Integrated Water Resources Management in the Lower Jordan Rift Valley

Sustainable Management of Available Water Resources with Innovative Technologies

Work package 6, Deliverables D602

DSS Module

HydroBudget Application

Jacob Bensabat, Sagi Dror, Tami Milgrom

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Corresponding author:

Jacob Bensabat
EWRE Environmental & Water Resources Engineering Ltd.
PO Box 6770 Haifa 31067, Israel. jbensabat@ewre.com , 972-4-838-3919

Funded by the German Federal Ministry of Education and Research (BMBF):

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Project Coordination:

Main Coordinator:

Prof. Dr. Heinz Hötzl
Department of Applied Geology
Karlsruhe University
Adenauerring 20b
76131 Karlsruhe
Germany
Phone: +49 (0) 721 608 3096
Fax: +49 (0) 721 606 279

Assistant Coordinators

Prof. Dr. Martin Sauter
Department of Applied Geology
Göttingen University
Goldschmidtstrasse 3
37077 Göttingen
Germany
Phone: +49 (0)551 39 79 11
Fax: +49 (0)551 39 93 79

Dr. Stefan Geyer & Dr. Roland Mueller
Helmholtz Centre for Environmental Research (UFZ)
Permoserstr. 15
04318 Leipzig
Germany
Phone: +49 (0)341 235 30 00
Fax: +49 (0)341 235 2885

http://www.iwrm-smart.org/

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1 Introduction

The planning and management of any water resources project, requires the evaluation of the sustainable yield of the relevant sources of water. This evaluation is based on the water budget of the considered resources/reservoirs. In principle, the water budget of any specified domain relies on the principle of mass balance/conservation; for a specified domain, the difference between all inflows and all outflows is being stored in the aquifer. In a similar way, a budget can be prepared for dissolved matter (total or specific) contained in and carried by the various components of the water budget, thus providing information not only on the total (annual or seasonal) volume of water that is potentially available, but also on water quality, say as divided into specific water quality categories.

By establishing a water balance for a given region, aquifer, or a set of aquifers, an comparing with water demands, we can evaluate the need for artificial recharge as a tool for augmenting the volume (in specific water quality categories) of water available.

The water budget constructed separately for 3 types of water bodies: 1) groundwater reservoirs, 2) lakes, and 3) river basins. In each test site, the region of interest will be divided into groundwater basins (either adjacent to the rivers, or at different depth), lakes and surface watersheds. Each budget test site is referenced as a budget unit.

2 Budget of a Groundwater Unit

The water budget for a specified period and unit (subscript i) takes the form

$$GWB_i = N_i + RFI_i - E_i + \sum_{j \in T(i)} F_{ij} - Q_i + \frac{V_i}{t_i} + \sum_{j \in SWC(i)} FSWC_{ij} \ ,$$

Where:

GWB_i	The water budget.
N_i	Natural replenishment from rainfall.
RFI_i	Return flow from irrigation.
E_i	Evaporation.
F_{ij}	Fluxes into unit i from adjacent unit j.
Q_i	Fluxes leaving the unit as flow to the sea or as spring discharge
V_i	Volume of water bodies suitable for exploitation as a one-time non-renewable reserve.
t_i	Time interval for the exploitation of the non-renewable water bodies
$FSWC_{ij}$	Fluxes into unit from surface water unit j above the groundwater unit.

In this budget, the components Q_i, V_i and t_i depend on policies or the decision making processes. The remaining parameters are physical ones that cannot be changed by design or planning measures.

3 Budget of Surface Water Unit

$$SWB_i = MDS_i + AF_i + IF_i - R_i + \sum_{j \in GWC(i)} IG_{ij} \text{ ,}$$

Where:

SWB_i	The budget of the surface water unit.
MDS_i	The flow measured at some downstream hydrometric station.
AF_i	Additional flow entering the river between the hydrometric station and the estuary.
IF_i	Influx of wastewater and/or drainage water.
R_i	Residual flux downstream.
IG_{ij}	Fluxes from underlying aquifer unit

4 Budget of a Lake Unit

$$LCB_i = \sum_{j \in RE(i)} RF_{ij} + \sum_{j \in A(i)} GW_{ij} - E_i + R_i - \sum_{j \in RL(i)} OF_{ij}$$

Where

LCB_i	The lake water budget.
RF_{ij}	Runoff from rivers entering the lake.
GW_{ij}	Fluxes entering the lake from underlying aquifers.
E_i	Evaporation.
R_i	Direct rainfall on the lake.
OF_{ij}	Flows leaving the lake.

