STRATEGIES USED TO GUIDE THE DESIGN AND IMPLEMENTATION OF A NATIONAL RIVER MONITORING PROGRAMME IN SOUTH AFRICA

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Abstract. This article explores the strategies that were, and are being, used to facilitate the transition from scientific development to operational application of the South African River Health Programme (RHP). Theoretical models from the field of the management of technology are used to provide insight into the dynamics that influence the relationship between the creation and application of environmental programmes, and the RHP in particular. Four key components of the RHP design are analysed, namely the (a) guiding team, (b) concepts, tools and methods, (c) infra-structural innovations and (d) communication. These key components evolved over three broad life stages of the programme, which are called the design, growth and anchoring stages.

Keywords: implementation strategies, maturation and competitive impact, river health programme, river monitoring design, technology creation and adoption

1. Introduction

It is in the interest of sustainable development that relevant scientific advances be passed on to the operational managers of natural resources. This is especially important where scientific progress relates to the monitoring, assessment and management of these resources. Unfortunately, the good intentions and sound scientific principles that may be used by developers of environmental monitoring and management programmes provide no guarantee that such programmes will be adopted by the intended end-user community. Apart from the design specifications, critical levels of technical expertise, institutional arrangements, financial resources and political support are required to turn the programme into an operational system which will achieve its objectives.

Certain mechanisms and dynamics are known to drive the transition of technology from scientific concepts to operational products and programmes (e.g. Steele, 1989; Rogers, 1995). An understanding of these mechanisms and dynamics is usually associated with the discipline of technology management, and commonly falls outside the realm of environmental researchers. However, the effective transfer and implementation of environmental technologies can only benefit from such an understanding.

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This article explores the transition from development (creation) to adoption (application) of an existing environmental monitoring programme, using the South African River Health Programme (RHP) as a case study. The RHP focuses on measuring, assessing and reporting on the ecological state of riverine ecosystems. This programme has the overall goal of expanding the ecological information available for rivers, in order to support the rational management of these systems (Roux, 1997). The RHP has largely progressed from its conceptual and technical design phases to widespread adoption by end users. As such, the development of the RHP, and implementation initiatives to date, are generally perceived as a success story.

This article documents the process and strategies that were followed, often unknowingly or intuitively at the time, to see the RHP grow from a mere idea to a national initiative. The development and implementation models that were, and are being, followed, and the lessons that emerge from these, are discussed. Emphasis is on obtaining an understanding of some of the critical issues that affected the transition from the creation to the application of the RHP. Although this article focuses strongly on the example of the RHP, several of the models used are generic to the management of technology. Developers of environmental technologies/programmes in general could benefit from taking cognisance of the experience gained through the design, growth and early anchoring stages of the RHP in South Africa.

2. Background to the Creation and Adoption of Technology

2.1. Relationship between the Creation and Application of Technology

The planning, development and implementation of appropriate technological capabilities are prerequisites for accomplishing strategic and operational objectives related to water resources management. Having a continual supply of the right kind of technologies is strongly dependant on the deliberate coordination of research and development (R&D) with associated application and service functions. Marketing, financial and human resources considerations form an integral part of this process. The overall process falls within the domain of technology management.

Technology management can be broadly divided into **creation** and **application** of technology. Creation consists of basic and applied research as well as the development of the technology. Application contains functions or disciplines such as design, production, quality control, application, integration (e.g. with information systems and decision making processes) and product service.

The two broad technology compartments and even their sub-components each represent a field of specialised activity. Many of these specialised activities are characterised by specialised language and skills and operate in different time frames. All of this commonly results in the fragmentation of the different activities or

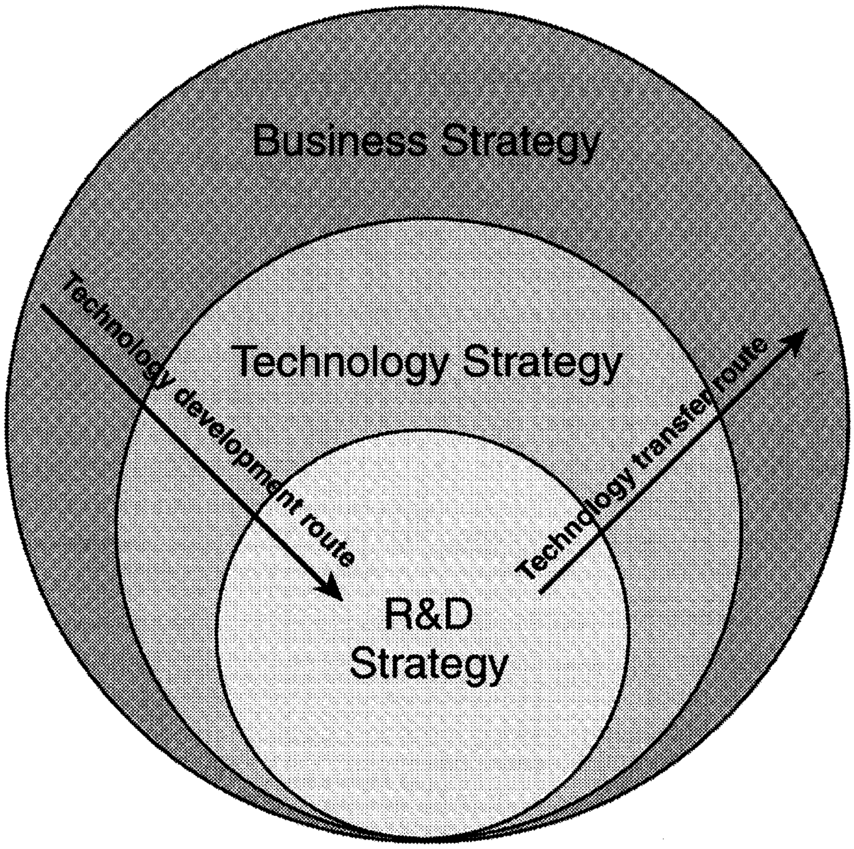

Figure 1. Progression from business, to technology, to R&D strategies, where technology strategy is a subset of business strategy and R&D strategy in turn is a subset of technology strategy (from van Vliet and Gerber, 1992).

functions, and too little recognition of an interdependent relationship between the compartments of creation and application (Steele, 1989).

In order to ensure the required coordination and integration between the two technology compartments, the creation of technologies should ideally be initiated by real operational needs with end-user involvement all along the way. It follows that R&D should be a means to an end, and that the application of technology should be influenced, in an ongoing and pro-active manner, by the results of R&D activities (Van Vliet and Gerber, 1992).

The relationship between the creation and the application of technologies essentially comes down to an interplay between (Figure 1):

- developing relevant technologies (technology development route), and
- applying these technologies in the appropriate way (technology transfer route).

