Technical Report No. X

PRELIMINARY WATER ASSESSMENT REPORTS OF THE TEST BASINS OF THE WATCH PROJECT

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WATCH is an Integrated Project Funded by the European Commission under the Sixth Framework Programme, Global Change and Ecosystems Thematic Priority Area (contract number: 036946). The WACH project started 01/02/2007 and will continue for 4 years.

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1. Introduction

Most of the analyses within the Watch project focus on the global and continental scale. To test what the value of these global result is at the local level a series of test basins is used within the prolect. The Catchment-level case studies are used to allow for a first-order translation (downscaling) of the WB6 type of water resource vulnerability assessments to scales which are actively managed. These catchments can also serve as a test bed for dissemination activities and facilitate an evaluation of the practical impact of WB6 findings. This report present the initial plans of the case studies how they link to rest of the Watch project and on which water resources they will focus. This report will function as the basis for further discussions on how to improve the integration of the case studies within the project and to develop a more general protocol for each of the case studies.

Currently five catchments are used within the Watch project, they differ in climatic and hydro-geological features and expected climate changes. Also the water resources issues vary over these cases. Agricultural (and domestic) water use is under pressure in the Mediterranean catchments probably aggravating with the expected increase in drought frequency under future climate. The Norwegian catchment provides hydropower services under threat of precipitation increase rather than decrease. The central European catchments are threatened mainly by increased variability, i.e. increased frequencies of extremes in a densely populated environment, and river flow may need additional buffers (reservoirs) to reduce floodrisk and store water for dry periods

2. GLOMMA STUDY BASIN – WB6 RELATED ISSUES

In the EU WATCH project, the Glomma River basin (Eastern Norway) is one of the case study basins, and research performed will contribute to WP6.4: Translating the global water cycle system to basins for water resources applications. The location of the Glomma river basin is shown in Figure 1. The upper Glomma, which is the focal area, is located in the Northeastern part of the basin (Aursunden). Available data and models in the Glomma river basin are listed in Watch Technical report number 4.

Many WATCH partners are doing research in Glomma. Some of the work will be performed within WB6, although most of the work will be performed within WB4. The WATCH partners working in Glomma are:

- University of Oslo, Norway (UiO)
- Norwegian Water Resources and Energy Directorate, Norway (NVE)
- Wageningen University, the Netherlands (WUR)
- Comenius University, Bratislava, Slowakia (UC)

NVE will do most of the work related to WB6, although work performed by other institutes will alse contribute to WP6.4. For the Glomma River basin, WATCH partners will contribute to work block 4 and work package 6.4 by performing hydrologic model simulations with various models and at various scales for current and future climates (and possibly current and future land use for some models), analyze the results with respect to propagation of drought at site, space-time development of droughts, and by looking at the effects of climate changes on snow, and on the hydro power sector. In this report the research plan for the Glomma River basin within WP6.4 is presented, including which models and forcing data to use, and what research results that will be delivered in the WATCH project.

Figure 1: The Glomma river basin, including reservoirs and hydropower plants.

2.1 Models and forcing data

Currently WATCH partners make use of several hydrologic models within the Glomma basin, with different complexity and at different spatial scales. There is already considerably research effort put into the topic “hydrologic effects of climate changes” (NVE), and within the WATCH project models and results that are also relevant to other projects will be used. In addition, model simulations specifically for the WATCH project will be performed, and a reservoir model will be developed. Table 2.1 lists relevant meteorological data that will be used as forcing data in the hydrological models (Table 2.2), and in Table 2.3 the reservoir models are listed. Figures 2.2 and 2.3 show the location of the sub-basins mentioned in Tables 2.2 and 2.3.

Table 2.1: Available meteorological data relevant to the WATCH project

	“Observed”	Climate A	Climate B – Transient run	Climate C	Climate D	Climate E
Scale	1x1km^2	1x1km^2	1x1km^2	~10 km	24 km	0.5 degrees
Area	Norway	Norway	Norway	Europe	Global?	Global
Time step	Daily	Daily	Daily	Sub-daily	Sub-daily	Sub-daily
Time period	01.09.1961-31.12.2007	2071-2100 (control period: 1961-1990)	1979-2049	2070-2100 (control period: 1960-1990)	?	?
Variables included	Mean daily precipitation and temperature. Max/min temperature?	Mean daily precipitation and temperature. Max/min temperature?	Mean daily precipitation and temperature. Max/min temperature?		?	?
Scenarios		Hadley A2 and B2, Echam B2 Hirham regional climate model (met.no version) Further downscaled to point/grid(1x1)	IS92A from Max Planck Hirham regional climate model (met.no version) Further downscaled to point/grid(1x1)	Hirham regional climate model, A2 scenario, HadAM3H boundary conditions	?	?
Available when?	Now	Nov 2008?	Nov 2008?	Early 2008?	?	?
Producer	met.no	met.no	met.no	WATCH	WATCH (Ensembles)	WATCH (Ensembles)

