

SUSTAINABLE MANAGEMENT AND PLANNING OF GROUNDWATER RESOURCES: CASE STUDY SANA'A BASIN

T. Taher¹, C. Ward², N.Fadl³, A. Saleh⁴ and M. Sultan⁵

¹*Civil Engineering, Faculty of Engineering, Fatih University, E-mail: tahataher@fatih.edu.tr*

²*Research Fellow, Institute of Arab and Islamic Studies, E-mail: Wardcsward@aol.com*

³*Free-lance consultant, E-mail: nasserarr@rambler.com*

⁴*National Water Resources Authority- Taiz Branch, E-mail: asas777046308@gmail.com*

⁵*National Water Resources Authority- Sana'a Basin, E-mail: mohammeda846@googlemail.com*

ABSTRACT

Sana'a Basin is experiencing a serious depletion of groundwater resources where critical water problems are pressing associated water quality degradation. The abstraction exceeds recharge by more than five folds. Water level declines about 4-8 meters annually. Groundwater is mainly used for agricultural activities, which have expanded several times since 1970's, and consume about 90% of groundwater. The situation is further aggravated by the absence of an integrated water resources management approach (IWRM) for the Basin, which should embrace a multitude of issues related to the resource that should result in suitable management plans and solutions acceptable to stakeholders. The IWRM approach would aim at: (i) balancing the use of available groundwater resources for agricultural, domestic and industrial uses in order to satisfy sustainable conditions of groundwater abstraction, (ii) enhancing and enabling community involvement and participation and (iii) establishing legal and institutional framework required for sustainable water resources management in the Basin. Being a topic of importance in management of water resources, the IWRM concept and its application to Sana'a Basin is reviewed in this paper to understand the shortcomings, and try to put forward the necessary parameters to assist in resolving the water crisis with an emphasis on their practical application. Mismanagement of water resources is mainly caused by lack of data, policy and institutional framework for groundwater abstraction and use, and inefficient irrigation practices. Lack of understanding the socio-economic aspects and local socio-political structure within the Basin is a major issue that caused drawbacks in sufficiently addressing the water management governance. Hence, a decentralized participatory approach is developed to suggest responsibilities for water governance and sustainable management and planning at the appropriate lowest level. Strengthen the technical planning and management function of the water organization and ensure a basin-level integrated approach to financing and implementation that translates plans into facts on the ground.

Keywords: IWRM, Sana'a Basin, water resources, groundwater, depletion, Management

1 INTRODUCTION

1.1 Yemen Water Situation

The present population of Yemen about 24 million and is likely to be doubled after 20-25 years which will reduce the present per capita availability of water from 120 m³/year to about 55 m³/year in 2031 as against the world average of 7,500 m³ per capita per year and 667 m³ per capita per year in the MENA region. About 74 % of the population lives in rural areas and dependent on agriculture, and provides most of rural income. Agriculture as a whole accounts for about 17 % of GDP and sector employment is estimated at 54 % of the total labour force (MoPIC, 2004). There are about 99,000 wells mining the groundwater from several basins in the country. The total annual consumed water quantity is about 3.9 Mm³ of which 82% mostly exploited for agricultural activities, 14% for municipal water supply sector and 2.7% for industrial sector and the rest for touristic sector. Against the renewable water supply of 2,500 Mm³, the water demand for the country during 1990-2010 is estimated to increase from 2,897 Mm³ in 1990 to 3,923 in 2010 (see Table 1). The annual deficit,

which was 397 Mm³ in 1990 is 1,423 Mm³ in 2010. This huge deficit is met from the deep aquifer storage, causing rapid depletion of groundwater.

Table 1: Water Demand by Sector and Deficit (Mm³)

Sectors	1990	1998	2000	2005	2010
Irrigation	2,675	2,896	2,958	3,119	3,224
Live- stock	25	29	30	33	37
Municipal	166	274	300	408	553
Industrial	31	64	72	118	109
Total	2,897	3,263	3,360	3,678	3,923
Deficit	397	763	860	1178	1423
% Deficit	16	31	34	47	57

The total water sectors deficit is also presented in figure (1) for two year i.e. 1990 and 2010 against the renewable water quantity.

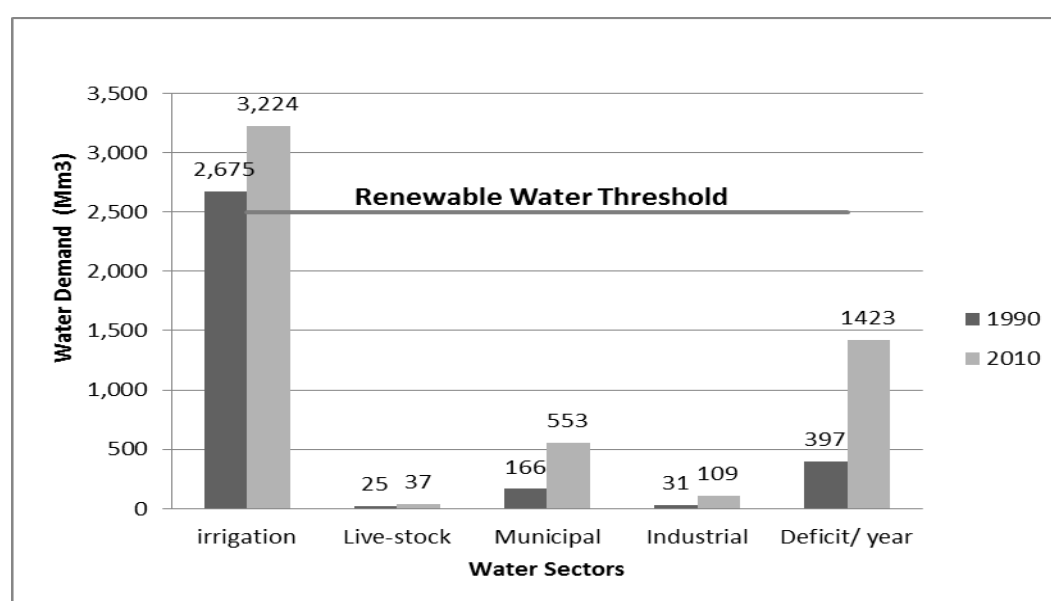


Figure 1: Water Demand for the Years 1990 and 2010 (Mm³)

