System of Integrated and Dynamic Water Balance of El Salvador

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Abstract

Between 2003-2005 the Integrated and Dynamic Water Balance was made in El Salvador, specifically in the quantification of superficial water resources component. Having in mind the necessity to update it permanently was developed the systematization of the calculation processes, and several scenarios of land use, climatic variations and variations in demand were included. Subsequently, the system of the calculation of the demand of the different types from consumption and the component of estimation of underground water charge were included. As a final result, the system determines the Index of Shortage at river basin level, which relates the total demand to the water availability, for any period.

Keywords: System, Water Balance, Integrated and Dynamic, Scenarios, Projections, Index Shortage

Introduction

In 2005, the Servicio Nacional de Estudios Territoriales of El Salvador, SNET, made an update of water balance of its water supply component, after 25 years ago that the Water Resources Master Plan was made. This update has the limitation to be a static result for a 30 years period between 1971 and 2001. With the objective of to have more dynamic results, which reflect the hydro-climatic conditions and the variability of land use changes, SNET designed and made the Dynamic and Integrated Water Balance System, in which it is possible to calculate the results of the variables involved in the water balance for any period of time (annual, monthly, year by year or years interval) for surface water, underground water and water demands to calculate a river basin level Shortage Index that reflects the water use condition as a function of its supply. For the development of the Calculate and systematization of underground water and demand modules, the enterprise Nippon Koie was contracted, these modules were linked to the total system. The whole system allows establishing several scenarios of land use changes, hydro-climatic variations and demand changes, which is an analysis tool to asset the impacts due some of these effects.

Objective

The objective of systematize the Water Balance in El Salvador, is to have a tool to make a periodical evaluation of the water resources, that allows to give guidelines of management, protection and control, taking into account the current and projected demand of each basin and its water availability.

Methodology

Language System:

The system has been developed in Visual Basic. NET language, and for the spatial analysis have been used programs: SURFER, ILWIS and ArcGis.

Databases:

The system has databases with information of rainfall stations, temperature, relative humidity and runoff, a monthly level, from the year 1970 until current date, which are updated continuously, so that the system can perform the calculation of any of the variables of water balance for any selected period.

Geographical Unit:

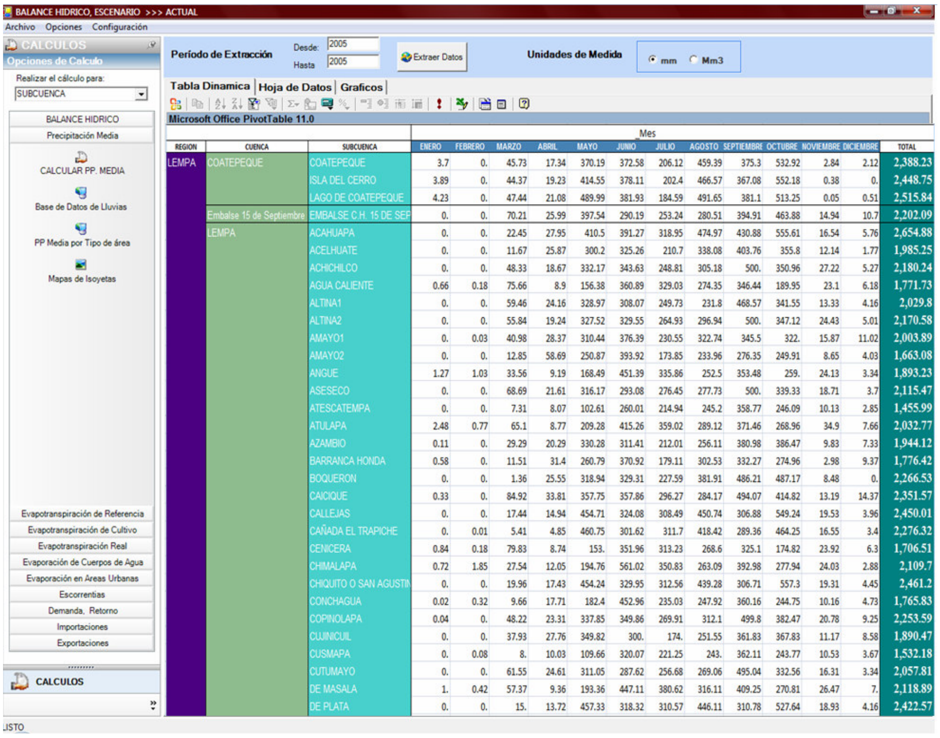
For the calculation of Water Balance or any of its variables, is possible to select any of the following geographical units: sub-basins, basins, regions hydrographical.

Calculation of areal average Precipitation and Evapotranspiration of Reference:

The calculation of areal Precipitation and Evapotranspiration of Reference, is made through of Krigging interpolation, based on information from Rainfall, Temperature and Relative Humidity databases (the methodology used for calculating the Evapotranspiration of Reference in El Salvador, is Hargreaves), giving like result grids at monthly level with values of the variable at cell level, with which the areal average value for the selected geographic unit is calculate, the size of the pixel to calculate of the variables is 50 meters.

In Figure 1, an example of the results of the calculation of areal precipitation for each month of the year 2005, at the sub-basin level, is presented.

Additionally, the system has a base of maps with the results of the Precipitation and Evapotranspiration of Reference in the country, month to month and year to year, from 1970 to the current date. This information is very useful to analyze the behavior of previous years, and allows you to select similar years as a tool for forecasting hydroclimate. Figure 2 presents an example of the annual Precipitation maps at El Salvador, for 1991 to 2005.