Table 2.2: Hydrologic models and simulations planned at NVE

	Coup	HBV	Distributed HBV	VIC
Scale	Point	Lumped	1x1 km^2	10 x 10 km, (24 x 24 km,) and 0.5 degrees
Area	5 locations[1]	14 sub-basins (45 to 15,000 km^2)[2] + Glomma river basin	Norway	Norway +
Time step	Daily	Daily	Daily	Daily
Time periods	1961-1990, 2020-2049, 2071-2100	1961-1990, 2020-2049, 2071-2100	1961-1990, 2020-2049, 2071-2100	1961-1990, 2071-2100
Input data	Climate A, Climate B (need also global radiation, relative humidity, wind speed)	Climate A, Climate B Others if available at appropriate spatial scale	Climate A, Climate B	Climate A (if max/min temp) aggregated to 10 km, Climate C, (Climate D), Climate E
Link to other projects	302HV10 Verktøypr EACC	Celect	EBL	302H06 Watch WP6.1
Person responsible at NVE	Hervé Colleuille	Deborah Lawrence	Stein Beldring	Ingjerd Haddeland

1: Nordmoen (Gardermoen), Kise (Mjøsa), Kvarstadseter (Åstadalen), Vinstra (Øyangen), Abrahamsvoll (Aursunden).
2: 14 catchments are already calibrated: Narsjø, Knappom, Akslen, Kråkfoss, Aulestad, Tora, Atnasjø, Fura, Rosten, Lena, Elverum, Losna, Unsetåa, and Aursunden. In addition, a model for Solbergfoss (total Glomma basin) will be calibrated.

Table 2.3: Reservoir models and simulations planned at NVE

	Reservoir model[1]	VAV model	"Samkjøringsmodellen"
Scale	Point	Point	
Area	Aursunden (Upper Glomma) +?	Aursunden (Upper Glomma)	Norway
Time step	Daily	Daily?	Daily
Time periods	1961-1990, 2020-2049, 2071-2100	1961-1990, 2020-2049, 2071-2100	1961-1990, 2020-2049, 2071-2100
Input data	Streamflow simulations from HBV, Distributed HBV and VIC	Streamflow simulations from Distributed HBV	Streamflow simulations from 84 HBV models across Norway
Link to other projects		VAV	Celect

1: Mike 11, under development

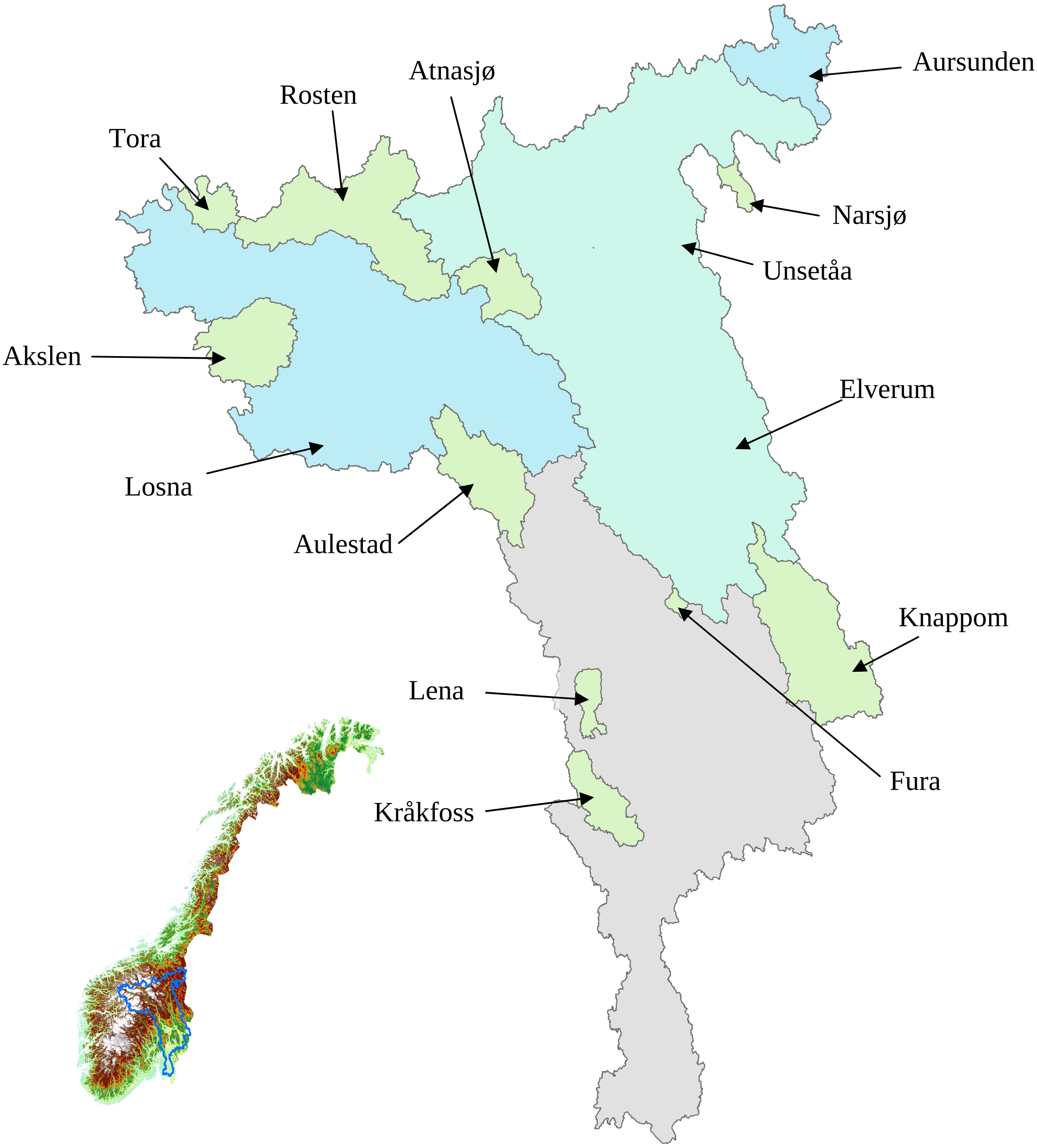

Figure 2.2: The location of the Glomma River basin (left), and the location of lumped HBV models in the Glomma River basin (right).