The quantity of water exploited exceeds the average groundwater. In some basins the drop in the water level is between 5 – 7 meters annually leading to a situation beyond recovery. In a number of basins, the groundwater mining is occurring at an alarming rate. Many towns are facing a serious water shortage. Some locations in Sada'ah basin are indicating groundwater drawdown of about 7 meters per year. The situation in Sana'a and Taiz basins is no better. The groundwater drawdown in the order of 4 – 8 meters per year is recorded in some locations in these basins. Besides, quantitative aspect of groundwater use, qualitative aspect is also facing serious setback. Untreated waste water from towns and industries is allowed to percolate into groundwater causing serious threat to groundwater quality. Also in some coastal region, sea water intrusion has caused groundwater salinity.

1.2 Sana'a Basin Water Issues

The Sana'a Basin is located in the eastern end of the western highland with the highest peak of the Jabal An Nabi Shu'ayb with the altitude of 3,666 m. The total area of the Basin is about 3,240 km² (GAFAG, 2007). Figure (2) shows the map of Yemen and the location of Sana'a Basin. The Basin mainly consists of the central plain area with the altitude of 2,100-2,400 m surrounded by the western and eastern mountainous area. The plain is sloping down from the south towards the north with the main city located at the centre expanding south-north. The Current populations and future increase in Sana'a Basin indicates that the population will increase from 2,876,774 in 2011 to 5,852,617 in 2025

which means more requests for water facing a major water disaster if no action are taken from now with special emphasis on IWRM and finding alternative resources (Taher, 2011).



Figure 2 Map showing the location of Sana’a Basin within Yemen (by Taher)

The annual rainfall generally varies between 120 and 330 mm, with an average of 212 mm/year. See figure (3) for rainfall distribution for the years 1989-2004.

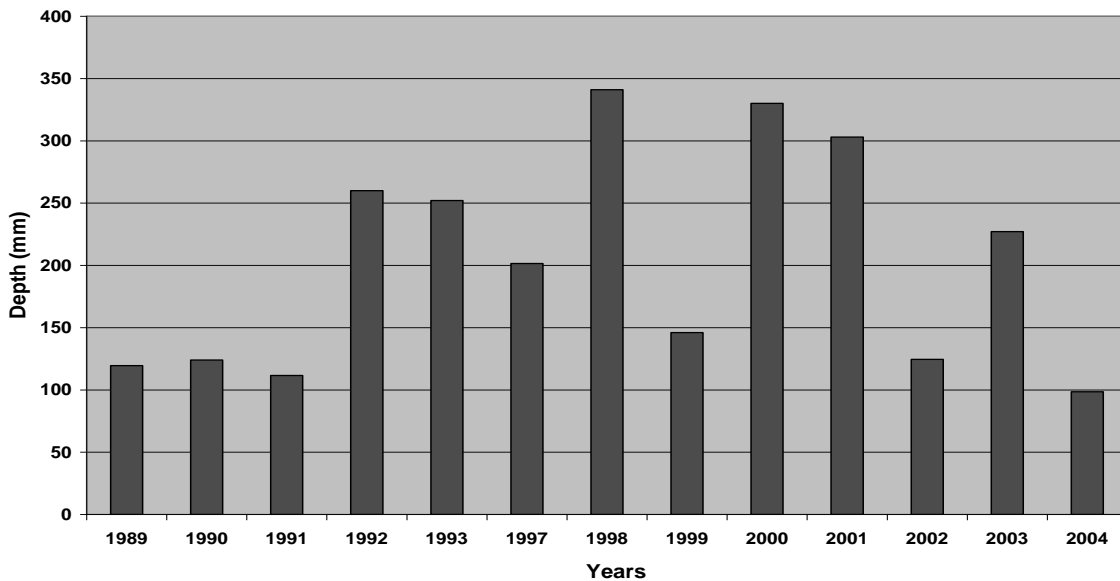


Figure 3: Rainfall Distribution in Sana’a Basin years 1989-2004

Agricultural activities in the basin mainly depend on groundwater which have expanded several times since 1980's, and consume about 90% of water. Over exploitation of groundwater resources

especially for agriculture, is the major factor causing aquifer depletion. Water table has dropped in all unconfined aquifers over the past three decades. Sana'a Basin is experiencing a serious depletion of groundwater resources with associated water quality degradation. The water resources situation in Sana'a Basin is extremely serious as abstraction exceeds recharge by more than five folds. Consequently, the groundwater level declines about 4-8 meters annually. Water balance of the basin means that the non-renewable fossil water resource is consumed every year and getting depleted rapidly. If these annual consumed amount is continued, the non-renewable water resources will continue to be depleted in a rate almost six times of recharge. The estimated water balance of the Sana'a Basin is summarized in Table (2) (Hydrosult, 2010).

Table 2 Average Annual Water Balance of the Sana'a Basin

Incoming components	Volume, Mm³	Outgoing components	Volume, Mm³
Component		Component	
Reservoir infiltration	5.7	Domestic and non-domestic demand (including 20% losses)	58.4
Rainfall and runoff infiltration	51.1	Irrigation water demand	221.1
Return flow infiltration	21.3		
Total groundwater recharge	78.3		
Inflow to the reservoirs	8.5		
Total incoming components	86.8	Total water demand	279.5
	Unmet demand		192.7

The distributed geology in the Sana'a Basin is categorized into five units, namely: Amran Group, Tawilah Group, Tertiary Volcanics, Quaternary Volcanic and Quaternary Deposits. The lithological summary of these five groups is described in the table (3) below (JAICA, 2007).

