Characterising cause-and-effect relationships in support of catchment water quality management

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Abstract

In the late 1980s the Department of Water Affairs and Forestry in South Africa initiated an ongoing process of reassessing its approach to water quality management. Fundamental to this new approach is the recognision of the need for catchment water quality management. Yet, in spite of a wide appreciation of the importance of catchment management few, if any, plans have been implemented. This is at least in part due to the inability, in practice, to reconcile the Department's water quality management policy with the processes which determine water quality in the catchment. Strategies and management practices which address water quality problems must be aimed at these processes. This paper highlights four generic processes which determine water quality in the catchment. These processes are production, delivery, transport, and use. Management of these four generic processes in sequence support a hierarchy of pollution prevention, impact minimisation, management of the assimilative capacity, and lastly management of the symptoms of pollution. This paper proposes that a management approach based on the characterisation and quantification of each of these processes forms a sound basis for catchment water quality management. This characterisation reconciles water quality management policies with the practices which address water quality problems in the catchment.

Background

In 1994 the World Bank outlined its "new agenda" for the provision of water and sanitation services to a growing population in developing countries world wide (Serageldin, 1994). Whilst recognising that the provision of safe water and sanitation services is essential to avoid the health risks associated with poor drinking water quality and inadequate sanitation (the "old agenda"), this new agenda also made provision for supplying these services in an environmentally sustainable manner. The new agenda therefore extended to both the quality and quantity of surface and ground water, and addressed protection of the whole of the aquatic environment including the functioning of the aquatic ecosystem. Serageldin (1994) also made the point that, in developing countries water quality is not only worse than in industrial countries, but that the quality of the waters in these countries had declined during the 1980s, at least with respect to the health related indices. This deterioration, he suggested, raised the costs of providing safe drinking water and hampered the ability of governments to meet the growing demands for safe water supplies.

This new agenda for the provision of water and sanitation has also been recognised in the White Paper on water supply and sanitation produced by the Department of Water Affairs and Forestry in South Africa (DWAF, 1994). In this policy document this Department outlined its primary objective as the supply of water and sanitation to disadvantaged communities throughout the country, but also recognised that:

> "(Water)...sustains the natural environment which is why it is not only the quantity of water available which is critical but also its quality.." (DWAF, 1994).

However, the importance of managing water quality is not new to the Department, and as far back as 1986 Water Affairs outlined its mission as:

> ".. to ensure the ongoing equitable provision of adequate quantities and qualities of water to all competing users..." (DWA, 1986).

Yet, in spite of nearly 40 years of the implementation of effluent standards, the quality of many of South Africa's surface and groundwaters has continued to deteriorate. Many water sources now present a human health risk associated with direct consumption without treatment, and widespread eutrophication and other water quality problems are increasing the costs of treating the water to potable standards. This is not only a direct threat to human health and to the aquatic ecosystem, but is making the supply of safe drinking water more expensive. Extensive salinisation affects the suitability of many of our surface waters for industrial and irrigation purposes, thereby incurring additional costs. This will frustrate attempts to manage and develop the water resources of the country for the economic and social prosperity of all its inhabitants.

Purpose of this paper

Recognising that the uniform effluent standards, whilst slowing the rate of the deterioration in water quality, were not sufficient to maintain the quality of our surface waters, the Department of Water Affairs and Forestry initiated an ongoing process of reassessing its approach to water quality management in the late 1980s (DWAF, 1991). At present the Department is again in the process of reassessing its water quality management function as part of the review of the South African water law. Fundamental to these recent developments in the Department's policy toward water quality management is the recognition that the catchment must form the basic management unit. The formulation of an approach to Integrated Catchment (Water Resource) Management (ICM), which addresses both the quality and quantity issues, is therefore seen as a priority for the Department. Yet, in spite of the wide appreciation of the importance of catchment management, few if any, plans have been implemented in South Africa.