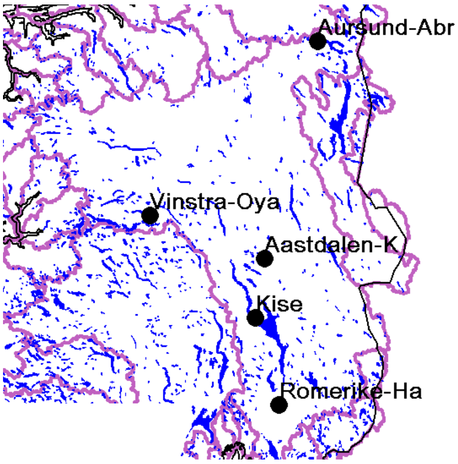

Figure 2.3: Location of available COUP models in the Glomma River Basin.

2.2 Research plan

Hydrologic simulations will be performed according to the plan listed in Table 2.2. The results will be analyzed with regards to droughts and snow. Model simulations will be performed at several points, and for various smaller catchments, within the Glomma River basin. In addition, distributed models will cover the entire Glomma River basin. This will give us the opportunity of studying the effects of climate changes in areas with similar climate, but different soil and catchment characteristics at the point scale and the catchment scale.

The link between the local (1x1 km^2) and regional (~10 km) /global (0.5 degrees) scales will be ensured by performing hydrologic model simulations at various scales, and by using one forcing data set that will be consistent at the local and regional scale. We assume that the forcing data supplied by the WATCH consortium will be consistent at the regional and global scales. The research plan is presented in more detail below.

Translating the global water cycle system to basins for water resources applications (WB6)

- Possible impacts of climate change on hydropower will be studied for reservoirs within the Glomma basin. The work will start at the relatively uncomplicated Aursunden reservoir (Upper Glomma).
- Simulation results from the Distributed HBV model, the VIC model, and/or the HBV model will be used as input to the reservoir model.
- Based on the results, impact of climate change on hydropower production and spill will be determined.
- Alternative operating rules for future climate scenarios will be investigated.
- Within the Celect project, “Samkjøringsmodellen” will be run for current and future scenarios. This model simulates hydro power production in the entire country (Norway), and the results from the Celect project should also be of interest to the Watch project.

Other water resources issues (WB6)

- Effects of climate change on snow and possibly vegetation will be studied using simulation results from the HBV model, the Distributed HBV model, and the VIC model.

Possible WB6 papers to be written (see also report to WB4).

- Effects of climate changes on the hydropower sector in Glomma, including the need for and effects of changing the operating rules. Lead: NVE
- Effects of climate changes on snow at various scales. Glomma, Norway, Scandinavia. Lead: NVE

3. The Upper Guadiana basin case.

The upper Guadiana basin is part of the Central Spanish Plateau, and covers an area of approximately 16000 km2. Morphologically, the main part of the basin is characterized by a smooth topography, with altitudes ranging 550-700 m.a.s.l. Nevertheless, the northern and southern boundaries (Sierra de Altomira and Campos de Montiel respectively) show a mountainous landscape with altitudes above 1000 m.a.s.l.

The basin has a typical continental, semi-arid, Mediterranean climate. The precipitation shows a marked temporal and spatial variability hardly above 400mm/yr while the potential evapotranspiration exceeds 800mm/yr.. Focussing on rainfall's specific contribution to runoff, it can be considered the driest river basin in Spain, with an average runoff lower than 30 mm/yr.

In the upper Guadiana basin some 66% of the domain is underlain by porous aquifers. These are connected with the rivers and wetlands in a complex way. Five major aquifer systems can be distinguished in the Upper Guadiana basin, been La Mancha Occidental the most important one (Figure 3.1).

