal scale.

In terms of which variables to use in sampling water quality, this Project reviewed the limited previous work done in the Kumasi area and, from the wider context, considered which variables would be likely to be of value in determining the scale of pollution in the context of peri-urban Kumasi. In the wider context, Chapman (1996) discusses the likely effects of specific land use activities on surface water quality. Table 4.7.1 is an adaptation, using the variables measured in the current study plus two heavy metals, of Chapman’s Table 3.9. The table illustrates the likely sensitivity of water quality parameters to specific land uses, and indicates which variables would be most appropriate for measurement in the present context.

TABLE 4.7.1: Sensitivity of water quality variables to land use (adapted from Chapman, 1996, Fig.3.9)

Variable	Urban runoff	Agriculture	Sewage & municipal waste	Waste disposal to land.
Colour	LOW	LOW	LOW	-
Suspended Solid	MEDIUM	HIGH	HIGH	MEDIUM
Conductivity	MEDIUM	MEDIUM	MEDIUM	HIGH
pH	LOW	LOW	LOW	MEDIUM
Dissolved Oxygen	HIGH	HIGH	HIGH	HIGH
Nitrite/Nitrate Nitrogen	MEDIUM	HIGH	HIGH	MEDIUM
Phosphorus	MEDIUM	HIGH	HIGH	LOW
Faecal Coliform	MEDIUM	MEDIUM	HIGH	-
Oil & Grease	HIGH	-	MEDIUM	MEDIUM
Iron	MEDIUM	-	MEDIUM	HIGH
Lead	HIGH	-	MEDIUM	HIGH

In the particular situation of Kumasi and its peri-urban fringe, urban industrial and waste disposal practices are likely to affect adversely both downstream peri-urban stream water quality and, in the longer term, groundwater quality, in the absence of planned preventive or ameliorative strategies. As well as point pollution sources resulting from disposal of waste within the urban and periurban zone, non-point pollution sources are associated with urban runoff. This source might be expected to be most active during the wet season when both infiltration-excess and saturation overland flow generation will link pollution sources to the river network. The patterns and levels of pollutants revealed in the two year water quality sampling programme can be compared to Table 4.7.1 to reveal the main causes of poor water quality in Kumasi's river systems.

To summarise the results to be discussed, in this context the high levels of oils & grease, faecal coliforms and phosphorus found in the Project's data set suggest that the sewage waste and urban runoff dominate the pollution of local rivers (*see discussion of each variable below).* Evidence for the importance of peri-urban agriculture, in degrading river water quality, is ambiguous. The relatively high phosphorus levels support the hypothesis of agricultural pollution, but relatively low nitrate-N levels provide much weaker support.

The water sampling programme aimed to provide an overview of water quality in the peri-urban environment. Only three point water sources (two boreholes and one spring site) were monitored due to the limited resources available for sampling. The remaining samples were from river sites. These 'areal' sources by their nature are more diffuse, and the integrative effects of downstream runoff allows only general linkages to be made between land use and pollution levels. However, the two-year run of data does allow us to identify those locations within the drainage system where river water supply would be most dangerous for human use

4.7.2 LITHOLOGY AND GROUNDWATER

Geological conditions are broadly similar throughout the study area. The geology of both catchments is dominated by granites and granodiorites of the Birimian Series. The occurrence of groundwater is controlled by jointing and fracturing of the local rocks, while the granites, due to their highly-weathered condition, produce some of the most productive groundwater bodies (Ministry of Works and Housing, 1998).

Groundwater recharge is around 17.5 percent of annual precipitation. Groundwater levels are variable, due to the spatially discrete nature of local aquifers. Static water levels vary from 0 to 26m within the granites, with an average of 10.6m (Ministry of Works and Housing, 1998). A proportion of aquifer recharge is derived from river discharge, hence groundwater quality is directly influenced by the quality of river flow. Poorly-functioning waste treatment systems or other adverse catchment activities which pollute water are likely to affect groundwater quality in the medium to long term, given the relatively shallow water tables.

4.7.3 PREVIOUS WORK

Although long term records of river water quality in the Kumasi area are absent, several studies provide data which can be compared to our samples. Anokye (1997) sampled water quality in the catchment of the Owabi reservoir and noted strong variations between wet and dry season phosphate, colour and certain heavy metals. Anokye's results suggest that peri-urban runoff is an important source of river pollution in this catchment. Anokye's sample location closest to the Suame Magazine area shows high concentrations of iron, reflecting the concentration of motor repair activities in that locality. Nitrate was not present in the samples and phosphate levels averaged between 51 and 105mg/1 during the wet season. Anokye suggests that these values reflect the dominance of sewage and detergent pollution, and the relative absence of agricultural activity in this rapidly urbanising sub-catchment. Cornish *et al* (1999) review data from UST student projects on water quality (See Table 4.7.2). This work, although carried out at different times and locations, shows the Subin River to be heavily polluted with high levels of faecal coliform, low dissolved oxygen levels, high TDS and suspended solids. This probably reflects nightsoil dumping in the urban area and the inadequacy of sewerage provision. Data from three other rivers, the Sisa, Wiwi and Aboabo show lower, but significant levels of pollution. The most rural catchment, the Wiwi, has the lowest levels, but still records an average faecal coliform reading of 9000/100ml. (See Table 4.7.2).

Table 4.7.2: Results from UST Studies (adapted from Cornish et al, 1999)

River	pH	Suspended Solids (mg/l)	TDS (mg/l)	Dissolved Oxygen (mg/l)	Faecal Coliform (/100ml)
Subin	7.08	436	809	0.76	6.7×10^{7}
Aboabo	6.98	134	318	0.85	1.3×10^{6}
Sisa	6.63	44	354	0.3	0.3×10^{4}
Wiwi	6.37	26	-	3.0	9×10^{3}

Cornish *et al* (1999) studied the microbiological, physico-chemical and heavy metal status of irrigation water sources in the Subin/Sisa/Oda catchments in the late dry season of 1999 (see Table 4.7.3). The microbiological data suggest a progressive deterioration from upstream of the main urban centre of Kumasi (at Sepetimpon and the Wiwi site) southward to Asago. Many of the faecal coliform levels were above the WHO limit for irrigation (1000/100mg), bringing into question the health status of some produce from peri-urban Kumasi. Heavy metal levels are above WHO guidelines for the following variables: As, Pb, Cd, Hg, Fe and locally for Ni (Cornish *et al*, 1999). Water conductivity also shows a similar spatial trend to that shown by microbiological variables. Average phosphorus (as Phosphate) levels ranged from 39.07- 45.61mg/1 and all sites appear to have phosphate pollution although Cornish *et al* point out that levels could have been exacerbated by flushing of accumulated stores early in the rainy season when the data were collected.

Table 4.7.3: Irrigation source water quality (Cornish et al 1999); n=5

Location	Faecal Coliform (/100ml)	Fe (mg/l)	As (mg/l)	Conductivity (dS/m)	Phosphate (mg/l)
Sepetimpon	890	3.23	0.001	0.044	44.42
Wiwi	1277	2.75	0.00051	0.04	39.07
Kaase	8568	2.84	0.00002	0.156	41.46
Daban	6524	1.19	0.00002	0.089	45.61
Asago	89707	3.27	0.00201	0.194	41.98

The relevant data of Gibb Ltd (1999) focus mainly on the Owasi Reservoir itself, and are not considered here.

4.7.4 WATER QUALITY MONITORING

The Project has sampled river water quality at three different temporal scales. The largest data set is provided by the monthly sampling programme carried out for the Project by EPA and GWC between September 1999 and September 2001. In addition three Royal Holloway undergraduate dissertations have monitored likely point/area sources, compared Sisa-Subin and Oda catchments, and monitored downstream changes on the Sisa at time-scales of less than a day. In these projects 5-6 samples per day were taken so that variation in water quality can be seen at a short time-scale. Thirdly, Omane.Poku, a principal local collaborator from EPA, has undertaken a Masters project in which daily samples were taken over a period of one week at some of the Project's monthly sample sites, together with samples at additional likely point source locations. Overall therefore the temporal coverage, by these *nested* sampling programmes, is possibly among the most comprehensive for any West African location.

All determinations were carried out using a *Paqualab* field water quality laboratory, thereby reducing one possible source of systematic variation between sets of results.

Detailed analysis of these data is presented elsewhere (Thompson *et al.* 2002). A synopsis is presented here, highlighting the principal results and their significance. Thompson et al. (2002) also presents an analysis of the extent to which seasonal trends may be distinguished in the data. Though important in the wider sense of determining the timing and scale of more precise interventions, for the purposes of this Report, the analysis concentrates on the overall scale of the problem.

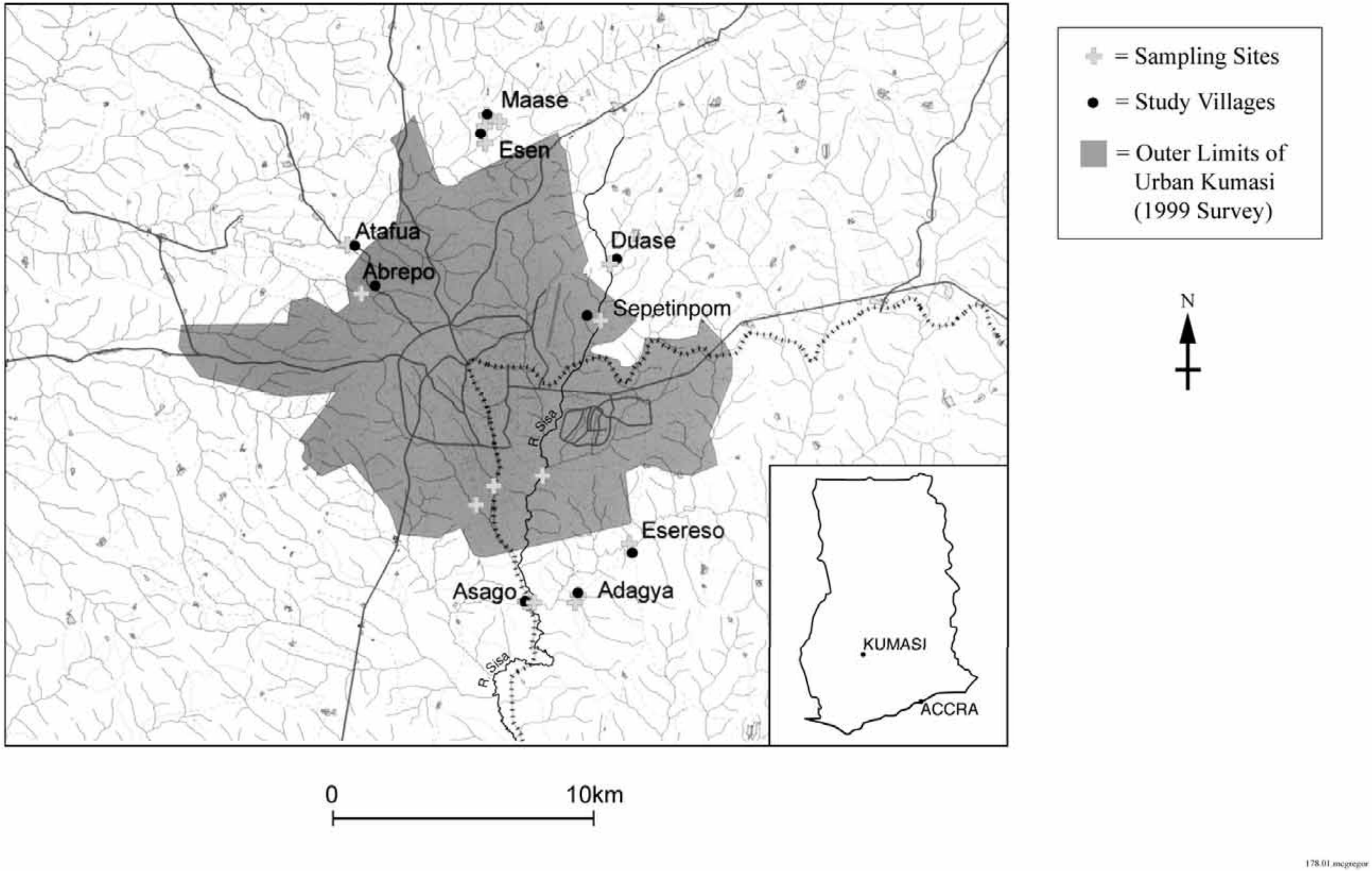
Monthly averaged samples for the two catchments (main Project data set)
The data discussed in this section cover the whole sampling period from September 1999 to September 2001. The averaged data for each sample site are given in Table 4.7.4 (*all data table*). The sampling locations are shown in Figure 4.7.1. All water quality maps were produced using the KUMINFO water quality interface. The map shows the 1999 outline of the built-up area, together with the locations of waste dumps within the city surveyed during the course of Project R6799.

Table 4.7.4 Average values for monthly sampling sites, September 1999 to September 2001

	Site	**pH**	**Turbidity (NTU)**	**Conductivity (μs.cm^{-1})**	**TDS (mg.l^{-1})**	**Suspended solids (mg.l^{-1})**	**Ammonia N (mg.l^{-1})**	**Nitrate N (mg.l^{-1})**	**Nitrite N (mg.l^{-1})**	**Phosphate (mg.l^{-1})**	**Dissolved O (mg.l^{-1})**	**Chloride (mg.l^{-1})**	**Oils & Greases (mg.l^{-1})**	**Coliform 37^{o}C (/100ml)**	**Coliform44^{o} C (/100ml)**
1	Maase (Asuabena)	6.02	17.23	44.67	22.65	11.60	0.04	0.08	0.01	0.71	4.42	11.44	3.63	1436	539
2	Maase borehole	6.44	1.67	81.08	47.82	0.67	0.07	0.15	0.00	1.37	3.91	11.33	1.50	437	246
3	Essen (Asubri)	7.05	74.65	96.42	61.99	78.11	0.34	0.68	0.05	1.23	2.79	7.89	8.57	3821	3648
4	Atafua (Owabi)	7.13	118.54	226.21	126.67	144.89	0.93	1.15	0.10	1.04	3.60	30.11	10.67	8168	5700
5	Chief's Palace (Akosu)	7.41	85.66	427.75	261.09	97.11	10.58	1.33	0.05	1.16	3.27	29.14	7.38	14821	12672
6	Duase (Sisa)	7.22	53.96	143.75	82.05	29.00	0.71	0.86	0.05	0.91	5.31	12.67	9.50	6611	3307
7	Sepetinpom (Sisa)	7.21	57.95	162.31	94.12	46.00	0.59	1.09	0.04	0.75	4.45	17.28	12.13	9233	5958
8	Atonsu (Sisa)	7.12	87.20	579.78	278.46	140.00	17.95	1.16	0.02	4.13	1.79	46.11	23.20	14160	10953
9	Kaase (Subin)	7.45	64.47	497.88	263.20	37.89	6.20	0.91	0.11	3.94	2.92	49.78	21.17	11420	10549
10	Daban (Daban)	7.38	29.51	377.95	225.73	29.78	5.33	1.11	0.17	1.39	2.96	….33.11	25.62	5301	3655
11	Esereso (Oda)	7.41	38.28	129.67	77.32	61.78	0.66	0.89	0.02	0.85	6.98	15.00	7.38	3685	2527
12	Adagya borehole	5.82	1.61	169.71	94.14	1.89	0.20	2.89	0.01	0.62	4.93	16.09	2.33	4	1
13	Adagya (Ankoni)	7.07	46.01	176.00	102.65	25.33	0.56	1.22	0.01	0.97	3.23	12.94	6.14	7219	3948
14	Asago hand-dug well	6.51	15.43	167.06	92.40	14.38	0.18	1.65	0.03	0.81	4.18	15.5	3.75	1136	550
15	Asago (Sisa)	7.30	86.78	465.59	339.63	96.56	19.15	1.52	0.05	7.13	2.45	51.11	20.75	16364	12168
16	Asago new borehole	6.08	3.29	180.87	91.67	6.00	0.28	3.82	0.00	1.35	4.27		-	-	-
	Recommended drinking water limits		5.00 *	400 @	1000 *		0.5 @	50.00 *	0.1 @			25.00 @	0.01 @		0 *

* WHO @ EU

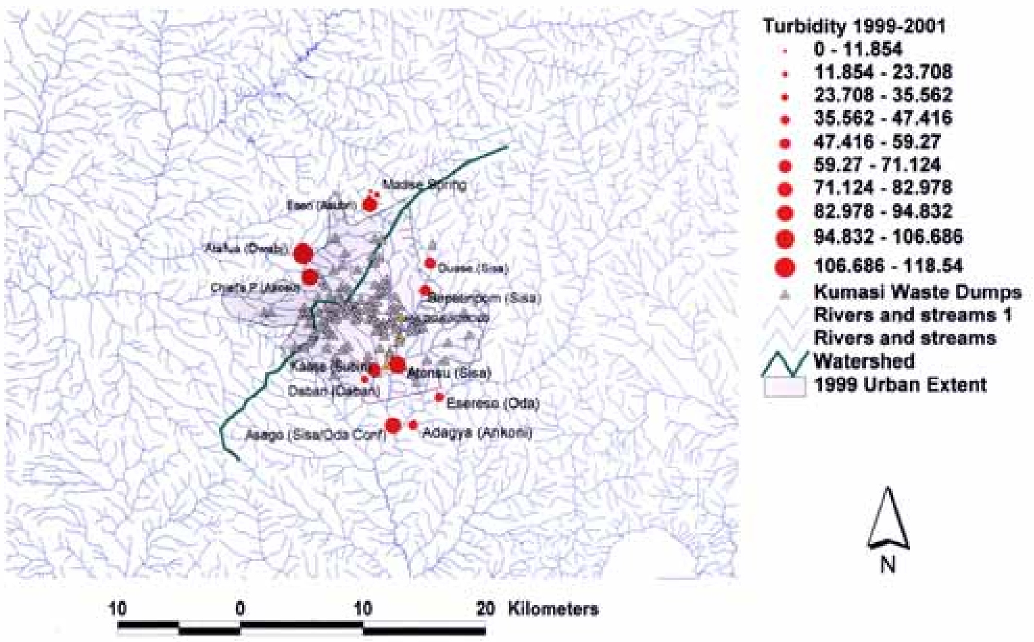
Figure 4.7.1: Water quality sample locations



Turbidity

The averaged data are shown in Figure 4.7.2. In the Oda catchment, turbidity rises very quickly in a short distance from source, probably in response to cultivation in this more rural part of the catchment. In the Sisa system, the major increase in turbidity at Atonsu reflects the concentration of sawmills and furniture shops just upstream.