REGION	CUENCA	SUBCUENCA	ENERO	FEBRERO	MARZO	ABRIL	MAYO	JUNIO	JULIO	AGOSTO	SEPTIEMBRE	OCTUBRE	NOVIEMBRE	DICIEMBRE	TOTAL
LEMPA	COATEPEQUE	COATEPEQUE	3.7	0.	45.73	17.34	370.19	372.58	206.12	459.39	375.3	532.92	2.84	2.12	2,388.23
		ISLA DEL CERRO	3.89	0.	44.37	19.23	414.55	378.11	202.4	466.57	367.08	552.18	0.38	0.	2,448.75
		LAGO DE COATEPEQUE	4.23	0.	47.44	21.08	489.99	381.93	184.59	491.65	381.1	513.25	0.05	0.51	2,515.84
	Embalse 15 de Septiembre	EMBALSE C.H. 15 DE SEP	0.	0.	70.21	25.99	397.54	290.19	253.24	280.51	394.91	463.88	14.94	10.7	2,202.09
	LEMPA	ACAHUAPA	0.	0.	22.45	27.95	410.5	391.27	318.95	474.97	430.88	555.61	16.54	5.76	2,654.88
		ACELHUATE	0.	0.	11.67	25.87	300.2	325.26	210.7	338.08	403.76	355.8	12.14	1.77	1,985.25
		ACHICHILCO	0.	0.	48.33	18.67	332.17	343.63	248.81	305.18	500.	350.96	27.22	5.27	2,180.24
		AGUA CALIENTE	0.66	0.18	75.66	8.9	156.38	360.89	329.03	274.35	346.44	189.95	23.1	6.18	1,771.73
		ALTINA1	0.	0.	59.46	24.16	328.97	308.07	249.73	231.8	468.57	341.55	13.33	4.16	2,029.8
		ALTINA2	0.	0.	55.84	19.24	327.52	329.55	264.93	296.94	500.	347.12	24.43	5.01	2,170.58
		AMAYO1	0.	0.03	40.98	28.37	310.44	376.39	230.55	322.74	345.5	322.	15.87	11.02	2,003.89
		AMAYO2	0.	0.	12.85	58.69	250.87	393.92	173.85	233.96	276.35	249.91	8.65	4.03	1,663.08
		ANGUE	1.27	1.03	33.56	9.19	168.49	451.39	335.86	252.5	353.48	259.	24.13	3.34	1,893.23
		ASESECO	0.	0.	68.69	21.61	316.17	293.08	276.45	277.73	500.	339.33	18.71	3.7	2,115.47
		ATESCATEMPA	0.	0.	7.31	8.07	102.61	260.01	214.94	245.2	358.77	246.09	10.13	2.85	1,455.99
		ATULAPA	2.48	0.77	65.1	8.77	209.28	415.26	359.02	289.12	371.46	268.96	34.9	7.66	2,032.77
		AZAMBIO	0.11	0.	29.29	20.29	330.28	311.41	212.01	256.11	380.98	386.47	9.83	7.33	1,944.12
		BARRANCA HONDA	0.58	0.	11.51	31.4	260.79	370.92	179.11	302.53	332.27	274.96	2.98	9.37	1,776.42
		BOQUERON	0.	0.	1.36	25.55	318.94	329.31	227.59	381.91	486.21	487.17	8.48	0.	2,266.53
		CAICIQUE	0.33	0.	84.92	33.81	357.75	357.86	296.27	284.17	494.07	414.82	13.19	14.37	2,351.57
		CALLEJAS	0.	0.	17.44	14.94	454.71	324.08	308.49	450.74	306.88	549.24	19.53	3.96	2,450.01
		CAÑADA EL TRAPICHE	0.	0.01	5.41	4.85	460.75	301.62	311.7	418.42	289.36	464.25	16.55	3.4	2,276.32
		CENICERA	0.84	0.18	79.83	8.74	153.	351.96	313.23	268.6	325.1	174.82	23.92	6.3	1,706.51
		CHIMALAPA	0.72	1.85	27.54	12.05	194.76	561.02	350.83	263.09	392.98	277.94	24.03	2.88	2,109.7
		CHIQUITO O SAN AGUSTIN	0.	0.	19.96	17.43	454.24	329.95	312.56	439.28	306.71	557.3	19.31	4.45	2,461.2
		CONCHAGUA	0.02	0.32	9.66	17.71	182.4	452.96	235.03	247.92	360.16	244.75	10.16	4.73	1,765.83
		COPINOLAPA	0.04	0.	48.22	23.31	337.85	349.86	269.91	312.1	499.8	382.47	20.78	9.25	2,253.59
		CUJINICUIL	0.	0.	37.93	27.76	349.82	300.	174.	251.55	361.83	367.83	11.17	8.58	1,890.47
		CUSMAPA	0.	0.08	8.	10.03	109.66	320.07	221.25	243.	362.11	243.77	10.53	3.67	1,532.18
		CUTUMAYO	0.	0.	61.55	24.61	311.05	287.62	256.68	269.06	495.04	332.56	16.31	3.34	2,057.81
		DE MASALA	1.	0.42	57.37	9.36	193.36	447.11	380.62	316.11	409.25	270.81	26.47	7.	2,118.89
		DE PLATA	0.	0.	15.	13.72	457.33	318.32	310.57	446.11	310.78	527.64	18.93	4.16	2,422.57