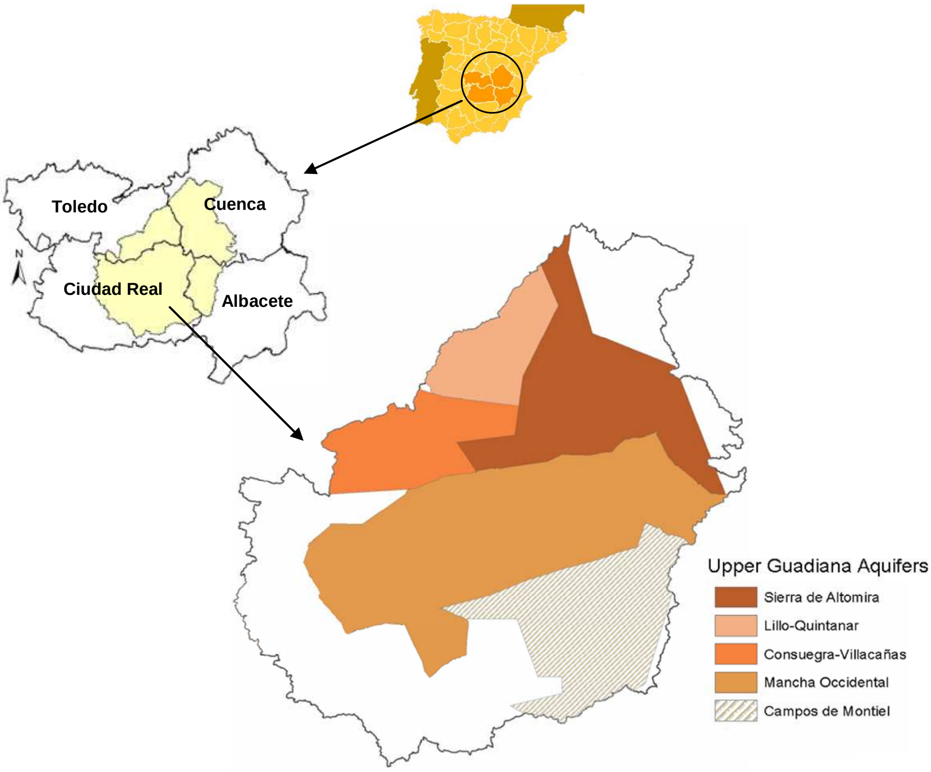

Figure 3.1: Geographical situation of the Upper Guadiana Basin, and location of their major aquifer Systems.

Until the 1960s, the basin was a typical rural and the economy was based mainly on dryland farming of cereal and vineyards and traditional small scale irrigation. After the 1960s irrigated cropping systems were implemented. Abstractions became a six fold larger than in the past. As a result, the groundwater levels dropped significantly and most of the wetlands in the La Mancha Occidental region were affected and some disappeared completely (e.g. the Tablas de Daimiel National Park (UNESCO, Biosphere Reserve). In response, the Spanish administration took action, involving decreasing abstractions and the promotion of crops that consume less water. In order to preserve Las Tablas de Daimiel, water was imported (water transfer) from another catchment (Tagus Basin) to the Guadiana. The wetter period after 1995 and the reduced abstractions induced some recovery of groundwater levels.

The expansion of irrigation resulted in significant economic and social progress in the region. Farmer income increased and important industrial activities related to agriculture were developed. In the region it is crucial to find a proper balance between economy (irrigated agricultural) and ecology (conservation and restoration of wetlands and springs), which considers climate change, and its impact over the whole basin from a hydrologic perspective.

Watch will assess the effects of the global water cycle changes driven by the so called “climate change” on the hydrologic resources given the complicated hydro-socio-economical framework. Figure 2 shows the methodology to be used in order to link with Watch (i.e. data, model, scaling issues, etc).

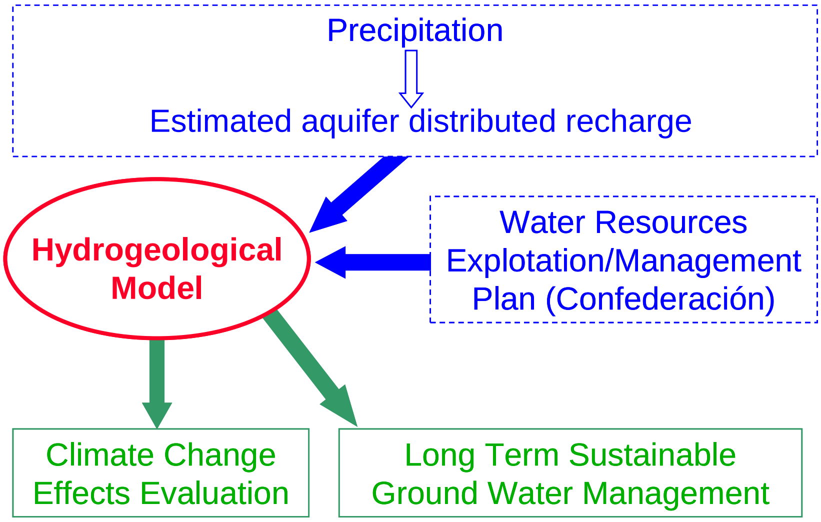

Figure 3.2: Flow diagram for assessing the changes driven by the climate change in the groundwater resources. Blue dashed lines are input data for the Hydrogeological model, and green solid lines are output data.

A numerical model of the Upper Guadiana aquifer system is already available. Data from RCM's will be used as the primary information source to evaluate the future aquifer recharge. Aquifer recharge will be computed through an atmosphere-soil water balance, paying special attention to the role of daily precipitation. Raw precipitation data from RCM's cannot be used directly because cell sizes of RCMs are typically larger than the hydrologic models used for the upper Guadiana basin. In this sense, the first problem to solve is the downscaling of rainfall data from RCM's scale to hydrological model scale.

To obtain downscaled precipitation rain fields a numerical code will be developed. This numerical tool will perform statistical downscaling by mean of sequential Gaussian simulation, conditioned upon both point (from meteorological stations) and areal averaged (from RCM's) data. The term 'statistical' refers to the use of a statistical model for this purpose. The downscaled precipitation fields will be consistent with the observations (i.e. the spatial correlation of the daily precipitation values measured in the meteorological stations in the hydrological basin) and also with the precipitation valued computed by the RCM's.

Once the precipitation field is downscaled, the following step is to compute aquifer recharge from precipitation. To do this will solve the atmospheric-soil water balance in every cell of the hydrologic model. To compute the water balance a prior estimation of potential evapotranspiration is needed. Potential evapotranspiration will be computed by using the Penman-Monteith method. This method needs daily precipitation values as input, but also a number of different daily atmospheric variables such as mean temperature, mean pressure, mean wind speed, etc. These variables are provided by the RCM as well. We will code a specific program to calculate the distributed recharge for the whole domain. To do this we will take advantage of the powerful Object Oriented (OO) programming techniques to define a new class of object to be "connected" to a more general hydrologic OO code for simulating hydrogeologic processes (i.e. single/multiphase flow and reactive transport) in aquifers. This module will compute daily recharge.