5 Total Water Budget of a region

$$WB = \sum_{i=ngw} GWB_i + \sum_{i=nsw} SFB_i + \sum_{i=nlc} LCB_i + WW$$

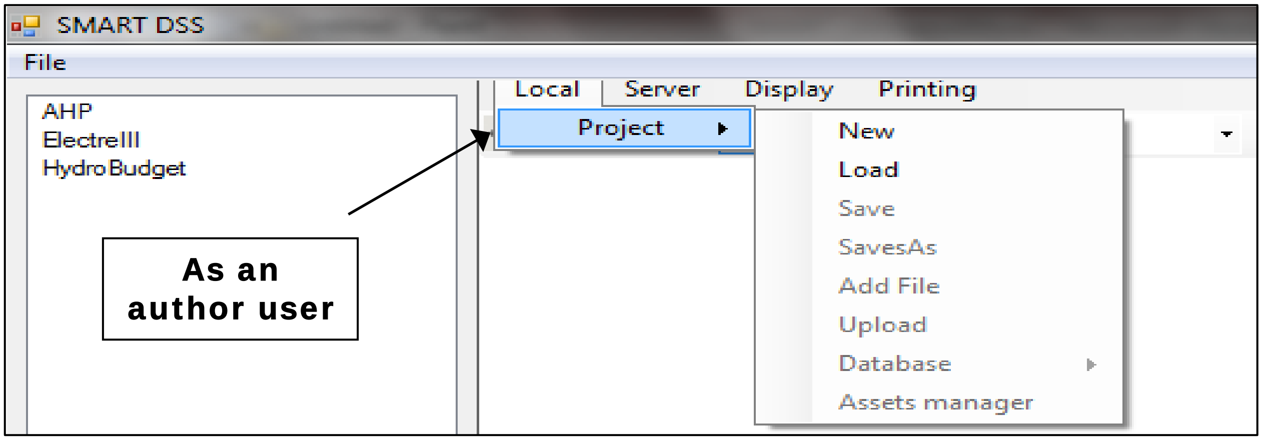
Where WW denotes wastewater influx. The water budget, WB, is the sum of the partial budgets of the groundwater, surface water and lake cells and of the wastewater that can be directly used. The need for additional water arises when WB is smaller than the water demand, D. W refer to the difference Q = D – WB (>0) as *water, or hydrologic deficit*

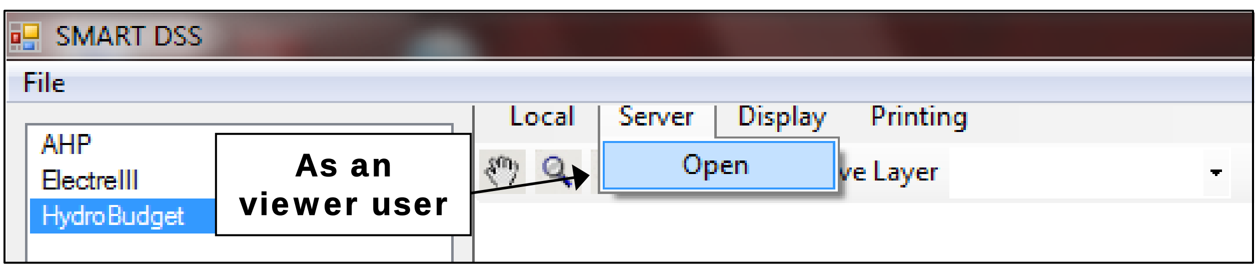
Artificial recharge is one possibility of reducing the hydrologic deficit. Additional options are: direct supply of water imported from regions with hydrologic surpluses, and water desalination.

The budget, WB, needs to be further split up according to water quality ranges. Components of the water budget can be also be calculated separately, say, from single unit lumped models, or by sophisticated simulation ones.

6 HydroBudget User's Guide

In the Hydrobudget application the user/author creates a HydroBudget project on the local PC machine. This HydroBudget project is uploaded on the server for viewing only, for other users. Hence, as an author the user uses the options under 'Local->project', and as a viewer/inspector the user uses the 'Server->open' option.





