



Work package 6, Deliverable D608

Step 2 of DSS development

Version 1.0

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November, 2013

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

FKZ 02WM0801

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1. Introduction

This deliverable summarizes the effort invested in the development of the decision making tools within work-package 6 and the finalization of the Graphical User Interface developed in order to host them. The SMART decision support tools (SMART-DSS) is a web deployed application in which the software is automatically installed from the hosting site (at the moment the EWRE web site) and the data can be stored either in the hosting site (read only) or in the client computer (read/write). The reason for not allowing the update of data in the host site is motivated by quality control and integrity concerns. It is our point of view that data made widely available should first be verified and validated by a team of designated experts with transparent validation and quality control criteria.

Originally the SMART-DSS platform should have included the following modules:

- **Water balance/Water Yield Hydrological budgets (HYDROBUDGET):** this application has been implemented and its interface has been redesigned in order to allow more flexibility and in the input and or assimilation of data (point data and vector data). The initial version of this module has been presented in Deliverable D601.
- **Decision support tools:** we have implement two of the most widely available decision making approaches: the *Analytical Hierarchy Process* (AHP, Saaty) and an easy to use version of the *ELimination and Choice Expressing Reality* (ELECTRE, Roy and others). These tools have been fully implemented and can be used as stand-alone applications and or as integrated into other modules (see below). These approaches are intuitive and subjective and leave room for the input of the decision maker. These approaches as well as guides for their use have been summarized in Deliverable D602.
- **Multi-Criteria optimization (MCO):** This is a more mathematically oriented approach in which the IWRM problem is formulated as an optimization problem with one or more competing objective functions to optimize and a set constraints that fully characterize the problem. This approach is much less intuitive and subjective than the decision support approaches and requires a higher degree of characterization/definition of the IWRM problem. It provide a much richer output but leaves little room to the decision maker input. These approaches as well as guides for their use have been summarized in Deliverable D603.
- **A platform for risk assessment:** one of the key domains of activity in the SMART/II project was to suggest approaches and methodologies for the definition and delineation of protective zones, to wells, to springs and to replenishment areas. A prerequisite to these activities resides in the determination/estimation of the incurred risk. We suggested to adopt the US-EPA RBCA (Risk Based Corrective Action) methodology as a basis for risk assessment. The method and some applications have been summarized in deliverable D604 but was not planned to be integrated into the SMART-DSS.
- **A knowledge management system module (KMS).** This has been integrated in the Dropedia platform and has not been linked to the SMART–DSS.
- **Review of computational models for the simulation of groundwater flow in variably saturated media and reactive transport:** we have reviewed three modelling platforms (Hydrus, PFLOTRAN and TOUGHREACT). Modern IWRM planning and design requires the availability of efficient computational models for highly complex applications involving flow in unsaturated media and reactive transport, particularly in application related to the

artificial replenishment of storm water, treated effluent etc. These have been summarized in Deliverable D607 but have not been integrated into the SMART–DSS.

- A scenario Generator (SG): This is the last application development in the frame of this work-package and can be characterized as a module that integrates and fully exploits decision making (DSS) and optimization (MCO) in order to generate IWRM scenarios and or alternatives following a flow logic that will be presented below. This module has been integrated in the SMART-DSS and is presented in this document.

This deliverable focuses essentially on the undocumented parts of the SMART-DSS, i.e., the update HYDROBUDGET interface and the MCO module. The other modules and or components of the IWRM tools summarized in the respective deliverables.