Finally, the numerical model of the aquifer will assess the effects of the global water cycle changes driven by the so called "climate change". Taken into account these changes the "Hydrologic

Confederation" (i.e. management entity in charge of the inspection and supervision of the water supply and management throughout the basin) will be able to design "long term ground water exploitation/management plans" from a sustainable the point of view.

4. Nitra River test basin

Nitra River basin covers an area of 4501.1 km2. It is located in the western part of the central Slovakia, with the co-ordinates between 47°30' – 49°00' of the N latitude and 17°30' – 19°00' of the W longitude.

Figure 4.1 Nitra River Basin location

The highest point of the river basin is Vtacnik with the 1346 m a.s.l.; the lowest point has an altitude of 108 m a.s.l. at the mouth to Vah River. The mean altitude of the catchment is 326 m a.s.l., the longitudinal slope is 4 ‰.Spatial and vertical relief dissection is very variable in different parts of the catchment, the highest is in the mountainous part of the catchment, the lowest is in the most downstream part. The relief features can be divided into plains covering 663.2 km2, lowland hill lands with 1713.7 km2, uplands of 470.7 km2, highlands of 470.6 km2, basin hill lands with 330.0 km2, undulated plains with 310.0 km2, pediment piedmonts and hill lands with 213.9 km2, plain-fork relief with 154.1 km2, relief of erosion furrows with 71.8 km2, relief of non-karst plains with 55.4 km2, sub-alpine relief covers 32.2 km2 and relief of karst plains with 15.2 km2.

Basic climatic characteristics are put in Table 4.1 for temperature data and Table 4.2 for precipitation data.

Table 4.1 Long-term average temperature data for the period 1951 – 1980 in degrees of Celsius

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year
Prievidza 260 m a.s.l.	-2.4	-0.3	3.4	8.7	13.5	17.1	18.2	17.7	13.8	9.0	4.2	-0.2	8.6
Nitra 135 m a.s.l.	-1.7	0.5	4.7	10.1	14.8	18.3	19.7	19.2	15.4	10.1	4.9	0.5	9.7
Hurbanovo 115 m a.sl.	-1.5	0.7	5.0	10.5	15.2	18.8	20.1	19.4	15.3	10.0	5.0	0.8	9.9

Table 4.2 Long-term average precipitation data for the period 1951-1980 in mm

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Year
Prievidza 260 m	36	38	36	46	58	88	87	74	51	46	56	55	672

a.s.l.													
Nitra 135 m a.s.l.	31	32	33	43	55	70	64	58	37	41	54	43	561
Hurbanovo 115 m a.sl.	33	34	29	41	52	69	61	52	41	38	54	42	547

Figure 2.2 shows the average ratio of evapotranspiration (76 %) and total runoff (24 %) on the precipitation amount for the long-term period of 1961 – 1990. In the 2006, the amount of precipitation P was 660 mm, runoff R reached 172 mm and the evapotranspiration ETP made 488 mm. The ratio of ETP/R was 73.94/26.06.

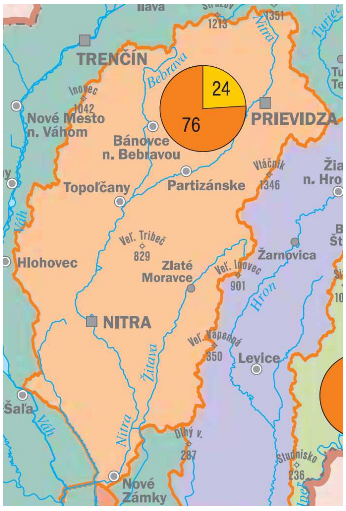

Figure 4.2 Ratio of evapotranspiration and total runoff on precipitation amount

Three hydrological models were selected for estimation of basic relationships of hydrological balance elements in the whole basin and in the focal area which is closed by Chalmova profile (see Figure 1). All of them work in a daily step. Two of them are lumped models – WatBal and Bilan, the third one – FRIER is a spatially distributed gridded model. Some results of the FRIER model concerning the spatial distribution of precipitation and potential evapotranspiration in the focal area are showed in Figure 4.3 and 4.5.