Table 3 Geology of Sana'a Basin [5]

Formation	Thickness	Lithology	Hydrogeological Description
Quaternary deposits	- 350m	Active alluvium, sand and gravel Gravel sheets, gravel plains and alluvial fans generally in areas of low relief with a stony surface Loess and ancient dunes: areas of wind-blown soils and sands (generally fertile land)	Unconfined aquifers are common, but semi-confined aquifers occur in places. Originally highly productive, but recently falling water tables are found throughout the alluvial aquifer. Water level fluctuations show a rapid response to rainfall.
Quaternary volcanics	- 400m	Trachytic flows and domes Basaltic lavas and scoria	Petrographically similar to Tertiary volcanics, but relatively unweathered and less permeable. Local and limited groundwater potential.
Tertiary volcanics (Yemen Volcanics)	2000m<	Gabbro Ignimbrite and ash-flow deposit Rhyolite and dacite Trachyte Basalt	Fracturing is widespread. Groundwater occurs in bedded ashes and tuffs, fractured lava flows, boundary zones between flows and major fault zones. Rhyolitic aquifers seem to provide higher yield. Overlie Tawilah group
Cretaceous Sandstone (Tawilah Group)	150 – 400m	Sandstones with minor calcareous horizons.	White, yellow or reddish fine to coarse grained sandstone. Generally productive aquifer, but highly anisotropic.
Jurassic Limestone (Amran Group)	100 – 400m	Bituminous limestone, dolomitic marl and sand	Fracture zones and bedding plane discontinuities, poorly productive aquifer

The Sana'a Basin is, therefore, a small example of Yemen where water shortage exists, due to low rainfall as a result of climatic change, high intensity of irrigation by groundwater, rapid increase in population and the limited water resources, the water situation in Sana'a Basin has been further aggravated by the following:

1. Improper planning and management.
2. Improper implementation of the water law and the by-laws.
3. Lack of public awareness.
4. The lack of up-to-date data and knowledge.
5. Lack of coordination amongst the real players (stakeholders) in the basin such as officials, local communities, experts, NGOs, donors etc.
6. High pumping technology and market conditions that are encouraging over-pumping.

It is, therefore, important to understand the necessity of IWRM as a tool able to reduce or alleviate the water and institutional problems in the basin.

2 IWRM TOOLS

IWRM is a process that 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 (GWP, 2001). An IWRM approach seeks to address a country's key water-related development problems in order to reach to a balancing state of demand and supply avoiding social-economical conflicts, loss of finances, waste of time and efforts and the fragmented decisions making about developing and managing water resources. IWRM approach will systematically be leading to avoid fragmented approaches and would aim at: (i) balancing the use of available groundwater resources for different users in order to satisfy sustainable conditions of groundwater abstraction, (ii) enhancing and enabling community involvement and participation (iii) establishing legal and institutional framework required for sustainable water resources management in the Basin, (vi) developing mechanisms to achieve financial sustainability, (v) empowering the roles of women in most, if not all, parts of management of water resources and according to the cultural and social aspects. IWRM approaches do not necessarily require making all these changes at once, nor do they imply starting in a broad-based manner (ESCWA, 2005A). The application requires the understanding of the process as a whole so as to get all parts chained to adopting a more sustainable and integrated approach to water planning and management.

The process of change is listed in the following steps:

- 1- Review the present statuses of the water resource and establish the overall goals
- 2- Build commitment from stakeholders to conduct the process including financial obligations
- 3- Analyze gaps and prepare possible mitigations especially for the socio-political-economic issues
- 4- Prepare strategy and action plan
- 5- Build commitment to action
- 6- Implement framework
- 7- Monitor and evaluate progress
- 8- Go back to step (1) if needed.

Figure (4) sketches the process graphically (www.gwptoolbox.org). The process is flexible and iterative and there could be additions in the chain flow according to the local conditions. The Global Water Partnership (GWP, 2001) has prepared an IWRM Toolbox offers a compendium of over 50 policies, actions and tools for putting IWRM into practice. The purpose of IWRM Toolbox is to provide water management professionals with clear examples of good and bad practices and lessons learned from real life experiences of implementing IWRM. These policy instruments allow the translation of IWRM principles into operational elements of IWRM national and local strategies, and plans of action and the monitoring of progress through performance indicators. While the proposed policy instruments in the Toolbox can be adopted and customized to local conditions; they are still

guided by three fundamental and inter-related principles, known as the three E-pillars of IWRM (GWP, 2001) (see figure 5). More description can be found in the same source.

The three E-pillars:

- **Economic Efficiency** : water must be used with maximum possible efficiency.
- **Social Equity**: secure basic right for all people to have access to water of adequate quantity and quality for the sustenance of human well-being.
- **Sustainable Environment**: present water resources should be managed in such a way that does not undermine the life support system, thereby compromising use of the same resource by future generations