Figure 1. **Precipitation areal by the year 2005 at the sub-basin level**

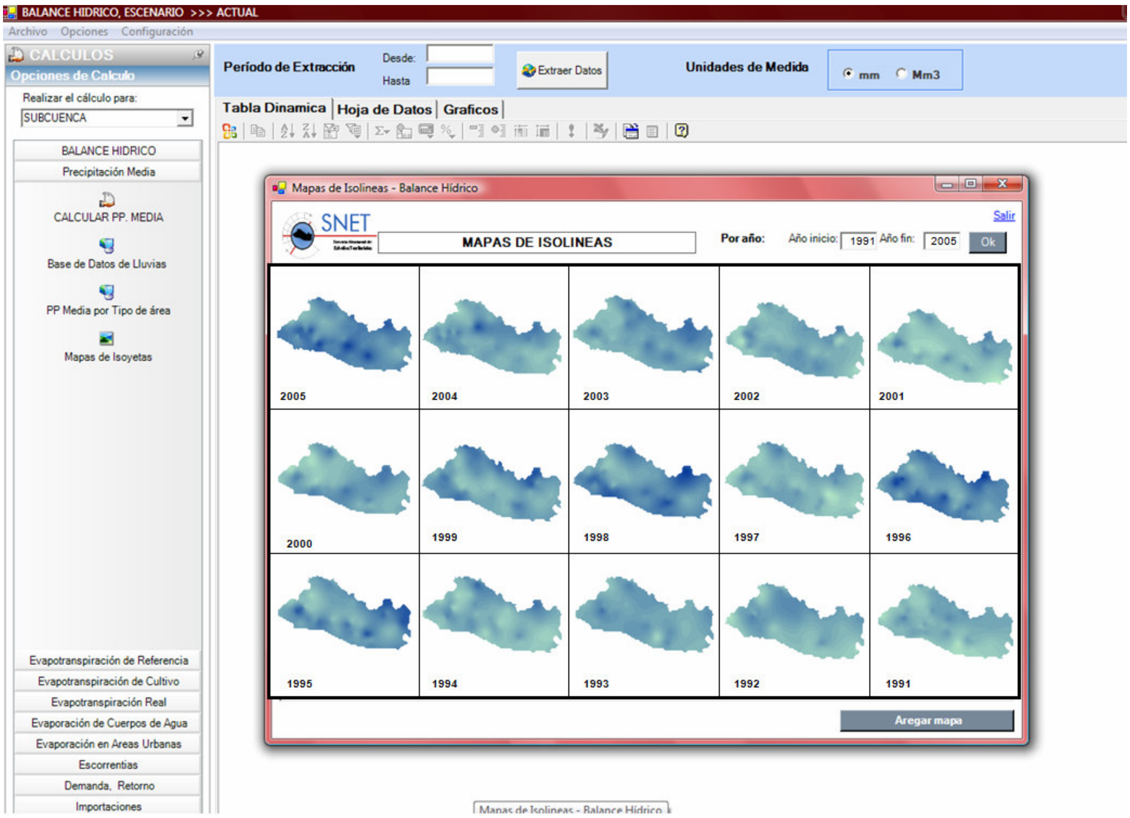
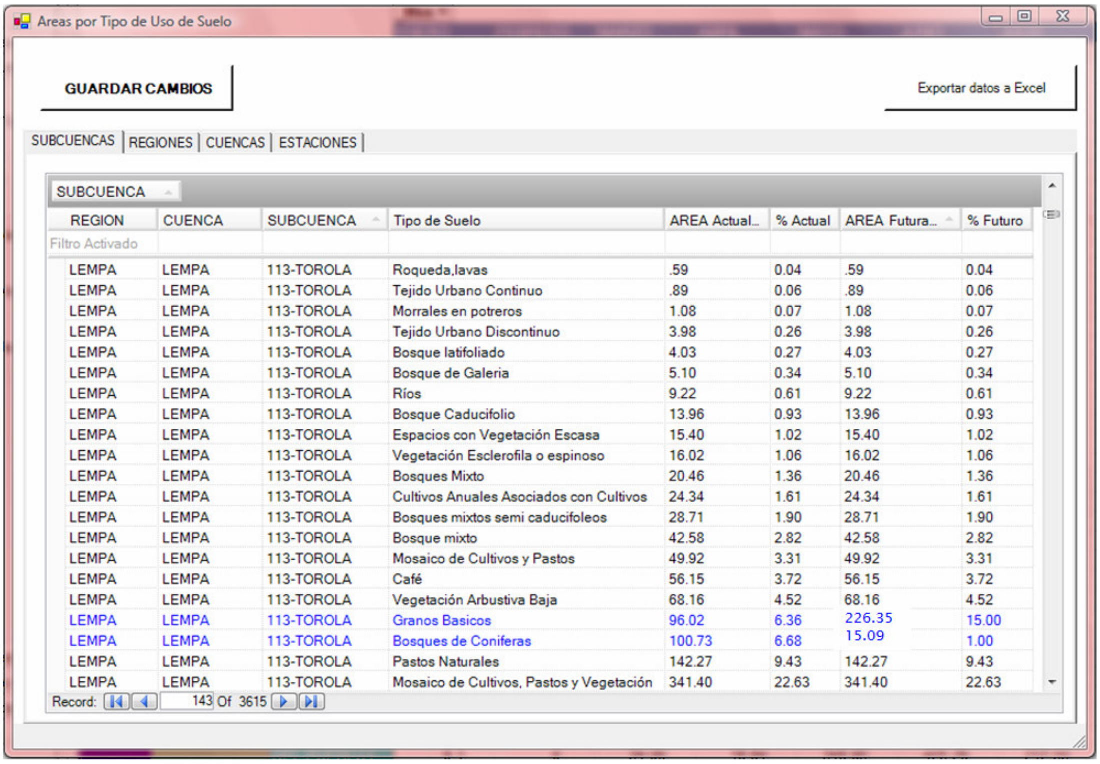


