Water demand management in the Mediterranean, progress and policies

ZARAGOZA, 19-21/03/2007

PAPER

Working group "Factoring WDM into water policies"

Frame's theory of a new Conceptual Water Integrated Model for Semi-Arid Mediterranean (CWIMSAM) countries : for a better sustainable water resources management

S. Jalala, J. Mania

3[RD] REGIONAL WORKSHOP "Water and sustainable development in the Mediterranean, monitoring progress and promotion of water demand management (WDM) policies", Zaragoza (Spain) - 19, 20 & 21 March 2007

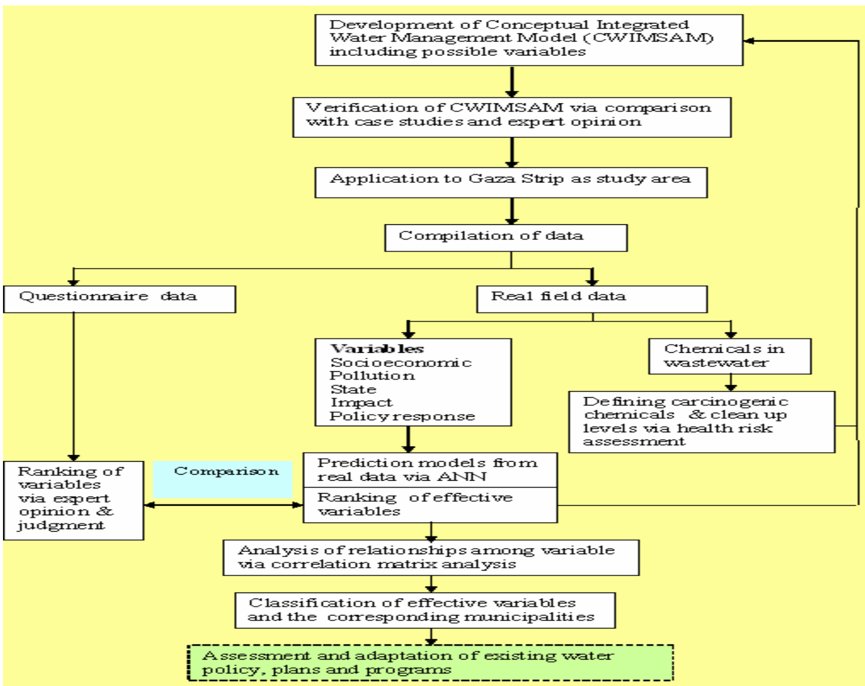
Frame's theory of a new Conceptual Water Integrated Model for Semi-Arid Mediterranean (CWIMSAM) countries : for a better sustainable water resources management

By Jacky Mania (**) and Said Jalala (*)
(*)University of Palestine International-Research Institute of Sustainable Development and Environment – Gaza City Email : said_jalala@hotmail.com
(**) Polytech'Lille – UMR 8107 LML-USTL- 59655 VILLENEUVE D'ASCQ Cedex (F)
Email : Jackymania@aol.com tel. (33) 03 81 58 03 75 / (33) 06 13 99 53 32

Abstract

The real problem in semi - arid areas is even the lack of an integrated water management policy (Sharma, 1998). So far, science has not advanced a comprehensive framework to address water issues in an integrated manner (Kamp et al., 2003). More research needs to be done to make sure that management of water resources is based on concrete science (Bouwer, 2000). Time has come for scientists involved in management of scarce water to move towards multidisciplinary approaches (Appelgren and Klohn, 1999).A new conceptual water integrated management model is proposed for the Gaza Strip (GS) water management (Jalalal,2005). The effective variables of water sector management are characterised and the geographical areas under water stresses within GS are defined. The aim is how establish the prediction relationships to be used as decision support tools? The CWIMSAM concept integrates socio-economic, pollution pressures, water quality, public health and ecological impacts and institutional responses together. It shifts water resources from supply management side to demand management side. The integrated, preventive and ecosystem approaches have been introduced .We apply the research methodology development (fig.1) and the validation of CWIMSAM to achieve sustainable water resources management. We discuss on the Driver- Pressure- State- Impact-Response (DPSIR) framework to develop the possible variables based on cause-effect relationship. We analyse the expert opinion and judgement methods for the development and validation of model and variables (appendix 1) and we make the comparison with well established water management models.

