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The Use of Geographic Information Systems (GIS) in Local Planning and Possible Contributions to Integrated Water Management in Sweden.

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ABSTRACT

This paper combines the planning problem of integrated water management with the application of the supportive tool GIS (Geographic Information Systems). It is structured in three different sections, a theory of GIS utilisation, a particular contextual embedding of local water management in Sweden and examples of local projects to support integrated water management and how these projects should be used in a municipal GIS.

INTRODUCTION:

When I was asked to give a presentation concerning GIS (Geographic Information Systems) and water management, I told the organisers that my occupation is landscape- and local planning. My interest in GIS is how to use it for professional communication and as visual language. My principal questions concern the purpose of a GIS system in local planning. What do we want to achieve with a GIS? Is it working satisfactorily in the local planning and decision making processes? Are there major advantages due to its use as compared to other means?

Water management is a highly interrelated procedure covering different spatial scales and various fields of expertise. However, different institutions usually reduce the meaning of water management to their individual requirements, and develop the subject isolated from each other. To reintegrate different approaches to water management is today a general aim in Sweden, but integrated water management is more easy to define in theory than to carry out in practice.

Communication during the local planning process has to bring together three different main groups; specialists, generalists and the public. First, specialists present their view of the affected landscape according to natural properties and social interests, second, planners or mediators combine the available information to conceivable scenarios, and third, the public concerned by the intended project should evaluate possible planning alternatives. GIS is supposed to be a suitable device to ease communication between all involved groups.

A) Theoretical considerations concerning GIS and local planning

What do we want to achieve with GIS in local planning?

GIS is a possible tool to improve local planning by simplifying continuously increasing information. If the pool of arguments for decision making increases, alternatives will better fit to the needs of the concerned people.

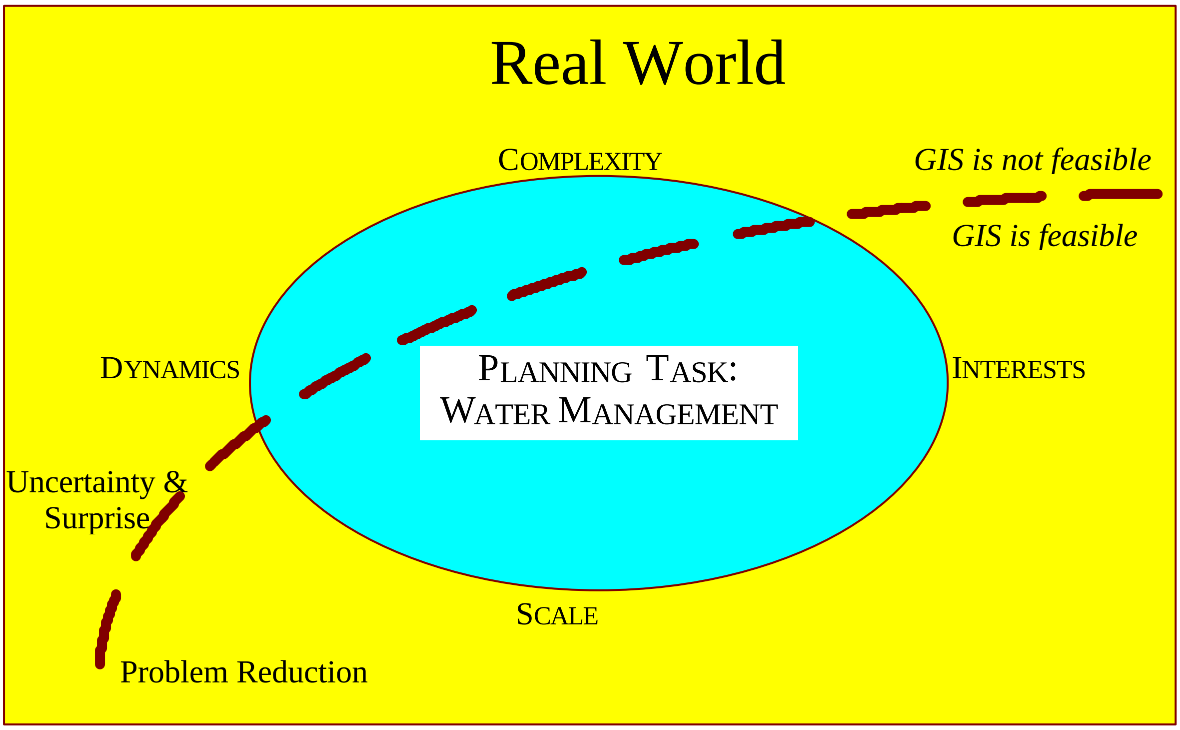
GIS is a possible means to visualise the likely local impacts of exogenous large scale transformations, such as global climate change or annual economic growth in different regions of the world and regional information such as climatic zones or regional characteristics of population development.