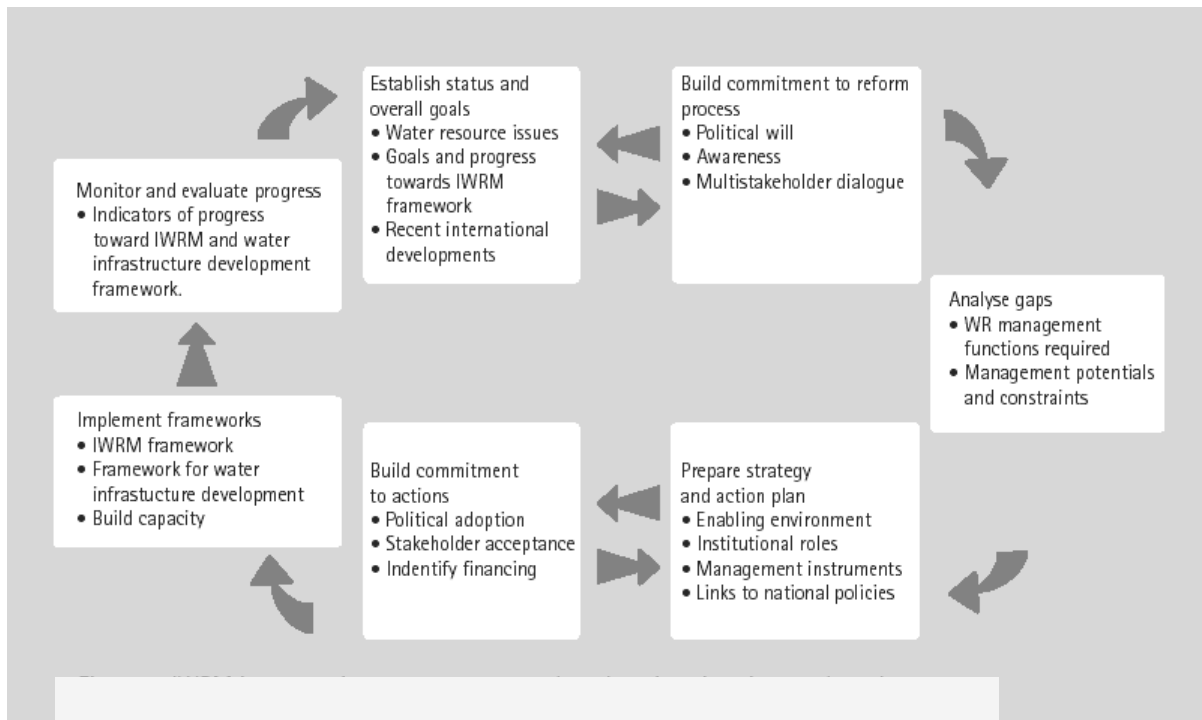


Figure 4 Process of IWRM for Change

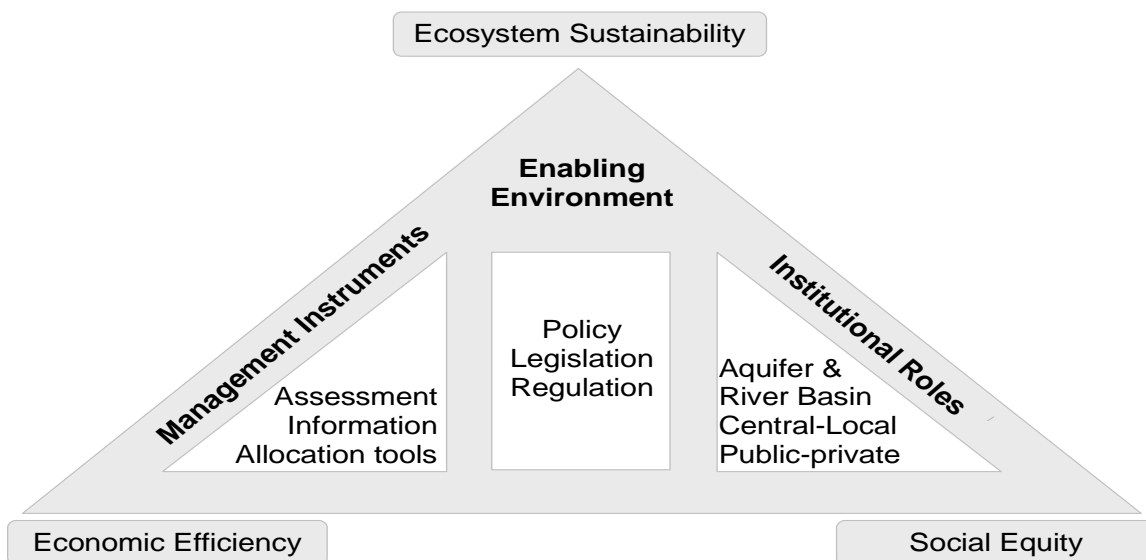


Figure 5 the three E-pillars of IWRM

3 SANA'A BASIN IWRM APPROACH FOR PHASE I

3.1 Background

In 2003, Yemen committed itself to a long term process of integrated water resources management in the Sana'a Basin, where critical water problems are pressing. Basically, IWRM approach is to develop and manage water resources and deliver water services, at different levels of the society. The approach is mainly depending on the broad understanding of IWRM principles and actions that allow the decision makers to make appropriate decisions in line with the IWRM objectives. The SB needs actions that would lead to the efficient use of its water resources. A fifteen year time horizon was selected, and divided into three phases. The first phase, designed to test technologies, demand and supply management approaches, and institutional arrangements, ended in 2010. The following is an assessment of the first phase by including the basic IWRM principles and the next steps for Phase II.

3.2 Institutional

Legal framework for basin management. Yemen has passed a water law that provides a sound legal framework for basin management. However, the law is being only partially implemented. The by-law has been to be issued but needs to be reviewed, and the provisions of the protection zone should be adapted to the varying characteristics of the different sub-basins stressing on the drinking water supply.

The Sana'a Basin Committee. To date, the Basin Committee has not been empowered and has been largely ineffectual. To make the Committee more effective, membership could be made more inclusive of key stakeholders, and the Committee's mandate could be strengthened to cover allocation of both water and financial resources. The Basin Committee could then become the supreme water governance authority in the basin, in tandem with local councils as the second line of authority, and WUAs as the front line resource managers, with NWRA-SB strengthened as adviser and secretariat.

Local councils. Local councils have only very partially fulfilled their statutory role of 'managing and controlling water resources in their area'. The role of local councils as second in line water resource managers - between the Basin Committee and the WUAs – needs to be more clearly defined, and their capacity strengthened.

