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Integrated Water Resources Management; The System of Systems for Sustainable Development: The Egyptian Experience

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Abstract

Egypt's global water resources system is a composite one which includes surface, ground, non-conventional and a few rainfall. The transported surface water through the Nile River predominates other sources. It forms 95% of Egypt's total water resources and recharge the shallow groundwater aquifer. Agricultural developments in the Nile Valley and Delta have exhausted the fertile clay deposit soil areas and for further land potential it should be searched in desert fringes and/or away from the geographic surface Nile system.

The water policy to 2025 is based on adding another 3.8 million feddan (almost 50% of the irrigated area) to the existing area. The strategy aims to resettle new communities in remote desert areas, in order to relief population pressure, as an integral part of the national development policy. At present, a number of mega projects are witnessed and others are still in the planning stage. Toshka in the south, Sinai in the north east, Delta fringes in the west of Delta, the north coastal zone on the Mediterranean Sea and others. Indeed each project has its unique physical, climatic, social, economic and environmental characteristics, but they are all converging towards one national goal for multipurpose sustainable development as one whole global system that must be managed in a monolithic aggregate approach.

However, each project has its self management strategy as separate economic unit to optimize the use of its input resources. At this point it deemed clear that the overall management of such sub-systems

in one system process can be termed integrated water resources management. Hence, the targeted objective is to globally maximize national economic and social welfare in a sustainable clean ecosystem, by coordinated development and management of water, land and related resources.

The paper discusses and describes in brief the development projects to focus on their objectives and constraints. Also it explains the water policy and strategy in Egypt to reclaim desert lands and introduce the concept of the integrated water resources approach in practice from the economic and engineering perspectives. The main points of strength and weakness faced in practice are stated and mitigation measures are indicated.

Introduction

The world water problem has been a sensitive issue of prime concern to international experts, technocrats, professionals, politicians, economists, environmentalists and others. Water problems and related subjects, stand at the top of the priority list at the national, regional and international levels. Indeed, the present statistics, where the world population is about six billion, half the population has no sanitation and one-third without access to clean water, it deemed clear that 50% in the developing countries suffer water born diseases and obviously serious pollution hits badly the environment.

Also, among the terrifying facts is the polluted water that is annually dumped to the environment and amounts to 12,000 cubic km, meaning equivalent to the annual discharge of the 10 largest rivers on earth. It is estimated that by the year 2050, when the world population reaches 9.3 billion, this amount of polluted water will become 18,000 cubic km, equivalent to nine times the world annual agriculture water requirements, unless drastic mitigation measures are taken.

The water situation in the Arab world is no exception, if not worst, aridity and desertification are the main symptoms. The area of the Arab countries are mostly deserts where about 83%

Receives less than 100 mm/year of rainfall, while less than 4% receives about 400 mm/year.

The groundwater levels, in most aquifers, are depleting due to over abstraction, and the wetlands are shrinking. These indicators are clear evidence of water scarcity in the Arab World, where the water per capita in some countries, dropped to less than 200 m^3/year, and on average the per capita is below the water poverty limit, i.e. 1000 m^3/year. This fact drives most Arab countries towards seawater/brackish water desalination, and most the Gulf countries own large desalination thermal plants (MSF, MED…etc).

Saudi Arabia have the largest, worldwide, in Jubail and Jeddah, and follows Kuwait and UAE, where about 60% of the world total desalinated water are produced. Jordon, Tunisia, Morocco …and the others are mostly using the membrane technology.

For the sake of argument, the fourth ranked country is Spain, where the northern part of the country has surplus water resources, while the southern suffers aridity. Although part of the water is transported from north to south, yet desalination stands competitive and not expensive for certain site specific conditions. Spain planned to establish, in the coming years, 21 membrane seawater desalination plants in the Mediterranean cost, where the overall capacity will be 650 million m^3/year. The total amount will be allocated as; 55.4% for urban uses, 22.4% for agriculture, 18.6% industrial and 3.6% tourism. The most attractive use of desalination is that for agriculture, what a few years ago was unbelievable. Although reduction of desalinated water costs are very important, but the confidence in a well managed system to supply water quality needed to irrigate different corps is essential. It is interesting to know that areas of the south-east cost of Spain are relying on desalination to develop a profitable out of season agriculture that is exported to many European countries. These statements emphasize one important fact which is the need for appropriate integrated management of water resources in a holistic approach for conventional and non-conventional sources together. Also, it indicates that, although desalination is expensive for agricultural uses, yet the advantage of excellent climate and clean environment open the door for economic analysis of export and trade the out of season crops.

