HOW MAY AN INTEGRATED APPROACH TO PLANNING AND MANAGEMENT OF GROUNDWATER RESOURCES BE ACHIEVED?

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"The reductionist, positivistic methods that have served so well in developing an understanding and predictive capability of aquifer behaviour will not be fully effective for designing remedial policies. If people are part of the problem they are part of the solution. Diagnosis and successful resolution of existing and potential aquifer over-exploitation will be best achieved by a co-ordinated interdisciplinary approach" (Young 1993).

1. Introduction

The need to improve management of water and other natural resources was recognised (belatedly) towards the end of the last century in both developing and developed countries. Attention multiplied in the last decade alongside the growing demand for water (for both production and consumption purposes) and threats from pollution as populations rise and economic activities intensify. Fresh water resources are finite, limited by the rate of natural replenishment. In many areas resources are being depleted and polluted, threatening future supplies and increasing the cost of abstraction and distribution. Managers have traditionally taken a supply-side or predict and provide approach, devising engineering solutions to satisfy human needs - building dams, pipelines and treatment plants for example – but such answers cannot continue indefinitely. More recently economists have put forward demand side approaches designed to improve water allocation efficiency and provide disincentives to polluting activities. Charging systems have been much criticised, however, as water is regarded as a public good that should be freely accessible to all, particularly the poor (Grimble, 1999).

About one third of the world's fresh water resources lie in aquifers generally containing water of high natural quality. As an essential part of the hydrological cycle, aquifers collect and store surface run-off that might otherwise be lost to the sea, thus providing natural storage that can be utilised as and when required. Depending on location and geology, aquifers can also perform other beneficial functions such as sustaining wetlands, sourcing surface water supplies, assimilating waste, and providing natural storage reservoirs suitable for artificial recharge.

Despite their importance, the management of groundwater resources (GWR) has often taken a back seat, a function of their invisibility ('out of sight out of mind'), inherent difficulties of study, limited opportunities for engineering solutions, and the small-scale and private nature of much access and exploitation. Study has been dominated by technical professions (particularly hydrogeology) that have modelled the physical aspects of how aquifers behave and groundwater flows. There has been limited collaboration with non-traditional disciplines or active integration of options for management. Where inputs have been provided from the social sciences, these have been largely self-contained and independent with little attempt made at genuine work integration. Generally there has been limited understanding of how studies can best fit together and contribute to the wider aim of GWR management to satisfy human needs.

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2. Integration

There is a clear need to improve GWR management in ways that make best economic (efficient) use of the resource while balancing social equity and environmental sustainability concerns. There is a similar need to plan and integrate the potential contributions of various disciplines bearing on the subject in ways that contribute to good water resource management in a practical way.

In the mid 1990s the Research Councils were becoming aware of this general deficiency and were looking for ways to involve the social sciences into traditional technical research in a variety of subject areas. One of the authors of the present paper (a resource economist) had personal experience of the difficulty of getting social science disciplines into the heart of traditional technical areas having on a number of occasions worked with technical agencies without any real attempt at integration by study managers; the need to include economists and later sociologists had become politically correct at the time but without recognition of the need for inter-disciplinarity. ESRC funding provided an opportunity for research to examine critical linkages and symbiosis between physical and social science parameters and consider the opportunities for real integration.

ESRC funded research (with supplementary funding from DFID) was conducted by a team from NRI and BGS with skills in resource economics, hydrogeology and social sciences based around ten case studies in different parts of the world. Adopting a holistic and systems-based perspective, the broad aim was to develop better conceptual and practical understanding of GWR degradation and its causation, impact and management. The research was principally addressed at the developing world in areas where degradation was serious but the issues raised were of global concern and related also to developed countries including the UK.

A conceptual framework was developed as a circular cause and effect process (Fig. 1). In its simplest form degradation was seen to result from the intensification of economic and human activities that put pressure on GWR by (i) increasing the demand for water over and above the level of replenishment (ii) increasing the pollutant load at levels that could not be naturally assimilated by the geology. Resource degradation in turn impacts on the human economic and livelihood systems they support. The nature of degradation and the severity of human impact was found to vary enormously from one area to another as governed by the locally-specific geological and institutional context.