In the context of the national water resources management function in South Africa, the business strategy is reflected by the development and acceptance of policy

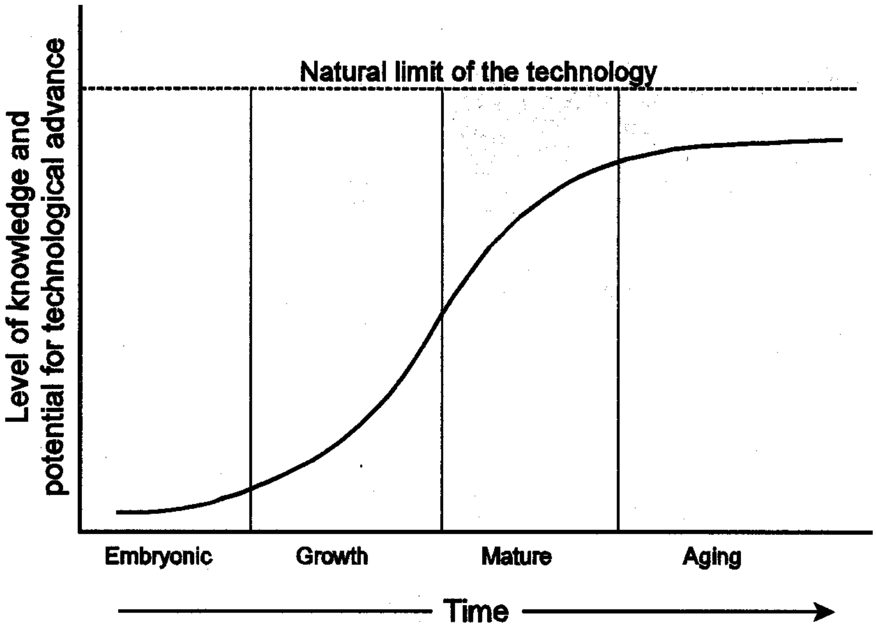

Figure 2. The technology maturation sequence (from Roussel *et al.*, 1991).

related to the management of water resources. This strategy stipulates the broad future direction to be followed, of which the integrated management of water resources and the adherence to the principles of sustainable development are examples (South African National Water Act; Act No. 36 of 1998). The business strategy provides the framework for the development of a technology strategy. A technology is seen as the process of applying scientific and engineering knowledge to achieve a practical result (Roussel *et al.*, 1991). In the water resources context, this may include ways of collecting data, of processing information, or of taking decisions. The R&D strategy should facilitate the development and testing of the concepts, tools and methods that are necessary to give effect to the broad technologies specified by the technology strategy.

Few people, no matter how competent, have the ability to conceptualise the combined developmental and operational worlds of creating and applying new technologies. This is understandable, as the working cultures between the creators and appliers of technology differ. Creators commonly accept change, innovation and risk taking as necessary conditions for sustained viability and survival of the technology that is being developed. Appliers, on the other hand, usually desire stability, rigour and discipline in their day-to-day operational management. These differences may easily result in misunderstandings or misconceptions, which will detract from aligning business, technology and R&D strategies (Steele, 1989).

2.2. TECHNOLOGY NATURATION AND COMPETITIVE IMPACT

Each new technology is exposed to a certain maturation sequence during its developmental and applied life cycle. Roussel *et al.* (1991) describe four sequential stages of technological maturity, namely the embryonic, growth, mature and aging stages (Figure 2). Technological maturity is intrinsic to any technology, and is not dependant on ways and scale of application (Roussel *et al.*, 1991).

The initial or embryonic stage of a programme will be characterised by the existence of little more than a vision of its possible application. In the growth stage of maturity, the accumulation of knowledge has led to a much more realistic picture of its application potential. Although much of the uncertainty has been removed, considerable potential for R&D advance still lies ahead. With continued generation of knowledge through R&D, the technology advances into the mature stage, where the pace of advance in understanding slows. With time, technologies advance to the aging stage, characterised by substantial completion of scientific and engineering advance (Roussel *et al.*, 1991).

A further concept of relevance is that of the competitive impact of technologies. The competitive impact of a technology is extrinsic and closely dependant on the community that applies it. There is a natural progression in the competitive impact of technologies, typically progressing from pacing (potential to change technological competition), to key (embodied in products and processes used by leading groups), to base technologies (essential, and known and practised by all relevant groups). Where the maturity of technology provides insights into the potential for future technological advances, their competitive impacts indicate the differences that such advances might make to a relevant field of application (Roussel *et al.*, 1991).

In the above context, there are several mature technologies to be used for the biological monitoring of rivers. However, when these technologies are packaged into a monitoring programme with a specific purpose, the programme itself starts as both an embryonic and pacing technology. The embryonic programme will mature as knowledge and understanding of the functioning and integration of its components (e.g. sampling, data assessment, information dissemination) are accumulated through R&D. However, the programme also has to find its way into an intended market, which will be determined by the ability of the programme to satisfy an existing need. As the value of applying the programme becomes clear, its impact will progress from where it is viewed as something with potential (pacing technology), through a stage during which its usefulness is demonstrated (key technology) to where it becomes a 'commodity' which is used by virtually all relevant parties (base technology).

2.3. INNOVATORS AND LAGGARDS

Several factors may play a role in determining the competitive impact of a new technology. One aspect that provides an important perspective on the likely nature

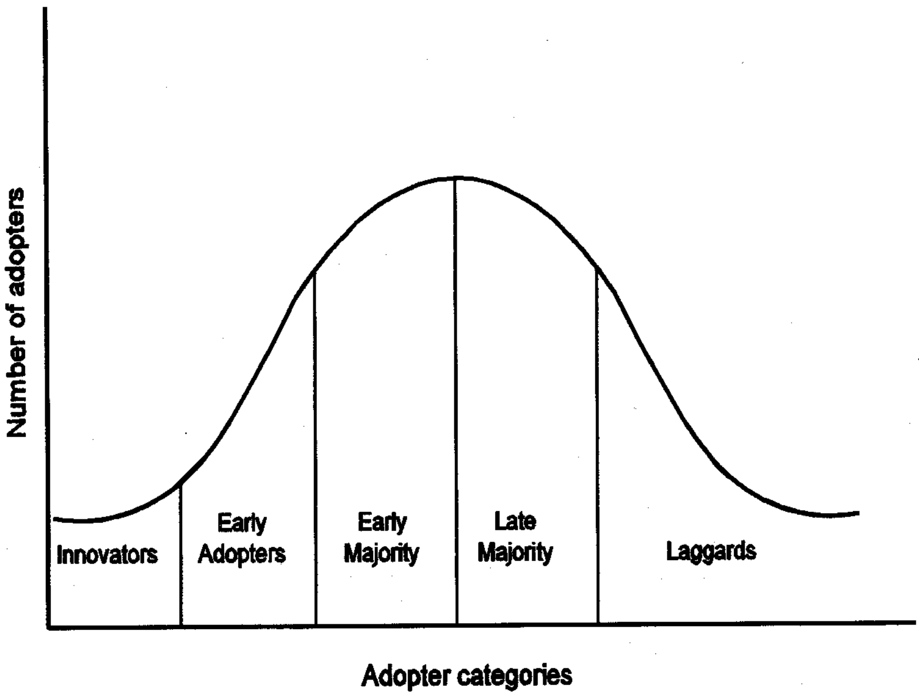

Figure 3. Categories of adopting new technologies (from Rogers, 1995).

of the transition between the creation and the application of a technology, is the process of technology adoption (Figure 3). The following brief description for each of the adopter categories is from Rogers (1995):

- *Innovators*: This group is characterised by venturesomeness and is responsible for launching the new idea into a system (e.g. an organisation or country). Innovators must be able to cope with a relatively high degree of uncertainty. Often the control of substantial financial resources is required to counter the risk of failure of a new innovation.
- *Early adopters*: This adopter category usually has the greatest degree of opinion leadership in most systems. Potential adopters look to early adopters for advice and information about a new technology. Early adopters know that to continue to earn this esteem of colleagues, they must make judicious innovation decisions. They decrease the uncertainty about a new idea by adopting it and then conveying a subjective evaluation to peers.
- *Early majority*: The early majority adopt new ideas just before the average member of a system. They may deliberate for some time before completely adopting a new idea. The thinking of this group is well described by the quote: 'Be not the first by whom the new is tried, nor the last to lay the old aside' (Alexander Pope, *An Essay on Criticism*, Part II). Although the early majority may interact frequently with their peers, they seldom hold positions of opinion leadership in a system.

