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SYSTEMS VIEW OF INTEGRATED WATER QUALITY MONITORING WITHIN THE REQUIREMENTS OF THE NEW NATIONAL WATER POLICY IN SOUTH AFRICA

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ABSTRACT

The new National water policy will change the way water quality is managed in South Africa. The paper considers the water policy and the repercussions it will have for water quality monitoring in South Africa. Using the systems approach the paper discusses an integrated water quality monitoring system for ambient water quality and point and non point sources of aquatic pollution. The proposed methodology makes possible continuos assessment of water quality in an efficient manner so as to support water quality management in South Africa.

KEYWORDS

Water quality monitoring; integrated catchment management; point sources; non-point sources; pollution.

INTRODUCTION

The new National water policy (DWAF, 1997) recently adopted by the South African Parliament establishes integrated catchment management as the way in which water resources of South Africa will be managed in the future. The new policy is based on a set of principles which call for efficient, timely, transparent, optimum and rational water quality management and pollution control based on co-operative governance and public participation.

The key to the success of the new policy in relation to water quality management in South Africa lies in the data and information necessary for its effective implementation (Figure 1). Unlike the traditional approaches to water quality management the new integrated approach requires that we actually manage the whole water cycle on a watershed scale. The repercussions of this are that previously separated systems for monitoring of water quality (surface water monitoring, groundwater monitoring, effluent monitoring etc.) have to be integrated and expanded to include those elements of the water cycle which were previously not subject to water quality monitoring. Furthermore, the new water quality monitoring system must account for the catchment level implementation as required by the National Water Bill (DWAF, 1998).

This paper takes a systems view of the managed water cycle and looks at main elements which must be accounted for in the design and implementation of the new water quality monitoring system for South Africa to support the effective implementation of a National Water Bill (Figure 2). A number of alternative approaches have been considered and the one selected is suggested as appropriate. Discussion of advantages and disadvantages of the different approaches is beyond the scope of this paper.

ELEMENTS OF A MANAGED WATER CYCLE AND SPATIAL DESEGREGATION

As a basis for planning and management which uses historical data to evaluate the existing state and identify the trends to plan for the future (both short term and long term), water quality monitoring has a time dimension which must be precisely defined. Data on existing use of water quality must be differentiated from the forecasts of future water quality and the historical one. Since we are dealing with monitoring for management purposes most of the quantitative data will need to be collected daily, while data on the water quality may be collected less frequently. The initial design of a water quality monitoring system and the information system to support it should be flexible enough to assimilate new information collected with different time scales. It would then be possible to carry water quality assessments for management and planning purposes on a time scales from one day to as long as 10 or more years.