The HydroBudget project

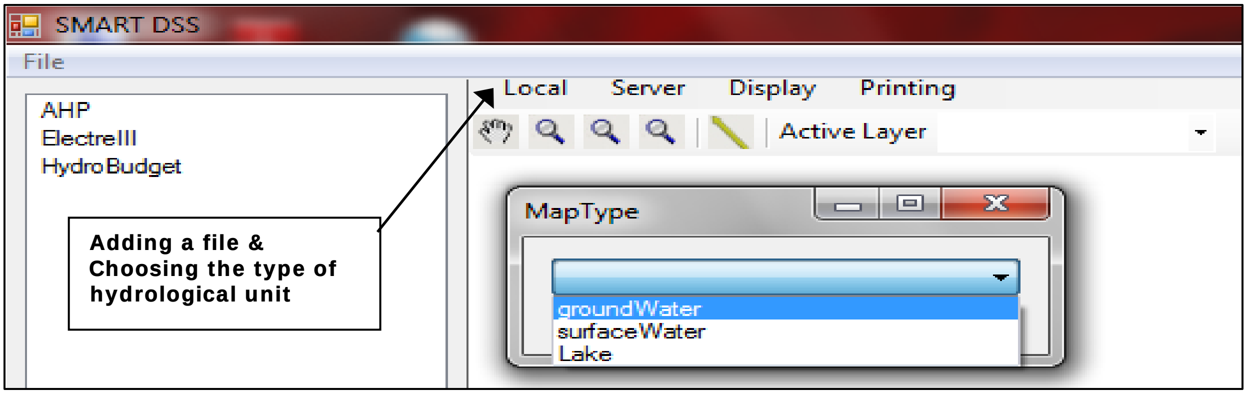
The HydroBudget project consists of:

1) Vector maps that depicts hydrological units of water (surface, aquifer or lake);
2) Hydrological data bases (wells, rain stations, and springs);
3) One raster map for the background (optional); and
4) A HydroBudget database created by the application, based on the input (hydrological units and hydrological data points) that holds the water budget, and updated by the author/s.

The projects inputs (vector map files, Microsoft Access files, raster image files) are inserted to the project with the 'Add File' option (Local->Project->Add File), and seen as the project resources/assets. According to the extension of the file opened, the application decides whether it's a vector map, a raster map, or a data base file.

Add a vector map

A vector map added should have only one layer of data, as it describes only one layer of hydrological units. Hence, the need to add one map that depicts the surface, and several maps for each geological layer of the aquifer. When adding the file (GML, Shape file or MapInfo file) the 'Map Type' dialog appears, and in it the user must choose the type of hydrological unit (surface, ground or lake) that this vector map describes.