Water user associations (WUAs). WUAs have developed well in the basin and have the potential for a sustainable role as front line water managers, in partnership with local councils and the Basin Committee. Institutional arrangements for consistent capacity building and empowerment need to be put in place. Nationwide, experience on WUAs needs to be pooled and the pathway to self-sustaining status needs to be traced out.

Water Users Groups (WUGs). Are the nucleuse of WUAs and are the front line of local the community. WUGs are much distanced from decisions and management of water resources even though the members are those on the site. Interlocking and communication with WUAs need to be established to foresee the challenges and the mitigations required.

NWRA Sana'a Basin Branch. Despite a fairly large staff and some support under SBWMP, NWRA-SB is struggling to fulfill its current limited mandate in regulation and monitoring. Careful planning and strong management will be necessary as a larger IWRM mandate is confided to the branch.

An improved governance architecture for the Sana'a basin. If the improvements mentioned (see box) are implemented, an integrated governance structure would be in place that would decentralize water resource management responsibility to the lowest accountable levels, in line with best IWRM practice.

Suggested improvements to the governance architecture

- To make the Water Law operational
- To delegate responsibility for water management to a trio of inter-related institutions: the Basin Committee to be the supreme water governance authority in the basin, in tandem with local councils as the second line of authority, and WUAs as the front line resource managers.
- To make the Basin Committee more inclusive, especially of representative user associations, and to empower it for both financial and water resource allocation
- To activate the local council role in water regulation
- To empower WUAs as front line water managers
- To adopt the sub-basin as the primary unit of water management, and to move towards institutional groupings at the sub-basin or district level that can adopt and implement water management strategies
- To greatly strengthen NWRA-SB to fulfill its role as planner and adviser, in partnership with other stakeholders and institutions

3.3 Water Resources Management

Quantification and trends in water resources. The water resources assessment conducted under the first phase has made available the basic data for practical planning at the sub-basin level. The assessment shows that, although all sub-basins are deficit, some have the potential to be returned to sustainability with careful strategic management.

Monitoring. Despite considerable investment, monitoring is almost at a standstill. Radical strengthening of capability is essential, and partnerships to collect and share data need to be developed especially with the local communities.

Regulation. Regulation of random drilling and drilling rigs has not slowed down the proliferation of illegal wells. Approaches that rely on a well-spacing rule of thumb and on community responsibility for regulating within their own area would be simpler and would place fewer burdens on NWRA. Formation of a professional drillers' association could help promote self-regulation. NWRA-SB could also focus on controlling the half dozen deep drilling rigs that could compromise the deep sandstone aquifer.

Towards integrated planning and management. Clear objectives need to be set for overall basin management, and reflected in detailed plans developed in a participatory way at the sub-basin level, working with stakeholders through the three part governance structure (Basin Committee – local councils – WUAs). A small but powerful basin planning unit needs to be set up in NWRA-SB to propose plans and to coordinate their implementation.

3.4 Supply Management

Recharge structures. Investment in recharge structures has only recently been completed, and a further monitoring period is needed before investing further. At first sight, the progressive construction of a series of check dams starting from the upstream looks a better choice than reservoir dams.

Treated wastewater. Proper management of wastewater requires careful training and regulation of farmers. Safe reuse of effluent from the proposed new treatment plant should be built in from the outset.

Other potential sources. A rapid economic review of rooftop rainwater harvesting is suggested.

3.5 Demand management

Irrigation improvement. According to a SBWMP survey, improved irrigation allows farmers to use 40% less water whilst increasing incomes by 10%. Clearly, irrigation improvement is the most important conservation investment and it needs to be factored in to sub-basin plans – but only where economically justified. As responsibility for irrigation improvement in the basin is transferred to NIP, care will be required to preserve the integrated approach of water resources management coupled with irrigation improvement and extension.

Meeting urban water demand. The priority Yemen gives to drinking water requires that: (1) planning and regulation must be used to reserve the deep Tawilah Sandstone for domestic supply; and (2) the Local Corporation, private providers and GARWSP have to work together to ensure affordable and sustainable network water for the whole population of the basin.

4 MOVING TO PHASE II

A basin-level bottom up planning process is proposed for allocating WSSP resources each year. An urgent priority is therefore to establish an integrated programming mechanism for the Sana'a basin and to submit a coherent integrated proposal for financing in 2011. The first phase is ending with no clarity on how IWRM is to be managed in the future. The key is to set up a strong IWRM planning function with assured financing and governance and supervision arrangements. The location of this planning function should be in NWRA-SB. The creation of the needed capacity will require high level support and substantial resources.

4.1 Overall assessment of Phase I and Next Steps

In summary, the first phase has piloted IWRM approaches in the Sana'a basin, and has demonstrated that many of them can work. However, many adjustments are required if a second phase is to be successful. Essentially, there will need to be:

- a technical planning function responsible for putting together IWRM plans, and for monitoring implementation and results
- a governance function that brings all stakeholders together to set long term hydraulic and socio-economic objectives, to debate and adopt plans, and to evaluate progress
- a financing and implementation function that translates plans into facts on the ground

Table 4 summarizes the achievements and challenges at the end of the first phase, and the options and key questions for the second phase (Ward, et al., 2010A)

Table 4 the long-term program for water resources management in the Sana'a Basin, Moving from Phase I to Phase II