GIS can describe the properties of an area in a visual form. Different elements of the landscape can be presented in different layers. GIS is suited to visualise conflicts between local interests, e.g. the ones of agriculture, industry, business, recreation and nature conservation.

GIS can be a useful tool, but it is not suited for every problem situation. Figure 1 illustrates that the planning problem (water management, oval) is embedded in the more comprehensive “real world“ (rectangle). The “real world“ consists of complexity which we will never understand completely. There are uncountable natural and social processes going on in different spatial scales combined with different interests leading to dynamic changes. This will lead to uncertainty and surprise, which we would like to reduce in the planning situation. We simplify complexity by giving weight to known facts and specific interests. We continue to simplify the real world by defining scales and territories with conventional borders. Each scale from the global down to a house garden level needs its own GIS, which has to be adopted to the relevant situation. But we can only assume that we are dealing with the right scales and the right topics. The linkage between different scales is still an aim which may occupy researchers for a long time. Problems concerning the different dynamics of processes can not be solved alone with the help of a GIS. In these cases other tools seem to be more appropriate, for instance systems analysis or operation research.

Accepting these insufficiencies a GIS can ameliorate the understanding of relations between known but not yet combined parameters (right under the dashed line). Insecurity and surprise can not be avoided (left over the dashed line) due to the impossibility to describe the real world but considerably reduced as a GIS can improve the “information carrying capacity“ in the planning situation by making different types of information accessible (problem reduction to known factors).

Figure 1: The Limits to GIS



How can we apply GIS?

Three different possibilities of practical use of GIS are proposed. All of them are closely related to communication and selection of information. Fig. 2 explains that GIS works in three phases, as a means for presentation of expert results, as a tool for co-ordination for planners and as a means for integration of the public into the local planning process. In every phase the information becomes more simplified and more homogenous, relative to individual opinions and closer to the situation of the real world.

1. GIS as a presentation tool.
   In this case the GIS produces maps of inventories of natural properties (climate, water, soil, vegetation, etc.) or human induced activities (agriculture, industry, traffic, settlement areas, nature conservation areas etc.). All collected data about a specific region, area or place can be transferred to a GIS. Specialists elaborate results of their disciplines in a detailed way. They transfer detailed information into various maps. Their view of the world is relatively restricted and is based on their own discipline (first dashed line of fig. 2). Their information has to be made known to others to get to know planning bases and needs. Instead of to present a huge amounts of tables and lists, specialists present information in pictures. Intuitively a person should understand the issue.
2. GIS as a co-ordination tool.
   The previous generated maps of inventories[1]have to be combined in a co-ordinated process. New perspectives will emerge that could not be detected from an isolated vantage point. Generalists having an overview of the situation shall connect different disciplines in a more comprehensive framework. Uncertainty and surprise during planning and implementation are already reduced because different opinions have to be taken into consideration (figure 2, second dashed line). New linked information becomes available for planning purposes. At the same time constraints and conflicts of interests become transparent.