Figure 1 : Research methodology



- ***Context***

Considering the doubling of population(1.16 10^6 millions in year 2000) of GS by the year 2020 (2.6 10^6 millions), the predicted water demand will increase to reach 260 hm3.y-1 which will definitely exceed by about three times the ecological limits and sustainable capacity of the GS coastal aquifer (CAMP, 2000).

The Gaza coastal aquifer is composed of Tertiary- Quaternary sands, calcareous sandstone and pebbles interbeded with impervious and semi-pervious clay. The aquifer extends from the coastal areas of Sinai in the South to Haifa in the North over some 120 km along the Mediterranean Coast . The width of the aquifer varies from 3-10 km in the north to about 20 km in the south. (WRAP, 1995).

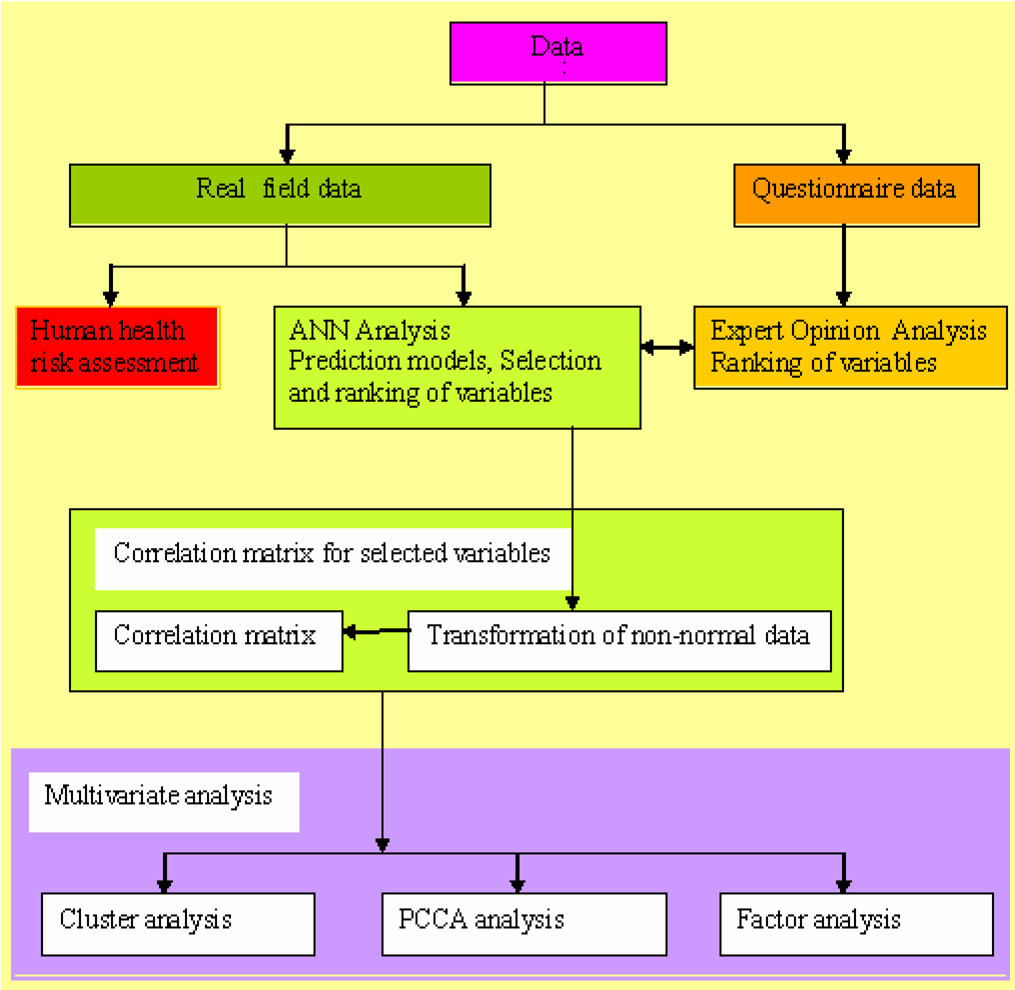
The current water management challenge is to remediate and restore the coastal aquifer as part of nature conservation and to bridge the present and future water supply-demand gap based on provision of water with adequate quantities and qualities according to WHO standards.