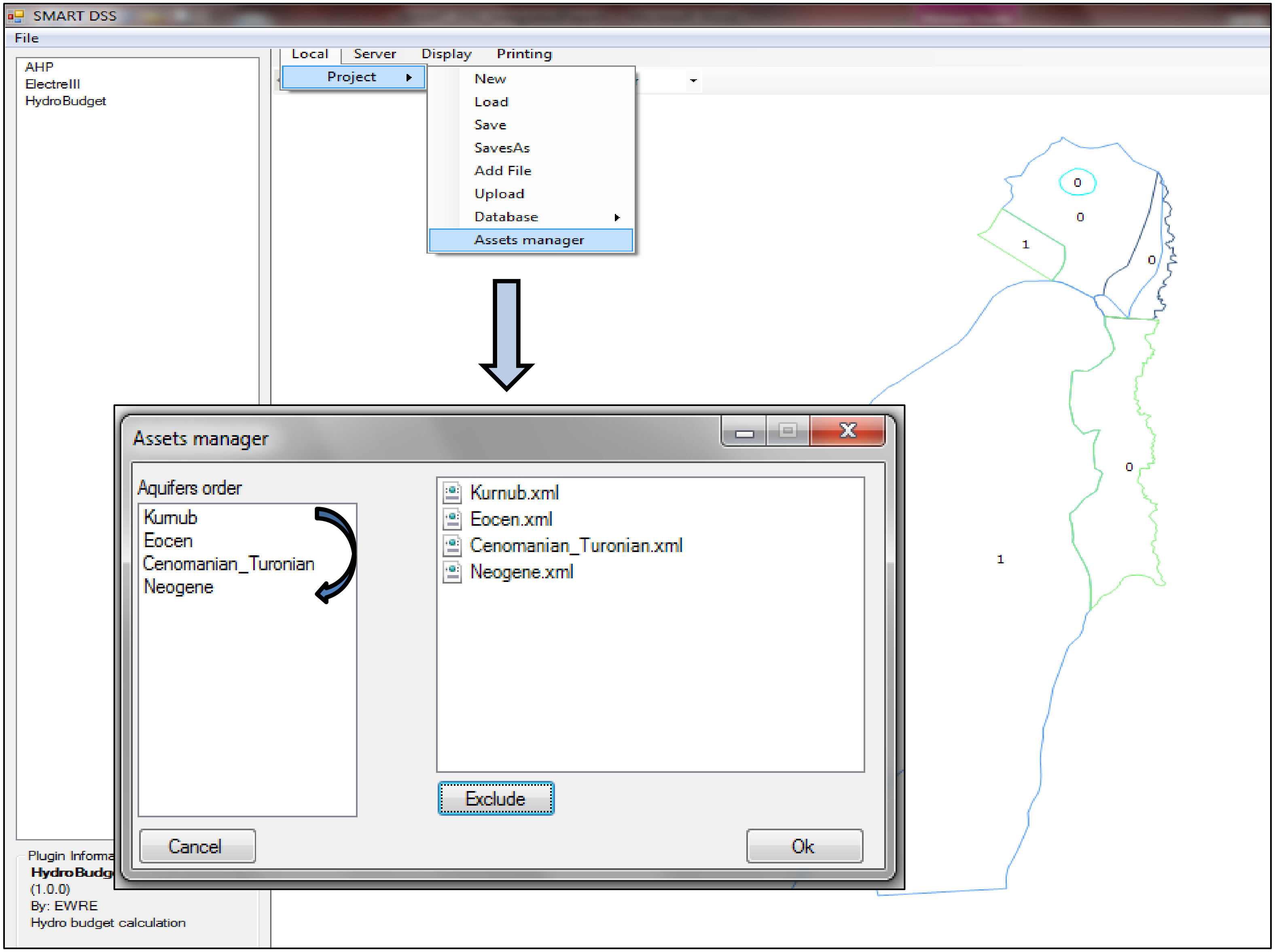


If the file opened is not a GML (Geographic Markup Language) file, it is saved as GML file, and this file will be included in the project, instead of the original one. This is done in order to facilitate the transfer of the data over the internet.

Then, the 'ID Field' dialog appears, and the user can choose the 'Id' field from the schema of the map (The Id is a unique identifier that serves as a primary key in the HydroBudget database). If the user fails to supply such an identifier, then, by default, the identity of a unit will be its internal order.

Order the ground layers

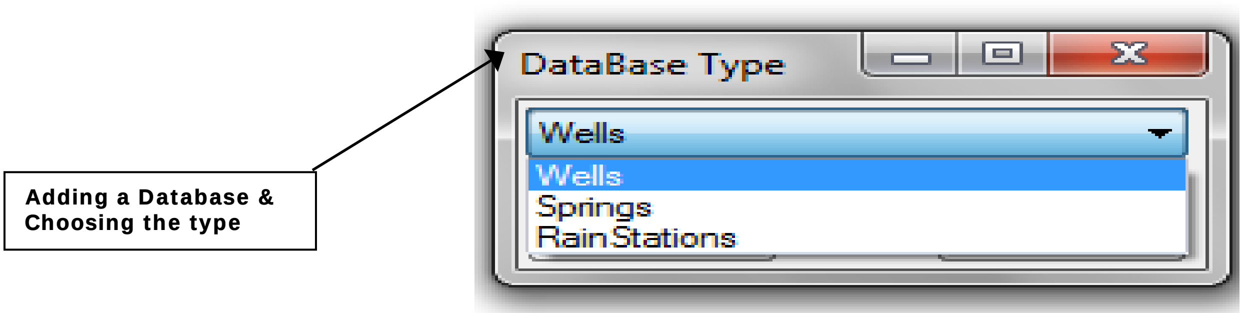
After loading all the vector maps associated with 'GroundWater' (geology layer) user must order the layers in their correct vertical order from bottom to top. This is done in the 'Aquifer order' list box that is in the 'Assets manager' dialog (local->Project->'Assets manager'). Left click and drag the entry in the list, and release when in correct order.



