Consulting Services for

SUPPORT TO WATER RESOURCES MANAGEMENT IN THE DRINA RIVER BASIN

PROJECT ID NO. 1099991

DRINA WATER MANAGEMENT MODEL IN WEAP

June 2017

WORLD BANK GROUP
Water

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Table of Contents

List of Figures

List of Tables

1 Introduction

This report provides a description of the development of a water management model for the Drina River Basin (DRB) that is one of the main deliverables of the “Support to Water Resources Management in the Drina River Basin” project.

The overarching objective of the project is to support more effective water resources management in DRB taking into consideration sustainable water use, flood mitigation and environmental management, while involving stakeholder consultations to ensure adequate public participation. This approach is meant to support water management authorities in preparation of investment plans and the river basin management plans.

Meeting the objective of integrated river basin management and strategic planning involves applying modern technology and scenario simulation tools. Development of a water management model is one of the key steps in reaching the above objectives for DRB. The model serves in considering different water management options over a range of development and climate scenarios in DRB. It also enables stakeholders to make adequate plans and be better prepared for future decisions.

This report describes work done on data collection and water management model development, and also presents the results of simulations with different development scenarios and future climate scenarios. It builds on other reports within the project: Inception Report, Integrated Water Resources Management (IWRM) Study and Plan – Background Paper, and Investment Prioritisation Framework (IPF) Report.

1.1 Brief description of the Drina River Basin

The Drina River Basin (DRB) has an area of 19,680 km^2, the largest part of which spreads over territory within three riparian states: Bosnia and Herzegovina (BiH), Montenegro (MNE) and Serbia (SRB); see Figure 1-1 and Table 1-1. In addition, Albania accounts for a very small part of the DRB (<1%) and is not within the scope of this project. The Drina River is the largest tributary of the Sava River, which in turn is the largest tributary by volume of water of the Danube River.

Figure 1-1: Extent of the Drina River Basin. Source [1].

Table 1-1: Subdivision of the Drina River Basin.

Riparian state	Area (km^2)	Portion of DRB	Portion of state territory	Basin population
Bosnia and Herzegovina	7,301	37.1%	14.3%	520,000
Republika Srpska	(6,242)	(31.7%)	(25.7%)	(450,000)
Federation of Bosnia and Herzegovina	(840)	(4.2%)	(3.2%)	(70,000)
Montenegro	6,219	31.6%	45.0%	150,000
Serbia	6,002	30.5%	7.7%	300,000
Albania	158	0.8%	0.5%	NA
TOTAL	**19,680**	**100%**		**970,000**

The Drina River originates in Montenegro where it drains a substantial karst mountainous plateau that receives the highest annual rainfall in Europe (about 3000 mm/year), resulting also in the highest specific runoff in Europe (up to 50 L/s/km^2). Two source-rivers of the Drina River, the Tara River and the Piva River, merge at Šćepan Polje along the BiH/Montenegrin border with a combined mean annual discharge of 154 m^3/s. Another source-river is the Lim River, which joins the Drina River at Višegrad with a mean annual discharge of 113 m^3/s. The Drina River reaches the confluence with the Sava River after a length of 346 km and a height difference of 350 m (equivalent to a 1% average slope), with mean annual discharge of about 400 m^3/s.

Almost one million people live within the basin. In Montenegro, an estimated population of 150,000 people are living within the basin arranged into 10 municipalities. In BiH, some 520,000 people are living in 31 municipalities, with 450,000 (86.5%) in 19 municipalities of the RS and 70,000 (13.5%) in 12 municipalities of the FBiH. In Serbia, about 300,000 people live in 15 townships/municipalities situated in the DRB.

The DRB is rich in endowments of natural resources and in development potential. It has significant hydropower generation potential; at present it hosts eight medium to large hydropower plants (HPPs), but an estimated 60% of the potential for hydropower generation remains untapped. The DRB also has a rich biodiversity. The river water is of generally good quality due to its high flow rates and low pollution and abundant in fish. A number of natural parks and protected areas are spread throughout the basin and the landscape is dotted with unique glacial lakes and canyons, among which is the Tara Canyon, a UNESCO World Heritage site.

The main water uses are municipal and industrial water supply, irrigation and hydropower generation. Water abundancy has not created significant water conflicts in the basin in the past. However, the present increasing development desires diverging across the countries and across the economy sectors as well as the increasing pollution and climate change threats call for pursuing an integrated water resources management approach to DRB planning and management.

1.2 Selection of the modelling tool

The Terms of Reference (Appendix 2, Task 4) require development of a simulation model as a tool in assessing impacts of large-scale developments and climate variability on water availability in DRB. The model should enable:

- review of each sector,
- checking the robustness of the system and within each sector,
- simulating future developments (climate variability or other changes in the basin),
- consideration of modifications to planning and infrastructure,
- simulations to support cost analysis and environmental evaluations for major infrastructure considerations.

In the Inception Report, the Consultant has proposed to meet the project objectives by employing the WEAP modelling software by SEI (Water Evaluation and Planning System by Stockholm Environment Institute) to develop the water management model for DRB. The decision to use the WEAP model as the modelling platform has been made for two reasons. First, the WEAP software is free for use by governmental institutions in developing countries, a category to which the Drina riparian countries belong.[1] Second, the WEAP software allows building water management models of different complexity, depending primarily on the available information. In case of general poor data availability in the Drina basin, WEAP has an advantage of offering a possibility to build a water management model with low data requirements.

Within this project, the WEAP software is used to develop only the water management part of the model. The hydrologic response from the basin can also be modelled in WEAP, but it requires a considerable amount of input data. Therefore, in this project the hydrologic response is provided as an input to WEAP and is simulated by a separate hydrologic model developed by JCI (the model is described in the IWRM country reports [3]; herein: the JCI hydrologic model). Such a coupling of models was indicated in the Inception Report and was motivated by the existence of a readily available hydrologic model for DRB.

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[1] SEI defines developing countires as those countries that are not on the World Bank's list of high-income countries (https://en.wikipedia.org/wiki/World_Bank_high-income_economy).

2 Brief overview of WEAP

2.1 WEAP software

The WEAP model operates on the basic principle of water balance accounting [2]. It is applicable to both single sub-basin and complex river systems. It uses an integrated approach to simulate water systems by taking into account both the water supply and the demand side of the water balance equation, and it enables examining alternative water development and management strategies. On the demand side, WEAP considers water use patterns, hydropower energy demand, equipment efficiency, allocation priorities, etc. On the supply side it considers streamflow, groundwater, reservoirs and water transfer. WEAP can also address water conservation, water rights, reservoir operation, ecosystem requirements, and the project cost-benefit analysis [2].

The water management model for DRB is developed in WEAP 2016.01 software version. WEAP software documentation includes a detailed User Guide and Tutorial. The software installation and documentation can be downloaded from the WEAP web site.[2]

2.2 Modelling water resources systems in WEAP

A water resources system in WEAP is called a **study area**. The study area represents the water resources system configuration and its components, and contains data and assumptions about the system. The system consists of linked demands and supplies (rivers, reservoirs, groundwater aquifers, demand nodes, etc.). The same geographic area or watershed under alternative configurations or different sets of demand data or operating assumptions can be represented by several different study areas. The study areas can be thought of as databases where different sets of water supply and demand data are stored, managed and analysed.

The **Current Accounts** represent the definition of the water system as it currently exists and include supply and demand data for the first year of the study. The Current Accounts are also assumed to be the starting year for all scenarios.

Scenarios in WEAP include assumptions on future policies, development and other factors that affect demand and supply. Scenarios can be built and then compared to assess their water requirements and impacts. All scenarios start from a common year for which the Current Accounts data are established. Scenarios in WEAP may include any factor that can change over time, such as factors reflecting different socio-economic assumptions.

Once the system (the study area) is described for Current Accounts and the scenarios are defined over specified time horizons, water balance and allocation is calculated for each system component (river reach, reservoir, aquifer, demand sites etc.). The results enable evaluation of the scenarios with regard to water sufficiency, compatibility with environmental targets, costs and benefits, and sensitivity to uncertainty in key variables.

2.2.1 System description – study area

The water resources system is represented in the WEAP schematic view (Figure 2-1) as a set of the system components. The components consist of the nodes and links between the nodes. They include:

- Rivers
- Diversions

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[2] www.weap21.org

- Reservoirs
- Run-of-river HPPs
- Groundwater sources
- Other supply sources
- Demand sites
- Transmission links (intakes)
- Return flows (discharges)
- Waste water treatment plants
- Flow requirements
- Catchment (hydrologic simulation; not used if flow in rivers is provided)
- Gauging stations (for comparison, where relevant)

The main component of the water resources system is the river and its reaches. A river reach is defined as the section of a river or diversion between two nodes. WEAP refers to a reach by the node above it. The nodes on the river represent reservoirs, run-of-river hydropower plants, starting points of diversions, starting points of transmission links as intake locations, ending points of return flows as the discharge locations, nodes with specified flow requirements etc.

Other nodes of the system that are not located on the river are demand sites (municipal, industrial, agricultural or other water supply) or groundwater aquifer nodes. Demand nodes are connected to the supply sources by transmission links, while the return flow links are used for discharges from the demand sites. Diversions divert water from one river node to another node on the same or on another river. Diversions are also used for derivation-type HPPs to convey water from the river or reservoir to the power plant.

The reservoirs may include dam-type hydropower plants. A run-of-river power plant can be located either on a river or on a diversion. Pumped-storage power plants could be modelled with a transmission link between the reservoirs provided that rules are defined about how much water is transferred and under what conditions.

WEAP allows importing GIS layers in ESRI formats (SHP vector files and ADF raster files) to support visual representation of the water resources system.

Figure 2-1: WEAP schematic representation of the water resources system with main components.

Table 2-1: Main variables reflecting crucial information for water balance assessment in WEAP.

WEAP components		**Variables**
Demand	Municipal water supply	Number of inhabitants, specific water demand, losses within the demand site
	Industrial water supply	Water use rate
	Agricultural water supply	Irrigated area, specific water demand
	Reservoir type HPPs	Energy demand, max. turbine flow, tailwater elevation, generating efficiency
	Derivation type HPPs	Energy demand, max. diverted flow
	Flow requirements	Minimum monthly instream flow required for social or environmental purposes
Supply	River reaches	Water balance for sub-basins between two nodes (surface water and groundwater inflows from sub-basin)
	Reservoirs	Storage capacity, volume-elevation curves
	Groundwater	Natural recharge, storage capacity, maximum withdrawal

Water balance is assessed by taking into account numerous variables related to the demand and supply nodes. Data needed to describe the system are specific to particular components. The most important information and data for calculating water balance and solving water allocation equations is given in Table 2-1.

When calculating water balance, WEAP determines the water allocation order based on two priority systems: demand priorities and supply preferences.

- **Demand priority** is related to the competing demand sites, reservoirs (priority for filling or hydropower) and flow requirements. Priorities can range from 1 to 99, with 1 being the highest priority and 99 the lowest. Demand sites can share the same priority. Default value for the reservoir filling priorities is 99, meaning that they will fill only if water remains after satisfying all other higher priority demands.

- **Supply preferences** are related to a demand site connected to more than one supply source to define the preferred source for the given site. The supply preferences are assigned to corresponding transmission links.

Additionally, there are two methods for specifying hydropower energy demands to prioritize reservoir releases to generate hydropower: as individual energy demands for each reservoir, or as an aggregate energy demand at the system level.

2.2.2 Creating scenarios

The scenarios in WEAP are conceived as story-lines of how a system might evolve over time under particular assumptions about future socio-economic, policy and technology conditions [2]. All scenarios start from a common year, for which the current system configuration and data are established (i.e. the *Current Accounts* year). Scenarios in WEAP may include any factor that can change over time. In addition, different system elements may have different start-up years in different scenarios.

The scenarios include certain assumptions about the changes in the water resources system (change in water use, population growth, hydrology etc.). These assumptions are formalized in WEAP as **Key Assumptions**, where the particular assumed values are assigned to Key Assumption variables. Different scenarios are generally based on different Key Assumptions.

By default, the specified time horizon is assigned to the Reference Scenario. Reference scenario is the one to which other scenarios are compared. The user can create one or more alternative scenarios.

A scenario can be can be nested under another scenario to inherit data and assumptions from the predecessor, meaning that only the parameters that change with the scenarios should be entered for the successor. By default, the Reference scenario is nested under the Current Accounts and inherits all data from the Current Accounts. Alternative user-defined scenarios can be nested directly under Current Accounts or under any other scenario.

2.2.3 Simulations and results

Once the simulation is performed, WEAP offers many ways to explore the results of water resources simulations. The values of all computed variables such as the reservoir storage or elevation, groundwater storage, water supply demand, supply delivered, supply coverage, hydropower generation etc. can be presented as time series or as aggregated values over the chosen time horizon.

3 Drina water resources management model

3.1 General modelling approach

The Drina River Basin water resources management model (hereinafter: Drina WRM model) is a part of the modelling framework that supports consideration of different development options and water management strategies in DRB. The modelling framework consists of the following elements (Figure 3-1):

- Water resources management model
- Basin development scenarios
- Socio-economic scenarios
- Climate scenarios
- Hydrologic model (“HIS Drina”)

Water resources management model is a simulation tool in WEAP software that performs water balance calculations and supports checking and evaluating the robustness of the water resources system. On the supply side, this model uses the results of hydrologic simulations with climate scenarios from the JCI hydrologic model as the information on the natural hydrologic regime. On the demand side, the model uses information on the requirements for municipal, industrial and agricultural water use, environmental flow requirements and energy demand for hydropower facilities. The water resources management model enables simulation of water allocation under various infrastructure configurations and under different future developments (climate variability or other changes in the basin), thus supporting considerations of modifications to planning and management of the system. The model development and implementation for DRB is the subject of this report.

Basin development scenarios represent different sets of system configurations and management options to reflect a range of possible developments in DRB. The scenarios are mainly related to the trade-off between environmental issues and hydropower development. Two opposite scenarios are Green Growth and Hydropower Maximisation. The first one reflects absence of new hydropower facilities and more green energy options (solar, wind). The latter reflects implementation of all planned hydropower facilities in the basin. Several “mid-way” scenarios are also defined between the two opposite scenarios, depending on the country (Table 3-1). The development scenarios are described in Chapter 4 of the IPF country reports [4]. Section 3.5.1 of this report discusses how the development scenarios are implemented in WEAP.

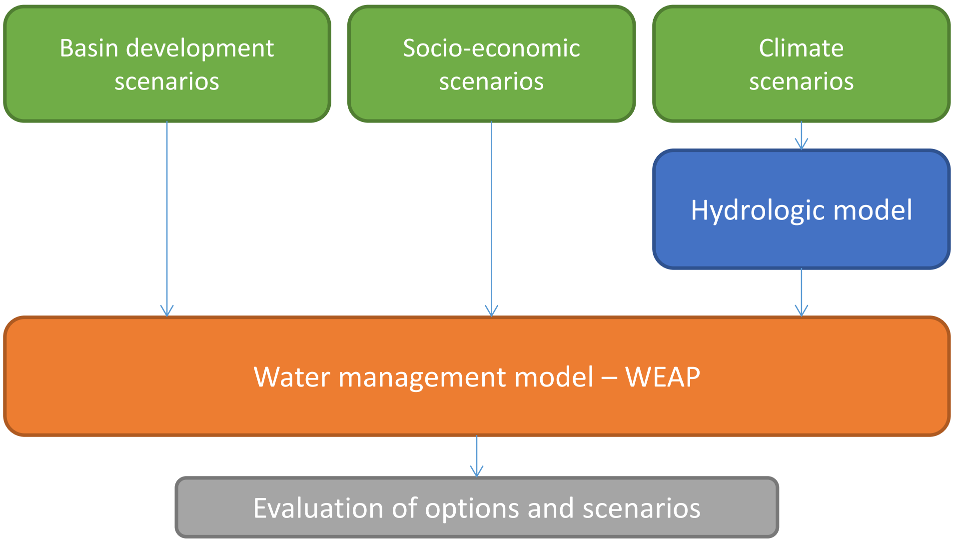

Figure 3-1: Modelling framework for developing the water management model for DRB.

Table 3-1: Development options for DRB (based on Chapter 4 of the IPF country reports [4]).

Montenegro	BiH	Serbia
Green Growth	Green Growth	Green Growth
Follows Energy Development Strategy	Reduced Hydropower per Sava RBMP	Reduced/Optimized Hydropower
	Reduced Hydropower over longer time frame	
Hydropower Maximisation	Hydropower Maximisation	Hydropower Maximisation

Socio-economic scenarios are referred to population growth rate and the growth rates for industrial and agricultural production, which would affect municipal, industrial and agricultural water use in the riparian countries of DRB (see section 3.5.2 for assumed rates).

Climate scenarios are developed within this project with a goal to create plausible climate change tendencies for precipitation and temperature in DRB. The scenarios consist of temperature and precipitation time series simulated with an ensemble of global and regional climate models (GCM/RCM) under two IPCC scenarios, RCP 4.5 and RCP 8.5 (see section 3.5.3). The methodology and the results of climate modelling are described in detail in IWRM country reports [3] and in IPF country reports [4].

The simulated precipitation and temperature series under both climate scenarios are used as the input for **hydrologic simulations** with the JCI hydrologic model in order to create hydrologic projections for the basin. Knowledge on the tendencies in future climate and hydrology and uncertainties in these tendencies enables examining and evaluating the robustness of the Drina water resources system under climatic and hydrologic variability, thus supporting the sustainable water resources management. The hydrologic model is described in IWRM country reports [3] and the results of hydrologic simulations with future climate are described in Section 5.2 of the IPF country reports [4]. Hydrologic simulations with simulated climate resulted in 12 different hydrologic data sets that supported simulations with the Drina WRM model (see Table 3-2 and section 3.5.3).

3.2 Stages in model development

Main stages in developing the Drina WRM model in WEAP were:

1. Study area definition – setting time horizons
2. Definition of the system configuration and input data entry
3. Scenario development
4. Evaluation of results

These steps are explained in the subsequent subsections.

3.3 Time horizons and model versions

In a typical WEAP application, a water resources system model is built for a specific starting year ("Current Accounts") for which the system state is known. The starting year is also the first year of the reference scenario and all other scenarios. In case of the DRB, choice of the starting year and the known system state was driven by the constraints related to available data for climate and hydrologic simulations.

The climate change is assessed in this project for two future 30-year time frames, 2011-2040 and 2041-2070, with 1961-1990 as the baseline (reference) period. The selected future time frames are typical in the climate change impact studies because the climate change impacts can only be evaluated along time spans of reasonable length for reliable statistical analysis. These time frames also cover the planning horizons 2020 and 2050 indicated in the Terms of Reference. On the other hand, the baseline period is chosen having in mind availability of climatological data in the region (huge data gaps in 1990's do not permit selection of a longer baseline period, such as e.g. 1961-2010). Hydrologic simulations were also performed for 1961-1990 and 2010-2070 time frames, but years 1961 and 2010 are not included due to the hydrologic model warm-up.

To include the climate change scenarios and corresponding hydrologic simulations, two Drina WRM models are developed: *baseline model* (1962-1990) and *future model* (2011-2070). The baseline WRM model consists of the Current Accounts (with 1962 as starting year) and the Reference Scenario. The future WRM model comprises the Current Accounts (starting from 2011) and five development scenarios (see Table 3-10 in section 3.5.1). It covers two 30-year periods (2011-2040 and 2041-2070) chosen to assess the climate change impact on the hydrology and water allocation. The results of the baseline model serve to assess the relative change in the future compared to the baseline period.

The time horizons and scenarios in WEAP are summarized in Table 3-2. The models that use hydrologic simulations with climate input from the climate modelling have four versions, each pertaining to a different climate modelling chain (see Table 3-13). The climate model outputs for the baseline period are the same for two climate scenarios RCP 4.5 and RCP 8.5, but are different for the future period. Therefore, there are four versions of the baseline WRM model and 8 versions of the future WRM model.

Monthly time step is selected for water balance computation as the seasonal variations in runoff and demand are important for the system performance.

Table 3-2: Time horizons and management scenarios in two versions of the Drina WRM model in WEAP.

WEAP model version	WEAP scenario	Time horizons	Hydrologic input	No. of model versions
Baseline Drina WRM model	Current Accounts Reference Scenario (Green Growth)	1962 1963-1990	Simulated hydrology with simulated climate	4
Future Drina WRM model	Current Accounts Green Growth Middle 1, Middle 2, Middle 3 Full HPP	2011 2012-2070 2012-2070 2012-2070		4 for RCP 4.5 4 for RCP 8.5

3.4 System configuration and input data

Configuration of the Drina WRM system is too complex to be presented graphically as a whole, but it is nevertheless shown in Figure 3-2. Figure 3-3 and Figure 3-4 present two details of the system (the Piva and Tara Rivers, and the Uvac River, respectively).

Main components of the Drina WRM and data used to define these components are explained in the subsequent subsections. Necessary input data varies from one component to another. The model has been built with the available data gathered within this project and from various documents.

Figure 3-2: Schematic of the Drina River Basin water resources system in WEAP.

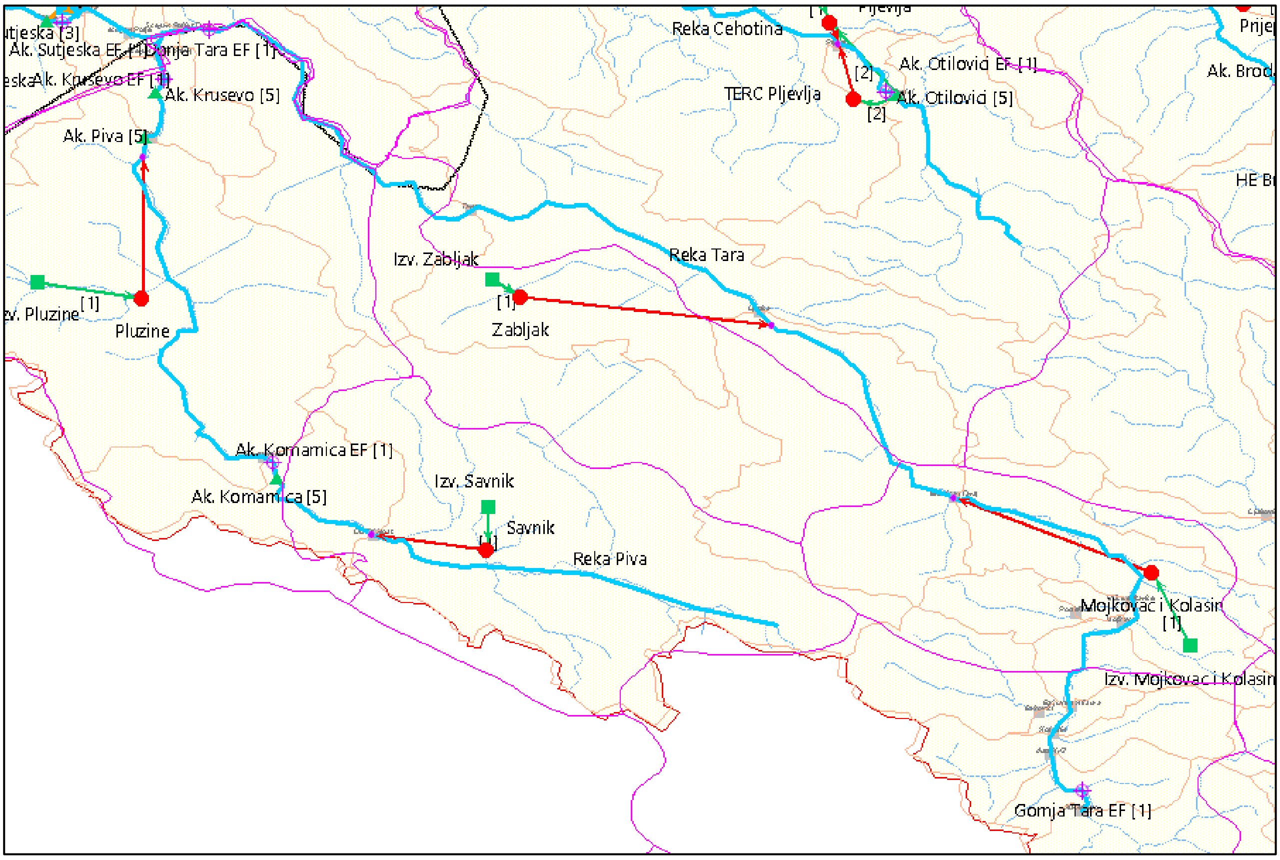

Figure 3-3: Detail of the schematic of the Drina River Basin water resources system in WEAP (Piva and Tara Rivers)

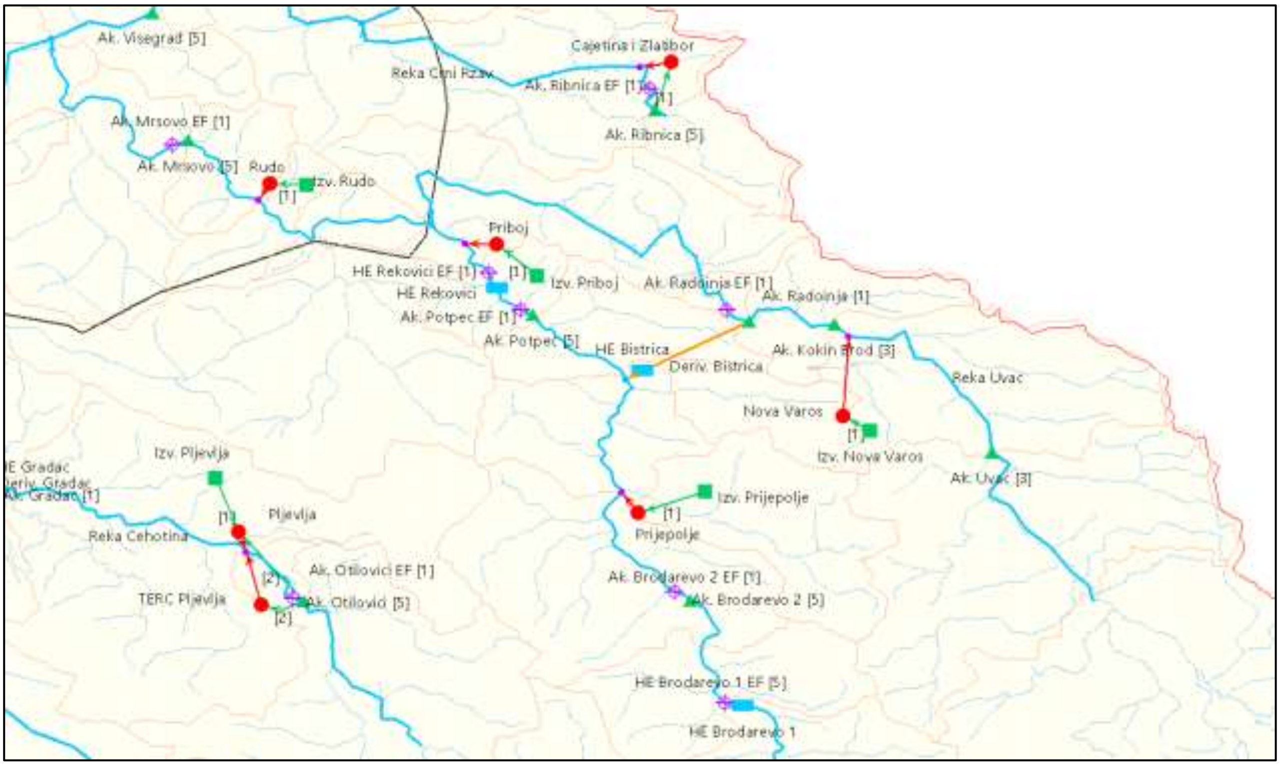

Figure 3-4: Detail of the schematic of the Drina River Basin water resources system in WEAP (Uvac River).