Development of the water quality component of ICM has been hampered, at least in part, by problems associated with

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reconciling the Department's developing policy towards water quality management with the processes which determine water quality in the catchment. The policy (or approach) to water quality management has also not been effectively linked to water quality management practices (or actions), which are aimed at improving water quality in the catchment. This paper addresses these issues by outlining the recent developments in the Department's water quality management policy, and then linking the policy to the processes which determine the quality of the water in the catchment. These processes form the basis of the cause-and-effect relationships which determine water quality in the catchment, and their characterisation and quantification provides the scientific and technical support for catchment water quality management. Some examples of the management practices associated with each of these processes are also given to illustrate that a management policy based on these processes forms a sound basis for catchment water quality management.

A history of water quality management in South Africa

Water quality management has a long history in South Africa dating from well before settlement by the Dutch in 1670. Its earliest forms were tribal laws which required that people washed downstream of the point at which drinking water was collected. Jan van Riebeeck also decreed that soldiers, or their slaves, were not allowed to wash their breeches in the river upstream of the water offtake point. However, the first national legislative recognition of the need to manage water quality came with the promulgation of the Union Health Act of 1919 (Act 36 of 1919) which gave the local health officer the responsibility of ensuring that the best known, or most practical methods, were used to dispose of effluent on land. The objective of this Act was to prevent the discharge of waste to surface waters.

By the early 1950s growing demands for water had made it clear that effluent reuse would have to be considered (Van der Merwe and Grobler, 1990). The Water Act of 1956 (Act 54 of 1956) therefore required that all effluent be returned to the water body from which it came. Recognising that this could lead to a deterioration in the quality of the receiving waters, the Act also stipulated that these effluents had to comply with given standards. These were the Uniform Effluent Standards (UES), and comprised the General Standard, the Special Standard, and later the Special Standard for Phosphate. Subsequent amendments to this Act, most importantly the Water Amendment Act (Act 96 of 1984), gave the Department wider powers to address all activities which could lead to water pollution. To date these Acts form the legal basis for water quality management in South Africa.

While the UES are thought to have served a good purpose, continuing deterioration in the quality of our water resources prompted the Department to revise its approach to water quality management (Van der Merwe and Grobler, 1990). This led to the adoption of the Receiving Water Quality Objectives (RWQO) approach, which together with a pollution prevention approach for hazardous pollutants, was widely recognised as the Department's policy towards water quality management in the late 1980s and early 1990s. This policy allowed for the formulation of site-specific effluent standards (waste load allocations) which would ensure that the receiving water body remained fit for its various uses, while the discharge of certain pollutants by virtue of their toxicity, persistence or capacity for bio-accumulation, would be limited or preferably prevented (DWAF, 1991). This policy document also indicated that widespread application of the RWQO approach would lead to the deterioration of the water quality to a point were waters would be marginally fit for use, and the Department therefore advocated an "anticipatory or precautionary" principle to environmental protection. This principle encompassed all actions to avert or minimise the risk to the environment by outlining a hierarchy of water quality management goals. These goals were specified as follows:

- Source reduction (by voluntary actions).
- Application of minimum effluent standards (at that time the UES).
- Waste load allocation based on the RWQO (if the existing standards were not sufficient to maintain instream objectives).
- Exemption from the minimum standards as a last resort, and only if the receiving water body has enough assimilative capacity.

At that time the Department also recognised five users of water when establishing the receiving water quality objectives. These were: domestic, industrial, agricultural, environmental and recreational.

The RWQO approach therefore assumed that surface waters had an assimilative capacity (also referred to as environmental capacity), which was defined as the difference between the receiving water quality objective and the present water quality. This assimilative capacity was therefore the ability of the receiving water to dilute or degrade (biologically, or chemically) the pollutant. The 1991 policy document indicated that:

> "This assimilative capacity is part of the water resource and must be judiciously managed and equitably shared by all water users" (DWAF, 1991).

This gave rise to the misconception that the assimilative capacity was a resource which could be allocated to different dischargers. Applied as such the RWQO approach could make provision for increasing waste loads where there was sufficient assimilative capacity in the receiving waters irrespective of the dischargers' ability to further lower the waste load.