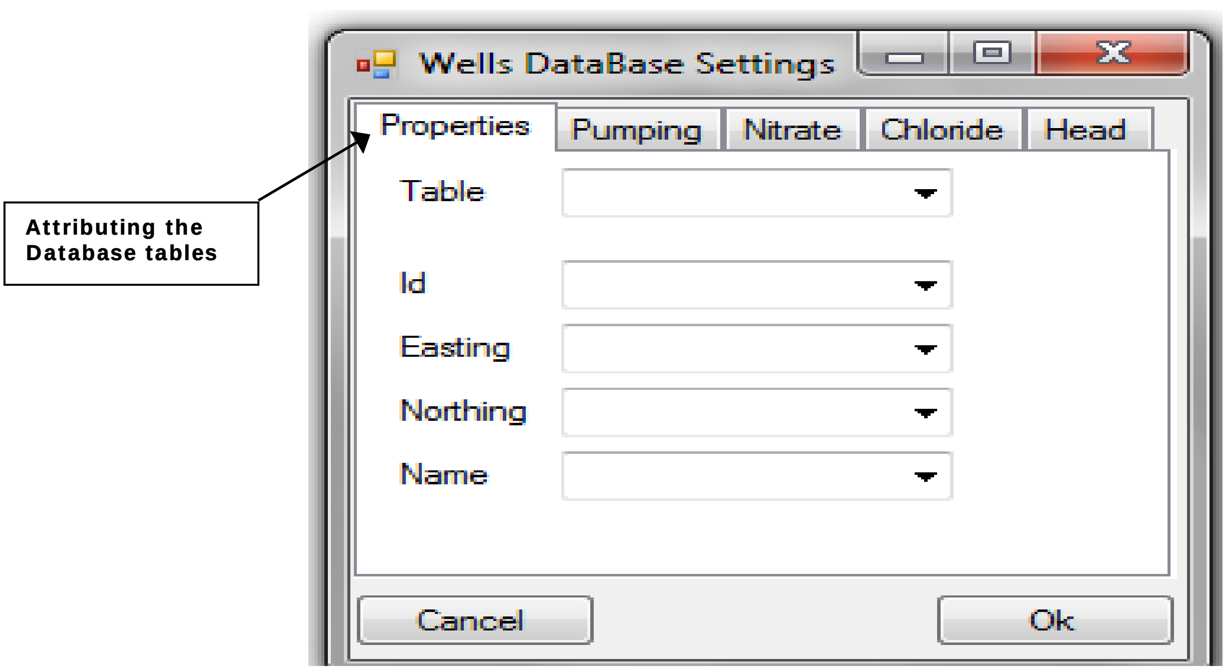
Add a hydrological database

Hydrological database is loaded from a Microsoft access file 'Add File' option ('Local->Project->Add File'). This kind of database generally consists of one table that contains all the data points (wells, springs, rain stations etc.) and several other tables that contain measurements (e.g. chemical characteristics, head, pumping) taken in these wells over the years (time series tables arranged by Year, Month, Day).

When the 'Database Type' dialog appears, the user has to identify the type of database loaded as 'wells', 'rain stations' or 'spring'.



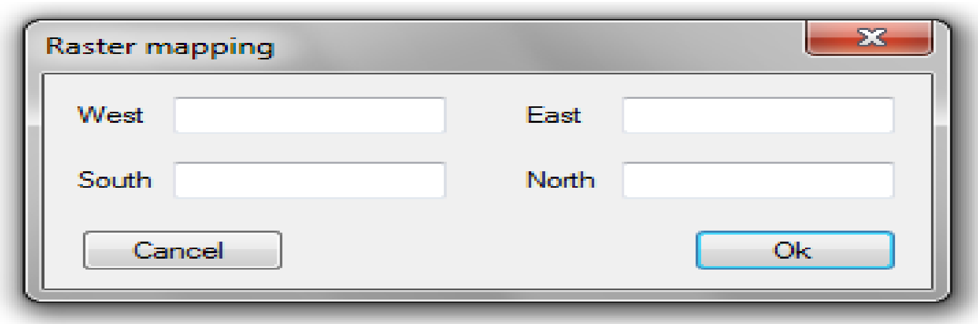
Then, in the corresponding 'Database Setting' dialog, user has to associate the main table (the one that contains the data points) with 'Properties', and several other tables with their corresponding tabs. For example, in 'Wells Database Settings' user can associate 'Pumping','Nitrate','Chloride','Head' tables , and in the 'Rain stations Database Setting' user can associate 'Monthly Times Series' or 'Daily Time Series'.



After associating a table, user has to define its schema. In the main table user has to define 'Id' witch is the primary key, 'Easting' and 'Northing' (the geographical coordinate), and 'Name' (label). In the time series tables, user has to define 'Id' witch is the foreign key, time fields (Year, Month, and Day), and 'Value' (of the measure taken).