Water is pumped from the coastal aquifer, as the only available natural water resource, to meet the growing demands through municipality and agricultural wells. The service coverage of domestic water supply in GS is estimated to be 95% which means that most of the population are served by indoor tap. Each municipality has its own water sources and separate distribution system. Most of the municipalities use ground water without any treatment except for disinfection. In three municipalities (Gaza, Khan Younis and Deir El-Balah), brackish water desalination have been established and operated using reverse osmosis technology to desalinate the brackish groundwater. Two seawater desalination plants have been constructed and operated in the Northern and Middle governorates (5000 $m3.d^{-1}$ and 2400 $m3.d^{-1}$) respectively. In the middle and the eastern part of Khan-Younis governorate, the municipalities depend mainly on water conveyance from the Regional water supply company (Mekorot). The urban water users include households, public institutions, schools, urban parks, commercial and industrial facilities. There are physical water losses from municipal water supply networks due to failures and deficiencies in the distribution facilities. The average physical losses for the year 2000 was 24%, which mainly represent the real leakage without being used. Besides, there are non-physical losses amounting to about 15% due to meter under-registration and illegal connections . Over-pumping in several municipal areas has resulted in lowering the water table which led to seawater intrusion or upcoming and hence increased water salinity. Socio -economic activities in urban areas have caused pollution from local sources including solid waste, cesspits, hazardous waste, industrial waste and petrol stations. In rural areas, water pollution has been resulted by point sources from wastewater treatment plants and solid waste dumpsites besides the diffuse sources from pesticides, organic and chemical fertilizers.

- ***Methodology and process used***

<u>In a first step</u> (fig. 2) we examine the data levels and the statistical tools as: *Artificial Neural Networks* (ANNs) for the ranking of variables versus expert opinion; *Correlation matrix* for testing the relationship between any two variables in the data set; *Cluster analysis* which organises both cases and variables to clusters so each cluster is homogeneous and distinct from other clusters; *Principal Components & Classification Analysis (PCCA)* which reduces the number of variables to a smaller number of, ‘representative’ and ‘uncorrelated’ factors ,classifies variables and cases; *Factor Analysis* which *r*educes variables into a small number of latent factors with possibility of rotating the factor solution.

Figure 2 ***: Data analysis plan & tools***



Human Health Risk Assessment and Clean-up levels characterises the potential adverse effects on human health and determines the levels of chemicals that can remain on site and still be adequately protective of public health.

The second step (fig. 3) includes the effective variables in the conceptual water integrated model. Also the predictive model shows the relationship between:

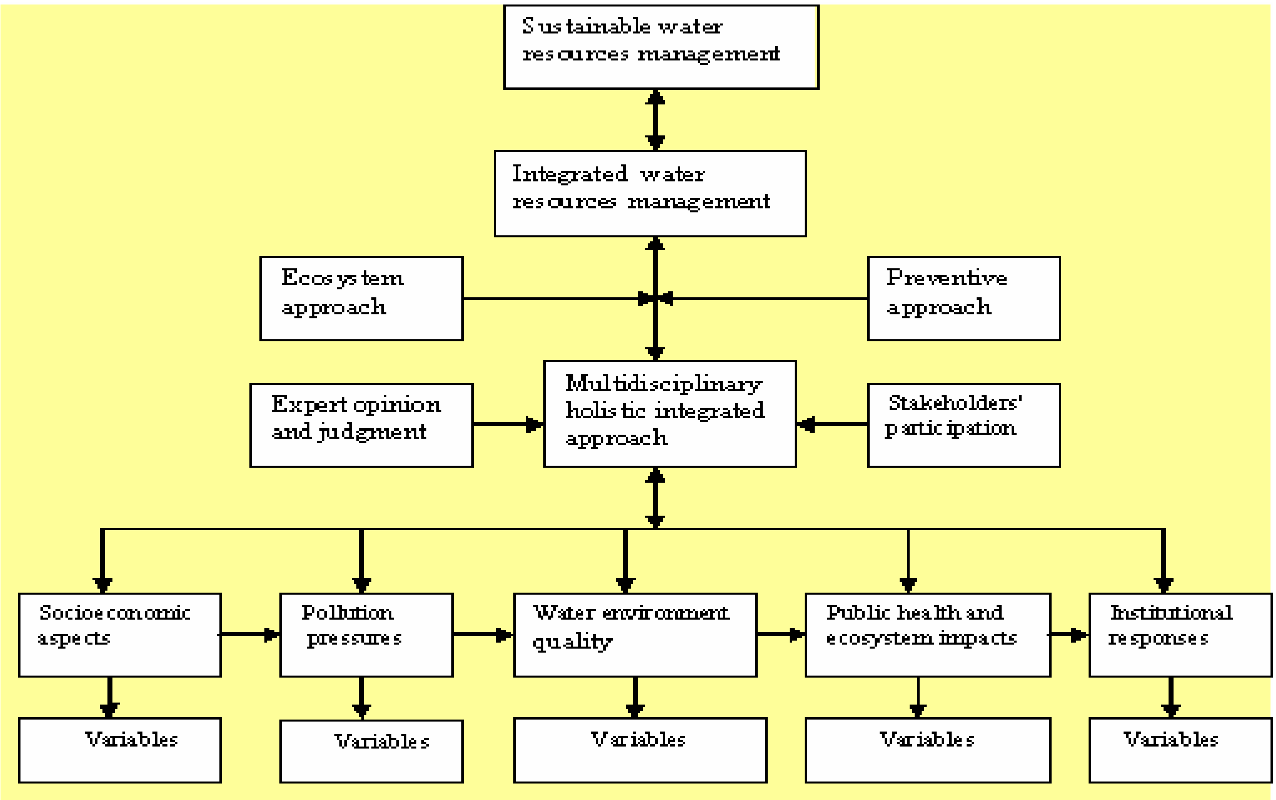
- groundwater abstraction and socio-economic driving forces,
- groundwater abstraction and water quality parameters,
- groundwater quality and pollution sources,
- groundwater abstraction and policy interventions.