In 1995 the Department again emphasised and expanded on its precautionary approach to water quality management (DWAF, 1995). This later document indicated that positive actions should be taken to avert or minimise undesirable impacts on the environment and that the aquatic environment was part of the resource base. As such water quality management should result in standards which are more stringent than what are simply necessary to meet the minimum instream water quality requirements (DWAF, 1995). This document also stressed that only once dischargers have indicated that all options for preventing and minimising waste discharge to the aquatic environment have been investigated, will relaxation to minimum effluent standards or the RWQO approach be considered, and only under special circumstances will further relaxations be allowed (DWAF, 1995).

The approach to water quality management, outlined in the 1995 document, therefore required that the discharger would first have to investigate all means to prevent the introduction of waste to the aquatic environment (i.e. pollution prevention). Should the discharger be able to demonstrate that this is not feasible or economical, then the impact of the stricter of minimum effluent standards, or calculated standards based on the RWQO approach would have to be implemented (i.e. impact minimisation). Current thinking recognises that, while the prevention of waste discharge to the water environment is a long-term ideal to strive for, it is unlikely to be practical in the short term. Waste prevention, nevertheless, remains a valuable means of reducing the risks to the water environment.

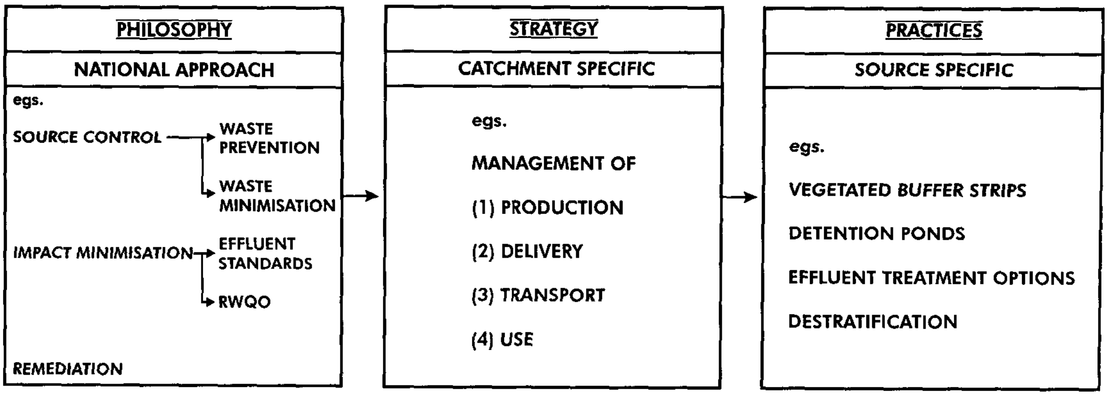

Figure 1
The components of the approach to water quality management in South Africa

The above paragraphs describe the Department of Water Affairs and Forestry's developing policy towards water quality management. When applied on a systematic basis this approach should result in significant improvements in the quality of surface waters in most catchments in South Africa. However, in many South African river systems the industrial use and population densities are out of proportion to the size of the rivers feeding these centres, hence the need for extensive interbasin transfers. As a result of this the quality of many of our rivers, particularly those in intensively utilised river systems, is dominated by effluent return flows. This means that source-directed controls, and impact minimisation may not be sufficient to meet instream quality objectives in all cases, and it may be necessary to address the symptoms of poor water quality either in-stream or at the point of use in some circumstances. Symptomatic treatment may also be necessary to address historical pollution which may have a lasting effect on water quality, for example the use of methods to address the internal loading of nutrients in impoundments which can prolong the effects of eutrophication.

Underlying this policy toward water quality management is the recognition that the catchment forms the logical unit on which to base water quality management plans (DWAF, 1995). The Department is therefore following a world-wide trend towards catchment management. A catchment water quality management plan presents the strategy or strategies necessary to manage water quality within any catchment, and should be consistent with the policy outlined above. These strategies must consequently outline, quantify and prioritise the land-use activities and processes within the catchment which contribute to the water quality problems in that catchment. The individual dischargers would then, in accordance with the requirement that the polluter pays, have to investigate which management practices are the most economical and which will ensure compliance with established catchment water quality objectives.