Figure 2. **Maps of annual Precipitation in El Salvador, for the period 1991 – 2005**

Calculation of Crop Evapotranspiration and Real Evapotranspiration: For calculate the Crop Evapotranspiration, the system has the latest map of Land Uses which was published for the country in 2003, however in a next stage will be possible introduced land-use maps available for periods prior and subsequent. Based on the information Uses of Land, the system calculates the areal Crop Evapotranspiration for geographical unit selected, assigning a Crop Coefficient for each using soil specific, monthly level, and calculates the weighted, monthly and for year. For Crop Evapotranspiration, the system has an option to change the percentage of area use soil, so that allows the calculation of the variable, and therefore the Water Balance for an actual Use Land and for a possible scenario in the geographical unit selected. Figure 3 presents the pattern in which the percentage changes from area to the Land Use Basic Grains and Conifer Forests for the sub basin Torola.



REGION	CUENCA	SUBCUENCA	Tipo de Suelo	AREA Actual...	% Actual	AREA Futura...	% Futuro
LEMPA	LEMPA	113-TOROLA	Roqueda,lavas	.59	0.04	.59	0.04
LEMPA	LEMPA	113-TOROLA	Tejido Urbano Continuo	.89	0.06	.89	0.06
LEMPA	LEMPA	113-TOROLA	Morrales en potreros	1.08	0.07	1.08	0.07
LEMPA	LEMPA	113-TOROLA	Tejido Urbano Discontinuo	3.98	0.26	3.98	0.26
LEMPA	LEMPA	113-TOROLA	Bosque latifoliado	4.03	0.27	4.03	0.27
LEMPA	LEMPA	113-TOROLA	Bosque de Galeria	5.10	0.34	5.10	0.34
LEMPA	LEMPA	113-TOROLA	Ríos	9.22	0.61	9.22	0.61
LEMPA	LEMPA	113-TOROLA	Bosque Caducifolio	13.96	0.93	13.96	0.93
LEMPA	LEMPA	113-TOROLA	Espacios con Vegetación Escasa	15.40	1.02	15.40	1.02
LEMPA	LEMPA	113-TOROLA	Vegetación Esclerofila o espinoso	16.02	1.06	16.02	1.06
LEMPA	LEMPA	113-TOROLA	Bosques Mixto	20.46	1.36	20.46	1.36
LEMPA	LEMPA	113-TOROLA	Cultivos Anuales Asociados con Cultivos	24.34	1.61	24.34	1.61
LEMPA	LEMPA	113-TOROLA	Bosques mixtos semi caducifoleos	28.71	1.90	28.71	1.90
LEMPA	LEMPA	113-TOROLA	Bosque mixto	42.58	2.82	42.58	2.82
LEMPA	LEMPA	113-TOROLA	Mosaico de Cultivos y Pastos	49.92	3.31	49.92	3.31
LEMPA	LEMPA	113-TOROLA	Café	56.15	3.72	56.15	3.72
LEMPA	LEMPA	113-TOROLA	Vegetación Arbustiva Baja	68.16	4.52	68.16	4.52
LEMPA	LEMPA	113-TOROLA	Granos Basicos	96.02	6.36	226.35	15.00
LEMPA	LEMPA	113-TOROLA	Bosques de Coniferas	100.73	6.68	15.09	1.00
LEMPA	LEMPA	113-TOROLA	Pastos Naturales	142.27	9.43	142.27	9.43
LEMPA	LEMPA	113-TOROLA	Mosaico de Cultivos, Pastos y Vegetación	341.40	22.63	341.40	22.63

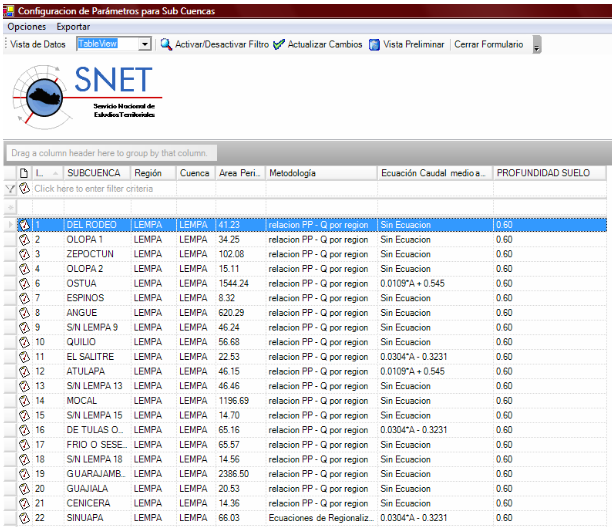
***Figure 3*. Variation in percentage of areas in the Land Use sub basin TOROLA, for calculating the Crop Evapotranspiration to the two situations**

The Real Evapotranspiration is calculated from the Crop Evapotranspiration and the type of soils map of the country, to which the system assigns a water capacity retention to a depth of soil that can be defined, which performs the calculation of moisture soil on a monthly level and the Real Evapotranspiration

Calculating of Evaporation of Water Bodies in urban areas: The system calculates the evaporation of water bodies in urban areas of each geographical unit, according to the map of Land Uses. For water bodies is assigned a coefficient of evaporation depending on the month of the year, and for urban areas has been established urban coefficient Ku (similar to the Crop Coefficient Kc), with an estimated value of 0.10.