Principals of Water Resources Management

Natural water resources, either rainfall- surface water- groundwater, form the main pillar for life on earth and gears sustainable development. But water is unevenly distributed and variable. Accordingly water resources engineers play a key role to reduce the differences between what is available and what is desired, with respect to quantity, quality and their distribution over space and time. Also, to increase the total benefits derived from water resources and improve the regional distribution of those benefits.

This will depend in part on few elements; a) available information, b) knowledge and skill of the analysts, c) the support and interest of the client (government or semi-government) and, d) effective communication between analyst and client.

However, management experiences in most developing countries face some challenges namely;

1. Weak, under-funded governmental institutions and low public interest and support.
2. fragmented governmental agency responsibilities and polices.
3. poor coordination among and within agencies.
4. lack of adequately trained/motivated personnel.
5. inadequate monitoring, operation, maintenance.
6. small attention to applied research before taking decisions and actions, as well the need to study environmental aspects.
7. short-term goals without consideration of future long-term impacts, i.e. lack of vision.

Accordingly, it is crucial in our Arab World, who witness water stress, to address concerned water experts and professionals, the question of sustainability; i.e. how can we plan, design and Do we Adequately Understand the Potential Value of our Regional Aquifers? manage our limited water resources so as to insure a continuing increase in the quality of life of our future generations?

Indeed, the cornerstone is to develop common understanding to integrated management concept in water resources in order to use its techniques and improve performance skills. It is well known that management is a process of decision making and developing an understanding and consensus that legitimize the decisions and enhances their successful implementation. But more important, it is an art learned experimentally, not analytically, hence it is a process that takes place in an institutional, social and political environment. This requires specific activities namely; planning-goal setting- debating- coordinating- motivating- deciding- implementing- monitoring and evaluating, bearing in mind that we have to do more with little amounts of water.

In the past, management techniques were based on the supply management approach, which simply to allocate and distribute the available water supply among stakeholders and activities. Then after shifting from the water abundance era to scarcity, the economic value of water became a limiting factor and accordingly management techniques changed from the supply to the demand management approach. This changes the concept towards use just what you need from water but not to share the available water. However, with the continuous pressure on water demand, due to population growth, extensive urbanization, increasing industrialization and other water needs, the world water experts turned to the recent accepted approach; Integrated Water Resources Management (IWRM). The Global Water Partnership in the Green Week at Bruxelles 27/ 4/ 2001 (Mediterranean Region) adopted the definition; "IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". The four agreed objectives for 2001- 2003 were;

1. establishing partnership and mobilizing political will,
2. building strategic alliances for action,
3. increase knowledge of IWRM good practices, and
4. developing and promoting regional actions.

Modeling Water Resources Systems for Management

It is well known that modeling is only part of the entire planning and management process. The role of models accordingly are;

- generate information, and predict impacts.
- help identify and evaluate alternatives to increase understanding.
- identify trade-offs among goals, objectives, interests, and data needs.

It is possible to increase the use and usefulness of water resources model through interactive programming.

Practical experience indicates that policy makers have to know some about models and modeling which include, but not limited to;

a- when modeling might help them make more informed decisions,
b- be aware of type of analysis, simple model development and analysis.
c- maintain considerable but informed skepticism, and
d- realize that models provide only information.

The most common types of models which have been widely applied in water resources are;

- Descriptive Models, and Prescriptive Models,
- Deterministic, or Probabilistic/Stochastic ,
- Static Models or Dynamic Models, and
- Mixed Models.