	Technical planning	Governance	Financing and implementation
What did Phase I achieve?	Prepared a Master Plan by (JICA 2007)	Set up Basin Committee	Assured financing through a single integrated project
	Prepared water balance and models by (Hydrosult)	Involved local councils	Integrated and efficient implementation through a PIU
	Set up monitoring and public awareness	Set up water user associations (WUAs)	NWRA-SB equipped for monitoring and regulation
	Demonstrated technical and economic value of water conservation in irrigation and recharge		Integrated M&E at project/basin level by the PIU. Integrated supervision by government and donors.
Challenges at the end of Phase I	Need to set up a permanent planning function for the basin	Need to get the elements of the governance structure (Basin Committee, local councils, WUAs) working together	Need to find a financing mechanism for Phase II which keeps the integrated basin focus
	Need to adopt and implement the Master Plan	Need to empower all three elements of the governance structure by making their decision making powers clear and by capacity building	Need to implement through the responsible mandated agencies and to keep the integrated basin focus despite (1) varying track records of the agencies; and (2) lack of structural or hierarchical linkages between them
	Need to set clear water resource management objectives and prepare a 5 year plan and annual programs		
	Need to link technical programs for water conservation to water resource management objectives		Need arrangements for integrated M&E and supervision

	Technical planning	Governance	Financing and implementation
Phase II options	<p>Proposal is to strengthen the planning function in NWRA-SB to:</p> <ul style="list-style-type: none"> - carry out continuous water resources assessment - prepare integrated 5 year plan and annual programs, integrating all supply and demand elements - conduct M&E of achievements against targets 	<p>Proposal is to consolidate a three part integrated and inclusive governance structure (Basin Committee, local councils, WUAs) that:</p> <ul style="list-style-type: none"> - decides on allocation and regulation of water resources and their development and uses - decides on the basin plan and the allocation of financial resources - takes responsibility for regulation 	<p>Proposal is to ensure a basin-level integrated approach to finance and implementation through:</p> <ul style="list-style-type: none"> - integrated plans and annual programs prepared by NWRA-SB, approved by the Basin Committee and financed by WSSP - implementation of the plans and programs by mandated agencies strengthened as needed (NIP, NWRA-SB, Sana'a LC, GARWSP.....) - M&E and supervision at the basin level by NWRA-SB reporting to the Basin Committee, and by GoY and donors under WSSP arrangements. <p>Phase II to be 'packaged' as a five year 'project' in order to have clear objectives, inputs and outputs, a clear five year action program, and assured financing and supervision for the entire Phase II</p>
Key questions	<p>If the difficult job of integrated planning for the basin is to be put in NWRA-SB, how to overcome all the many constraints to building effective institutional capacity in Yemen?</p>	<p>Can authority over (1) water resource allocation; and (2) financial resources be given to the Basin Committee?</p> <p>Is Yemen ready for this level of stakeholder participation?</p> <p>Can WUAs, local councils and the Basin Committee really work together to regulate use and stop illegal drilling?</p>	<p>Can an integrated focus be maintained without a 'project' vehicle?</p> <p>As irrigation investment transfers to NIP, will the link between water resources plans and irrigation water conservation be cut?</p> <p>Similarly, will NIP and NWRA-SB lose coherence on WUAs, as they have different approaches to WUA objectives?</p>

4.2 Sana'a Basin IWRM Approach for Phase II

The following paragraphs describe the issues and the actions required that are principally important in implementation of the IWRM in Sana'a Basin:

- (1) **Improvements of the institutional set up that would deliver more effective IWRM results;** starting from the concept of reform of institutions for better water governance, from regulatory bodies, to local authorities and civil society organizations, and from basins to sub-basins and developing human resources by upgrading the skills and undertaking capacity building for regulatory bodies particularly local users. The improvements required for SB are essentially upgrading the recent statuses of the governance and include more authority and links. Therefore the suggested additional strengthening and improvements are highlighted below:
 - To delegate responsibility for water management to a trio of inter-related institutions: the Basin Committee to be the supreme water governance authority in the basin, in tandem with local councils as the second line of authority, and WUAs as the front line resource managers (Ward, et al., 2010B).
 - To make the Basin Committee more inclusive, especially of representative user associations, the private sector and women, and to empower it for both financial and water resource allocation and the strong implementation of the water law.
 - To activate the local council role in water regulation
 - To make WUAs inclusive of all water stakeholders and to empower them as front line water managers where Community-based groundwater management can be considered as an essential building block for efficient, sustainable and equitable use of groundwater in Yemen (Taher, et al., 2011).
 - To adopt the sub-basin as the primary unit of water management, and to move towards institutional groupings at the sub-basin or district level that can adopt and implement water management strategies.
 - To greatly strengthen NWRA-SB to fulfil its role as planner and adviser, in partnership with other stakeholders and institutions

If these improvements are implemented, an integrated governance structure would be in place that would decentralize water resource management responsibility to the lowest accountable levels, in line with best IWRM practice. Figure (5) below illustrates the respective and complementary roles that are played by each level (Ward, et al., 2010B).

- (2) **Strengthening the planning and management of the local organizations (National Water Resources Association- Sana'a Branch (NWRA-SB));** the planning function would have the following activities:
 - Setting objectives and priorities: this would include a participatory learning approach so that all stakeholders understand and are trained in IWRM. The output would be agreed long term objectives and measures for IWRM in the basin, including: (i) groupings of sub-basins with similar characteristics and objectives; (ii) measures to be implemented for each group of sub-basins; and (iii) priorities for phasing.
 - Water resources assessment and modeling: this would involve building simplified models of the water resources in the basin using all the available data, at both basin and sub-basin level; explaining the models to all stakeholders, showing the strengths and weaknesses of the models; employing the models to predict water resources and the water balance; maintaining and improving the models by constant flow of data; and disseminating results regularly, particularly at sub-basin level. The Planning Team would work jointly with the Water Resources Monitoring and Decision Support Department on this.
 - Preparation of plans, programs and policies: preparing, in a participatory way (i) the revision and update of the master plan of the basin based on previous studies; (ii) a five year plan (2011-2015) covering Phase II of IWRM in the basin; (iii) annual Action Plans for NWRA-SB and the basin as a whole. Stakeholders would be involved in determining implementation

priorities within available financial and water resources. The Team would also analyze and propose policies needed to accompany IWRM implementation.