Calculating Runoff:

The runoffs are taken from flow database for the river basins that have registry, and for the river basins that do not have it, have been developed two methodologies: precipitation-runoff relation and regionalization, also having the possibility of introducing calculated data through hydrometeorological modelling. For both methods have been established factors for estimating runoff, in a case depending on the area and the other in terms of rainfall, depending on the homogeneous region to which it belongs basin.Each particular basin has been analyzed to determine which of the methodologies presented better results in the case of not having information recorded or modeled.

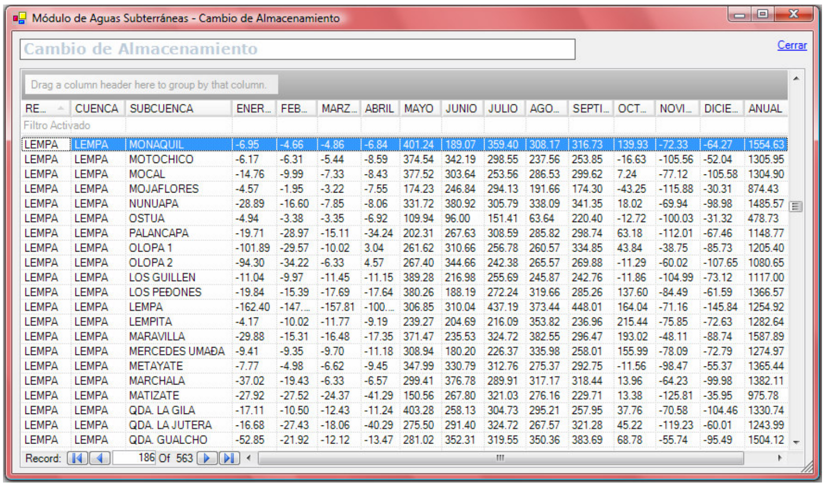


I...	SUBCUENCA	Región	Cuenca	Area Peri...	Metodología	Ecuación Caudal medio a...	PROFUNDIDAD SUELO
1	DEL RODEO	LEMPA	LEMPA	41.23	relacion PP - Q por region	Sin Ecuacion	0.60
2	OLOPA 1	LEMPA	LEMPA	34.25	relacion PP - Q por region	Sin Ecuacion	0.60
3	ZEPOCTUN	LEMPA	LEMPA	102.08	relacion PP - Q por region	Sin Ecuacion	0.60
4	OLOPA 2	LEMPA	LEMPA	15.11	relacion PP - Q por region	Sin Ecuacion	0.60
6	OSTUA	LEMPA	LEMPA	1544.24	relacion PP - Q por region	0.0109*A + 0.545	0.60
7	ESPINOS	LEMPA	LEMPA	8.32	relacion PP - Q por region	Sin Ecuacion	0.60
8	ANGUE	LEMPA	LEMPA	620.29	relacion PP - Q por region	Sin Ecuacion	0.60
9	S/N LEMPA 9	LEMPA	LEMPA	46.24	relacion PP - Q por region	Sin Ecuacion	0.60
10	QUILIO	LEMPA	LEMPA	56.68	relacion PP - Q por region	Sin Ecuacion	0.60
11	EL SALITRE	LEMPA	LEMPA	22.53	relacion PP - Q por region	0.0304*A - 0.3231	0.60
12	ATULAPA	LEMPA	LEMPA	46.15	relacion PP - Q por region	0.0109*A + 0.545	0.60
13	S/N LEMPA 13	LEMPA	LEMPA	46.46	relacion PP - Q por region	Sin Ecuacion	0.60
14	MOCAL	LEMPA	LEMPA	1196.69	relacion PP - Q por region	Sin Ecuacion	0.60
15	S/N LEMPA 15	LEMPA	LEMPA	14.70	relacion PP - Q por region	Sin Ecuacion	0.60
16	DE TULAS O...	LEMPA	LEMPA	65.16	relacion PP - Q por region	0.0304*A - 0.3231	0.60
17	FRIO O SESE...	LEMPA	LEMPA	65.57	relacion PP - Q por region	Sin Ecuacion	0.60
18	S/N LEMPA 18	LEMPA	LEMPA	14.56	relacion PP - Q por region	Sin Ecuacion	0.60
19	GUARAJAMB...	LEMPA	LEMPA	2386.50	relacion PP - Q por region	Sin Ecuacion	0.60
20	GUAJIALA	LEMPA	LEMPA	20.53	relacion PP - Q por region	Sin Ecuacion	0.60
21	CENICERA	LEMPA	LEMPA	14.36	relacion PP - Q por region	Sin Ecuacion	0.60
22	SINUAPA	LEMPA	LEMPA	66.03	Ecuaciones de Regionaliz...	0.0304*A - 0.3231	0.60

Figure 4. **Methods of estimating runoff assigned to each particular basin.**

Calculation Storage Change and Aquifers Recharge:

As a mathematical result of the rainfall minus the losses of real evapotranspiration, water bodies evaporation, urban zones evaporation and runoff, the change of storage is fixed, from which one the underground water recharge is estimated. . Figure 5 presents the results of Change Storage at sub basin level.