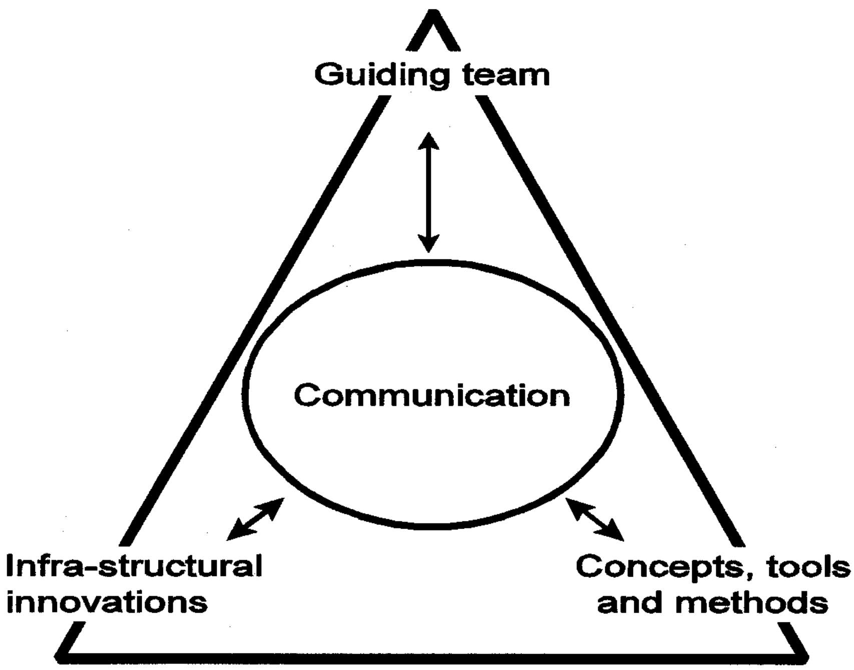

Figure 4. The key components focussed on in the design of the RHP, modified from the 'architecture' of a learning organisation as presented by Senge *et al.* (1994).

- *Late majority*: The relatively scarce resources of this group mean that most of the uncertainty about a new idea must be removed before they will feel that it is safe to adopt. Adoption by this sceptical group is often as a result of economic necessity or increasing network pressure from peers.
- *Laggards*: Laggards are the last in a social system to adopt a technology, and they possess almost no opinion leadership. Laggards tend to be suspicious of new technologies. Their resistance to adoption may be entirely rational from a laggards' viewpoint, as their economic position is often precarious.

3. Architectural model for developing the RHP

The above background to the creation and adoption of technology provides the context for analysing the transition from development to initial application of the South African RHP. To facilitate this analysis, the development of the RHP is conceptualised in terms of key architectural components and life stages. Firstly, the key components that are used in this article to investigate the factors that influenced the development of the RHP are (Figure 4):

- *Guiding Team*: The leadership who provides the vision and drive which guides the future development of the programme.

- *Concepts, Tools and Methods*: To make the monitoring programme functional, it needs appropriate concepts and sound technical tools and methods, e.g. for conducting monitoring and assessing the resulting data.
- *Infra-structural Innovations*: Once the programme has been designed, certain individuals and organisations will be required to implement, maintain and improve the programme over time. The appropriate infra-structural arrangements would ensure that the programme design becomes operational and remains sustainable.
- *Communication*: Internal communication is the glue that aligns the different components, and keeps the overall programme together and on track. External communication presents the programme to, and obtain feedback from, the user-community and relevant stakeholders.

Secondly, three broad life stages are used within which to assess the development of the RHP to date. These stages are referred to as the design, growth and anchor stages. The key architectural components, and how these relate to each of the sequential life stages, are the focus of the remainder of the article.

4. Designing the RHP

The realisation of the need for a new type of management information regarding water resources, and thus a new type of monitoring capability, led to the DWAF initiating the design of the RHP (Hohls, 1996). The RHP design was benchmarked against several approaches to the design and implementation of biomonitoring programmes in other parts of the world. The most noteworthy of these are:

- the British River Invertebrate Prediction and Classification System (RIVPACS) (Wright *et al.*, 1993);
- the Australian River Assessment Scheme (AUSRIVAS) (LWRRDC, 2000);
- the Environmental Monitoring and Assessment Programme (EMAP) of the United States (EPA, 2000; National Research Council, 1995; Stevens, 1994).

A phased approach facilitated formulation of a design framework, the conceptual development and testing of the programme within that framework, and specifying structures for the implementation of the programme. This design process is summarised by Roux (1997).

4.1. Guiding Team

The RHP started as an idea shared by a small group of scientists and managers (the early guiding team). This idea was triggered by a worldwide trend towards the use of biological indicators in water resources management. The idea developed into a vision, based on shared knowledge; a vision which was expected to change with time. A general characteristic of members of the early guiding team was that they were visionary, conceptual and systemic in their thinking.

The initial guiding team was brought together by means of a once-off and relatively short-term contractual arrangement between the DWAF (applier) and the CSIR, a research organisation (creator). Although seen as short-term at first, longer time frames and higher frequency of knowledge sharing was soon established in the funding framework.

4.2. Concepts, tools and methods

The guiding team visualised the process of creating and implementing a national programme for monitoring the integrity or health of riverine ecosystems. They were then able to break the process down into parts and to identify the types of expertise that would be required for developing each part. Relevant specialists were involved in order to develop technical specifications for each part. At the same time, resource mangers at national and regional (provincial and local) spheres of government were consulted in order to align the available technical capabilities with their information needs. During this stage, the guiding team essentially formed an interface between the larger creator and applier communities. As their knowledge and understanding increased, they shaped the overall vision and at the same time conceptualised the links for integrating the different parts into one programme.

An important outcome of the framework design was to define the objectives of the programme. These are to: (a) measure, assess and report on the ecological state of aquatic ecosystems, (b) detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems, (c) identify and report on emerging problems regarding the ecological state of aquatic ecosystems in South Africa, and (d) ensure that all reports provide scientifically and managerially relevant information for national aquatic ecosystem management (Murray, 1999). The set objectives influenced the conceptual design and specifications of the programme within the bounds of feasibility in terms of available resources and capabilities.

The concept of integrity, as developed for riverine biota (e.g. Karr *et al.*, 1986) and for in-stream and riparian habitats (Kleynhans, 1996), was adopted as the basis for measuring and assessing the ecological state of aquatic ecosystems. This essentially means that the condition of an ecosystem is assessed relative to how that system would function within its hypothetical natural state. Any reduction in the natural abilities of an ecosystem is viewed as a reduction in integrity.

As the main purpose was for the programme to serve as a source of information regarding the overall ecological integrity of riverine ecosystems, the RHP would essentially rely on the use of biological indicators (e.g. fish communities, riparian vegetation, invertebrate fauna) of river condition. The rationale for using biological monitoring is that the integrity of biota inhabiting riverine ecosystems provides a direct, holistic and integrated measure of the integrity of the river as a whole. (e.g. Karr and Chu, 1997).