There are also in common use the Descriptive Simulation Models to answer the "What if" question, and the Perspective Optimization Models to answer the "What should be".

For planning and management the most popular optimization models for water resources are;

a- Linear Programming Models,
b- Discrete Dynamic Programming Models, and
c- Continuous Non-Linear Programming Models.

These models could be Deterministic or Stochastic, and Dynamic or Steady-State.

In real life, the common practice in water resource optimization problems are,

1. allocation of water to various competing users,
2. design storage tanks for municipal to contain a certain volume,
3. expanding the capacity of treatment plants,
4. reservoir system storage-yield functions and operation policies, and
5. water pollution control in streams or canals.

Accordingly, the objective functions could be;

a- economic (minimize cost, maximize net benefits, … etc),
b- environmental (maximize stream/ lake/ reservoir quality),
c- social (minimize maximum deviation from various water quantity/ quality targets, … etc), and risk (maximize vulnerability, … etc).

Indeed the modeling process requires thorough understanding to the system configuration and function, as well as a clear realization to the interrelationships and interactions among the system components. Also, being an integral part of the environment, it is impacted by and impacting on it hence modeling should be flexible and expandable. However, mathematical formulation of complicated systems may give misleading results and in such case physical modeling should be the solution for verification and model validation.

System Analysis of IWRM

The system by definition is part of the environment which is determined by a set of rules and criteria to define its boundaries, interaction among components, inputs and outputs. System components may be considered sub-systems which can be handled as a separate system by itself. The important point is to search deeply in the parameter space for the relationship functions between the system components and the interaction of the whole system with the environment. This definition is extremely important when referring to the case study of Egypt and IWRM in the next section.

Water resources systems in general may be represented as a circle combining components interacting with the environment; where the inputs can be classified into three types of variables; controlled, partially controlled and uncontrolled, while the resulting outputs are categorized; desirable, undesirable and neutral.

The real challenge is how to convert undesirable and neutral outputs to desirable. This may be obtained by controlling the partially controlled and if possible partially control the uncontrolled inputs. There must be feedback between inputs and outputs and vice-versa. The schematic of Fig. (1) illustrates a simple representation to a system subject to input variables and the interactive system components produce a set of outputs.

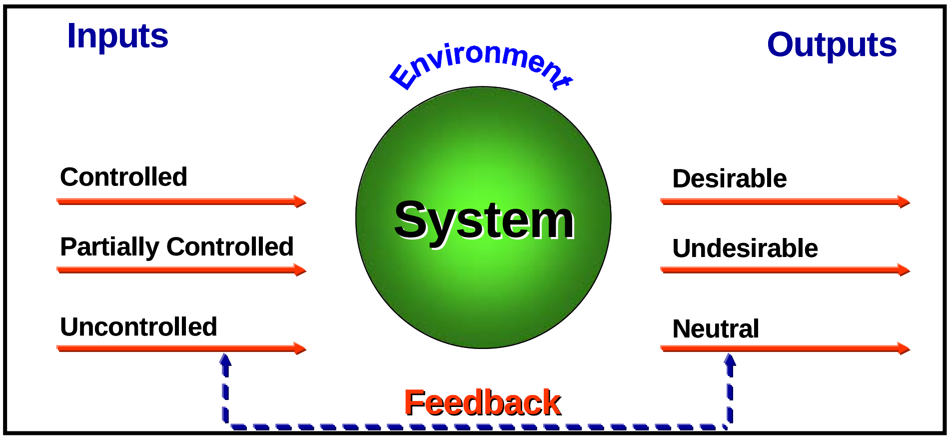

Figure 1: All possible feasible is termed the policy space which vary w.r.t time and physical space

The process of assigning certain values by decision makers to the controlled and/or partially controlled input variables is termed the water policy space. Accordingly, systems modeling include three basic steps;

a- Systematic methods of analyzing systems of independent components to identify and evaluate alternative designs and operating policies,
b- a framework for assisting those responsible for making decisions, solving problems, or gaining an improved understanding, and
c- a process intended to focus and force clear thinking about "Large, Complex" systems problems and to promote more informed decisions.