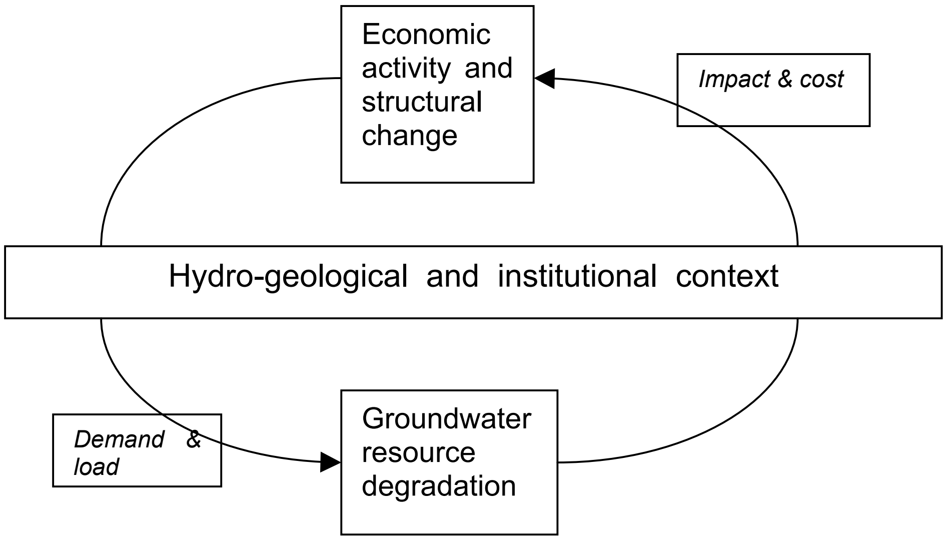


Fig. 1 The Degradation Cycle: Activities, Pressures, Degradation and Impacts

A simple model was also developed as part of the research to facilitate understanding of the steps required for managing GWR and degradation problems in different contexts (Fig. 2). This was undertaken from the perspective of a state authority faced with the task, though institutional systems are by no means always as straightforward as this. Although the ideas are simple indeed, the research findings represented a practical departure in viewing GWR primarily in terms of human management needs rather than aquifer properties and water resource behaviour.