RE...	CUENCA	SUBCUENCA	ENER...	FEB...	MARZ...	ABRIL	MAYO	JUNIO	JULIO	AGO...	SEPTI...	OCT...	NOVI...	DICIE...	ANUAL
LEMPA	LEMPA	MONAQUIL	-6.95	-4.66	-4.86	-6.84	401.24	189.07	359.40	308.17	316.73	139.93	-72.33	-64.27	1554.63
LEMPA	LEMPA	MOTOCHICO	-6.17	-6.31	-5.44	-8.59	374.54	342.19	298.55	237.56	253.85	-16.63	-105.56	-52.04	1305.95
LEMPA	LEMPA	MOCAL	-14.76	-9.99	-7.33	-8.43	377.52	303.64	253.56	286.53	299.62	7.24	-77.12	-105.58	1304.90
LEMPA	LEMPA	MOJAFLORES	-4.57	-1.95	-3.22	-7.55	174.23	246.84	294.13	191.66	174.30	-43.25	-115.88	-30.31	874.43
LEMPA	LEMPA	NUNUAPA	-28.89	-16.60	-7.85	-8.06	331.72	380.92	305.79	338.09	341.35	18.02	-69.94	-98.98	1485.57
LEMPA	LEMPA	OSTUA	-4.94	-3.38	-3.35	-6.92	109.94	96.00	151.41	63.64	220.40	-12.72	-100.03	-31.32	478.73
LEMPA	LEMPA	PALANCAPA	-19.71	-28.97	-15.11	-34.24	202.31	267.63	308.59	285.82	298.74	63.18	-112.01	-67.46	1148.77
LEMPA	LEMPA	OLOPA 1	-101.89	-29.57	-10.02	3.04	261.62	310.66	256.78	260.57	334.85	43.84	-38.75	-85.73	1205.40
LEMPA	LEMPA	OLOPA 2	-94.30	-34.22	-6.33	4.57	267.40	344.66	242.38	265.57	269.88	-11.29	-60.02	-107.65	1080.65
LEMPA	LEMPA	LOS GUILLEN	-11.04	-9.97	-11.45	-11.15	389.28	216.98	255.69	245.87	242.76	-11.86	-104.99	-73.12	1117.00
LEMPA	LEMPA	LOS PEĐONES	-19.84	-15.39	-17.69	-17.64	380.26	188.19	272.24	319.66	285.26	137.60	-84.49	-61.59	1366.57
LEMPA	LEMPA	LEMPA	-162.40	-147....	-157.81	-100....	306.85	310.04	437.19	373.44	448.01	164.04	-71.16	-145.84	1254.92
LEMPA	LEMPA	LEMPITA	-4.17	-10.02	-11.77	-9.19	239.27	204.69	216.09	353.82	236.96	215.44	-75.85	-72.63	1282.64
LEMPA	LEMPA	MARAVILLA	-29.88	-15.31	-16.48	-17.35	371.47	235.53	324.72	382.55	296.47	193.02	-48.11	-88.74	1587.89
LEMPA	LEMPA	MERCEDES UMAĐA	-9.41	-9.35	-9.70	-11.18	308.94	180.20	226.37	335.98	258.01	155.99	-78.09	-72.79	1274.97
LEMPA	LEMPA	METAYATE	-7.77	-4.98	-6.62	-9.45	347.99	330.79	312.76	275.37	292.75	-11.56	-98.47	-55.37	1365.44
LEMPA	LEMPA	MARCHALA	-37.02	-19.43	-6.33	-6.57	299.41	376.78	289.91	317.17	318.44	13.96	-64.23	-99.98	1382.11
LEMPA	LEMPA	MATIZATE	-27.92	-27.52	-24.37	-41.29	150.56	267.80	321.03	276.16	229.71	13.38	-125.81	-35.95	975.78
LEMPA	LEMPA	QDA. LA GILA	-17.11	-10.50	-12.43	-11.24	403.28	258.13	304.73	295.21	257.95	37.76	-70.58	-104.46	1330.74
LEMPA	LEMPA	QDA. LA JUTERA	-16.68	-27.43	-18.06	-40.29	275.50	291.40	324.72	267.57	321.28	45.22	-119.23	-60.01	1243.99
LEMPA	LEMPA	QDA. GUALCHO	-52.85	-21.92	-12.12	-13.47	281.02	352.31	319.55	350.36	383.69	68.78	-55.74	-95.49	1504.12

Figure 5. **Result of Storage Change for the year 2005**

The module groundwater estimated the aquifer recharge, from the information of storage, change, considering two storage in the soil, an upper storage, representing the soil and unsaturated zone and a lower storage representing groundwater. The subsurface storage feeds subsurface flows such as springs and wells dug, while the extraction of water by deep wells is fed for storage of groundwater. Figure 6, provides an outline of the concept of the module.