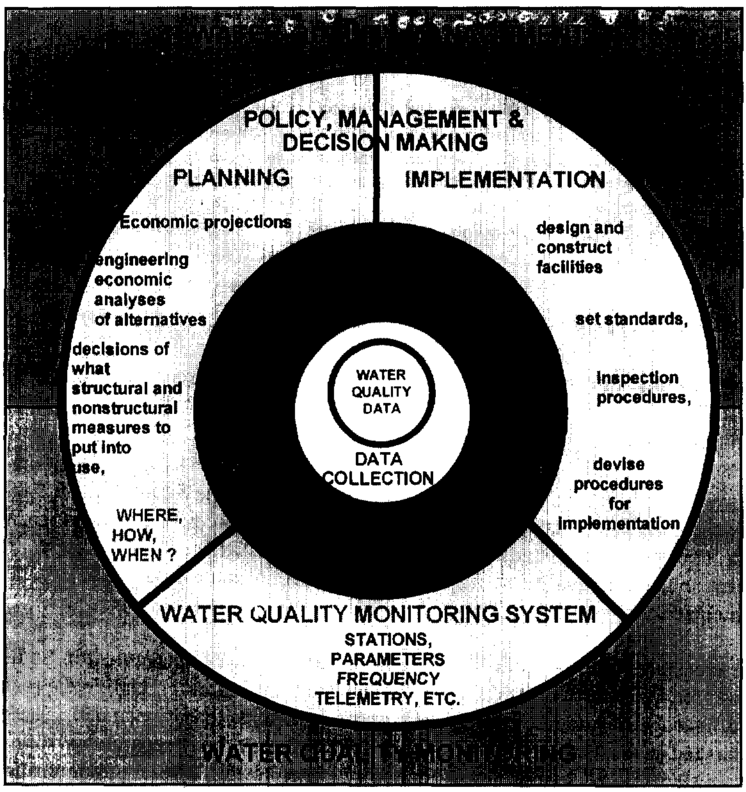

Figure 1. Role of water quality monitoring in water quality management.

Experience has shown that the most enduring and reliable water quality monitoring systems are those using the qualitative and quantitative water budget approach involving all the definable elements of a hydrological cycle and all the elements of water use for a whole scope of different uses (withdrawals and discharges). The manner in which information is collected and stored should be compatible with foreseeable information needs and data collection efforts in the future and with short-term objectives.

The effectiveness of a water quality monitoring system also depends on the accuracy and reliability of the data collected (DWAF, 1995). Procedures, which can ensure the adequate accuracy and reliability of the basic data, have been extensively considered by many authors and will not be discussed here. It is enough to mention that each data collection program must include strict quality control and quality assurance protocols. Without these protocols data collection programs will yield only a limited amount of information for use in integrated catchment management.

SPATIAL DESEGREGATION FOR WATER QUALITY MONITORING

In theory major river basins are the basic and the most convenient unit for any planning, assessment or appraisal of water quality. Drainage divides of surface water systems are topographic features that are easily discernible. In most places these drainage divides also separate ground water systems and areas of water use. However, in practice the situation is often not that simple. Watersheds are often divided into units that are under different planning and political jurisdictions. While this may seem to present a major problem in practice it is not the case. All that is required is that an adequate spatial desegregation of water resources is implemented and that the principle of continuity of volume (mass) is maintained for adjacent spatial units (Miloradov, Marjanovic, 1997).

The first step in any water quality monitoring system design or planning is to spatially divide the 'catchment' into manageable unit areas for which water quality data can be collected and for which after aggregation on the catchment scale, water quality assessment can be carried out.

Different systems for spatial desegregation exist in many countries but they all share the following common characteristics:

a. The information gathered is systematically organised in a geographic format.
b. The information is usually divided into two basic divisions: water resources information (information on the natural, physical and other factors, etc.); water quality management information (information on water quality, administrative divisions including political units, management aspects, and specific problems related to the management of the water quality, etc.)

The territorial desegregation into water quality-management unit areas (WQMUA) must be done systematically to define 'catchment' boundaries and hydro-geologic, administrative, territorial, economic, and water quality management characteristics. Since 'catchments' generally cover large areas with different natural and man made characteristics, it is clear that watersheds need to be divided into smaller 'water-management unit areas (WQMUA)'. When dividing a watershed or a given territory into 'WQMUA' and establishing a system for spatial and temporal water quality data collection, it is important to:

- try to have the 'catchment' divide between the surface and ground waters coincide with WQMUA
- establish a system of *reference water quality data collection stations* (RWQDCS) (see Figure 2) and coincide them with the existing flow or water quality observation stations;
- establish a system of *reference withdrawal monitoring stations* (RWMS), a data collection station used to monitor quantity and quality of water withdrawn from the surface and ground waters;
- establish a system of *reference discharge monitoring station* (RDMS), a data collection station used to monitor quantity and quality of water discharged into the surface waters from point sources of pollution;

- When defining the boundaries of an WQMUA and the locations and number of RWQDCS, bear in mind the changes in the water quality regime. This means that RWQDCS should be located in the zones of major tributaries and where there are bigger discharges and water intakes.