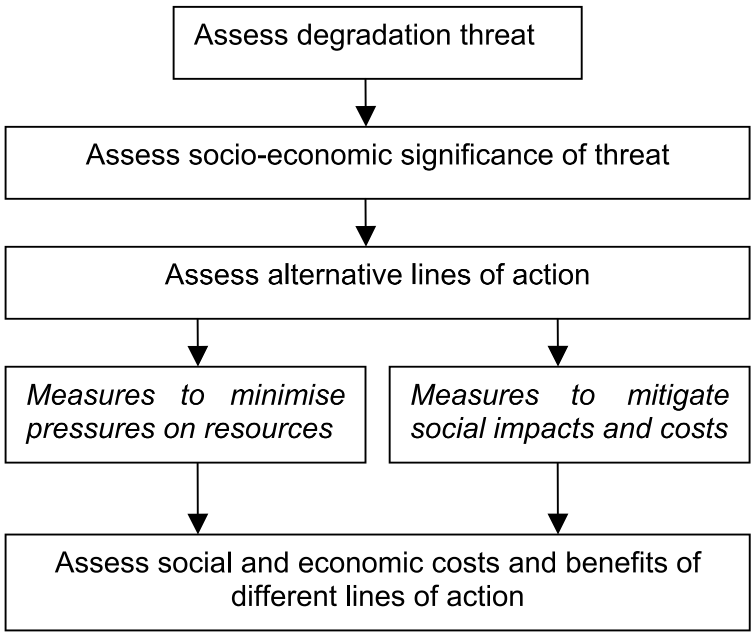


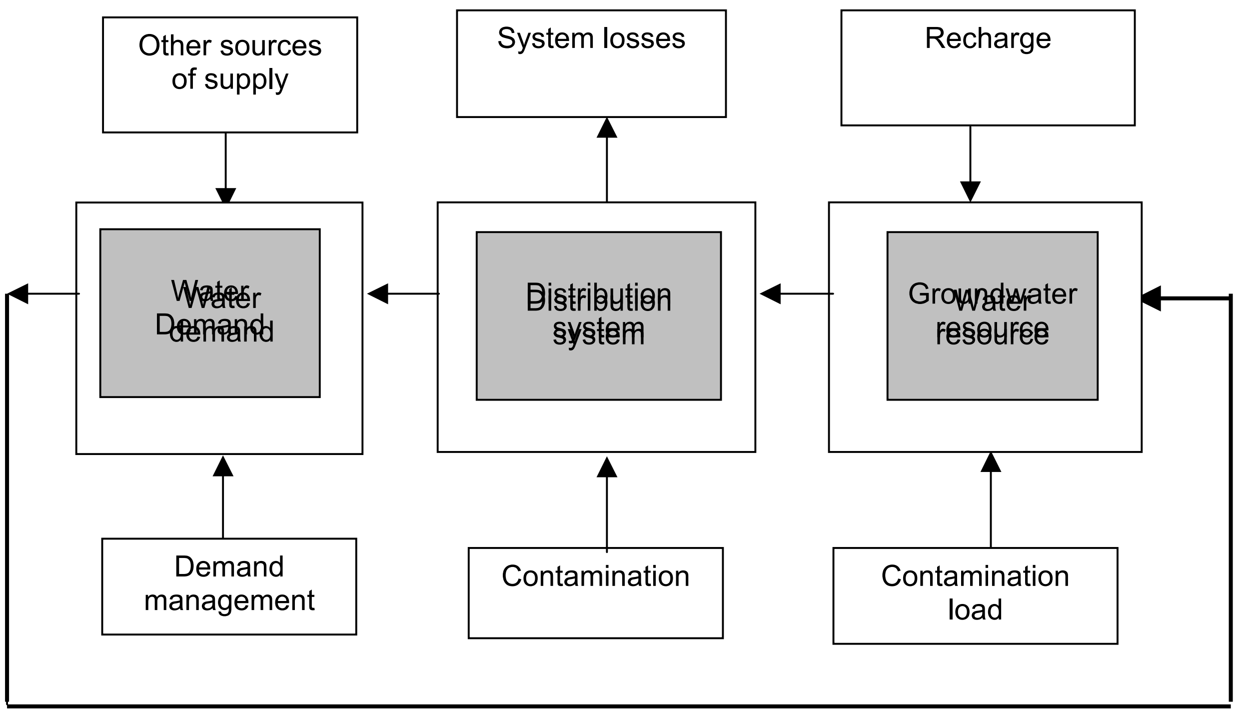
Fig. 2 A Simple Mitigation Framework

3. The Colombian Project

While the integrative concepts and processes were now clear, the need at this juncture was to develop a practical management framework that could be applied in different institutional and geological circumstances. The opportunity to do this arose in a DFID study entitled “Integrated Groundwater Management Pilot Project in Colombia” which WMC had successfully bid for. The broad objective of the project was the establishment of approaches replicable to the management of groundwater in Colombia that are socially equitable, economically viable and environmentally sustainable. Two contrasting pilot areas were selected under the project, one a large industrial city (Cali) in the Cauca Valley and the other a small Caribbean island (San Andres). The work was conducted by WMC together with two very different environmental bodies responsible for local groundwater management. A national geological body was also closely involved.

The aim was to prepare an approach for integrated groundwater management that was sufficiently flexible yet generic enough to allow replication to other parts of Colombia with diverse geological and institutional conditions. Radical rethinking was required of a group of natural scientists to change their way of thinking to a holistic and systems approach and to work conjunctively as an integrated team towards common management objectives. To achieve this a problem-centred approach was developed based around the following conceptual model (Fig. 3).