1. HYDROBUDGET

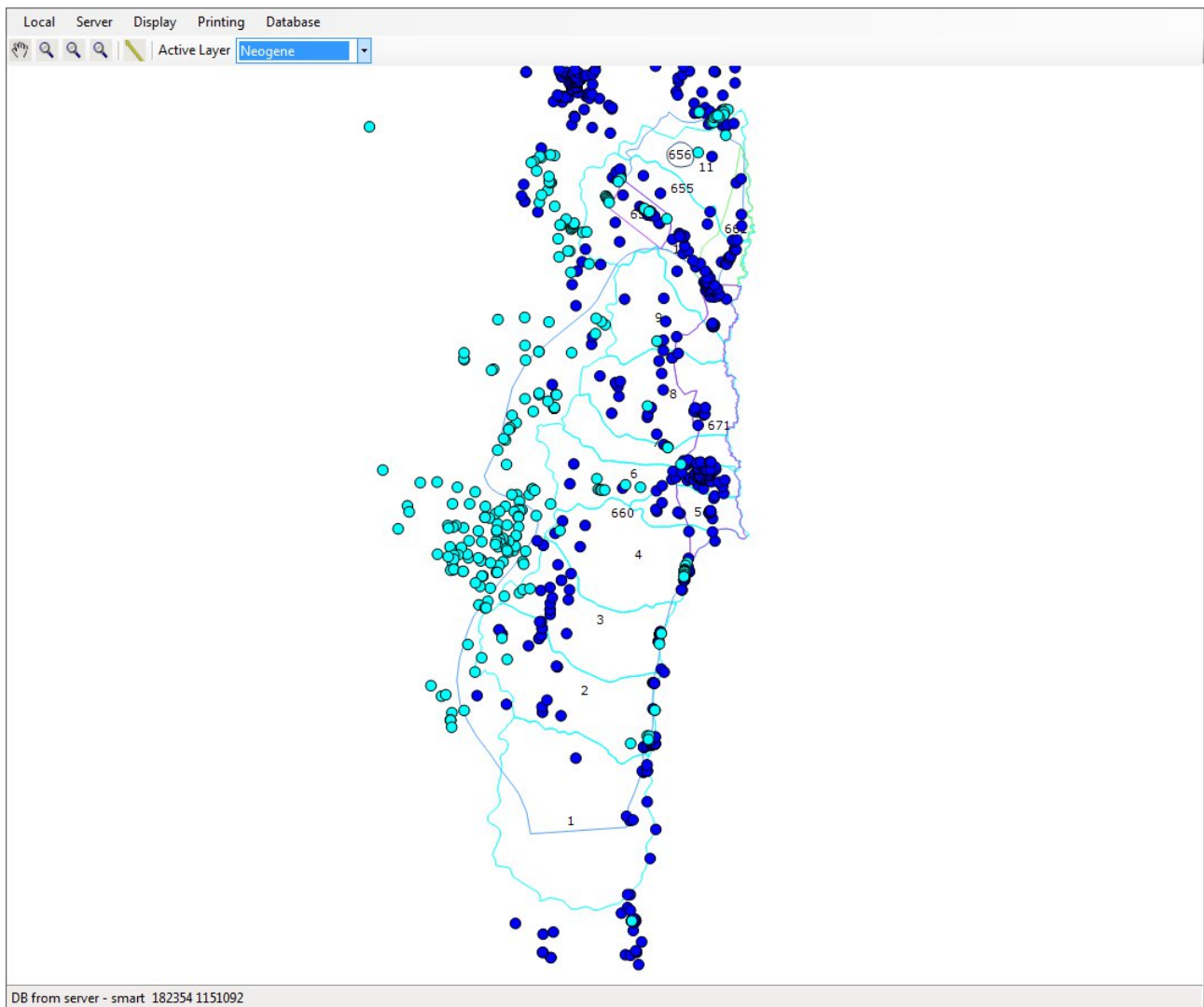
The HYDROBUDGET module logic and interface has been presented in Deliverable D601. Originally the data needed for this module was supposed to be provided by the DAYS! Data management system via a transparent internet connection through an ORACLE database providers. However, despite repeated attempts it became clear that this access will not be allowed. We decided in order to allow the development of the module to create our own DBMS (database management system) that would serve as a replacement to the inaccessible project data server. We gathered data from wells, springs and rain stations, maps of basins etc. in the western part of the project and created an application that demonstrated the functionality of this module. The updated version of the HYDRBUDGET module is essentially a substantial update of the data access interface (more generic and more flexible).

In this section we present, for the sake of consistency, the HYDROBUDGET application, including the interface items that remained unchanged.

HYDROBUDGET creates and maintains data and information for evaluation of the hydrological budget of region that can comprise a number subsurface and surface water resources. It can then present the results in a visual format. Each water resource is tessellated into one or more polygonal cells. The tessellation can be motivated either hydrological/geological and or administrative considerations. Each cell is Hydrological Reporting Unit (HRU), on which the components of the water balance are evaluated and can be inspected. It is possible to aggregate the water balance components of one or more cells in order to achieve the water balance of a sub-basin, a basin or a region comprising a number of basins.

This approach was implemented in the inventory of the water resources if Israel. EWRE, together with the TAHAL Company, was in charge of one of the updates, in 1996, a project commissioned by the Israel Water Authority.

Below we present the basic steps for creating, populating and managing a HYDROBYUDGET project.



Building a Hydro Budget project

1. Add vector maps that depict the aquifer/drainage basin layers, and define their vertical order (some aquifer basins may be deeper than others). Vector map formats include Arview Shape, Map Info, Autocad DXF, GML, XML and others.
2. Optionally add raster map for the background (this can be a geo-referenced aerial and or satellite photography or a raster map, in BMP, TIFF, ECW, PNG, GIF and other formats).
3. Optionally add Hydro databases.
4. Create the Hydro Budget database.
5. Define every HRU.
6. Prepare the project for publishing.

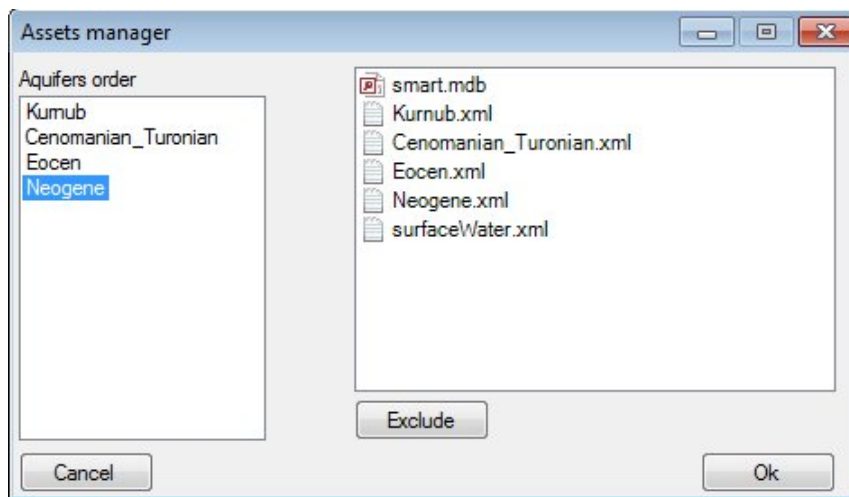
Adding a vector map

Local->project->Add File

Choose a vector map file (GML, shape, or MapInfo). This vector map has to have just one layer of closed polygons. If the file is not a GML file then there is a need to save it as GML first. Next define it thematically (ground water, surface water or Lake), and set its Id filed (Every polygon/unit has to have an identification).