What are the findings?

-Income per capita is the most important socio-economic driving forces,

-Domestic wastewater is the most pressing pollution source,

Figure 3 *: Diagram of CWIMSAM*



-Nitrate and Chloride are the most important water quality parameters,
-The impacts of water sector management are morbidity and loss of wetlands and agriculture productivity,
-Reuse of treated wastewater should have the top priority in the water policy followed by desalination of sea water,
-Coastal municipalities as well as municipalities located close to the eastern border of GS are characterised with high Chloride content,
-Khan Younis and Gaza are characterised by significant anthropogenic pollution, high water abstraction and their need for additional water.

- ***Types of tools for water demand management and for integrated water resources management used***

This research work was intended to contribute to the advancement of water resources management through the development of new conceptual integrated water model based on systematic and multidisciplinary approach. The new conceptual integrated water model can be applied in the semi-arid Mediterranean region. It has been the first experience that tackled the big picture of IWRM including sustainability concepts. Besides, it has been based on integrated, preventive and ecosystem approaches with the view to optimize water resources management whilst sustaining the ecological limits and carrying capacity of the natural water resources.

- ***Results of the experience***

What kind of recommendations for improvement of *water demand management)*?

The water resources management should be based on integrated, preventive and ecosystem approaches. The ecosystem water use and demand requirements must be considered when

calculating the overall demand. The selection and the adaptation of the most appropriate de-nitrification technology to remediate groundwater is a priority. The preparation of salinity management strategy for stream coastal aquifer system using Accelerated Salt TRANsport (ASTRAN) method to handle the saline groundwater in eastern GS is necessary.
The planning and the building regulations should allow for water harvesting and conservation. In the future the adaptation of water management to climate change is envisaged.
The national water plan should be reformulated to take account of the priority water problems and the geographical areas under stresses. All water policies, plans and programs should undergo Strategic Environmental Assessment.

- **Justification of the importance of the paper :**

What are the expected impacts on water management in GS?

-Contribution to the advancement of water resources management through the development of new conceptual integrated water model,
-Assistance decision makers to gain better knowledge and understanding of the actual baseline conditions,
-Definition for the first time, the effective multi-criteria parameters for water sector analysis and monitoring besides the geographical areas under stresses,
-Concluding on the potential interventions needed to ensure water availability; suitability and supply- demand balance.