[1] If the information foundation is covering many topics it may be wise to divide them into subgroups. The structuring will provide a better overview and reduce the amount of unnecessary combinations.

3. GIS as a public participation tool.

The information load might be too dense for a general public that therefore keeps it passive. For this purpose a GIS has to be further simplified and contain only the main planning information. Instead of presenting hundreds of inventories and their combinations on maps one has to restrict oneself to a few essential results. A planner with sufficient overview should select this information . Uncertainty and surprise effects on planning are mostly reduced (third dashed line of fig. 2) since the public opinion is included and new aspects might appear.

Why does GIS not work satisfactorily in local planning ?

The previous arguments for GIS show the theoretical advantages of GIS in local planning. But what are the practical obstacles of GIS application in local planning?

1. Understanding of GIS

GIS became widely popular and affordable for local planning and administration. A GIS alone can not solve any problems. Behind GIS always people are involved who give their opinion and direct the content of GIS to a certain purpose. Even though the advancement of computerised GIS technology is impressive by itself, it needs first a user philosophy on how to apply GIS in an efficient way for local planning. (compare also Skage 1995). Only producing information without having a specific aim can rather complicate the problem than solve it.

2. Scale of GIS

What is the appropriate scale for the local GIS? If the scale is larger (above the scale 1: 10,000), the GIS is not suited to answer detailed questions. If the scale is smaller[2] (under the scale 1 : 10,000) it demands an enormous input of local information, which requires an exponential increase of data input and preparation work.

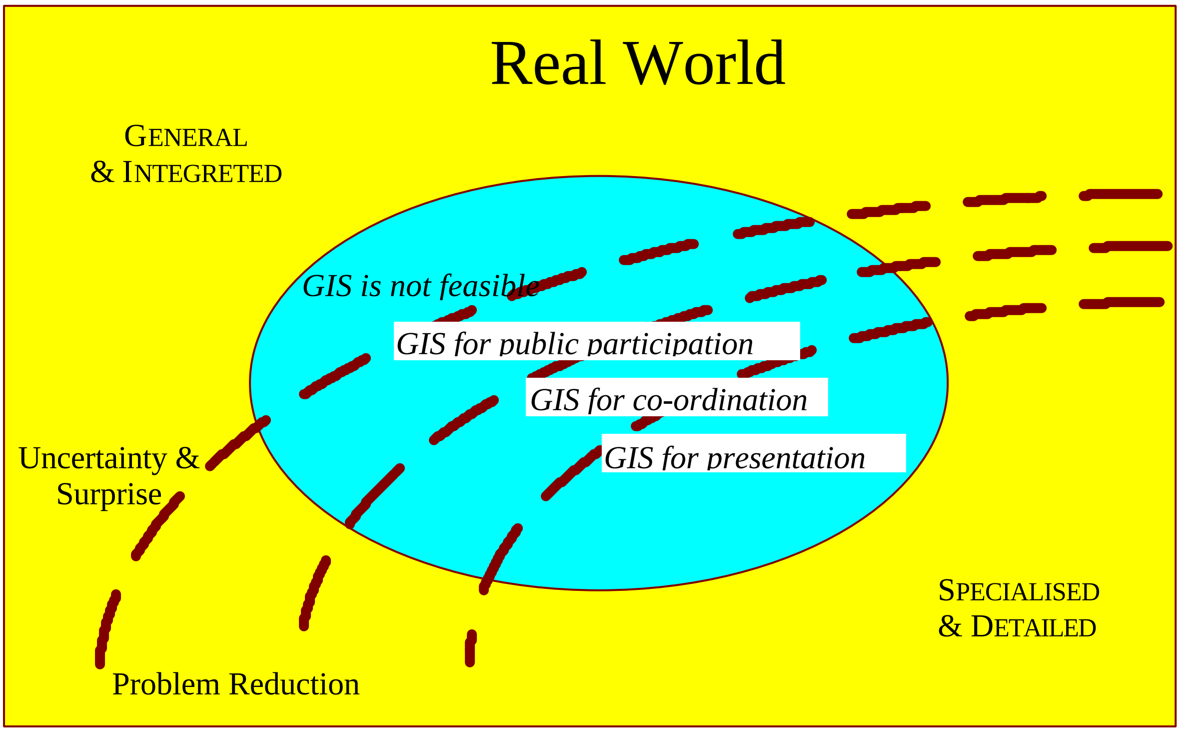
GIS generalises and mostly works with averaged values. On the small local basis the chances increase that the actual values differ from the averaged values of GIS.