Define vertical order of appearance:

Local->project->Assets Manager



In the aquifer order list, drag the item (geological layer Name) to its order.

Adding a raster map:

Local->project->Add File

Choose a raster map file (jpg, png, tiff or bmp), and anchor it (set its geographical extent). Only one map can be used for the background.

Create the Hydro budget database:

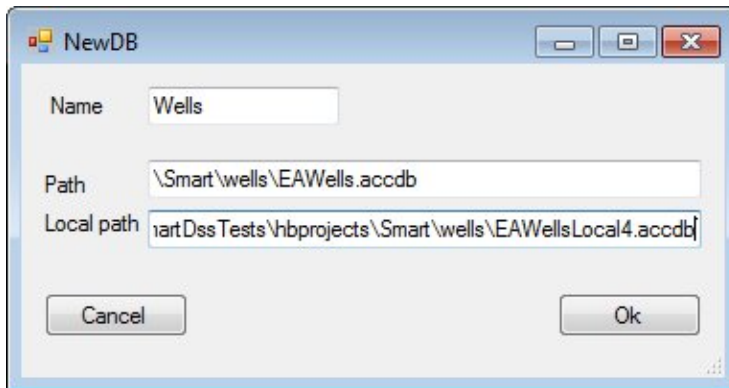
Local->project->Database->Create

When the aquifer is well defined, then a budget database is created (MS access file) on demand.

Add Hydro database:

Database->Open

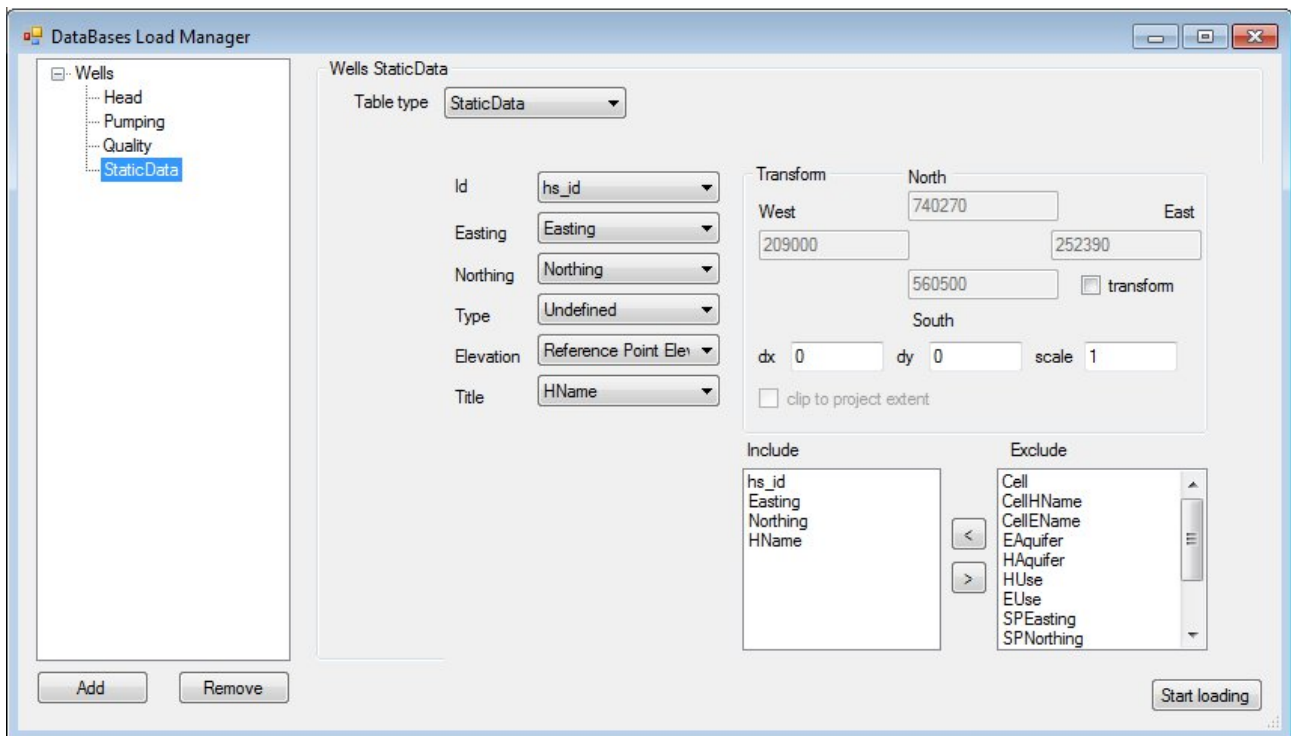
In the 'Database Load Manager', add a database layer, name it, and set its corresponding path and local path. Expand the data layer entry, to see its tables.