Therefore, the systems analysis exercises follows a certain procedure in order to achieve its practical targets,

1. problem recognition, definition and bounding,
2. identification of goals and objectives,
3. generation of alternatives and evaluation,
4. decision, implementation and monitoring.

It should be emphasized that re-evaluation of any of the steps may be necessary, if the process may reveal any non-realistic results or ambiguities.

The Egyptian Experience and IWRM Approach

Egypt historic experience with the Nile River was characterized by the unique irrigation management techniques that were inherited until modern history. No doubt the Nile water is Egypt's life and that irrigated agriculture is the principal water consumer. After the construction of Egypt's High Aswan Dam (HAD) in 1960's, the Nile water quota was limited to 55.5 billion m^3/year. The population increase since then is almost doubled and accordingly more agricultural lands for food are needed, industrialization is uprising, urbanization is expanding and many other water demand projects are growing. The natural flow of the River Nile can only be increased, at the macro level, by development of its upper catchments through integrated river basin planning and management.

But at the regional and national scale, optimization of each country's water quota can be achieved by appropriate management policy. Management is concerned with the quantitative, qualitative and environmental aspects. Arid regions use conventional water as well as non-conventional (reuse, recycle, treated water, groundwater, rainfall harvesting, desalination … etc). These sources are inputs to the main water system which are allocated to the system components, namely; the agricultural, the industrial, the domestic, the tourism, and other components. Egypt water policy to 2025 is to add some 3.8 million feddans under irrigation, increase the industrial and domestic quota.

The ongoing mega projects are;

1) Toshka in the south, the most arid area in Egypt, but there exist untapped groundwater that will supplement the surface water to irrigate more than half million feddan. There is also great potential of solar radiation that can be harnessed for clean energy production which can be used for irrigation and domestic purposes.
2) El-Salam Canal is Sinai, the largest ever project in Egypt for the reuse of drainage water mixed with equal amounts of fresh Nile water to irrigate more than 0.6 million feddan. Natural gas in this area forms a promising energy potential which is also environmentally friendly.

Hence each component of the global water system must be treated as separate system where its input variables include a water element in the production process and there are released wastewater effluents with different quality and quantity. Also, the output products, specially from the agriculture and industrial sectors, of the overall water system, such as units of (cotton, rice, wheat …etc), or industrial units (steel, paper, fertilizers.. etc) or else, where water is not apparent but embedded in plant tissues or evaporated to the atmosphere, these intangible water is termed "virtual water". There is also what is so called "unaccounted for water", which is simply the unknown water losses that disappear and could not be captured or computed

Accordingly, tracing and managing each and every water drop in the main water system and through each individual system component (agriculture, industrial … etc), at their input and output (tangible or intangible) and weather output products are used at local market or exported, and accordingly it deemed important to develop a model to minimize water uses and maximize economic benefits, this in essence the IWRM process providing a clean ecosystem is maintained.

Fig. (2) shows an overview of the configuration of the hierarchy integrated water resources management along the Nile system in Egypt. The outflow from the Upper Nile catchments is the inflow to Lake Nasser (HAD). The Forecast Center of the ministry of Water Resources and Irrigation (MWRI) have the forecast modeling facilities and on-line data access to the satellite images recording the cloud conditions over the Ethiopian Plateau (the sources of the Blue Nile, the principal annual flood tributary), as well the down scaling models to translate expected precipitation from the upper atmospheric layers to the ground. The sophisticated modeling tools are continuously receiving data from land sat and analyzing it to give indicators about the annual flood nature.

This information are the input to Lake Nasser simulation models to set the storage and regulation policy as well as the operating rules for the downstream releases pattern including the hydro power operation. However, the abstraction from Lake Nasser to Toshka Project is pumped by a huge pump station to secure irrigation water supply even when the reservoir at the lowest stage.