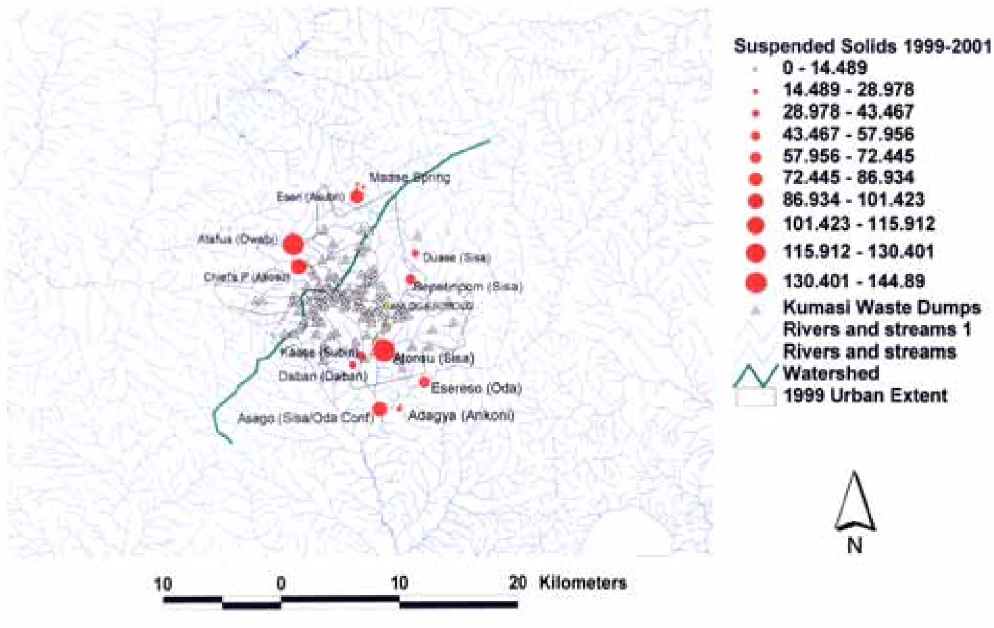
Fig 4.7.2:Turbidity (NTU): Sept 1999-Sept 2001



Suspended Solids

Figure 4.7.3 shows a similar distribution to turbidity. Some decline in concentration downstream to Asago can be noted.

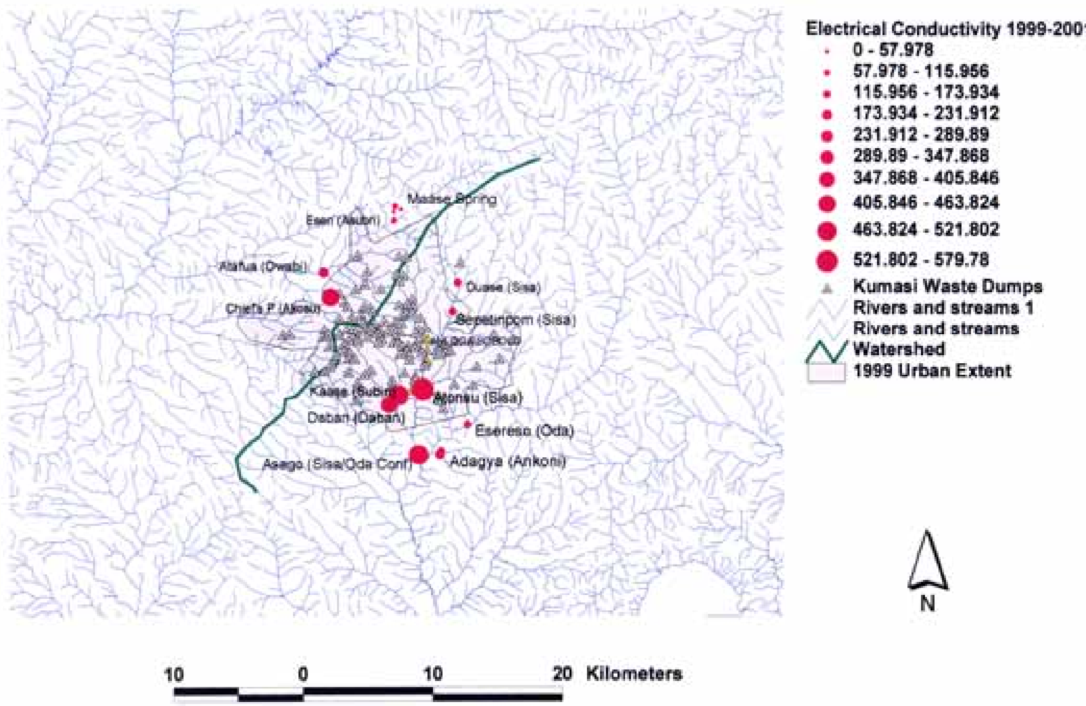
Fig 4.7.3: Mean Suspended Solids (mg/l): Sept 1999 - Sept 2001



Electrical Conductivity

The spatial relationships in both Owabi and Sisa catchments (Figure 4.7.4) confirm the results of Cornish et al (1999) and conform to expectations of an *urban pollution effect.* The clear increase from Maase/Essen to Atafua, and especially, the values at Chief's Palace suggests the effects of sewage and other pollutants within the more urbanised environment.

Fig 4.7.4: Mean Conductivity (Microsiemens/cm) : Sept 1999- Sept 2001



The spatial pattern is even more striking in the Sisa catchment, with clear evidence of a three fold increase within the urban-affected area represented by the sites at Atonsu and Asago compared to the more rural locations at Duase and Sepetimpon.

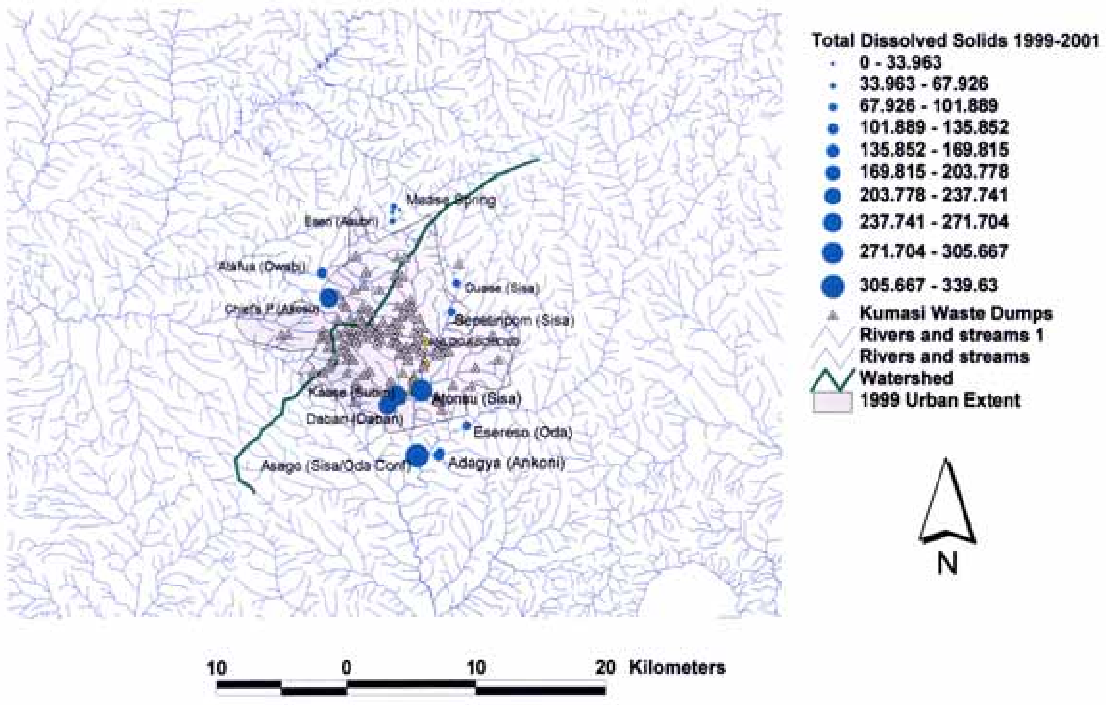
The River Subin sites at Kaase and Daban also have high conductivity values which, taken with the data at Atonsu and Asago, clearly reflect the polluting effects of sewage effluent reaching the rivers and the industrial processes active in central Kumasi (Simon, Poku & Gyabaah, 2001). In contrast, the rural Oda catchment, represented by sites at Esereso and Adagya, has relatively low conductivities that probably reflect natural weathering processes and some input from agricultural activities.

However, the absolute levels of contamination for both catchments are put into perspective when the EU drinking water limit of 400 micro-siemens is applied. On this criterion, only the sites at Chief's Palace (Owabi catchment), Atonsu (Sisa), Kaase (Subin) and Asago (Sisa-Oda) are non-potable by this measure.

In a natural, unpolluted river, conductivity levels would not be expected to show great variation over small distances in the absence of major changes in soil type or lithology. The variations seen in our data therefore provide a clear indication of the urban effects on water quality even if the absolute levels are not remarkably high.

Total Dissolved Solids:
The spatial pattern (Figure 4.7.5), not unexpectedly, is very similar to that for conductivity and supports the urban pollution effect. On this measure all sites are within WHO drinking water limits. Again the worst area of pollution is seen in the Subin/Sisa rivers south of central Kumasi.

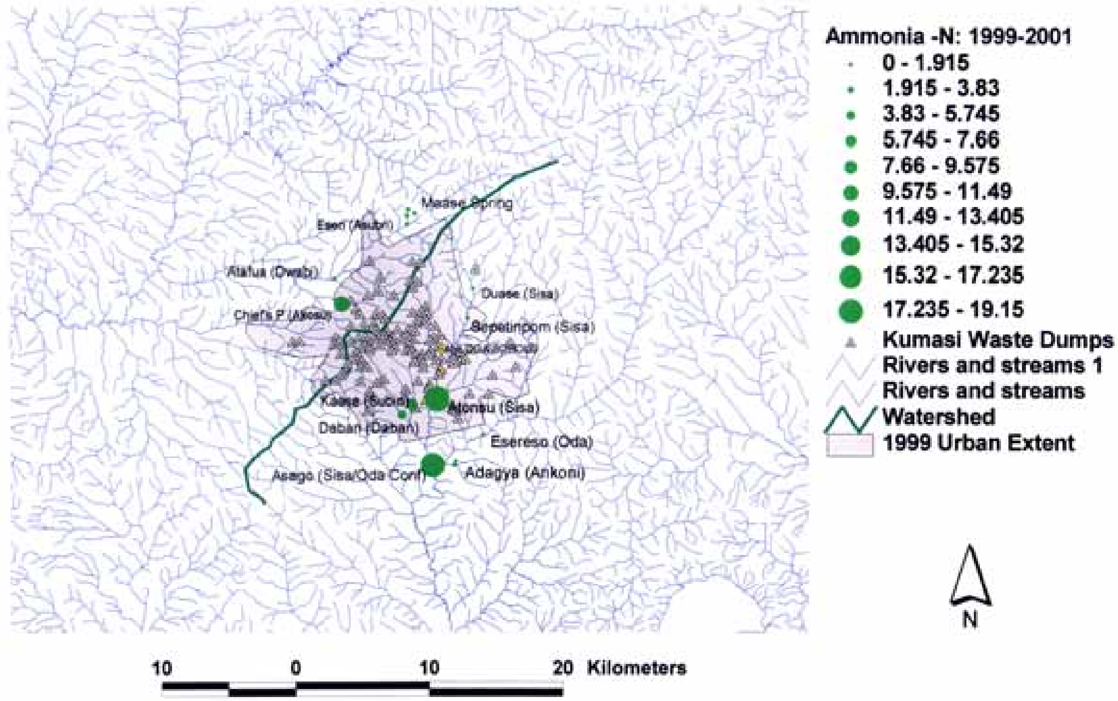
Fig 4.7.5: Mean Total Dissolved Solids (mg/l): Sept 1999-Sept 2001



Ammonia-Nitrogen

The upper Owabi sites (Maase and Esen) have light ammonia-N loading that is within the WHO drinking water limit (Figure 4.7.6). All other river samples, in both catchments, are well above the limit and there are some heavily polluted locations. Chapman (1996) points out that ammonia levels higher than 2-3mg/l are indicative of organic pollution from sewage, industrial waste and fertiliser. Pulp and Paper operations also may use ammonia-based processes. The levels at Chief's Palace (R.Akosu) are 10.58mg/l averaged over the period of measurement.

Fig 4.7.6: Mean Ammonia-N (mg/l) Sept 1999 - Sept 2001



Relatively light contamination upstream is replaced downstream by ammonia-N levels in excess of 17mg/l at Atonsu and Asago in the Sisa catchment. Pulping and paper activities are found upstream of the Atonsu site, and the Nuuro Kente cloth dying factory is just downstream, and there is clear evidence of direct pollution of the river by these activities.

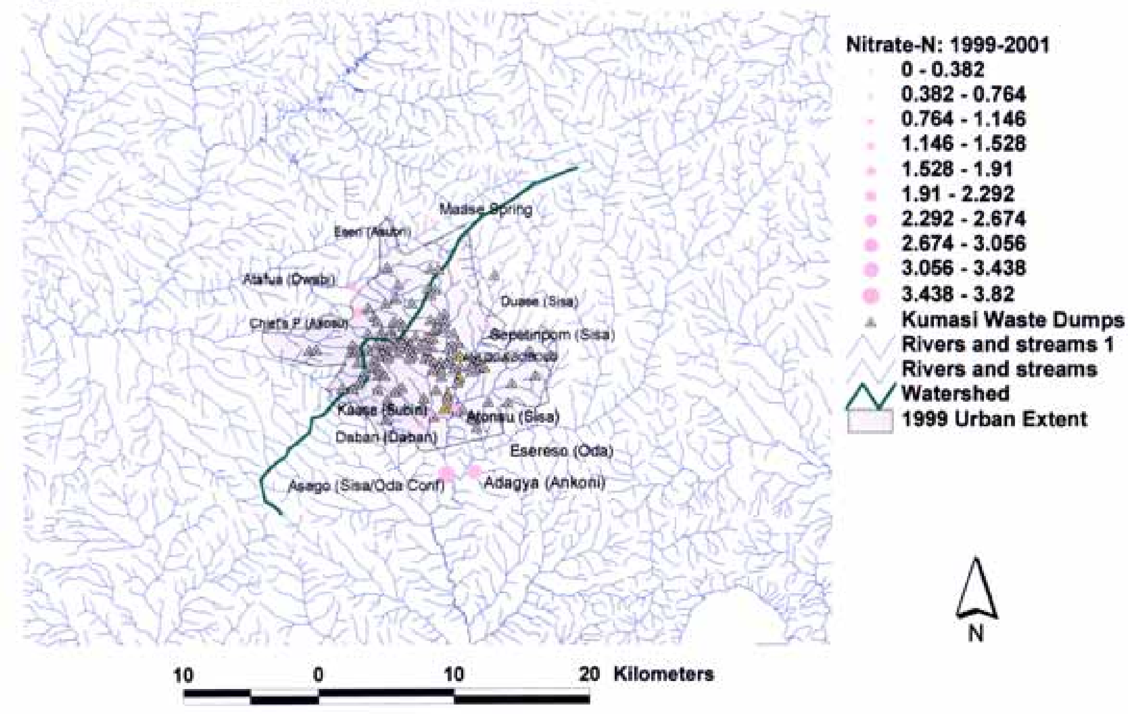
The high levels in the Sisa at Asago are a direct reflection of overspill and leakage from the KMA's temporary liquid waste settling ponds approxmately 1 km upstream of the Sisa-Oda junction.

It is also worth remarking here that Figure 4.7.6 also indicates the location of waste dumps (surveyed in project R6779). The map shows that many waste sites are very close to the rivers. Such locations appear to show little awareness of the implications of runoff from point pollution sources such as waste tips.

Nitrate-N:

Although nitrate levels are very low and present no hazard in themselves, the pattern reinforces that shown for the other variables and indicates an urban – peri-urban effect downstream in both catchments (Figure 4.7.7). However, the highest mean levels are found in the borehole water at Adagya and Asago. This suggests a groundwater- natural weathering source. River water levels are generally 1.5mg/l or less. This would suggest that fertilisers are not leaching into the rivers or being delivered in large amounts by runoff.

Fig 4.7.7: Mean Nitrate-N (mg/l): Sept 1999-Sept 2001



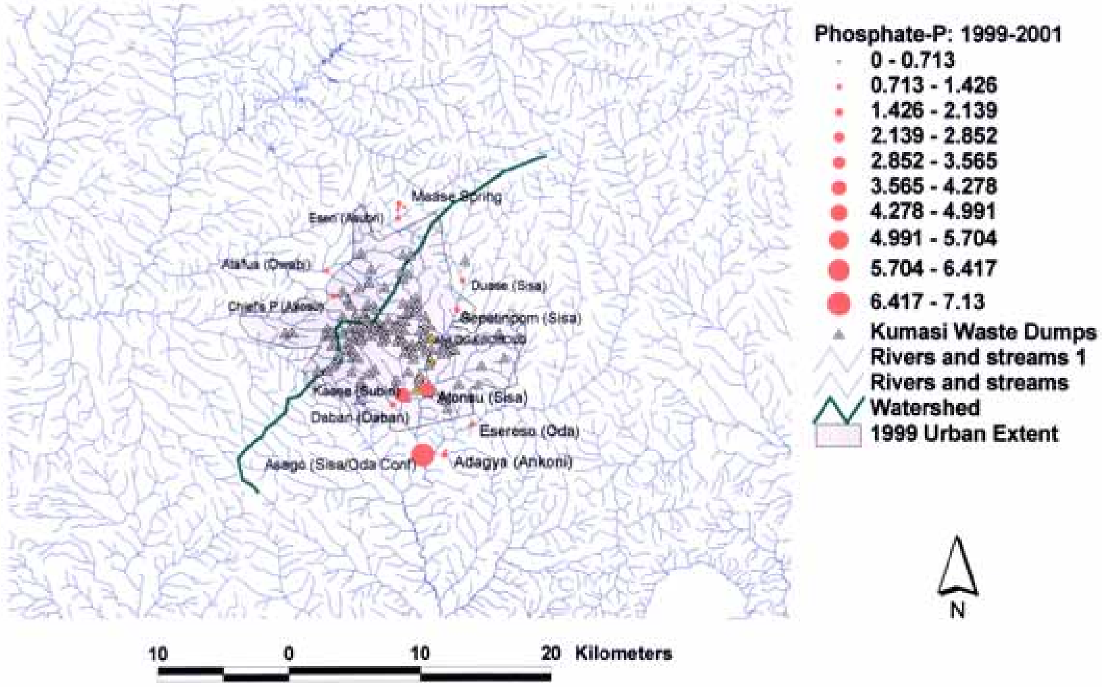
Nitrite –N

Nitrite levels are very low, and indicate that the production of nitrites is not a problem in these samples.

Phosphate:

Phosphate levels show little variation downstream in the Owabi catchment (Figure 4.7.8) and no significant urban effect. Chapman (1996) notes that phosphate levels in natural surface waters are generally in the range 0.005-0.02mg/l. The Owabi catchment data all exceed these levels significantly and are all over 1.0mg/l. This suggests contamination from detergents, fertilisers and possibly sewage. Practice in many communities is to wash utensils or clothing near or in the river. Domestic waste water often runs, via roadside gullies, from dwellings into valley bottoms and rivers. Car washing commonly takes place on river banks or where rivers cross roads. Such practices would be consistent with the widespread but relatively low contamination levels in the Owabi catchment.