The 'NewDB' dialog box is shown with the following fields:

- Name:** Wells
- Path:** \Smart\wells\EA Wells.accdb
- Local path:** \artDssTests\hbprojects\Smart\wells\EA WellsLocal4.accdb
- Buttons:** Cancel, Ok

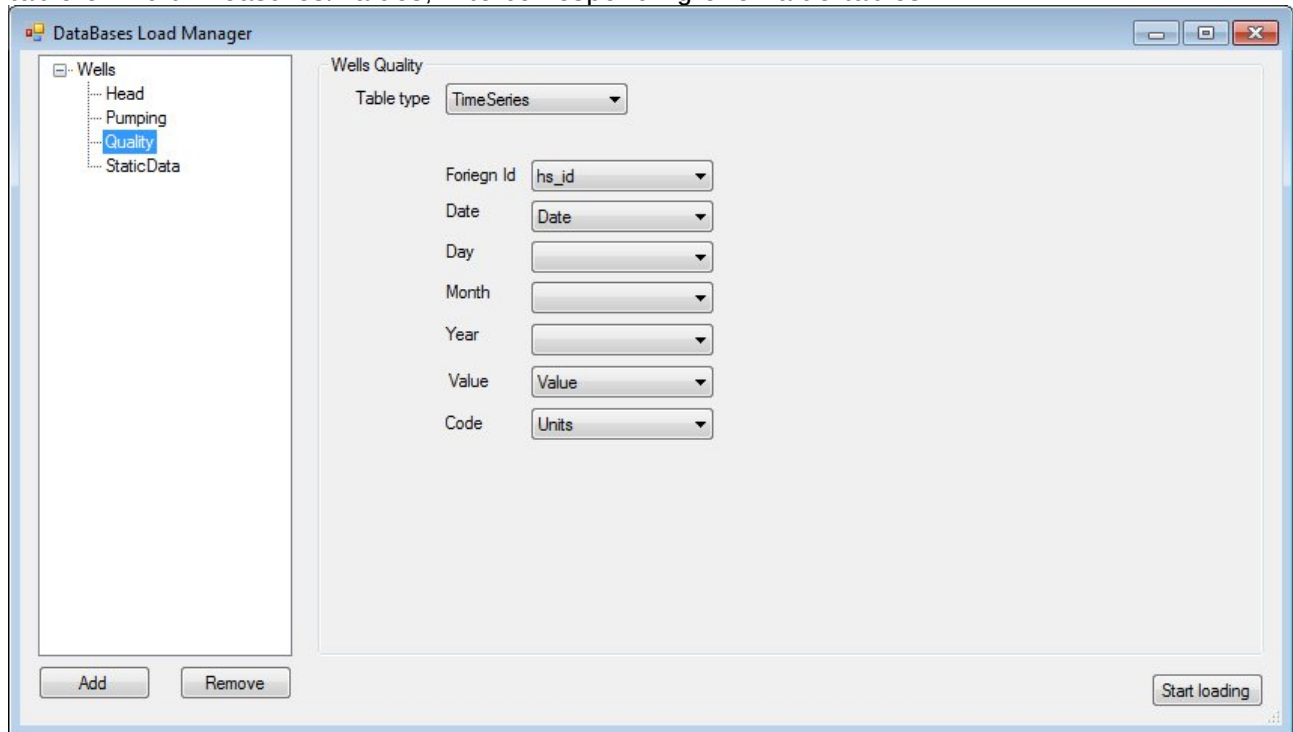
Next define one table as 'Static Data', and the others as 'Time Series'. Static data schema include mandatory fields ('Id' of the data point and its coordinates), and optional fields ('Type', 'Elevation', and 'Title' to display). When the coordinate's fields are chosen the geographical extent is displayed. If needed the coordinates can be transformed, and data can be clipped to project extent if it is defined already.



The 'DataBases Load Manager' dialog box is shown with the following configuration:

- Wells StaticData**
 - Table type:** StaticData
 - Fields:**
 - Id:** hs_id
 - Easting:** Easting
 - Northing:** Northing
 - Type:** Undefined
 - Elevation:** Reference Point Ele
 - Title:** HName
 - Transform:**
 - North:** 740270
 - West:** 209000
 - East:** 252390
 - South:** 560500
 - dx:** 0, **dy:** 0, **scale:** 1
 - transform:** ☐
 - clip to project extent:** ☐
 - Include:**
 - hs_id
 - Easting
 - Northing
 - HName
 - Exclude:**
 - Cell
 - CellHName
 - CellEName
 - EAquifer
 - HAquifer
 - HUse
 - EUse
 - SP_Easting
 - SP_Northing
 - Buttons:** Add, Remove, Start loading

Time Series schema include 'Foreign ID'- the connection to the static table, 'Day','Month','Year' or 'Date' to describe the date time, and 'Value' of the measure taken. The 'Code' field is used to split a table of multi measures/values, into corresponding one value tables.



Click the 'Start loading' to load data. A local database file is created and data selected into its tables.

Concepts:

Hydro Database:

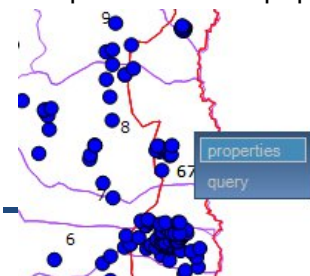
A data base that include one table of data points (wells, rain station etc.) and several tables of time measures taken in them. The data points may be seen as the static portion of the data, and the measures as the dynamic data.

Local database:

A specialized database that may include only a portion of the data points (those that fall in project extent (maybe their coordinates need translation to the project geographical system, first)) and only a portion of the measures taken. This data base is not just a sub set of the original one, but also organized in a different manner as one multi-value table translates into multiple one-value tables.

Define and Edit HRU:

Select the corresponding layer in the 'Active layer' combo, and right click the polygon/cell. Choose 'Properties' in the pop up menu and the cell property pages appear:



Characteristics page:

Fill aquifer and outcrops attributes as well as storativity, and statistics for rainfall, head salinity and nitrate.