The Department's approach to water quality management can therefore be seen to have three components, a national policy, a catchment management planning or strategy level, and finally the implementation of management practices to address given water quality problems (Fig. 1). The policy component of water quality management has been described in some detail above; however, the strategies as well as the management practices necessary to implement these plans must be based on the generic processes which determine water quality in the catchment. The following section outlines these processes, and demonstrates how quantification of each of these supports the water quality policies described above. Pegram et al. (1997) have addressed the methods and techniques which may be used to quantify these processes.

Elements of the cause-and-effect relationship

The processes which impact on the water quality in any catchment can be divided into four generic elements (Pegram et al., 1995). These may be natural or anthropogenic, and together they make up the sum of the cause-and-effect relationships which determine the impact natural characteristics and anthropogenic activities have on water quality in the catchment. These elements form a continuum which follows the path of contaminants from their point of production to the point at which they impact on the use of the water, or on the health of the aquatic ecosystem. While there is considerable overlap in these elements, they can at least be conceptually separated into the four processes presented in Fig. 2. The following paragraphs show how management of these processes supports the water quality management policy outlined above.

Production

This refers to the production or generation of wastes at their point of origin. This may be in a single industry, urban centre, or may be spread over a wider area such as an irrigation scheme where it may act as a non-point source of pollution. Production is commonly quantified for non-point sources in terms of mass per unit area per time (e.g. tons/ha·a) or mass per unit area per rainfall (e.g. tons/ha·mm). Typical examples would be sediment production, or non-point sources of agricultural nutrients in a catchment. However, production can also refer to the origin of certain pollutants in industrial and domestic processes, which are eventually discharged as point sources of pollution. For example, phosphorus originating from household detergents, or the production toxic wastes in certain industrial processes. Production therefore occurs before wastes reach the aquatic environment, and before these wastes are mobilised away from the point of origin. As such production management forms part of the source control strategy (see Fig. 1). Waste in this case would also apply to excess substances like fertilisers or pesticides which, when mobilised away from the point of application, can reach the aquatic environment. Production management practices are aimed at preventing or minimising the amount of waste reaching the effluent stream, or from being mobilised away from the point of application. As such these wastes do not reach the aquatic

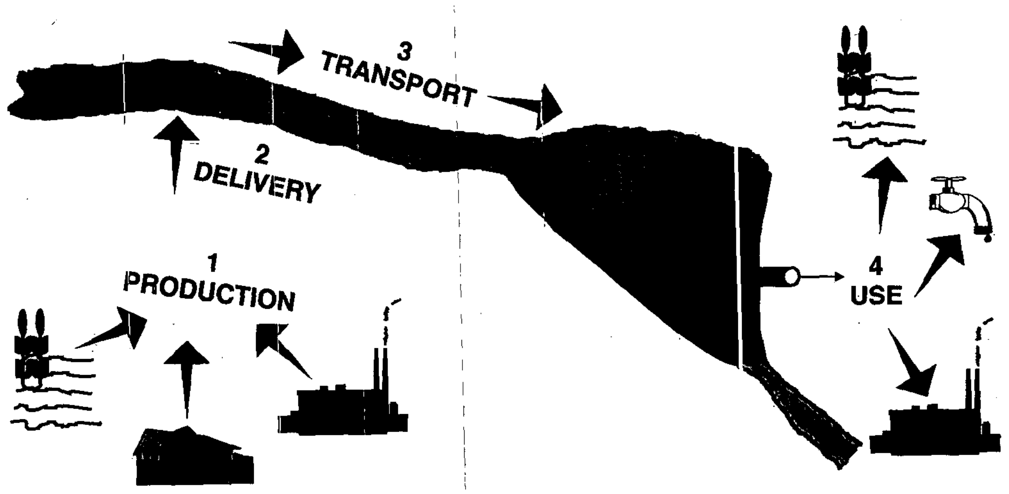

Figure 2
Elements of the cause-and-effect relationships which determine water quality (after Pegram et al., 1995)

environment, and production management would therefore also ensure pollution (or waste) prevention.

Examples of production management would be to use phosphorus free detergents, or to limit the application of phosphorus and nitrogen as fertilisers in certain catchments. Management of the production of pollutants may also entail the isolation of certain industrial processes (particularly those producing highly toxic pollutants), from the aquatic environment, or the use of alternative processes which do not produce toxic wastes. The management of acid mine drainage by preventing infiltration into the underground workings can also be considered to fall into this category. Production management is also achieved by cleaner, more environmentally production technologies.