3.4.1 Demand sites

Municipal, industrial and agricultural demand sites are included in the model. General approach was to define one demand site of each type per municipality since information on water use can generally be obtained for the municipalities. In some cases, demand sites are aggregated if they share same source or if they are located within the same sub-basin (as defined in the hydrologic model). The model includes a total of 35 domestic demand sites, 11 industrial demand sites, and 15 agriculture demand sites.

Table 3-3 lists main variables in WEAP related to demand sites, while tables in Appendix B show all input data related to demand sites.

Table 3-3: Main variables in WEAP related to demand sites.

Demand type	WEAP variables	Description and comments
Municipal water supply	Annual Activity Level	Number of inhabitants: population in portion of municipality within DRB or number of people connected to public water supply systems.
	Annual Water Use Rate	Specific water demand (per capita).
	Monthly Variation	Intra-annual distribution of specific demand. Assumed.
	Consumption	% of inflow consumed (lost from the system); it defines return flow as Inflow * (1 – Consumption). Estimated as percentage of population connected to water supply system and using on-site sanitation.
	Loss Rate	Losses within the demand site.
Industrial water supply	Annual Water Use Rate	Industrial water demand for each site.
	Monthly Variation	Not considered (demand throughout a year considered uniform).
	Consumption	Percentage of inflow consumed (lost from the system). Assumed.
Agricultural water supply	Annual Activity Level	Size of the irrigated area. Estimated from Google Earth.
	Annual Water Use Rate	Specific irrigation water demand (volume per unit area).
	Consumption	Assumed to be 100% (no groundwater recharge from irrigated areas).

Domestic water demand for municipalities (listed in Table B-1 in Appendix B) is defined with population connected to water supply systems and specific water demand. Only the population within the DRB is taken into consideration, as presented in sections 7 of the IWRM country reports. Values of the specific demand for each country (and both entities in BiH) are adopted in the IWRM country reports, and are declared as Key Assumption variables (see section 3.4.11). Monthly variation has been assumed and also declared as Key Assumption variable to be applied for all demand sites in all countries. The Consumption variable, which is used to define water lost from the system, is assumed to be 15% according to the values commonly reported in literature and is defined in WEAP as a key assumption. Data on loss rates within the distribution system of a demand site is generally available for municipalities (based on data from public water companies), except for Montenegro where a unique loss rate value was adopted based on information about the general loss rate for the whole country.

Major **industrial water demand** in the basin comes from the thermal power plants, mine excavating and ore processing, cement and alumina factories, as well as wood and food processing factories (Table B-2 in Appendix B). Annual water use rates were estimated from various reports. Industrial demand is considered constant throughout the year (no monthly variation) and the consumption percentage is assumed. The only exception is the industry in the Pljevlja municipality, where detailed specification of water demand was available, including monthly variation (Table B-3 in Appendix B). The parameters of the industrial water demand in Serbia are estimated from information obtained from “JVP Srbijavode” and are given in Table B-4 in Appendix B.

Agriculture water demand is assumed to be the greatest in the lower Drina basin. The agricultural areas in this part of the basin are assigned to the sub-basins downstream of Kozluk in BiH and Serbia (Figure 3-5).

Additionally, two agricultural demand nodes in FBiH near Ustikolina and Goražde are included. Data on agricultural demand nodes are shown in Table B-5 in Appendix B. The extent of the agricultural areas in the lower Drina region is estimated from the satellite imagery (using Google Earth), while the areas of two sites in FBiH is taken from [23]. Irrigation water demand (i.e. annual water use rate) is adopted from strategic documents [5] [6]. Water used for irrigation is assumed to be lost from the system due to high evapotranspiration losses. An alternative approach would be to link the agricultural areas with groundwater aquifers in WEAP and to employ an external groundwater modelling in order to provide proper groundwater balance. However, due to lack of knowledge on groundwater within each sub-basin, this approach would be beyond the available time and resources in this project.

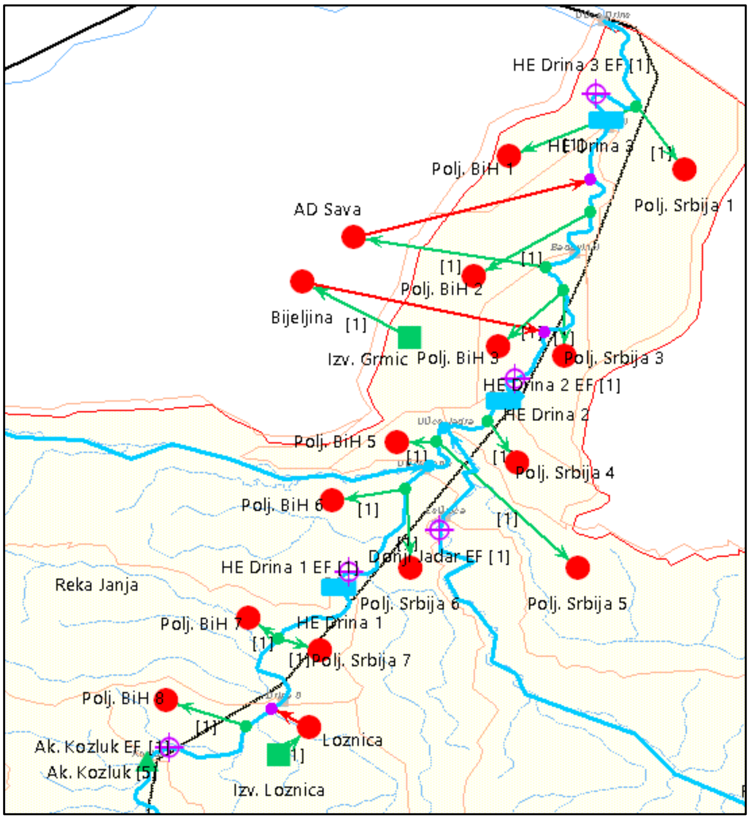

Figure 3-5: Agriculture demand sites in the Drina WRM model.

3.4.2 Rivers

Rivers included in the model are those where the important nodes (reservoirs, links to and from demand sites) are located. Beside the Drina main course, the following rivers are represented in the model: Tara, Komarnica, Piva, Ćehotina, Sutjeska, Bistrica (BiH), Lim, Uvac, Prača, Rakitnica, Rzav, Crni Rzav, Drinjača, Jadar and Janja. In addition, for the purpose of including the Buk Bijela pumped-storage HPP as an inactive component in the model, the Bjelava River is also included. There are no available hydrologic data for this river and it can also be considered inactive component.

Each river is defined in WEAP starting from a specific node corresponding to a hydroprofile (sub-basin outlet) in the hydrologic model. The flow rate at that hydroprofile, simulated by the hydrologic model, is assigned as headflow for each river. See Appendix C for specification of river headflows.

3.4.3 Reservoirs

A total of 23 reservoirs – 12 existing and 11planned – are included in the Drina WRM model (Table D-1 in Appendix D). Four existing reservoirs do not have associated HPPs (Radoinja, Zaovine, Ribnica and Snježnica). The planned reservoirs and the corresponding HPPs are set not to be active in Current Accounts. They are assigned different start-up years in the scenarios in which they are included. Specific setup is made for the Otilovići reservoir on the Ćehotina River, which is the existing reservoir, but its planned HPP is introduced into the system under “Middle 1” scenario later in the future. This reservoir is therefore included in Current Accounts, but its hydropower variables are activated in the starting year by using the Step function in WEAP (see first row in Table D-1 in Appendix D).

The model also includes four inactive reservoirs. These are: the upper reservoir of the Buk Bijela pumped-storage HPP and three reservoirs on the Ćehotina River with derivation-type HPPs (Gradac, Mekote i Falovići). These reservoirs and corresponding HPPs are not a part of any development scenario, but are included in the model to be eventually used later by stakeholders.

Table 3-4 presents WEAP variables related to reservoirs. They are categorized in four groups. Main **physical variables** that describe the reservoirs are storage capacity and volume-elevation curves. The storage capacity of the reservoirs in the Drina WRM model is set as the active reservoir volume. The volume-elevation curves in the Drina WRM model are defined as the relationship between active reservoir volumes and elevations (i.e. dead or inactive storage is not included). Data on the volume-elevation curves were available for a number of existing reservoirs and a smaller number of planned reservoirs. For the reservoirs with no available volume-elevation curves, a linear relationship was assumed between the minimum and maximum operating levels and corresponding volumes. The volume-elevation curves as given in WEAP are shown in table D-2 in Appendix D.

Operation of the reservoirs can be controlled in WEAP with a number of variables defining characteristic elevations and volumes (see second group of variables in Table 3-4). As the reservoir capacities In the Drina WRM model are set as the active volumes, this group of variables is used with default values in the model.

Table 3-4: Main variables in WEAP related to reservoirs.

WEAP variables		Description/Comment
Reservoirs – Physical	Storage capacity	Reservoir total volume. Specified as active volume.
	Initial Storage	Full reservoirs assumed.
	Volume-elevation curve	See explanations in the text
	Net evaporation	Evaporation minus precipitation (negative values indicate increase in water). Not considered.
	Maximum Hydraulic Outflow	Hydraulic constraints. No constraint assumed.
	Loss to Groundwater	Positive for seepage, negative for net gain from groundwater. Not considered.
Reservoirs – Operation	Top of Conservation	Maximum volume in reservoir. Default = Storage Capacity.
	Top of Buffer	Volume in reservoir below which releases are constrained by the Buffer Coefficient. Default = Top of Inactive.
	Top of Inactive	Volume in reservoir not available for allocation. If Storage Capacity is only the active volume capacity, then Top of Inactive = 0.
	Buffer Coefficient	Fraction of volume in buffer zone (below Top of Buffer) available for release. Default = 1.
Reservoirs – Hydropower	Max. Turbine Flow	Installed turbine capacity.
	Tailwater Elevation	Needed to calculate working water head.
	Generating Efficiency	KKD Coefficient of plant efficiency. Default = 100%.
	Hydropower Priority	Priority with which Energy Demand will be satisfied (no priority = 0, highest priority = 99).
	Energy demand	Hydropower production requirements.
Reservoirs – Priority	Priority	Reservoir-filling priority (highest priority = 1, lowest priority = 99).

For all reservoirs with associated HPPs, data is needed for the **Hydropower** group of variables. Data on installed turbine capacity, tailwater elevation and generating efficiency are essential for operation of HPPs in WEAP. Tailwater elevation is specified as a fixed value for all dam-type HPPs except the Piva and Sutjeska reservoirs, where it is set that tailwater elevation depends on the elevation in the reservoir. For example, the following formula is used for the Piva reservoir:

If(PrevTSValue(Storage Elevation[m])-492.61>=162, PrevTSValue(Storage Elevation[m])-162, 492.61)

where 492.61 represents calculated/design tailwater elevation and 162 is the rated head (in meters). Generating efficiency is calculated based on installed power, installed discharge and net head. Calculated generated efficiency for several planned HPPs did not make sense (e.g. it was > 1) and it was set to value of 0.85.

The model is built having in mind that most existing reservoirs operate without considerable storage effects, except for the Piva reservoir that can have significant storage effects. One of the main obstacles in modelling is lack of information on the energy demand, which, in combination with hydrologic input, drives the seasonal or even longer-term storage effects. Without energy demand specified in WEAP, reservoir-type HPPs operate as run-of-river HPPs. The energy demand is therefore specified in the model based on limited knowledge on the energy production of the Piva HPP.

Operation of the reservoirs and their associated HPPs is also governed by the **priorities** in the system. Two types of priorities are related to the reservoirs (Table 3-4): reservoir-filling priority (which also related to priorities of satisfying downstream flow requirements) and hydropower priority to satisfy energy demand. In Drina WRM model, these priorities are set for several reservoirs and HPPs in order to get realistic results (see Table D-1 in Appendix D).

3.4.4 Run-of-river hydropower plants

The criterion for defining a HPP as run-of-river (ROR) type was that its storage could be emptied with the installed turbine capacity flow within less than 2 hours. In addition to the conventional ROR HPPs located on the rivers, the derivation-type HPPs are also represented in WEAP by the ROR HPP located on the diversion components.

As a result, a total of 13 ROR HPPs (1 existing and 12 planned) are included in the Drina WRM model. Among them, Bistrica (existing) and Sutjeska (planned) HPPs are the derivation-type HPPs. Three derivation-type HPPs (Gradac, Mekote and Falovići) on the Ćehotina River are also included in the model as inactive components to be eventually used later. Another inactive ROR HPP is defined on the diversion link from the upper to lower Buk Bijela reservoir, as a part of the Buk Bijela pumped-storage HPP.

The planned HPPs are generally set not to be active in Current Accounts and they are assigned different start-up years in the scenarios in which they are included.

Main variables related to ROR HPPs are shown in Table 3-5. Most are the same as for dam-type HPPs, except that Fixed Head is used instead of variable one (see Appendix E for data on ROR HPPs). The net fixed head is specified for ordinary ROR HPPs, while it is estimated for the derivation-type HPPs as the difference between the reservoir elevation in the previous time step and calculated tailwater elevation:

Net Head = Current Storage Elevation – Tailwater Elevation

where the tailwater elevation is calculated from:

Tailwater Elevation = Normal Operating Elevation – Nominal Net Head

For the derivation-type HPPs, specifying energy demand and priority for hydropower production is necessary in order to have some flow diverted from the upstream reservoir through the diversion toward the power plant. The Hydropower Priority is set to 99. The energy demand is specified in the model as the energy that could be generated with the installed discharge and the nominal net head:

$$\text{Monthly Energy Demand} = \text{Installed Discharge} * \text{Net Head} * \text{Efficiency} \\ * 9.81 * 24 * \text{Days In Month} * 10^{-6}\ (\text{GWh})$$

The values of the WEAP variables for the ROR HPPs are shown in Table E-1 in Appendix E. Table E-2 provides input parameters and calculated values for the fixed head and energy demand for the derivation-type HPPs in the Drina WRM.

Table 3-5: Main variables in WEAP related to run-of-river power plants.

WEAP variables		Description
Run of river HPPs	Max. Turbine Flow	Installed turbine capacity
	Plant Factor	Percentage of time in each month that hydropower plant is running. Default = 100%
	Generating Efficiency	KKD Coefficient of plant efficiency. Default = 100%
	Fixed Head	Head difference for hydropower calculation.
	Hydropower Priority	Priority with which Energy Demand will be satisfied (no priority = 0, highest priority = 99).
	Energy demand	Hydropower production requirements.

3.4.5 Diversions

Diversions are introduced to represent derivation-type HPPs. As mentioned in the previous section, the Drina WRM model includes two derivation-type HPPs, and consequently two diversion components. The first one diverts water from the existing Radoinja reservoir to the existing Bistrica HPP and the Lim River. The second diversion component is related to the planned Sutjeska reservoir and its downstream HPP, which are not active in Current Accounts and become active in the “Full HPP” development scenario. The model also includes three inactive diversions corresponding to derivation-type HPPs Gradac, Mekote and Falovići HPPs on the Ćehotina River, and an inactive diversion link from the upper to the lower Buk Bijela reservoir within the the Buk Bijela pumped-storage HPP.

Data that describe a diversion component in WEAP is the maximum diversion flow, which is set to be equal to the installed turbine capacities of two HPPs (Table E-3 in Appendix E). As explained in previous subsection, in order to have some water flowing through the diversion, a requirement must be set on the diversion. This is achieved by placing run-of-river power plants on the diversion and by specifying energy demand and hydropower priority for them.

3.4.6 Pumped-storage hydropower plants

Only one pumped-storage hydropower plant (PS-HPP) exists in DRB, namely PS-HPP Bajina Bašta. Two other PS-HPPs are planned: Buk Bijela in BiH and Bistrica in Serbia. There is no adequate component in the WEAP tool that would support modelling of PS-HPPs.

The WRM model of DRB includes a set of inactive components that could indirectly model the Buk Bijela PS-HPP (Figure 3-6). This set of components consists of upper reservoir on the Vrbnička River (tributary to Bjelava, left tributary of Drina), the lower reservoir Buk Bijela on the Drina River (component that becomes active in Middle 1 development scenario) and two separate links between two reservoirs. The link from upper to lower reservoir is represented by the diversion component with a run-of-river HPP component on it. The link from lower to upper reservoir is represented by a transmission link component. With such a setup it could be possible to calculate hydropower generation at PS-HPP Buk Bijela, but not the energy consumption for the pumping operating regime. The Buk Bijela PS-HPP is inactive in the Drina WRM model. To enable water balance computations through the components of this PS-HPP, data on its operational regime on monthly level are needed. These data were not available during the model development.

The existing Bajina Bašta PS-HPP and the planned Bistrica PS-HPP are not included in the model because it was estimated that their operation cannot affect water redistribution in the system for the adopted monthly time step.

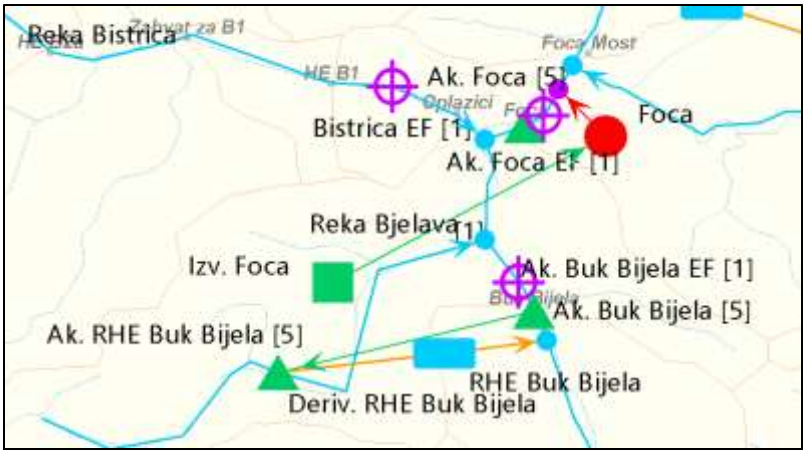

Figure 3-6: Representation of the pumped-storage HPP Buk Bijela in the Drina WRM model.

3.4.7 Flow requirements

Flow requirements are set at 36 locations in the basin following the analytical work of the environmental team of the project, who estimated the minimum environmental flow requirements in accordance with national regulations in three countries. Detailed discussion on environmental flows is presented in the IWRM country reports. Some flow requirements are given as constant flow rates throughout the year, while some have seasonal distribution. Environmental flows recommended in IWRM country reports are shown in Table F-1 in Appendix F. The only exception in this table is the adopted valued of the environmental flow below the Otilovići reservoir of 0.8 m^3/s, which the currently effective value according to technical documentation, instead of the proposed value of 1.27 m^3/s, which is estimated on the basis of the proposed methodology in Montenegro.[3]

In order to analyse the effects of adopting different environmental flows on water balance in the Drina WRM model, a set of higher flow requirements is prepared for a number of sites in accordance with regulations in the riparian countries and the available technical documentation. These higher values are given in Table F-2 in Appendix F.

Among the nodes with specified flow requirements, 6 are located in the head part of the basins. There are no reservoirs upstream of these nodes and therefore the flows in these nodes cannot be controlled. The results of water balance calculations therefore represent the requirement coverage by the natural hydrologic regime.

The flow requirements downstream of the existing reservoirs are specified at 10 locations within the basin. No requirements are specified below two existing reservoirs, Sjenica and Kokin Brod, which belong to a series of three cascading reservoirs. Similarly, three cascading reservoirs are planned on the Komarnica and

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[3] Based on the comments provided by stakeholders from Elektroprivreda Crne Gore, the calculated value of 1.27 m^3/s corresponds to the Ćehotina River section further downstream from the Otilovići reservoir, where the Ćehotina River receives two significant tributaries.

Piva Rivers (existing Piva reservoir and planned Komarnica and Krusevo reservoirs). The only flow requirement node is therefore located below the planned Kruševo reservoir in the model.

The remaining flow requirement nodes are located downstream of the planned reservoirs. The flows at these nodes become controllable under specific scenarios when the corresponding reservoirs become active. Therefore, the flow requirements also need to be activated once the reservoirs are activated. Since there is no possibility in WEAP to specify the startup year for the flow requirement nodes, this has been resolved by using the following expression:

If(Year >= *start year*, *flow requirement*, 0)

where *start year* is taken as the value of the Startup Year variable for the corresponding reservoir, while *flow requirement* is either a single value or 12 monthly values. Table F-3 in Appendix F shows how the flow requirements are specified in WEAP at particular nodes.

Water allocation in WEAP is sensitive to the flow requirements and it primarily depends on the priority for meeting these requirements. Meeting the flow requirement in a specific node affects all upstream reservoirs because WEAP will try to meet the requirement by releasing water from all upstream reservoirs. For the highest priority (1), the release from each reservoir is proportional to the reservoir storage. For the lowest priority (99), coverage of the flow requirement is proportional to water available for release after meeting other requirements or demands. In Drina WRM model, the priority for meeting the minimum flow requirement is set to be the highest (1), except below Brodarevo 1 HPP under „Full HPP" scenario where it is set to 99 because in this scenario the required flow is supplied from the downstream Brodarevo 2 reservoir with priority 1.

3.4.8 River reaches

River reach between two nodes is the one of WEAP components where the natural water balance is introduced into the system. Simple water balance for a river reach between two nodes is given with (see Figure 3-7-a):

Outflow = Inflow + Sub-basin contribution

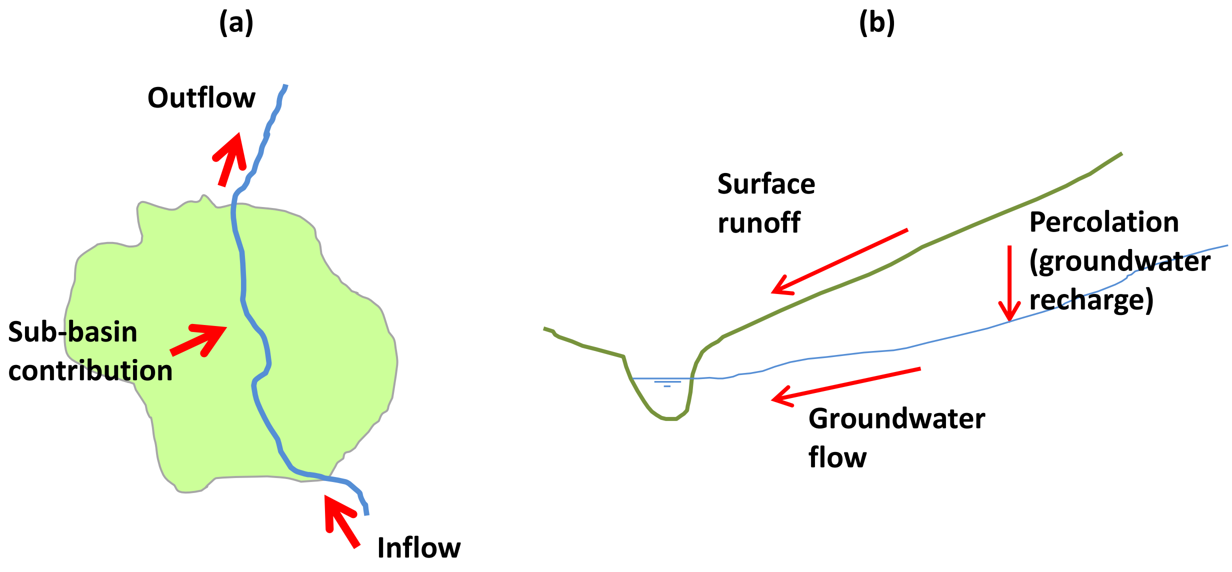

Figure 3-7: Natural water balance components for river reach and corresponding sub-basin.

Table 3-6: Main variables in WEAP related to river reaches.

Supply component	WEAP variables	Description
Rivers	Headflow	Inflow at head of the river. From hydrologic model
Rivers – Reaches	Surface Water Inflow	Surface water inflow to reach. Input from hydrologic model.
	Groundwater Inflow	Groundwater inflow to reach. Input from hydrologic model.
	Groundwater Outflow	Outflow to groundwater as % of river flow. Used in lower Drina.

Contribution from the sub-basin to the reach consists of surface runoff (Surface Water Inflow variable) and groundwater flow (Figure 3-7-b). Groundwater flow can be either from the hillslope toward the river (Groundwater Inflow variable) or from the river into the hillslope (Groundwater Outflow variable), so the water balance equation becomes:

$$\text{Outflow} = \text{Inflow} + \text{Surface Water Inflow} + \text{Groundwater Inflow} - \text{Groundwater Outflow}$$

The last three water balance components are the WEAP variables that describe the reaches (Table 3-6).

Data on surface runoff and baseflow (groundwater inflow), as well as groundwater recharge, are obtained from the output of the JCI hydrologic model. This model provides hydrologic output in terms of water balance components for 123 locations (*hydroprofiles*) in DRB. The most important components available from the hydrologic model include:

- sub-basin surface runoff Q_{sub_surf},
- sub-basin baseflow Q_{sub_base},
- sub-basin natural recharge (percolation) W_{perc}.

Water balance is treated differently for river reaches whose sub-basin(s) do or do not include groundwater sources (Table 3-7). If there is a groundwater source within the river reach sub-basin, the sub-basin percolation component represents the aquifer natural recharge, while the sub-basin baseflow component is used as the outflow from this groundwater aquifer. In case of a river reach with no groundwater source within its sub-basin, there is no explicit link with groundwater and total inflow from the sub-basin to the reach is made of surface flow and baseflow components. An abstraction directly from the reach for various water users can also be an outflow from the sub-basin related to the reach.

Table 3-7: Natural water balance components in WEAP with corresponding components from the JCI hydrologic model.

Water balance component in WEAP	„HIS Drina“ hydrologic model component	
	Sub-basin with no groundwater sources	Sub-basin with groundwater sources
Surface water inflow for the reach	Qsub_surf + Qsub_base	Qsub_surf
Groundwater inflow for the reach	0	Qsub_base
Natural recharge for groundwater source	–	Wperc

River reaches with assigned hydrologic input are listed in Appendix G. The external hydrologic data is introduced to WEAP via the *ReadFromFile* function, which has a general form:

ReadFromFile(*filename*, *column no.*)

where *filename* is the name of the CSV file with hydrologic model output for the particular sub-basin and *column no*. is the number of the column with particular water balance component. Surface flow is read from column 11, groundwater flow is read from column 12 and percolation is read from column 8 (see also section 3.4.12 and Table 3-9).