Cell: 671

Filled by: sagi 16:00 יום חמישי 04 יולי 2013

Name: Jordan valley Id: 671

Characteristics Utilization Inflows Outflows Outflow control policy Water Yield Exploitation GW Budget

Aquifer

Geology: Quarter

Symbol: 20

Area (skm): 330.00

Total storage (MCM/m):

Level for storage (m):

Outcrop

Type: Quarter

Code: 20

Area (skm): 330.00

	Variable	Units	Avg	Max	Min	Variance	Fro
▶	Rainfall	mm	150	200	100		
	Head	m	-301	-301	-301		
	Salinity	mgCl/l	500	1590	135		
	Nitrate	mg/l					

Utilization page:

Fill current and average utilization, and thresholds for salinity and nitrate.

Characteristics Utilization Inflows Outflows Outflow control policy Water Yield Exploitation GW Budget

Aquifer

Geology: Quarter

Symbol: 20

Area (skm): 330.00

Total storage (MCM/m):

Level for storage (m):

Outcrop

Type: Quarter

Code: 20

Area (skm): 330.00

	Variable	Units	Avg	Max	Min	Variance	Fro
▶	Rainfall	mm	150	200	100		
	Head	m	-301	-301	-301		
	Salinity	mgCl/l	500	1590	135		
	Nitrate	mg/l					

Inflows page:

Fill natural replenishment, flux from adjacent ground cells, and flux for the surface, irrigation and artificial replenishment.

Characteristics	Utilization	Inflows	Outflows	Outflow control policy	Water Yield	Exploitation	GW Budget
-----------------	-------------	---------	----------	------------------------	-------------	--------------	-----------

Natural Replenishment (MCM/YR)

	Average	Maximum	Minimum	Variance
▶	5.5	5.5	5.5	55

Influx from adjacent GWHRU (MCM/YR)

	ID	Flux	Salinity	Nitrate
▶	673	0		

Influx from adjacent SWHRU (MCM/YR)

	ID	Flux	Salinity	Nitrate
▶	8			
	9			
	10			
	7			
	6			

Returning flow from irrigation (MCM/YR)

	Variable	Current	Expected 2020	Expected 2030
▶	Flux	3.8	2	2
	Salinity			

Artificial replenishment (MCM/YR)

	Origin	Current	Expected 2020	Expected 2030
▶	Surface Water			
	Water supply			
	Treated Effluent			

Outflows page:

Fill evaporation, flux to adjacent cell as well as spring, drainage, and flow to the sea/river.

Characteristics	Utilization	Inflows	Outflows	Outflow control policy	Water Yield	Exploitation	GW Budget
-----------------	-------------	---------	----------	------------------------	-------------	--------------	-----------

Evaporation (MCM/YR)

Flow to the Dead sea (MCM/YR)

Flow to the Jordan River (MCM/YR)

Flux to adjacent GWHRU (MCM/YR)

	ID	Flux	Flux variance	Salinity (mgCl/l)	Nitrate (mg/l)
▶	673				

Spring discharge (MCM/YR)

	ID	Flux
▶	8	2
	9	
	10	

Engineered drainage (MCM/YR)

	ID	Flux
▶	8	
	9	
	10	

Outflow control policy page:

Characteristics	Utilization	Inflows	Outflows	Outflow control policy	Water Yield	Exploitation	GW Budget						
Minimum driving head for spring (m) Current water level (m) Year													
Minimum discharge of springs (MCM/YR) 2.00 Current storage level (m) Year													
Target water level (m) Mode of calculation													
Residual flow to adjacent GWHRU (MCM/YR)													
<table border="1"> <thead> <tr> <th></th> <th>ID</th> <th>Flux</th> </tr> </thead> <tbody> <tr> <td>▶</td> <td>673</td> <td></td> </tr> </tbody> </table>									ID	Flux	▶	673	
	ID	Flux											
▶	673												

Set springs, residual flows from adjacent cell, and target water level and storage.

Water yield page:

Fill total yield and set salinity and nitrate thresholds.

Characteristics	Utilization	Inflows	Outflows	Outflow control policy	Water Yield	Exploitation	GW Budget
Current total (MCM/YR) 10.30							
By Salinity thresholds (mgCl/l)							
	Year	<250	251-400	401-800	>801		
▶	Current	0.4	2.4	2.5	2		
	2020	0.5	2	0	2		
	2030	0.5	17	2	2		
By Nitrate thresholds (mg/l)							
	Year	<35	36-70	71-90	>91		
▶	Current						
	2020						
	2030						

GW Budget:

Storage is calculated : $\text{Storage} = \text{Inflows} - \text{Outflows} - \text{Utilization}$.

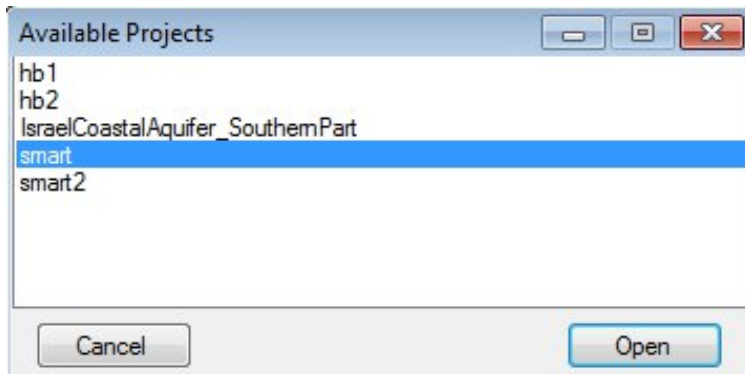
Use the update button to save your changes, who made these changes and when.