The conceptual design phase dealt with defining the underlying technical specifications of the various components of the programme (such as selecting monitoring sites and ecological indicators to measure, deciding on monitoring frequency and creating management systems for data and information). To accommodate a range of regional requirements, capabilities, and the availability of resources, alternative monitoring protocols were proposed. The options range from the use of a single biological index to the use of a comprehensive suite of biological and non-biological indices (Uys *et al.*, 1996).

4.3. Infra-structural innovations

Without infra-structural mechanisms (political and management support, expertise, money, equipment, people, time, etc.) The programme would not be sustainable. Such mechanisms are most likely to be achieved through organisational arrangements for co-participation and coordination in the development and implementation of the monitoring programme.

The DWAF realised that it did not have the infrastructure and expertise to implement the RHP nationally, and that it was necessary to specify an institutional design that would allow the practical and sustainable implementation and maintenance of the programme. As this would require infrastructures at the river, catchment and provincial levels, it was proposed that the operational responsibilities and ownership of the programme be devolved to appropriate institutions within provinces. A model of national coordination (custodianship) and provincial and local implementations (ownership) was proposed (Roux, 1997).

4.4. Communication

During the design stage, the composition of the guiding team was exclusive. An advantage of this exclusivity was that communication within the team was personal and easy, characterised by mutual trust, a shared vision and matching work ethic and values. During this stage, communication within the guiding team was important for shaping the vision and developing sufficient understanding and clarity of the future role of the RHP. External communication was limited to selected specialists or resource managers whose opinions were sought.

5. Growing the RHP

The design of a monitoring programme represents a mere plan on paper. It still needs to grow through research results, testing, demonstration and implementation, before it can be regarded as a fully operational monitoring programme. However, the rate of growth may be dependant on many factors, of which some may be very concrete and some of a more subtle nature.

The growth stage of the RHP saw the expansion of the guiding team and a strong emphasis on developing, testing and selecting tools and methods for the programme. Provincial stakeholders started to implement the programme on a pilot scale, and communication regarding the programme reflected the growing network of interested parties.

5.1. Guiding Team

During the growth stage of the RHP, the nature, size and composition of the guiding team changed radically from the small nucleus that it was during the design stage. This change resulted from weighing up two basic scenarios for continued R&D of methods and tools for the RHP and a decision to follow the more inclusive option (Roux, 1997).

The first option was to develop the methods and tools within a relatively small project team until the scientific validity and technical detail of all programme components could be specified with considerable certainty. Such an approach would most likely focus on one geographic area for development and testing. An implementation manual would then have to be produced to prescribe in detail the techniques and protocols to be followed to implement the RHP in other parts of the country.

The advantages of conducting R&D within a small group are that this option will only require a moderate degree of coordination, will probably result in a product of considerable scientific standing (technical quality), and will allow available funds to be focussed. A limitation of this approach is that there will be a very limited degree of exposure among political, managerial and operational stakeholders. As a result, a relatively long transitional phase may be required between design and full-scale implementation of the RHP, to allow transfer of the technology to relevant groups.

The second option was to conduct research and development in collaboration with virtually all the groups, organisations and authorities which would ultimately be involved with, or responsible for, the implementation and maintenance of the RHP. This approach would spread developmental activities, in varying intensities, over the whole of the country. This would result in an operational manual shaped through the experiences and involvement of a large and diverse group of stakeholders.

The approach of wider collaboration will have the advantages of:

- fostering a natural progression from involvement in development to involvement in implementation of the RHP by participating groups;
- highlighting, at an early stage, the real-world realities relevant to the implementation of a national monitoring programme;

- gradually creating the capacity for each participating region(e.g. province), and upgrading participation as capacity and more techniques become available;
- institutionalising the RHP in terms of budgets, priorities and workloads at an early stage; and
- mobilising a wider resource base and creating a richer variety of ideas.

On the down side, the latter option will require strong coordination, as its success will largely depend on the level of support volunteered by the relevant organisations and authorities, and a limited pool of funds will have to be distributed among more participants. A further limitation of this option is that standardisation may be hampered by allowing separate developments (Roux, 1997).

Through a process of consultative planning with national, provincial and local stakeholders, it became apparent that the option of wider participation was the desired way ahead. Indications were that there was sufficient support from relevant provincial departments, Water Boards, Parks Boards etc., to continue confidently with as wide an involvement as possible (DWAF, 1996).

Adoption of the inclusive option for the development of the methods and tools paved the way for inclusive institutional collaboration. Part of the resulting arrangements was that two national statutory bodies, the Department of Environmental Affairs and Tourism (DEAT) and the Water Research Commission (WRC), have together with the DWAF become joint custodians of the programme. This provided considerable weight and credibility to the programme. To facilitate the provincial branching of the RHP, a Provincial Champion was elected for each province.

The DWAF provided the funding which allowed the establishment of a National Coordinating Committee (NCC), consisting of representatives of the national custodian organisations, the Provincial Champions, a number of specialist contributors and advisors, specialist portfolio managers (e.g. for communication and fund raising), and a secretariat. The NCC became the new guiding team, to oversee the development, testing and selection of tools and methods. This structure was seen as a sufficiently powerful and representative body to guide the introduction of the RHP, as a major new technology, into its intended market.

5.2. Concepts, Tools and Methods

5.2.1. *Balance Coordination and Freedom*

It was recognised that the design of the RHP represented the beginning of a new line of thinking for water resource managers and aquatic scientists. In general, any new line of thinking is characterised by a variety of product features and types (methods and tools) from different contributors. With time, a dominant configuration of product features and attributes will emerge (Figure 5). This is a natural process of selection, that will ensure the strongest possible final product (Steele, 1989).

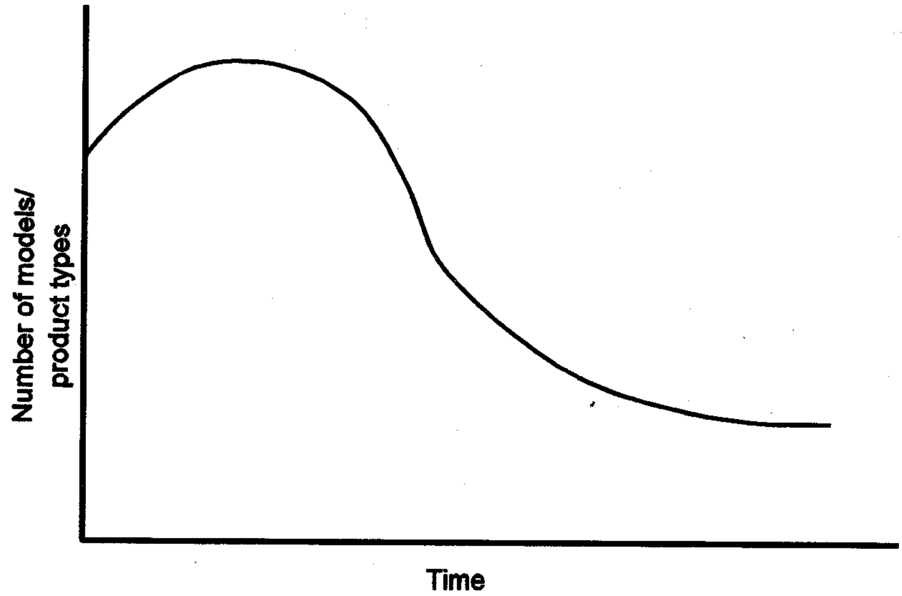

Figure 5. The route from allowing flexibility of product types at the initiation of a new capability, to standardising on those tools and methods which prove to serve the intended capability best (from Steele, 1989).