WEAP nodes generally correspond to locations of the hydroprofiles in hydrologic model. Drainage area of a river reach between two WEAP nodes therefore corresponds to one or more sub-basins in the JCI hydrologic model. There are several exceptions where interventions or adjustments were needed:

- The sub-basin between hydroprofiles “Ušće Rzava” and “Bajina Bašta” on the Drina River (corresponding to the confluence of the Rzav River and the Bajina Bašta reservoir) is very large (drainage area of 809 km^2) and it includes two separated demand sites Han Pijesak and Višegrad and their corresponding groundwater sources. Such a large sub-basin is therefore not suitable to describe groundwater balance components since local groundwater sources cannot be associated with large natural recharge and baseflow from the whole sub-basin. This sub-basin is therefore sub-divided into three sub-areas: below “Ušće Rzava” to “Višegrad Return”, below “Višegrad Return” to “Han Pijesak Return”, and from “Han Pijesak Return” to “Bajina Bašta” hydroprofile. The corresponding sub-areas are estimated at 3%, 6% and 91% of the whole sub-basin area, respectively, and the water balance components in WEAP are scaled accordingly.

- Due to disproportionately large baseflow resulting from hydrologic modelling for the sub-basin between “Srebrenica i Bratunac Return” and “HE Dubravica EF” nodes on the Drina River (i.e. between “Ušće Ljubovidje” and “Dubravica” hydroprofiles), 35% of modelled baseflow flow is added to surface flow, while the remaining 65% constitutes groundwater inflow to the reach.

- The sub-basin between the “Zvornik” and “Radalj” hydroprofiles on the Drina River is subdivided to two sub-basins draining toward left and right river bank. This is necessary to accommodate two groundwater sources (for Zvornik on the left and for Mali Zvornik on the right) since a sub-basin can be linked to only one groundwater component in WEAP. The left and right sub-areas are estimated at 73% and 27% of the whole sub-basin area, respectively, and the water balance components in WEAP are scaled accordingly.

- The reach between “Berane Return” and “Bijelo Polje Return” nodes on the Lim River covers multiple sub-basins in hydrologic model from which surface water and groundwater inflows to the reach are summed. Such a large baseflow creates unrealistically large outflow from the “Izv. Bijelo Polje” groundwater node. This situation is amended so that just 27% of the sub-basin area between “Zaton” and “Bijelo Polje” hydroprofiles is set to contribute to the groundwater inflow for this reach, while the groundwater components on the remaining part of this sub-basin and from other constituting sub-basins are added to the surface water inflow.

- In addition to the water balance components from the hydrologic model, groundwater outflow is included in the Drina WRM model in some of the lower Drina sub-basins (see last column of Table G-1 in Appendix G). This is done in order to get more realistic water balance of the groundwater aquifers located in the sub-basins of the lower Drina valley where lowland dominates and where water abstraction from wells near the Drina River facilitates groundwater flow from the river toward the river banks.

3.4.9 Groundwater sources

Groundwater (GW) is the prevailing water supply source in DRB. In cases where demand sites are supplied from more than one GW source, the sources are aggregated into a single one to reflect entire supply for these demand sites. The model comprises 33 GW sources.

GW nodes in WEAP represent aquifers for which water balance is computed. Water balance of an aquifer is given with:

Natural recharge – Groundwater flow – Abstraction + Wastewater return
= Change in groundwater storage

where *Groundwater flow* is the difference between baseflow from the sub-basin (represented by the Groundwater Inflow variable for the river reach with sub-basin containing the aquifer node) and inflow from the river (represented by the Groundwater Outflow for the corresponding river reach). The abstraction from the GW source is defined by the supply requirements of the demand sites connected to this GW source. Wastewater return is estimated as a percentage of wastewater from population not connected to public sewer systems and is specified in WEAP as the Loss To Groundwater variable for the return links from the municipal demand nodes toward rivers (see section 3.4.10).

Data related to GW sources are shown in Table 3-8. For GW water balance computations, it is essential to specify the natural recharge component, which is one of the outputs of the JCI hydrologic model. Data on percolation is read from the output files of the JCI hydrologic model in the same way as the data for river reaches. The percolation is given in millimetres and is multiplied with drainage areas in WEAP to obtain corresponding volumes in cubic metres. Table H-1 in Appendix H gives an overview of all groundwater sources and their links to the hydrologic model. Drainage areas for the sub-basins between the computational nodes of the hydrologic model are shown in Table J-1 in Appendix J.

Table 3-8: Main variables in WEAP related to groundwater sources.

Supply component	**WEAP variables**	**Description**
Groundwater	Storage Capacity	Aquifer capacity. Assumed unlimited.
	Initial Storage	Key Assumption
	Maximum withdrawal	Monthly maximum volume that can be abstracted from aquifer. Assumed unlimited.
	Natural Recharge	From hydrologic model

Similar to water balance calculation for the river reaches, several corrections of the simulated natural recharge are made to obtain more realistic water balance:

- Percolation for the GW nodes “Srebrenica i Bratunac” is reduced in accordance with the corresponding reduction of baseflow in the sub-basin where these GW nodes are located.

- Total percolation in the sub-basin where the GW nodes Zvornik and Mali Zvornik are located is distributed to the two GW nodes in the proportion equal to the proportion of their drainage areas (73% for Zvornik and 27% for Mali Zvornik).

- The sub-basin area that contributes to percolation to the Bijelo Polje GW node is reduced in accordance with the reduction of the remaining water balance components described for the river reaches.

- Small corrections toward increasing drainage areas that contribute to recharging GW nodes Pljevlja, Mojkovac and Kolašin, Berane, Goražde and Kladanj are introduced to take into account the effects of karst.

In addition to the natural recharge component, GW storage capacity and maximum withdrawal from GW source are also important parameters that could represent a constraint in solving the water allocation problem. However, this data is not readily available for the GW sources in the basin. The supply sources in DRB are the least known water management component, in many aspects (lack of knowledge on karstic groundwater bodies, very little readily available information on the sources for particular public water supply systems or industries; virtually no information on crucial parameters for WEAP such as storage capacity and maximum withdrawal). Groundwater storage capacity and maximum withdrawal are therefore assumed unlimited in the model. For BiH, a considerable effort to describe groundwater resources was made in the framework of developing the River Basin Management Plan for the Sava River in Bosnia and Hercegovina [7] [8], where information on selected groundwater sources could be found. However, this data was not included in the model in order to keep the same level of uncertainty in this respect for the whole basin.

The initial GW storage is assumed to be at a level that enables GW storage to fluctuate in time without drying out (this assumption is defined in Key Assumptions in Appendix A). Such an assumption allows analysing the computation results in a relative sense compared to the initial storage.

3.4.10 Transmission links and return flows

Transmission links are used to for withdrawals/abstractions from surface and groundwater and return flows represent discharges from demand sites to rivers. Return flow nodes are generally located at the outlets of the sub-basins from the hydrologic model.

There are several variables in WEAP that can be used to describe operation of transmission and return flow links. Only a few such entries are made for the Drina WRM model and these are shown in Table I-1 in Appendix I.

The *Loss To Groundwater* variable is specified for the return flow links from the municipal demand sites toward the rivers. This variable is estimated as a percentage of population not connected to the public sewer system. The estimated values are shown in Table I-2 in Appendix I. The remaining return flow links operate without limitations.

3.4.11 Key Assumptions

Some data such as the assumed specific domestic demand or specific agricultural demand are defined as the Key Assumptions. These are the variables with the values that can be referenced in expressions for data variables in WEAP. This is convenient for data entry and enables consistent assumptions throughout the model. The following Key Assumptions are included:

- specific demand for domestic water supply (for each country);
- monthly variation of domestic demand (the same for all countries);
- municipal supply loss rate for Montenegro;
- specific irrigation demand (for each country);
- monthly variation of agricultural demand (the same for all countries);
- growth rates for population, industry and agricultural water demand (for each country);
- groundwater initial storage (for all groundwater sources).

The values of the Key Assumptions are listed in Appendix A to this report.

3.4.12 Input from hydrologic model

The results of the simulations with the JCI hydrologic model consist of time series of a number of water balance components, listed in Table 3-9. The following components are used in WEAP:

- surface flow,
- groundwater flow (baseflow),

- percolation (groundwater recharge).

For each simulation, the results are provided in 123 files for each computational node (hydroprofile) available in the JCI hydrologic model. The files are prepared in CSV file format with a structure required by WEAP (see Box J-1 in Appendix J). These files are read from WEAP to provide input data for river reaches and groundwater sources (sections 3.4.8 and 3.4.9). For each model version, these files are located in the subfolder named “HydrolModel” in the particular Drina WRM model folder (within the “WEAP Areas” folder).

The list of hydroprofiles (computational nodes of the hydrologic models) with the corresponding filenames is given in Table J-2 in Appendix J. The filenames are the same for each model version (the user should therefore be careful to prepare data files corresponding to each model version). This table also provides data on drainage area corresponding to each hydroprofile, used to covert the natural recharge data W_{perc} from millimetres to volume units.

Table 3-9: Water balance components from the JCI hydrologic model.

Column	Name	Description
1	padavine [mm]	Sub-basin rainfall in millimetres
2	sneg [mm]	Sub-basin snowfall in millimetres
3	Ecan [mm]	Evaporation from vegetation in millimetres
4	Esub [mm]	Evaporation from snowpack (sublimation) in millimetres
5	Es [mm]	Evaporation from soil in millimetres
6	Et[mm]	Transpiration in millimetres
7	Qsurf [mm]	Surface runoff in millimetres
8	Wperc [mm]	Percolation to groundwater in millimetres
9	Rint [mm]	Throughfall (excess water after interception) in millimetres
10	SW [mm]	Soil moisture content in millimetres
11	Qsurf [m3/s]	Surface runoff from sub-basin in m^3/s
12	Qbase [m3/s]	Groundwater flow (baseflow) from sub-basin in m^3/s
13	Qsurf_upstream [m3/s]	Surface runoff at sub-basin outlet, including all upstream sub-basins, in m^3/s
14	Qbase_upstream [m3/s]	Groundwater flow at sub-basin outlet, including all upstream sub-basins, in m^3/s
15	Qmin_upstream [m3/s]	Minimum daily flow in current month at sub-basin outlet in m^3/s
16	Qmax_upstream [m3/s]	Maximum daily flow in current month at sub-basin outlet in m^3/s

3.5 Scenarios in WEAP

3.5.1 System configuration scenarios

The development scenarios for the Drina River basin are described in Chapter 4 of the IPF country reports [4]. These scenarios consist in general of three options:

- **Green Growth** option. Under this option, no new reservoirs and HPPs are built.
- **Hydropower Maximisation** option. Under this option, the greatest number of HPPs is planned.
- **Middle** or **Reduced/Optimised Hydropower** option. This option includes a limited number of new HPPs and differs from country to country.

Table 3-10: Scenarios in WEAP related to development options for DRB as defined in the IWRM country reports.

WEAP scenario	Development scenario		
	Montenegro	BiH	Serbia
Green Growth	Green Growth	Green Growth	Green Growth
Middle 1	Follows Energy Development Strategy	Reduced Hydropower per Sava RBMP	Reduced/Optimized Hydropower
Middle 2		Reduced Hydropower over longer time frame	
Middle 3		Hydropower Maximisation	
Full HPP	Hydropower Maximisation		Hydropower Maximisation

In order to accommodate differences among the countries, three middle scenarios are defined in WEAP in addition to the “Green Growth” and “Hydropower Maximisation” scenarios (Table 3-10). “Middle 1” scenario includes Middle option for Montenegro and Serbia and the Variant #1 of the Middle option for BiH. “Middle 2” scenario in WEAP includes additional three HPPs under Variant #2 of the Middle option for BiH. “Middle 3” scenario in WEAP includes three HPPs which belong to Middle option in Serbia and to “Full HPP” option in BiH. Therefore, the following WEAP scenarios correspond to the proposed development scenarios in the IWRM reports for the riparian countries:

- Montenegro:
    - Green Growth = Green Growth
    - Middle = Middle 1
    - Full HPP = Full HPP

- Bosnia and Herzegovina:
    - Green Growth = Green Growth
    - Middle Variant #1 = Middle 1
    - Middle Variant #2 = Middle 2
    - Full HPP = Full HPP

- Serbia:
    - Green Growth = Green Growth
    - Middle = Middle 3
    - Full HPP = Full HPP

Table 3-11 lists all HPPs across the scenarios in the Drina WRM model. In WEAP, different components may have different start-up years in different scenarios. This allows gradual introduction of the investments in new reservoirs and HPPs over time. Assumed start-up years for HPPs are shown in Table 3-11.

Table 3-11: List of HPPs included in the specific scenarios in WEAP.

Country	River	Reservoir / HPP	Startup year	Current Accounts	Green Growth	Middle 1	Middle 2	Middle 3	Full HPP
MNE	Piva	Piva		+	+	+	+	+	+
SRB	Lim	Potpeć		+	+	+	+	+	+
SRB	Uvac	Sjenica/Uvac		+	+	+	+	+	+
SRB	Uvac	Kokin Brod		+	+	+	+	+	+
SRB	Uvac/Lim	Radoinja/Bistrica		+	+	+	+	+	+
BiH	Drina	Višegrad		+	+	+	+	+	+
SRB/BiH	Drina	Bajina Bašta		+	+	+	+	+	+
SRB/BiH	Drina	Zvornik		+	+	+	+	+	+
MNE	Piva	Komarnica	2034			+	+	+	+
MNE	Piva	Kruševo	2028			+	+	+	+
BiH	Drina	Buk Bijela	2022			+	+	+	+
BiH	Drina	Foča	2022			+	+	+	+
MNE	Ćehotina	Otilovići	2022			+	+	+	+
BiH	Drina	Ustikolina	2022			+	+	+	+
SRB	Lim	Brodarevo 1	2047			+	+	+	+
SRB	Lim	Rekovići	2031			+	+	+	+
BiH	Lim	Mrsovo	2040			+	+	+	+
BiH	Drina	Paunci	2022				+	+	+
BiH	Drina	Goražde	2022				+	+	+
SRB/BiH	Drina	Dubravica	2025				+	+	+
SRB/BiH	Drina	Rogačica	2022					+	+
SRB/BiH	Drina	Tegare	2025					+	+
SRB/BiH	Drina	Kozluk	2025					+	+
BiH	Sutjeska	Sutjeska	2022						+
BiH	Ćehotina	Vikoč	2043						+
MNE	Lim	Andrijevica	2037						+
MNE	Lim	Lukin Vir	2047						+
SRB	Lim	Brodarevo 2	2047						+
SRB/BiH	Drina	Drina I	2050						+
SRB/BiH	Drina	Drina II	2050						+
SRB/BiH	Drina	Drina III	2050						+

3.5.2 Socio-economic scenarios

Socio-economic scenarios include growth rates for population, industry and agriculture (Table 3-12). The growth values indicated in the table are defined as Key Assumptions in WEAP (Appendix A).

Table 3-12: Socio-economic scenarios: growth rates for population, industrial production and agricultural production.

Socio-economic category	Scenario	BiH	Montenegro	Serbia
Population growth rate[1]	Real growth	-0.9945%	-1.16%	-0.7%
	Flat	0%	0%	0%
	High	+0.1812%	+1.07%	+0.9%
Industrial production growth rate[2]		+3-5%	-1.5%	+3-5%
Agricultural production growth rate[2]		+5.3%	–[3]	+3%

[1] Source: IWRM Country Reports [3]; [2] Sources: [5], [9], [10] , [11], [12]; [3] Not specified in the model

3.5.3 Climate scenarios and hydrologic projections

To consider climate change effects on water management in DRB, two steps are needed:

- development of climate projections, i.e. precipitation and temperature series that reflect future climate in DRB under a particular climate change scenario,
- hydrologic simulations with climate projections to obtain hydrologic projections for DRB at locations of WEAP nodes.

Results of the climate and hydrologic modelling are described in detail in IWRM and IPF country reports, and are presented here just briefly. Two IPCC climate scenarios are considered: RCP 4.5, as a “middle line” and RCP 8.5 as a GHG intensive scenario. An ensemble of the outputs from four chains of global and regional climate models (GCM/RCM) has been established for both climate scenarios. Climate modelling outputs are taken from the Med-CORDEX project.[4] Table 3-13 lists the GCM/RCM combinations for each chain. Each modelling chain provided simulated temperature and precipitation time series for two future 30-years periods, 2011-2040 and 2041-2070, and for the baseline period 1961-1990. The baseline simulations are needed to evaluate changes in future precipitation and temperature relative to the baseline period. Climate simulations under two climate scenarios by one modelling chain are the same for the baseline period, but different for the future. Therefore, there are 12 different data sets of climate simulations to be used in the study (4 for baseline and 8 for future period).

Hydrologic simulations are provided from the JCI hydrologic model with climate projections as the input. Twelve data sets of climate simulations resulted in 12 different hydrologic data sets that supported simulations with the Drina WRM model. These simulations are labelled as shown in Table 3-14.

Table 3-13: List of climate modelling (RCM/GCM) chains used in the study.

Climate model	Institute	GCM	RCM
1	CNRM	CM5	ALADIN 5.2
2	CMCC	CM	CCLM 4-8-19
3	LMD	IPSL-CM5A-MR	LMDZ
4	GUF	MPI-ESM-LR	CCLM 4-8-18

Table 3-14: Hydrologic simulations with climate projections.

Period	Climate scenario	Climate model	Hydrologic simulation label
Baseline (1961-1990)	N/A	1	Baseline_m1
		2	Baseline_m2
		3	Baseline_m3
		4	Baseline_m4
Future (2011-2070)	RCP 4.5	1	Future_RCP45_m1
		2	Future_RCP45_m2
		3	Future_RCP45_m3
		4	Future_RCP45_m4
Future (2011-2070)	RCP 8.5	1	Future_RCP85_m1
		2	Future_RCP85_m2
		3	Future_RCP85_m3
		4	Future_RCP85_m4

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[4] www.medcordex.eu

4 Simulation results

The following main indicators are used to assess the DRB water resources system performance under different baseline and future scenarios:

- quantitative coverage and temporal reliability of municipal, agricultural and industrial water supply and of satisfying environmental flow requirements,
- hydropower generation (energy production).

The quantitative coverage is defined here as the percentage of the delivered water volume relative to the demand volume. The temporal reliability is defined as the percentage of time with supply delivery equal to the demand (calculated as the number of months with the 100% demand coverage relative to the total number of months during the specified time frame). Hydropower generation is presented as the average annual energy production during the specified time frame.

In general, the median of the ensemble of four simulations under each climate scenario is adopted to present general tendencies in the simulation results and projections for the future. The uncertainty can be described by the range of the projections obtained by each climate/hydrologic model chain.

4.1 Water supply

The results of simulations for the future time frame 2011-2070 have shown that water supply to the municipal, agricultural and industrial demand sites has 100% coverage and 100% temporal reliability for all demand sites.

Preliminary simulations showed that the industry in the Pljevlja municipality, which is supplied from the Otilovići reservoir on the Ćehotina River, does not have full coverage of 100% if the flow requirement below the Otilovići reservoir is specified as 1.27 m^3/s This flow requirement results from calculations of the minimum environmental flows according to the official methodology in Montenegro and is significantly greater than the value of 0.8 m^3/s, which is currently effective value according to the technical documentation. Coverage of water supply to this demand site (representing thermal power plant, coal mine and wood processing industry) from the preliminary simulations is shown in Figure 4-1. The figure shows medians of simulations with the ensemble of four climate model chains for two climate scenarios. The Otilovići reservoir is also used for municipal water supply of the Pljevlja municipality. Greater environmental flow requirement downstream of the Otilovići reservoir creates additional pressure on the reservoir. Yet, this happens rarely and under such conditions the industrial supply coverage remains rather high (above 99% in near future, and in distant future more than 99% under RCP 4.5 and more than 98% under RCP 8.5). The coverage under the “Full HPP” scenario is not reduced as much as under other options because the Otilovići reservoir is trying to satisfy not only the immediate downstream flow requirements but also that further downstream when the planned Vikoč reservoir is introduced under the “Full HPP” scenario. Figure 4-1 also shows the ranges of the results based on different climate modelling outputs. These ranges indicate a small uncertainty in the results for 2011-2040 and somewhat greater uncertainty for 2041-2070, especially under RCP 8.5.

Based on the results of the preliminary and final simulations, it can be concluded that the environmental flow requirement below the Otilovići reservoir of 0.8 m^3/s does not decrease water supply of the users in the Pljevlja municipality, while the greater value of 1.27 m^3/s results in decreased coverage of supply to industry. It should also be noted that the results are obtained under an assumption that the municipal water supply at Pljevlja from groundwater is not limited, meaning that the water from the Otilovići reservoir is not used for municipal water supply in the model. In reality, during periods of reduced groundwater capacity and yield in Pljevlja municipality, the pressure on the Otilovići reservoir can be even greater.

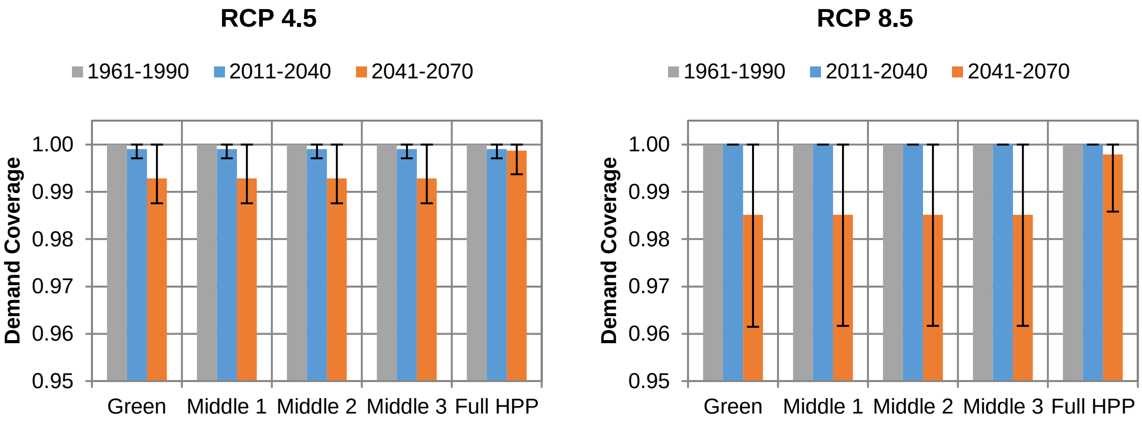


Figure 4-1: Coverage of water supply to Pljevlja industry with greater flow requirement of 1.27 m^3/s below the Otilovići reservoir: ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right).

4.2 Hydropower generation

Annual hydropower generation in DRB under different development options is shown in Figure 4-2 as the median values of the results for the ensemble of climate and hydrologic simulations. New infrastructure appears starting from 2022. Therefore, from 2022 the annual energy production in DRB remains roughly constant under “Green Growth” scenario while it increases gradually with introduction of new infrastructure until 2050. After 2050, all power plants for specific scenarios are operational and the time series over 2051-2070 reflects expected energy production in the basin. Similar graphs are presented in Appendix K.1 with energy production for each country.

Average annual energy production under different climate and development scenarios, calculated as the median values of the ensemble of four simulations, is compared in Table 4-1 for three riparian countries and for the whole basin. Hydropower generated in HPPs shared between BIH and Serbia is shown separately. The hydropower production is averaged over the baseline period and over three future periods: 2011-2021, 2022-2050 and 2051-2070. The first period 2011-2021 includes only the existing HPPs and therefore the energy production is the same under all development options. The second period, 2022-2050, is the period over which the new HPPs are introduced gradually into the system. Finally, in the third period, 2051-2070, all HPPs planned under different development options are operational. The values for the whole basin shown in Table 4-1 are also shown graphically in Figure 4-3, which also shows uncertainty related to climate modelling. Similar graphs for each country are shown in Appendix K.1. The uncertainties are small in the baseline period (about 3% on average over the basin) and increasing in the future. In the last period 2051-2070 the uncertainties from climate modelling reach 25% on average over the basin relative to the median.