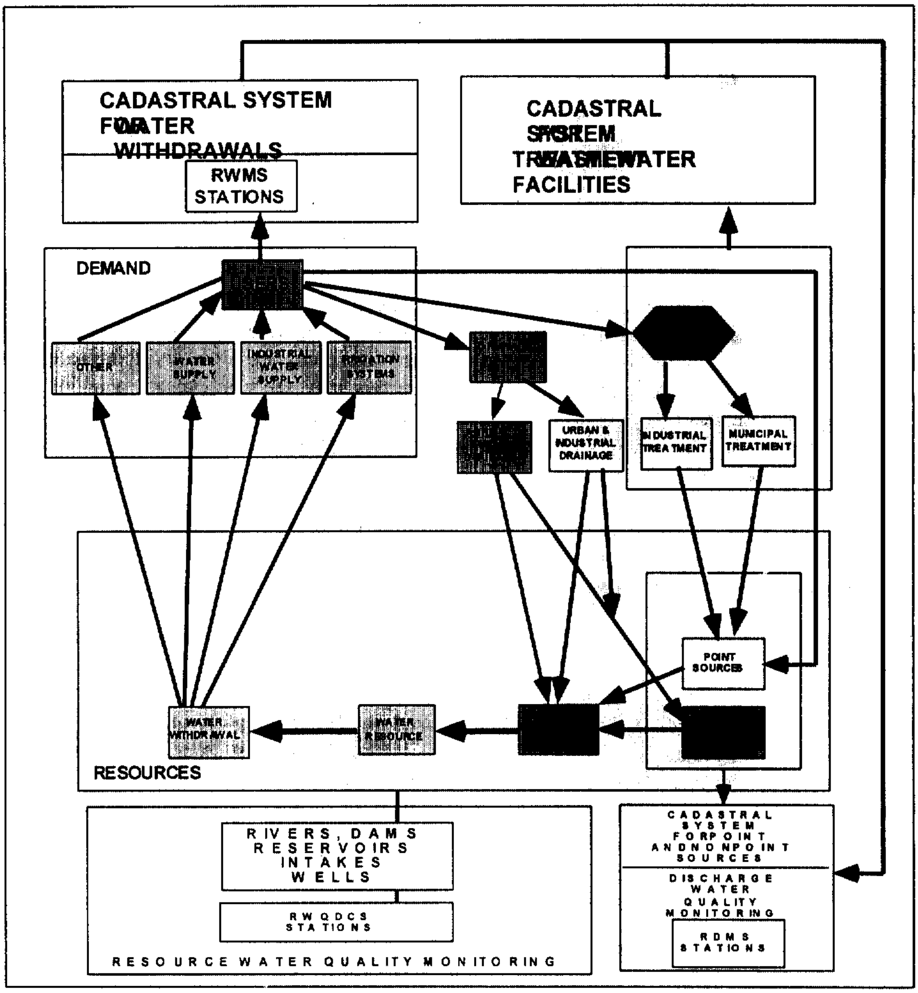

Figure 2. System diagram of managed water resources.

It would be best if all the mentioned principles could be satisfied when deciding on the boundaries of the WQMUA and the locations of the RWQDCS. In practice however this is not always possible because often enough, some of the principles oppose each other while some cannot be satisfied at all.

There is no doubt that the choice of boundaries for a WQMUA and the locations of the RWQDCS should be given due attention bearing in mind the reality of the water resources in time and space. In this respect it would sometimes be necessary to allow for the phased development of a water quality monitoring system.

This means that the standard methodology for the establishment of WQMUA needs to be implemented for the development of a WQ monitoring system.

STANDARD SPATIAL ORGANISATION FOR WATER QUALITY MONITORING

This standard methodology of territorial division needs to be hierarchical in principle as suggested in Figure 3.

The first level of territorial division is the *Water Quality Management Unit Area* (WQMUA) for which all the computations and analyses are carried. The size of the WQMUA depends on the degree of hydro-graphic development, the topography of the terrain and the size of the country and its administrative division. In accordance with past experience such a unit should have an area anywhere between 500 and 2000 km^2.