Management of waste production occurs on site and is consistent with pollution prevention policies. However, to date the quantification of waste production is not well advanced in South Africa, and practices to ensure waste production management are not generally implemented. In addition the institutional and legislative arrangements to enforce this process are still being established. Most catchment management plans only address the delivery of wastes, and have rarely explored the actual origin or production of the wastes, or means to manage the production of these wastes. The management of sediment production by the application of on farm practices like contour ploughing, and the prevention of overgrazing, are nevertheless, well established in South Africa.

Delivery

This refers to the process of introducing wastes to the aquatic environment. This may be in the form of a point discharge, or a non-point source washoff from a wide area. Quantification of point source delivery requires the calculation of pollutant loads, and is one of the fundamental steps in assessing the impact of point loads on the aquatic environment (DWAF, 1995). Delivery of non-point sources of pollution is more difficult to quantify (Pegram et al., in press). This is usually done by modelling both production and delivery of wastes, and as in-stream samples are used to calibrate these models, a component of the transport process (see the next section) is included. This combination of elements is referred to as yield (Pegram et al., 1997).

Management at the point of delivery would involve the reduction or minimisation of the waste load reaching the aquatic environment. As such delivery management occurs after the production of the pollutant, and before it has reached the aquatic environment. Delivery management is therefore consistent with an impact or waste minimisation policy.

Delivery management for point sources is usually aimed at enforcing effluent standards which reduce the waste load reaching the aquatic environment. Managing the delivery process for non-point sources may require trapping of overland runoff, or the underground seepage for treatment or reuse, for example in oxidation dams, detention ponds, or leachate sumps. Vegetated buffer strips may also be used to trap sediment and nutrient washoff from agricultural lands. The delivery process can also be managed by promoting infiltration rather than runoff. This slows the rate at which wastes reach the environment, and allows for transformation or uptake within the soil. This process has been successfully used to manage eutrophication in the Occoquan River catchment in the USA (Randall and Grizzard, 1995). The provision of water-borne sanitation, or the upgrading of existing sewage systems to limit the number of blockages, i.e. the combination of non-point sources into a single point source which can be treated, can also be considered as management of the delivery process. Ashton and Grobler (1988) have also shown that phosphorus from point sources, because it is delivered directly to the river, has a greater impact than non-point sources of phosphorus which are attenuated in the delivery process.

Management of the delivery process for point sources is perhaps the best known and most common form of water quality management in South Africa. The permitting of point source dischargers, and enforcement of the UES is well established in the Department of Water Affairs and Forestry. However, while the Water Amendment Act of 1984 allows for the management of non-point sources, and some regulations to control non-point source waste delivery are available, relatively little has been done to manage the delivery of non-point sources of pollutants in this country. In the USA and UK management of urban stormwater runoff, and runoff from agricultural lands is well advanced, and most best management practices (BMPs) proposed in these countries deal with the delivery process from non-point sources.

Quantification and comparison of the delivery of wastes from both point and non-point sources in a catchment can focus attention on those land-use activities which have the greatest impact on the quality of the receiving water. As such quantification of waste delivery is critical to prioritise management actions. In addition, a comparison between waste production and waste delivery can indicate where little is being done to limit the impacts of land use on the water environment. Where the waste delivery to waste production ratio is low, waste delivery management is effective, conversely as this ratio approaches unity, increasingly little is being done to manage the delivery of wastes. These analyses can therefore focus attention on areas where waste production management should be promoted.

Transport

Transport is the third element of the cause-and-effect relationship, and refers to the movement and fate of wastes in rivers, impoundments and lakes, and in the groundwater. Here the pollutant may undergo dilution and/or some form of chemical, physical and biological alteration. Transport processes are quantified using a variety of water quality models. These models typically describe the advection and dispersion of the pollutants, as well as the chemical, biological and physical processes acting on these pollutants. As such these models describe and quantify the assimilative capacity of the system.