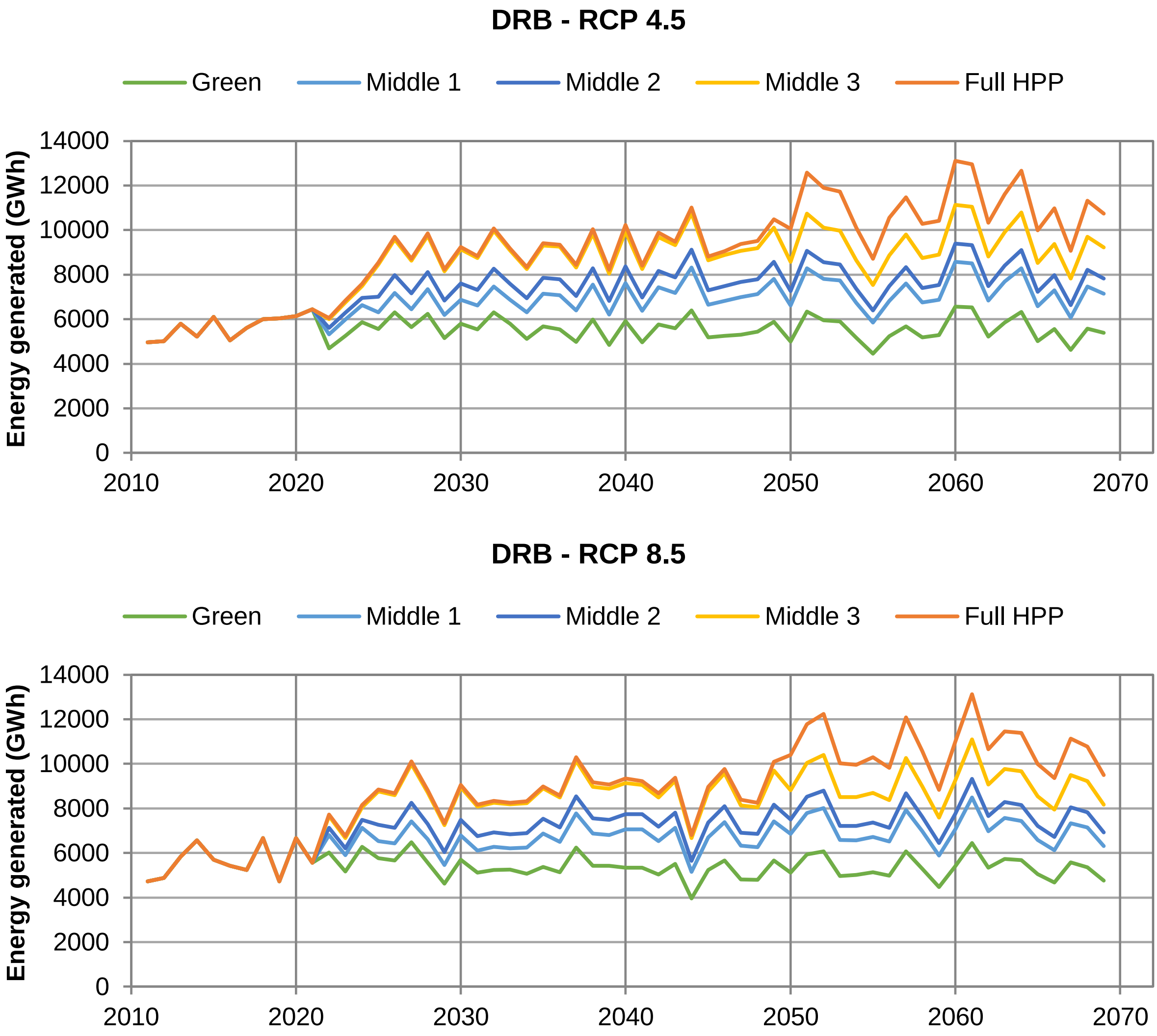


Figure 4-2: Annual hydropower generation in DRB for different development options; ensemble medians for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

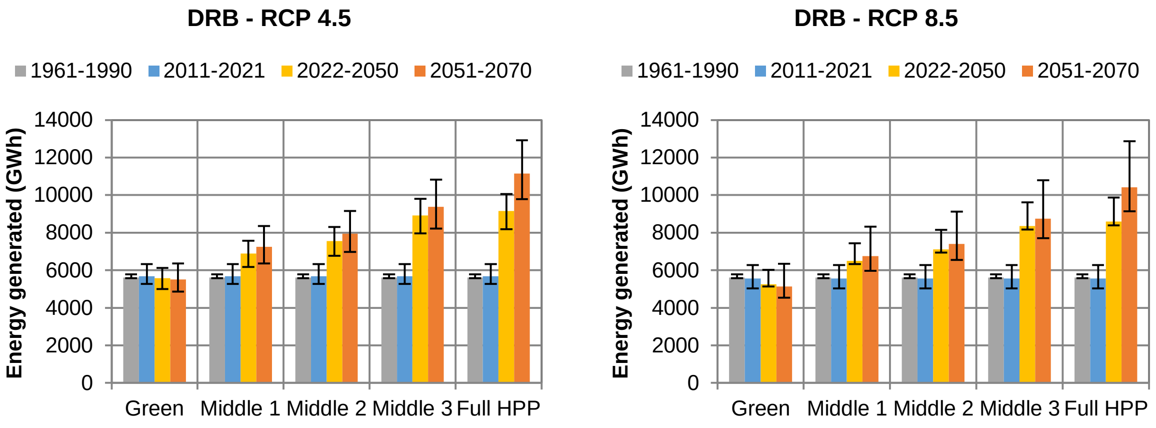


Figure 4-3: Average annual hydropower generation in DRB for different development options; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

Table 4-1: Average annual hydropower generation for different development options and for different periods under two climate scenarios (ensemble median values).

	Baseline	**RCP 4.5**			**RCP 8.5**		
	1961-1990	**2012-2021**	**2022-2050**	**2051-2070**	**2012-2021**	**2022-2050**	**2051-2070**
MNE							
Green	845	819	809	793	856	783	766
Middle 1			1286	1504		1242	1455
Middle 2			1286	1504		1242	1455
Middle 3			1286	1504		1242	1455
Full HPP			1340	1650		1296	1598
BiH							
Green	1359	1362	1332	1335	1356	1284	1281
Middle 1			2128	2224		2054	2139
Middle 2			2445	2540		2360	2445
Middle 3			2445	2540		2360	2445
Full HPP			2537	2635		2448	2536
BiH/SRB							
Green	2378	2398	2366	2336	2381	2283	2257
Middle 1			2365	2337		2283	2259
Middle 2			2708	2716		2610	2626
Middle 3			4057	4155		3899	4017
Full HPP			4095	5443		3937	5266
SRB							
Green	1031	1065	1022	1069	1016	1000	998
Middle 1			1063	1215		1036	1135
Middle 2			1063	1215		1036	1135
Middle 3			1063	1215		1036	1135
Full HPP			1074	1303		1049	1229
DRB							
Green	5613	5643	5529	5532	5609	5350	5303
Middle 1			6842	7281		6617	6987
Middle 2			7501	7976		7249	7660
Middle 3			8850	9415		8539	9051
Full HPP			9047	11031		8730	10629

When assessing the change relative to the baseline period, it is necessary to separate the effect of climate change from the introduction of new infrastructure under different development options. The climate change effect is shown in Figure 4-4 for average annual energy generation in the whole basin under “Green Growth” scenario. This figure shows that the expected effect of changing climate on hydropower production is small under RCP 4.5 climate scenario (less than 5%), while there could be a significant drop in hydropower generation under RCP 8.5 climate scenario due to reduced runoff (up to 10%). The same figure also shows that the uncertainty stemming from hydrologic and climate modelling in the climate change effects on hydropower production is relatively great and is the greatest in the last future period 2051-2070.

Figure 4-5 compares the hydroelectricity production for the development scenarios with planned facilities relative to the “Green Growth” scenario with the existing facilities. It can be seen that the “Full HPP” option doubles the current energy production under both climate scenarios. Uncertainty related to the climate modelling outputs in this case is negligible, because relative increase in production by new facilities does not depend on climate changes (in other words, impact of climate change on hydroelectricity production is reflected on all facilities so the proportion among productions of individual facilities remains the same). The corresponding results for the countries are given in Appendix K.1.

Figure 4-6 gives combined climate change and development option effects by showing percent change in annual hydropower generation relative to the baseline period 1961-1990. Corresponding results across the countries are shown in Appendix K.1.

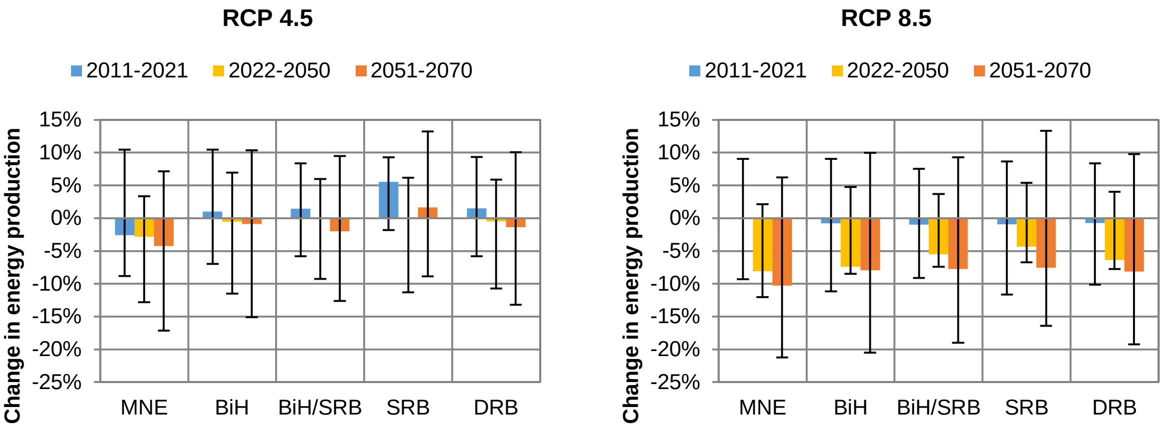


Figure 4-4: Climate change impact: change in average annual hydropower generation in DRB relative to 1961-1990 under Green Growth option (existing HPPs only); ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right).

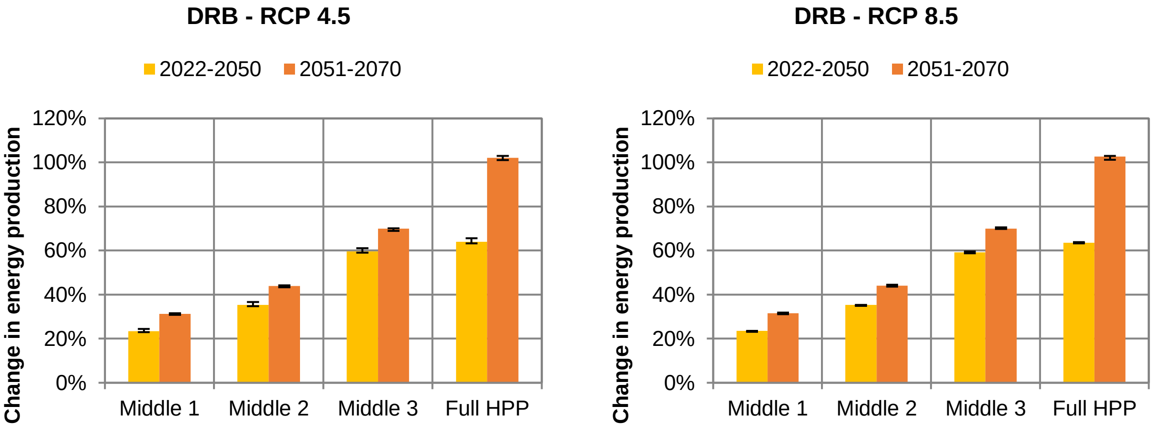


Figure 4-5: Development options effect: change in average annual hydropower generation in DRB relative to Green Growth option; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

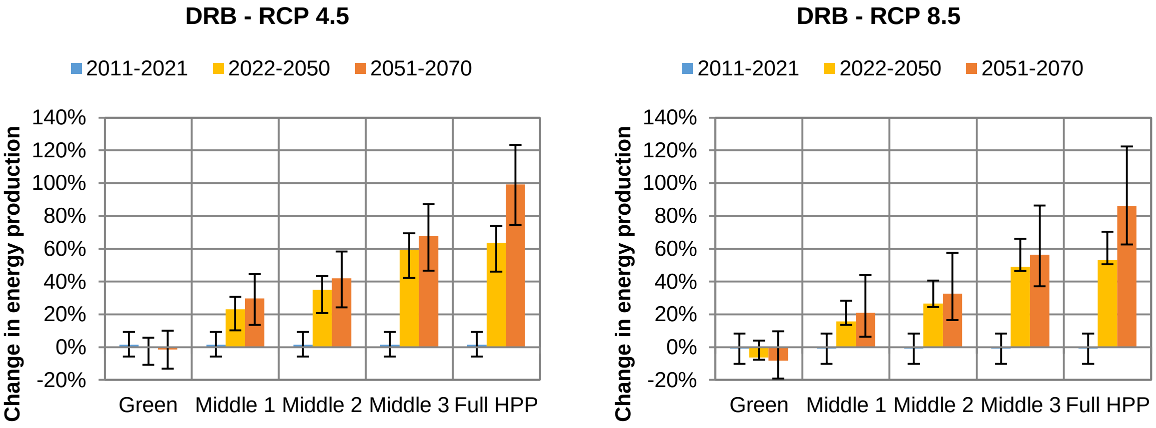


Figure 4-6: Combined climate change and development options effects: change in average annual hydropower generation in DRB relative to 1961-1990; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right).

4.3 Flow requirements

This section describes the results of computations with the Drina WRM model with the flow requirements specified as the environmental flow values recommended in the IWRM country reports and as the environmental flow values providing higher requirements. The environmental flows used as the flow requirements are presented in Tables F-1 and F-2 in Appendix F.

As described in section 3.4.7, instream flow requirements in the Drina WRM model are set for 36 locations in the basin. At 6 locations these requirements are set in in the head part of the basin and cannot be managed by any upstream reservoir, but are included in the model to assess their coverage by natural runoff regime.

Flow requirement coverage at these six locations is the same under all development scenarios since the planned reservoirs are situated downstream of them and the flows at these locations are not affected by outflows from the reservoirs. The coverage decreases in time with decreasing runoff under both climate scenarios except for the Jadar River where the coverage is always high and never smaller than 99.7% (Figure 4-7). The coverage at other sites is greater than 95% for Lower Tara and Bistrica until 2050, for Upper Lim only until 2021, and is less than 95% in the latest period 2051-2070. Temporal coverage (reliability) of the instream flow requirements is smaller than 95% for all sites except for the Jadar River, over both baseline and future periods (except Upper Tara in the baseline period; see Figure 4-8). The uncertainties in the coverage are small in the baseline period and in future until 2050 (less than 3%). For 2051-2070 the uncertainties due to climate modelling are more pronounced and for certain locations can be up to 10% under the RCP 8.5 scenario.

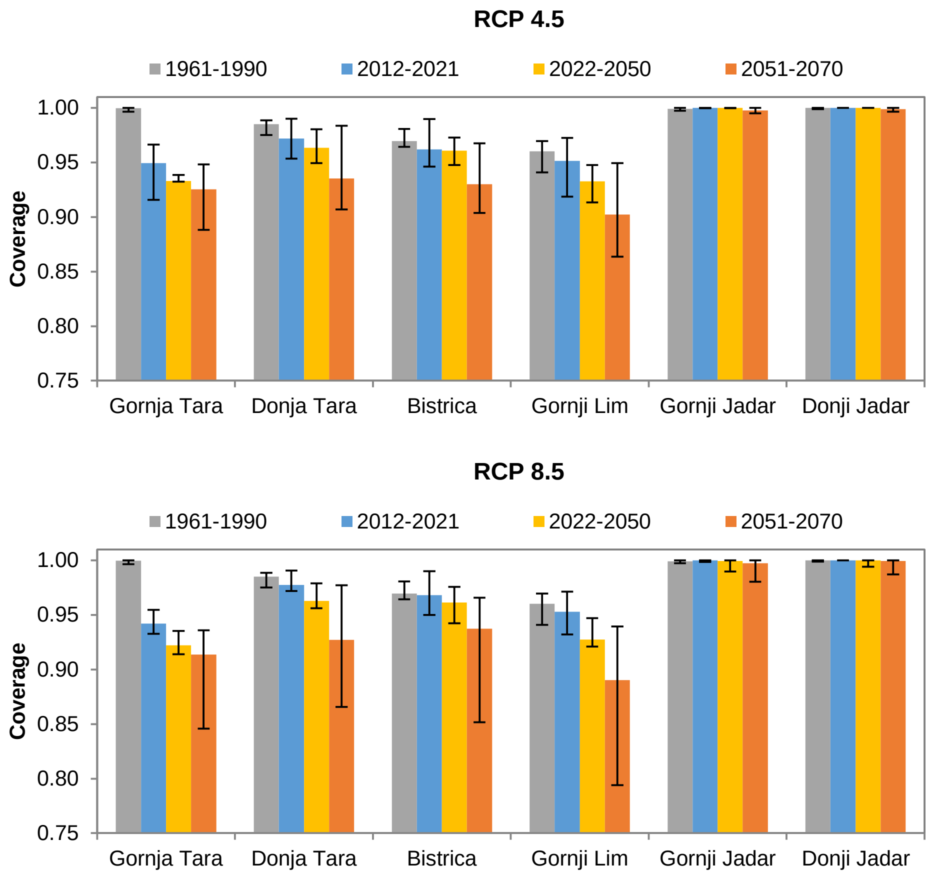


Figure 4-7: Coverage of environmental flow requirements at head parts of the basin; ensemble medians with ranges of results from different climate models for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

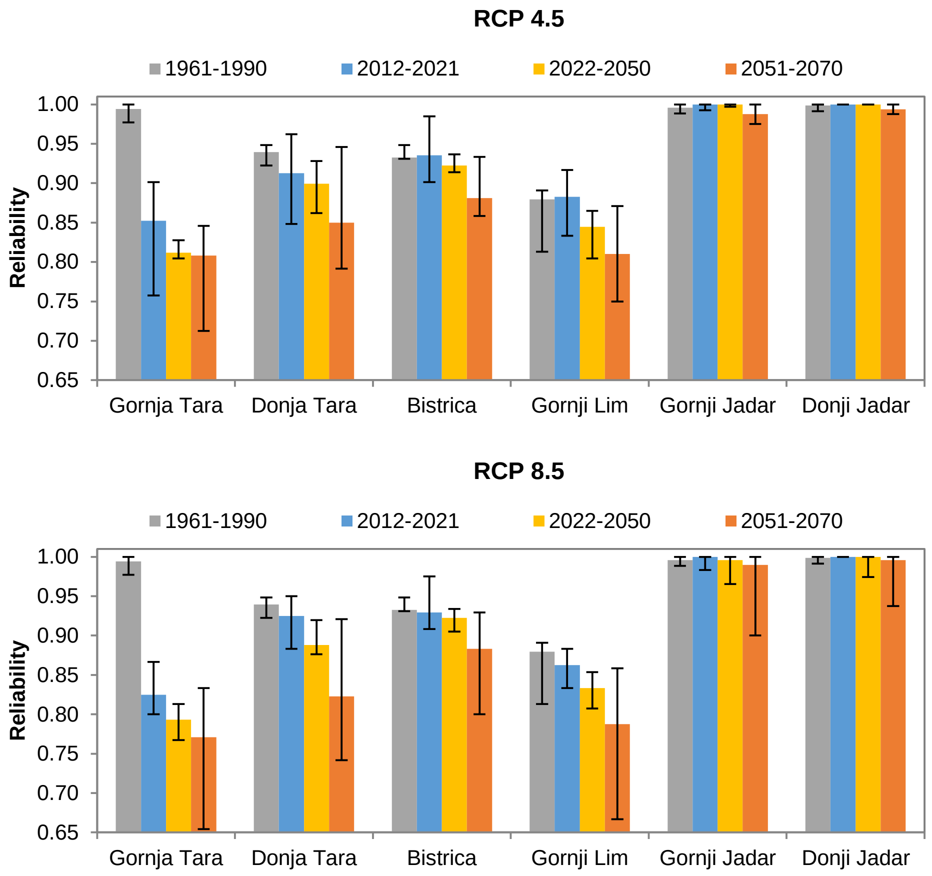


Figure 4-8: Temporal reliability of environmental flow requirements at head parts of the basin; ensemble medians with ranges of results from different climate models for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

The simulations have shown that the flow requirements below the existing reservoirs and HPPs (Green Growth scenario) are fully satisfied (with 100% coverage). The flow requirements below the planned reservoirs and HPPs are fully satisfied everywhere except for the Lim River. The results for all locations are given in Appendix K-2.

The nodes on the Lim River where the instream flow requirements are not fully satisfied include four nodes below the planned reservoirs and HPPs: Andrijevica reservoir, Lukin Vir reservoir, Brodarevo 1 run-of-river HPP and Brodarevo 2 reservoir. The “Brodarevo 1” run-of-river HPP is a part of the “Middle 1” development scenario and becomes active in 2047. In this scenario the flow requirements cannot be controlled at any of these four nodes on the Lim River because there are no upstream reservoirs and the results represent the requirement coverage by the natural runoff regime (Figure 4-9). Under the “Full HPP” development scenario, all four facilities are active: the Andrijevica reservoir from 2037 and the remaining facilities from 2047. Coverage of the flow requirements at these sites for 2051-2070 is presented in Figure 4-10, which shows that the coverage is high when the requirements are met by discharging from all three planned reservoirs. The flow requirement below the planned Brodarevo 1 reservoir is satisfied by discharging from the upstream reservoirs Lukin Vir and Andrijevica. Figure 4-12 shows how the storage volume of these three reservoirs changes in order to meet the downstream requirements. It can be seen that the Andrijevica reservoir, which has the largest storage capacity, has the greatest contribution to meeting the downstream requirements. The results for two climate scenarios RCP 4.5 and RCP 8.5 are very similar, while the modelling uncertainty is small. Temporal reliability of flow requirements in this part of the Lim River (Figure 4-11) has similar ensemble medians as the volumetric coverage, but with somewhat greater uncertainty.

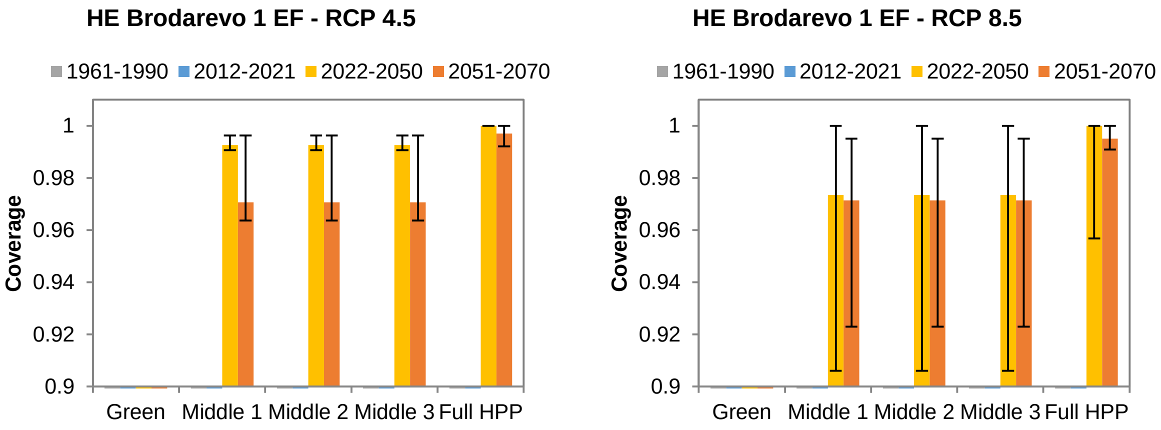


Figure 4-9: Coverage of flow requirements below the planned Brodarevo 1 run-of-river HPP; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

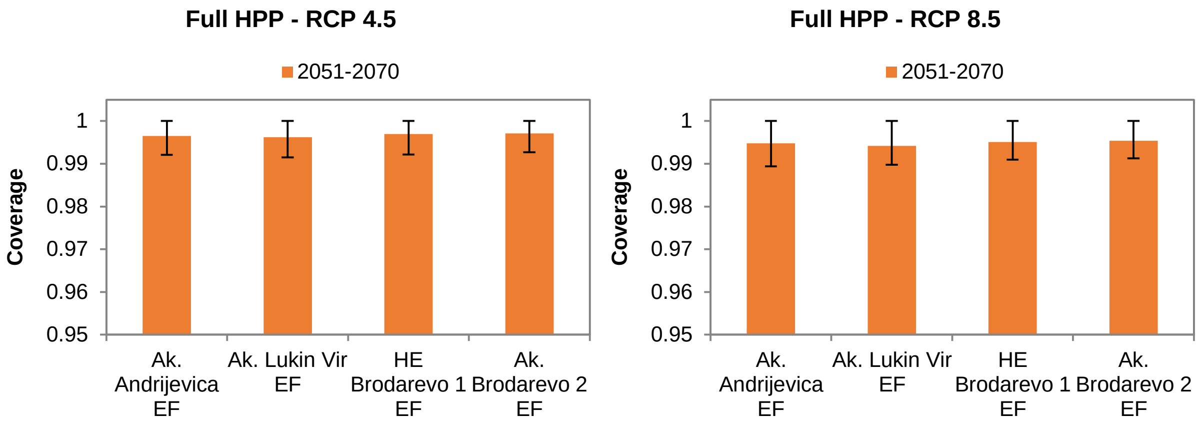


Figure 4-10: Coverage of flow requirements for the Lim River to Prijepolje under “Full HPP” scenario; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

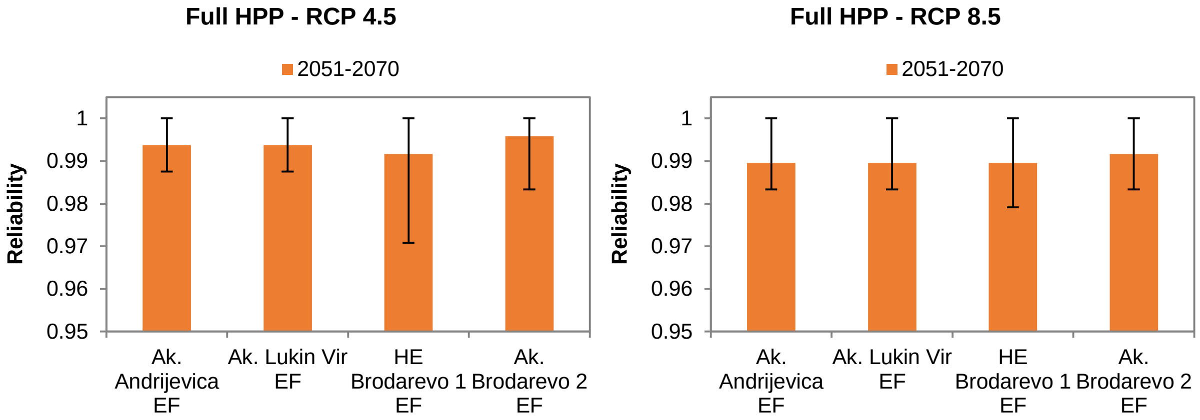


Figure 4-11: Temporal reliability of flow requirements for the Lim River to Prijepolje under “Full HPP” scenario; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

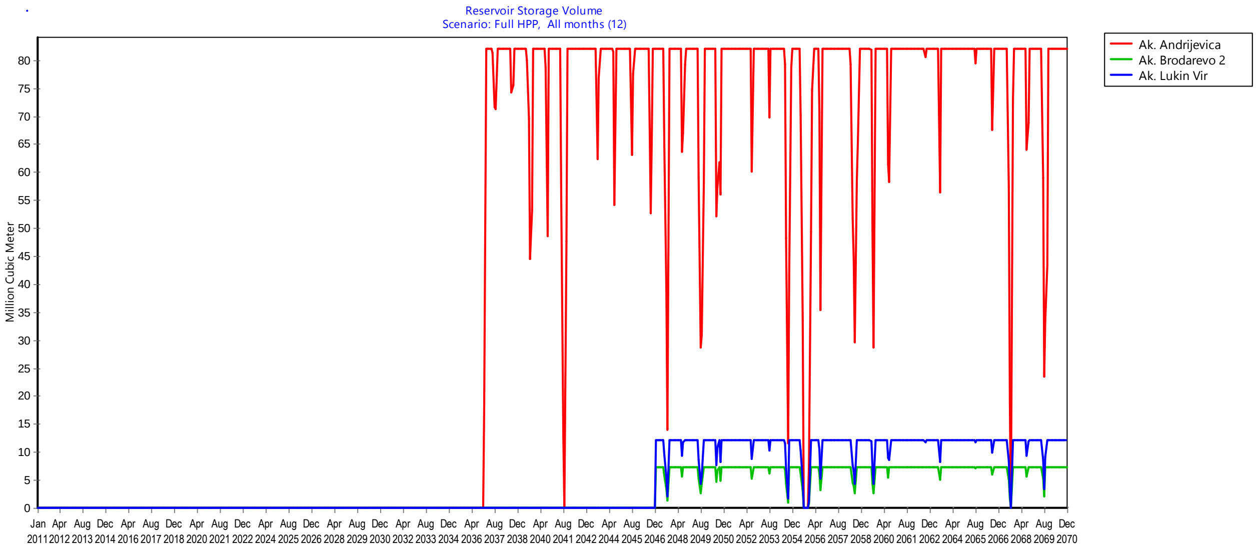


Figure 4-12: Time series of storage volume in the planned reservoirs in the Lim River to Prijepolje under the "Full HPP" scenario (Andrijevica, Lukin Vir and Brodarevo 2); simulation with the RCP 4.5 climate scenario, model 4.