Fig. 3 Conceptual model for integrating supply and demand systems for the management of groundwater resources



The conceptual model provides a ‘big picture’ of the water resources supply and demand system. It is a flow diagram centred on the three ‘black boxes’ of water demand, water distribution and water resources. Placing demand on the left hand side reverses the traditional supply side focus of most approaches and illustrates the importance of considering water supply as an objective-led or demand-pull service that sets out to satisfy water needs. There is, however, nothing sacrosanct about the ordering; what is key is that water demand and water resources are viewed as part of the same circular and balanced system.

In each of the case study areas, specialists sat together to attempt to put figures to the summary boxes (and a succession of more detailed boxes that lay behind them), using best-estimates sometimes little better than guesses. Quantifying the natural flows, losses and levels of contamination as rigorously as possible but with whatever information was available helped to clarify the relative importance of different problems and opportunities for action. Balancing inflows and outflows provided an independent check and helped identify data uncertainties and information gaps. Careful cross-checking for inconsistencies gave rise to a lot of heart searching in the team meetings (and revision of thinking when figures did not add up) but generally the method was well understood and much appreciated.

There was considerable variation between the two situations with respect to both institutions and geology. In Cali it turned out that, although there were local water supply problems in some poor communities, natural regeneration of aquifers was still adequate owing to high rainfall and the availability of surface water supplies; the main problem here was one of declining water quality resulting from industrial activity with little or no environmental control. In San Andres, on the other hand, growth in population and tourism alongside limited rainfall was leading to over-exploitation of the limestone aquifers and, in consequence, serious intrusion of (saline) sea water and local contamination from domestic cess pits.