Prepare the project for publishing:**Local->Project->prepareUpload**

Instead of uploading the project straight into the server/cloud this method will create a folder named after the project name with all the project files/resources copies in it. Then user will send the folder to the support.

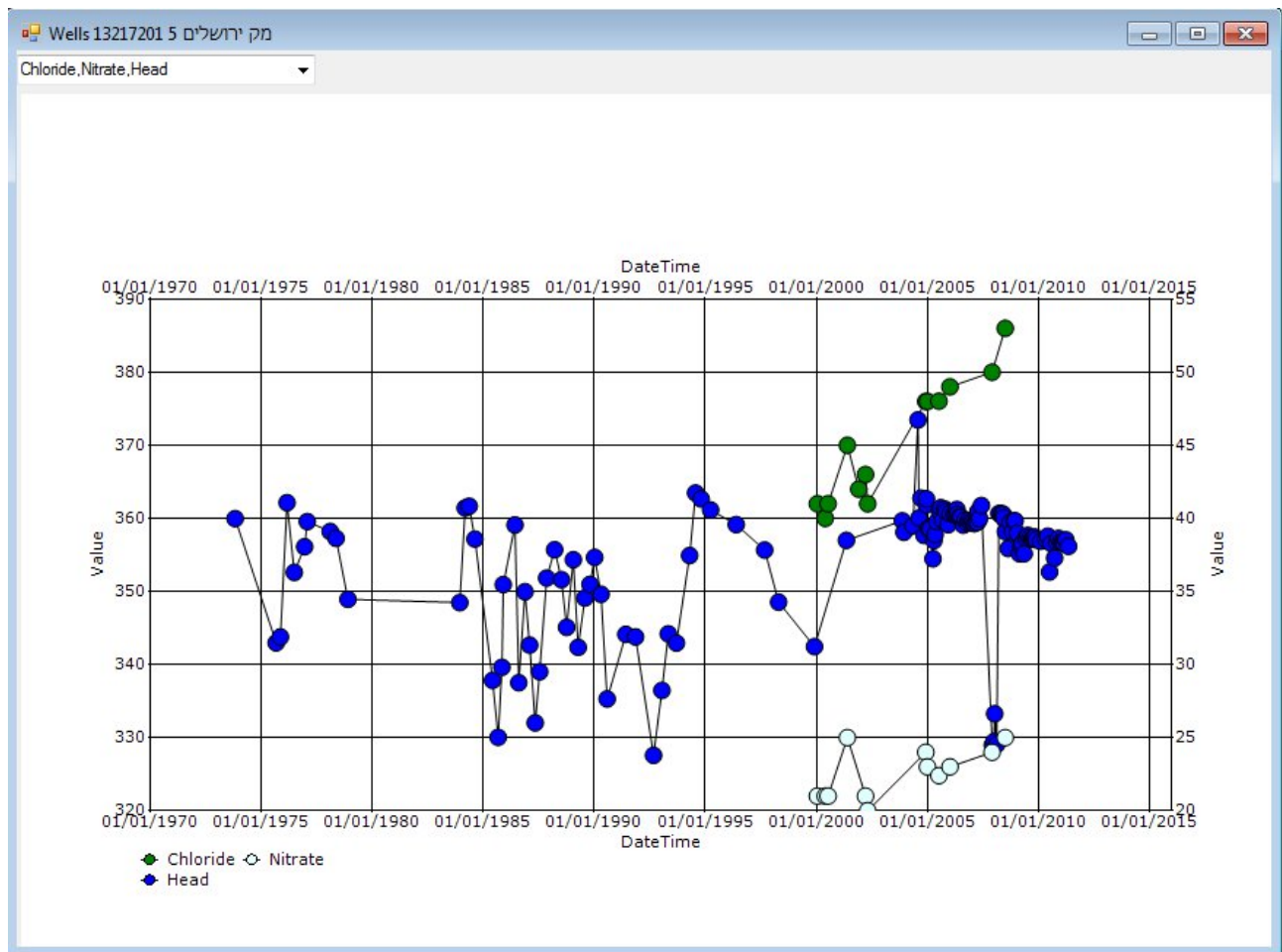
Viewing /inspecting a Hydro Budget project:**Server->Open**

Display a list of all available published projects. Select one and open it. As a viewer you will not be able to make any changes to the project.

**Inspect HRU data:**

Select the corresponding layer in the 'Active layer' combo, and right click the polygon/cell. Choose 'Properties' in the pop up menu and the cell property pages appear.

Viewing measures taken in Hydro data point:



Double click a data point and the date graphs viewer will open:

As default all the measures will appear. Use the display combo, to select the measures you are interested in.

Right click the dialog screen, and the 'Graph setting' dialog will appear. In it you can make changes to the graphic display of the graphs and the graph systems. Graph can be displayed in one or two systems (common axis time but different value axis). As general the pumping values are in different scale (much bigger absolute values) then other values, and deserve display in their own system.