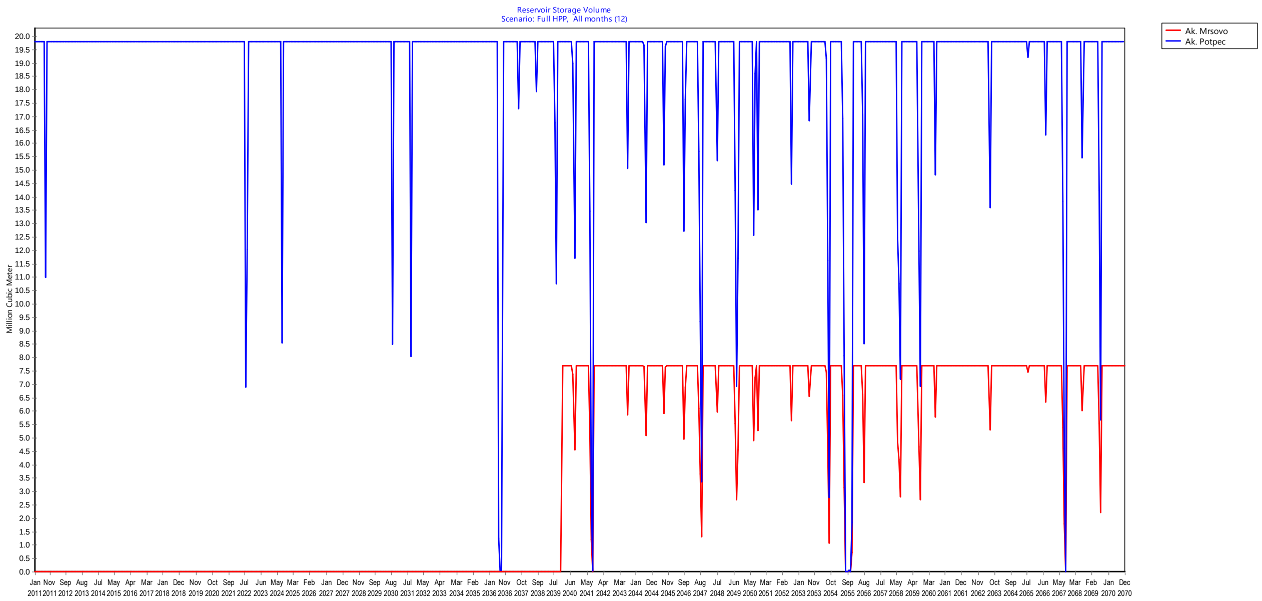


Figure 4-13: Time series of storage volume in the reservoirs in the Lim River below Prijepolje under the "Full HPP" scenario (existing Potpeć reservoir and planned Mrsovo reservoir); simulation with the RCP 4.5 climate scenario, model 4.

Having in mind that all dam-type HPPs in the Drina WRM except the Piva HPP are simulated as the run-of-river facilities (no energy demand is specified), their reservoirs are generally full except when an additional discharge is needed to meet the downstream requirements. Therefore it is possible that the reservoir storage is emptied if the inflow to the reservoir is very low and the reservoir must meet the downstream requirement. For example, the existing Potpeć reservoir (Figure 4-13) is emptied often during summer seasons after 2031, when the planned Rekovići HPP and the corresponding flow requirement become active in the model. In addition, the flow requirement below the Potpeć reservoir is 13.9 m^3/s, while it is much greater (18.2 m^3/s) almost immediately downstream below the planned Rekovići HPP. Such a difference in flow requirements at small distance is the cause for the frequent decreses and emptying of the Potpeć reservoir.

The preliminary simulations with the greater flow requirement below the existing Otilovići reservoir on the Ćehotina River (1.27 m^3/s compared to 0.8 m^3/s in final simulations), the requirement was not met fully, although both quantitative and temporal coverage at this location remained high in distant future under all scenarios (at least 99.7% for quantitative coverage and at least 99% for temporal coverage; see Figure 4-14). In addition to not having full coverage, this greater flow requirement below the Otilovići reservoir also affects the coverage of the water supply to industry in the Pljevlja municipality from the Otilovići reservoir, as explained in section 4.1.

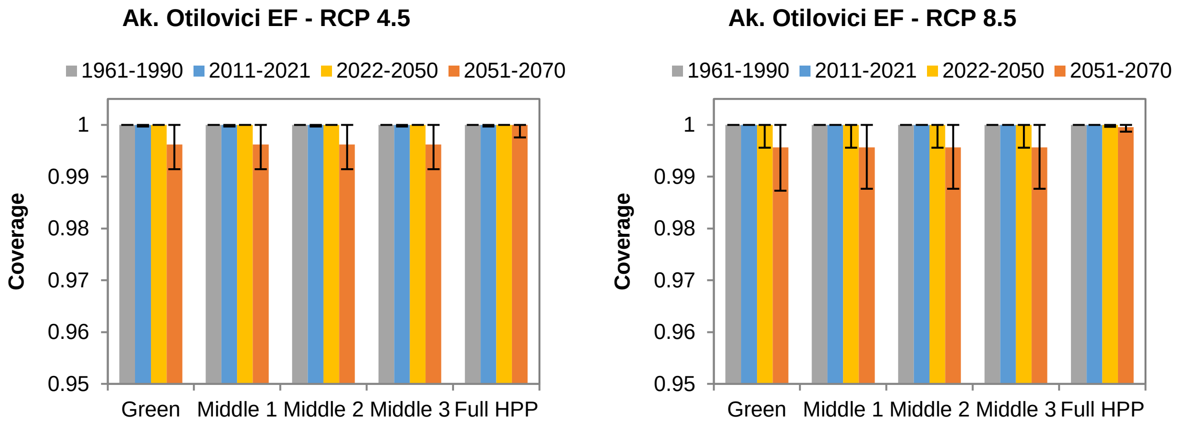


Figure 4-14: Coverage of greater flow requirement (1.27 m^3/s) below the existing Otilovići reservoir; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

The analysis of the effects of specifying greater flow requirements on water balance in DRB is undertaken with only one version of the hydrologic input for the Drina WRM model. The hydrologic simulations with the outputs of the climate model 4 under the RCP 4.5 climate scenario is chosen for this analysis. The first option of this analysis includes flow requirements specified with the higher values of environmental flows than those recommended in IWRM country reports. The higher values correspond to values calculated according to regulations in Republika Srpska (Table F-2 in Appendix F). The second option included even greater flow requirements at four most downstream nodes (downstream of Kozluk, Drina I, Drina II and Drina III HPPs) in accordance with the information obtained from the Steering Committee Chairman of the current project in May 2017 (values in parentheses in Table F-2 in Appendix F). The computation results have shown that, under the same hydrologic input, the higher flow requirements along the Drina main course can be fully satisfied (with 100% coverage) with both options of higher requirements. Increased flow requirements are not reflected upon hydroelectricity production or upon coverage of municipal, industrial and agricultural water supply.

5 Concluding remarks

5.1 Summary of the model development

The water resources management model developed for the Drina River Basin is a simulation tool that supports strategic planning in the basin leading to proposing the infrastructure configurations for different basin/region development scenarios. The model enables reviewing and checking the robustness of the system, simulation of future developments (climate variability or other changes in the basin), and consideration of modifications to planning and infrastructure.

Simulations have been performed with the Drina WRM model with two ensembles climate/hydrologic projections for two climate scenarios to provide an insight to water balance under different climate, development and socio-economic scenarios. The results on key system performance indicators (demand coverage, flow requirement coverage and hydropower production) are presented in this report, while the results on a range of other system state variables are also available in the model database.

Key features of the developed water management model of the Drina basin are:

- The model performs water balance computations with monthly time step.
- Municipal, industrial and agricultural water demand is included in the model.
- The flow requirements reflecting minimum environmental flows are included.
- Hydrologic input is provided from the hydrologic model developed by JCI at about 80 locations in the basin (including surface water, groundwater and percolation components).
- All hydropower plants (except HPP Piva) act like run-of-river HPPs in the model. Because the information on the energy demands was not available, the HPPs work with the available monthly water flows and generate the corresponding energy regardless of the demand. If the energy demand data were introduced in the model, only the water needed to satisfy the demand would be released from the reservoirs through HPPs, while the surplus would be accumulated in the reservoirs.
- Operation of the Piva reservoir and power plant, as the major system component in the basin, is driven by the energy demand specified as the average monthly demand according to the historical data.
- Meeting water demand and flow requirements has the primary priority, while the hydropower production has secondary priority.

The model is developed under certain assumptions and has certain limitations. The model does not optimize water allocation to the given users, nor does it optimize the management of the reservoir operation. The WEAP tool performs water allocation only at one time instance (during one month in this case) based on the specified priorities. In this regard, the tool provides a desired water allocation to the users in terms of the priorities for their supply, but it does not provide optimum water allocation according to specific criteria (e.g. criteria of quantitative coverage or financial benefits).

The water balance computations performed with the adopted monthly time step allow considering different options within the strategic planning framework, but are not adequate for operational management of water supply and reservoir operation. As such, this model cannot support the analysis of the effects of the reservoir operation during floods. The analysis of the flood wave propagation along the Drina River and their tributaries requires developing a hydraulic model with a sub-daily time step. Also, the WEAP software cannot model operational decisions such as reservoir releases prior to a forecasted flood without user intervention and therefore does not allow an analysis of the effects of such decisions on the flood wave attenuation.

The complexity of the Drina River basin as the water resources system has put significant challenges in front of the model developers. The major problem has been the availability of information needed for the comprehensive model development, including both hydrometeorological inputs and information on water users and management policies. Most of this information is scattered over innumerable reports and with numerous responsible institutions in three countries, thus requiring major efforts to collect such information. The Consultant has developed the water management model with the best available data within the given time frame and has built a tool that will enable stakeholders to make adequate plans and be better prepared for future decisions.

5.2 Recommendations for further model development

The model is open for further upgrading in terms of providing better or more reliable data and in terms of modifying system configuration to suit the needs of particular stakeholders. A significant improvement could be made in regard to specifying the properties of the groundwater nodes in order to improve the results related to water supply from the groundwater sources. More detailed description of the reservoir parameters (especially the volume-elevation curves) and the hydroelectric energy demands would contribute to more precise computations and finer consideration of operation of the hydropower reservoirs.

Further model development in terms of expanding the system configuration under specific development scenarios is possible in different ways depending on the nature and location of the system components to be added. Adding demand sites is not limited by the current model setup. The groundwater sources can be added to the sub-basins between the computational nodes of the hydrologic model in order to provide input data on the natural groundwater balance from the hydrologic model. For the sub-basins in the Drina WRM model where the groundwater nodes are already included, new demand sites should be connected to the existing groundwater node in the model.

If the model is to be developed further by introducing new infrastructure on the rivers (e.g. reservoirs and hydropower plants), then the new component should be positioned at the corresponding computational node of the hydrologic model (listed in Appendix J) because the hydrologic model most likely includes all locations of interest for hydropower in DRB that have been subject of the studies in the past. If the location of the new infrastructure (new component in WEAP) does not have a corresponding node in the hydrologic model, but is located between two computational nodes of the hydrologic model, then the natural water balance components for the sub-basin (surface inflow, groundwater inflow, as well as the natural recharge of a groundwater node is present within the sub-basin) should be distributed to the reaches upstream and downstream of the new node. This distribution of the water balance components can be proportional to the drainage areas upstream and downstream of the new node, or can be estimated by more sophisticated hydrological methods.

It is very important to emphasize the aspect of the transboundary cooperation in the Drina River basin in regard to maintenance and further development of the Drina WRM model. Since the water resources management systems are highly dynamic systems, each change anywhere within the basin is reflected throughout the basin. The possibility to use the model for integrated water management in the basin will therefore always depend on the exchange of information among the riparian countries. Harmonisation of the model structure and input data is very important for BiH and Serbia, two countries at two banks of the same river. Although Montenegro could maintain the model independently from the other two countries, its contribution to the downstream model users is of the utmost significance. It is therefore highly recommended that the countries develop a protocol for exchange of data and information related to the Drina WRM model. Cooperation on the exchange can be regulated as a part of a general agreement between the governments or by a joint document signed by all relevant institutions. The cooperation in this respect can take various forms. The simplest form would be that the model files are exchanged annually, and that rotation of countries in charge of harmonising the input data occurs every three years. Occasional meetings on the technical level, with participation of stakeholders' staff actually maintaining the model, would also be beneficial.

Having in mind that some institutions from the Sava River riparian countries have signed the Policy on the exchange of hydrological and meteorological data and information in the Sava River Basin [25], it is also recommended that other institutions from the riparian countries of DRB also sign this policy if they are interested in exchanging, maintaining and developing the Drina water management model. It is also advised that the model versions maintained or developed individually by the riparian countries are delivered to the ISRBC Secretariat (e.g. annually) and in such a way enable efficient exchange of the updated model versions between the riparian countries and their institutions.

6 References

[1] REC: Pollution in the Drina River Basin – An inventory of potential sources. Edited by J. Ignjatovic. Regional Environmental Center, Hungary, 2011. http://www.rec.org/publication.php?id=281

[2] SEI: WEAP – Water Planning and Evaluation System, User Guide, Stockholm Environment Institute, 2015. www.weap21.org.

[3] Support to Water Resources Management in the Drina River Basin, "Integrated Water Resources Management Study and Plan – Background Paper", country reports, World Bank Project no. 1099991, 2016. http://www.wb-drinaproject.com/index.php/en/documents

[4] Support to Water Resources Management in the Drina River Basin, "Investment Prioritization Framework", country reports, World Bank Project no. 1099991, 2016. http://www.wb-drinaproject.com/index.php/en/documents

[5] Strategija upravljanja vodama na teritoriji Republike Srbije, nacrt. Ministarstvo poljoprivrede i zaštite životne sredine, 2015.

[6] Strategija integralnog upravljanja vodama Republike Srpske, Aneks 6: Navodnjavanje poljoprivrednig zemljišta (Strategy of integrated water management in Republik Srpska, Annnex 6: Irrigation of agricultural land), Zavod za vodoprivredu, Bijeljina, Vlada Republike Srpske/Government of Republika Srpska, 2012.

[7] Plan upravljanja oblasnim riječnim slivom rijeke Save Republike Srpske, Prateći dokument br. 4: Podzemne vode. Eptisa, 2015.

[8] Plan upravljanja vodama za vodno područje rijeke Save u Federaciji Bosne i Hercegovine, Prateći dokument br. 4: Podzemne vode, Eptisa, 2015.

[9] Ekonomska politika Republike Srpske za 2016. godinu (Economic policy of Republika Srpska for 2016), Narodna skupština Republike Srpske/National Assembly of Republika Srpska, 2015. http://www.vladars.net/....pdf

[10] Strateški plan razvoja poljoprivrede i ruralnih područja Republike Srpske 2016–2020, prijedlog (Draft Strategic Plan of Development of Agriculture and Rural Areas in Republika Srpska), Vlada Republike Srpske/Government of Republika Srpska, 2015. http://www.vladars.net/.../Strategija%202020.pdf.

[11] Strategija poljoprivrede i ruralnog razvoja Republike Srbije za period 2014–2024 (Strategy of Agriculture and Rural Development in the Republic of Serbia for 2014–2024), Vlada Republike Srbije/Government of Republic of Serbia, Sl. glasnik RS/Official Gazette 85, 2014.

[12] Zavod za statistiku Crne Gore/Statistical Office of Montenegro: Bruto domaći proizvod Crne Gore za 2010-2015 (Gross domestic product of Montenegro for 2010-2015), 2016. http://www.monstat.org/cg/page.php?id=19&pageid=19.

[13] Zavod za statistiku Crne Gore/Statistical Office of Montenegro: Statistika voda za 2011. http://monstat.org/cg/page.php?id=1006&pageid=64

[14] Strategic Master Plan for Sewage and Wastewater in Central and Northern Region of Montenegro, 2005. http://www.procon.me/pdf/strategicframework/strategies/Wastewater%20Tretment%20Master%20plan%20for%20central%20and%20north%20part%20in%20Montenegro.pdf.

[15] Plan upravljanja vodama za vodno područje rijeke Save u Federaciji Bosne i Hercegovine, Prateći dokument br. 6: Analiza pritisaka, Eptisa, 2015.

[16] Plan upravljanja oblasnim riječnim slivom rijeke Save Republike Srpske, Prateći dokument br. 6: Analiza pritisaka. Eptisa, 2015.

[17] Eko-bilten 2013, Republički zavod za statistiku Republike Srbije, 2014.

[18] Strategija integralnog upravljanja vodama Republike Srpske, Aneks 4.1: Snabdijevanje vodom naselja i privrede koja troši vodu iz gradskih vodovoda (Strategy of integrated water management in Republik Srpska, Annnex 4.1: Water supply of population and industry from public water supply systems), Zavod za vodoprivredu, Bijeljina, Vlada Republike Srpske/Government of Republika Srpska, 2012.

[19] Strategija integralnog upravljanja vodama Republike Srpske, Aneks 4.2: Snabdijevanje vodom industrije i energetike vodom za tehnološke potrebe (Strategy of integrated water management in Republik Srpska, Annnex 4.2: Water supply of industry i energy sectors), Zavod za vodoprivredu, Bijeljina, Vlada Republike Srpske/Government of Republika Srpska, 2012.

[20] Dopunjeni plan aktivnosti za hidroakumulaciju „Snježnica“. JP Elektroprivreda BiH d.d. Sarajevo, Podružnica “Elektrodistribucija” Tuzla, 2010.
http://www.fmoit.gov.ba/userfiles/file/Dopunjeni%20Snije%C5%BEnica%20novi_27sept2010.pdf

[21] Pokazatelji uspešnosti preduzeća koja se bave snabdevanjem vodom i kanalisanjem naselja u 2014. godini (Performance indicators of water supply and sewerage companies in 2014), Udruženje za tehnologiju vode i sanitarno inženjerstvo za potrebe MGSI i IAWD, Beograd, 2014.

[22] Stanje sektora voda i pokazatelji uspešnosti preduzeća koja se bave snabdevanjem vodom i kanalisanjem naselja u 2015. godini (Water sector status and performance indicators of water supply and sewerage companies in 2015), Udruženje za tehnologiju vode i sanitarno inženjerstvo za potrebe MGSI i IAWD, Beograd, 2015.

[23] Projekat razvoja sistema navodnjavanja u Bosni i Hercegovini (IDP), Plan upravljanja okolišem i procjena uticaja na društvo za podprojekat Goražde (Federacija BiH), Institut za hidrotehniku Građevinskog fakulteta u Sarajevu, 2012.
http://fmpvs.gov.ba/upload_files/1440612751-302_533_1039_b.pdf

[24] Energy budget of Montenegro, annual reports (Energetski bilans Crne Gore, izveštaji po godinama), Elektroprivreda Crne Gore. http://www.epcg.com/o-nama/proizvodnja-i-elektroenergetski-bilans

[25] International Sava River Basin Commission (ISRBC): Policy on the exchange of hydrological and meteorological data and information in the Sava River Basin, WMO, 2014.
http://www.savacommission.org/dms/docs/dokumenti/documents_publications/basic_documents/data_policy/dataexchangepolicy_en.pdf

7 Abbreviations

BiH	Bosnia and Herzegovina
DRB	Drina River Basin
FBiH	Federation of Bosnia and Herzegovina
GCM	Global Climate Model
GHG	Green House Gases
HPP	Hydropower Plant
IPCC	International Panel on Climate Change
IPF Report	“Investment Prioritisation Framework” Report
ISRBC	International Sava River Basin Commission
IWRM Report	“Integrated Water Resources Management Study and Plan – Background Paper” Report
JCI	“Jaroslav Černi” Institute
MNE	Montenegro
PS-HPP	Pumped-storage hydropower plant
RCM	Regional Climate Model
RS	Republika Srpska
SEI	Stockholm Environment Institute
SRB	Serbia
WEAP	Water Evaluation and Planning Tool
WRM	Water Resources Management

Appendix A: Key Assumptions

Table A-1: Variables defined as Key Assumption and their values.

Branch	Name	Value	Comment
Demand	Specific demand MNE	83.585 m^3	= 229 L/capita/day. Source [3].
Demand	Specific demand BiH RS	81.03 m^3	= 222 L/capita/day. Source [3].
Demand	Specific demand BiH FBiH	81.03 m^3	= 222 L/capita/day. Source [3].
Demand	Specific demand SRB	73 m^3	= 200 L/capita/day. Source [3].
Demand	Monthly variation	see Table A-2	Assumed.
Demand	Loss rate MNE	54.6 %	Share of total losses in total abstracted water for Montenegro in 2011. Source [13].
Demand	Irrigation specific demand BiH	4200 m^3/ha	Gross specific irrigation demand. Source [6], Table 3.2.1.
Demand	Irrigation specific demand SRB	2500 m^3/ha	Source [5].
Demand	Irrigation demand monthly variation	see Table A-2	Assumed.
Demand	Population growth rate BiH	-0.9945 %	Source [3].
Demand	Population growth rate MNE	-1.16 %	Source [3].
Demand	Population growth rate SRB	-0.7 %	Source [3].
Demand	Industrial growth rate BiH	4 %	Source [9].
Demand	Industrial growth rate MNE	-1 %	Source [12].
Demand	Industrial growth rate SRB	3 %	Source [5].
Demand	Agriculture growth rate BiH	5.3 %	Source [10].
Demand	Agriculture growth rate SRB	3 %	Source [11].
Demand	Consumption	15 %	Part of wastewater lost from the system. Assumed.
Groundwater	Initial storage	200 million m^3	Assumed.

Table A-2: Monthly distributions of municipal and irrigation demand.

Month	Municipal demand		Irrigation demand	
	monthly share of annual demand (%)	relative to average demand	monthly share of annual demand (%)	relative to average demand
Jan	6.667	0.8	0	0.0
Feb	7.5	0.9	0	0.0
Mar	7.5	0.9	0.42	0.1
Apr	8.333	1.0	1.17	0.1
May	8.333	1.0	8.99	1.1
Jun	9.167	1.1	16.74	2.0
Jul	10	1.2	36.46	4.4
Aug	10	1.2	31.06	3.7
Sep	9.167	1.1	4.83	0.6
Oct	8.333	1.0	0.33	0.0
Nov	8.333	1.0	0	0.0
Dec	6.667	0.8	0	0.0
Average	8.333	1	8.333	1

Appendix B: Demand sites data

Table B-1: Municipal demand sites

Country	Demand Site	Annual Activity Level (cap.)	Loss rate (%)
MNE	Pljevlja	24713[1]	Key\Demand parameters\Loss rate MNE[% share]
MNE	Mojkovac i Kolasin	26332[2]	Key\Demand parameters\Loss rate MNE[% share]
MNE	Zabljak	2622	Key\Demand parameters\Loss rate MNE[% share]
MNE	Savnik	3979[3]	Key\Demand parameters\Loss rate MNE[% share]
MNE	Pluzine	2706	Key\Demand parameters\Loss rate MNE[% share]
MNE	Plav	13549	Key\Demand parameters\Loss rate MNE[% share]
MNE	Andrijevica	4011	Key\Demand parameters\Loss rate MNE[% share]
MNE	Berane	33148[4]	Key\Demand parameters\Loss rate MNE[% share]
MNE	Bijelo Polje	42058[5]	Key\Demand parameters\Loss rate MNE[% share]
BiH	Foca	20090[6]	55
BiH	Gorazde	25181[7]	82
BiH	Visegrad	11740	45
BiH	Srebrenica i Bratunac	15228+21592	50
BiH	Rogatica	11599	55
BiH	Vlasenica i Sekovici	12313+6366	50
BiH	Milici	12251	50
BiH	Zvornik	63652	55
BiH	Bijeljina	32113	50
BiH	Ugljevik i Lopare	13726+4379	47.5
BiH	Cajnice	5439	45
BiH	Han Pijesak	1188	50
BiH	Rudo	8830	45
BiH	Sokolac	826	55
BiH	Kladanj	7680	82
SRB	Loznica	67500	60
SRB	Mali Zvornik	9190	45
SRB	Krupanj	17295	25
SRB	Ljubovija	8450	20
SRB	Osecina	3450	48
SRB	Bajina Basta	11000	55
SRB	Cajetina i Zlatibor	11000	55
SRB	Priboj	19000	30
SRB	Sjenica	13000	50
SRB	Nova Varos	8404	20
SRB	Prijepolje	20000	23

[1] Includes all population in the Ćehotina basin.
[2] Includes all population in the Tara Basin except Žabljak.
[3] Includes all population in the Piva Basin except Plužine.
[4] Also includes population from Rožaje, Mojkovac and Kolašin municipalities in the Lim River basin.
[5] Also includes population from Plejvlja municipality in the Lim River basin.
[6] Also Includes population from Gacko and Kalinovik municipalities in DRB.
[7] Also Includes population from Foča-Ustikolina and Pale-Prača municipalities.
Sources: Population: [3], Consumption: [14], [15], [16], [17], [21], [22]; Loss rates: [13], [17], [18] , [21], [22].

Table B-2: Industrial demand sites

Country	Demand Site	Annual Water Use Rate (1000 m^3)	Consumption[1] (%)	Comment
MNE	TERDI Pljevlja[2]	5600	72.3	Includes Pljevlja thermoelectric plant, coal mine and wood industry. Monthly variation of the demand is also specified (see Table B-3).
BiH	AD Sava	506.88	50	Source [19].
BiH	Tvornica glinice Birac	3294.72	90	Source [19].
BiH	Boksit	1647.36	4	Source [19].
BiH	TE Ugljevik	7300	90	Average water delivered to TE Ugljevik for 2005-2009. Source [20].
SRB	Ind. Bajina Basta[3]	16.74	20	See Table B-4.
SRB	Ind. Loznica[3]	619.094	20	See Table B-4.
SRB	Ind. Ljubovija[3]	459.3528	50	See Table B-4.
SRB	Ind. Sjenica[3]	319.062	10	See Table B-4.
SRB	Ind. Nova Varos[3]	160.79	20	See Table B-4.
SRB	Ind. Osecina[3]	156.613	20	See Table B-4.

[1] Assumed.

[2] Data received from Elektroprivreda Crne Gore.

[3] Data received from JVP "Srbijavode".