Fig 4.7.8: Mean Phosphate-P (mg/l): Sept 1999-Sept 2001.

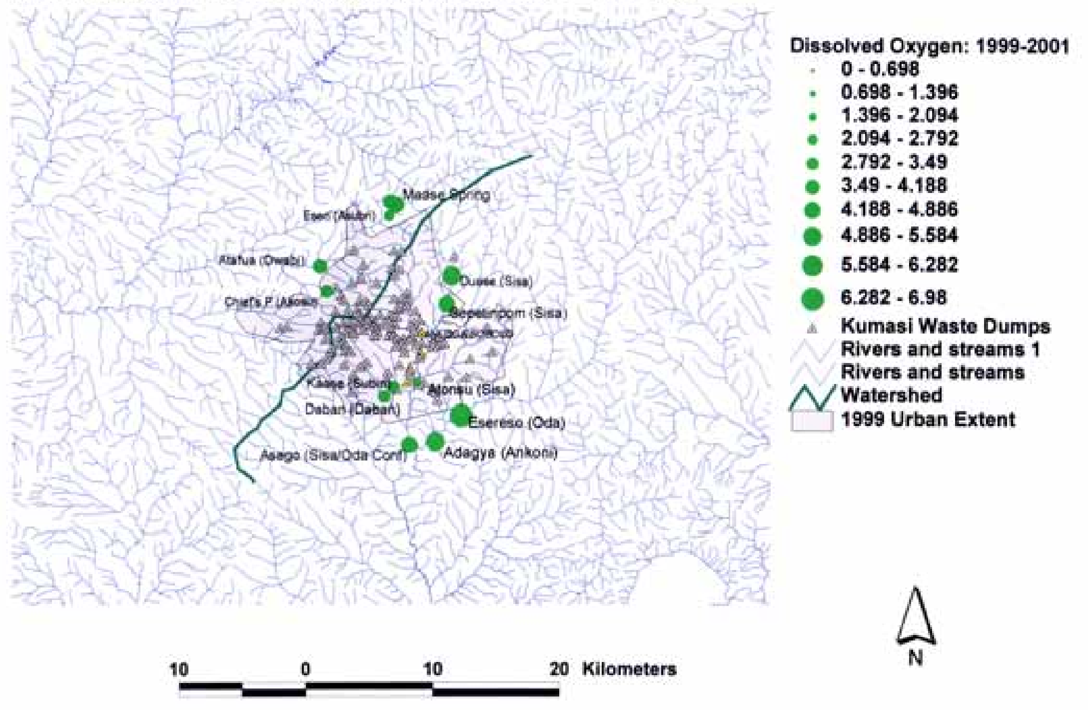


The Sisa catchment does show a significant downstream increase in phosphate levels (Figure 4.7.8). The Subin at Kaase also has an average concentration of 3.93mg/l\, similar to the 4.13mg/l at Atonsu on the Sisa. These high values contribute to the downstream peak at Asago (7.13mg/l). Industrial processes as well as human waste contamination is clearly a major contributor to pollution at these sites, which drain the central city area. It is notable that at Daban, draining an area within the city which is more residential, has much lower contamination levels that are similar to those upstream in the peri-urban and more rural locations of both catchments. Asago's position is clearly serious, as it lies below the Subin/Sisa confluence, and reaps the combined pollutants from the two most industrialised localities of Kumasi. The ubiquitous and locally high levels of phosphate may be associated with eutrophication of the rivers in the peri-urban zone.

Dissolved Oxygen:

Relatively low dissolved oxygen levels should be expected at all sites given the high water temperatures in excess of 25^{o}C . The highest mean levels are 6.98mg/l, found in the R.Oda at Esereso. Pollution by phosphates might be expected to suppress dissolved oxygen levels by triggering local eutrophication. There is some evidence that this is the case from the generally low DO levels throughout the peri-urban catchments. No site exceeds 5.31mg/l, which is well below the 8mg/l indicative level for natural waters, at a temperature of 25 ^{o}C, mentioned by Chapman (1996). Figure 4.7.9 shows the distributions for both catchments. In the Owabi the highest DO values are found at the R.Asuabena spring at Maase (the borehole also has a high level compared to other sampling locations. Levels at Atafua and Chief's Palace are lower. In the Sisa/Subin catchments, highest levels are found upstream of central Kumasi and there is a general decline with increasingly urban-affected location downstream.

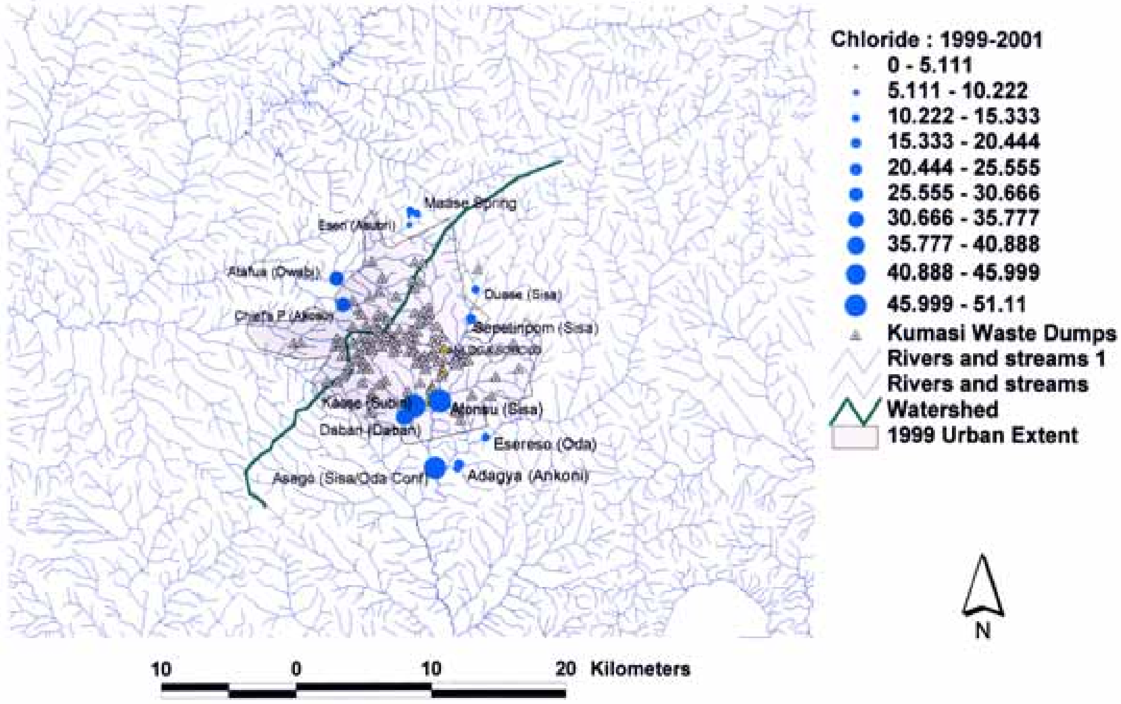
Fig 4.7.9: Mean Dissolved Oxygen (mg/l): Sept 1999 - Sept 2001



Chloride

The spatial distribution of chloride is based on the GWC 3-monthly sample. Sources of chloride include weathering of sedimentary rocks, saline intrusions and aerosol deposition. However, the large spatial variability of concentrations within the relatively small Sisa and Owabi catchments suggests non-natural sources. Sewage effluent, agriculatural and road runoff provide the main sources. The distribution, shown in Figure 4.7.10, reinforces the patterns of other solutes in the clear urban effect and the peak loads on the Subin at Kaase and at Atonsu (Sisa). With such large source areas upstream the relatively high concentrations at Asago are little surprise. In this context the chloride distribution supports the evidence for severe sewage pollution in central-south Kumasi drainage although not in itself being a dangerous substance.

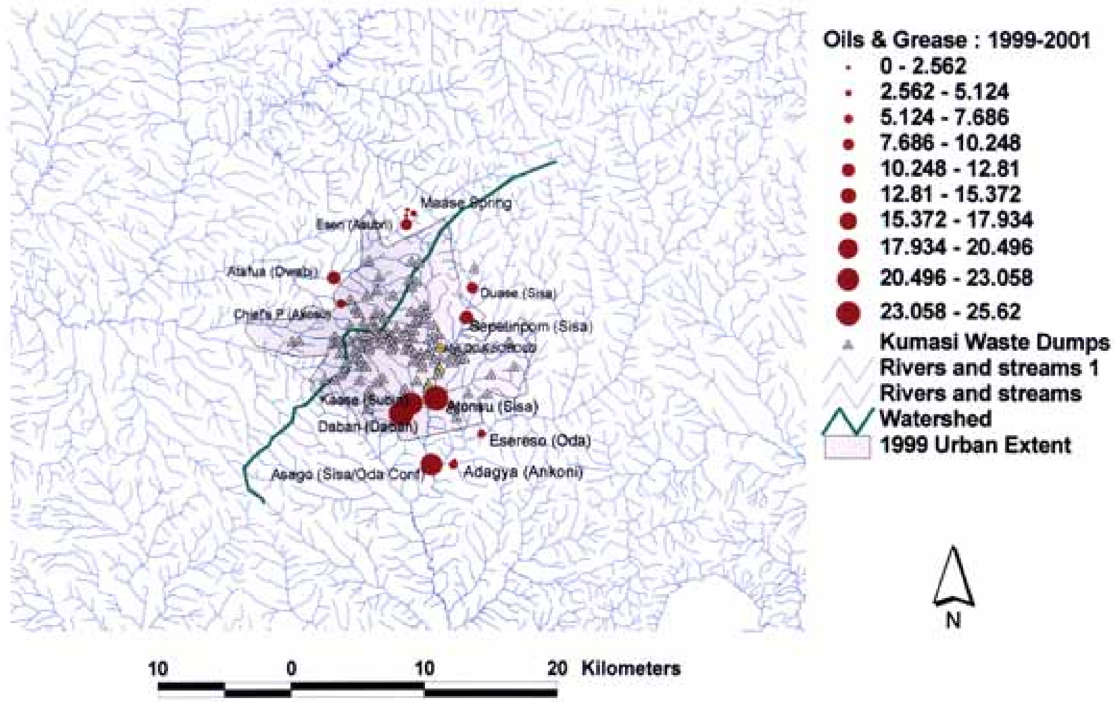
Fig 4.7.10: Mean Chloride levels (mg/l): Sept 1999-Sept 2001



Oils & Grease

This variable is highly indicative of polluted urban runoff. Chapman (1996) notes that the maximum permissible concentrations of petrol and oil products in drinking water are between 0.01-0.1mg/l. She also notes that concentrations in excess of 0.3mg/l can be toxic to fish. The levels found by this sampling programme suggest high contamination levels throughout the catchments. The Sisa catchment is much more contaminated than the lower Owabi (Figure 4.7.11). This finding is surprising in one sense. The Suame Magazine area, located across the local watershed upstream of the Atafua and Chief's Palace sampling sites, is reputedly one of the largest car repair and servicing areas in west Africa, and visual inspection confirms large amounts of oil and other by-products on the ground surface in this district. Surface runoff would thus be expected to transport oils and grease residues to local rivers. The Chief's Palace site should receive most of the Suame runoff but actually has lower contamination than the Atafua site. Either hydrological linkage from the Suame Magazine is imperfect, or the disposal of oils from Suame Magazine is more efficient than visual inspection indicates. In contrast the industrial contamination of the Sisa/Subin systems produces oils ad grease levels over twice those of Atafua at the four sampling locations downstream of central Kumasi.

Fig 4.7.11: Mean Oils & Grease (mg/l): Sept 1999-Sept 2001



Coliform bacteria

Sampling of both faecal coliform bacteria (surviving at 37°C) (Figure 4.7.12) and e-coli coliform bacteria (surviving at 44°C (Figure 4.7.13) indicates high levels of river contamination. Faecal contamination is derived from the systematic activities of KMA, for example the temporary liquid human waste disposal site between Kaase and Asago, as well as smaller point and area sources associated with individual households and communities. Direct defecation into the river Sisa is reported from the Anloga district (Frantzen & Post 2001) and overspill and runoff from community latrines is also a significant source of contamination where toilet facilities are poorly sited or badly maintained. Clearly such contamination makes water dangerous for drinking purposes. Health hazards may also be associated with irrigation water drawn from rivers (Cornish et al, 2000) and activities such as washing and bathing in rivers.

Fig 4.7.12: Mean Faecal Coliform (/100ml): Sept 1999- Sept 2001

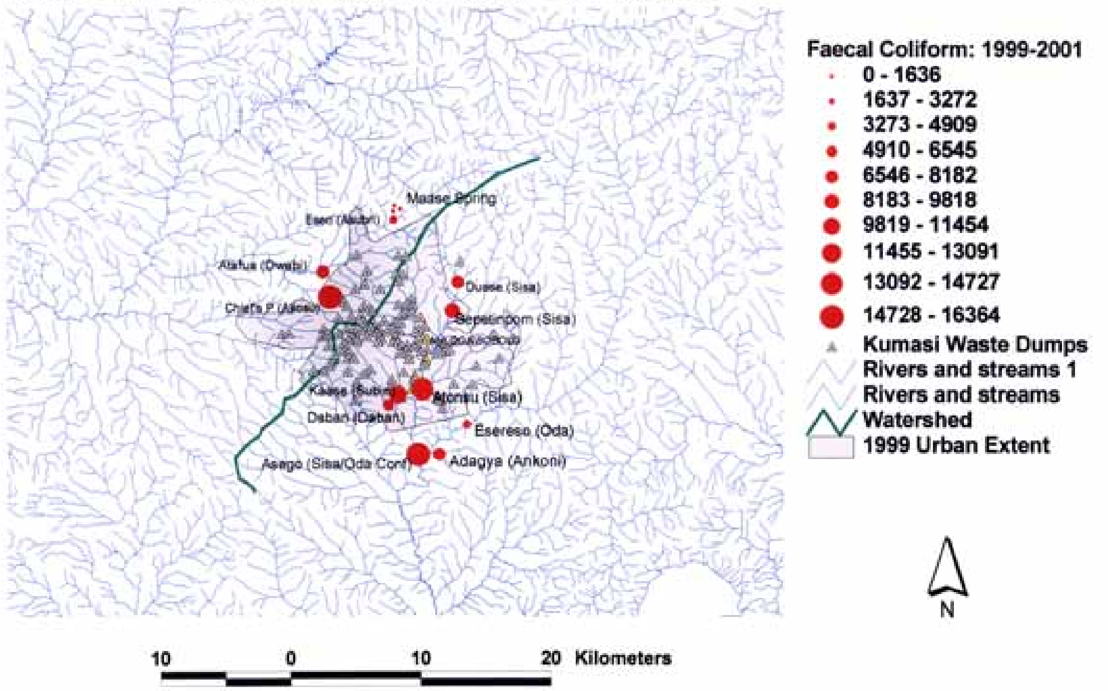
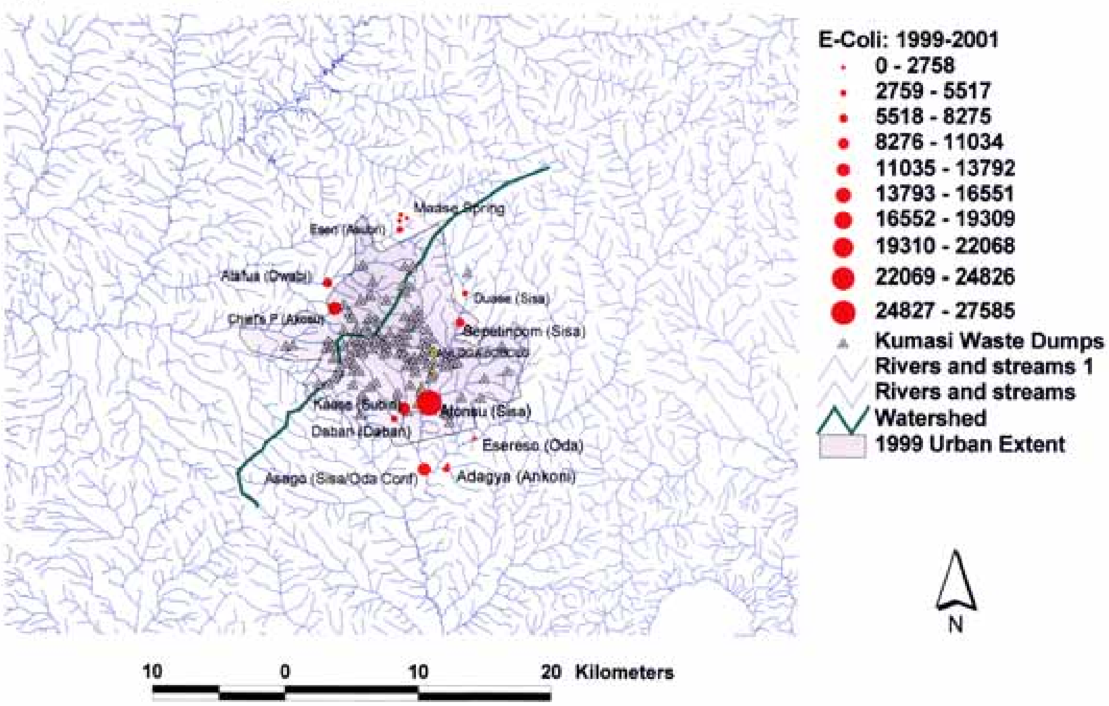


Fig 4.7.13: Mean E-Coli (/100ml): Sept 1999-Sept 2001



In the Owabi catchment the spring at Maase has a mean contamination level of 1436 faecal coliform/100ml. This is a site well away from many community activities and such levels are most likely associated with individuals defecating in the immediate area, which is close to land being cultivated. Contamination levels more than double at Esen and reach more than 8000 /100ml at Atafua. The River Akosu at Chief's Palace shows the second highest faecal coliform contamination of any location at

14821/100ml. This location is clearly subject to sewage disposal and runoff from human waste disposal sites and Akosu sub-catchment clearly is a major source of coliform contamination.

In the Sisa catchment overall contamination is even higher. In the upper catchment levels range from about 6000/100ml (Duase) to more than 9000/100ml (Sepetinpom). The middle Sisa and Subin catchments once again indicate the high pollution levels of central Kumasi, Kaase (11,420/100ml) and Atonsu (14,160/100ml). The temporary KMA settling ponds just upsetram of Asago, which are clearly discharging untreated waste into the Sisa, will result in high levels of contamination downstream. This factor, as well is the combined effects of the waste from the Subin, Wiwi and Sisa Rivers, lead to the highest coliform levels at Asago. Ironically, this community is one of the poorer, and has still to resort to the river for water supply under some dry season circumstances, and still fish in the river. Asago is the most seriously contaminated location by both coliform measures and it can clearly be seen that the river there poses a major health hazard.