Management of the transport component of the cause-and-effect relationship requires the use of the assimilative or environmental capacity of the water environment. This is also inherent in the RWQO approach. In cases were assimilative capacity exists, authorizations to discharge (i.e. permits) issued based on the RWQO approach may allow for the relaxation of permit conditions. However, if no assimilative capacity exists, transport management can be aimed at creating assimilative capacity. This can be done in several ways. Water may be released from upstream impoundments to further dilute the pollutant, or the chemical, physical and biological processes which remove or transform pollutants, could be enhanced (for example by placing wetlands within the river channel). Extra assimilative capacity can also be created by establishing more stringent effluent standards for upstream dischargers.

However, management of the transport element focuses on the fate of wastes once already in the aquatic environment, and is therefore not consistent with a source-directed management philosophy. It may, nevertheless, be necessary to manage the transport process in highly impacted catchments where flow in the rivers is dominated by effluent. In these catchments the concentration of point and non-point sources may make it difficult and economically unjustifiable to achieve instream water quality objectives by production and delivery management alone.

Management of the transport process is well established in South Africa. Apart from the application of the RWQO approach to calculate allowable pollutant loads for several dischargers around the country, the Department of Water Affairs and Forestry has also implemented a 600 mg/ℓ dilution option for the Vaal Barrage and middle Vaal River (Havenga, 1993). Under this operating rule, the water in the Vaal Barrage is diluted to 600 mg/ℓ total dissolved salts (TDS) by releases of water from the Vaal Dam. This approach is also being followed in several other system analyses being conducted by the Department. In these studies the movement or transport of water and wastes around the catchment is optimised to maximise water quality benefits, without unacceptably impacting on the total water yield of the system.

Additional components of the transport process are the chemical, biological and physical processes occurring in standing water bodies, for example the manifestation of nutrient loading as eutrophication. These processes tend to be very different from those occurring in rivers, and fate of pollutants within standing water bodies therefore requires special consideration.

Impoundment processes which impact on water quality can be quantified in a number of ways, ranging from simple empirical models (Rossouw, 1990), to more complex impoundment process models (Görgens et al., 1993). There are a number of methods aimed at manipulating impoundment or reservoir processes to manage, mostly eutrophication related, water quality. These may range from altering the physical characteristics of the water body to limit algal growth, for example by destratification, to processes to inactivate the phosphorus within the bottom sediments, for example by alum dosing (EPA, 1990). Methods such as food web manipulation, copper sulphate dosing and scouring phosphorus from the system by bottom releases are also commonly in practice elsewhere in the world (EPA, 1990). All of these techniques are, however, directed at treating the symptoms of pollution. As such they should only be considered as a last resort, although in-lake treatment may be necessary to address the internal loading of nutrients which can prolong the effects of eutrophication.

In-lake or in-stream management of water quality in South Africa lags behind the rest of the world. To date only two attempts to destratify water bodies have been made in South Africa, one in the Hartbeespoort Dam (Toerien et al., 1982), and one in the Inanda Dam (Thirion and Chutter, 1993) both unsuccessfully. Copper sulphate dosing of the Vaal Dam to destroy blooms of the blue-green alga *Microcystis* sp. (Bruwer, 1980) has also been attempted. Copper sulphate dosing of filamentous algae in irrigation canals is, however, a common practice in South Africa.

While the DWAF policy toward water quality management focuses on source-directed controls, quantification of the transport component of the cause-and effect relationship serves to link the various point and non-point sources, as well as the water quantity (flow) in an integrated manner. As such quantification of the transport element is essential in the formulation of an integrated catchment water quality management plan. This may also allow the development of strategies to alleviate water quality problems in intensively utilised catchments, and/or in cases where further production and delivery management is not viable.

Use

This forms the final element of the cause-and-effect relationship and refers to the process or action of using the water, rather than the impact of water quality on the user. Use management may require treatment to make the water fit for its intended use, or may involve the avoidance of poor quality water. (Note: The aquatic ecosystem is regarded as part of the resource. "Use" therefore does not refer to the impact water quality has on the functioning of the aquatic ecosystem. As such management actions to protect the aquatic environment can only be aimed at the production, delivery and transport elements.)