3. Experimental period

A lot of time is necessary to learn the software, to digitise and homogenise existing information, to fill gaps of lacking information and to harmonise prototypes of local GIS. In some cases the technical problems become more significant than the planning tasks themselves. Less sophisticated traditional methods provide sometimes faster and cheaper results for ongoing local planning. For practical local planning a parallel approach seems advisable until the GIS is adjusted on the local base.

Figure 2: GIS as Tool in Local Planning

[2]For practical reasons, I consider any GIS going under the scale of the overview level as problematic to provide a balanced view of intrests. Economic questions may be answered at a larger scale than ecological or aesthetical questions, that go more into qualitative details.



B) LOCAL PLANNING AND WATER MANAGEMENT

Local planning is usually carried out in the smallest administrative unit of a municipality. Local planning also has to reflect more and more exogenous influence. The local administrators and decision makers have to react on them. External orientation and active search for information are requirements to cope actively with this development. This counts also for water management. Water management should not be limited to the local scale.

In the following part relevant Swedish characteristics concerning water management are described.

Water facts of Sweden

Water and urban development are closely linked to each other. Looking at the map of Sweden we find the largest towns located either by the sea or close to rivers.

Few countries in the world enjoy the same access to water resources as Sweden. Only 0.5% of the available water is used by the 8.7 million inhabitants. This low percentage is not surprising because Sweden is a sparsely populated country. Out of a total area of 450,000 km^2, one fifth is dominated by water[3]. Water is more equally distributed than the Swedish population. Water saving is a minor issue in Sweden. Only occasional local problems occur primarily in the intensively used agricultural areas and in the more densely populated areas of Southern[4] Sweden.

Most of the Swedish population lives in urban areas[5] (83% in 1991). The term “urban“ is in Sweden not limited only to cities. Each municipality has urban areas as the main space for human activity.

[3]8.7% are water area (lakes) and 11% under permanent water influence (wetlands).

[4]The river Dal divides the country: 20% of the population and 80% of the available water are north, while 80% of the population and 20% of the water resources can be found south of this border.

[5]The definition of urban area is: two buildings have to be less than 200m away from each other. This is a generous definition as compared to other countries. Some 550,000 ha or 1.25% of the total Swedish land area belong to this category. The highest urban population densities count 2000 inhabitants per km^2 in the three major cities namely Stockholm, Gothenburg and Malmö.

Water is supplied from the urban periphery nearby or in some cases, like in Southern Sweden, from distant areas[6]. Therefore water management in the urban areas is a task that goes far over the borders of the narrow defined agglomeration. The average annual precipitation in Sweden is 700 mm, varying between 380 mm and 1000 mm in different climatic zones. The annual total precipitation of Sweden is 300 km^3 or 0.8% of the global one. The total water use is 1.5 km^3 or 0.5% of the annual total precipitation[7]. This is equivalent to approx. 500 litres per person and day.

Water management in urban areas

In the urban areas planners always tried to give protection against extreme events of water as for instance flooding. This fact has somehow been lost in water management during the last decades. The water cycle is strongly influenced by the sealed surfaces of urban areas. Water retention is low as there is relatively few vegetation and percolation areas. This causes increased run off during high precipitation events. The peaks of water flow in the drainage system of the cities therefore increased excessively.