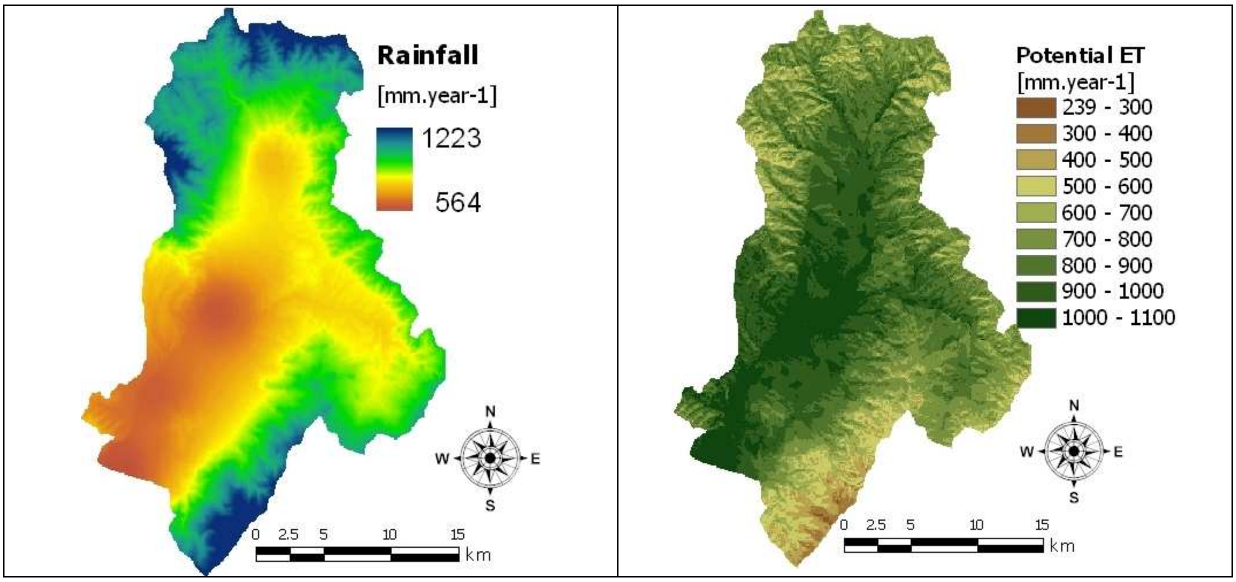

Figure 4.3 Spatial distribution of the precipitation in mm	Figure 4.4 Spatial distribution of the potential evapotranspiration in mm

Data on precipitation from 59 stations, temperature from 7 stations, relative humidity and cloudiness from 7 stations and discharges from 26 stations were stored in the database and used for model runs.

WatBal model was applied on three discharge gauging profiles: Nitra-Nove Zamky (whole river basin closing profile), Nitra-Chalmova – closing profile of the focal area and Nitra Nedozery (profile in the part of the focal area where stream-flow discharges are not affected by human activities, located above the Chalmova profile. Results showed that the model accuracy was highest in the case of the whole basin area modelling, as it can be seen from the double-mass curve course in Figure 4.5. FRIER and BILAN models were run for the Chalmova gauging profile.

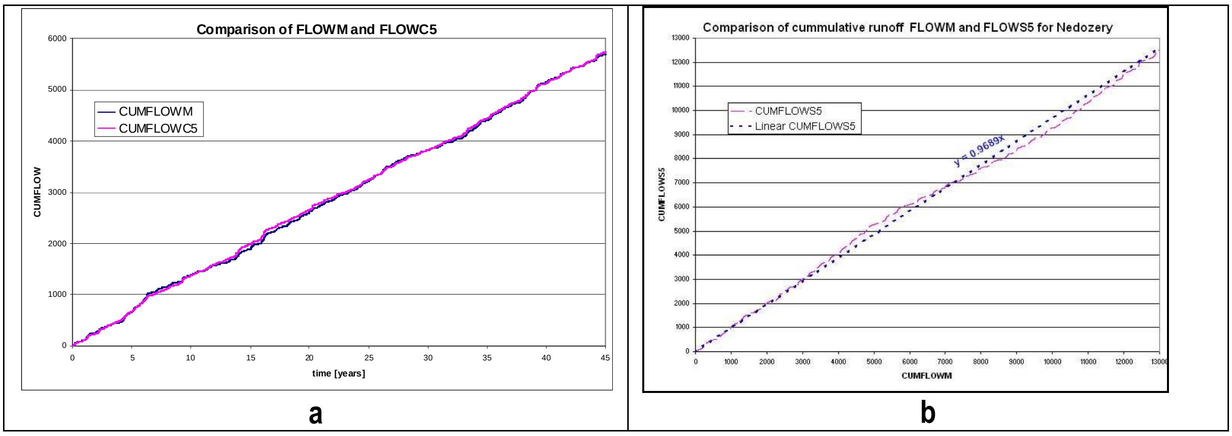

Figure 4.5 Double-mass curve for the simulated and observed discharge at Nove Zamky closing profile (a) and Nedozery profile (b)

Water resources balance is being calculated for 13 profiles in the whole river basin (left-hand tributary Handlovka in Handlova city, Handlovka mouth to Nitra River, Nitra above Novaky city, Chalmova profile, right-hand tributary Nitrica below the Nitrianske Rudno water reservoir, Nitrica mouth to Nitra River, Nitra below the Nitrica mouth, right-hand tributary Bebrava mouth to Nitra River, Nitra at Nitrianska Streda profile, Nitra above the Mala Nitra, tributary left-hand tributary Zitava at Vieska nad Zitavou profile, Zitava at Dolny Ohaj profile, Zitava at transfer to Stara Zitava, Nitra at Nove Zamky profile – closing profile).

The latest available results on the water resources balance concerning abstractions of the surface (SWA) and groundwater (GWA) and discharging into the surface streams (SSD) for the Chalmova profile (focal area closing profile) and Nove Zamky (whole river basin closing profile) are given in Table 4.3. Table includes also minimal discharge values necessary for stream-flow ecological balance (MQ), influenced discharge (ID), influence of water reservoirs (IWR), influence of water transfer (IWT) and balance stage (BS). The balance stage could be active (A) which means that the natural resources are higher than needs, strained (B) meaning that the value of natural water resources is close to needs(± 10 %) and passive (C), where value of natural resources is lower than needs.