4.7.5 SUMMARISING STREAM CONTAMINATION

Many of the individual pollutants discussed above show similar spatial patterns but individually only present a partial indication of water quality problems in the Kumasi area. Some combination of indicative variables is desirable if a more complete overall impression is to be gained.

One way of approaching this issue is to sum concentrations for related variables, to give a ‘pollution profile’. Figure 4.7.14 shows the summative pollution levels for four key variables in the Owabi system. Chloride, Oils and Grease, phosphate and ammonia were chosen since these represent sewage, industrial, domestic and agricultural contaminants.

The downstream increase in pollution levels from Maase to Atafua is clear and represents a doubling of contamination levels from source to the fourth order channel at Atafua. The Akosu sub-catchment (Chief’s Palace) contributes even higher levels from what is only a second order channel and a much smaller sub-catchment. The Akosu sub-catchment is clearly a major source of river contamination.

Figure 4.7.15 shows the corresponding situation in the Sisa catchment. Contamination levels increase by a factor of 3 to 4 between the upstream, rural to peri-urban, sub-catchment and main channel downstream at Atonsu and Asago. Chloride levels provide around 50-60 percent total contamination by the four pollutants throughout the catchment but ammonia-N becomes significant only in the urbanised reaches downstream.

Total contamination plots can be constructed using all measured variables where concentrations (mgl^{-1}) were determined. Conductivity, TDS, turbidity and coliform counts have thus been excluded here, along with dissolved oxygen (where higher values indicate *less* pollution).

Figure 4.7.14: Owabi Catchment Pollutants

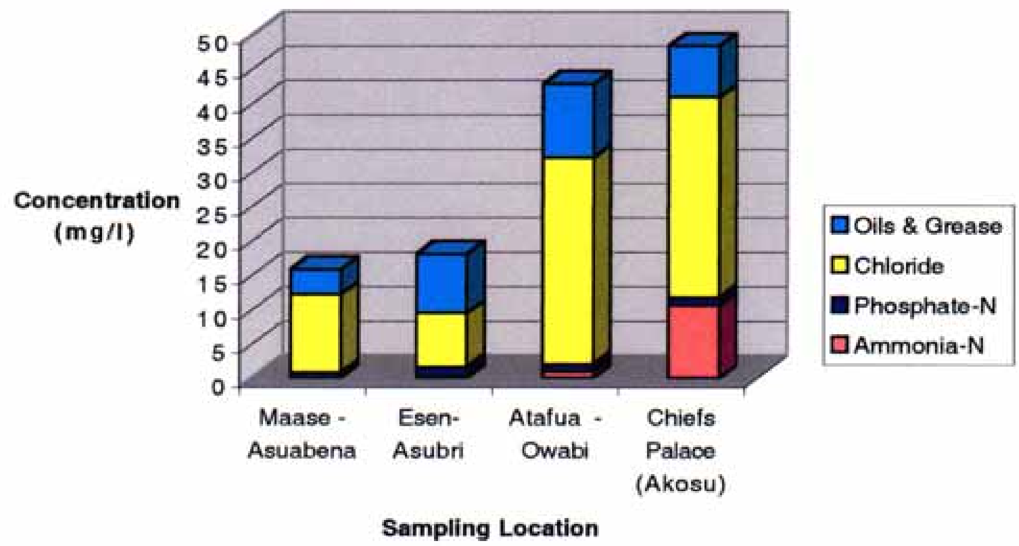
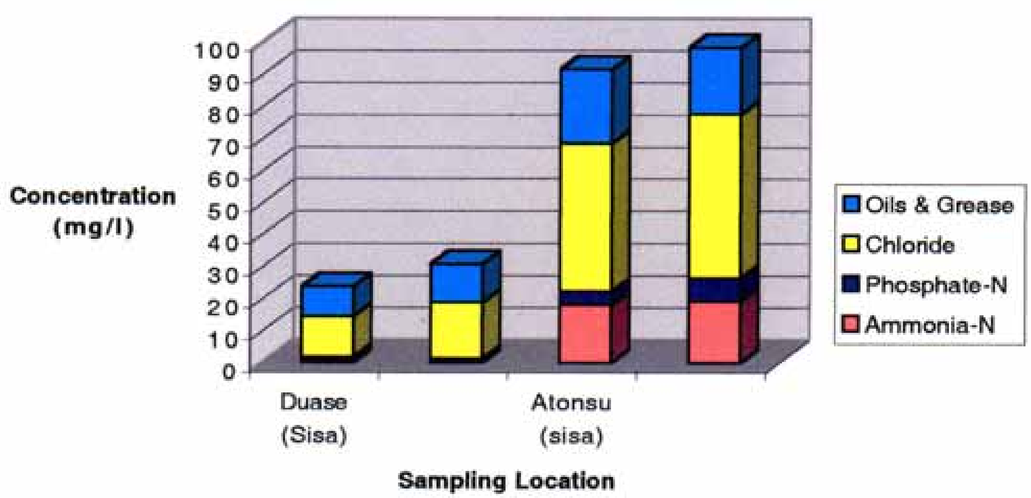
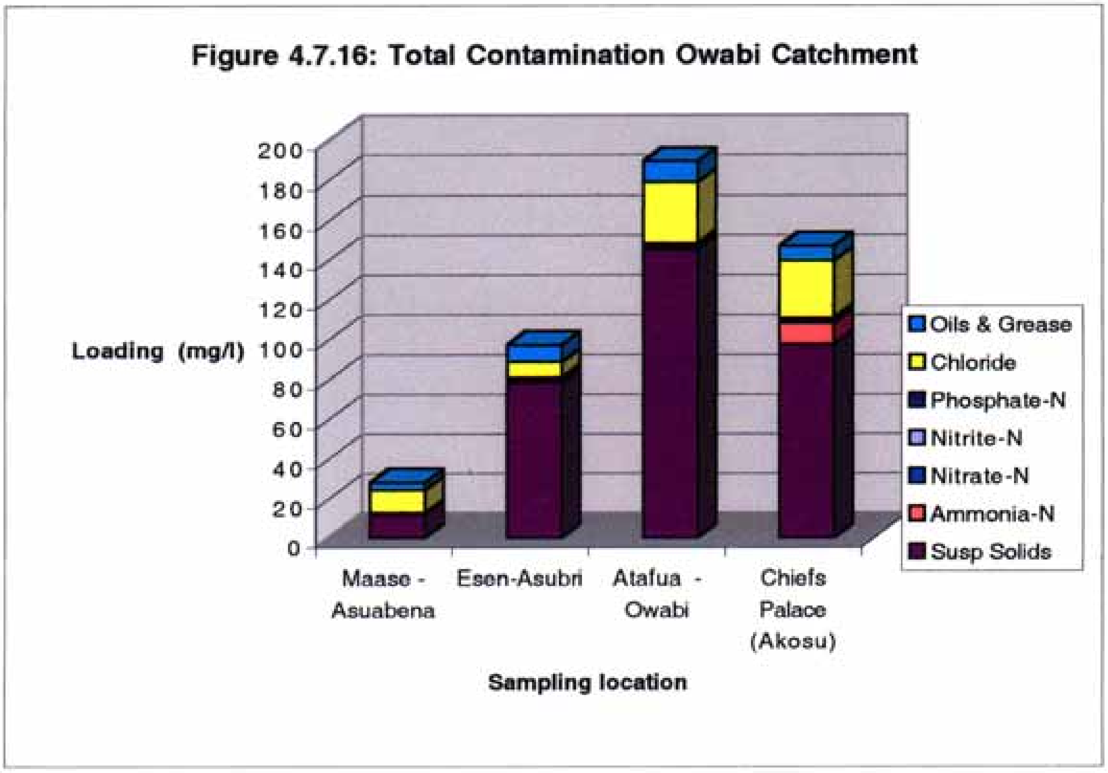


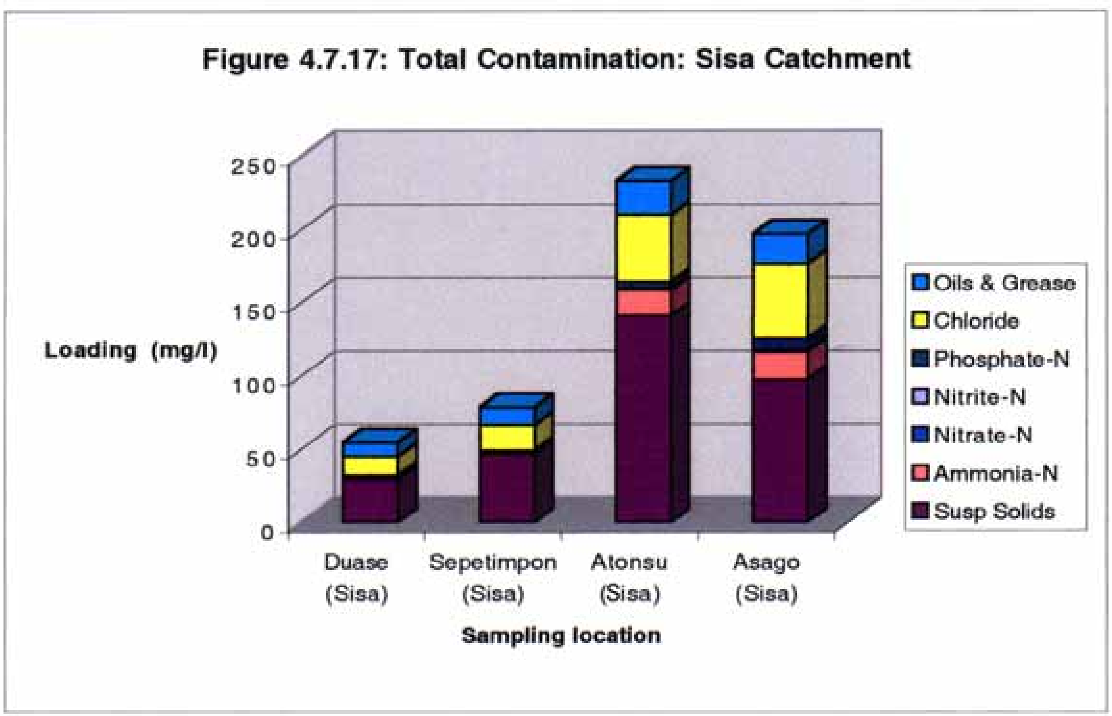
Figure 4.7.15: Sisa Catchment Pollutants



For the Owabi catchment the suspended solids component (much of which is natural to river environments) is 50 percent or more of the total load measured (Figure 4.7.16). Otherwise chloride and oils & grease dominate the loads to an increasing extent downstream to Atafua. The Akosu sub-catchment is responsible for the only significant ammonia-N input. Atafua emerges with the highest total concentrations. However, excluding suspended solids, Chief's Palace (and the Akosu sub-catchment) has the highest load of pollutants. No great dilution effects are apparent (except perhaps for chloride between Maase and Esen).

For the Sisa (Figure 4.7.17), the steep increase in total load is seen between Sepetinpom and Atonsu. Including suspended solids, Atonsu has the highest materials load of any location around Kumasi. Asago's total load is lower primarily due to lower suspended material concentrations but has the highest loading, just ahead of Atonsu, of any site if suspended load is excluded. The significance of ammonia-N only becomes apparent in the highly urban-influenced areas of the Sisa catchment.





4.7.6 WATER QUALITY INDICES

Examination of the spatial water quality variation for individual parameters has indicated the main source areas of contamination within the Owabi amd Sisa catchments. Amalgamation of key variables into a Water Quality Index, however, allows a simplified manner of expressing their *combined* effect. This may be used in planning management of the water resource, communication to stakeholder groups, long term assessment of the resource (Chapman, 1996) and identification of trends. Pesce & Wunderlin (2001) note that development of such indices normally requires calculation of scores for individual water quality variables by comparison with a 'parameter-specific rating curve, optionally weighted'. As a result of this, each variable is usually expressed on a 0-100 scale where 100 indicates the highest quality water. Weighting factors are applied to reflect relative importance of each variable. As Pesce and Wunderlin (2001) point out, the object of the index is to be easily understandable to non-specialists.

Water Quality Indices are being widely applied in LCDs. Jonnalagadda & Mhere (2001) use them to assess the spatial effects of mine waste seepage on the Odzi river in Zimbabwe, while Pesce & Wunderlin (2001) compare several types of index whilst illustrating the deleterious effects of Cordoba City on the quality of the Suquia River in Argentina.

We have followed the methodology of Pesce & Wunderlin (2001) in calculating a water quality index (Index 1) based on three variables:

$$WQI = (C_{DO} + C_{Cond} + C_{turb}) / 3$$

where C_{DO}, C_{Cond} and C_{turb} are index values of dissolved oxygen, conductivity and turbidity respectively after normalisation on a 0-100 scale following Pesce & Wunderlin's (2001) Table 2 (reproduced below as Table 4.7.5)

Table 4.7.5: Parameters for WQI Calculation (Derived from Pesce & Wunderlin 2000, Table 2).

	Normalisation factor										
Parameter	**100**	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
Ammonia	<0.01	<0.05	<0.1	<0.2	<0.3	<0.4	<0.5	<0.75	<1.0	<1.25	>1.25
Dissolved Oxyge	>7.5	>7.0	>6.5	>6.0	>5.0	>4.0	>3.5	>3.0	>2.0	>1.0	<1.0
Turbidity	<5	<10	<15	<20	<25	<30	<40	<60	<80	<100	>100
Oils & Grease	<0.005	<0.02	<0.04	<0.08	<0.15	<0.3	<0.6	<1.0	<2.0	<3.0	>3.0
Total Coliform	<50	<500	<1000	<2000	<3000	<4000	<5000	<7000	<1000	<1400	>1400
Conductivity	<750	<1000	<1250	<1500	<2000	<2500	<3000	<5000	<8000	<1200	>1200

Following Pesce & Wunderlin (2001), the first water quality index is based on three variables which have an important *impact on river fauna.* Conductivity is broadly indicative of contamination by dissolved salts, turbidity is often linked to bacterial contamination (Pesce & Wunderlin 2001) while dissolved oxygen levels below about 5mg/l become increasingly harmful to aquatic species.

Figure 4.7.18 presents the results of Index 1 as a bar chart to provide an easy comparison. The larger the bars, the better the water quality. In the Owabi catchment it is clear that good overall quality is only found in first order channels around Maase. Even in such a 'rural' location as Esen the index is comparable to the 'urbanised' locations at Atafua and Chief's Palace. The very low mean level of dissolved oxygen is mainly responsible. In the Sisa/Subin catchments, as expected, Atonsu and Asago have the poorest index level while Kaase also has an index of less than 50. It is noticeable that the best quality by this index is found for the boreholes at Maase and Adagya. Overall the index supports expectations of the land use surveys at, and upstream of, the monitoring sites. Figure 4.7.19 shows the spatial relationships (*smaller circles indicate worse water quality).*

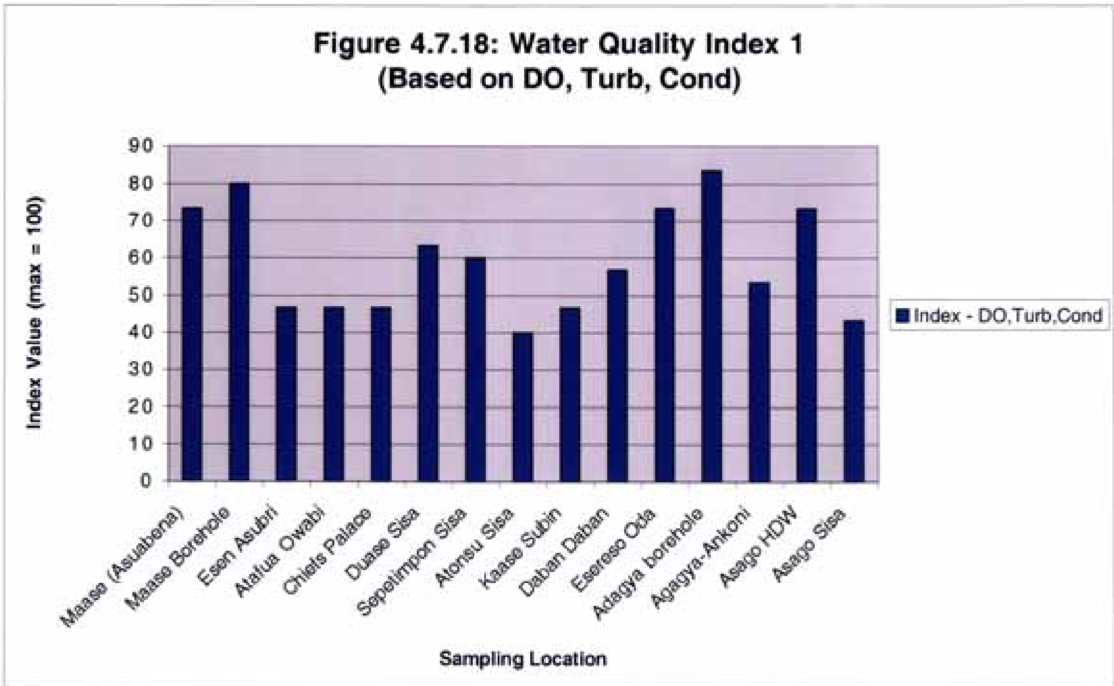
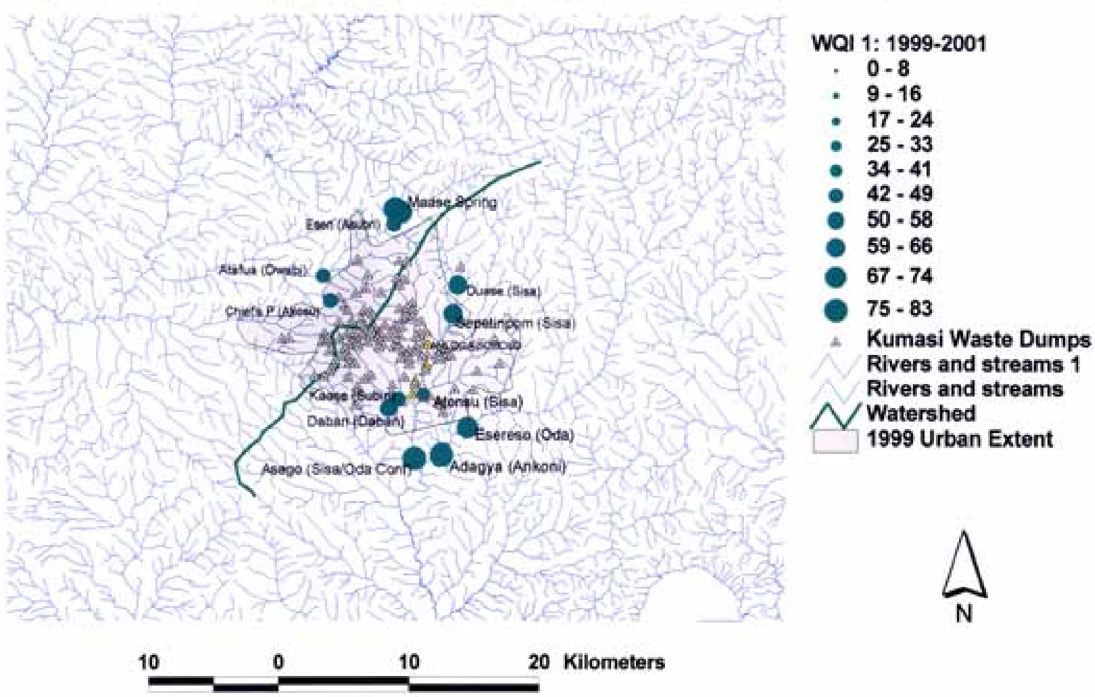


Fig 4.7.19: Water Quality Index 1 (Dissolved Oxygen, Conductivity, Turbidity)



Index 2 was computed in the same manner as Index 1 but utilises three variables more directly linked to industrial and human waste pollution, namely Ammonia-N, Oils and Gases and total coliform. Index 2 (Figure 4.7.20) suggests a worse state of pollution than Index 1. Chief's Palace (R.Akosu) and Atonsu

(Sisa) have indices of zero. All other locations have indices of less than 30 with the exception of the first order sites at Maase, Esen and borehole water samples. Otherwise there is ubiquitous contamination and extreme pollution at Chief's Palace (Akosu), Atonsu (Sisa) and Asago (Sisa). Figure 4.7.21 shows the spatial relationships.