When the water supply system was constructed in the 60s and 70s[8] huge future industrial water consumption was included, disregarding the today usual water recycling technologies in industries. In addition the expected rural exodus from the North to the South and from inner to coastal regions was also overestimated. The now existing excess capacity in water supply systems creates often problems concerning water quality, since the water remains too long in the pipes.

Following the water supply system the sewer system with sewage treatment was built. For the coming years annual investments of 250 million Swedish crowns will be required for the renovation of the pipe and canalisation system. This will induce planning activities and entails a challenge to introduce new concepts in water management. Those concepts have to fit not only to ecological needs as restoring the natural water cycle but also to social values as for instance features of water as landscape elements.

Water management in the urban hinterlands and remote areas

Sweden consists to more than 90% of marginally used areas, covering forests, water areas and mountains. Forest areas can be seen as natural water filters and a massive natural water treatment system. As the forest land extends over 54% of the Swedish area we find there also a good water quality.

The intensified agriculture of Southern Sweden can be a threat to local water quality. Eutrophication of fresh water and nitrogenous pollution of sea water are the two major issues. The agricultural sector is independent and sometimes isolated from the municipal water management. At the beginning of 1996, an EU agricultural support program started for southern Sweden (Gotaland, and partly Svealand). The aims are to reduce agricultural surpluses and improving at the same time the environmental qualities. Restoring waters either as freshwater resources or as landscape elements with ecological and aesthetic functions are of major concern now. Thereby the European agricultural policy might help to achieve better water quality in rural areas.

It should be mentioned that the acid rain problem with the consequences of forest die back and lake acidification were already discussed as a main environmental problem in the 70s. Large liming programs - to counter lake acidification and the resulting fish death - were considered emergency

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[6]Malmöhuslän built in the 70s a huge water supply system transporting water from Småland to its communities.

[7]Personal communication with Jan Falk, Water Supply and Sewage Disposal Association of Swedish communities in Stockholm.

[8]In connection with the “miljon program“, when one million flats where built in less than one decade.

measures which did not solve the problem itself, the root of which mainly lies outside Sweden. Large scale international environmental problems, such as climate change[9], ozone depletion, loss of biological diversity are also a threat to peripheral areas. Those kind of problems can not be solved only on a local or even regional base. These exogenous factors can be responsible for disturbance of the water cycle in the peripheral areas, which supply urban areas with water. A good protection of urban water resources means therefore also a good protection of the periphery.

Towards integrated water management

The current practice

Various institutions manage special local water cycles. Water supply and sewage treatment is supervised by the municipal technical office. The water quality is controlled by the municipal environment and public health division. In addition other offices like the municipal planning and building division have some influence on the design of water facilities or the use of water as aesthetic component in cities. Single water systems for enterprises, agriculture and households are controlled by these municipal institutions.

Usually the control is based on existing laws regulating specific items of water management oriented on specific indicators. Problems are shifted from one sector to another without solving them. Efforts for integrated water management are primarily based on individual efforts and are not yet incorporated in the Swedish administration system.

The proposed future practice

Borders between sectors have to be bridged and spatial scales have to be linked. GIS can overcome sector borders within a given geographical scale. In the future GIS may be used more often as a tool to link different scales. It may be used to answer the practical question: what can be done on the local scale for local water management and what should be done on the regional, national, European and global scale for the same purpose? There exists already a lot of regional and national information that could be made available for local planning in a standardised GIS system.

One has to measure the fluxes of imported and exported waters as well as their quality. Hence, municipal water management is more than supervising and supplying water to individual consumers like it used to be in the past. In future we have to protect the whole water cycle including quantity and quality of water.

The “Local Agenda 21 Plan“ based on the Rio conference 1992, which has to be prepared by each Swedish municipality is a challenge for integrated water management.