The released flow is managed through routing models where the conveyance of the Nile discharges pass through a series of barrages to control upstream levels for water diversion through main canals and generate local hydropower electricity. The main Nile ends at Delta Barrage and splits into two main branches. Along such long travel (about 1000km) the abstractions for agriculture, industry, domestic and others are managed and controlled. For agriculture which covers the Nile Valley and Delta, there is special agro-economic distribution model to comply with the cropping pattern requirements and a drainage model was developed to capture all the data concerning the drainage system to the sea. This complex global integrated water management approach is schematized in Fig. (3) where the overall input to the Nile system in Egypt is denoted by 1) the Upper Nile catchments and 2) lake Nasser simulation model.

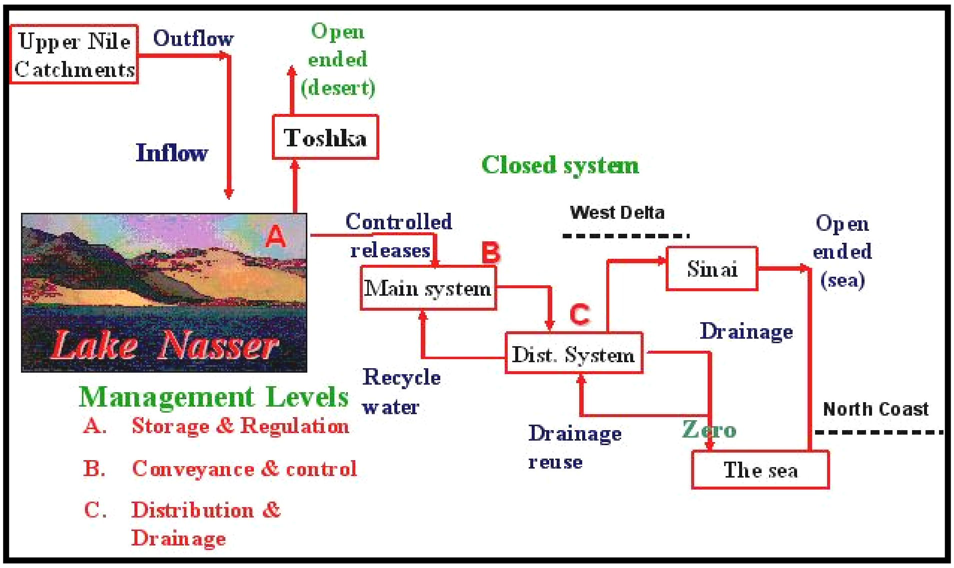

Figure 2: Hierarchy of Integrated water Resources Management

The released discharges are routed through the Nile and sectoral allocations take place and managed as indicated at the input and output of each component. The tail end of the drainage system terminates in the sea. The IWRM as illustrated stands as a global management system of all specific systems under one umbrella to avoid losses and the misuse of available water taking into consideration the quantity, quality and ecosystem conservation.

It should be stated that there are points of strength and others of weakness associated with the ongoing mega projects;

a) The points of strength at Toshka is the hot climate and good water quality are favoring the export of the agricultural products, also the access to the hydropower station and the transportation facilities which encourage the resettlements and creates new opportunities. The Sinai project being close to several tourists projects, natural mining resources and accessible markets gives good marketing opportunities and attraction to investors
b) The points of weakness are the harsh climate in Toshka requires special residential arrangements and working environment. As far is Sinai the weak point is the monitoring and adjustment of the mixed water (reuse of drainage and Nile Water).

Applied Research the Mechanism for Efficient IWRM

Upgrading the management skills and techniques must be supported by technology advancements, on one hand and the national plan needs driven, on the other. For each component a detailed system analysis is needed to explore the water policies and conservation practices based on technical outcome from the applied research capabilities and consult the most appropriate technologies for water savings.

Technology advancements whether available or foreseen or need to be developed aims at recommend most efficient techniques for water based components (agriculture, industry, domestic … etc). accordingly applied research is a bridging plat form between; a) national plans decision making, b) technology advancements and know-how, and c) the actions on the ground. Management levels are responsible of the quality control and assurance (Q & A) with the help of consulting firms and research centers, if required.