GraphSettings

Graphs settings | Left | Right

Name	Active	Line pattern	Symbol	System
Chloride	☒			TopRight
Head	☒			BottomLeft
Nitrate	☒			TopRight

Verdana 8

frame 0.1

☒ X top ☒ X bottom ☐ Rotate 90

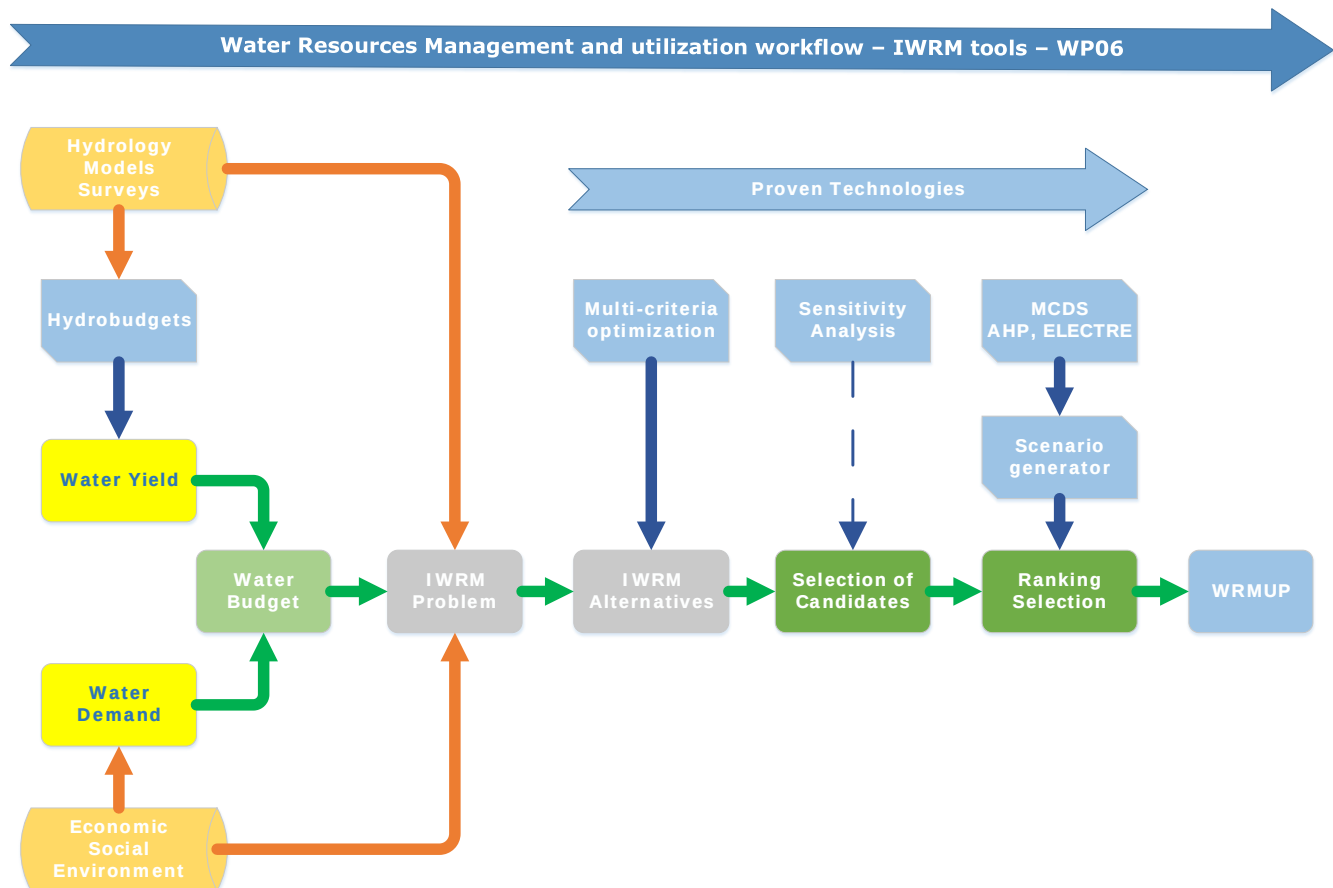
☒ Y left ☒ Y right

Store Delete Untitled fix

OK Cancel Apply

3. The Scenario Generator (SG) module

This is one of the most integrating modules of the SMART-DSS platform. Generally speaking a IWRM project includes a number of logical stages that need to be completed, as illustrated in the chart below.



Namely an IWRM project must always start from a definition of the problem, a characterization of the water resources (both the ones under utilization and then potential ones) and information on the water demand that is driven by Economic, social and environmental constraints. The part of the water demand is determined outside the working scope of this work-package but its outcome and values are an integral part of it. Data and information on the available and potential water resources are evaluated outside the scope of the work-packages (by means of hydrogeological modelling and surveys). Its output is fed into the HYDROBUDGET application (or some equivalent one) and the aim is to determine the water yield, or the amount of water per quality categories that can be produced in a region in way that is either sustainable or risk qualified. Water Yield and water demand constitute the water budget that is at the root of the of IWRM problem definition. The scenario Generator module, HG, is the module that transform the IWRM problem into a set of IWRM alternatives that have the capability to resolve the problem.

The logical sequence followed by SG comprises the following steps:

1. Translate the IWRM problem into a multi-criteria optimization problem, i.e., 1) objective functions representing the, usually conflicting, interests of economic, social and environmental factors and 2) a set constraints that fully define the limitations and physical properties of the system.
2. The solution of the MCO problem is not unique. It is rather in form of surface (or hyper-surface in higher dimensions) of non-dominated solutions, or the Pareto surface. Any solution belonging to this surface or set is characterized by the fact one of the objectives functions cannot be improved without altering one or more of the others. This set can be large and represent the set of preferred solutions for a wide range of interests and it needs to be further analysed.
3. The suggested step here is to use MCDM (either AHP or ELECTRE) in order to further reduce the set of preferred solutions and achieve the one that corresponds best to the objectives of the decision makers and or stakeholders.