4. The Planning Framework

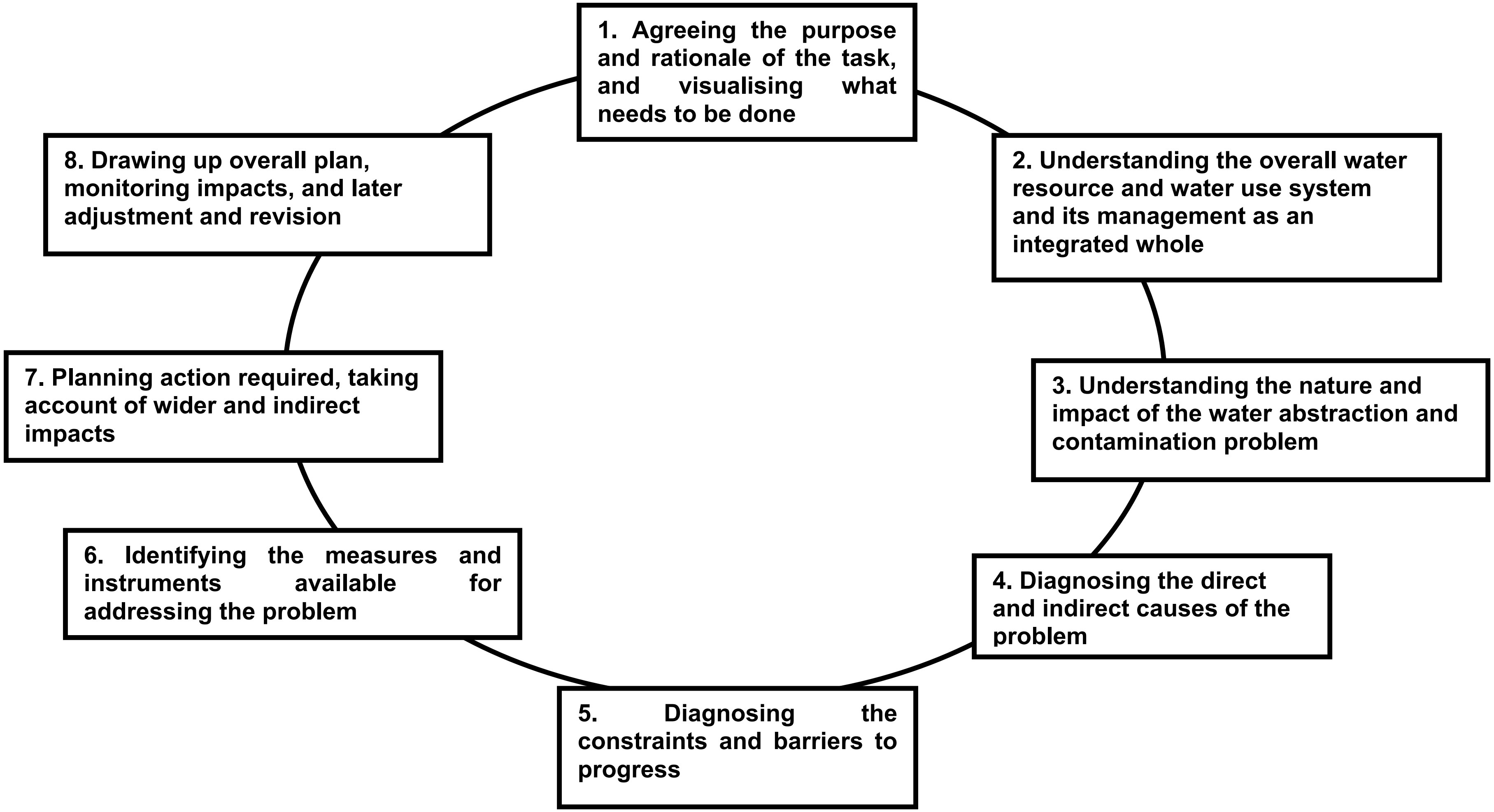
From this understanding of the local water supply and demand situation and the quantitative and qualitative pressures on them, a generic planning framework emerged (see Fig. 4). This is a series of steps for managing resources in an integrated way, while also assisting team members to maximise their contribution to the common goal. Although the steps are broadly iterative and sequential, they need not be followed in the order indicated, especially as information may later become available at which time the box should be revisited. The four main thrusts of the framework are:

- understand the overall water system and balance
- analyse the human ‘problem situation’ and causes
- visualise broadly what needs to be done
- determine options available and action required.

There is inadequate room in this paper to describe individual steps except in the briefest of terms.

There is no single ‘correct’ starting point but for convenience we assume the framework begins by developing a vision of where the plan is going and what it should achieve, providing a goal from which practitioners can work back. In the experience of the team arriving at this vision is not a single ‘conversion’ but something that gradually becomes clearer over time. In Colombia the list (see below) was extended and changed as the pilot projects developed. Though priorities may vary from case to case, generally the vision or goal involves satisfying the following:

Figure 4 Eight overlapping steps for improved water resources planning and management



- water is provided in adequate quantities to all customers
- water is supplied regularly and reliably to customers
- water is of acceptable quality for different uses
- water resources are managed sustainably with no degradation (quantitative or qualitative) over time
- water is supplied efficiently and at minimum cost
- water losses and system wastage are minimised.

Where possible, objectives should be mutually compatible (so called ‘win-win’ situations) but in some situations trade-offs between them are unavoidable. Where prioritisation is necessary it should be done as deliberately and transparently as possible, with full account taken of the costs and sacrifices involved and the way these impact on different stakeholder groups. In developing countries especial attention should be given to the poor and vulnerable and those with inadequate political representation.

The second step in the process concerns providing the ‘big picture’ of water resources, distribution and demand, as discussed above and illustrated in Fig. 3. Quantifying the flows helps clarify the relative importance of different physical problems, integrate supply and demand side flows, and prioritise options for management. The step is closely linked to step three which considers the human impacts of the physical problem, focusing on the specifics of groundwater resource consumption and quality, and also assesses the causes and consequences for stakeholders. Examples of these include:

- supply shortages and irregularities
- leakage or other forms of water loss
- poor water quality, due to natural causes or pollution
- non-sustainability, due to resource depletion or pollution.