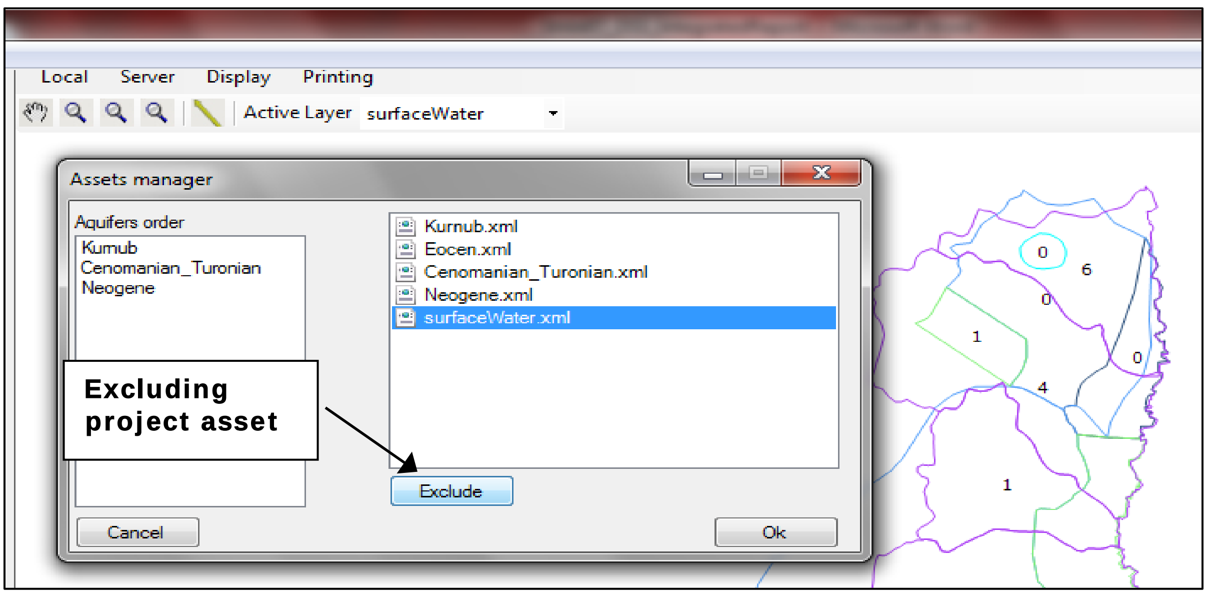
Add a raster map

User can add a single simple image file (jpg, tiff, png) to serve as a background reference. When the 'Raster mapping dialog appears the user should supply the geographical boundaries of the map.



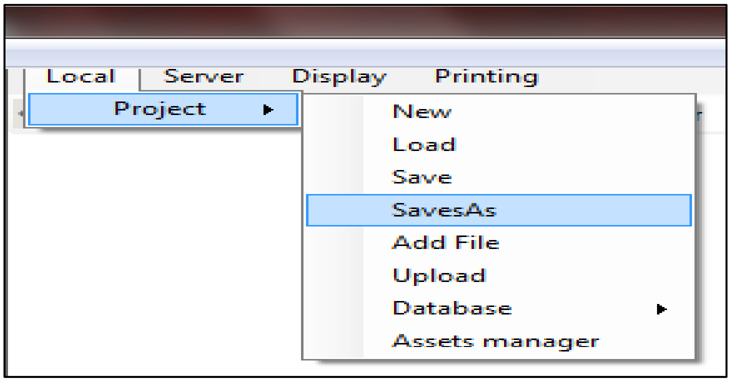
Exclude project asset

In the 'Asset Manager' ('local->Project->Asset Manager) user can exclude an asset from the project. The assets appear in a kind of file list, as behind each named resource there is a file. Select the resource from the list , and click the 'Exclude' button.



Saving and loading a project

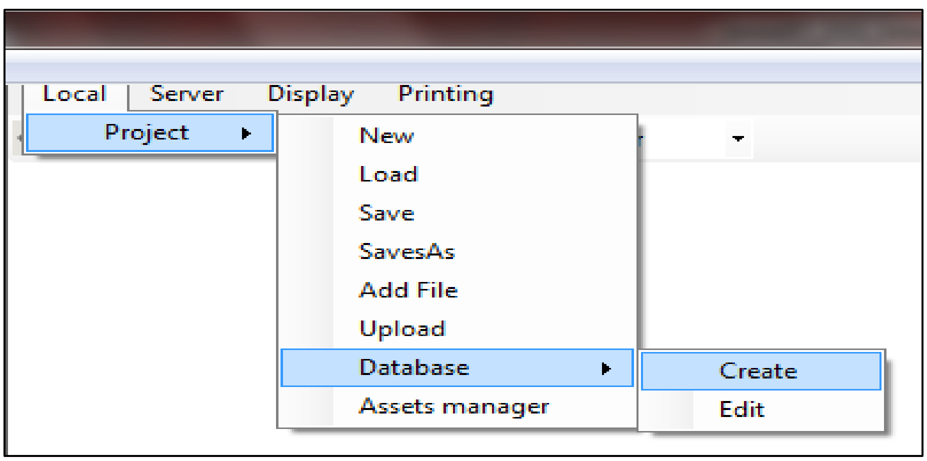
The project is saved as an xml file with the *.hbp (hydro budget project) extension.