- Sub-basin planning: this would involve breaking down data and models by sub-basin; discussing with stakeholders (especially WUAs and local councils) the local water management objectives and measures; agreeing on a sub-basin plan together with implementation and financing responsibilities; supporting implementation; and monitoring, evaluating and reporting. It is expected that by the end of Phase II about four fully integrated sub-basin plans will have been completed, and others will be under way.
 - Capacity building: building the capacity of NWRA-SB and other water sector agencies in the field of IWRM. Essentially, all branch activities would become an input for IWRM.
 - Monitoring, reporting, public awareness: monitoring and evaluating the inputs for plans, evaluating the results, and reporting and dissemination encouraging water oriented civil society through school curricula, university water courses and professional and mid-career training. Transparency, product labelling and access to information are other key instruments (ESCWA, 2005B).
 - Carry out participatory water resources planning, monitoring and assessment: it includes the collection of hydrological, physiographic, demographic and socio-economic data, through setting up systems for routine data assembly and reporting involving local water users to be able to take the necessary decision; focusing on the better use of existing water withdrawals or reducing excessive use rather than developing new supplies (ESCWA, 2005B).
 - Conflict resolution: managing disputes, ensuring sharing of water. Conflict management has a separate focus as conflict is endemic in the management of water in many places and resolution models must be at hand.
- (3) **Suggest a governance function that brings all stakeholders together to set long term hydraulic and socio-economic objectives, to debate and adopt plans, to support implementation and to participate in governance, and to evaluate progress**; the specific proposal is for a three part integrated and inclusive governance structure - basin committee, local councils, water user associations - WUAs, supported by NWRA-SB as technical adviser. This governance structure would:
- Decide on allocation and regulation of water resources and their development and uses;
 - Decide on the basin plan and the allocation of financial resources;
 - Carry out specific water management functions, particularly at the local level within local water management plans; and
 - Take responsibility for regulation. In line with the sub-basin management approach, it is proposed to move towards institutional groupings at the sub-basin or district level that can adopt and implement water management plans. This decentralized and participatory approach is designed to locate responsibility for water governance and management at the appropriate lowest level, in line with good IWRM practice.
- (4) **Ensure a basin-level integrated approach and commitments to financing and implementation that translates plans into facts on the ground**; through:
- Integrated plans and annual programs prepared by NWRA-SB in a participatory manner, approved by the Basin Committee and financed by the Water Support Sector program (WSSP);
 - Implementation of the plans and programs by mandated agencies and authorities sharing the water resource management in the basin and
 - M&E and supervision at the basin level by NWRA-SB reporting to the Basin Committee, and by government and donors under WSSP arrangements

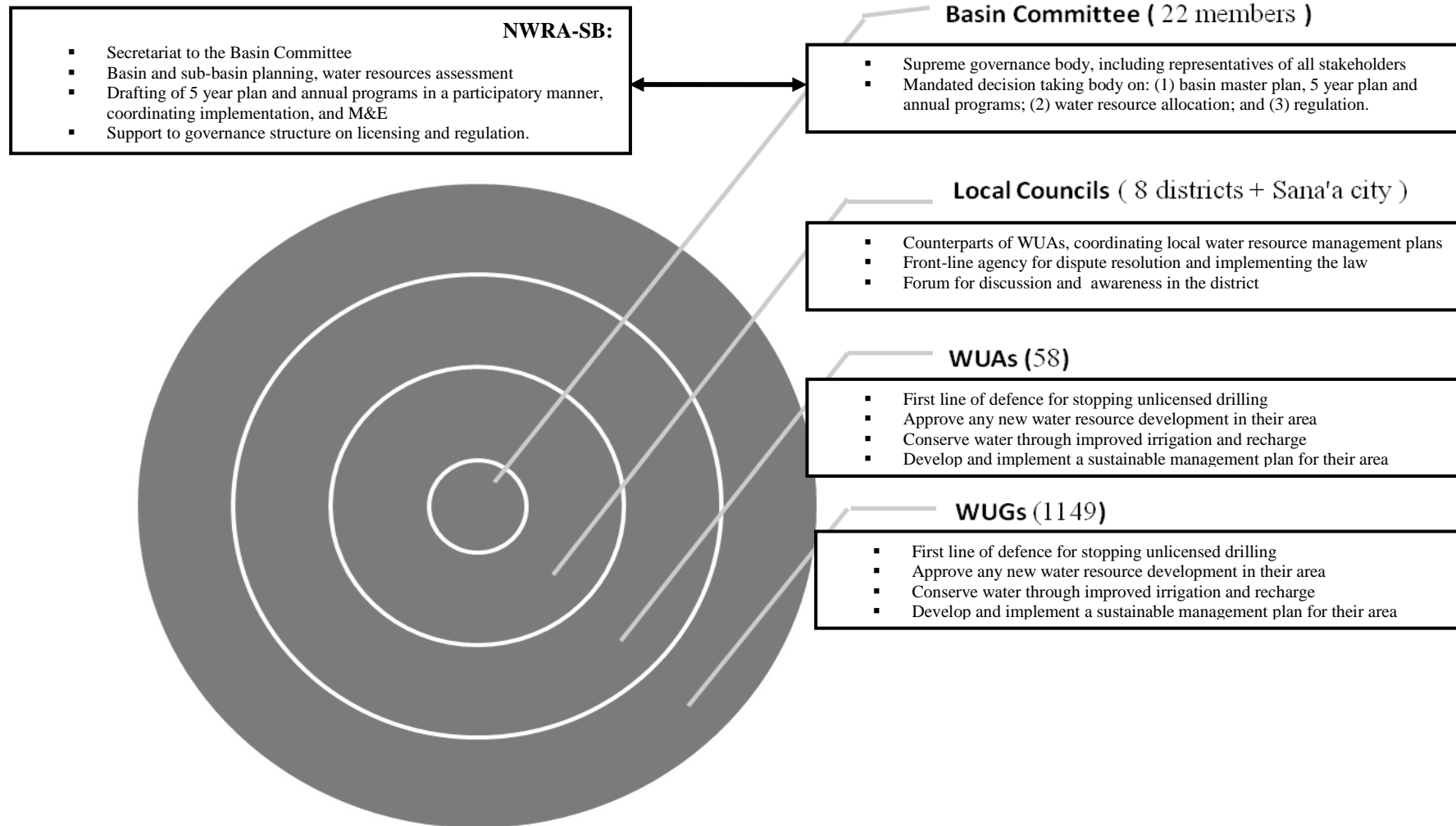


Figure 5 relations of the elements of basin governance, and their respective and complementary roles