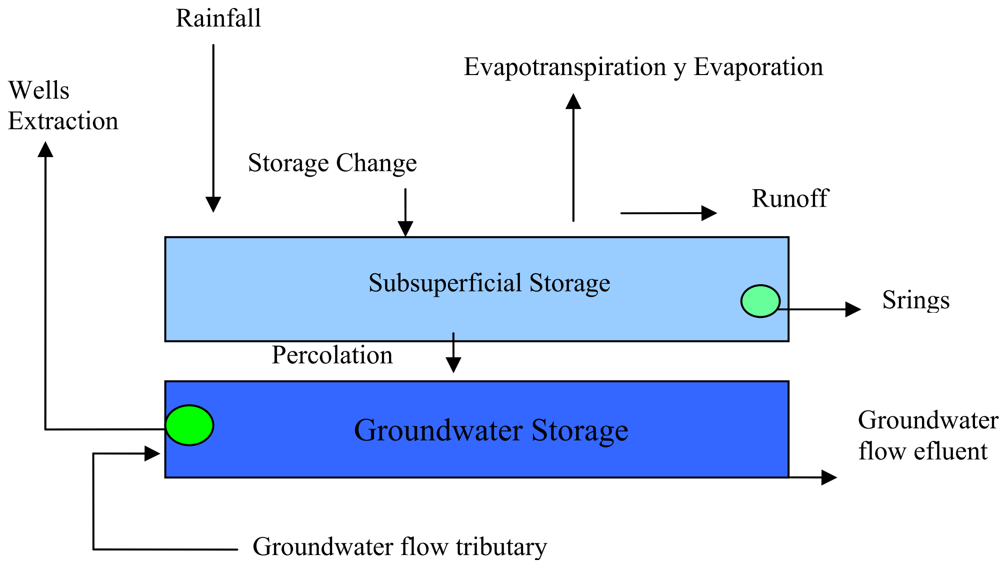


Figure 6. **Conceptualization Module Groundwater**

The module considers that the infiltration is happening in those areas permeable, and storage change is divided into two parts: one part will recharge underground water storage the catchment area where there are suitable conditions, ie it has significant aquifers, and the other party can not infiltrate will be transformed into subsurface flow. Therefore, the recharge is determined taking into account the existence or not of aquifers in the basin studied.

To make the calculations, the module groundwater overlaid the basins map with the hydrogeological map to determine impermeable areas and aquifers and calculates the direct recharge and subsurface flow.

Estimated Demands and Returns:

The quantification of the demand has been done to the human, agricultural, industrial, livestock, hotel, fish, thermal and ecological consumption sectors, and projections have been done until year 2050 for each one of such, considering macroeconomic projections, with indexes like the GDP and AGDP.

Demand for human consumption: the demand for human consumption is based on the method of estimating the population and assigns a unit demand. The system contains a database of population projections at the level of sub basin up to 2050, both for urban and rural population, which were undertaken based on existing census. The consulting firm hired for the estimation of demand, Nippon Koei, determined that the demand for human consumption was a function of the water service coverage, finding a correlation between demand per capita in liters / person / day and coverage aqueduct system, which was made a projection of municipal coverage up to 2050, which were introduced in the system. For the demand on rural population, it was assumed a consumption of 50 liters / person / day.

Demand for Industrial Consumer: The consulting firm found the demand for rural industry (since the urban is reflected in the demand for human consumption) is proportional to the number of employees of the total manufacturing sector in the country. To which gave a unit demand for the industrial sector, and projected employees in the manufacturing sector based on the population of country and Gross Domestic Product GDP; The system calculates industrial demand when multiply the database of employees industry by demand unit.

Demand for Agricultural Consumer: The system has included databases with projections of total irrigation areas in the country, which were undertaken on the basis of available statistics; in the system exist the crop distribution based on the information given by the Ministry of Agriculture what the system calculates the planted area each month of the year for each crop and have been established crop patterns depending on the crops that require irrigation during dry months. For those crops the system establishes the demand for irrigation pattern chosen according to the Potential Evapotranspiration, consumptive use, effective rainfall, the net laminate irrigation, efficiency of irrigation, gross laminate which it calculates the volume or laminate of water demand. The system distributes spatially the demand in proportion to the agrologic areas, and the temporary projections are made based on equations in terms of population and AGDP.

Demand for Livestock Consumer: in the system, livestock demand is composed of cattle, swine and poultry demands; the system has databases with projection of the number of animals of the three sectors, which was calculated according of the population and Agriculture Gross Domestic Product AGDP; For these projections has been made a space distribution by catchments according to the percentage of area representing each sector based on the country maps of the sector. To project the total demand, the system projects the number of animals, and based on a demand by animal projected total demand.

Demand for Aquaculture Consumer: the system has the database with the projection of aquaculture production (in Kilograms), which was calculated based on the production of the year 2005, and the relationship between population of a given year and the population in the year 2005, including a factor in consumer preference. Based on the production, it is possible determinate the area of pond per year, which is distributed at every catchment based on a points aquaculture map. Estimating area under cultivation in each watershed is multiplied by consumption of water per hectare per year.