In view of the above, the approach adopted by the NCC during the growth stage of the RHP was to be explicit about the desired capabilities of the methods and tools required for the programme, yet to follow an inclusive approach for considering what was on offer. In other words, relatively strong coordination was exercised regarding the vision, scope and objectives of the programme, and sufficient time, freedom and flexibility were allowed for the best tools to emerge from research, development and testing. The ideal scenario is where 'natural selection' over time, within practical boundaries, becomes the mechanism of standardisation.

5.2.2. *Apply Prototyping*

A basic principle of allowing a natural selection of tools and methods, is that they should be subjected to constant testing and review to ensure their practical relevance. This was achieved through prototyping, which means that you apply, accept and use the results from the most current developmental prototype, until such time as an improved version is available. This is done even when you know further development and testing will be required to the prototype. Prototyping was found to be invaluable for rapid learning and coordination. This sentiment is shared in the 400 BC quote from Sophocles: 'One must learn by doing the thing, for though you think you know it, you have no certainty until you try' (from Rogers, 1995).

Leonard-Barton *et al.* (1994) state that effective development teams build prototypes, often and early, to learn rapidly, minimize mistakes and successfully integrate the functions of the many components involved in a project. In the RHP, prototyping facilitated interaction between managers and researchers, ensuring a high degree of relevance in terms of the information requirements of resource managers, the scientific validity of the methods and tools, and the feasibility of implementing the programme at a national level. Prototyping was also valuable for developing the links between different programme components, for example, the different ecological indices used for monitoring, procedures for assessing the collected data, and mechanisms for storing the data and disseminating the information resulting from the programme. As a result, cohesion and synergy was experienced within the overall project, even though several different developmental teams from different backgrounds and disciplines participated.

5.3. INFRA-STRUCTURAL INNOVATIONS

Appropriate institutional and infra-structural arrangements are necessary to provide the environment within which a new technology can grow to maturity. In this regard, the NCC provided a platform from which to penetrate government and other relevant institutions at both national and provincial/local levels. The custodians represented organisations responsible for natural resource management at national level, and the Provincial Champions were to transfer the monitoring capability to organisations and institutions with a similar responsibility at provincial and local (e.g. catchment) levels. The latter would be accomplished through the creation of provincial consortia of owners, referred to as Provincial Implementation Teams (PITs).

The NCC's vision was to increase the RHP's circle of influence systematically – from the guiding team responsible for the design to the critical mass of people required for ensuring successful application and long-term maintenance of the programme. It was important to realise that not all provinces would adopt the RHP right from the start, and it was necessary to make decisions regarding which provinces to invest in initially.

Figure 6 shows the steps that have been, and are being, taken to increase the RHP's circle of influence. The following discussion of the steps is partly factual (developments to date: STEPS A to D) and partly hypothetical (possible future scenario: STEPS E to G):

STEP A: This step represents the start of the RHP, when it was a mere idea shared by a small number of people (the initial guiding team). The DWAF was an important part of this guiding team, as it provided the funding that allowed STEP B to take place.

STEP B: Members of the initial guiding team shared their vision with researchers and managers who were perceived as potential role players in the design of a RHP. Wider buy-in led to the guiding team including individuals able to develop conceptual methodologies to form the scientific basis of the programme, as well as individuals familiar with the management needs and implementation requirements associated with such a

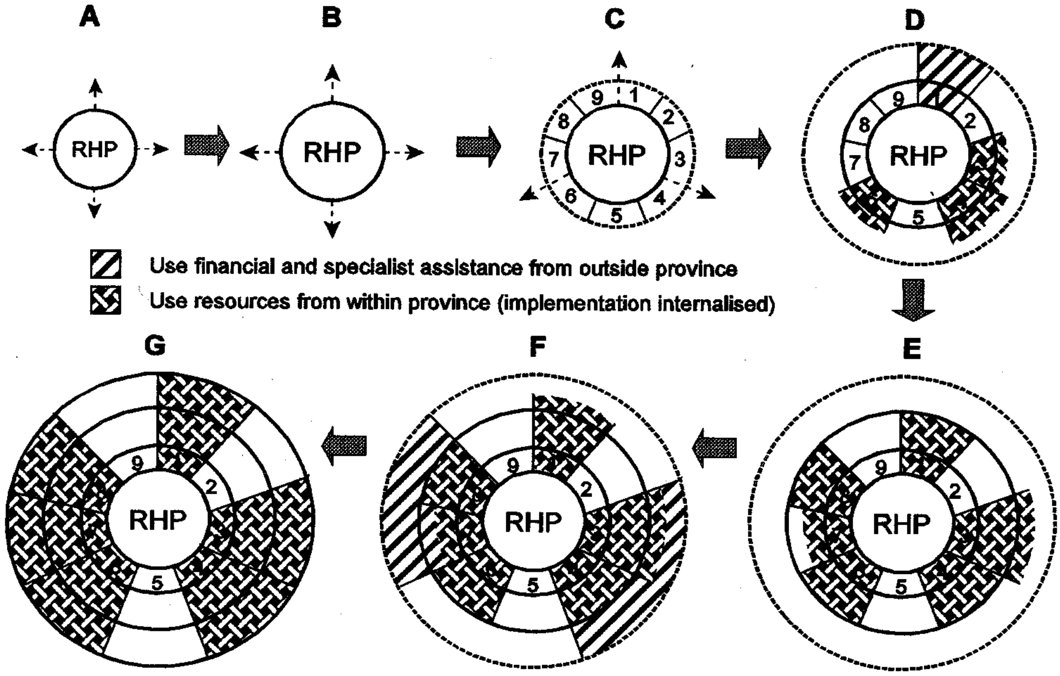

Figure 6. Model by which the circle-of-influence of the RHP was, and is being, increased through strategic involvement and investment.

programme. This larger guiding team developed a conceptual programme design, again with the financial support of the DWAF.

STEP C: The conceptual design was demonstrated to a larger group of possible stakeholders, during a 'consultation planning meeting' (DWAF, 1996). This demonstration led to further support for the vision of a RHP, and the NCC was established. The NCC was comprised of a representative(s) from the three custodian organisations, a champion for each of the country's nine provinces, and the scientists and resource managers that were responsible for the conceptual design.

STEP D: While the NCC continued to develop methods and tools, as well as the vision of the RHP, each provincial champion started to develop a vision for implementing the programme in his/her province. The NCC invested, through another custodian member (the WRC), in one province to further develop and refine the conceptual programme design. The Province of Mpumalanga was selected because of considerable capacity and keenness from organisations within the province. These groups, notably the Mpumalanga Parks Board and the Kruger National Park, formed the core of the PIT. With the assistance of external funding and specialist input, this province started and progressed rapidly with their implementation initiative. This demonstration of commitment, from both the NCC and Mpumalanga, was followed by similar initiatives from early adopter provinces. These early adopters had to source their own funds and expertise for their initiatives. STEP D reflects the approximate status of the RHP at the time of writing this article.