Create the Hydrobudget database

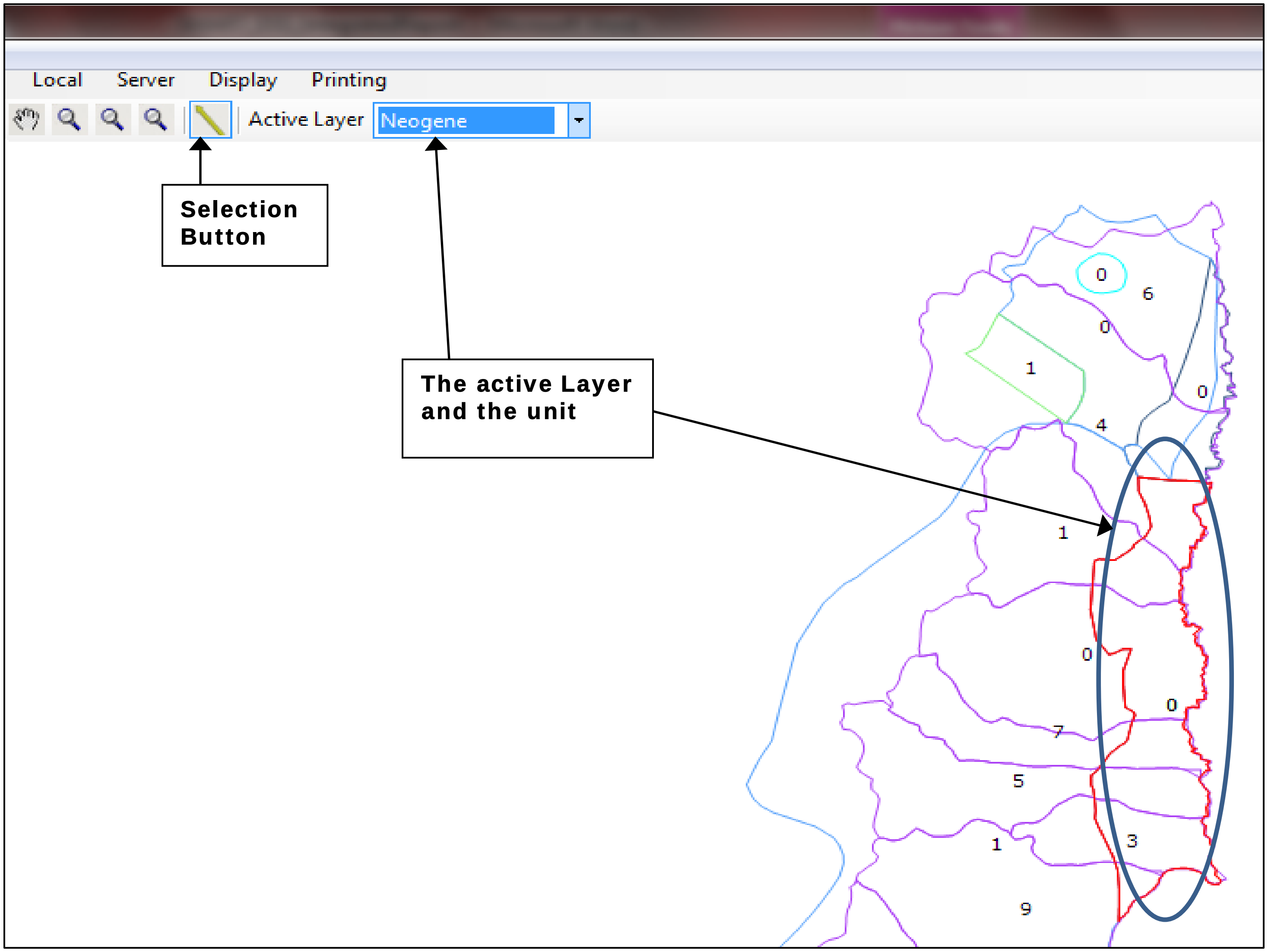
Before creating the database the user must ensure that the project contains a surface river basin layer, all the geology layers in their correct vertical order, and all the data points (wells, springs, rain station, etc.). The database file that will be created will replace the former one. Use the 'local ->Project->Database->Create' option to create the Hydrobudget Database. In order to create such a database by the application, it first finds the adjacencies between ground units, and between top ground units and surface units. The application also finds the inclusion of the data points in the corresponding surface unit.

After the hydrobudget database file is created, user can start editing it.