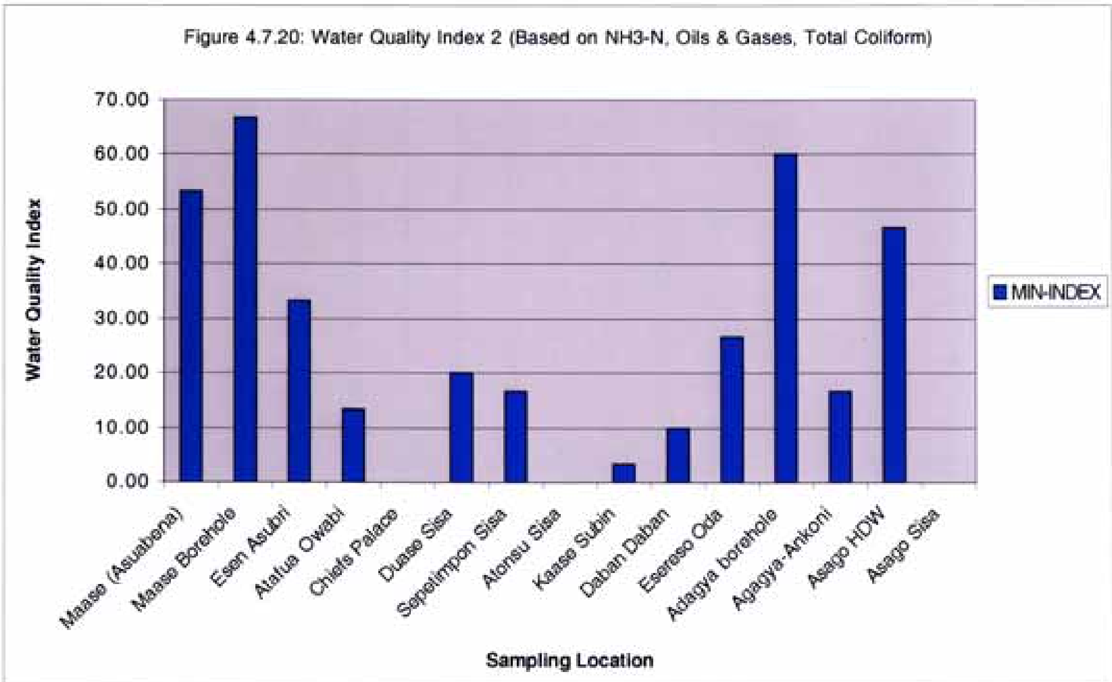
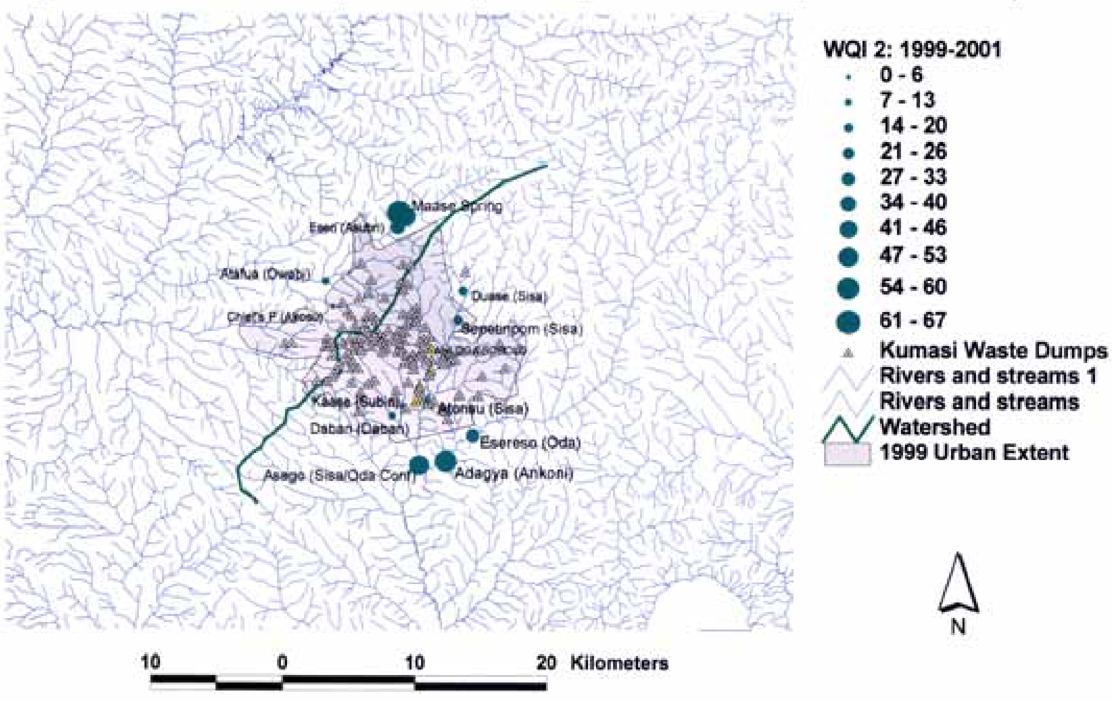


Figure 4.7.20: Water Quality Index 2 (Based on NH3-N, Oils & Gases, Total Coliform)

Fig 4.7.21: Water Quality Index 2 (NH4-N, Oils & Grease, Total Coliform)



4.7.7 SHORT TERM VARIATIONS IN WATER QUALITY

The monthly sampling programme has provided a clear indication of the effect that peri-urban and urban land uses have on the spatial variation in water quality within the drainage network. The data have provided a valuable base-line resource on water quality. However, short term sampling is needed to assess the short term dynamics of pollution and runoff. Whilst Project funds did not extend to such high temporal resolution data sets, we were able to facilitate such a data gathering exercise by students from Royal Holloway and by supporting the masters dissertation by Mr Omane Poku from EPA Kumasi. Table 4.7.6 summarises the projects. The three UK students undertook final year undergraduate dissertations based in Kumasi while Omane Poku's project formed a large part of the dissertation research component of a Masters degree at UST, Kumasi.

Table 4.7.6 Summary of short-term studies

Student	No Sites Study aim	Temporal resolution	Sampling locations	Catchment	Variables
Paul Stevenson (RHUL)	5 Sisa down-stream variation.	2 days/5 samples per day Sampling intervals: 30-60 mins	Sepetimpon Duase Atonsu Daban Bekwai	Sisa Sisa-Oda Daban	temp, DO,Cond, pH, NO3,NH4,NO2, K,PO4, Coliform, Turbidity, App Col.
Michael Johnson (RHUL	3 Sisa-Oda Compare catchment	2 days 5 samples/ day Sampling interval: 30-60 mins	Esereso Atonsu Bekwai	Sisa-Oda	pH, Turb, Cond, K, NH4, NO3, NO2, PO4, Cl, Coliform 37/44
Ben Beaton (RHUL)	4 Near likely 'point' sources	2 days/5 samples per day sampling interval: 30-60 mins	Esereso Kaase Anloga Jct Kaase-Guiness outlet	Sisa	DO,Temp, Cond, pH, App.Col, NH4, NO2,NO3, Cl, PO4, Coliform37/44
Omane Poku (EPA-Kumasi)	8 Point sources	7 days 1 sample /day at each site.	Asafo Anloga Ahinsan Atonsu Kaase Asago-Sisa Asago-Oda Asago- Sisa/Oda	Sisa Subin, Daban Oda	pH, turb, Cond,TDS, K, NO3, NO2, PO4, DO, Cl, O&G, Coliform 37/44, Turb.

Clearly the undergraduate data is more susceptible to error, although all students were advised by Mr Daniel Benefor of EPA during their data analysis. As with the monthly data set, only brief notes on the data sets are presented here. A fuller analysis will be found in Thompson *et al.* (2002).

Stevenson Project

This study examined the downstream changes in contamination for the Sisa River from Duase in the headwaters to Bekwai, about 30km south of the Sisa-Oda confluence. Monitoring took place on two days at each site and the daily sample size is 5-6 with a 30-45 minute sampling interval. This data-set thus provides some information on short term water quality at each sampling site as well as spatial comparisons.

Short term water quality variation:

There is some evidence of specific pollution 'events' within the data sets. The most prominent 'event' is seen in the data for the R.Sisa at Sepetinpom for the 15th July 2001. Figure 4.7.22 shows ammonium-nitrogen, potassium, phosphate and water level variations. Ammonium-N shows extreme variability within the 3-hour measuring period. The highest readings were >100mg/l (beyond the threshold for measuring by the *Paqualab* kit available and total variation ranged therefore over at least 6-fold. Similarly potassium (K) shows 6-fold variability over the morning reaching nearly 120mg/l in the period around 1000hrs. Phosphate levels fall rapidly from a very high 80mg/l at 0900hrs. The sampling site is close to, although just upstream of, car-washing areas and outlets for domestic drains entering the Sisa river, and will thus be influenced by particular discharges from these sources.

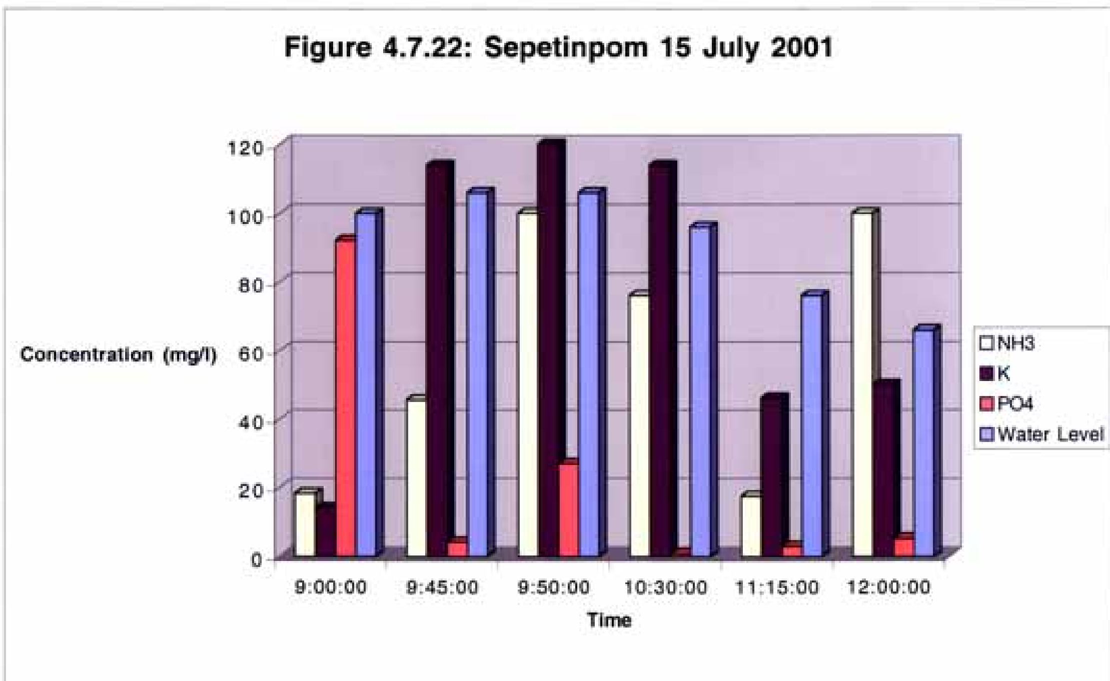


Table 4.7.7 below summarises key statistical data for the combined two day monitoring at each site. One-way ANOVA results are shown for the downstream differences for each variable and separated by day 1 differences and day 2 differences respectively in the right hand AOV column. Bold figures in the 'Mean' column indicate exceedance of WHO/EU drinking water limits. ANOVA Ho rejection values at $p < 0.05$ are in bold and underlined.

Table 4.7.7: Data from Stevenson 2002

Electrical Conductivity (micro-siemens)

Site	**N**	**Mean**	**St.Dev**	**SE Mean**	**AOV (F:p)**
Duase	10	187.8	40.3	12.7	Day 1
Sepetinpom	11	358	545	164	(1.47:**0**.246)
Atonsu	10	538.1	71.1	22.5	Day 2
Daban	10	178.7	49.8	15.7	(2404: **0.0**)
Bekwai	10	329.3	37.7	11.9	

Potassium (mgl^{-1})

Site	**N**	**Mean**	**St.Dev**	**SE Mean**	**AOV (F-p)**
Duase	10	88.4	75.7.0	24.0	Day 1
Sepetinpom	11	74.6	50.6	15.3	(57.78:**0.0**)
Atonsu	9	264.2	191.3	63.8	Day 2
Daban	10	26.9	17.99	5.69	(1.76: 0.179)
Bekwai	10	56.6	14.55	4.6	

Ammonium-Nitrogen (mgl^{-1})

Site	**N**	**Mean**	**St.Dev**	**SE Mean**	**AOV (F-p)**
Duase	10	21.55	16.43	5.2	Day 1
Sepetinpom	11	55.4	39.2	11.8	(8.28:**0.0**)
Atonsu	9	67.8	39.2	13.1	Day 2:
Daban	10	9.92	11.31	3.58	(3.19: **0.036**)
Bekwai	10	37.85	23.01	7.28	

Apparent Colour

Site	**N**	**Mean**	**St.Dev**	**SE Mean**	**AOV (F-p)**
Duase	10	4.5	0.0	0.0	
Sepetinpom	11	2.418	1.653	0.499	
Atonsu	10	8.5	0.0	0.0	
Daban	10	7.00	0.0	0.0	
Bekwai	10	7.0	0.0	0.0	

Phosphate (mgl^{-1})

Site	**N**	**Mean**	**St.Dev**	**SE Mean**	**AOV (F-p)**
Duase	10	3.75	4.53	1.43	Day 1
Sepetinpom	11	11.99	27.68	8.35	(1.29: 0.307)
Atonsu	8	4.36	4.95	1.75	Day 2
Daban	10	1.05	2.279	.721	(2.22: 0.105)
Bekwai	10	3.19	3.78	1.2	

Dissolved Oxygen (mgl^{-1})

Site	**N**	**Mean**	**St.Dev**	**SE Mean**	**AOV (F-p)**
Duase	10	9.18	1.147	0.363	
Sepetinpom	11	9.236	1.208	0.364	
Atonsu	9	5.544	1.457	0.486	
Daban	10	7.59	0.731	0.231	
Bekwai	10	3.54	2.28	0.721	

Stevenson's data confirm many of the spatial patterns brought out by the monthly samples. However, mean levels of ammonia-N are much higher than the monthly averages although in line with some of the peaks. Clearly this variable is subject to high concentration discharges. It is likely that such sources are point rather than areal.

Beaton Project

This dissertation sought to examine short term water quality near to likely 'hot spots'. That is, those industrial or municipal plants or activities which produce high quantities of waste.

Such hot spots might include sewage storage areas such as the temporary locations near Kaase, or point sources, where waste discharge is released regularly, for example the Guinness brewery, the abattoir or cloth dyeing activities. Waste tips and saw mills might produce areal sources of leachate.

Table 4.7.8 Monitored sites from Beaton (2002)

Location	Type of activity
Esereso	Village waste tip adjacent to tributary of R.Oda
Kaase	Downstream of temporary sewage dump
Anloga Junction	Sawmills and wood treatment activities
Kaase	Guinness brewery outlet

The context of these monitoring sites is worth discussing briefly.

Esereso: The waste tip acts as the community dumping site. Mostly domestic waste is left there but human and animal excreta is also extensive. A small tributary channel to the Oda runs around the tip. This leachate will be flushed directly into the Oda river during heavy rainstorms.

Kaase: The sampling site is in the newly channelised section of the Subin river, an improvement funded by the World Bank (Urban4 phase). Water here is grey and opaque and is frequently dark blue from flushing of dye wastes directly into the Subin. Children were often observed catching fish or playing in the water at this site. Sewage dumping is a major source of contamination at this site. Beaton also observed that the river banks were almost entirely composed of accumulated domestic rubbish at some points.

Anloga: This site is dominated by the many informal carpenters units which employ around 8000 in total (Frantzen & Post 2001). The Aboabo river dissects this area and enormous amounts of sawdust are dumped directly in or on the margins of the stream. Phosphates, sulphates and humic acids might be expected to be a major contaminant. Lack of sanitation means that most of the workers both urinate and defecate directly in the Aboabo. Such latrines as there are overhang the river. Thus sewage related contaminants would also be expected to be very high.

Kaase-Guinness: Outlet pipes discharge from the brewery regularly. The flow then passes the abattoir and cattle grazing. Beaton suggests that cleaning agents from the brewery would lead to high phosphate levels in the discharged waste. Animal excreta would also be expected to cause high levels of contamination.

Table 4.7.9 below presents the averaged contaminant levels from the two-days of sampling at each site.

Table 4.7.9 Data from Beaton (2002)
Bold figures indicate exceedance of WHO or EU drinking water limits. Note: Ammonium-N figures at 100 should be interpreted as at least 100 as limit of instrumentation reached. (x.xx) = SE Mean.