The nature of research focuses on the water conservation element. For instance, the agriculture component has to conduct research of the on-farm water savings, use of short duration high valued cash crops, introduce safe genetic engineering to increase productivity, apply tissue culture and bio technology, introduce new hybrid seeds that tolerate salinity and water stress …etc. For industry the elements of the system are the different industries using water as an input source for cooling, processes, municipalities and hence industrial wastewater released to the drainage or the environment will vary in quantity and quality (different types of pollutant). Research must take the lead to save water, such as change form water cooling to air cooling, also to manage and control polluted effluents by treatment and recycling in a closed system, and others research directions.

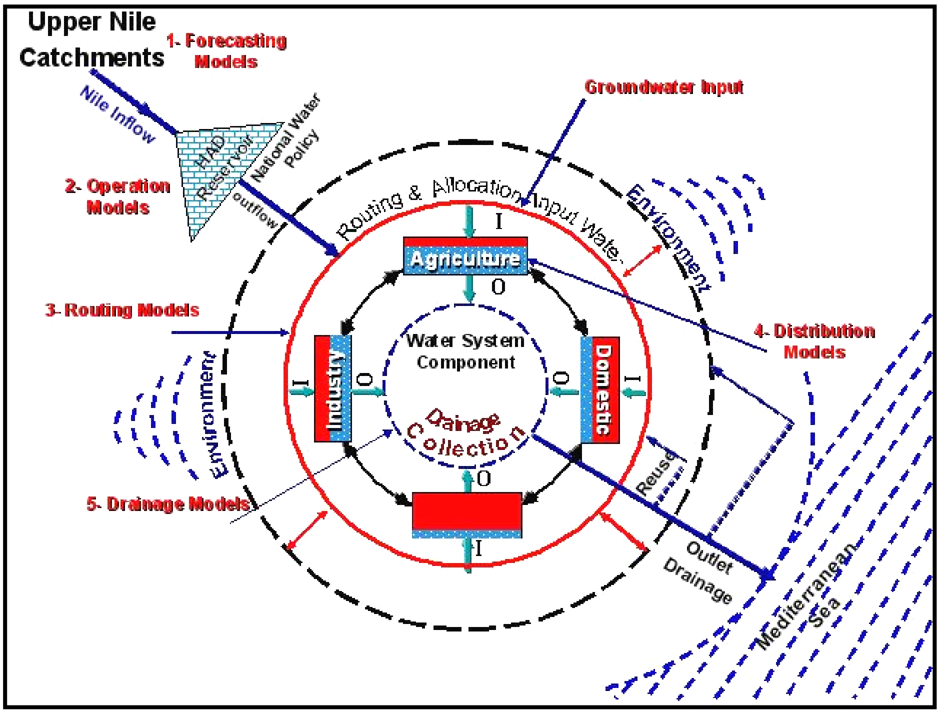

Figure 3: Models & Configuration Of IWRM System Components

The same apply to the other components, but the targeted objective remain unchanged to save water input and manage water quality outputs. The scope of research is unlimited and dynamic. It should be strongly emphasized that applied research must take place before action plans, and monitoring and evaluation of research results should be of great concern and a continuous process at all levels. Although applied research is more costly than pure theoretical academic research, yet the outcome is more realistic, practical and cost effective on the long run.

Therefore applied research, in order to become an effective and efficient tool for enforcement the IWRM policy, it must receive from top officials the very special care and attention as well as the necessary funds needed for the expected remarkable research results. Needless to mention that scientists and technologists are the brains of the modern nations.