Talbe 4.3 Water management parameters in the Nitra River Basin in 2006 (expressed in $m^3.s^{-1}$)

Profile/Parameter	SWA	GWA	SSD	MQ	ID	IWR	IWT	BS
Chalmova	0.001	0.164	0.670	0.530	5.984	0.000	0.000	22.0 A
Nove Zamky	0.379	0.813	1.588	2.022	24.208	0.002	-0.079	14.7 A

The results show that in 2006, which was a normal year according to ratio of the yearly amount of precipitation on the long-term yearly precipitation average (95 %), the water management balance stage was active (A) in all months and profiles except the month of October in Nitrica profile below Nitrianske Rudno water reservoir, where the balance stage was passive. Total abstractions in the catchment decreased in 0.9 % (from 1.203 $m^3.s^{-1}$ to 1.192 $m^3.s^{-1}$) in comparison with 2005. Surface water abstractions for irrigation increased in 18.2 % (from 0.011 $m^3.s^{-1}$ to 0.013 $m^3.s^{-1}$).

Method of intercomparison of natural resources and needs will be used for linking the WB4 results (hydrological drought modelling studies in the Nitra River Basin) with the WB6 (water resources assessment under different climate change scenarios) conclusions.

5. for the Upper-Elbe basin

Selected basins and data availability

The Upper-Elbe basin (51 394 km^2) is that part of the Elbe River basin which is located within the Annual precipitation in this basin varies from 450 to 1700 mm with an average value of about 660 mm. The mean annual runoff is 290 mm. The runoff regime is influenced by water reservoirs with total storage capacity 250 mil.m^3.

Time-series of spatially averaged precipitation, temperature and relative air humidity are available in monthly time step for the period 1931–2001. Runoff data (from the period 1931–2001) were corrected to exclude effect of reservoir management. Digital elevation model and land cover maps are also available.

Two small sub-basins with contrasting geological conditions were selected for detailed analyses – Metuje River basin located in the north-east part of the Upper-Elbe basin and the Sázava River basin in the eastern part of the Upper-Elbe basin.

The Metuje River basin (74 km^2) is characterized by relatively slow hydrological response because of cretaceous bedrock with high storage of groundwater and its deep circulation. Data of precipitation, temperature and air humidity are available for period 1980–2007, the other meteorological variables are available since 1999. Runoff measured in several gauging profiles, groundwater levels in boreholes and information on groundwater abstraction are also provided.

The Sázava River basin (131 km^2) is example of crystalline catchment with poor hydrogeological conditions and relatively fast hydrological response, opposite to the previous basin. Data of precipitation, temperature, relative air humidity, snow cover and runoff are available from 1961 to 2006.

The methodology and applied models

The aim of studies for Upper-Elbe and its selected subcatchments is to simulate and analyze space-time development of droughts and impact on water resources. This is carried out for current state and for conditions affected by climate change (alternatively for conditions given by land use change). The quantification of uncertainty to the hydrological extremes and water resources availability will be also included.

It is possible to use different sources of climate change scenarios based on results of regional climate models (from the PRUDENCE project, ENSEMBLES project or Work Block 3 of the WATCH project). The climate change impact will be assessed by using results of different regional climate models or emission scenarios. For lumped modelling purposes the scenarios will be spatially and time averaged for given basin.

Three types of hydrological models will be applied for calculation of water balance and for estimation of climate change impact on hydrological processes for the Upper-Elbe Basin or two focal sub-basins. The Bilan model, lumped conceptual water balance model (for the Upper-Elbe and sub-basins), the FRIER model, physically based distributed model, and the semi-distributed version of HBV model (for the two focal sub-basins). Preliminary results show that runoff could decrease up to 60% due to climate change and consequently water supply reliability will decrease significantly. Time-series of simulated variables will be described in terms of frequency and severity indexes of extreme events.

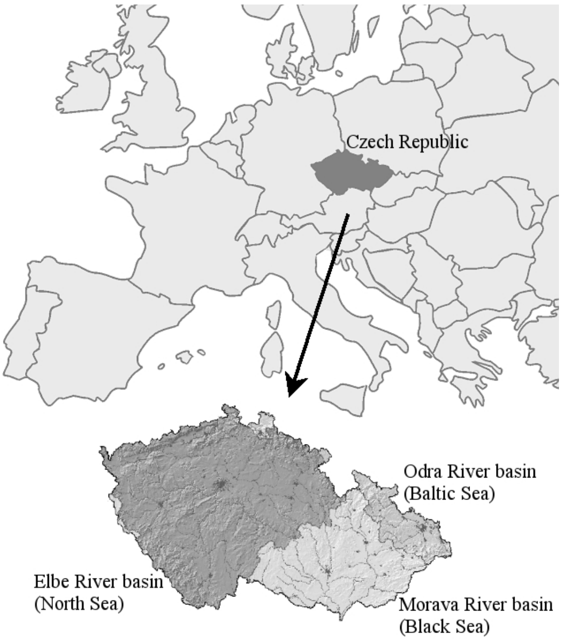

Figure 5.1 Map showing location of the Elbe River basin

It will be useful to link Upper-Elbe data with larger scale hydrological models and consequently to compare resulting hydrological time-series of these models with results of basin-scale modelling.

The estimation of climate change impact will be focused especially on surface water resources. Availability of groundwater resources is supposed to be assessed for the Metuje River basin, analyzing base flow which is computed by water balance models and simulated by groundwater flow model, which requires simulated groundwater recharge as input.

Human impacts of the Upper-Elbe basin will be estimated from point of view of water reservoirs and its capability to ensure water supply requirements and environmental minimum flows. A simple water management model will be applied for these purposes. This will be combined with studying of the influence of reservoir management on flood events. These analyses will be also carried out for observed state of climate and for climate change conditions, including specification of changes in water supply reliability due to changed climate and efficiency of possible adapting measures.