- ***Discussion*** **&** ***Concluding Remarks***

A new conceptual water integrated management model (CWIMSAM) is applied for the GazaStrip water management. We have combined multivariate analysis with a correlation matrix for selected variables, the expert opinion analysis, artificial neural network for selection and ranking of variables and human health risk assessment.
The conclusions of data analysis using the techniques of ANN, basic statistics, multivariate, health risk assessment and expert opinion and judgment can be summarized as follows:
• The results obtained in the ANN analysis indicate that a feed-forward Multilayer Perceptron (MLP) network with a back propagation algorithm proved to be the best ANN structure to model and predict the relationship between the groundwater quantity and quality on one hand and the other categories of independent variables on the other hand. These categories are socio-economic, pollution pressures, state of water quality, impact and management response. Besides, MLP networks can characterize and prioritize the effective variables in each category.
• The ANN models can be used for independent data sets in water and environmental sciences. There are significant discrepancies between the results of ANN analysis and expert opinion and judgment in terms of ranking and prioritizing the socioeconomic, pollution pressure and management responses variables. These results are consistent for the categories of state of water quality and impact variables.Therefore, the research output assists water managers to gain better understanding about he actual water problems.
• Characterization of the priority effective socio-economic driving forces indicates that water managers and planners can introduce demand-based groundwater management in place of the existing supply-based groundwater management. This ensures the success of undertaking responsive technical, managerial and regulatory measures. Income per capita has the highest priority. Efficiency of revenue collection is not a significant socio-economic factor.
• Selection of the priority pollution determinants of groundwater quality assists water managers and planners to introduce cheap proactive and preventive based groundwater management policy measures in place of the existing expensive engineering -based groundwater protection actions. Focus should be given to domestic wastewater as the most

pressing pollution source followed by domestic solid waste. Petrol stations and pesticides are not significant pollution pressures.

• Definition of the priority water quality determinants influencing the attractiveness of groundwater users makes clear the groundwater quantity- quality interactions and adjusting them to each other to progress towards the provision of appropriate quantities of water of suitable quality. Highlighting the parameter of nitrate stresses the need to remove Nitrate from groundwater using appropriate techniques. The Chloride parameter demonstrates the need for desalination of both brackish water and seawater.

• All public health and ecological impacts are significant to water sector management. These impacts are morbidity and loss of wetlands and agriculture productivity.

• All water policy and management responses are significant. Sustainable coastal aquifer management must take into consideration technical engineering as well as managerial interventions such that top priority should be given to the reuse of treated wastewater in agriculture followed by desalination of water.

• Coastal municipalities as well as municipalities located close to the eastern border of GS are characterized with high Chloride concentration. This is due to seawater intrusion in coastal municipalities and the salt transport from the upstream irrigated agriculture areas in Negev to the downstream along the eastern border of GS (Nativ, Adar, Dahan and Nissim, 1997).

Data analysis plan and tools lead to a comparison between the NewModel (CWIMSAM) versus the Existing Model (fig.4). The research work defined for the first time, the effective multi criteria parameters for water sector analysis and monitoring besides the geographical areas under water stresses on objective scientific basis. It concludes also the potential interventions needed to ensure water availability; suitability and supply- demand balance. The new model addressed a key objective on the levels of Mediterranean region in general and GS in particular "to achieve sustainable use and management of natural water resources and effective protection of the environment". Protection ensures that the water resources base is utilized wisely so that it can continue to provide benefits for improving people's livelihoods and fostering economic development on sustainable basis.

Key words : water management , water resources, policy , decision tools , research methodology, sustainable limits, ANN model

Appendix 1 : List of Variables

Socio-economic :Population ,Income per capita ,Land use ,Tourism ,Access to safe water supply, Wastewater system coverage , Storm water system coverage , Water consumption per capita, Water price, Efficiency in revenue, Agricultural water , consumption, Gender empowerment , Unaccounted for water

Pollution sources:Hazardous wastes, Domestic wastewater, Pesticides, Chemical fertilisers , Organic fertilisers , Petrol stations , Domestic solid waste , Industrial wastewater , Carbon dioxide , Seawater intrusion

Water quality :Nitrate ,Chloride ,Sodium ,Calcium ,Magnesium ,Potassium ,Fluoride , Sulphate ,pH ,Alkalinity, Total Coliform