STEP E: This hypothetical step shows how the early adopter provinces have grown their influence, in terms of awareness (among scientists, resource managers, politicians and the public at large), experience, and skills in applying the RHP methods and tools. As these provinces do not receive much help from outside, they have to institutionalise their efforts to build a sustainable basis for long-term maintenance and improvement of their monitoring programmes. Because of this, it is possible that these provinces may in due course exceed the progress by Mpumalanga.

STEP F: The transfer of technology and exchange of experience between provinces have resulted in considerable expansion of the national programme. Yet, it may be necessary for the NCC to become involved again in funding the development of tools with which to bridge the gap between just monitoring and actively making use of monitoring results in the management of water resources. Such tools may include a national database and data management procedures, quality control and assurance procedures, and formats for the dissemination of river health information. It may be necessary to select a province(s) as a test ground for these developments. Again the perceived return from the investment may be the basis for choice. Demonstration of how the monitoring results can be used to support decision-making regarding water resource management, will convince even more provinces to implement the programme.

STEP G: This step represents a pragmatic vision of a mature RHP. Stakeholders in the majority of provinces are participating, at provincial and catchment levels, in implementing and maintaining the RHP. The programme operations are fully institutionalised within these stakeholder groups, with participating group using the national methods and tools. Whereas the RHP is firmly established in most provinces, there may be two or three provinces that can be classified as laggards (Figure 3). However, the national programme can be regarded as successfully implemented at this stage. The lagging provinces may have such limiting resources and expertise that it would be inappropriate to interpret their lack of participation as failure of the programme. These provinces may still, through some future intervention, become part of the programme; or they may miss out on this wave of technology altogether.

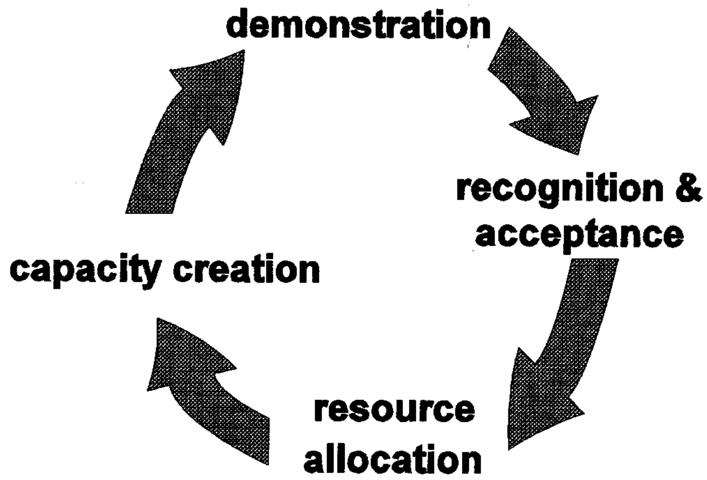

Figure 7. The reinforcing 'demonstration-for-resource-allocation' spiral.

5.4. Communication

5.4.1. *Demonstration-for-Resource-Allocation Spiral*

To grow a new technology, the objectives and priorities of the management of the target applier community (often non-technical) need to be influenced. A new technology is rarely recognised and accepted without some demonstration of its worth. The NCC viewed demonstration as an iterative process of actively packaging the results obtained through prototyping, in ways that would clearly demonstrate the potential of the relevant technology. If the demonstration convinces the appliers that the new capability will get them closer to where they want to be, their initial resistance to change is likely to turn into momentum towards change. Thus, demonstration was seen as an essential part of the communication process.

The demonstration model employed by the RHP can be called the 'demonstration-for-resource-allocation spiral' (Figure 7). Small-scale demonstration of the role of biological monitoring in water resource assessment and management has led to a recognition of the usefulness of this type of monitoring. This recognition, and the acceptance of a need for the monitoring capability, resulted in the allocation of the resources (financial and human) which made the framework and conceptual design of the programme possible. The conceptual design is a further demonstration of the potential worth of the programme to South Africa, which has resulted in considerable recognition of the need for, and acceptance of, the programme (e.g. the buy-in of all 9 provinces through their relevant authorities (DWAF, 1996)). Results from pilot testing of the RHP in the Province of Mpumalanga have been used to demonstrate the value of the programme for the purpose of state-of-the-environment reporting (State of the Crocodile River, 1998), which assisted in leveraging resources to conduct similar work in other provinces.

In general, it was experienced that demonstrating how the RHP can address a specific need, led to increased support for the programme by those experiencing the need. Effective demonstration thus has a reinforcing effect on recognition and acceptance, resource allocation and capacity creation (Figure 7).

5.4.2. *Coordination Through the NCC*

The NCC had to promote the national interest through marketing the programme, yet be sensitive to local needs and constraints in order to develop a sufficiently pragmatic programme to ensure adoption and ongoing maintenance. One mechanism for achieving this was to organise NCC meetings, generally twice per annum. These meetings provided a forum that supported various types of communication needs, for example:

- national custodians report on progress regarding R&D activities as well as funding opportunities, being coordinated at the national level;
- Provincial Champions report on practical problems (equipment, political support, funding, etc.) experienced as well as successes in terms of pilot application of the programme;
- future work programmes could be coordinated to foster technology transfer (e.g. where inexperienced technicians would join an experienced field team during a biological survey of a river) and optimal use of limited resources.

Apart from a technical report series, a newsletter was instituted and the printed media was selectively targeted to reach a much wider audience than those directly involved with the development or implementation of the programme. Furthermore, a series of fact sheets, produced in several languages, was used to communicate the RHP to audiences with lesser skills levels. Also, an experimental project is being directed at schools and riverside communities, to investigate the potential of using the RHP as a tool in environmental education and awareness creation.

The communication component of the RHP became relatively expensive, but was viewed as a critically important injection to ensure strong growth of the programme.

6. Anchoring the RHP

A single application of the RHP on the rivers of a province is still one step short of success. Monitoring, and the use of the resulting information, need to become a routine activity over the long term before the programme can live up to its objectives. However, Kotter (1996) warns that, until a new technology becomes 'the way we do things around here', it will remain fragile and subject to regression. The new way of doing things must be reflected in the organisational structure, the expertise and skills of associated human resources, budget allocations, etc. (Kotter, 1996).

At this stage of pilot implementation of the programme, there is still the risk that the critical momentum can be lost and regression may set in. In order to support the eventual firm anchoring of the RHP in the country, certain strategies can be followed. Some factors that are, or likely to be, playing a role in the anchoring of the RHP in South Africa, are discussed in the following section.

6.1. The Guiding Team

The NCC will remain relevant as a coordinating body. However, the nature of its coordination will gradually shift from the R&D of technical products to the processes used to apply the final products. Increasingly, the PITs will develop their separate visions for the implementation and maintenance of the programme and become a network of guiding teams in the country. Required levels of standardisation in the application of the national programme will be achieved through their representation on the NCC.

Provincial Champions are primarily from organisations with a) an interest in, or perceived responsibility to, implement the RHP; and b) some capability and capacity, in terms of human and financial resources and equipment, to apply the minimum suite of tools and methods that would constitute the RHP. It is the responsibility of each champion to institutionalise the RHP in his/her province, in terms of budgets, resource development priorities, policy planning etc. Therefore, the PITs need to be sufficiently representative and powerful to achieve this anchoring of the programme in their regions. Each PIT would essentially become a guiding team for RHP-related activities in its region of concern.