Site	pH	Turbidity (NTU)	Conductivity ($\mu s.cm^{-1}$)	K(mg/l)	NH4-N
Esereso –Waste Tip	6.94 (.228)	**24.6** (4.57)	642 (143)		**56.3** (14.2)
Kaase- sewage dump	6.72 (0.06)	**126.0** (5.27)	819.0 (24.2)		**100.0**
Anloga – woodwork	7.29 (.145)	**109.6** (15.5)	874.5 (75.4)		**100.0**
Guiness - Brewery	6.91 (.336)	**114.0** (9.79)	869 (173)		**6.3** (3.47)
Bekwai	7.16 (.04)	**54.2** (2.67)	364.8 (2.31)	**64.0** (7.04)	**29.9** (1.96)

Site	NO3- N	NO2- N	PO4	Cl	Coliform 37°C (/100ml)	Coliform44°C (/100ml)
Esereso –Waste Tip	.455 (0.153)	.00211 (.00102)	2.37 (.871)	**128.9** (54.1)	**4177** (973)	**2297** (624)
Kaase- sewage dump	.633 (.094)	.005 (.002)	**13.7** (1.8)	**60.7** (13.7)		**150366** (39393)
Anloga – woodwork	.664 (.126)	0	**12.84** (3.0)	7.5 (3.02)	**200000** (33333)	**150000** (16667)
Guiness - Brewery	.918 (.08)	.0452 (.026)	**52.0** (9.58)	0.0	**99033** (41304)	**114870** (41484)
Bekwai	.1238 (.055)	**.2354** (.015)	4.42 (2.2)		**12016** (4646)	**14496** (1704)

When examined in detail (see Thompson *et al.* 2002), these data show the effects of individual discharge events. For example, dramatic evidence was measured of a discharge 'event' at the Guinness sampling site on 26 July 2001. In a 10 minute pulse event the electrical conductivity rose 4-fold and there were substantial step increases in both turbidity and pH. The latter parameter changes from acidic to strongly alkaline. In another event measured at the Guinness outflow on 23 July 2001, phosphate levels increased by a factor of 5 over 10 minutes and ammonium-N also showed a significant increase. Phosphates may be related to cleaning agents used in the plant and could be flushed out periodically.

Such point events are obviously adding to the overall pollution load. Further research is indicated to link such pulsed events to background pollution levels. However, comparison of the mean levels of several pollutants for the 4 'hot spot' sites examined by Beaton, with the monthly mean levels at our other sites in the Kumasi region support the suggestion that *pollution sources* or 'hot spots' are in evidence. As an example, Figure 4.7.23 indicates that conductivity values at the assumed point of pollution are much higher than the averaged monthly values of the main Project sampling sites.

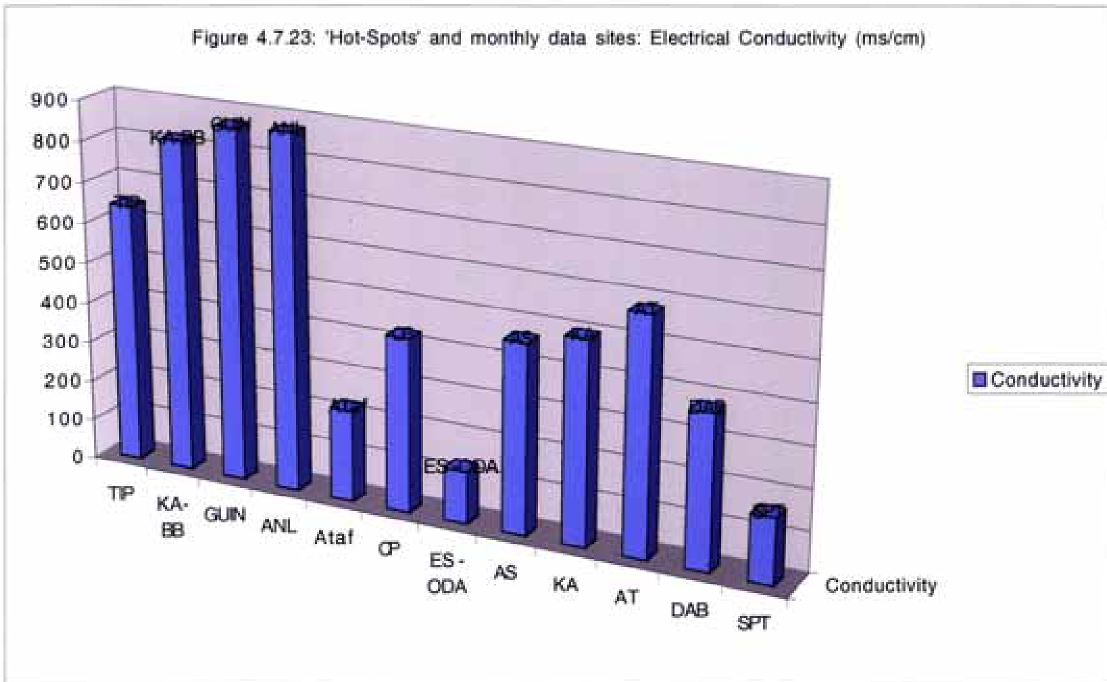


Figure 4.7.23: 'Hot-Spots' and monthly data sites: Electrical Conductivity (ms/cm)

One element of caution should be applied to this interpretation however. The monthly sample sites include annual variation whereas the 'hot spots' sampling sites are sampled only during the wet –season when flushing mechanisms and source linkage is thus high. Even if we take this interpretation, however, Beaton's data do indicate some interesting aspects of the dynamics of pollution transport.

Omane Poku Project

This study sampled on a daily basis at nine sites for one week. The mean value data for each site is shown in Table 4.7.10.

Table 4.7.10: Poku daily sample. Mean values.

	Omane Poku -Site	pH	Turb (NTU)	Cond ($\mu s.cm^{-1}$)	TDS ($mg.l^{-1}$)	K (mg/l)	NH3- N ($mg.l^{-1}$)
1	ASAFO	8.006	144.3	1501.7	908.0	330	52.2
2	ANLOGA	7.97	97.3	1459.1	854.6	358	54.4
3	AHINSAN	8.88	11.857	259.1	170.4	261	44.3
4	ATONSU	8.202	38.86	1088.1	669.1	405	40.8
5	KAASE	8.274	95.1	1074.6	658.5	222	48.9
6	DABAN	8.06	39.4	540.0	321.57	221	54.9
7	ASAGO – ODA	8.11	67.0	1077.1	617.4	192	37.1
8	ASAGO-SUBIN	8.09	127.6	1224.9	727.0	249	54.8
9	ASAGO-CONFLUENCE	8.26	73.14	1111.3	666.1	225	56.6
	Recommended drinking water limits		5.00 *	400 @	1000 *		0.5 @

* WHO @ EU

Omane Poku Site	Nitrate N (mg.l^{-1})	Nitrite N (mg.l^{-1})	Phosphate (mg.l^{-1})	Dissolved O (mg.l^{-1})	Chloride (mg.l^{-1})	Oils & Greases (mg.l^{-1})	Coliform 37^{o}C (/100ml)	Coliform 44^{o}C (/100ml)
ASAFO	.243	.1474	54.9		115.9	44.5	367996	236973
ANLOGA	.1741	.0613	45.9		104.1	25.0	62413	50280
AHINSAN	.317	.0436	31.3		103.4	4.5	6375	4544
ATONSU	.1301	.0973	31.0		110.6	15.5	70733	59080
KAASE	.1170	.0933	35.8		132.5	21.5	40620	23335
DABAN	.513	.1326	20.99		66.5	3.5	7184	14289
ASAGO – ODA	.1429	.1366	35.7		93.4	6.5	47490	37355
ASAGO-SUBIN	.212	.0387	38.2		100.8	12.0	73305	63700
ASAGO-CONFLUENCE	.358	.0486	40.8		142.4	34.3	56973	51110
Recommended drinking water limits	50.00 *	0.1 @	5.0@		25.00 @	0.01 @		0 *

* WHO @ EU

The Poku study shows extremely high levels of contamination by coliform bacteria at Asafo, immediately south of the city centre, and very high levels at all other sites. Conductivity levels are the highest (with the exception of Ahinsan (to the east of Kaase) and Daban) measured during the Project period. At Anloga, where carpentry and wood industries are concentrated, high levels of potassium, ammonium, phosphate are seen. All these variables may be ascribed to industrial processes including use of detergents and paper/pulp processes.

Asafo receives large amounts of urban runoff pollution (see Oils & Grease) as well as sewage and municipal waste (see coliform levels). Phosphate levels are highest at this site and probably reflect industrial processes and detergents rather than fertiliser runoff.

Poku's study supports the other sampling programmes in finding generally low levels of nitrate contamination. Since this variable is largely derived from fertilisers (as well as human waste) it can be postulated that agriculture is of less importance as a source of pollution in Kumasi than other activities.

This study supports that of Beaton in confirming the importance of Anloga as a prime pollution source, and adds Asafo. These inner city sites are sources of major inputs of pollutants to the Subin-Sisa system and contribute significantly to the poor water quality problems of downstream peri-urban communities such as Asago.

Johnson Project

The work of Johnson was focussed on the contrast between water quality in predominantly urbanised catchments (Sisa/Subin system) and a much more rural environment (Oda catchment). Samples were taken at Esereso (Oda), Atonsu (Sisa) and Bekwai (below the confluence). Table 4.7.11 shows the averaged observations (two days sampling at each site was carried out). Table shows the t-test results for pair-wise comparisons between the rural (Oda) site at Esereso and the urban (Sisa) site at Atonsu, and the 'combined' site at Bekwai which receives the water from both catchments.

Table 4.7.11: Johnson (2002) averaged data for Sisa-Oda catchments

Site	pH	Cond	NH4	K	Turb	NO3	PO4	NO2	Col37	Col44
Atonsu	7.44	546.2	57.6	234.2	94.6	0	0	0	192000	166000
Esereso	7.83	127.9	0.228	33.4	28.8	0.32	4.4	0.328	5700	5670
Bekwai	7.46	323.5	59	39.4	56.2	0.14	0.42	.327	21417	13184

As would be expected, the Atonsu values (urban catchment) are significantly higher than those at Esereso (rural catchment). As the catchment below the Sisa-Oda confluence is predominantly rural, with relatively small settlements bordering the river, a degree of dilution of most pollutants would be expected. This is the case, but the significantly higher values of most parameters at Bekwai compared with Esereso indicate the lasting effect of urban pollution, even some 30 km from the urban area.

4.7.8 SUMMARY

Taken together, these data indicate without question the significant polluting effect of Kumasi on its rivers and water bodies. The headwaters of the sampled rivers, in the peri-urban zone, are relatively unpolluted, with the conspicuous exception of coliform bacteria - a clear indication of ubiquitous use of rivers and water bodies as recipients of human wastes. Pollution is attenuated through the city, and specific pollution 'hot spots' have been identified. These hot spots are merely representative of the scale of pollution by the formal and informal sectors alike. Specific measurements at industrial outfalls cast into doubt the claims of larger industries (see Simon *et al*., 2001) not to be polluters of the environment.

The effects of urban pollution are most keenly felt by the peri-urban communities downstream, with high levels of pollution at Asago, and persisting, if somewhat diluted, effects seen 30 km downstream at Bekwai.

The main data set provides unequivocal evidence of the nature and scale of pollution, and should be disseminated to government officials and decision-makers alike, as firm evidence of what has long been postulated.

The short-term data sets indicate that high 'spikes' of pollution can be attributed to particular sites of polluting activities, and to individual polluting events.

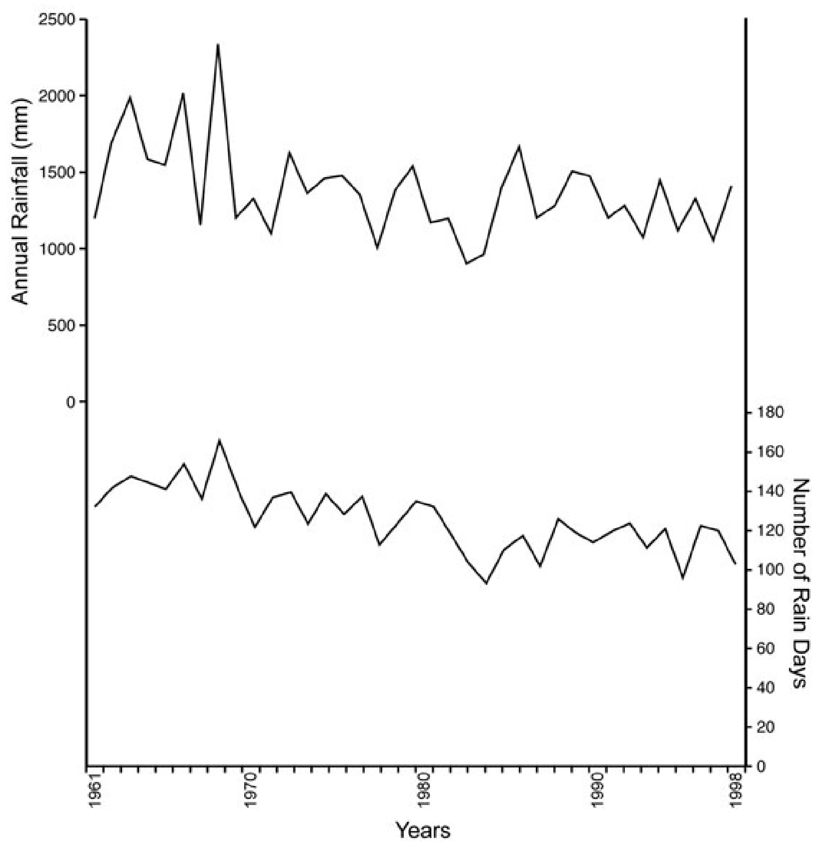
The linkages between these, and between these and the coarser-resolution main data set, should be the subject of further study.

It is clear that stream and river water quality is problematic in the peri-urban zone, and particularly so within and downstream of the urban area. The evidence of pollution of shallow groundwater in the hand-dug well at Asago, and observations in other hand-dug wells in Kaase, gives further cause for concern. There is no evidence of systematic pollution in the boreholes sampled by this Project. However, two factors must be considered.

Firstly, the rapid expansion of house building in the peri-urban zone is accompanied by an increase in the number of hand-dug wells and boreholes abstracting groundwater. While this is not regarded as problematic at present (see Section 5.9, where a preliminary modelling of groundwater balance is set out), the overall effect of urbanisation must be to increase groundwater abstraction, perhaps unsustainably so in the longer term.

Secondly, the rainfall record from Kumasi Airport shows a significant decline in total rainfall and number of rain days in recent decades (Figure 4.7.24). This trend has been noted elsewhere in the region, though there is no evidence as to whether this is a 'normal' short-tem fluctuation or a longer-term response to global warming. However, this does represent a situation where groundwater recharge is declining.

Figure 4.7.24: Total annual rainfall and number of rain days at Kumasi airport, 1961-1998



In these circumstances, a strategy which helps to preserve the groundwater resource is be seen as desirable. To this end, the Project emplaced simple roof catchment water harvesting systems in the JSSs collaborating with the Project, or in the Project communities. A fuller discussion of this initiative is given in Thompson *et al.* (2001), where a detailed quantitative evaluation is given of the potential yield of these systems against the pattern of rainfall throughout the year.

4.8 Water quality at Asago, including a preliminary investigation of the presence and concentrations of heavy metals [1E, 2B]

It was realised early in the Inception phase of the Project that a particular problem of water quality and human health issues existed at the village of Asago, situated on the floodplain at the confluence of the Sisa and Oda Rivers, approximately 8 km south of the city centre. In addition to regular sampling of the River Sisa just above the confluence and a hand-dug well in the village itself, it was decided to undertake a preliminary investigation of heavy metals in the river and overbank sediments, and of fish tissue. The Project is indebted to Dr Samuel Osafo-Acquaah, Department of Chemistry at KNUST, for undertaking the collection and analysis of samples.

4.8.1 WATER QUALITY ISSUES

Water quality has been an important issue in Asago for some time, as raised levels of reported sicknesses, particularly among children, have been ascribed to the obviously polluted Sisa (see Table 4.7.4). That the rivers are polluted is also signified by the fact that, particularly in the dry season, fish have become scarce in recent years (though this could also be a consequence of over-fishing). The Oda continues to support tilapia, which occasionally stray into the more polluted waters below the confluence; but above the confluence, only scarce bottom-living mud fish are found in the Sisa. This is unsurprisingly considering the very low levels of dissolved oxygen (DO) in the Sisa at this point (see Table 4.7.4). Most fish require a DO level of between 5 and 8 $mg.l^{-1}$, though mud fish and carp can survive at levels below that.

The village does have an active WATSAN Committee, with a membership of 9 (7 males and 2 females), mostly farmers but with one teacher, recorded in early 2001. The committee members are responsible for the operation and maintenance of the borehole and for general sanitation in the village. They organise the community to tidy up the township at weekends. The committee collects user fees per bucket of water from the recently-installed borehole, the money accruing being used partly to maintain the borehole and partly being earmarked to finance the provision of a further borehole.

In terms of village sanitation, it was claimed that the people carry out regular maintenance of the refuse dump in the village through communal labour. Water collects at the refuse dump and serves as a breeding ground for mosquitoes. It was observed during visits to the community that the sanitary situation in the village was poor. This is because there is indiscriminate littering in the village, despite the WATSAN claim that regular cleaning up takes place. For example, people drop small polythene bags used for packaging of iced-water after drinking the contents. The WATSAN committee indicated during an early visit (July 2000) that it planned to place dustbins at various points in the village for collection of litter to keep the village tidy, but this had not been implemented by March 2002.

There are two latrines serving the people in the village but people reportedly still defecate in nearby bushes, posing health hazards to the community. It was argued that those who live some distance away from the latrines feel reluctant to use the facilities, especially at night, and resort to the use of the surrounding bush. It was alleged that the culprits are young people who are reportedly on drugs and are 'difficult to deal with'.

The KMA maintains a refuse dumpsite on the floodplain of the Sisa River, a short distance (c. 1km) upstream of the village on land belonging to Kaase Stool. The health of the people is reported as having been adversely affected by the environmental effects of the dumpsite. Perhaps more importantly, the major 'temporary' KMA sewage settling ponds at Kaase, about 2km north of the village, are reported by villagers to be susceptible to indiscriminate direct dumping of night soil, and to overflow into the river system. The villagers have sent protest letters over the past two years to KMA but report that no action was forthcoming. A visit to the site by the authors in mid 2001 confirmed that raw sewage was indeed overflowing straight into the River Sisa. The long-delayed commissioning of KMA's major sewage settling ponds at Buobai (southwest of Duase) and the delays in starting work on the joint settling ponds and solid waste tip at Dompoase have meant that this significant environmental risk has been allowed to continue to pollute the river system, with undoubted effects on the health of downstream inhabitants such as those of Asago.

4.8.2 HEAVY METALS

Samples of river water, river sediment, riverbank and floodplain sediments, and fish were taken in July 2000 (equivalent to a 'wet season' sample) and January 1999 (equivalent to a dry season sample), and analysed for a range of heavy metals (Tables 4.8.1 and 4.8.2). The analyses were performed with a Perkin Elmer 51 10B Atomic Absorption Spectrophotometer (AAS). Analyses were done in triplicate and the means of the three readings recorded. The data on arsenic (As) levels for July 2000 (ie wet season samples) gave poor recovery and low sensitivity, and have not been included.