C) LOCAL PROJECTS TO INTEGRATED WATER MANAGEMENT AND THE ROLE OF GIS

The practical design of a local GIS system.

GIS is today successfully introduced in the administrative work of state agencies[10]County administration offices (länstyrelser) and other national bodies (statliga verk). While most county administration offices of Sweden have already developed a local GIS, it is currently introduced in some municipalities[11]. If a GIS is to be introduced in local planning the relevant question may be at what scale. As mentioned before each scale from the global to the house garden level needs its own

[9]A possible sea level rise is a major threat in connection with climate change. It would effect 70% of the Swedish population living along a 3000 km long coastline.

[10]executive bodies of ministries, e.g. Lantmäteriverket (Surveying agency), Naturvårdsverket (Nature protection agency), Jordbruksverket (Agricultural agency), Boverket (Local Planning Agency), Vägverket (Roadconstruction Agency) and several more.

[11]Sweden has 24 prefectures (län) and 288 communities (kommun).

GIS. A small scale GIS (e.g. in the scale of 1:1000) may be desired, but it will cause enormous costs. There has to be a particular interest if one is going to built up such a detailed GIS for a certain place. In general we can say, the larger the scale the cheaper the system and the more probable it is to have a GIS covering the entire country and not only single spots. Today GIS systems covering specific topics for whole Sweden exist in the scale of 1:50000, for the more populated areas of Sweden even down to a the scale of 1:10000. (Lantmäteriverket 1995).

Integrated water management projects for Lomma municipality

Lomma municipality is with 52 km^2 land and 34 km^2 of sea one of the smallest municipalities in Sweden and situated between Lund and Malmö. Some 17,500 people live in the area. A computerised GIS is not yet publicly available. Lomma municipality invited my students[12] to design projects related to water management for the local AGENDA 21 plan. The students had primarily focused the ecological aim of integrated water management: to minimise throughput flows of water and increase the local use, re-use and multiple use of water (Lyle 1993).

The projects could not take advantage of a computerised GIS as the municipality had not readily prepared digital base maps. To transfer the available data to the computer for a project GIS in a scale of 1:1000 would have taken long time without a comparable advantages for the ongoing planning process[13]. The projects could be seen as properties of a larger municipal GIS system (app. 1:50000) for integrated water management, which does not exist yet. Each project has a qualitative character, and appropriate computerised maps in a larger scale would have allowed to estimate the quantitative effects to water management, if the presented projects will be applied wherever possible. The potential of new systematic solutions could be tested by this way. In the following I will explain what calculations could be done if a municipal GIS in large scale would have been available and disregard the design qualities in small scale, which could easily fill the content of another paper.

"Project A" dealt with collecting rain water from roofs to supply toilets. According to the amount of precipitation and required supply, the requirements of roof surface could be calculated. A computerised GIS system of Lomma would have allowed to calculate easily the amount of roof areas available for this purpose.

"Project B" was investigating how to improve the water quality by measures on agricultural land. Vegetation can filter out considerable amounts of leaching nutrients from agriculture and thereby water quality could be improved. Combining computerised land use and soil quality maps the different impact categories within the agricultural area can be visualised.

"Project C" was investigating the possibilities of improving the water quality in urban areas by infiltration and percolation of precipitation water. A computerised map of geological underground, vegetation and settlement areas could be combined to explain where infiltration and percolation is possible and where supportive measures are necessary.

"Project D" was to design a vegetation sewage treatment facility for houses on the urban fringe. A GIS could be used to investigate the rough amount of area necessary to clean a relevant amount of waste water by a planted vegetation or to answer how much sewer piping could be saved.

The four projects tried to link the urban natural water cycle directly with single water cycles of individual users without using the intermediate technical water supply and sewer system. The

[12] A. Larsson, E.Lloyd/K. Slättberg, N. Saitzkoff, J. Öster (1995) "Bärkraftig Utveckling som Kommunal Ansvarsområdet: sektor vatten", Dep. for Landscape Planning, Alnarp.