6. Crete Island

During the process of framing of the Case Study over the Crete test site and in relation with M6.4-1, communication and meetings between TUC and the local water authority (the Water Resources Management authority of Crete) had to take place. Various water management issues where set on the table, regarding actions up to the present as well as perspectives for policy and management until 2030. These future scenarios scale from the augmentation of agricultural practices, improvement and extension of the already available irrigation network to tourism and population trends and demand. This way, the key points that have to be studied in the context of WATCH project were defined.

- Regarding WB1, a preliminary assessment of the first reanalysis outputs was conducted. Specifically, reanalysis data of gridded observed hydro-meteorological datasets for the 20th century from ERA40 and ECHAM5 models was compared to actual interpolated and gridded observations. A precipitation analysis for Messara Valley test case was performed in order to examine future trends compared to the past climate. The outputs will be presented in the Bratislava meeting. Moreover, the preliminary assessment report and development of alternative scenarios for the Crete basin were completed This report will includes the assessment of water practices of the local water managing authority as well as the current status and the future plans for water use (demand and supply).

- Regarding WB4 (extremes), a map of 100-year return-period of daily precipitation across the island of Crete was constructed. This map was based on 30-year long precipitation time series from about 53 raingauges distributed over the whole island. Moreover, the spatial and temporal patterns of drought for the last 3 decades over the island were examined using the SPI (Standardized Precipitation Index).

- Finally, downscaling techniques were investigated regarding water resources application issues on watershed scale studies. One possible area for applying these downscaling techniques is the well defined case of Messara Valley, where intense agricultural activities take place.

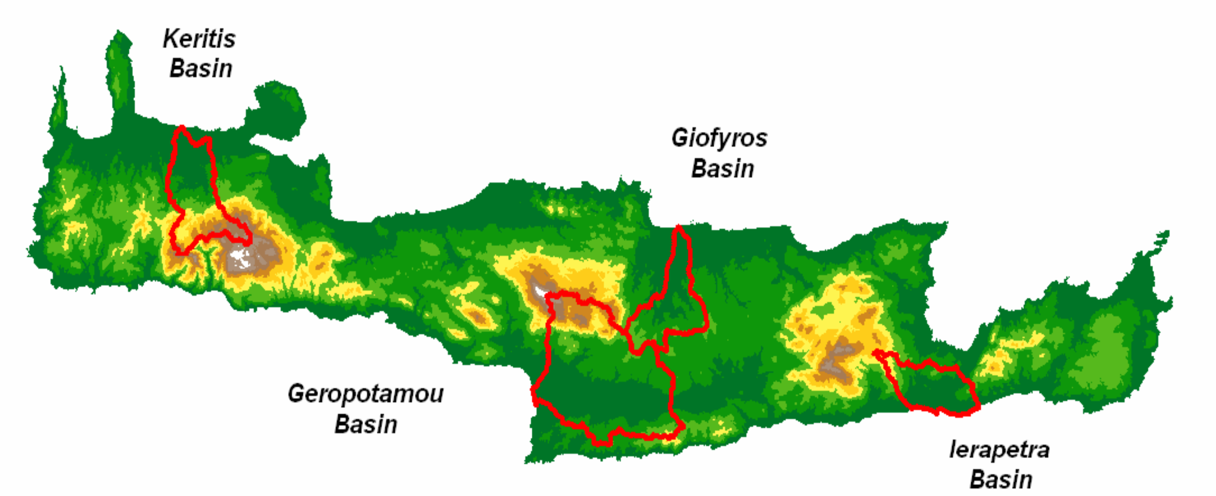

Figure 6.1.Catchment locations on Crete

6.1 Future plans

In order to facilitate a better understanding of the impacts of climate change in the island of Crete, the problem of water resources management and extreme events (floods and droughts) is approached is multiple scales. Therefore, downscaling techniques are applied apart from the test case of Crete in smaller watershed like the over-exploited in terms of water pumping and irrigation Messara Valley. Future plans:

- Preliminary assessment of water status for the last decades of the 20th century. The results of the reanalysis of the forcing climate scenarios will be compared with measured values (e.g. precipitation) in order to examine the validity of WB1 results.
- It is crucial to short out the available RCM datasets covering Crete Island. Further analysis will be based on these data.
- The WATERGAP model in the frame of "WP6.4 Translating the global water cycle system to basins for water resources applications" will be used for estimation of water availability under the current conditions and future including climate change conditions.
- Examine drought and flood patterns of present and future conditions over the island of Crete. Also, examine the statistical properties of the occurrence of extreme events (e.g. for droughts using indices like SPI and Palmer) because are important for the water resources management.
- Maximum precipitation patterns and seasonality of extreme rainfall over Crete will be analyzed for the past and future climate, in order to examine future variations.
- The same analysis could be carried out in a finer scale for the test basin of Messara valley.
- Examine downscaling issues of climatic scenario projections and perspective of water management at small basin scale (e.g. Messara Valley)

The above actions are dependent on the data from the other Work Packages.

7. Conclusions.

All study basin of the Watch projects have decided on the focus of the water resources assessment and how they will study the impacts of climate change. However, the methods used within the basins, differ considerably. Different models are used, different climate scenarios of often different scales. The links with other parts of the Watch could also be improved. There is the need to develop a more general protocol on how the case studies could use and testt some of the regional and global data sets developed within the watch project. These issues will be discussed during a workshop in early 2009.