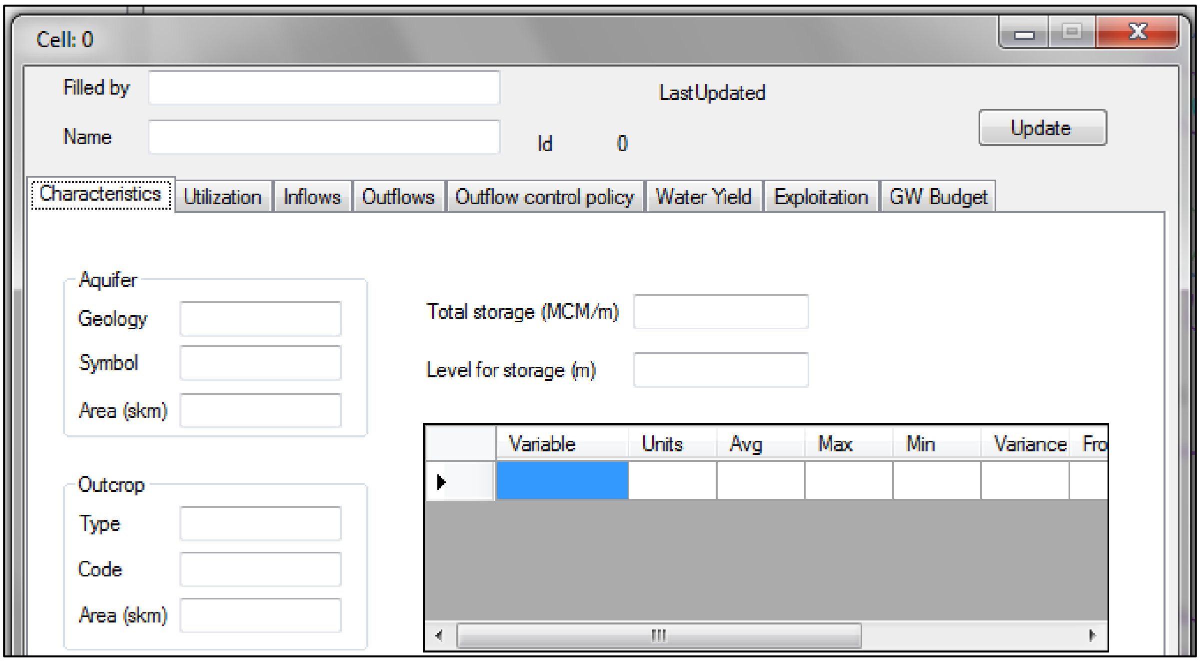


Editing/Inspecting of the hydroBudget database

Editing the database is done indirectly by editing the data of a specific unit. User must check that the layer of this unit is the active one (in the 'Active Layer' combo), right click the unit, and when a floating menu appears choose the 'properties ' entry.



Then, the user has to fill the hydrobudget data (see the table below for further details) according to the 6 different tabs (Characteristics, Utilization, Inflows, Outflows, Outflows control policy, Water Yield) before an exploitation diagram is developed, and the Ground Water Budget is calculated.



HydroBudget data required:

Tab			units	Details
Characteristics	Aquifer	Geology		Name of the utilized layer
		Symbol		Code
		Area	km^2	Total area
	Outcrop	Type		Name of outcrop
		Code		Geological code
		Area	km^2	Total outcrop area
	Total storage		MCM/m	Volume of available water per m of aquifer thickness
	Level for storage		m	Current water level in the aquifer
Utilization	Reference Year			Year of determination
	Water abstraction by quality thresholds	Current	MCM	
		Average	MCM	
	Salinity thresholds		mgCl/l	
	Nitrate thresholds		Mg/l	
Inflows	Natural Replenishment		MCM/YR	
	Influx from adjacent GWHRU		MCM/YR	
	Influx from adjacent SWHRU		MCM/YR	
	Returning flow from		MCM/YR	

	irrigation			
	Artificial replenishment		MCM/YR	
Outflows	Evaporation		MCM/YR	
	Flow to the Dead Sea		MCM/YR	
	Flow to the Jordan River		MCM/YR	
	flux to adjacent GWHRU		MCM/YR	
	Spring discharge		MCM/YR	
	Engineered drainage		MCM/YR	
Outflow control policy	Min. driving head for spring		m	
	Min. discharge of springs		MCM/YR	
	Current water level + year		m	
	Current storage level + year		m	
	Target water level		m	
	Mode of calculation			
	Residual flow to adjacent GWHRU		MCM/YR	
Water Yield	Current total		MCM/YR	
	By Salinity thresholds		mgCl/l	
	By Nitrate thresholds		Mg/l	