[13] This may also explain the resistance to prepare GIS at a small scale. Traditional methods with maps are considerably faster.

combined use of all projects for the water sector could be savings in the extent and maintenance of the municipal water network.
However, it is understandable that there will rise resistance to the mentioned projects, e.g. from the people in charge of the technical water system, who are confronted with a too high level of water supply. To keep the same service personnel in place the prices for water supply and treatment should be increased[14]. The power of water supply and sewage treatment institutions will decrease as soon as responsibility is decentralised. The mentioned obstacles show that changes in local water management based on ecological aims will proceed slowly. In long term planning it is essential that the interests of all concerned groups are taken into consideration. Thereby it may be less important to realise projects at once than that institutions dealing with water management are continuously confronted with new ecological visions.

What is the role of participants using GIS in water management

Finally, I will refer to the role of my students (landscape architects) in GIS of different scales as proposed in the theoretical part of this paper.
Landscape architects can act as specialists if a municipality starts with an integrated water management project. In this case a person respected from all parties dealing with water management in Lomma will be the co-ordinator. All inhabitants of Lomma municipality shall be regarded as concerned parties.
Landscape architects can be co-ordinators if we consider the smaller scale of a design project. They get specific knowledge from experts of other disciplines, e.g. botanists, engineers, soil scientists, hydrologists or farmers, businessmen and others. The concerned public are all persons who are in any way connected to those projects.
Landscape architects belong to the concerned public if we regard large scale problems, such as climate change. There atmospheric scientists, geophysicists, geographers, engineers, and others researching on the larger scale are then the specialists. A mediating forum like the International Panel of Climatic Change is the co-ordinating forum and all local planners represent concerned public.
Switching between scales means taking on various roles. It is of crucial importance to recognise one's own role in the problem's context. This is indispensable to make a GIS effective for the local planning purpose and to protect from an unmanageable information flow.

CONCLUSION

Integrated water management is a vision we should follow in any scale. Integrated water management means covering the whole water cycle in a global, regional and local dimension. Different water processes have to be understood in relation to each other. At the local scale it is no longer tolerable that different institutions only deal with their separated water system. To improve communication GIS can become a supportive instrument and can act as catalyst. It combines information originating from different sources. We can come closer to integrated water management in a step by step approach where all interested institutions should be involved and all geographical scales should be considered.
Theoretical consideration of GIS application in local planning are presented as follows. GIS is a presentation, a co-ordination and a public participation tool. GIS can combine information of different fields but to use it for local planning, interpretation and simplification are needed. It can increase communication by reducing complex information to a few and practical categories. Sector interests and conflicts become obvious and manageable. GIS technologies can be used to motivate

[14] This has a paradox effect on people who expected a decrease of their costs for water services by more ecological behaviour.

the public which is required for more integrated water management. Many planning processes take place simultaneously over different geographic scales. The role of the participants in several ongoing planning processes may be different in each one. Being a specialists, co-ordinator or concerned public may change according to the topic and scale of the planning problem. Awareness of which role the participants are playing will contribute a lot to the efficiency of GIS.

But there are also risks for applying GIS technology. It should not be only a technical playground but primarily should help to solve problems. GIS sometimes uses averaged values, which are not always congruent with the real world. By the way it is not always necessary to use advanced computerised GIS, sometimes simple drawings can also demonstrate the planning needs at a lesser cost.

Further limitations of GIS are: It can not cope with the dynamics of single water management issues. Without having a clear idea of the purpose of GIS, the amount of information can rather complicate the matter than solve it. Considerations of local GIS use should start first with a large scale approach, then an approach to smaller scales is recommended. The smaller the scale of the planning task the more problematic is the use of a large scale GIS.

The “Local Agenda 21 Plan“ of the Swedish municipalities is a major challenge to achieve more integrated water management and the application of an adapted GIS may be of interest.

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