Table B-3: Water demand for the industrial demand node TERDI Pljevlja (data from Elektroprivreda Crne Gore)

Month	Water demand (1000 m^3)			Total (1000 m^3)	Monthly variation
	TE Pljevlja	Coal mine	Wood industry		
Jan	455.3	0.898	53.6	509.8	9.17%
Feb	411.3	0.811	48.4	460.4	8.28%
Mar	455.3	0.898	53.6	509.8	9.17%
Apr	0.0	0.869	51.8	52.7	0.95%
May	455.3	0.898	53.6	509.8	9.17%
Jun	440.6	0.869	51.8	493.3	8.87%
Jul	455.3	0.898	53.6	509.8	9.17%
Aug	455.3	0.898	53.6	509.8	9.17%
Sep	440.6	0.869	51.8	493.3	8.87%
Oct	455.3	0.898	53.6	509.8	9.17%
Nov	440.6	0.869	51.8	493.3	8.87%
Dec	455.3	0.898	53.6	509.8	9.17%
Total (1000 m^3)	4920.5	10.6	630.7	5561.8	
Consumption (%)	70	90	90	72.3*	

* Computed as (0.7 · 4920.5 + 0.9 · 10.6 + 0.7 · 630.7)/5561.8

Table B-4: Water demand for the industrial demand sites in Serbia (data from JVP Srbijavode)

Municipality	Supply source	Demand (1000 m^3/yr)	Loss rate (%)	Supply requirement (1000 m^3/yr)	Total water demand (1000 m^3/yr)
Bajina Bašta	water supply system	10.8	55	16.74	16.74
Loznica	water supply system	27.92	60	44.672	619.094
	groundwater wells	574.422	–	574.422	
Ljubovija	water supply system	4.794	20	5.7528	459.3528
	groundwater wells	93.6	–	93.6	
	mine pit (groundwater)	216	–	216	
	river[1]	144	–	144	
Nova Varoš	groundwater wells	160.79	–	160.79	160.79
Osečina	groundwater wells	156.613	–	156.613	156.613
Sjenica	water supply system	5.348	50	8.022	319.062
	mine pit (groundwater)	311.04	–	311.04	

[1] Withdrawal from river is limited at 144000 m^3/yr (see Table I-1)

Table B-5: Agriculture demand sites

Country	Demand Site	Annual Activity Level (ha)	Annual Water Use Rate (m^3/ha)
BiH	Polj. BiH 1	2700	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. BiH 2	5300	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. BiH 3	710	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. BiH 5	800	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. BiH 6	1670	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. BiH 7	1060	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. BiH 8	1090	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. Foča Ustik.	88	Key\Demand parameters\Irrigation specific demand BiH[m^3]
BiH	Polj. Goražde	65	Key\Demand parameters\Irrigation specific demand BiH[m^3]
SRB	Polj. Srbija 1	6210	Key\Demand parameters\Irrigation specific demand SRB[m^3]
SRB	Polj. Srbija 3	1360	Key\Demand parameters\Irrigation specific demand SRB[m^3]
SRB	Polj. Srbija 4	900	Key\Demand parameters\Irrigation specific demand SRB[m^3]
SRB	Polj. Srbija 5	1640	Key\Demand parameters\Irrigation specific demand SRB[m^3]
SRB	Polj. Srbija 6	2880	Key\Demand parameters\Irrigation specific demand SRB[m^3]
SRB	Polj. Srbija 7	720	Key\Demand parameters\Irrigation specific demand SRB[m^3]

Appendix C: Rivers – Headflow

Table C-1: Rivers in Drina WRM model and assigned headflow.

River	Headflow expressions
Reka Cehotina	0
Reka Tara	ReadFromFile(HydrolModel\HP9024-Matesevo.csv, 13)+ReadFromFile(HydrolModel\HP9024-Matesevo.csv, 14)
Reka Piva	0
Reka Lim	ReadFromFile(HydrolModel\HP9060-Grncar.csv, 11)+ReadFromFile(HydrolModel\HP9060-Grncar.csv, 12)
Reka Sutjeska	ReadFromFile(HydrolModel\HP9114-Igoce.csv, 11)+ReadFromFile(HydrolModel\HP9114-Igoce.csv, 12)
Reka Uvac	0
Drina	0
Reka Bistrica	ReadFromFile(HydrolModel\HP9115-Oplazici.csv, 13)+ReadFromFile(HydrolModel\HP9115-Oplazici.csv, 14)
Reka Janja	0
Reka Praca	0
Reka Rakitnica	0
Reka Drinjaca	0
Reka Rzav	ReadFromFile(HydrolModel\HP9067-Kruscica.csv, 11)+ReadFromFile(HydrolModel\HP9067-Kruscica.csv, 12)
Reka Crni Rzav	0
Reka Jadar	0
Reka Bjelava	0
Reka Komarnica	0

Appendix D: Reservoirs

Table D-1: Reservoirs in Drina WRM model.

River	Reservoir	Startup year	Storage Capacity (Million m^3)	Initial Storage (Million m^3)	Max. Turbine Flow (m^3/s)	Tailwater Elevation (m)	Generating Efficiency (%)	Hydropower Priority	Priority
Cehotina	Ak. Otilovici	existing	13	13	Step(1962,0, 2022,9)	Step(1962,0, 2022,798)	Step(1962,0, 2022,85)	Step(1962,0, 2022,2)	
Cehotina	Ak. Vikoc	2043	105		45	487.6	87		
Komarnica	Ak. Komarnica	2034	160		130	664.6	87		98
Piva	Ak. Piva*[3]	existing	742.3	742.3	240	*[1]	90	99	
Piva	Ak. Krusevo	2028	18		240	439	91		
Sutjeska	Ak. Sutjeska	2022	42.3		2	*[2]	85	1	2
Lim	Ak. Andrijevica	2037	82		100	770	87		
Lim	Ak. Lukin Vir	2047	12		100	720.5	85		
Lim	Ak. Brodarevo 2	2047	7.21		150	460.94	83		
Lim	Ak. Potpec	existing	19.8	19.8	165	398	84		
Lim	Ak. Mrsovo	2040	7.7		260	338.7	89		
Uvac	Ak. Uvac	existing	160	160	43	890.5	88		2
Uvac	Ak. Kokin Brod	existing	209	209	37.4	812.5	80		2
Uvac	Ak. Radoinja	existing	4.1	4.1					1
Drina	Ak. Buk Bijela	2022	11		350	405	85		
Drina	Ak. Foca	2022	4.6		350	389.3	95		
Drina	Ak. Visegrad	existing	105	105	800	291.6	96		
Drina	Ak. Bajina Basta	existing	218	218	644	224.9	89		
Drina	Ak. Zvornik	existing	21.32	21.32	620	137	78		
Drina	Ak. Kozluk	2025	15		800	122.1	92		
Crni Rzav	Ak. Ribnica	existing	3.5	3.5					
Rzav	Ak. Zaovine	existing	153	153					
Janja	Ak. Snijeznica	existing	18.264	18.264					

*[1] If(PrevTSValue(Storage Elevation[m])-492.61>=162, PrevTSValue(Storage Elevation[m])-162, 492.61)

*[2] If(PrevTSValue(Storage Elevation[m])-451.5>=66,PrevTSValue(Storage Elevation[m])-66,451.5)

*[3] Energy demand for Ak. Piva: MonthlyValues(Jan, 80, Feb, 68, Mar, 73, Apr, 58, May, 28, Jun, 45, Jul, 68, Aug, 63, Sep, 58, Oct, 48, Nov, 78, Dec, 83). Source: [24].

Table D-2: Volume-elevation curves.*

River	Reservoir								
Cehotina	Ak. Otilovici	V (mill. m^3)	0	2.15	6	10.4	16	17	21.6
		Z (m)	822	825	830	835	840	841	845
Cehotina	Ak. Vikoc	V (mill. m^3)	0	105					
		Z (m)	540	574					
Piva	Ak. Piva	V (mill. m^3)	0	19.927	207.677	405.657	595.523	667.079	726.981
		Z (m)	595	600.1	630	650	665	670	674
		V (mill. m^3)	745.373	745.527	745.681	745.835	745.99	746.144	783.6
		Z (m)	675.2	675.21	675.22	675.23	675.24	675.25	677.7
Piva	Ak. Krusevo	V (mill. m^3)	0	18					
		Z (m)	475	495					
Komarnica	Ak. Komarnica	V (mill. m^3)	0	41	100	160			
		Z (m)	760	780	800	818			
Lim	Ak. Andrijevica	V (mill. m^3)	0	20	46.9	82			
		Z (m)	800	810	820	830			
Lim	Ak. Lukin Vir	V (mill. m^3)	0	12					
		Z (m)	730	740					
Lim	Ak. Potpec	V (mill. m^3)	0	1.34	7.54	18.4	19.8		
		Z (m)	423.6	425	430	435	435.6		
Lim	Ak. Mrsovo	V (mill. m^3)	0	7.7					
		Z (m)	347	355					
Lim	Ak. Brodarevo 2	V (mill. m^3)	0	721					
		Z (m)	478	488					
Sutjeska	Ak. Sutjeska	V (mill. m^3)	0	42.3					
		Z (m)	495	532					
Uvac	Ak. Uvac	V (mill. m^3)	0	20	46.6	82	128	160	
		Z (m)	940	950	960	970	980	988	
Uvac	Ak. Kokin Brod	V (mill. m^3)	0	14	52	102	166	210	
		Z (m)	845	850	860	870	880	885	
Uvac	Ak. Radoinja	V (mill. m^3)	0	1.53	4.1				
		Z (m)	805	808	812				
Drina	Ak. Visegrad	V (mill. m^3)	0	6	56	105			
		Z (m)	319	320	330	336			
Drina	Ak. Bajina Basta	V (mill. m^3)	0	21	111	218			
		Z (m)	267	270	280	290			
Drina	Ak. Zvornik	V (mill. m^3)	0	21.32					
		Z (m)	155	157.3					
Drina	Ak. Buk Bijela	V (mill. m^3)	0	11					
		Z (m)	420.5	434					
Drina	Ak. Foca	V (mill. m^3)	0	4.6					
		Z (m)	396	403					
Drina	Ak. Kozluk	V (mill. m^3)	0	15					
		Z (m)	129.5	135					
Janja	Ak. Snijeznica	V (mill. m^3)	0	18.264					
		Z (m)	275	298.5					
Rzav	Ak. Zaovine	V (mill. m^3)	0	153					
		Z (m)	815	880					

* Volume-elevation curve for the Ribnica reservor on the Crni Rzav River is not defined.

Appendix E: Run-of-river hydropower plants and diversions

Table E-1: Run-of-river hydropower plants.

River	Run of river HPP	Startup year	Max Turbine Flow (m^3/s)	Generating Efficiency (%)	Fixed Head (m)	Hydropower Priority	Energy Demand (GWh)
Lim	HE Brodarevo 1	2047	150	79	22.39		
Lim	HE Rekovici	2031	165	91	4.9		
Drina	HE Paunci	2022	450	89	10.98		
Drina	HE Ustikolina	2022	450	94	14.5		
Drina	HE Gorazde	2022	450	86	9.8		
Drina	HE Rogacica	2022	800	89	16.8		
Drina	HE Tegare	2025	800	89	17.4		
Drina	HE Dubravica	2025	800	89	12.51		
Drina	HE Drina 1	2050	800	92	12.8		
Drina	HE Drina 2	2050	800	92	12.21		
Drina	HE Drina 3	2050	800	92	15		
Deriv. Sutjeska	HE Sutjeska	2022	50	85	*[2]	99	*[3]
Deriv. Bistrica	HE Bistrica	postoji	36	81	*[1]	99	*[4]

*[1] PrevTSValue(Supply and Resources\River\Reka Uvac\Reservoirs\Ak. Radoinja:Storage Elevation[m])-452
*[2] PrevTSValue(Supply and Resources\River\Reka Sutjeska\Reservoirs\Ak. Sutjeska:Storage Elevation[m])-436
*[3] 0.9105642*ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)
*[4] 2.471555*ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)

Table E-2: Calculated tailwater elevation and energy demand for the derivation-type hydropower plants.

River	HPP	Normal operating elevation (m)	Net head (m)	Installed discharge (m^3/s)	Generating efficiency	Calculated tailwater elevation[1] (m)	Calculated daily energy demand[2] (GWh/day)
Deriv. Bistrica	HE Bistrica	812	360	36	0.81	452	2.471555
Deriv. Sutjeska	HE Sutjeska	527	91	50	0.85	436	0.9105642

[1] Calculated as: Normal operating elevation – Net Head.
[2] Calculated as: Generating Efficiency * Installed Discharge * Net Head * 9.81 * 24 * 10^{-6}.

Table E-3: Diversions.

Diversion	Scenario	Startup year	Maximum Diversion (m^3/s)
Deriv. Bistrica	Current Accounts, all scenarios	existing	36
Deriv. Sutjeska	Full HPP	2022	50

Appendix F: Flow requirements

Table F-1: Flow requirements defined as the recommended minimum environmental flows in IWRM country reports.

River	Node	Minimum environmental flow (m^3/s)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tara	Gornja Tara EF*	2.33	1.1	3.17	5.01	3.05	1.1	1.1	1.1	1.1	1.1	2.96	3.73
Tara	Donja Tara EF*	13.7	13.7	13.7	28.8	32.2	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Piva	Ak. Krusevo EF	12.7	12.7	12.7	29.2	30.2	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Sutjeska	Ak. Sutjeska EF	2.07											
Bistrica	Bistrica EF*	1.4											
Cehotina	Ak. Otilovici EF	0.8											
Cehotina	Ak. Vikoc EF	2.5											
Lim	Gornji Lim EF*	3.57	3.57	3.57	3.57	8.15	3.57	3.57	3.57	3.57	3.57	3.57	3.57
Lim	Ak. Andrijevica EF	3.57	3.57	3.57	3.57	8.15	3.57	3.57	3.57	3.57	3.57	3.57	3.57
Lim	Ak. Lukin Vir EF	4.9											
Lim	HE Brodarevo 1 EF	10.4											
Lim	Ak. Brodarevo 2 EF	10.4											
Lim	Ak. Potpec EF	13.9											
Lim	HE Rekovici EF	18.2											
Lim	Ak. Mrsovo EF	31.3											
Uvac	Ak. Radoinja EF	1.4											
Crni Rzav	Ak. Ribnica EF	0.025											
Rzav	Ak. Zaovine EF	0.05											
Janja	Ak. Snijeznica EF	0.03											
Jadar	Gornji Jadar EF*	0.31											
Jadar	Donji Jadar EF*	0.83											
Drina	Ak. Buk Bijela EF	24.5	24.5	24.5	24.5	16.5	16.5	16.5	16.5	16.5	16.5	24.5	24.5
Drina	Ak. Foca EF	27	27	27	27	18	18	18	18	18	18	27	27
Drina	HE Paunci EF	30.5	30.5	30.5	30.5	20	20	20	20	20	20	30.5	30.5
Drina	HE Ustikolina EF	57	57	57	57	38	38	38	38	38	38	57	57
Drina	HE Gorazde EF	57	57	57	57	38	38	38	38	38	38	57	57
Drina	Ak. Visegrad EF	50											
Drina	Ak. Bajina Basta EF	50											
Drina	HE Rogacica EF	50	50	50	50	33.5	33.5	33.5	33.5	33.5	33.5	50	50
Drina	HE Tegare EF	50	50	50	50	33.5	33.5	33.5	33.5	33.5	33.5	50	50
Drina	HE Dubravica EF	51	51	51	51	34	34	34	34	34	34	51	51
Drina	Ak. Zvornik EF	60											
Drina	Ak. Kozluk EF	55	55	55	55	37	37	37	37	37	37	55	55
Drina	HE Drina 1 EF	55	55	55	55	37	37	37	37	37	37	55	55
Drina	HE Drina 2 EF	56	56	56	56	37.5	37.5	37.5	37.5	37.5	37.5	56	56
Drina	HE Drina 3 EF	56.5	56.5	56.5	56.5	37.5	37.5	37.5	37.5	37.5	37.5	56.5	56.5

Source: IWRM country reports

* Upstream of all reservoirs in all development scenarios

Table F-2: Flow requirements with the greater environmental flows along the Drina River.

River	**Node name**	**Minimum environmental flow (m^3/s)**											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tara	Gornja Tara EF*	2.33	1.1	3.17	5.01	3.05	1.1	1.1	1.1	1.1	1.1	2.96	3.73
Tara	Donja Tara EF*	13.7	13.7	13.7	28.8	32.2	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Piva	Ak. Krusevo EF	12.7	12.7	12.7	29.2	30.2	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Sutjeska	Ak. Sutjeska EF	2.07											
Bistrica	Bistrica EF*	1.4											
Cehotina	Ak. Otilovici EF	0.8											
Cehotina	Ak. Vikoc EF	2.5											
Lim	Gornji Lim EF*	3.57	3.57	3.57	3.57	8.15	3.57	3.57	3.57	3.57	3.57	3.57	3.57
Lim	Ak. Andrijevica EF	3.57	3.57	3.57	3.57	8.15	3.57	3.57	3.57	3.57	3.57	3.57	3.57
Lim	Ak. Lukin Vir EF	4.9											
Lim	HE Brodarevo 1 EF	10.4											
Lim	Ak. Brodarevo 2 EF	10.4											
Lim	Ak. Potpec EF	13.9											
Lim	HE Rekovici EF	18.2											
Lim	Ak. Mrsovo EF	31.3											
Uvac	Ak. Radoinja EF	1.4											
Crni Rzav	Ak. Ribnica EF	0.025											
Rzav	Ak. Zaovine EF	0.05											
Janja	Ak. Snijeznica EF	0.03											
Jadar	Gornji Jadar EF*	0.31											
Jadar	Donji Jadar EF*	0.83											
Drina	Ak. Buk Bijela EF	**24.4**											
Drina	Ak. Foca EF	**27.0**											
Drina	HE Paunci EF	**30.2**											
Drina	HE Ustikolina EF	57	57	57	57	38	38	38	38	38	38	57	57
Drina	HE Gorazde EF	57	57	57	57	38	38	38	38	38	38	57	57
Drina	Ak. Visegrad EF	50											
Drina	Ak. Bajina Basta EF	50											
Drina	HE Rogacica EF	**60.5**											
Drina	HE Tegare EF	**61.6**											
Drina	HE Dubravica EF	**63.8**											
Drina	Ak. Zvornik EF	60											
Drina	Ak. Kozluk EF	__57.5 (67.5**)__											
Drina	HE Drina 1 EF	__57.5 (67.5**)__											
Drina	HE Drina 2 EF	__60.0 (67.5**)__											
Drina	HE Drina 3 EF	__60.0 (67.5**)__											

Source: IWRM country reports
* upstream of all reservoirs in all development scenarios
** values updated in May 2017 according to data given by the BiH Focal Point.

Table F-3: Flow requirements in the Drina WRM model in WEAP.

River	Node	Scenario	Flow requirement (m^3/s)	Priority
Tara	Gornja Tara EF*	all	MonthlyValues(Jan, 2.33, Feb, 1.1, Mar, 3.17, Apr, 5.01, May, 3.05, Jun, 1.1, Jul, 1.1, Aug, 1.1, Sep, 1.1, Oct, 1.1, Nov, 2.96, Dec, 3.73)	
Tara	Donja Tara EF*	all	MonthlyValues(Jan, 13.7, Feb, 13.7, Mar, 13.7, Apr, 28.8, May, 32.2, Jun, 13.7, Jul, 13.7, Aug, 13.7, Sep, 13.7, Oct, 13.7, Nov, 13.7, Dec, 13.7)	
Piva	Ak. Krusevo EF	all	MonthlyValues(Jan, 12.7, Feb, 12.7, Mar, 12.7, Apr, 29.2, May, 30.2, Jun, 12.7, Jul, 12.7, Aug, 12.7, Sep, 12.7, Oct, 12.7, Nov, 12.7, Dec, 12.7)	
Sutjeska	Ak. Sutjeska EF	Full HPP	If(Year >= 2022, 2.07, 0)	
Bistrica	Bistrica EF*	all	1.4	
Cehotina	Ak. Otilovici EF	all	0.8	
Cehotina	Ak. Vikoc EF	Full HPP	If(Year >= 2043, 2.5, 0)	
Lim	Gornji Lim EF*	all	MonthlyValues(Jan, 3.6, Feb, 3.6, Mar, 3.6, Apr, 3.6, May, 8.2, Jun, 3.6, Jul, 3.6, Aug, 3.6, Sep, 3.6, Oct, 3.6, Nov, 3.6, Dec, 3.6)	
Lim	Ak. Andrijevica EF	Full HPP	If(Year >= 2037, MonthlyValues(Jan, 3.57, Feb, 3.57, Mar, 3.57, Apr, 3.57, May, 8.15, Jun, 3.57, Jul, 3.57, Aug, 3.57, Sep, 3.57, Oct, 3.57, Nov, 3.57, Dec, 3.57), 0)	
Lim	Ak. Lukin Vir EF	Full HPP	If(Year >= 2047, 4.9, 0)	
Lim	HE Brodarevo 1 EF	Middle 1, 2, 3, Full HPP	If(Year >= 2047, 10.4, 0)	99
Lim	Ak. Brodarevo 2 EF	Full HPP	If(Year >= 2047, 10.4, 0)	
Lim	Ak. Potpec EF	all	13.9	
Lim	HE Rekovici EF	Middle 1, 2, 3, Full HPP	If(Year >= 2031, 18.2, 0)	
Lim	Ak. Mrsovo EF	Middle 1, 2, 3, Full HPP	If(Year >= 2040, 31.3, 0)	
Uvac	Ak. Radoinja EF	all	1.4	
Crni Rzav	Ak. Ribnica EF	all	0.025	
Rzav	Ak. Zaovine EF	all	0.05	
Janja	Ak. Snijeznica EF	all	0.03	
Jadar	Gornji Jadar EF*	all	0.31	
Jadar	Donji Jadar EF*	all	0.83	
Drina	Ak. Buk Bijela EF	Middle 1, 2, 3, Full HPP	If(Year >= 2022, MonthlyValues(Jan, 24.5, Feb, 24.5, Mar, 24.5, Apr, 24.5, May, 16.5, Jun, 16.5, Jul, 16.5, Aug, 16.5, Sep, 16.5, Oct, 16.5, Nov, 24.5, Dec, 24.5), 0)	
Drina	Ak. Foca EF	Middle 1, 2, 3, Full HPP	If(Year >= 2022, MonthlyValues(Jan, 27, Feb, 27, Mar, 27, Apr, 27, May, 18, Jun, 18, Jul, 18, Aug, 18, Sep, 18, Oct, 18, Nov, 27, Dec, 27), 0)	
Drina	HE Paunci EF	Middle 2, 3, Full HPP	If(Year >= 2022, MonthlyValues(Jan, 30.5, Feb, 30.5, Mar, 30.5, Apr, 30.5, May, 20, Jun, 20, Jul, 20, Aug, 20, Sep, 20, Oct, 20, Nov, 30.5, Dec, 30.5), 0)	
Drina	HE Ustikolina EF	Middle 1, 2, 3, Full HPP	If(Year >= 2022, MonthlyValues(Jan, 57, Feb, 57, Mar, 57, Apr, 57, May, 38, Jun, 38, Jul, 38, Aug, 38, Sep, 38, Oct, 38, Nov, 57, Dec, 57), 0)	
Drina	HE Gorazde EF	Middle 2, 3, Full HPP	If(Year >= 2022, MonthlyValues(Jan, 57, Feb, 57, Mar, 57, Apr, 57, May, 38, Jun, 38, Jul, 38, Aug, 38, Sep, 38, Oct, 38, Nov, 57, Dec, 57), 0)	
Drina	Ak. Visegrad EF	all	50	
Drina	Ak. Bajina Basta EF	all	50	
Drina	HE Rogacica EF	Middle 3, Full HPP	If(Year >= 2022, MonthlyValues(Jan, 50, Feb, 50, Mar, 50, Apr, 50, May, 33.5, Jun, 33.5, Jul, 33.5, Aug, 33.5, Sep, 33.5, Oct, 33.5, Nov, 50, Dec, 50), 0)	
Drina	HE Tegare EF	Middle 3, Full HPP	If(Year >= 2025, MonthlyValues(Jan, 50, Feb, 50, Mar, 50, Apr, 50, May, 33.5, Jun, 33.5, Jul, 33.5, Aug, 33.5, Sep, 33.5, Oct, 33.5, Nov, 50, Dec, 50), 0)	
Drina	HE Dubravica EF	Middle 2, 3, Full HPP	If(Year >= 2025, MonthlyValues(Jan, 51, Feb, 51, Mar, 51, Apr, 51, May, 34, Jun, 34, Jul, 34, Aug, 34, Sep, 34, Oct, 34, Nov, 51, Dec, 51), 0)	
Drina	Ak. Zvornik EF	all	60	
Drina	Ak. Kozluk EF	Middle 3, Full HPP	If(Year >= 2025, MonthlyValues(Jan, 55, Feb, 55, Mar, 55, Apr, 55, May, 37, Jun, 37, Jul, 37, Aug, 37, Sep, 37, Oct, 37, Nov, 55, Dec, 55), 0)	
Drina	HE Drina 1 EF	Full HPP	If(Year >= 2050, MonthlyValues(Jan, 55, Feb, 55, Mar, 55, Apr, 55, May, 37, Jun, 37, Jul, 37, Aug, 37, Sep, 37, Oct, 37, Nov, 55, Dec, 55), 0)	
Drina	HE Drina 2 EF	Full HPP	If(Year >= 2050, MonthlyValues(Jan, 56, Feb, 56, Mar, 56, Apr, 56, May, 37.5, Jun, 37.5, Jul, 37.5, Aug, 37.5, Sep, 37.5, Oct, 37.5, Nov, 56, Dec, 56), 0)	
Drina	HE Drina 3 EF	Full HPP	If(Year >= 2050, MonthlyValues(Jan, 56.5, Feb, 56.5, Mar, 56.5, Apr, 56.5, May, 37.5, Jun, 37.5, Jul, 37.5, Aug, 37.5, Sep, 37.5, Oct, 37.5, Nov, 56.5, Dec, 56.5), 0)	

Appendix G: River reaches

Table G-1: Surface and groundwater inflows to reaches – links to hydrologic model outputs.