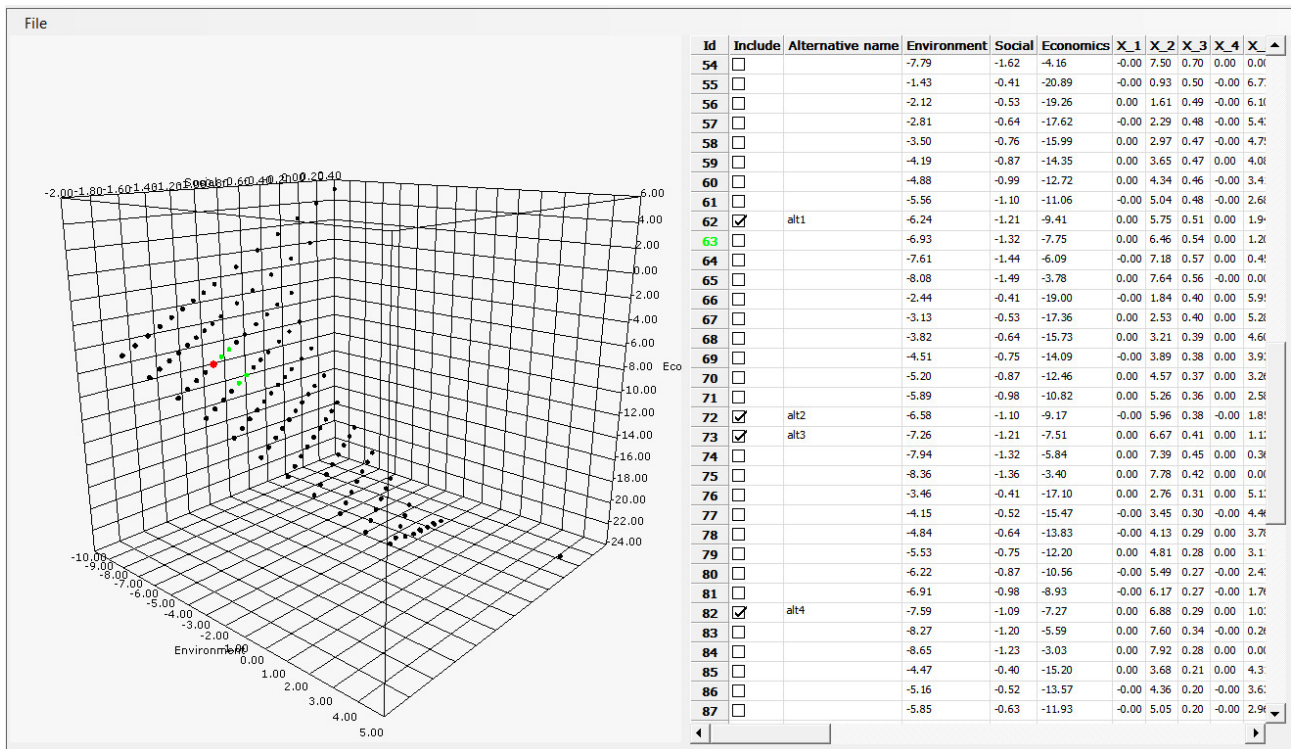
Therefore, the role of SG is to limit the space of the IWRM alternatives to smaller set of “good” solutions, thus limiting margin of error and or the impact subjective and inconsistent decision making. Of course the quality and suitability of the Pareto set heavily depends on how we represent the IWRM problem specific to a region into an MCO problem. Usual suggestion and recommendation is to use the simplest possible formulation. However, the tools that have been developed allow for a full non-linear MCO problem.

In what follows we present the procedure for generating and solving SG. A practical implementation will be presented in Deliverable D803.

Remark: One important component of the suggested flow is sensitivity analysis. It is not included in this of development of the SMART-DSS.

SG functions as a hub allowing the output from the MOC module (Alternatives as Pareto surface points, and criteria as objective functions), to be used as an input in the AHP and the ElectreIII applications. At present, the only manipulation available on the data is selection, either graphically or through the table.

The user can select only a few solutions from the Pareto (extreme solutions giving advantage to only one objective function or more compromise solutions). Then we can use AHP or ELECTRE for further processing. It must be stressed that this method is highly suitable to the implemented version of ELECTRE as by providing reference states (Pareto solutions).



On the left we have the same representation as within the MOC module, but the fact that picking of points is enabled. On the right is a list of the points, and their corresponding values for each of the objectives/criteria and for each of decision variables.

Included alternatives are marked as included, and appear as green points. The current point is red and the corresponding alternative Id is green.

Project file:

File->Open, Save, Save as
Saves as an Xml .csg file.

Input files:

File->Import
Open .par file created by the MOOC application.

Output files:

File->Export
Save file as .ahp (AHP) and as .elc (ElectreIII) and use it as an input file.

4. Conclusions

This deliverable seals the work carried in WP06 in the development of tools for IWRM. At the exception of HYDROBUDGET and SG, which are proprietary developments of EWRE, all the other decision making and MCO modules are available in other software packages (either commercial or not). The advantage of SMART-DSS though resides in the fact all modules are integrated into a unified Graphical User Interface, or easy access and can be jointly used for more improved of the results and the delineation of IWRM alternatives.