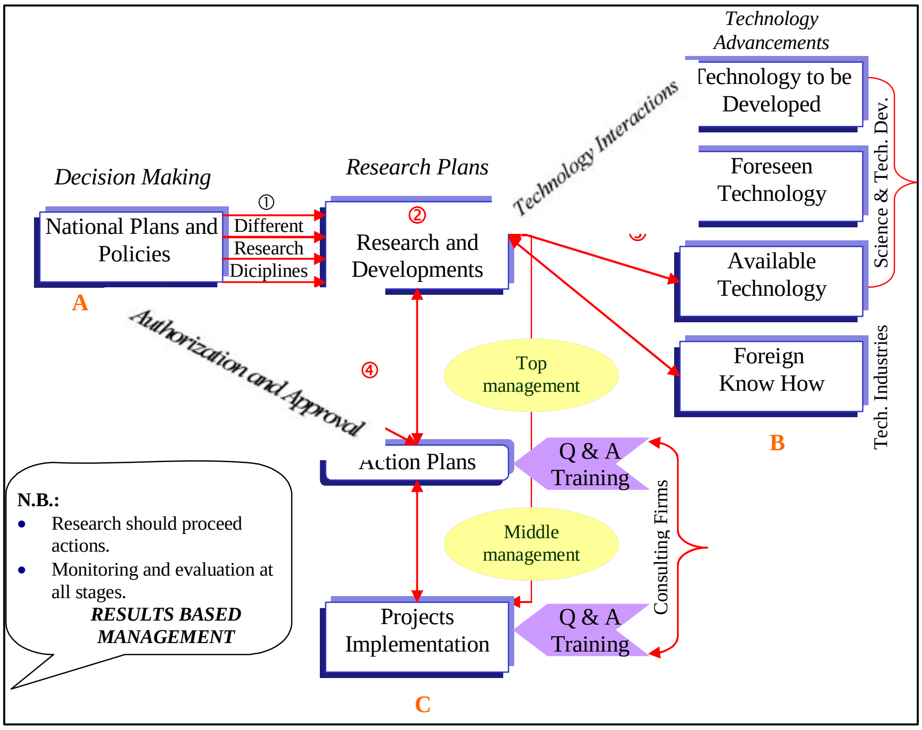

Figure 4: The Role of Research is the Bridging Between: A. National Plans, B. Technology & Know How, C. Action Plan

Again, the Arab scientists, technologists and people of wisdom are no exception, if not better than many others, providing they get the suitable comfortable environment, and history tells us that clearly.

Conclusion and Recommendations

- Water availability and security has become the dominant issue for life or death in most arid countries where pollution levels have reached extremely serious records that are not only life threatening but also inhibit developments as a whole.

- IWRM is the most technically accepted approach worldwide to rescue the deteriorating water scarcity impacts on humans and developments. It comprises two themes a) water integration policy, and b) integrated management strategy. Each specific component forming the global water system (agriculture, industry,
- domestic …etc) must be analyzed as a separate system to search for means of water saving and ecosystem conservation.
- The developed global water model to capture fragmented water policies of each concerned system component under one management strategy umbrella which aims at optimizing the water use quantitative and qualitative with respect to time and space, is the ultimate target of IWRM.
- The backbone for efficient and effective IWRM policy is the activated applied research centers in the fields of water and related subjects. It should be realized that IWRM is not merely a software that could be used, but rather integrated efforts of multidisciplinary nature where its keyword is "management".
- Most of the Arab countries are either suffering or severely facing water scarcity problems, or on the border or will soon be facing the same destiny. Therefore water security in the Arab region must be a first priority.
- The one and only one way to face water challenges in the Arab world is to join forces, particularly the applied research capabilities in order to find our own way towards best understanding, planning, developing and managing all aspects relevant to our water security. Hence, it is our historic responsibility to strengthen the "Arab Water Council" initiative which took place in the Arab Water Conference in Cairo, Egypt last year based on the previous intensive efforts made during the "First Regional Conference on Perspectives of Arab Water Cooperation" 2002 in Cairo where the recommendation with the "Arab Network for Water Research" (ANWAR) was first established for the welfare and prosperity of our future generations.
- Energy is significantly affecting the IWRM, since optimum water allocation and distribution of modern irrigation systems, operation and control of mechanical systems including pump stations, systems automation, wastewater treatment plants, desalination and others, these are all energy dependent. Therefore, in the Arab region where solar radiation is abundant, there is great need for research and development of low cost renewable energy and/or natural gas.

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