River	Reach	WEAP variables		
		Surface Water Inflow (m^3/s)	Groundwater Inflow (Million m^3)	Groundwater Outflow (%)
Komarnica	Below Reka Komarnica Headflow	ReadFromFile(HydrolModel\HP9061-Duski Most.csv, 11)	ReadFromFile(HydrolModel\HP9061-Duski Most.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Komarnica	Below Savnik Return	ReadFromFile(HydrolModel\HP9018-Komarnica.csv, 11)+ ReadFromFile(HydrolModel\HP9018-Komarnica.csv, 12)		
Komarnica	Below Ak. Komarnica	ReadFromFile(HydrolModel\HP9017-Piva.csv, 11)	ReadFromFile(HydrolModel\HP9017-Piva.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Piva	Below Ak. Krusevo EF	ReadFromFile(HydrolModel\HP9130-Scepan Polje (Piva).csv, 11)+ ReadFromFile(HydrolModel\HP9130-Scepan Polje (Piva).csv, 12)		
Tara	Below Gornja Tara EF	ReadFromFile(HydrolModel\HP9023-Zuti Krs.csv, 11)+ReadFromFile(HydrolModel\HP9022-Bakovica Klisura.csv, 11)+ ReadFromFile(HydrolModel\HP9120-Bakovici.csv, 11)+ ReadFromFile(HydrolModel\HP9121-Kolasin.csv, 11)+ ReadFromFile(HydrolModel\HP9021-Mojkovac.csv, 11)+ ReadFromFile(HydrolModel\HP9118-Podbisce.csv, 11)+ ReadFromFile(HydrolModel\HP9119-Usce Stitarice.csv, 11)+ ReadFromFile(HydrolModel\HP9117-Bistrica (Tara).csv, 11)	(ReadFromFile(HydrolModel\HP9023-Zuti Krs.csv, 12)+ ReadFromFile(HydrolModel\HP9022-Bakovica Klisura.csv, 12)+ ReadFromFile(HydrolModel\HP9120-Bakovici.csv, 12)+ ReadFromFile(HydrolModel\HP9121-Kolasin.csv, 12)+ ReadFromFile(HydrolModel\HP9021-Mojkovac.csv, 12)+ ReadFromFile(HydrolModel\HP9118-Podbisce.csv, 12)+ ReadFromFile(HydrolModel\HP9119-Usce Stitarice.csv, 12)+ ReadFromFile(HydrolModel\HP9117-Bistrica (Tara).csv, 12))* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Tara	Below Mojkovac i Kolasin Return	ReadFromFile(HydrolModel\HP9020-Ljutica.csv, 11)+ ReadFromFile(HydrolModel\HP9020-Ljutica.csv, 12)		
Tara	Below Zabljak Return	ReadFromFile(HydrolModel\HP9019-Tepca.csv, 11)+ ReadFromFile(HydrolModel\HP9129-Scepan Polje (Tara).csv, 11)+ ReadFromFile(HydrolModel\HP9129-Scepan Polje (Tara).csv, 12)	ReadFromFile(HydrolModel\HP9019-Tepca.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Tara	Below Reka Piva Inflow	ReadFromFile(HydrolModel\HP9116-Scepan Polje.csv, 11)+ ReadFromFile(HydrolModel\HP9116-Scepan Polje.csv, 12)		
Sutjeska	Below Reka Sutjeska Headflow	ReadFromFile(HydrolModel\HP9140-HE Sutjeska.csv, 11)+ ReadFromFile(HydrolModel\HP9140-HE Sutjeska.csv, 12)		
Cehotina	Below Reka Cehotina Headflow	ReadFromFile(HydrolModel\HP9030-Otilovici.csv, 11)+ ReadFromFile(HydrolModel\HP9030-Otilovici.csv, 12)		
Cehotina	Below Ak. Otilovici EF	ReadFromFile(HydrolModel\HP9084-Pljevlja.csv, 11)+ReadFromFile(HydrolModel\HP9084-Pljevlja.csv, 12)		
Cehotina	Below Pljevlja Return	ReadFromFile(HydrolModel\HP9029-Gradac.csv, 11)	ReadFromFile(HydrolModel\HP9029-Gradac.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Cehotina	Below Ak. Gradac	ReadFromFile(HydrolModel\HP9028-Mekote.csv, 11)+ ReadFromFile(HydrolModel\HP9028-Mekote.csv, 12)		
Cehotina	Below Ak. Mekote	ReadFromFile(HydrolModel\HP9026-Vikoc.csv, 11)+ ReadFromFile(HydrolModel\HP9026-Vikoc.csv, 12)		

River	Reach	WEAP variables		
		Surface Water Inflow (m^3/s)	Groundwater Inflow (Million m^3)	Groundwater Outflow (%)
Cehotina	Below Ak. Vikoc EF	ReadFromFile(HydrolModel\HP9059-Falovici.csv, 11)+ ReadFromFile(HydrolModel\HP9059-Falovici.csv, 12)		
Uvac	Below Reka Uvac Headflow	ReadFromFile(HydrolModel\HP9112-Cedovo.csv,11)	ReadFromFile(HydrolModel\HP9112-Cedovo.csv,12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Uvac	Below Sjenica Return	ReadFromFile(HydrolModel\HP9037-Sjenica.csv,11)+ ReadFromFile(HydrolModel\HP9037-Sjenica.csv,12)		
Uvac	Below Ak. Uvac	ReadFromFile(HydrolModel\HP9036-Kokin Brod.csv,11)	ReadFromFile(HydrolModel\HP9036-Kokin Brod.csv,12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Uvac	Below Ak. Kokin Brod	ReadFromFile(HydrolModel\HP9035-Radonja.csv, 11)+ ReadFromFile(HydrolModel\HP9035-Radonja.csv, 12)		
Uvac	Below Ak. Radoinja EF	ReadFromFile(HydrolModel\HP9066-Klak.csv, 11)+ ReadFromFile(HydrolModel\HP9066-Klak.csv, 12)+ ReadFromFile(HydrolModel\HP9085-Usce Uvca.csv, 11)+ ReadFromFile(HydrolModel\HP9085-Usce Uvca.csv, 12)		
Lim	Below Reka Lim Headflow	ReadFromFile(HydrolModel\HP9049-Plavsko jezero.csv, 11)	ReadFromFile(HydrolModel\HP9049-Plavsko jezero.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Gornji Lim EF	ReadFromFile(HydrolModel\HP9050-Djuricka Rijeka.csv, 11)+ ReadFromFile(HydrolModel\HP9095-Usce Komaracke Rijeke.csv, 11)+ ReadFromFile(HydrolModel\HP9094-Plav.csv, 11)+ ReadFromFile(HydrolModel\HP9094-Plav.csv, 12)	(ReadFromFile(HydrolModel\HP9050-Djuricka Rijeka.csv, 12)+ ReadFromFile(HydrolModel\HP9095-Usce Komaracke Rijeke.csv, 12))* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Plav Return	ReadFromFile(HydrolModel\HP9057-Andrijevica.csv, 11)+ ReadFromFile(HydrolModel\HP9057-Andrijevica.csv, 12)		
Lim	Below Ak. Andrijevica EF	ReadFromFile(HydrolModel\HP9048-Zlorecica.csv, 11)+ ReadFromFile(HydrolModel\HP9126-Usce Zlorecice.csv, 11)	(ReadFromFile(HydrolModel\HP9048-Zlorecica.csv, 12)+ ReadFromFile(HydrolModel\HP9126-Usce Zlorecice.csv, 12))* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Andrijevica Return	ReadFromFile(HydrolModel\HP9056-Lukin Vir.csv, 11)+ ReadFromFile(HydrolModel\HP9056-Lukin Vir.csv, 12)		
Lim	Below Ak. Lukin Vir EF	ReadFromFile(HydrolModel\HP9047-Trebacka.csv, 11)+ ReadFromFile(HydrolModel\HP9047-Trebacka.csv, 12)+ ReadFromFile(HydrolModel\HP9046-Sekularska rijeka.csv, 11)+ ReadFromFile(HydrolModel\HP9046-Sekularska rijeka.csv, 12)+ ReadFromFile(HydrolModel\HP9062-Usce Sekularske Rijeke.csv, 11)+ ReadFromFile(HydrolModel\HP9062-Usce Sekularske Rijeke.csv, 12)+ ReadFromFile(HydrolModel\HP9045-Kaludarska rijeka.csv, 11)+ ReadFromFile(HydrolModel\HP9045-Kaludarska rijeka.csv, 12)+ ReadFromFile(HydrolModel\HP9044-Beranska Bistrica.csv, 11)+ ReadFromFile(HydrolModel\HP9093-Usce Kaludarske Rijeke.csv, 11)+ ReadFromFile(HydrolModel\HP9093-Usce Kaludarske Rijeke.csv, 12)+ ReadFromFile(HydrolModel\HP9043-Ljesnica.csv, 11)+ ReadFromFile(HydrolModel\HP9043-Ljesnica.csv, 12)+ ReadFromFile(HydrolModel\HP9091-Bioce.csv, 11)	(ReadFromFile(HydrolModel\HP9044-Beranska Bistrica.csv, 12)+ ReadFromFile(HydrolModel\HP9091-Bioce.csv, 12))* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	

River	**Reach**	**WEAP variables**		
		Surface Water Inflow (m^3/s)	Groundwater Inflow (Million m^3)	Groundwater Outflow (%)
Lim	Below Berane Return	ReadFromFile(HydrolModel\HP9089-Zaton.csv, 11)+ ReadFromFile(HydrolModel\HP9089-Zaton.csv, 12)+ ReadFromFile(HydrolModel\HP9042-Ljubovidja.csv, 11)+ ReadFromFile(HydrolModel\HP9042-Ljubovidja.csv, 12)+ ReadFromFile(HydrolModel\HP9111-Ravna Rijeka.csv, 11)+ ReadFromFile(HydrolModel\HP9111-Ravna Rijeka.csv, 12)+ ReadFromFile(HydrolModel\HP9088-Bijelo Polje.csv, 11)+ ReadFromFile(HydrolModel\HP9088-Bijelo Polje.csv, 12)*0.73+ ReadFromFile(HydrolModel\HP9041-Bjelopoljska Bistrica.csv, 11)+ ReadFromFile(HydrolModel\HP9041-Bjelopoljska Bistrica.csv, 12)+ ReadFromFile(HydrolModel\HP9086-Gubavac.csv, 11)+ ReadFromFile(HydrolModel\HP9086-Gubavac.csv, 12)+ ReadFromFile(HydrolModel\HP9110-Dobrakovo.csv, 11)+ ReadFromFile(HydrolModel\HP9110-Dobrakovo.csv, 12)	(ReadFromFile(HydrolModel\HP9088-Bijelo Polje.csv, 12)*0.27)* FromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Bijelo Polje Return	ReadFromFile(HydrolModel\HP9040-Brodarevo 1.csv, 11)+ReadFromFile(HydrolModel\HP9040-Brodarevo 1.csv, 12)		
Lim	Below HE Brodarevo 1 EF	ReadFromFile(HydrolModel\HP9039-Brodarevo 2.csv, 11)+ReadFromFile(HydrolModel\HP9039-Brodarevo 2.csv, 12)		
Lim	Below Ak. Brodarevo 2 EF	ReadFromFile(HydrolModel\HP9038-Prijepolje.csv, 11)+ ReadFromFile(HydrolModel\HP9038-Prijepolje.csv, 12)		
Lim	Below Prijepolje Return	ReadFromFile(HydrolModel\HP9109-Prijepolje (Milesevka).csv, 11)+ ReadFromFile(HydrolModel\HP9108-Bistrica (na Bistrici).csv, 11)+ ReadFromFile(HydrolModel\HP9108-Bistrica (na Bistrici).csv, 12)+ ReadFromFile(HydrolModel\HP9123-Usce Bistrice.csv, 11)+ ReadFromFile(HydrolModel\HP9123-Usce Bistrice.csv, 12)	ReadFromFile(HydrolModel\HP9109-Prijepolje (Milesevka).csv,12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Deriv. Bistrica Inflow	ReadFromFile(HydrolModel\HP9034-Potpec.csv, 11)+ReadFromFile(HydrolModel\HP9034-Potpec.csv, 12)		
Lim	Below Ak. Potpec EF	ReadFromFile(HydrolModel\HP9033-Priboj.csv, 11)	ReadFromFile(HydrolModel\HP9033-Priboj.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Reka Uvac Inflow	ReadFromFile(HydrolModel\HP9107-Ustibar Most.csv, 11)+ ReadFromFile(HydrolModel\HP9107-Ustibar Most.csv, 12)+ ReadFromFile(HydrolModel\HP9032-Usce Poblacanice.csv, 11)+ ReadFromFile(HydrolModel\HP9032-Usce Poblacanice.csv, 12)+ ReadFromFile(HydrolModel\HP9106-HS Rudo.csv, 11)	ReadFromFile(HydrolModel\HP9106-HS Rudo.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Lim	Below Rudo Return	ReadFromFile(HydrolModel\HP9031-Mrsovo.csv, 11)+ ReadFromFile(HydrolModel\HP9031-Mrsovo.csv, 12)		
Lim	Below Ak. Mrsovo EF	ReadFromFile(HydrolModel\HP9105-Strgacina.csv, 11)+ ReadFromFile(HydrolModel\HP9105-Strgacina.csv, 12)+ ReadFromFile(HydrolModel\HP9104-Usce Radonje.csv, 11)+ ReadFromFile(HydrolModel\HP9104-Usce Radonje.csv, 12)		
Rakitnica	Below Rogatica Return	ReadFromFile(HydrolModel\HP9101-Rogatica.csv, 11)	ReadFromFile(HydrolModel\HP9101-Rogatica.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	

River	Reach	WEAP variables		
		Surface Water Inflow (m^3/s)	Groundwater Inflow (Million m^3)	Groundwater Outflow (%)
Praca	Below Sokolac Return	ReadFromFile(HydrolModel\HP9100-Mesici.csv, 11)	ReadFromFile(HydrolModel\HP9100-Mesici.csv, 12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Praca	Below Reka Rakitnica Inflow	ReadFromFile(HydrolModel\HP9103-Ustipraca.csv, 11)+ ReadFromFile(HydrolModel\HP9103-Ustipraca.csv, 12)		
Crni Rzav	Below Reka Crni Rzav Headflow	ReadFromFile(HydrolModel\HP9139-Zlatibor.csv, 11)+ ReadFromFile(HydrolModel\HP9139-Zlatibor.csv, 12)		
Rzav	Below Reka Rzav Headflow	ReadFromFile(HydrolModel\HP9053-Lazici.csv, 11)+ ReadFromFile(HydrolModel\HP9053-Lazici.csv, 12)+ ReadFromFile(HydrolModel\HP9068-Spajici.csv, 11)+ ReadFromFile(HydrolModel\HP9068-Spajici.csv, 12)		
Rzav	Below Ak. Zaovine EF	ReadFromFile(HydrolModel\HP9128-Usce Crnog Rzava.csv, 11)+ ReadFromFile(HydrolModel\HP9128-Usce Crnog Rzava.csv, 12)		
Rzav	Below Reka Crni Rzav Inflow	ReadFromFile(HydrolModel\HP9142-Usce Rzava.csv, 11)+ ReadFromFile(HydrolModel\HP9142-Usce Rzava.csv, 12)		
Drinjaca	Below Reka Drinjaca Headflow	ReadFromFile(HydrolModel\HP9099-Sekovici.csv, 11)	ReadFromFile(HydrolModel\HP9099-Sekovici.csv, 12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drinjaca	Below Vlasenica i Sekovici Return	ReadFromFile(HydrolModel\HP9064-Drinjaca.csv, 11)	ReadFromFile(HydrolModel\HP9064-Drinjaca.csv, 12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Jadar	Below Reka Jadar Headflow	ReadFromFile(HydrolModel\HP9098-Zavlaka.csv, 11)	ReadFromFile(HydrolModel\HP9098-Zavlaka.csv, 12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Jadar	Below Krupanj Return	ReadFromFile(HydrolModel\HP9074-Lesnica.csv, 11)	ReadFromFile(HydrolModel\HP9074-Lesnica.csv, 12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Janja	Below Reka Janja Headflow	ReadFromFile(HydrolModel\HP9063-Snijeznica.csv, 11)+ ReadFromFile(HydrolModel\HP9063-Snijeznica.csv, 12)		
Janja	Below EF Ak. Snijeznica	ReadFromFile(HydrolModel\HP9097-Ugljevik.csv, 11)	ReadFromFile(HydrolModel\HP9097-Ugljevik.csv, 12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Reka Tara Inflow	ReadFromFile(HydrolModel\HP9081-Bastasi.csv, 11)+ ReadFromFile(HydrolModel\HP9081-Bastasi.csv, 12)		
Drina	Below Reka Sutjeska Inflow	ReadFromFile(HydrolModel\HP9016-Buk Bijela.csv, 11)+ ReadFromFile(HydrolModel\HP9016-Buk Bijela.csv, 12)		
Drina	Below Ak. Buk Bijela EF	ReadFromFile(HydrolModel\HP9015-Foca.csv,11)	ReadFromFile(HydrolModel\HP9015-Foca.csv,12)* ReadFrom-File(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Reka Cehotina Inflow	ReadFromFile(HydrolModel\HP9080-Foca Most.csv,11)+ReadFromFile(HydrolModel\HP9080-Foca Most.csv,12)		
Drina	Below Deriv. Falovici Inflow	ReadFromFile(HydrolModel\HP9014-Paunici.csv,11)+ ReadFromFile(HydrolModel\HP9014-Paunici.csv,12)		
Drina	Below HE Paunci EF	ReadFromFile(HydrolModel\HP9013-Ustikolina.csv,11)+ ReadFrom-File(HydrolModel\HP9013-Ustikolina.csv,12)		
Drina	Below HE Ustikolina EF	ReadFromFile(HydrolModel\HP9012-Sadba.csv, 11)+ ReadFromFile(HydrolModel\HP9012-Sadba.csv, 12)		

River	**Reach**	**WEAP variables**		
		Surface Water Inflow (m^3/s)	Groundwater Inflow (Million m^3)	Groundwater Outflow (%)
Drina	Below HE Gorazde EF	ReadFromFile(HydrolModel\HP9011-Gorazde.csv, 11)	ReadFromFile(HydrolModel\HP9011-Gorazde.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Cajnice Return	ReadFromFile(HydrolModel\HP9079-Usce Lima.csv, 11)	ReadFromFile(HydrolModel\HP9079-Usce Lima.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Reka Lim Inflow	ReadFromFile(HydrolModel\HP9010-Visegrad.csv, 11)+ ReadFromFile(HydrolModel\HP9010-Visegrad.csv, 12)		
Drina	Below Reka Rzav Inflow	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv,11)*0.03	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv, 12)*0.03* FromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Visegrad Return	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv,11)*0.06	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv, 12)*0.06* FromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Han Pijesak Return	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv,11)*0.91+ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv,12)*0.91		
Drina	Below Ak. Bajina Basta EF	ReadFromFile(HydrolModel\HP9052-HS Bajina Basta.csv, 11)+ ReadFromFile(HydrolModel\HP9052-HS Bajina Basta.csv, 12)		
Drina	Below Bajina Basta Return	ReadFromFile(HydrolModel\HP9138-Crvica.csv,11)+ ReadFromFile(HydrolModel\HP9008-Rogacica.csv,11)+ ReadFromFile(HydrolModel\HP9008-Rogacica.csv,12)	ReadFromFile(HydrolModel\HP9138-Crvica.csv,12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below HE Rogacica EF	ReadFromFile(HydrolModel\HP9137-Zlijebac.csv, 11)+ ReadFromFile(HydrolModel\HP9137-Zlijebac.csv, 12)+ ReadFromFile(HydrolModel\HP9007-Tegare.csv, 11)+ ReadFromFile(HydrolModel\HP9007-Tegare.csv, 12)		
Drina	Below HE Tegare EF	ReadFromFile(HydrolModel\HP9065-Ljubovidja.csv, 11) + ReadFromFile(HydrolModel\HP9065-Ljubovidja.csv, 12) + ReadFromFile(HydrolModel\HP9141-Usce Ljubovidje.csv, 11)	ReadFromFile(HydrolModel\HP9141-Usce Ljubovidje.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Srebrenica i Bratunac Return	ReadFromFile(HydrolModel\HP9006-Dubravica.csv,11)+ ReadFromFile(HydrolModel\HP9006-Dubravica.csv,12)*0.35	ReadFromFile(HydrolModel\HP9006-Dubravica.csv,12)*0.65* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below HE Dubravica EF	ReadFromFile(HydrolModel\HP9076-Kuslat.csv, 11)+ ReadFromFile(HydrolModel\HP9076-Kuslat.csv, 12)		
Drina	Below Reka Drinjaca Inflow	ReadFromFile(HydrolModel\HP9005-Zvornik.csv,11)+ReadFromFile(HydrolModel\HP9005-Zvornik.csv,12)		
Drina	Below Ak. Zvornik EF	ReadFromFile(HydrolModel\HP9075-Radalj.csv, 11)*0.73	(ReadFromFile(HydrolModel\HP9075-Radalj.csv, 12)*0.73)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	0.04 (Izv. Zvornik)
Drina	Below Zvornik Return	ReadFromFile(HydrolModel\HP9075-Radalj.csv, 11)*0.27	ReadFromFile(HydrolModel\HP9075-Radalj.csv, 12)*0.27* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	
Drina	Below Tvornica glinice Birac Return	ReadFromFile(HydrolModel\HP9004-Kozluk.csv, 11)+ ReadFromFile(HydrolModel\HP9004-Kozluk.csv, 12)		
Drina	Below Ak. Kozluk EF	ReadFromFile(HydrolModel\HP9051-Drina 0.csv, 11)	ReadFromFile(HydrolModel\HP9051-Drina 0.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	0.04 (Izv. Loznica)

River	**Reach**	**WEAP variables**		
		Surface Water Inflow (m^3/s)	Groundwater Inflow (Million m^3)	Groundwater Outflow (%)
Drina	Below Loznica Return	ReadFromFile(HydrolModel\HP9003-Drina I.csv,11)+ ReadFromFile(HydrolModel\HP9003-Drina I.csv,12)		
Drina	Below HE Drina 1 EF	ReadFromFile(HydrolModel\HP9125-Usce Janje.csv, 11)+ ReadFromFile(HydrolModel\HP9125-Usce Janje.csv, 12)		
Drina	Below Reka Janja Inflow	ReadFromFile(HydrolModel\HP9073-Usce Jadra.csv,11)+ ReadFromFile(HydrolModel\HP9073-Usce Jadra.csv,12)		
Drina	Below Reka Jadar Inflow	ReadFromFile(HydrolModel\HP9002-Drina II.csv, 11)+ ReadFromFile(HydrolModel\HP9002-Drina II.csv, 12)		
Drina	Below HE Drina 2	ReadFromFile(HydrolModel\HP9072-Badovinci.csv, 11)+ ReadFromFile(HydrolModel\HP9072-Badovinci.csv, 12)		
Drina	Below AD Sava Return	ReadFromFile(HydrolModel\HP9001-Drina III.csv, 11)	ReadFromFile(HydrolModel\HP9001-Drina III.csv, 12)* ReadFromFile(HydrolModel\BrojDanaUMesecu.csv)*24*3600/1000000	0.01 (Izv. Bijeljina)
Drina	Below HE Drina 3 EF	ReadFromFile(HydrolModel\HP9000-Usce Drine.csv,11)+ ReadFromFile(HydrolModel\HP9000-Usce Drine.csv,12)		

Appendix H: Groundwater

Table H-1: Groundwater nodes in Drina WRM model.

Groundwater node	Natural Recharge (million m^3)
Izv. Pljevlja	ReadFromFile(HydrolModel\HP9029-Gradac.csv, 8)*(5+494.955)/1000
Izv. Mojkovac i Kolasin	(ReadFromFile(HydrolModel\HP9023-Zuti Krs.csv, 8)*48.445+ ReadFromFile(HydrolModel\HP9121-Kolasin.csv, 8)*87.140+ ReadFromFile(HydrolModel\HP9120-Bakovici.csv, 8)*91.175+ ReadFromFile(HydrolModel\HP9022-Bakovica Klisura.csv, 8)*14.530+ ReadFromFile(HydrolModel\HP9021-Mojkovac.csv, 8)*39.705+ ReadFromFile(HydrolModel\HP9118-Podbisce.csv, 8)*38.865+ ReadFromFile(HydrolModel\HP9119-Usce Stitarice.csv, 8)*10.295+ ReadFromFile(HydrolModel\HP9117-Bistrica (Tara).csv, 8)*177.605)/1000*1.005
Izv. Zabljak	ReadFromFile(HydrolModel\HP9019-Tepca.csv, 8)*443.350/1000
Izv. Pluzine	ReadFromFile(HydrolModel\HP9017-Piva.csv, 8)*511.220/1000
Izv. Savnik	ReadFromFile(HydrolModel\HP9061-Duski Most.csv, 8)*597.170/1000
Izv. Plav i Murino	(ReadFromFile(HydrolModel\HP9049-Plavsko jezero.csv, 8)*197.715+ ReadFromFile(HydrolModel\HP9050-Djuricka Rijeka.csv, 8)*47.445+ ReadFromFile(HydrolModel\HP9095-Usce Komaracke Rijeke.csv, 8)*96.0845)/1000
Izv. Andrijevica	(ReadFromFile(HydrolModel\HP9048-Zlorecica.csv,8)*157.605+ ReadFromFile(HydrolModel\HP9126-Usce Zlorecice.csv,8)*22.975)/1000
Izv. Berane	(ReadFromFile(HydrolModel\HP9044-Beranska Bistrica.csv, 8)*122.040+ ReadFromFile(HydrolModel\HP9091-Bioce.csv, 8)*(131.365+5))/1000
Izv. Bijelo Polje	(ReadFromFile(HydrolModel\HP9088-Bijelo Polje.csv, "Wperc[mm]")*(110.625*0.27+8))/1000
Izv. Foca	ReadFromFile(HydrolModel\HP9015-Foca.csv, 8)*114.415/1000
Izv. Cajnice	ReadFromFile(HydrolModel\HP9079-Usce Lima.csv, "Wperc[mm]")*259.56/1000
Izv. Gorazde	ReadFromFile(HydrolModel\HP9011-Gorazde.csv, "Wperc[mm]")*(129.905+22)/1000
Izv. Bijeljina	ReadFromFile(HydrolModel\HP9001-Drina III.csv, "Wperc[mm]")*74.055/1000
Izv. Rogatica	ReadFromFile(HydrolModel\HP9101-Rogatica.csv, "Wperc[mm]")*334.47/1000
Izv. Sokolac	ReadFromFile(HydrolModel\HP9100-Mesici.csv, "Wperc[mm]")*770.75/1000
Izv. Han Pijesak	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv, "Wperc[mm]")*50/1000
Izv. Srebrenica i Bratunac	ReadFromFile(HydrolModel\HP9006-Dubravica.csv, "Wperc[mm]")*299.55*0.7/1000
Izv. Milici	ReadFromFile(HydrolModel\HP9064-Drinjaca.csv, "Wperc[mm]")*710.15/1000
Izv. Kladanj i Vlasenica i Sekovici	ReadFromFile(HydrolModel\HP9099-Sekovici.csv, "Wperc[mm]")*(12+401.64)/1000
Izv. Zvornik	ReadFromFile(HydrolModel\HP9075-Radalj.csv, "Wperc[mm]")*253.8*0.73/1000
Izv. Ugljevik i Lopare	ReadFromFile(HydrolModel\HP9097-Ugljevik.csv, "Wperc[mm]")*171.14/1000
Izv. Rudo	ReadFromFile(HydrolModel\HP9106-HS Rudo.csv, "Wperc[mm]")*52.625/1000
Izv. Visegrad	ReadFromFile(HydrolModel\HP9009-Bajina Basta.csv, "Wperc[mm]")*25/1000
Izv. Prijepolje	ReadFromFile(HydrolModel\HP9109-Prijepolje (Milesevka).csv, "Wperc[mm]")*150.66/1000
Izv. Nova Varos	ReadFromFile(HydrolModel\HP9036-Kokin Brod.csv, "Wperc[mm]")*211/1000
Izv. Priboj	ReadFromFile(HydrolModel\HP9033-Priboj.csv, "Wperc[mm]")*56.62/1000
Izv. Bajina Basta	ReadFromFile(HydrolModel\HP9138-Crvica.csv, "Wperc[mm]")*116/1000
Izv. Ljubovija	ReadFromFile(HydrolModel\HP9141-Usce Ljubovidje.csv, "Wperc[mm]")*189.33/1000
Izv. Krupanj	ReadFromFile(HydrolModel\HP9074-Lesnica.csv, "Wperc[mm]")*605/1000
Izv. Osecina	ReadFromFile(HydrolModel\HP9098-Zavlaka.csv, "Wperc[mm]")*277.5/1000
Izv. Loznica	ReadFromFile(HydrolModel\HP9051-Drina 0.csv, "Wperc[mm]")*91.94/1000
Izv. Mali Zvornik	ReadFromFile(HydrolModel\HP9075-Radalj.csv, "Wperc[mm]")*253.8*0.27/1000
Izv. Sjenica	ReadFromFile(HydrolModel\HP9112-Cedovo.csv, "Wperc[mm]")*724.9/1000

Appendix I: Transmission links and return flows

Table I-1: Transmission links parameters in Drina WRM model.