5 CONCLUSION AND RECOMMENDATION

The present situation in Sana'a Basin is very much aggravated by the water scarcity problem and the improper planning and management which might lead to social conflicts and instability if not considered by the official authorities. Several studies and researches suggest the importance of IWRM as an important tool to alleviate or at least reduce the severe water situation and the socio-economic instability. It has the advantage as being coherent, chained and flexible in its adaptation according to the local conditions and needs. Implementation of the institutional improvements would lead to an integrated governance structure in place that would decentralize water resource management responsibility to the lowest accountable levels which is being in line with best IWRM practice. More emphasis should be on the development of a decentralized participatory approach that suggests responsibilities for water governance and sustainable management and planning at the appropriate lowest. Water management responsibilities should be delegated to the Basin Committee to be the supreme water governance authority in the basin, in tandem with local councils as the second line of authority, and WUAs as the front line resource managers. Strengthen the technical planning and management function of the water organization and ensure a basin-level integrated approach to financing and implementation that translates plans into facts on the ground. More emphasis should be placed to improve water legislation and make it readily available according to the needs and requirements of implementation. To ensure a basin-level integrated approach of financing and implementation through:

- Integrated plans and annual programs prepared by NWRA-SB, approved by the Basin Committee and financed by WSSP
- Implementation of the plans and programs by mandated agencies strengthened as needed (NIP, NWRA-SB, Sana'a LC, GARWSP.....)
- M&E and supervision at the basin level by NWRA-SB reporting to the Basin Committee, and by GoY and donors under WSSP arrangements.

Phase II is need to be 'packaged' as a five year 'project' in order to have clear objectives, inputs and outputs, a clear five year action program, and assured financing and supervision for the entire Phase II. The process and findings in this paper is competent and can be applied to areas of similar water resources management and socio-economic issues that apparently exist in most of the Arab Countries bearing in mind the special characteristics of these countries which might produce more improvements to this process.

ACRONYMS

AOPP	Action Oriented Policy Paper
ESCWA	Economic Social Countries of Western Asia
GARWSP	General Authority for Rural Water Supply Projects
GWP	Global Water Partnership
IWRM	Integrated water resource management
JICA	Japanese aid
LC	Local Corporation (for water supply and sanitation)
M&E	Monitoring and evaluation
MENA	Middle East and North Africa
MWE	Ministry of Water and Environment
MoPIC	Ministry of Planning and International Cooperation
NIP	National Irrigation Program
NWRA-SB	NWRA Sana'a Branch
PIU	Project Implementation Unit
SBWMP	Sana'a Basin Water Management Project
WEC	Water and Environment Centre (Sana'a University)
WUA	Water User Association
WUG	Water User Group
WSSP	Water Sector Support Program

REFERENCES

- [1]. ESCWA, (2005A), "Survey of Training Demands and Needs on Integrated Water Resources Management in the ESCWA Region" in IWRM Guidelines in the Arab Region, Kuwait, 14-18 May.
- [2]. ESCWA, (2005B), "Enabling Environment with an emphasis on National IWRM Strategies" in IWRM Guidelines in the Arab Region, Kuwait, 14-18 May.
- [3]. GAFAG, (2007) *Satellite Imagery/Data Analysis Study along with Ground Truth and Meteorological Monitoring*, Version 1.0, 138p.
- [4]. GWP, 2001, "ToolBox for Integrated Water Resources Management", Stockholm, Sweden.
- [5]. http://www.gwptoolbox.org/images/stories/Docs/catalyzing_change-final_diagram%20image_1000.jpg
- [6]. Hydrosult, (2010) *Assessment of Water Resources Potential of the Sana'a Basin Strategic; Options for the Sustainable Development and Management of the Basin's Water Resources*", Ministry of Water and Environment, Sana'a, Yemen, February.
- [7]. JAICA, (2007) *Water Resources Management Action Plan for Sana'a Basin*, NWRA, Sana'a, Yemen.
- [8]. MoPIC, (2004) *Statistical Year-Book*, Sana'a, Yemen.
- [9]. Taher, T., Bruns, B., Bamaga, B., Al-Weshali, A., and Frank van Steenberg, (2012) *Local Groundwater Governance in Yemen: Building on Traditions and Enabling Communities to Craft New Rules*, Hydrogeology Journal, (Springer-Verlag), Vol. 20, No. 6, May, pp. 1177-1188
- [10]. Taher, T., (2011) *Rooftop Rainwater Harvesting in Modern Cities: A Case Study For Sana'a City, Yemen* International Conference on Drought Management Strategies in Arid and Semi-Arid Regions, Muscat, Oman, 11-14 December.
- [11]. Ward, C., Taher, T., Al-Sakaf, O., Fadl, N., Saleh, A., M., Sultan (2010A) *Action Oriented Policy Paper: Assessment of Phase I (AOPP)*, Sana'a Basin Integrated Water Resources Management, Sana'a Basin Water Management Project, Sana'a, Yemen, June.
- [12]. Ward, C., Taher, T., Al-Sakaf, O., Fadl, N., Saleh, A., M., Sultan (2010B) *Phase II proposal for IWRM in the Sana'a Basin*, National Water Resources Authority, Sana'a, Yemen, August.