All the WQMUA need not be of equal size but care should be taken that each WQMUA represents a logical unit for which it is possible to collect all the required data and carry out all the necessary analyses for the purposes of water quality management. It should be understood that for each WQMUA, at least two *reference WQ Data Collection Stations*, (RWQDCS), must be established (an inflow station and an outflow station) at which the water quantity and quality are regularly monitored. There should also be at least one hydro-meteorological station within the boundaries of each WQMUA.

The second level in the hierarchy of the territorial division includes parts of the 'catchment' or a group of the previously defined WQMUA representing the so called *water quality assessment unit area* (WQAUA) or '*water quality accounting unit*' WQAUA. Water quality plans or water quality objectives are usually developed for these units.

The third level in the hierarchy of the territorial division is 'Sub regions'. A sub region is an area which may best be described as a water quality district similarly to the famous Lake District in England but which is confound by political and administrative boundaries rather than by a given river system or a reach of the river. Sub-region should include the tributaries along the relevant reaches or a closed basin or a group of streams forming a coastal drainage area. If basic principles for defining the boundaries of the WQMUA are adhered to it is usually possible to define them so that no single WQMUA falls within the territory of more than one sub region. In situations when this occurs it is necessary to establish RWQDCS along the sub-regional boundary within the divided WQMUA area/areas.

The fourth level in the hierarchy of territorial division is represented by major geographic areas, which divide the state (country) into the regions or basins. The region or a basin contains either the drainage area of a major river such as the Rhine, the Danube or similar, or the combined drainage areas of a series of rivers draining into the sea or coastal regions. It basically consists of a group of sub regions.

In order to make communications easier and the use of the state of the art information technology possible an adequate location coding system must be established. It must have an identification code consisting of eight digits, and additional three digits to identify the type and number of the data collection station (Figure 3).

The basic criteria to be used for the territorial division and the corresponding mapping including the following:

- All boundaries internal to the country are hydrologic (hydrographic) in nature (with a few exceptions when special procedures apply). Regional and sub regional boundaries can coincide with international boundaries. However, because the boundaries of the WQMUA and WQAUA are hydrologic in nature, they should be extended into neighbouring countries through bilateral agreements if possible. If not additional RWQDCS along the border should be established. Every effort should be made to keep the topography of stream drainage basins as the sole preferred determinant for hydrologic unit boundaries in any given country.

All smaller aerial units nest within the next larger unit. All the boundaries of units within the continental part of a given country should match precisely.

A number of basic principles must be adhered to in selecting suitable spatial and time scales for water quality monitoring. These basic principles are:

- Spatial and temporal scales for data collection must be such as to allow the data to reflect spatial and temporal variability in the values of the parameters being measured or observed. If for example a WQMUA encompasses complex topographic features and if weather patterns are known not to be fairly uniform (higher precipitation at higher altitudes for example) one hydro-meteorological station will not be sufficient to characterise precipitation and evaporation over a given WQMUA. In such a case a number of stations should be installed.
- Spatial and temporal scales for data collection must be able to detect spatial and temporal variability in the values of major parameters that depend upon the purpose of the data use. If for example long term planning is the main goal of the assessment daily variations with space and time may not be important but if a goal is operational assessment of water quality than such variability must be considered.

With respect to temporal scales special care should be devoted to water quality parameters. Here a differentiation should be made between water quality of the different components of water resources. For example, ground water quality does change only relatively slowly while surface water quality changes much faster. To complicate the matter water quality of the water discharges may change quite quickly and may depend on the process technology and so on. In a similar way water quality changes with time also depend on the quality parameter being observed. For example surface water temperature may not change as quickly as may dissolved oxygen and so on.