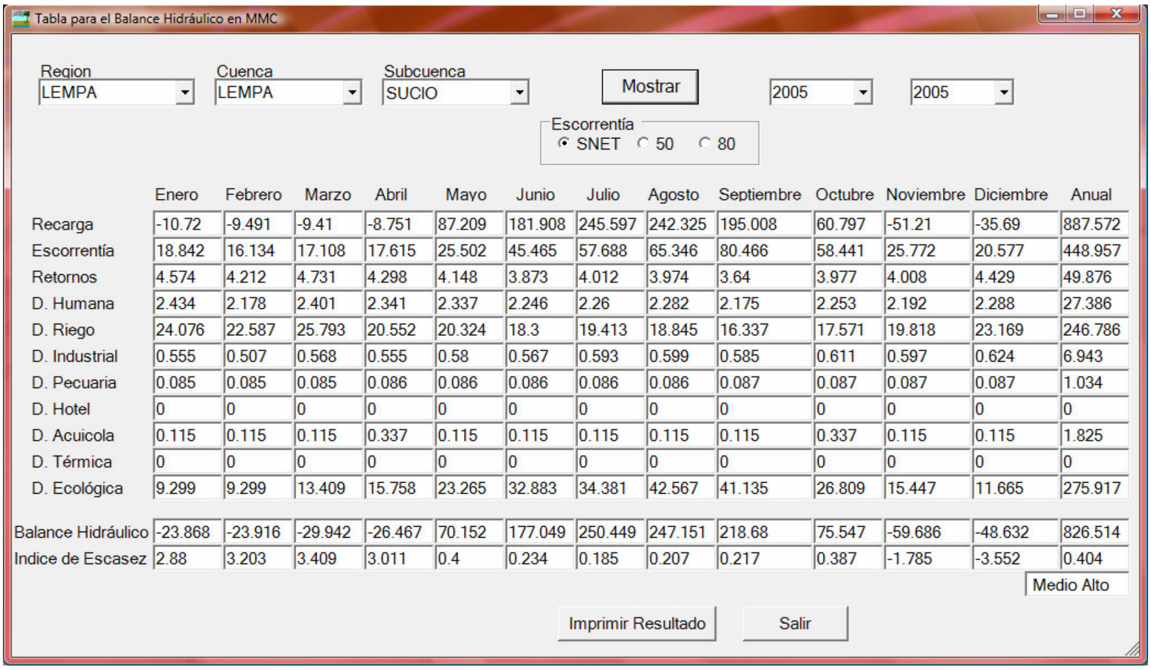
Consumer Demand Hotel: is based on the database with projection of the number of room for both beach and rural sector, depending on the population and GDP. The system assigns a value of 0.7 m3/room by day in beach and 0.35 m3/room per day in rural, and assumes an occupancy rate of 60%, which is distributed throughout the year. Similarly, is made the spatial distribution of river basins, from a location map of hotels sites in the country.

Demand for Thermal Consumer: from the analysis of the installed power and energy produced in the country, it was made the projection of the same in terms of population and GDP, which are in the databases system, together with the distribution of thermal production in currently existing plants. Taking the projection of the thermal power that will produce each plant associated with consumption of water per MWh produced, the system calculates the thermal demand in each of the sub basins.

Returns: in the system, returns are considered as a percentage of demand returning to the hydrological system, assuming that is quality to be considered. These percentages can be changed depending on the condition of water quality, but in the system are considered some reference rates for each type of demand.

Shortage Index: This index is calculated by the system and represents a percentage relationship of the total demand in the basin and water availability, giving a quantitative and qualitative value of the pressure on the basin, indicating whether the pressure of demand is high, medium, low or non-significant.

Figure 7 presents the results of aquifer recharge, runoff, demands, returns and the Shortage Index for the Sucio river sub basin for 2005 year.



	Enero	Febrero	Marzo	Abril	Mayo	Junio	Julio	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Anual
Recarga	-10.72	-9.491	-9.41	-8.751	87.209	181.908	245.597	242.325	195.008	60.797	-51.21	-35.69	887.572
Escorrentía	18.842	16.134	17.108	17.615	25.502	45.465	57.688	65.346	80.466	58.441	25.772	20.577	448.957
Retornos	4.574	4.212	4.731	4.298	4.148	3.873	4.012	3.974	3.64	3.977	4.008	4.429	49.876
D. Humana	2.434	2.178	2.401	2.341	2.337	2.246	2.26	2.282	2.175	2.253	2.192	2.288	27.386
D. Riego	24.076	22.587	25.793	20.552	20.324	18.3	19.413	18.845	16.337	17.571	19.818	23.169	246.786
D. Industrial	0.555	0.507	0.568	0.555	0.58	0.567	0.593	0.599	0.585	0.611	0.597	0.624	6.943
D. Pecuaria	0.085	0.085	0.085	0.086	0.086	0.086	0.086	0.086	0.087	0.087	0.087	0.087	1.034
D. Hotel	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Acuicola	0.115	0.115	0.115	0.337	0.115	0.115	0.115	0.115	0.115	0.337	0.115	0.115	1.825
D. Térmica	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Ecológica	9.299	9.299	13.409	15.758	23.265	32.883	34.381	42.567	41.135	26.809	15.447	11.665	275.917
Balance Hidráulico	-23.868	-23.916	-29.942	-26.467	70.152	177.049	250.449	247.151	218.68	75.547	-59.686	-48.632	826.514
Indice de Escasez	2.88	3.203	3.409	3.011	0.4	0.234	0.185	0.207	0.217	0.387	-1.785	-3.552	0.404

Figure 7. **Result of System for subbasin Sucio, year 2005**

Scenarios:

The system makes it possible to calculate scenarios of land use changes, hydro-climatic variations and demand changes. For the land use changes, as shown in Figure 3, it is possible to change the percentage of areas in the Land Use and make the new calculus of Water Balance. For changes in demand, the system allows percentage variations of each of the sectors of consumption, and likewise for hydro-climatic variations, percentage changes are possible on the current conditions at the monthly, so that the result can be obtained Water Balance with the changes.

Conclusion

As result the Water Balance is obtained of any river basin of the country, in any period of time from 1970 to the present year, and projected water balances are obtained to year 2050, with scenarios of land use changes, water demand changes and climatic variability. Also the Index of Shortage of each river basin is obtained, which make possible assess the state of water consumption in relation to the existing supply.

The system appears like a tool of diagnosis of the current water resources and future possible scenarios, which allows to analyze, protection and regulation policies and management of the resource.