Table 4.8.1: Heavy Metal Analysis: River Sisa at Asago. Samples taken July 2000

Water Samples	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$
	Cd	**Co**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
W1a	0.009	0.009	0.034	3.305	0.094	0.200	0.011	0.029	0.022
W2a	0.023	0.023	0.032	3.558	0.22	0.209	0.023	0.048	0.010
W4a	0.035	0.035	0.028	2.656	0.252	0.132	0.011	0.009	0.019
Limits for Drinking Water *	0.003		2.0	0.3	0.001	0.5	0.02	0.01	3.0
Limits for Cropping @	0.01		0.2	5.0	-	0.2	0.2	5.0	2.0
Fish Samples	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$
F3a	<0.001	<0.001	0.459	25.048	32.194	3,652	1.158	3.154	22.254
F4a	<0.001	<0.001	0.160	5.312	25.681	0.998	0.919	3.854	8.906
F5a	<0.001	<0.001	0.395	10.450	18.894	0.100	0.779	0.679	4.156
F7a	<0.001	<0.001	0.119	7.944	9.153	0.357	1.347	2.060	5.369
Soil and Sediment Samples	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$	$mg.kg^{-1}$
	Cd	**Co**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
S1a	2.398	2.298	1.199	1650.150	138.961	13.487	1.499	0.200	17.283
S2a	<0.001	<0.001	1.290	1187.773	63.716	11.810	1.489	2.481	10.520
S8a	<0.001	<0.001	1.096	2411.624	59.862	24.424	4.685	17.944	20.138
S10a	<0.001	<0.001	2.495	2881.725	20.062	40.523	5.689	23.855	34.734
S11a	<0.001	<0.001	3.975	2837.209	25.343	26.834	7.851	23.753	37.368

* WHO (1993) @ cited by Pescod (1992)

Table 4.8.2: Heavy Metal Analysis: River Sisa at Asago. Samples taken January 2001

Water Samples	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}
	Cd	**Co**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**	**As**
W1b	0.420	0.000	0.000	5.946	0.773	0.386	0.000	0.218	0.202	2.400
W2b	0.840	0.000	0.066	16.520	0.781	0.546	0.000	0.368	0.530	1.238
W4b	0.006	0.000	0.000	9.480	0.851	0.064	0.004	0.112	0.276	0.986
Limits for Drinking Water *	0.003	-	2.0	0.3	0.001	0.5	0.02	0.01	3.0	0.01
Limits for Cropping @	0.01	-	0.2	5.0	-	0.2	0.2	5.0	2.0	0.10
Fish Samples	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}
F3b	0.000	0.000	0.079	4.496	0.134	0.000	0.506	0.677	3.875	6.145
F4b	0.000	1.153	0.311	40.345	0.128	0.000	2.050	4.044	5.928	5.836
F5b	0.000	0.000	0.121	10.425	0.013	0.000	0.000	1.920	9.170	6.903
F7b	0.000	0.326	0.041	13.299	0.030	0.000	0.000	1.792	5.804	3.208
Soil and Sediment Samples	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}
	Cd	**Co**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**	**As**
S1b	0.000	0.000	0.000	2701.685	0.448	9.217	0.000	6.739	29.435	11.903
S2b	0.000	0.000	6.544	3327.714	0.253	24.888	0.000	5.354	44.621	13.965
S8b	0.000	4.837	6.022	5081.935	0.252	42.843	4.640	14.018	65.350	11.469
S10b	0.000	0.000	0.395	654.563	0.522	10.010	2.748	1.766	9.323	13.048
S11b	0.000	0.000	2.572	2888.229	0.207	34.125	0.000	18.497	32.416	16.150

* WHO (1993) @ cited by Pescod (1992)

Water samples W1a, W1b and W2a, W2b were from the Sisa above the confluence with the Oda, and W4a, W4b were taken c. 20 m below the confluence. Sediment samples S1a, S1b and S2a, S2b were from the Sisa, S10a, S10b and S11a, S11b were from the river bank (1.5m and 20m from the river respectively) of the Sisa, while S8a, S8b were taken from the floodplain about 20m below the confluence. Only mud fish samples (F3a, F3b and F4a, F4b) were trapped in the Sisa above the confluence, after several attempts; though two tilapia varieties (F5a and F7a) were trapped about 20m below the confluence. Fish were not plentiful, even in the wet season, and it required many visits in the January period before enough fish were trapped for analysis (including mud fish F5b, F7b 20m below the confluence). The age of the trapped fish could not be determined.

Though two such small samples can not be regarded as conclusive, it is noticeable that the recorded levels of heavy metals in the fish are significantly higher than those in the river water (Tables 4.8.1 and 4.8.2). Only cadmium (Cd) and cobalt (Co) values were lower in general in fish than the equivalent values in river water, and in most cases lower than detectable limits.

With respect to bank and floodplain sediments, although concentrations of heavy metals are in general significantly higher than those in river water or fish, no clear pattern emerges from these results (Tables 4.8.1 and 4.8.2). Levels of iron (Fe), zinc (Zn), nickel (Ni), lead (Pb) and manganese (Mn) are higher in the samples of land sediments compared with those from the river; whereas levels of cadmium and mercury are higher in the river sediments.

Likewise, there is no very clear pattern of difference between the wet season and the dry season results. However, levels of cadmium, iron, mercury, lead and zinc are generally higher in the dry season river water samples. This does indicate that there might be some concentration of heavy metals during times of lower flow. As might be expected, there is no systematic difference in fish tissue or bank/overbank sediments between wet and dry seasons. Dry season stream sediment samples do show higher concentrations of copper, iron, manganese, lead and zinc, though with such small sample numbers, this should be regarded as indicative only.

It is noticeable that the mercury determinations show very much smaller concentrations in dry season fish tissue and bank/overbank sediments than the equivalent wet season values. This systematic difference is not readily explicable by field variables, and it is suggested that these particular results be treated with caution.

With regard to averages of three samples taken in early (dry-season) 1999 by Cornish *et al* (1999), it should be noted that the present analytical values are generally higher than those of Cornish *et al*., if consistent in pattern. This may be due to between-laboratory variatrion, and would require careful consideration in any further work.

4.8.3 IMPLICATIONS FOR HEALTH

At first sight, the limits for safe drinking water as set out by WHO and EU standards are not consistently exceeded by the averaged water chemical data from the River Sisa at Asago, though the averaged values for turbidity, conductivity ammonia, chloride, oils and greases and E-Coli bacteria do, and those for nitrites are relatively close (Table 4.7.4). However, individual readings of all measured parameters do exceed the threshold values at times, reflecting sampling closer to individual polluting events, or patterns related to water levels. There is no clear temporal variation evident in data, though some parameters show increases in the drier part of the year (December to February). Some increases in the early part of the main wet season (April to June), presumably caused by pollutants which have built up in the dry season being flushed through the system, are also evident.

The bulked water chemical data show a decline in most measured parameters from the highly polluted sites within the southern part of the city (Atonsu, Kaase, Daban) to Asago. In contrast, values of total dissolved solids build up in the Sisa system from within the city to Asago, while most other parameters remain over or relatively close to threshold conditions (Table 4.7.4) despite this dilution effect. The main sources of these pollutants are partly directly human, in that the presence of high levels of coliform bacteria are evidence of direct or indirect additions of human wastes, but also ‘industrial’ in the broadest sense. There is less evidence of pollution from agriculture, as might be evidenced, for example, by high general or time-specific levels of nitrates.

With respect to heavy metals (Tables 4.8.1 and 4.8.2), safe drinking water standards are exceeded consistently by cadmium, iron, mercury and lead levels in river water at Asago, strongly suggesting that the river water is unsafe to drink, even when boiled. The dry season arsenic levels in the river water are also significantly higher than the WHO limit for drinking water (Table 4.8.2), although as explained earlier, reliable wet season arsenic levels were not obtained. These heavy metal concentrations tend on the whole to increase during the dry season of low river flow, at the times when use of river water for domestic (or even drinking) purposes will be at its highest. The evidence of build up of heavy metals in fish tissue as compared with the river water suggests that caution should be urged in consuming these fish until a study of uptake pathways and residence times can be effected.

A further health concern must be the dubious quality of the water taken from the private hand-dug well in the village (Table 4.7.4). This well is approximately 150 m from the river, and only a few metres above river level. The level of contamination (including faecal coliforms) suggests that the groundwater here is extensively contaminated by leachate of sewage and chemical pollutants. As a direct result of Project activities, this well is now reported as being regularly decontaminated by the addition of chlorine, though this did not have an appreciable effect on the monthly data in the latter period of monitoring. Although this well has been much less used since the village borehole was fully commissioned in 2001, it is still used by those households close by, and for general domestic purposes. If used for drinking water untreated, it still appears to be a risk to health.

4.8.4 IMPLICATIONS FOR IRRIGATED AGRICULTURE

The principal concentration of irrigated land encountered in the Project surveys is used for vegetable cultivation on the left bank of the Oda below its confluence with the Sisa. Farmers believe that the water provides a detectable fertiliser benefit to the irrigated crops, and it would be expected that the polluted waters downstream of Kumasi would make a significant contribution to the nitrogen requirements of irrigated crops there. The concerns lie with the concentrations of faecal coliforms and heavy metals.

Many heavy metals, such as lead, are not plant nutrients and thus, if taken up by vegetation, would tend to accumulate therein. The question of uptake rates is, however, not straightforward. For example, Drescher (1994) found that in some circumstances heavy metals (cadmium, copper, zinc) present in high concentrations in the soil do not enter the food chain via vegetable cultivation. However, as Cornish *et al* (1999) point out, there are currently no guidelines for threshold values of heavy metals in water used for irrigation. The standards used for cropping (Pescod 1992 - see Tables 4.8.1 and 4.8.2) are, however, exceeded by river water at Asago for cadmium and manganese. Additionally, levels of mercury are high.

The build-up of heavy metals in fish and river/bank/floodplain sediments does indicate that residence levels are high, and problematic. Irrigation is a likely contributor to these, particularly in the drier parts of the year when relative evaporation levels are higher. As Westcot (1997) points out, the presence in river water of faecal colifom concentrations above 1000 per 100ml does not necessarily preclude the use of such water for irrigation, but concentrations such as those found in the Sisa at Asago (Table 4.7.4) suggest a likely danger. As noted earlier for the river itself, the principal sources of these pollutants in overbank deposits are human wastes and industrial effluents.

Fertiliser additions to the soil would add to the levels of undesirable residues. The use of nitrogenous fertilisers leads not only to the export of nitrogen in crops, but the build-up of nitrate in groundwater. In fact, the majority of the farming systems described around Kumasi use low amounts of fertiliser inputs, and this was confirmed by the Project's investigations of farming systems (see Section 4.6).

4.8.5 RECOMMENDATIONS

The particular problems of water quality at Asago are not easily solved, and require, above all, a much more rigorous enforcement of controls on the dumping of human and industrial wastes into the Sisa/Oda system. In the short term as far as health is concerned, simple measures will help. These should include the provision of a second borehore (ideally reserved for drinking water and cooking), further away from the river and as far upslope as possible, for domestic use; more systematic use of rainwater harvesting techniques; the boiling and filtering of river water and contaminated well water when forced to use it; and avoidance of fish consumption (in fact already reported in our survey – fish is consumed less locally than in the past, but instead is sold in Kumasi!). The concerns raised as to the possibility of groundwater pollution (suggested by hand dug well contamination) should be addressed by a survey of groundwater status in and around the village. The presumption that relatively shallow water is contaminated but that deeper parts of the aquifer (as tapped by a borehole) remain uncontaminated at present needs to be tested.

With respect to irrigation, while it is undoubtedly true that the river water provides crops with a nitrogen boost, other parameters remain problematic. In particular, there is an urgent need for detailed research into the residence times and uptake pathways of heavy metals in order to ascertain whether or not crops irrigated by river water are, or are not, a danger to health.

4.9 Schools' Water Quality Test Kits: an experiment in environmental awareness-raising [3A]

4.9.1 INTRODUCTION

In fostering sustainable and equitable watershed management practice, the involvement of all stakeholders is essential. In this respect, a key step in ensuring that communities participate in decision-making, and have access to ownership of the process of watershed management, is the raising of awareness at the community level, of the nature of their environment and the necessity to monitor (and if necessary control) resource use within it.

In this respect, the Project team see schoolchildren and teachers as key potential adopters and disseminators of awareness and 'good practice' in relation to daily behaviour affecting the local environment in general, and water quality in particular.

In order to test the feasibility of a possible system of environmental self-monitoring, a pilot scheme was initiated in September 1999 by placing relatively simple water quality test kits (the *Catchment Action Starter Kit*, manufactured in South Africa by Umgeni Water Company) in five Junior Secondary Schools and one High School the catchments of which included the villages close to water quality sampling points. These kits are designed for use by children, youth and community groups as part of their formal education (where this relates to their syllabus) or as part of broader community education and awareness of the state of their local environment.

The principal aims of this part of the wider Project were, firstly, to test the effectiveness of relatively simple water quality test kits at schools' level as a relatively low-cost means of improving environmental awareness (and also contributing to science education); and, secondly, to encourage the schools to use their newly-acquired knowlege for the wider benefit of their communities. Underlying this is the aim of increasing community awareness of the necessity to protect the most vital of natural resources for peoples' health and wellbeing. At present, most Junior Secondary Schools in Ghana, and particularly those in peri-urban and rural areas, lack the laboratory facilities for their pupils to experience 'hands on' experimentation, and this Project has piloted this approach in Ghana.

Following initial demonstrations to the teachers of the use of the kit, by Project staff local assistance was provided throughout the Project from the Kumasi offices of the Environmental Protection Agency (EPA) and the Ghana Water Company (GWC). The regular commitment to visiting schools and providing advice has been invaluable in maintaining a support network for the project schools. EPA has also been responsible for maintaining supplies of reagents, booking sheets and other appropriate materials.

It must be emphasised here that there was no compulsion involved – no requirement to involve any specific cohort of pupils, no rigid sampling framework, and no targets of any kind to be met. This was very much in the nature of an 'experiment' to see how willing teachers and pupils would be to take on this new knowledge, what they would gain from it, and what use they made of it in interactions with their communities.

More detail of the results obtained and problems encountered can be found in McGregor *et al.* (2001).

4.9.2 PHASE 1: THE 'CATCHMENT ACTION' TEST KIT

The tests carried out in the first phase of the project (September 1999 to July 2000) included:

- Visual estimation of number of types of pollutant near the site
- Visual inspection of the water
- Water life
- Water temperature
- Water pH
- Dissolved Oxygen
- Turbidity

Each test grades water quality from 0 percent (unpolluted) to 100 percent (totally polluted).

The schools were asked to test at the same locations as those being tested regularly by EPA and GWC as part of the wider project, but were encouraged from the start to test additional sources, either regularly or occasionally if specific requests were made by members of their communities as a result of perceived problems. The frequency of testing was left to the teachers to decide, and would be dependent on the time allowed by the priority demands of the formal school syllabus, the degree to which the teachers themselves were motivated by the project, and the degree to which the pupils were willing to participate. Bearing in mind the regular EPA/GWC sampling interval of 1 month, a guideline of 3 weeks to a month between samples from a specific site was suggested as an appropriate sampling interval for the key sites.

The schools were invited to participate in the Project Workshop held in February 2000, to facilitate all six schools involved meeting together for the first time to exchange experiences and to report on their progress and problems. All six schools were represented, and in the case of the 5 JSSs, some of the pupils participating directly in the Project attended. A number of minor issues were raised regarding the operation of the kits, and were followed up by visits to the schools during the week following the Workshop.

At the end of summer term (July 2000), 10 months after the introduction of the schools to the test kit, the 5 JSSs were continuing to support the project enthusiastically, and had started the process of taking their newly-acquired knowledge of water quality issues to their communities. In three cases this had taken the form of plays acted out by the pupils in front of community gatherings, as part of the wider dissemination and community participation activities of the project. The High School chosen (a prestigious fee-paying school) was unable to implement the project successfully owing to the more stringent requirements of their curriculum and competing demands on student time. The inference from this is that the JSS level (approximately 11 to 14 years old) is an appropriate level at which to focus this effort in the Ghanaian context.

Feedback to the schools included sets of 'Teachers Notes' on how the kit results could be interpreted, a report on the results obtained during Phase 1, and a comparison of the test kit results with the 'scientific' results obtained by GWC and EPA from the same sites (see McGregor *et al.* 2001 for details).

A range of problems were encountered, and were resolved satisfactorily for the most part (Table 4.9.1).

Table 4.9.1 Problems encountered in Phase 1 of Project, and solutions implemented

PROBLEM	SOLUTION
1. Logistical Problems	
Availability of large plastic bottle for turbidity test	Empty bottles obtained and supplied to schools
Availability and cost of accessories	Kerosene stoves and pans for boiling water supplied where requested
Staining of bottles for dissolved oxygen test	Supply of clean bottles provided; test now superceded
Reluctance of children to carry samples from more remote locations	See how this goes. It tells us something if they are unwilling to do this. Suggestion of paying children not encouraged, as this would not be sustainable.
2. Problems with Technique	
Understanding the manual	EPA followed up with visit to schools shortly after kits were issued. Explanatory notes provided where deemed necessary
Difficulties with booking sheet supplied	Customised booking sheet developed
Use of 'water creatures' chart	Presence/absence criteria adopted - ongoing development
Nature of the coliform test: reluctance to carry out test	Test stated as optional
Data recording errors (eg not recording date or not recording which water source sampled)	Need for consistency stressed
3. Problems of Interpretation	
Initial alarm at presence of occasional negative indicators of poor water quality	Reassurance that a range of negative indicators or a sudden observed deterioration in quality of water source is required for a problem to be identified

The problems encountered could be split into three broad categories - logistical, technique and interpretation.

Minor logistical problems were solved by supplying appropriate backup materials such as large plastic bottles (not easily obtainable locally) and support for boiling water for sterilisation. One unforeseen problem was the reluctance of children living some distance from their school to carry water samples to school. A teacher's suggestion that the children should be paid transport costs on the days they travelled with samples was resisted, as this would not encourage sustainability, and the central plank of motivation for knowledge would be subjugated to one of motivation for financial reward.

Initial problems relating to technique centred around the initial phase of getting to know unfamiliar techniques. Teachers encountered some difficulties in using the manual provided with the kit, and assistance was provided through visits to the schools by by EPA. A further problem encountered with the test kit relates to its development within the context of South Africa. Many of the 'water creatures' indicated in the test kit are either not present or not common in Ghanaian water bodies. In order to overcome this problem with what is a very useful indicator of water quality, the Project considered, with the schools’ assistance, a system for identifying and assessing faunal indicators of water quality in the waters around Kumasi.

The nature of the test for faecal coliforms, which involves extracting the bacteria from a water sample and then incubating the extract at body temperature for 24 hours, caused some understandable concern. The suggested method of incubation involved strapping the petri dishes containing the extract to the upper body for the 24 hour period. It was made clear to the teachers that this had to be a personal decision to proceed with this test, and that 'no blame' would be attached should the teachers decide not to undertake this particular test.

Data recording errors were made by some teachers, and these persisted despite reminders of the need for consistency.