The fourth step is analytical, namely the process of diagnosing the immediate and underlying causes of the problems identified. Detailed consideration of the factors giving rise to the problem is fundamental to good planning, helping provide a deeper understanding and identify ways of preventing or treating the problems in ways that address causes rather than symptoms. In both case study areas in Colombia assumptions had been made about the problem and its causation that proved less than fully adequate on closer investigation.

The fifth step is to identify and diagnose the constraints and barriers to progress. This requires a good understanding of the overall socio-economic and cultural context and the strengths and limitations of the relevant institutions, legislation and existing policies and practices. It also requires knowledge of water sourcing and provision by different routes, which may be more complex than meets the eye. Only with substantial enquiry did we establish, for example, that water in San Andres comes from four sources:

- the public supply (well) network
- large private suppliers with their own wells
- wells owned by individual households
- hotel desalination plants.

The local environmental body (CORALINA) had initially concentrated attention on the public supply network and this was changed only when WMC enquiries indicated that only a small proportion of water in fact came from this source.

Building on the knowledge gained of constraints and barriers, the sixth step concerns the identification of options for improved management of GWR and water-use efficiency. These can be broken down into supply-side (such as sinking more boreholes and leakage control) and demand-side solutions (reducing wastage and inefficient consumption). In general, water management can be improved through use of:

- improved water-saving technologies (for use by end consumers and in the distribution system)
- volumetric pricing to discourage unnecessary consumption (economic incentives to use water wisely and efficiently)
- polluter-pays initiatives reckoned according to the severity of discharge (especially applicable to point source effluent discharge)
- improved effluent collection, treatment and sanitation facilities
- regulatory instruments and land use planning procedures
- public environmental education.

It is important that the instruments or measures used relate to the local nature of the problem diagnosed and ease of implementation. Consideration should be given to the costs and benefits of implementation to various stakeholder groups, the likely effectiveness of each instrument or action, and the practicality and the cost of implementing them. The results of this stage of the planning process form the basis of the policy and practices for improved water management.

The seventh step is to select and prioritise the options for action as the basis of an implementation plan. The selection of options should be made by the authority responsible for water management on the basis of likely cost-effectiveness of action as constrained by budgetary limits.

The eighth and final step involves drawing up the plan for implementing the measures to achieve sustainable water management, where necessary dealing with unwanted environmental and socio-economic impacts and putting together arrangements for monitoring progress, evaluation of success and adjustment. These factors are often ignored but are very necessary parts of action planning. Additional activities may be required to mitigate adverse impacts.

5. Conclusions

The paper has attempted to show the need for improved integration in the planning and management of GWR and described a problem-centred method developed for achieving this. The framework should be viewed as an interactive system, with multi-level and dynamic linkages and interactions, rather than a prescriptive or mechanistic tool or cast in stone. The steps used provide an indication of sequential logic but this should not supplant intelligent and flexible usage, and the need to revisit steps as new information becomes available.

The approach is integrative and interdisciplinary (as opposed to multidisciplinary), bringing together both supply side and demand side (production and consumption) approaches and contributions from different disciplines, including systems thinking. In theory it requires a multidisciplinary team from natural, social and engineering sciences to address the different issues and work through the process indicated, though for budgetary reasons this may not always be possible and compromises may be required. However the need to focus on a clearly identified problem and agree on a common purpose is fundamental to integrated management. The methodology also helps people feel and be involved, work together and assist job satisfaction.

Our experience in developing and applying this approach suggests it can be successful in bringing together individuals with widely different skills and potential contributions to work as an integrated team to common objectives. It was developed largely for the purpose of groundwater management but we see no reason why it should not be more widely applicable to water resource management in general. Indeed, some of the fundamental ideas are considered to be helpful to team-building and work integration at any level of endeavour.

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