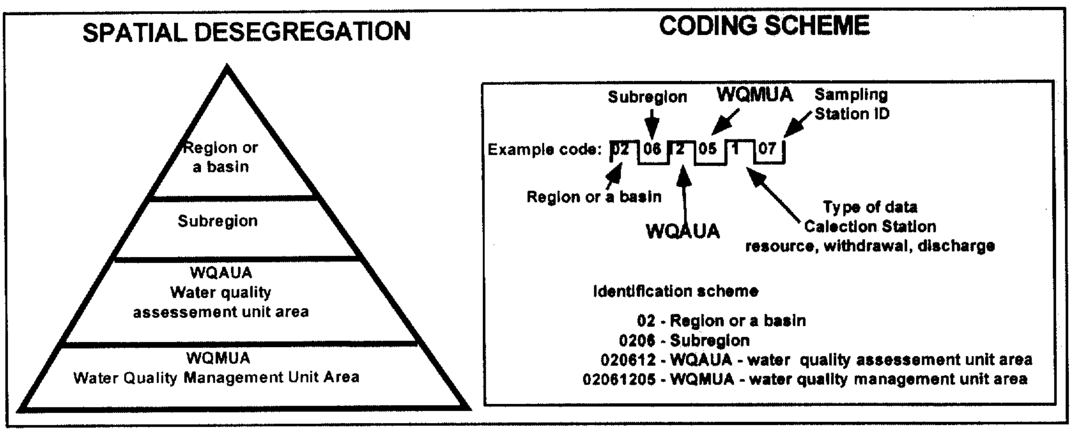

Figure 3. Spatial desegregation and the associated coding scheme.

The most important principle is to collect representative data and if necessary data should be collected frequently and with a dense network of stations and then aggregated. For example for polluter discharges it may be necessary to collect water quality data hourly during a typical week and than aggregate it to average daily concentration or a load disregarding what week of the year one is considering. On the other hand if the parameter of interest does not change with space or time one observation per month may be sufficient to characterise the discharges water quality. Each particular situation should be analysed carefully before the data collection program is implemented.

LOCATING DATA COLLECTION STATIONS

Because water quality management requires qualitative and quantitative balancing, the basic criteria for the selection of stations and their positioning are very important. The same holds for the extent of data collection at each station within the same WQMAU.

The selection of the location for all types of stations primarily depends on the water quality regime and the quantity and quality of the water withdrawn and discharged within the WQMUA. The criteria for selecting the locations of stations and the observation and monitoring program should be based on the following (Figure 4):

- A *reference water quality data collection station* (RWQDCS) should be located at each confluence of a tributary if the flow of the main river is increased by more than 5 % immediately below the confluence.
- A *reference withdrawal monitoring station* (RWMS) should be located at each individual or group water withdrawal point if the amount of withdrawn water is greater than 10% of the 95% probability low flow or if it is greater than 50 l/sec.
- A *reference discharge monitoring station* (RDMS) should also be located at each discharge point if the amount of water discharged is greater than 10% of the 95% probability low flow or if it is greater than 10 l/sec. If a number of discharge points are located close to one another (in cities for example) then each discharge point should be monitored separately. If this is not possible, a RWQDCS should be established immediately downstream of the last discharge point and the stream water quality and quantity should be monitored accordingly. In such situations, it is important to adjust the sampling program to account for the mixing of the discharged effluents with the stream water (multiple sampling points, composite samples etc.) (Marjanoic, Miloradov, 1997).
- For reservoirs and lakes (existing and planned) the RWQDCS should be located at the entry and discharge point from the above.
- A RWQDCS should be established wherever a stream crosses an international or regional border.

Depending upon the hydro graphic network and the previously established criteria within a WQMUA it is also possible to have not only two RWQDCS (inflow and outflow) but also a number of other '*second-order*' RWQDCS and RWMS or RDMS. These second order stations should be located at each point within the WQMUA where there are significant changes in the water quality.