Management of water quality at the point of use can only be attempted after impacts on water quality have been noted, and is therefore also a form of symptomatic management. Although it is recognised that some form of water treatment may be inevitable, particularly for potable use, management at the point of use may require improved treatment facilities, for example the inclusion of activated carbon and/or dissolved air flotation. Use management may also involve altering irrigation practices to minimise the impact of poor water quality on the crop, or the cultivation of more resistant crops. The use of alternative water sources, the erection of signs warning against poor water quality, or the use of variable level offtakes to ensure that the best quality of water is abstracted, can also be considered as use management.

The technologies for water treatment are well established and researched in South Africa, but in many cases the high costs of some treatment methods make them prohibitive. More attention should be paid to small-scale simple treatment methods which can be used in rural communities. Further research in this field will allow more widespread management of water quality at the point of use in rural communities. This form of management may be critical to address historical pollution of many groundwater supplies, which may take many years to react to management at the point of production, and delivery.

Discussion

The need for catchment management planning is widely recognised in this country, and was addressed by a number of authors at the Kruger Park conference on river basin management (Van Zyl, 1995; Brown and Van Niekerk, 1995; and Ashton et al., 1995). Yet, in spite of the fact that several plans have been formulated, few if any, have come to fruition. Although there are a number of reasons for this, at least in some cases the Department's developing water quality management policy has not been reconciled with the processes which determine water quality in the catchment. To date the Department has concentrated on the development of the policy for water quality management, while less attention has been paid to the need to integrate this policy with the strategies and practices necessary to implement catchment water quality management plans (see Fig. 1). These plans must be based on an understanding and quantification of the processes which determine water quality in the catchment. Together these processes make up the sum of the cause-and-effect relationships which determine water quality in the catchment.

This paper has shown that four processes (or elements) can be used to describe the cause-and-effect relationships which determine water quality in the catchment. While these processes are not always necessarily discrete and easy to identify, quantification of these processes individually or in combinations can assess the impact land-use activities (both point and non-point) have on water quality. This will allow the prioritisation of waste sources for the implementation of catchment water quality management plans. In addition the impact that the combination of all land uses have on water quality in the catchment as a whole can be addressed. Characterisation and quantification of these four elements therefore form a sound scientific and technical support base for the water quality management function. More importantly water quality management strategies based on these physical processes have clear links with both the management practices which must be applied in each case, and the water quality management policy advocated by the DWAF. Moreover, this paper has demonstrated that the stepwise implementation of production, delivery, transport, and use management approaches is consistent with the hierarchy of management outlined in DWAF (1995).

This paper has, thus far, concentrated on the water quality component of integrated catchment management planning. It is generally recognised that one of the first priorities of water resource management is to ensure that there is sufficient water for all present and future users, as well as for the functioning of the aquatic ecosystem. This approach to water resource management is well established in South Africa, and is evidenced by the water resource system analyses which have been undertaken in many parts of the country. These system analyses are supported by system wide water resource models which simulate the availability of water under various runoff scenarios. Unfortunately the water quality components of these system analyses often only addressed the transport component of the cause-and-effect relationship. This was done by designing operating rules which could maximise the water quality benefits while ensuring acceptable risks of water supply. However, it is essential that, if these system analyses are to fully address the water quality issues of the catchment, they be expanded to address all four processes outlined in this paper. This may require an integration of a number of separate models, which together characterise and quantify all the elements of the cause-and-effect relationship from production to use. This integrated modelling approach will form an effective basis for catchment management in South Africa.

Conclusions

There is a general consensus that catchment management must form the basis of water resource planning in this country. This must include an analysis of both the quantity and quality issues in the catchment. In South Africa we have seen the development of a policy for water quality management, but to date there has been little successful implementation of this policy. This is, at least in part, due to the inability to reconcile the policy with the processes which determine water quality in the catchment. Water quality management strategies and practices in any catchment water quality management plan must be aimed at these processes. A management approach based on these processes will therefore form a sound platform for catchment water quality management planning. This paper has indicated how quantification of these processes can be integrated with the water resource planning function to allow for the development of Integrated Catchment Management Plans which address both the quality and quantity issues.

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