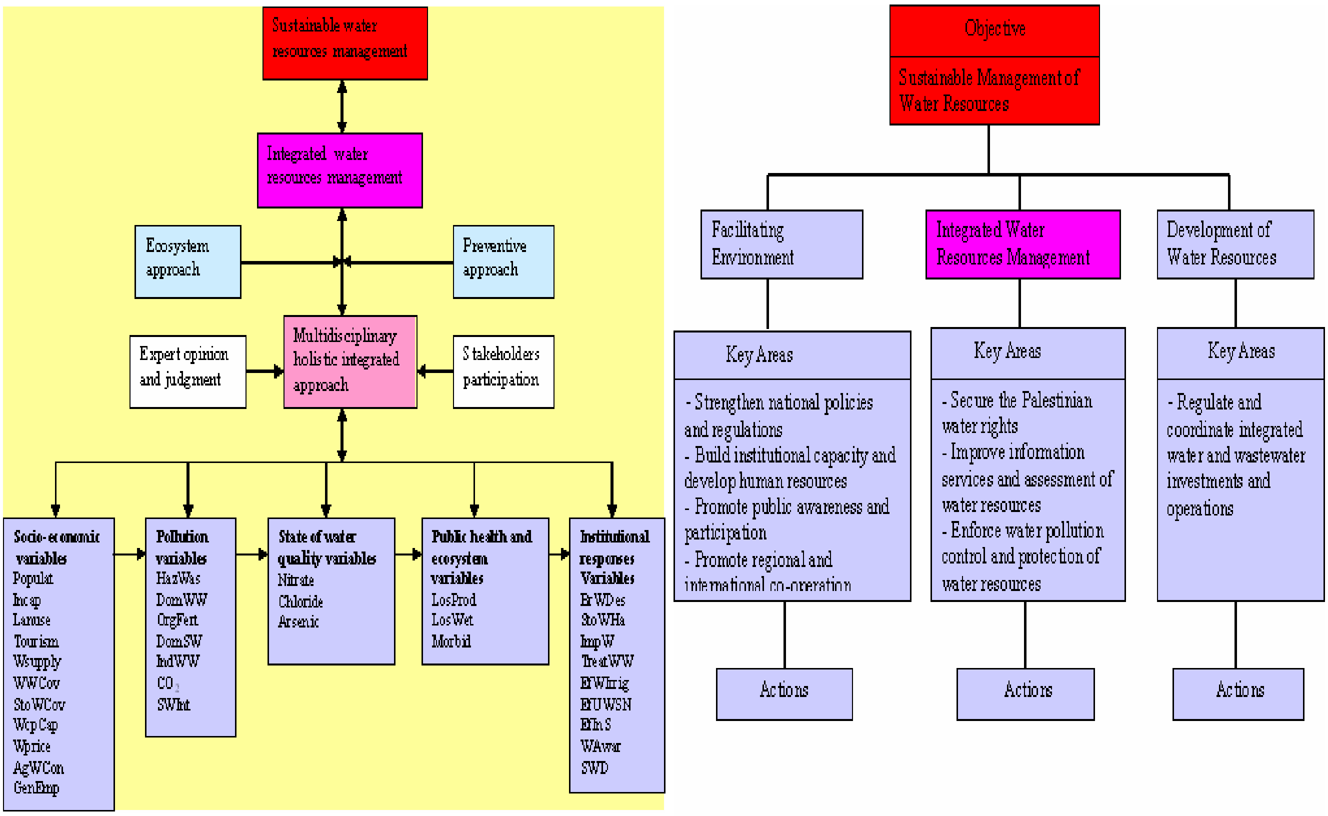
Public health and ecological impacts:Loss of productivity , Loss of wetland , Morbidity

Management responses :Brackish water desalination ,Storm water harvesting , Regional water conveyance, Treated/partially treated , wastewater, Efficiency in water irrigation , Efficiency in urban supply networks , Efficiency of information system, Awareness and education , Seawater desalination.

***Figure 4 :* Comparison between the New Model (CWIMSAM) versus the Existing Model**

New Integrated Water Management Model (CWIMSAM)

Existing Water Management Model



Bibliography

Appelgren B. and Klohn W., 1999- Management of water scarcity : a focus on social capacities and options. Physics and Chemistry of the Earth 25,361-373

Blue Plan, 2000- Environment for the 21st Century - reports

Bouwer H., 2000- Integrated water management : emerging issues and challenges. Agricultural Water Management 55, 217-228

CAMP, 2000 – Coastal aquifer management program : integrated aquifer management pian. USAID/PWA. Metcalf & Eddy Edition

Jalala.S,2005- Characterising the multi-criteria parameters of integrated water management model in the semi-arid Mediterranean region : application to Gaza Strip as a case study. PhD Univ.Sciences and Technology of Lille (France),2005,1-244

Kamp I., Leidelmeijer K., Marsman G. and Hollander A., 2003- Urban environmental quality and human well-being towards a conceptual framework and demarcation of concepts ; a literature study. Landscape and Urban Planning 985,1-15

Sharma K.D., 1998-The hydrological indicators of desertification. Arid Environments 39,121-132

WRAP,1995- Palestinian Water Resources- A Rapid Interdisciplinary Sector Review and Issues Paper. Water Resources Action Program- Palestine.

Nativ, R., Adar, E., Dahan, O., Nissim, I., 1997. Water Salinization in arid regions-observations from the Negev desert, Israel. Hydrology 196, 271-296.