OTHER TYPES OF OBSERVATION AND MONITORING

Since integrated catchment management also includes groundwater resources and water resources from springs, it is necessary to collect data about these resources too. This means that the relevant data on the geology, hydro-geology, hydraulic conductivity and other parameters required for the evaluation of groundwater aquifers and their yield should also be collected regularly for each WQMUA. To collect all the necessary data, the following observations, studies and monitoring should be carried out:

- Monitoring of the sustainable yield of the groundwater aquifers, the groundwater elevation and the quality of groundwater resources.
- Monitoring of the quantity and quality of springs.
- Geological, geophysical and hydro-geologic studies of the potential groundwater sources for water supply.
- Monitoring of the quantity and quality of ground water withdrawn from the aquifers if these quantities are in excess of 10 l/sec.
- Monitoring of meteorological parameters

All the data acquired from the above observations, studies and monitoring programs along with the data on the surface water resources and the hydro-meteorological data for a given unit represent the necessary data base for water quality management.

CONCLUSIONS

Water quality monitoring is a complex problem and if it is to be a major tool for water quality management it must be established in an integral manner. Only then we can achieve optimum water quality management.

The new water policy in South Africa creates all the necessary preconditions for the development and implementation of an efficient water quality monitoring system.

The methodology proposed in this paper can be used in the water quality monitoring system development.

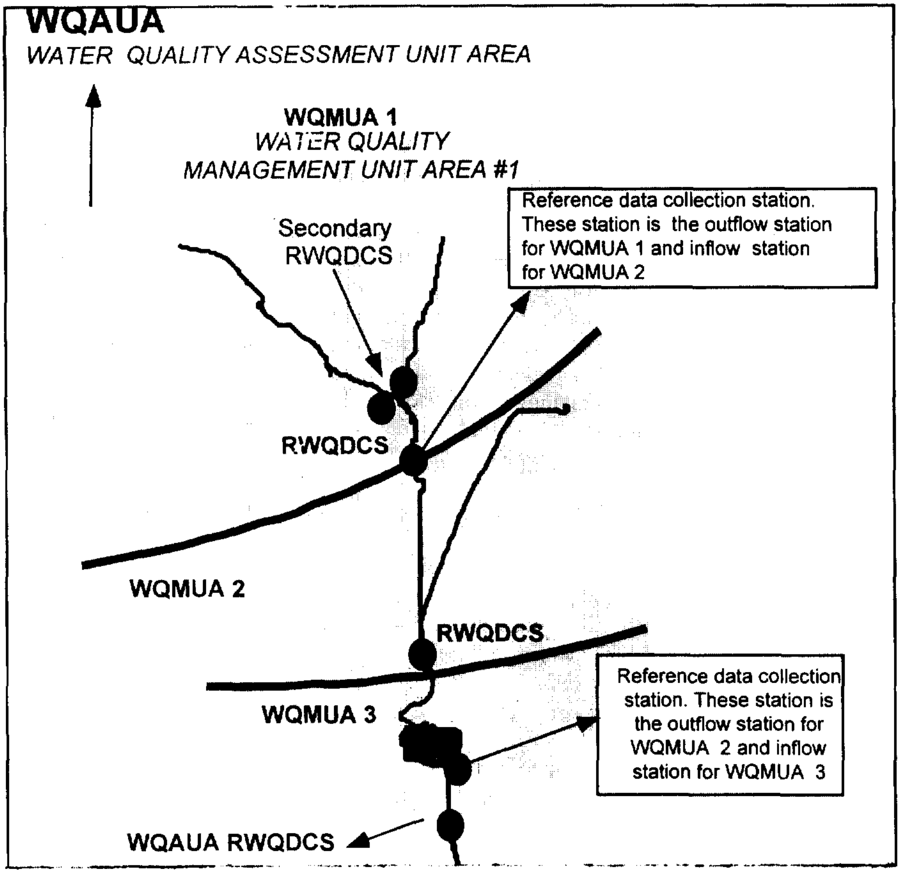

Figure 4. Selecting locations of data collection stations.

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