6.2. Concepts, Tools and Methods

Ongoing testing and review of the RHP and its individual components will ultimately stabilise the programme design. Once the RHP has matured to a stage where it is evident that a dominant design has emerged, it would be increasingly difficult to make further technical advances to the RHP or to its underlying tools and methods. At this stage, contributions to improve the application of the programme will become increasingly important. The focus will shift from what to do (product innovation), to how to do it (process innovation) (Utterback, 1994).

Process innovations would largely determine the operational effectiveness of the RHP; this in turn will determine the success of adoption and maintenance among the applier communities. In the context of the RHP, process innovations would include:

- procedures for quality control and assurance (under development (Palmer, 1998));
- an implementation manual which spells out what to do (tools and methods), how to do it (procedures) and who should do it (roles, responsibilities and functional interaction) in the RHP (Murray, 1999);
- simplification of monitoring protocols and automation of data assessment procedures to allow more people than a few specialists to be able to do the work;

- procedures for the storage, management and transfer of data (under development (Dallas, University of Cape Town, pers. comm.))
- formats for disseminating information to different target groups (politicians, resource managers, public at large);
- formal links between the monitoring programme and the decision-making process of water resource managers, in order for the RHP to have an impact on the health of rivers and not to stop at just collecting data (e.g. Roux *et al.*, 1999); and
- reduction of cost.

The end result of proper process development is that biomonitoring, as packaged in the RHP, will have become a 'commodity', which could be applied by all organisations who desire or need to do so. The programme will no longer be perceived as a competitive advantage to those organisations applying it, but as a competitive necessity for conducting effective assessment and management of water resources.

6.3. Infra-structural innovations

The fact that the elected Provincial Champions were from different types of organisations, including a Provincial Parks Board, University, Water Board, Provincial Department of Nature Conservation, and a regional office of the DWAF, resulted in a varied nature of the PITs within the different provinces. Also, the theme of reasonable freedom and flexibility was followed in the creation of PITs. Where one PIT would consist mainly of conservation agencies, another will have strong representation from the industrial sector or regulatory agencies. This freedom in organisational composition was viewed as a way to accommodate the skew geographic distribution of resources and appropriate capacity across South Africa. It was also seen as a potential strength, in that the number of implementation scenarios and associated mistakes, victories and lessons, would be maximised.

Each PIT would bear the overall responsibility for implementing the RHP in its region. The PIT will, for example, have to attain the appropriate political endorsement of RHP activities in its region. This is essential to ensure the sustainability of the programme in terms of having sufficient resources allocated for maintenance and improvement of the programme. Members of the PIT need not, however, conduct all the work associated with RHP implementation. As the programme has (at this stage) to a large extent been commercialised, specialist service providers will increasingly offer cost-effective services to the PITs. These services may include data collection through to the compelation of reports on the health status of certain rivers.

A best-case implementation scenario is where a province has an active PIT, political endorsement, sufficient resources and skilled service providers to execute certain specialised components of the RHP. However, even under such a scenario, it must be realised that anchoring of the RHP is a process and not a single event.

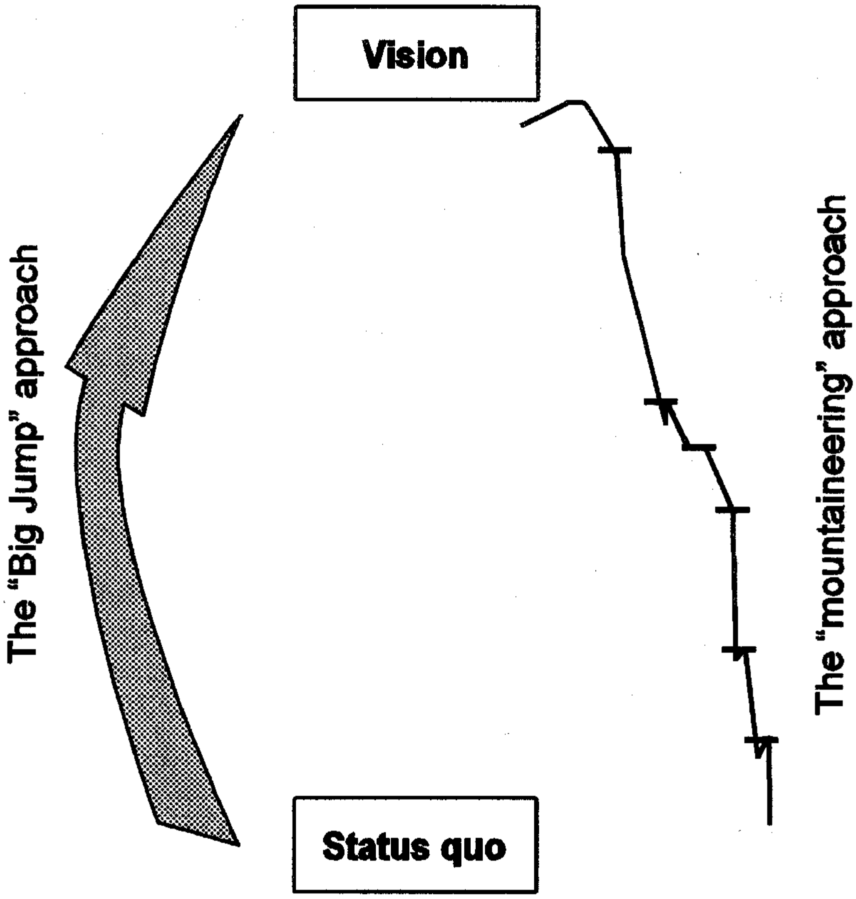

Figure 8. The 'big jump' versus 'mountaineering' approaches for progressing towards anchoring the RHP.

An important concept here is that a process consists of sequential steps, and that successful completion of the process may require considerable time. Kotter (1996) says that anchoring a new approach requires that sufficient time be taken to ensure that the next generation of leaders really does personify the new approach.

By focussing on, and securing, one step at a time while keeping the ultimate destination in mind, a team can experience a sense of achievement and motivation. The motivated team would be able to progress from step to step and will ever get closer to their destination. This can be called the mountaineering approach (Figure 8), and is the approach of choice for moving towards national anchoring of the RHP.

However, when the team only focusses on the final destination, they may become disheartened when it seems as if they will never reach this goal. This may cause the team to surrender or to lower their vision of what should be achieved. This is called the 'big jump' approach (Figure 8). Following either the big jump or mountaineering approach will determine how much regression is likely to set in when given an opportunity. With the mountaineering approach, every step (for example: compilation of a sampling manual; establishment of a PIT; completion of a monitoring exercise; each report, publication or brochure) represents a tangible gain. Consolidation of all the gains achieved to date will provide a strong basis from which to approach the next step. Proper consolidation will also make it unlikely that a specific implementation effort can regress from the furthest step that was secured. However, when following the big jump approach, any regression that sets in is likely to have a much more severe effect. In other words, the big jump may be followed by a 'big fall'.

Further advantages of the mountaineering approach are that taking one step at a time is less threatening to those who still stand sceptical of the new technology, and it also allows more opportunity for other people to become involved and to participate in the process.

6.4. Communication

During the anchoring stage, the NCC remains responsible for communication regarding aspects in the national interest. This may include information on:

- the progress of a state-of-the-rivers report for the country;
- a national quality control workshop;
- research findings that are relevant to implementation initiatives in general; and
- certain procedures that would encourage standardisation.