In terms of problems of interpretation of test results, a further unforeseen development was the way in which minor changes in water quality, or individual test changes from 'good' to 'bad' indicators, were taken up as indicators that the water source was polluted, and should not be used. It was made clear from the outset that the tests were indicative only, and that GWC/EPA would investigate any perceived problems with the water sources, but alarm occurred nevertheless, and quickly spread to the schools' communities! This took some careful repetition of the basic principle of 'indicative only' to overcome. The notion that one or two indicator changes were not necessarily indicative, but a broad pattern of change was, required reinforcement.

In addition, EPA and GWC followed up any specific concerns raised by the schools or their communities as a direct result of the schools' water quality testing, or as a result of increasing community awareness. These interventions included:

- laboratory analyses of samples from a range of water sources where concern has been raised
- investigation of an alleged incident of tampering with a hand-dug well
- investigation of an incidence of 'Guinea worms' in a hand dug well
- regular chlorination of a hand dug well found to be polluted
- repair of a leaking pipe within the GWC distribution network.

4.9.3 PHASE 2: THE 'MICHROCHEM FIELD KIT'

The 5 JSSs were issued in July 2000 with a more sophisticated water quality test kit, Somerset Educational's *MicroChem Field Kit.* This kit is also manufactured in South Africa, but comprises a wider range of tests and provide a more systematic description of water conditions. Coincidentally, an agency for Somerset Educational was established in Accra in late 2000. It was anticipated that the new testing procedures would be implemented from the start of the new school year in September 2000.

The kit provides quantitative measures of the following parameters:

- pH
- turbidity
- water temperature

and a qualitative assessment of:

- coliform bacteria
- dissolved oxygen*
- electrical conductivity
- nitrite*
- nitrate*
- orthophosphate*

These tests enable the pupils and their teachers to monitor the relative health of their water sources in a more sophisticated manner than was possible with the original test kits, and to identify any qualitative changes in them. The tests marked * above rely on a colour change to indicate whether or not a particular indicator is in a 'good', 'probably OK' or 'bad' condition. As with the initial test kit, any major fluctuations or measurements that cause concern are reported to EPA and GWC for verification and follow-up.

The general impression gained from this phase was that the more elaborate requirements of the new kit did not prove to be problematic, almost certainly as a result of the experience gained in using the simpler test kit initially. The reluctance of children to transport samples from further distances was reported as persisting, although in both cases these more distant sites were sampled in the new school term. Few other logistical problems have been encountered so far (Table 4.9.2).

Table 4.9.2 Problems encountered in Phase 2 of Project, and solutions implemented

PROBLEM	SOLUTION
1. Logistical Problems	
Reagent for coliform test requires accurate weighing	EPA to supply pre-weighed and sealed test tubes of reagent
Relatively few dissolved oxygen tablets supplied with kit	More supplied; manufacturer is looking at supplying more with kit
Reluctance of children to carry samples from more remote locations	Continue to see how this goes. 'Field trip' option has been explored by the two schools affected by this
Staff changes	Changes of staff in summer 2000
2. Problems with Technique	
Minor errors or inconsistencies in manual supplied with the kit	Errors or inconsistencies explained to schools and notified to manufacturer
Understanding the context of the new tests	Explanatory notes developed (ongoing)
Difficulties with booking sheet supplied	Customised booking sheet developed
Difficulty with improved coliform test	Coliform test left as optional
Electrical conductivity test: difficult to perceive differences in strength of light	Practice with different strength salt solutions until more confident in interpretation
Accurate use of propette to supply correct amount of reagents is difficult	Filling appropriate vessel to just below the rim is accurate enough for tests
Lots of colour change indicators - a problem with colour blindness	No obvious solution as kit is designed at present. Manufacturer has taken point on board

Coincidentally, staff changes took place in three of the five schools over summer 2000, namely a new Head Teacher in one school, transfer of one of two teachers involved in a second school, and in a third school all three teachers involved left to take up further studies. These changes proved not to be problematic. The new Head Teacher was enthusiastic, and a new teacher (with help from established staff) took over from the group of three. The transferred teacher was keen to experiment in her new Primary School situation, to see if younger pupils could benefit from access to the material. She was supplied with a kit and some consumables, and asked to liaise with EPA.

There were minor problems of technique (Table 4.9.2), though these relate as much to the kit itself, rather than to any difficulties of interpretation by teachers or pupils. A point made by several of the teachers was that they need a better local context to explain the meaning of the new range of tests, as these relate to pollution commonly occurring in the Kumasi peri-urban zone. Accordingly, a set of explanatory notes was developed.

The coliform test, though improved in terms of reducing the potential for contact between skin and sample, remained problematic, though most schools did attempt the test with varying degrees of success. The manufacturer does produce an incubator which runs off mains electricity, but this is relatively expensive to purchase, and in any case not all of the selected schools had electricity. The future feasibility of obtaining and adapting small solar cells which would store enough heat energy to maintain sample temperature overnight was raised with the manufacturer of the kits.

In general, the response of schools remained positive through the school year September 2000 to July 2001. All schools reported that the new kit was both easier to use and gave a much better picture of water quality. All spoke in detail about their activities with their communities, or their plans to take the new knowledge forward. Three of the schools had already put on plays, and the remaining two schools said that they had plans to do so. All schools commented on the interest already engendered in their communities by their activities. Among the groups with whom the test kit and its results had been discussed by teachers were Parent-Teacher Associations, village chiefs and elders, Unit Committees (the main forum for planning activities and group action at community level), and the community WATSANs (water and sanitation committees). As was noted, often the same people serve on all or most of these, and these tend to be the more ‘aware’ members of society. The local District Assemblyman or Assemblywoman had been contacted by some of the schools, again with positive feedback.

Some schools expressed concern as to the financial costs involved, specifically in the two schools which were some distance from the Project sample points. This is linked to the reluctance of pupils travelling from outlying communities to carry water samples to school. It was agreed to reimburse transport costs for teachers involved, though not for pupils who would be going to school in any case.

The teachers and pupils were brought together at the second Project Workshop in March 2001, when the outcome of a 'brainstorming' session was presented in plenary discussion. This elicited the direct interest of a range of stakeholders, and a lively discussion ensued.

Following the 2001 Workshop, in order to improve the local context of the test kit results, and to provide teachers with a structured approach to better integrating the new knowledge obtained from the use of the test kit, a 'manual' was produced for the teachers. The manual was in six parts, and started with a brief overview of the kinds of polluting activities found in the Kumasi area, and comments on the sources of water, waste management and sanitation, and industrial uses of water.

Part 2 gave the context of the various water quality tests in peri-urban Kumasi, outlining why each particular test tells us something about the quality of the water being sampled. Part 3 was a set of tables, taking each test in turn and setting out the kinds of questions that might be posed by the teachers to their pupils; or taken forward into community awareness-raising exercises (see Section 6, Table 3.6). Part 4 was a similar set of tables, but in this case more geared towards community education. In these tables (see Section 6, Tables 3.1 to 3.5) specific activities are interrogated in the context of where it is better not to carry them out. This is followed by a block diagram illustrating examples of bad practice in a typical landscape. The manual concludes with a synopsis of how to set out the results obtained from using the new water quality test kit.

It should also be stressed that we were encouraging the use of the tests in the wider curriculum by the teachers. The test kit provides a working resource to demonstrate such concepts as electrical conductivity, acidity and alkalinity, chemical composition of rocks and soils as well as water, aspects of river biology such as the importance of dissolved oxygen, and so on. Additional reagents were promised as required to enable teachers to use the kit as a wider teaching resource. In the end, this initiative did not appear to have been taken up. Why this was so is not entirely clear. Teachers repeatedly (including at the Final Workshop in March 2002) stated their willingness to do this, but did say that it could not be fitted into the syllabus, despite its obvious potential as a demonstration tool. The explanation is most likely an understandable reluctance to depart in any radical from the syllabus without the overt sanction of the District Education Authority. District Education officers we spoke to (including two Directors and one Deputy Director) were supportive, but even with their support direct financing would be problematic.

4.9.4 STATUS AT THE END OF THE PROJECT (March 2002)

The major question exercising Project staff (including those at EPA) and the teachers involved was sustainability after the end of the Project. This was discussed at the Final Project Workshop (March 2002), in the context of a gradual dropping-off of the frequency of test results carried out by the schools as the date approached.

The Ashanti Regional Office of EPA expressed a strong wish to assist in keeping the schools testing alive until further funding could be provided, and undertook to continue to liaise with the schools. Accordingly, the Project supplied sufficient reagents to keep the schools supplied for approximately a further 12 months from March 2002.

There are several problems of longer-term sustainability, principal amongst which is the cost of replacement reagents. Staff continuity is a further issue in this respect. Also, in order to keep the project 'alive' the continuing involvement of EPA, GWC and, for the community liaison, CEDEP is crucial. But these organisations have a range of competing claims on their resource, and were totally dependent on the Project to underwrite these activities with financial assistance. EPA have expressed a strong interest in the schools' activities, and a joint bid for funding (EPA, Royal Holloway and the local Agent) to widen the scope and geographical coverage was put together. This fell foul of the change at the top of EPA following the change of Government, but will be revisited shortly.

However, the West Africa office of the International Water Management Institute (IWMI) has expressed strong interest in the proposal (November 2002) and we are currently putting together a modified bid for a pilot project in collaboration with IWMI. Further, the Ashanti Regional Office of EPA is presently seeking funding from the national office in Accra, to set up Science Clubs, based initially on our Project schools, and including continuation funding of reagents for the water test kits.

An encouraging development has taken place in Cameroun recently, where the kits have been introduced to schools, and where a number of schools have raised funds to purchase and maintain kits. Again, the question here is whether communities would support such an initiative, as the schools themselves do not have the finance to do this, and their more immediate priorities in most cases are in maintaining or refurbishing the school buildings.

As in many such Projects, there is a danger of raising expectations. This Project did not have the funding to expand the water quality test programme, nor indeed was it the remit of the research to do so. Yet it is inevitable that the creation of new knowledge, and the raising of awareness, both in turn create raised expectations. The linkage established by this Project was progressively with the Project's work in the communities (with the involvement of CEDEP and the Bureau of Integrated Rural Development (BIRD) at KNUST), where the focus was latterly on setting up and testing the Watershed Management Framework - a 'best practice' methodology for sustainable environmental co-management (See Section 6).

Although the test kit project was only one strand in a wider research Project, it was increasingly seen by the Project staff as an important element of not only helping to educate the children themselves, but also to take this knowledge into the communities in a positive way. This is seen as important generation of new knowledge for a range of stakeholders, and the potential is underlined by the impact even this small experiment has made. The strong interest shown by EPA and IWMI in taking this forward is testament to the potential. The work done here has indicated the most appropriate channels for dissemination, but more research needs to be done in this respect than was possible under the Project.

It is hoped, then, that the facilitation of these water quality test kits by the Project will act as a catalyst to improved science education in the selected schools; will increase environmental awareness in general, and an appreciation of water quality issues in particular, in the schools; will provide a platform for the education of communities on these issues by the schoolchildren themselves; will assist in the promotion of better hygiene and health practices; and will enhance the role of EPA and GWC in environmental resource protection in peri-urban Kumasi.

The major beneficiaries will be the children themselves, and through their acquired knowledge to their families and to future generations. It is anticipated that through their increased awareness of the necessity to protect their environment, communities will become more aware through their childrens' experience. A further benefit will be the direct interface between EPA, GWC and schoolchildren, thus paving the way for effective environmental education and more efficient use and protection of water resources. By thus linking schools, communities and the environment, this Project will have impacted positively on hygiene, health and environmental protection.

ACKNOWLEDGEMENT
We wish to acknowledge the support of the District Education Offices of Kwabre and Bosumtwi-Atwima-Kwinwoma Districts and the Kumasi Metropolitan Education Office in agreeing to Project activities in the JSS, under their jurisdiction.

4.10

Local Agenda 21 issues in Kumasi [1B, 2A2]

Perhaps because of the local political complexities and implementational weaknesses, Kumasi has been slow to embark upon the UNCED Local Agenda 21 process. A formal agreement with the International Council for Local Environmental Initiatives (ICLEI) was signed only in May 1999 (KMA et al. 1999). By contrast, Accra has received substantial external funding for such initiatives by virtue of its capital city status, and became a member of the United Nations Centre for Human Settlements' (UNCHS/Habitat's) Sustainable Cities Programme in the mid-1990s.

The agreement, actually a three-way contract between the KMA, the Local Agenda 21 Stakeholder Group and ICLEI, provided for incentive grant funding in support of LA 21 activities, and, most importantly in the present context, financial support for a pilot 'Micro-enterprise refuse collection scheme for Atonsu Zones 4 (Monaco) – Kumasi'. This was designed as a pilot small enterprise development scheme to test different models of solid refuse collection, in terms of which two neighbourhoods served by a conventional contractor using large refuse lorries would be compared with two where community-based micro-enterprise collection would be organised and evaluated.

In line with the proposal, donkey carts were used initially for the latter, but as a result of environmental and cultural constraints, they were replaced by small tractors with trailers. Two of the original factors behind the choice of technology were poverty alleviation through employment creation, and the unsuitability of the road infrastructure for conventional large refuse trucks. The original scheme (for Zone 4 only) is now gradually being expanded into Zones 2 and 3. So far this process is incomplete and – partly as a result – it appears from informal feedback that the communities are losing their initial enthusiasm.

It was hoped that preliminary evaluation results might become available in time to consider its potential relevance in the more urbanised peri-urban villages where this Project (R7330) was working, especially Abrepo and Sepetinpom. However, delays in the inauguration of the Atonsu scheme meant that the KMA's preliminary evaluation had not yet been completed by mid-2001, when the final decisions regarding which demonstration micro-projects we could implement within R7330 were taken. Accordingly, we felt it appropriate to exclude refuse collection from our activities, although our WMF contains advice on the separation and safe disposal of waste in villages. Furthermore, an ESRC-funded doctoral student of ours, working on community-based solid waste management in peri-urban Kumasi in close association with this project, will be following up the Atonsu experiment and considering its relevance in the PUI. The latest information is that the KMA will not be evaluating the Atonsu scheme until the current phase of the Urban Environmental Sanitation Programme (UESP), of which it forms a component, ends in December 2003, with completion of the new Dompoase landfill site facility.

As far as we are aware, the four District Assemblies in our study area have no known agreements and activities relating specifically to LA21.

Although not forming an explicit component of the LA21 agreement between KMA and ICLEI, the strategy to deal with night soil warrants mention here. As identified in our Inception Report, the dumping of nightsoil collected from communal latrines and domestic tanks by the KMA and its private contractors has been a persistent health and environmental problem. Until 1998/9, many of the tanker trucks dumped their contents into the Subin River at a point adjacent to the Georgia Hotel in central Kumasi. This polluted the river, causing downstream contamination and a major local health hazard in stagnant pools. Following sustained protests, and as part of the World Bank-funded UESP, dumping ceased. Instead, temporary settling ponds were constructed close to the river banks further downstream, at Kaase, immediately to the south of the built-up urban area, for use while appropriately designed permanent settling ponds were built at Buobai, close to Duase (north east of the city) and at Dompoase, near Atonsu to the south of Kumasi city.

Although long completed and originally scheduled to commence operation on 1 August 2001, the new settling ponds at Buobai still stand empty, apparently on account of ongoing disagreements between the KMA and Environmental Protection Agency over environmental impact assessment procedures. Meanwhile, some 150 tanker trucks per day continue to discharge their contents into the temporary ponds at Kaase. However, the surrounding bund developed a major leak shortly after commissioning. This has never been repaired, with the result that – as we observed – a high proportion of new discharges flow downslope, through the breach and into the river.

The second set of settling ponds at Dompoase was also scheduled to be commissioned by August 2001, but excavation work on these has only recently commenced. As mentioned above, the solid waste landfill site at Dompoase is also now under construction.

As a result of these delays, a twofold public health and environmental problem persists: localised contamination, accompanied by an extremely noxious smell and extensive disease vector breeding site at the ponds themselves; along with heavy contamination of the river downstream. This has adversely affected riverine biodiversity and aquatic life, and has caused particular problems for peri-urban villages downstream. Asago, one of our study villages, has been severely affected. Not only is it the poorest of our study villages but its inhabitants were previously dependent upon the river for a high proportion of their water needs as well as for subsistence fishing. We discuss the implications of this situation in Section 4.8.

Local perceptions of the KMA and of environmental deterioration are thus very negative. The same is true more generally, as a result of irregular and inadequate solid waste collection even where the refuse skip system operates. The new KMA Chief Executive appointed by the new NPP government in early 2001, acknowledged the problems and promised to address them, but there appears to have been little generic improvement so far.

One other experiment in line with LA21 objectives warrants mention. In 1998/9, the Guinness Brewery sponsored construction of a biogas digester at Kaase. Undertaken under management of CEDEP, this was designed as a labour-intensive pilot project to provide some employment while also providing and testing a novel form (for Ghana) of sewage treatment facility in an area of high population density, low incomes, and totally inadequate sanitation infrastructure. Moreover, it would provide a steady supply of usable gas. Awareness was raised through public meetings in the community and the distribution of a cartoon leaflet. The facility raised several issues, including cultural acceptability of the process and the gas product, and whether a small user charge could be levied to cover maintenance (CEDEP 1999). Residents responded less than enthusiastically overall, and a design or construction fault soon rendered it inoperative. When we last heard in late 2001, it had still not been repaired. Thus, a potentially valuable experiment had apparently failed, in terms both of its continued operation and its anticipated role as a demonstration site (pilot project).

Even before the change of government, a process of revising Kumasi's environmental sanitation bye-laws had begun in the light of the government's new Environmental Sanitation Policy, published in mid-1999 (Government of Ghana 1999), which aims to prioritise and improve the country's sanitation services. The bye-laws update the definitions of categories of waste, and the responsibilities of the KMA, its agents and others in respect of safe disposal (KMA 2000). Somewhat surprisingly, there is little evidence in the bye-laws of any significant new departure, in terms, for instance, of providing more flexible and appropriate standards for different categories of residential area, or for participatory or SMME initiatives in this sphere in line with LA21. Overall, in the context of resource, equipment and personnel constraints, as well as the legacy of poor service and reputation, the KMA Waste Management Department will not readily be able to reverse the current situation on the ground.

More positively, the Ghana office of the International Water Management Institute (IWMI) is currently conducting an experiment on a novel method of compost production at the Buobai site, in co-operation with the KMA. This involves aerobic decomposition of a mixture of sewage sludge and paper/cardboard waste. If successful, this has the potential to provide large quantities of cheap organic compost while reducing the volumes of sludge and of waste paper currently sent to landfill or burnt. However, we now understand that funding for this project may end in early 2003, for as yet unknown reasons.

Overall, therefore, there has been little substantive progress in Kumasi and its peri-urban interface with respect to LA 21 issues. Although the KMA is a partner in a formal agreement with ICLEI, progress on the pilot refuse collection scheme has been slow. There has been no attempt to raise public awareness and the concepts and initiative are thus largely unknown. In the peri-urban areas, nobody we have been in contact with showed any recognition of LA21 and its objectives and associated issues.