However, the main emphasis of communication activities shifts to the provincial level, where it serves the purpose of enabling the networks of PITs and service providers to run the operations of implementing the RHP. Apart from the coordination required to do the practical work, ongoing and focussed communication will be required to obtain the full support of the relevant political and managerial groups, as well as the public at large. To achieve the latter, the demonstration-for resource-allocation spiral (Figure 6) will become increasingly relevant for anchoring the RHP at the provincial level.

The PIT will have to demonstrate the advantages or strengths associated with the RHP clearly, to all the relevant target audiences. The importance of this communication component should not be underestimated, as new approaches usually sink into a culture only after it is very clear that they work and are superior to old methods (Kotter, 1996). The ability, and sometimes capacity, to demonstrate the strengths of the RHP may determine whether the attempt at introducing the programme will succeed in the long run (Steele, 1989).

7. Assessment Criteria

The context within which environmental monitoring programmes around the world is designed and implemented vary tremendously. Based on the South African experience, the following are suggested as assessment criteria for the success of the design and implementation of such programmes:

- *Clarity and consensus regarding objectives:* This does not mean that the objectives should be static. On the contrary, these objectives should be allowed to evolve on the basis of continuous and effective dialogue.
- *Ownership and implementation at local levels:* Although programme design and development can take place at a national level, the institutional architecture of the programme should cater for operational ownership at local levels. This is to ensure that information are managed and decision are made as close to the ecosystems being monitored as possible.
- *Scientific validity:* Technical soundness and relevance are essential to ensure sustainable support and resource allocation for any monitoring programme. Continued development and improvement must be invested in to maintain the technical relevance of the programme in the face of evolving ecological understanding and management needs – adjustment must be allowed over time.
- *Feasibility of implementation*: The long-term maintenance of a monitoring programme is dependant on the efficiency and cost-effectiveness at which the operational activities can be executed. This includes logistics and costs associated with training, travel, information management, equipment acquisition and replacement, quality control and assurance, and field work. A further consideration is the availability of appropriately skilled human resources.
- *Institutional acceptability:* To ensure adoption and application of the monitoring programme, it must be acceptable to the intended user community. Such acceptance is often based on the perceived value that the programme adds to the user community or the part of society that it reports to.
- *Achievement of objectives:* Ultimately, the success of a programme can be audited against achievement of the objectives that were set for the programme.
- *Impact on resource management:* Care must be taken that the presentation of the results should highlight their relevance for specific management applications. Information that are being collected must support management decision and allow quantification of the success of past decision. There is no place for monitoring programmes that monitors and stores data without this data having an influence in the management and decision-making arena.

In view of the above criteria, the performance of the RHP to date can be summarised as follows: The objectives of the RHP were set after many consultations with scientists and resource managers, and these objectives carry the approval of all the main participants and stakeholders of the programme. The institutional design of the programme ensures that ownership at the provincial or local level of government is possible and desirable. Significant investment has been made to ensure that scientific rigour is build into the RHP design. This is seen as an ongoing process, and most of the technical protocols currently in use are likely to still be significantly improved over time. Care has been taken to make the RHP pragmatic in terms of resource availability in South Africa. This has been an important factor in the high degree of adoption that have been experienced amongst the programme's intended user community. These adopters also perceive that implementing the programme will support them in fulfilling their institutional mandates and responsibilities. To date, pilot projects have shown that proper implementation of the RHP will result in all of the programme's objectives being achieved. It is only the spatial scale of implementation that still needs to spread to make the programme truly national. A further area which deserves more focus in future is that of packaging the monitoring results in such a way that resource managers can optimally use the information in making decisions. The link between the RHP monitoring results and water resource management strategies has not yet been formalised.

8. Summary and Future Challenges

The development of the RHP has seemingly escaped the common trap of ambitious environmental monitoring and management programmes, namely to remain programmes in concept or design only and not to become operational realities. This article explores the design, growth and anchoring stages that characterise the life cycle of the RHP for lessons that can be linked to successful implementation. Table I provides a summary of the main issues that emerge from this case study.

Challenges regarding the implementation of the RHP that will have to be faced in the future, and which have not been addressed in detail, include:

- The relatively high degree of political flux, especially at provincial level, that prevails in the country has a negative impact on continuity. Mandates, roles and responsibilities change more rapidly than desirable. As a result, key individuals and groups need to be identified and relationships need to be established on an ongoing basis.
- As the focus of activities moves from the national to more local levels, the future roles and responsibilities of the national custodians will need to be clarified. To date these custodians were an essential source of funding and high-level political support. From a national perspective, their continued and active involvement in certain functions and processes of the RHP will remain important. The development of a complementary and mutually beneficial relationship between the national custodians and the provincial implementers will be a critical success factor for maintenance of the programme.

TABLE I

Characteristics of the architectural components of the RHP over the three life stages of the programme

Components of the architectural plan		Life stages in the creation and application of the RHP		
		Design	Grow	Anchor
Guiding team		*Committed nucleus* – benchmarking – pro-active/visionary – conceptual/systemic – willing to experiment – freedom	*National Coordinating Committee* – implementers/change agents – pragmatic but assertive – technical detail – coordination – integration	*Provincial Implementation Teams* – managers – builders/finishers – operational rigour – maintenance – standardisation
Concepts, tools and methods	Concepts	– design of monitoring programmes – biological monitoring and indicators – ecological integrity and ecosystem health – technological maturation and competitive impact	– demonstration through prototyping – technology adoption – increase the circle of influence – technological maturation and inpact	– secure one step at a time – ongoing learning and improvemen – technological maturation and competitive impact
	Tools and Methods	*Product definition* – dialogue between creators (developers) and appliers (end-users) – audit available expertise, resources, tools – develop underlying technical specifications	*Product innovation* – develop and refine the design – balance coordination and freedom – emergence of dominant design – prototyping	*Process innovations* – project management – efficiency – quality control and assurance – de-skill/commoditise programme

TABLE I
(continued)

Components of the architectural plan	Life stages in the creation and application of the RHP		
	Design	Grow	Anchor
Infra-structural innovations	*Specify future institutional design* – explore potential for inter-institutional collaboration – recognise need for harnessing competencies across organisational boundaries	*Design becomes operational* – reflects multiplicity of skills and input – gain political support – integrate multiple skills and perspectives – resource key functions – build capacity in terms of future service providers	*Programme is internalised* – network of service providers – implement with political endorsement – flexible to reflect local resource realities
Communication	*Tactical to win alliances* – exclusive – trust and open sharing within small group – mainly internal to nucleus, but 'lobby' outside – listen to selected end-users and stakeholders	*Strategic to establish networks* – controlled, but increasingly inclusive – personal within increasing group size diversity – increasing external focus	*Practical within networks* – diminishing control – emphasis on external environment

- To date the RHP has relied heavily on the commitment and enthusiastic contributions of a number of individuals. As activities regarding the programme changes from a predominantly developmental mode to a more routine and operational nature, equally committed and enthusiastic people, but with different skills, will have to emerge to become key players in the RHP. The fact that any long-term programme will experience turnover of role players must be recognised and managed for.
- The final test of the RHP will be in the degree to which information resulting from it will become part of the decision-making process in water resources management. In other words, the RHP should become an essential tool to achieve better understanding and management of riverine ecosystems, and not a programme which conducts monitoring for monitoring's sake (e.g. Gunderson *et al.*, 1995).

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