Transmission link To	Transmission link From	Variable	Unit	Value
to Pljevlja	from Ak. Otilovici	Maximum Flow Volume	L/s	80
to Pljevlja	from Ak. Otilovici	Supply Preference		2
to Cajetina i Zlatibor	from Ak. Ribnica	Maximum Flow Volume	m^3/s	0.15
to Ind. Ljubovija	from Withdrawal Node 12	Maximum Flow Volume	m^3/yr	144000
to Ind. Ljubovija	from Izv. Ljubovija	Supply Preference		2

Table I-2: Return flow variables in the Drina WRM model.

Return Link From	To Groundwater	Loss to Groundwater (%)
Pljevlja	Izv. Pljevlja	46
Mojkovac i Kolasin	Izv. Mojkovac i Kolasin	77
Zabljak	Izv. Zabljak	77
Savnik	Izv. Savnik	86
Pluzine	Izv. Pluzine	79
Plav	Izv. Plav	66
Andrijevica	Izv. Andrijevica	89
Berane	Izv. Berane	67.5
Bijelo Polje	Izv. Bijelo Polje	37
Foca	Izv. Foca	73
Gorazde	Izv. Gorazde	25.22
Visegrad	Izv. Visegrad	63.1
Srebrenica i Bratunac	Izv. Srebrenica i Bratunac	32
Rogatica	Izv. Rogatica	35
Vlasenica i Sekovici	Izv. Kladanj i Vlasenica i Sekovici	56
Milici	Izv. Milici	74
Zvornik	Izv. Zvornik	47
Bijeljina	Izv. Bijeljina	70
Ugljevik i Lopare	Izv. Ugljevik i Lopare	63.2
Cajnice	Izv. Cajnice	17
Han Pijesak	Izv. Han Pijesak	32.7
Rudo	Izv. Rudo	61
Sokolac	Izv. Sokolac	74.6
Kladanj	Izv. Kladanj i Vlasenica i Sekovici	5.7
Loznica	Izv. Loznica	67.5
Mali Zvornik	Izv. Mali Zvornik	71.7
Krupanj	Izv. Krupanj	78.7
Ljubovija	Izv. Ljubovija	78.3
Osecina	Izv. Osecina	97.9
Bajina Basta	Izv. Bajina Basta	64.9
Priboj	Izv. Priboj	49.3
Nova Varos	Izv. Nova Varos	59.4
Prijepolje	Izv. Prijepolje	57.4
Sjenica	Izv. Sjenica	55.5

Appendix J: Input from hydrologic model

Box J-1: An example of the CSV file structure for hydrologic input data.

```
# Profil: HP9010-Visegrad
# Scenario: RCP85 model 4
$ListSeparator =
$DecimalSymbol = .
$DateFormat = d/m/y
$Columns =
   Year,Month,padavine[mm],sneg[mm],Ecan[mm],Esub[mm],Es[mm],Et[mm],Qsurf[mm],Wperc[mm],
   Rint[mm],SW[mm],Qsurf[m3/s],Qbase[m3/s],Qsurf_upstream[m3/s],Qbase_upstream[m3/s],
   Qmin_upstream(m3/s),Qmax_upstream(m3/s)
2010,1,7.5542128e+001,2.6700540e+001,3.6566947e-001,8.9163349e+000,
   4.2804758e-001,6.8819615e+000,9.4038392e-001,0.0000000e+000,0.0000000e+000,
   1.5489398e+001,2.8741495e-002,0.0000000e+000,1.7830008e+001,1.1170258e-001,
   0.0000000e+000,1.0845262e+002
2010,2,1.3951149e+001,2.4806349e+001,3.5491566e-001,8.2399060e+000,
   1.6798848e+000,3.4432718e+000,0.0000000e+000,0.0000000e+000,0.0000000e+000,
   4.6935807e+001,3.3114752e-006,0.0000000e+000,1.5693061e+001,2.0675634e+000,
   3.3065596e+000,1.0195651e+002
2010,3,2.1271325e+001,1.8741937e+000,8.5415746e-001,3.4278400e+000,
   6.1829046e+000,5.6901797e+000,3.1063721e+000,0.0000000e+000,0.0000000e+000,
   6.5021552e+001,9.4792645e-002,0.0000000e+000,9.0825184e+001,1.2684289e+001,
   3.2611937e+000,2.2657486e+002
2010,4,1.2363488e+002,0.0000000e+000,9.9232383e+000,0.0000000e+000,
   1.6028320e+001,1.9985599e+001,2.0164838e+001,2.2149952e-002,0.0000000e+000,
   1.0466227e+002,6.3292922e-001,6.2612870e-004,4.6208327e+002,9.3459955e+001,
   2.2215247e+002,1.3530487e+003
etc.
```

Table J-1: List of CSV files for hydrologic input data.

Deo sliva Drine	Ime fajla	Reka	Slivna površina (km^2)
Piva	HP9061-Duski Most.csv	Komarnica	597.17
	HP9018-Komarnica.csv	Komarnica	123.79
	HP9017-Piva.csv	Piva	511.22
	HP9130-Scepan Polje (Piva).csv	Piva	57.785
Tara to Trebaljevo	HP9025-Opasanica.csv	Tara	133.965
	HP9024-Matesevo.csv	Tara	135.88
	HP9023-Zuti Krs.csv	Tara	48.445
	HP9121-Kolasin.csv	Tara	87.14
	HP9120-Bakovici.csv	Plašnica	91.175
	HP9022-Bakovica Klisura.csv	Tara	14.53
Tara from Trebaljevo to Đurđevića Tara	HP9021-Mojkovac.csv	Tara	39.705
	HP9118-Podbisce.csv	Štitarica	38.865
	HP9119-Usce Stitarice.csv	Tara	10.295
	HP9117-Bistrica (Tara).csv	Tara	177.605
	HP9020-Ljutica.csv	Tara	284.05
Tara from Đurđevića Tara to Šćepan Polje	HP9019-Tepca.csv	Tara	443.35
	HP9129-Scepan Polje (Tara).csv	Tara	302.745
Drina from the Piva and Tara confluence to the confluence of Ćehotina; Sutjeska and Bistrica	HP9116-Scepan Polje.csv	Drina	13.095
	HP9081-Bastasi.csv	Drina	12.17
	HP9016-Buk Bijela.csv	Drina	39.635
	HP9015-Foca.csv	Drina	114.415
	HP9080-Foca Most.csv	Drina	131.405
	HP9114-Igoce.csv	Sutjeska	305.98
	HP9140-HE Sutjeska.csv	Sutjeska	12.485
	HP9133-Zahvat za B3.csv	Bistrica	157.495
	HP9136-HE B3.csv	Bistrica	50.66

Deo sliva Drine	Ime fajla	Reka	Slivna površina (km^2)
	HP9132-Zahvat za B2a.csv	Bistrica	5.655
	HP9135-HE B2a.csv	Bistrica	15.14
	HP9131-Zahvat za B1.csv	Bistrica	189.995
	HP9134-HE B1.csv	Bistrica	10.255
	HP9115-Oplazici.csv	Bistrica	13.07
Ćehotina	HP9030-Otilovici.csv	Ćehotina	331.24
	HP9084-Pljevlja.csv	Ćehotina	21.475
	HP9029-Gradac.csv	Ćehotina	494.955
	HP9028-Mekote.csv	Ćehotina	225.715
	HP9026-Vikoc.csv	Ćehotina	302.356
	HP9059-Falovici.csv	Ćehotina	13.24
Drina from the Ćehotina confluence to Višegrad; Prača	HP9014-Paunici.csv	Drina	24.775
	HP9013-Ustikolina.csv	Drina	218.865
	HP9012-Sadba.csv	Drina	131.1
	HP9011-Gorazde.csv	Drina	129.905
	HP9103-Ustipraca.csv	Drina	188.72
	HP9010-Visegrad.csv	Drina	81.715
	HP9101-Rogatica.csv	Rakitnica	334.47
	HP9100-Mesici.csv	Prača	770.7535
Lim to Prijepolje	HP9060-Grncar.csv	Lim	135.865
	HP9049-Plavsko jezero.csv	Lim	197.715
	HP9050-Djuricka Rijeka.csv	Đurička Rijeka	47.445
	HP9095-Usce Komaracke Rijeke.csv	Lim	96.0845
	HP9094-Plav.csv	Lim	36.995
	HP9057-Andrijevica.csv	Lim	98.045
	HP9048-Zlorecica.csv	Zlorečica	157.605
	HP9126-Usce Zlorecice.csv	Lim	22.975
	HP9056-Lukin Vir.csv	Lim	58.286
	HP9047-Trebacka.csv	Trebačka	28.945
	HP9046-Sekularska rijeka.csv	Šekularska rijeka	49.855
	HP9062-Usce Sekularske Rijeke.csv	Lim	30.345
	HP9044-Beranska Bistrica.csv	Beranska Bistrica	122.04
	HP9045-Kaludarska rijeka.csv	Kaludarska rijeka	54.525
	HP9093-Usce Kaludarske Rijeke.csv	Lim	66.085
	HP9043-Ljesnica.csv	Lješnica	204.605
	HP9091-Bioce.csv	Lim	131.365
	HP9089-Zaton.csv	Lim	182.8595
	HP9042-Ljubovidja.csv	Ljubovиđa	257.935
	HP9111-Ravna Rijeka.csv	Ljubovиđa	59.935
	HP9088-Bijelo Polje.csv	Lim	110.625
	HP9041-Bjelopoljska Bistrica.csv	Bjelopoljska Bistrica	201.6
	HP9086-Gubavac.csv	Bjelopoljska Bistrica	35.98
	HP9110-Dobrakovo.csv	Lim	109.115
	HP9040-Brodarevo 1.csv	Lim	122.56
	HP9039-Brodarevo 2.csv	Lim	129.535
	HP9038-Prijepolje.csv	Lim	237.08
Lim from Prijepolje to Strmica	HP9109-Prijepolje (Milesevka).csv	Mileševka	150.66
	HP9108-Bistrica (na Bistrici).csv	Bistrica	68.85
	HP9123-Usce Bistrice.csv	Lim	116.215
	HP9034-Potpec.csv	Lim	98.195
	HP9033-Priboj.csv	Lim	56.62
	HP9112-Cedovo.csv	Vapa	724.9
	HP9037-Sjenica.csv	Uvac	352.855
	HP9036-Kokin Brod.csv	Uvac	210.995
	HP9035-Radonja.csv	Uvac	84.62
	HP9066-Klak.csv	Uvac	14.79
	HP9085-Usce Uvca.csv	Lim	232.985
	HP9107-Ustibar Most.csv	Poblačnica	377.28
	HP9032-Usce Poblacanice.csv	Lim	41.335

Deo sliva Drine	Ime fajla	Reka	Slivna površina (km^2)
	HP9106-HS Rudo.csv	Lim	52.625
	HP9031-Mrsovo.csv	Lim	64.615
	HP9105-Strgacina.csv	Radojna	37.185
	HP9104-Usce Radonje.csv	Lim	195.965
	HP9079-Usce Lima.csv	Drina	259.56
Rzav; Drina from the Rzav confluence to Bajina Bašta	HP9067-Kruscica.csv	Beli Rzav	17.815
	HP9053-Lazici.csv	Beli Rzav	38.13
	HP9068-Spajici.csv	Beli Rzav	10.32
	HP9128-Usce Crnog Rzava.csv	Rzav	145.68
	HP9139-Zlatibor.csv	Crni Rzav	52.825
	HP9142-Usce Rzava.csv	Drina	367.96
	HP9009-Bajina Basta.csv	Drina	808.79
Drina from the Bajina Bašta to Zvornik; Drinjača	HP9052-HS Bajina Basta.csv	Drina	137.565
	HP9138-Crvica.csv	Drina	116.03
	HP9008-Rogacica.csv	Drina	222.805
	HP9137-Zlijebac.csv	Drina	42.155
	HP9007-Tegare.csv	Drina	261.52
	HP9065-Ljubovidja.csv	Ljubovića	73.28
	HP9141-Usce Ljubovidje.csv	Drina	189.33
	HP9006-Dubravica.csv	Drina	299.555
	HP9099-Sekovici.csv	Drinjača	401.64
	HP9064-Drinjaca.csv	Drinjača	710.15
	HP9076-Kuslat.csv	Drina	94.165
	HP9005-Zvornik.csv	Drina	142.13
Drina from Zvornik to the confluence; Jadar and Janja	HP9075-Radalj.csv	Drina	253.8
	HP9004-Kozluk.csv	Drina	136.55
	HP9051-Drina 0.csv	Drina	91.94
	HP9003-Drina I.csv	Drina	119.855
	HP9063-Snijeznica.csv	Brzava	40.14
	HP9097-Ugljevik.csv	Janja	171.14
	HP9125-Usce Janje.csv	Drina	239.105
	HP9098-Zavlaka.csv	Jadar	277.555
	HP9074-Lesnica.csv	Jadar	604.955
	HP9073-Usce Jadra.csv	Drina	117.885
	HP9002-Drina II.csv	Drina	17.465
	HP9072-Badovinci.csv	Drina	37.07
	HP9001-Drina III.csv	Drina	74.055
	HP9000-Usce Drine.csv	Drina	98.98

Appendix K: Simulation results

K.1 Hydropower generation

K.1.1 Montenegro

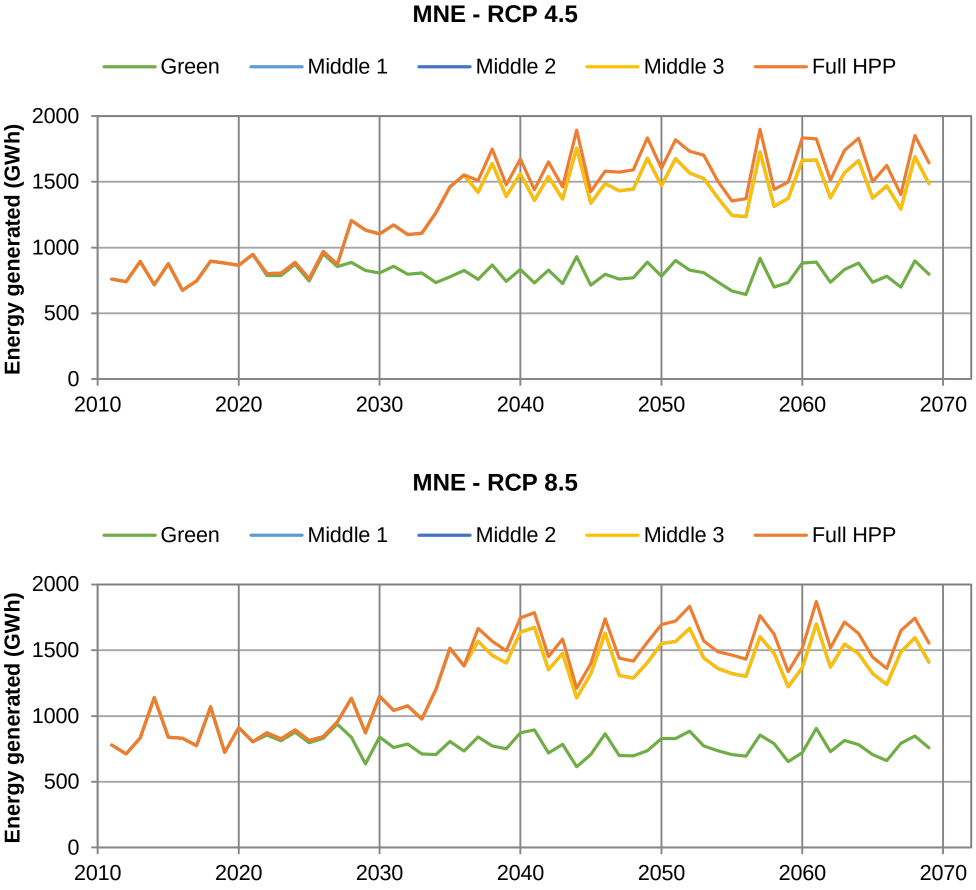


Figure K-1: Annual hydropower generation in Montenegro for different development options; ensemble medians for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

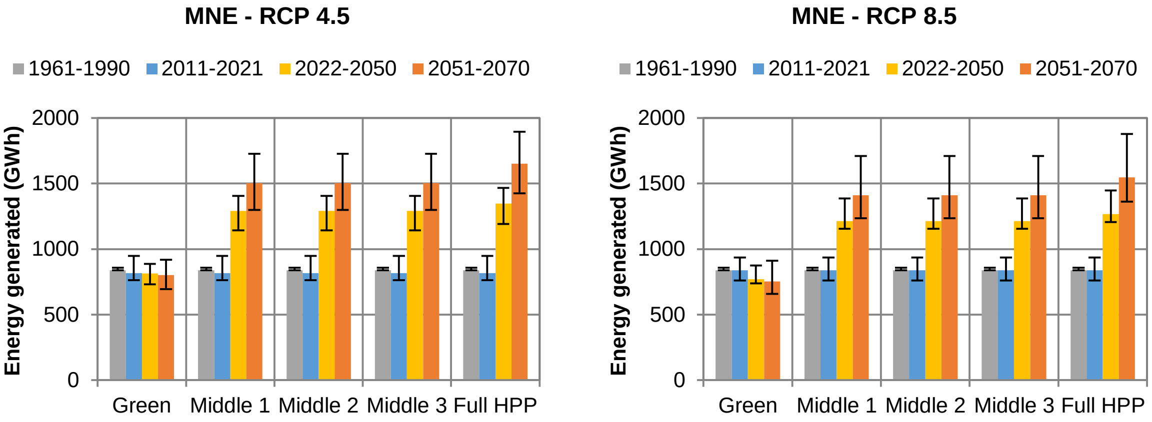


Figure K-2: Average annual hydropower generation in Montenegro for different development options; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

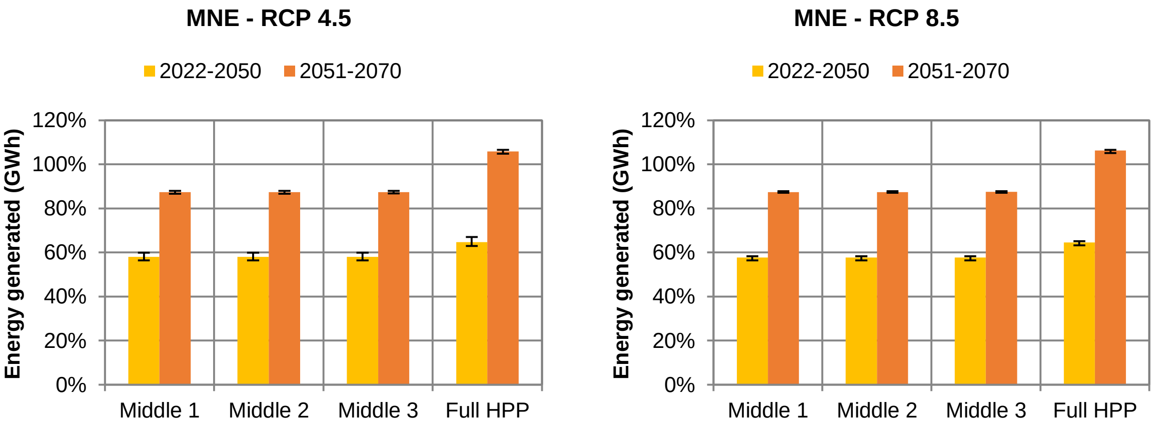


Figure K-3: Development options effect: change in average annual hydropower generation in Montenegro relative to Green Growth option; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

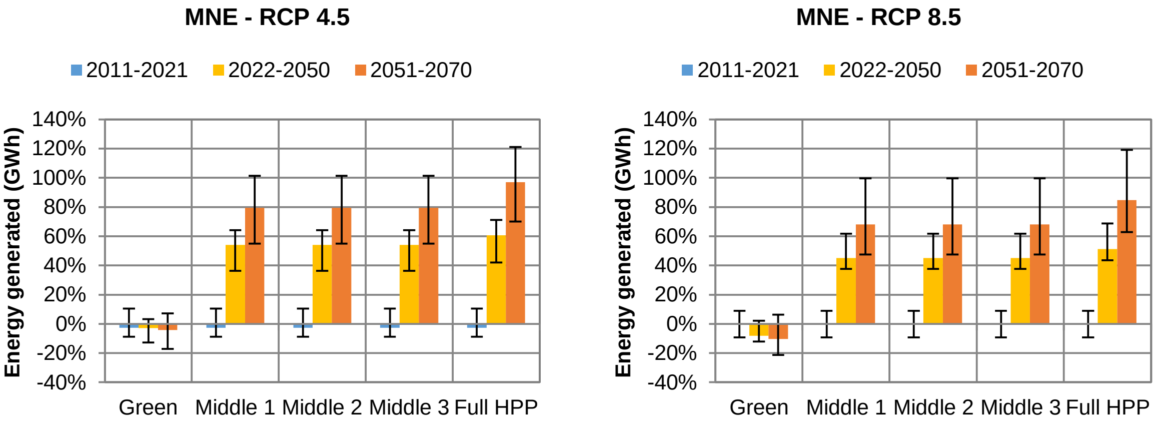
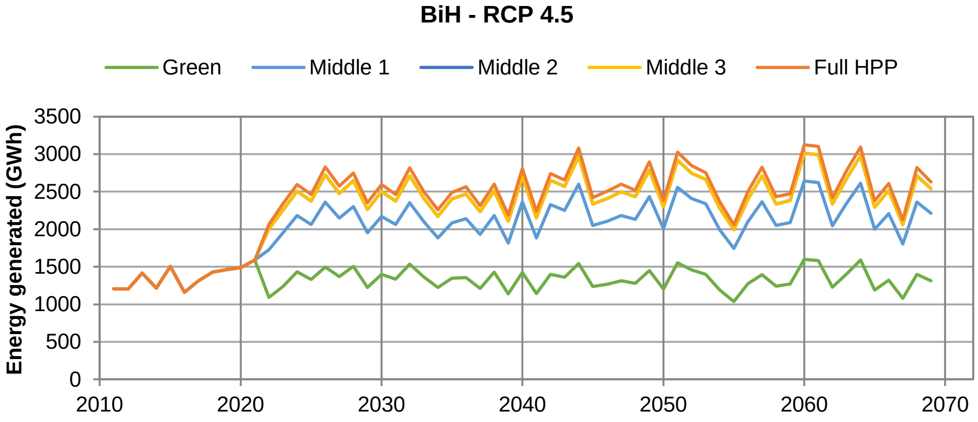


Figure K-4: Combined climate change and development options effects: change in average annual hydropower generation in Montenegro relative to 1961-1990; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right climate scenarios).

K.1.2 Bosnia and Herzegovina



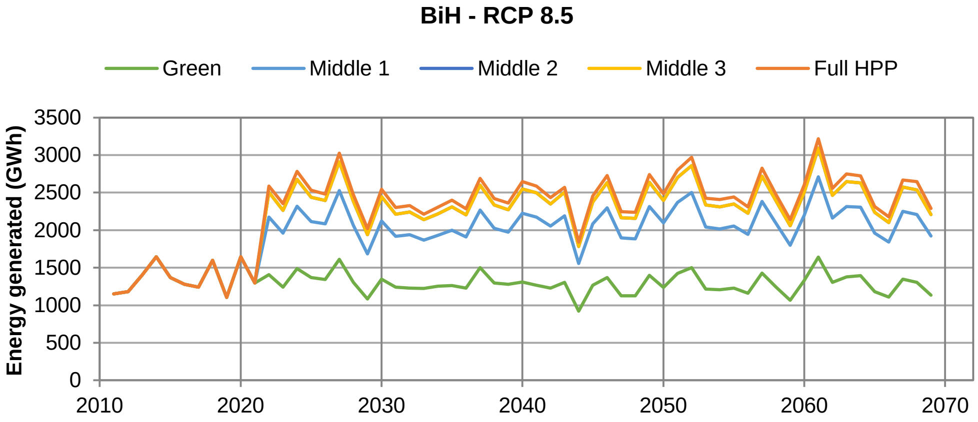


Figure K-5: Annual hydropower generation in Bosnia and Herzegovina (excluding joint HPPs with Serbia) for different development options; ensemble medians for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

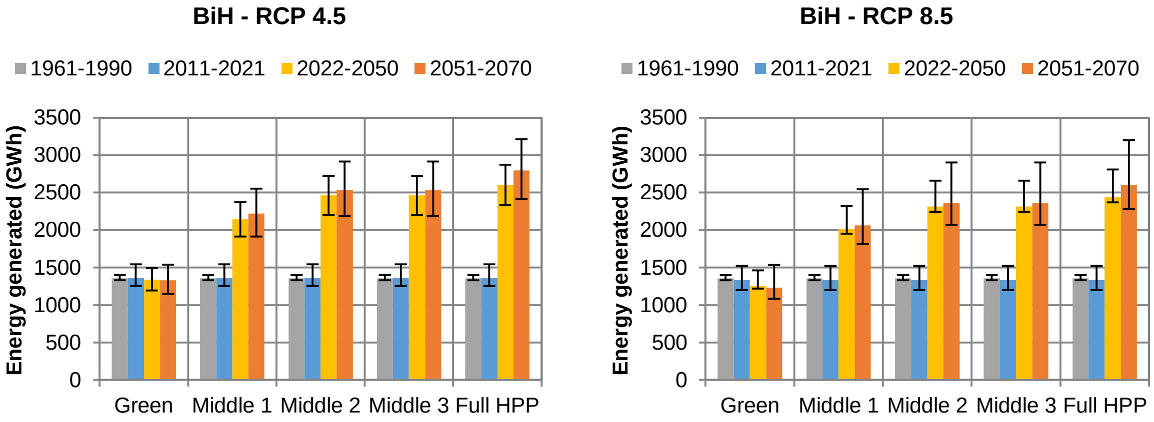


Figure K-6: Average annual hydropower generation in BiH (excluding joint HPPs with Serbia) for different development options; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

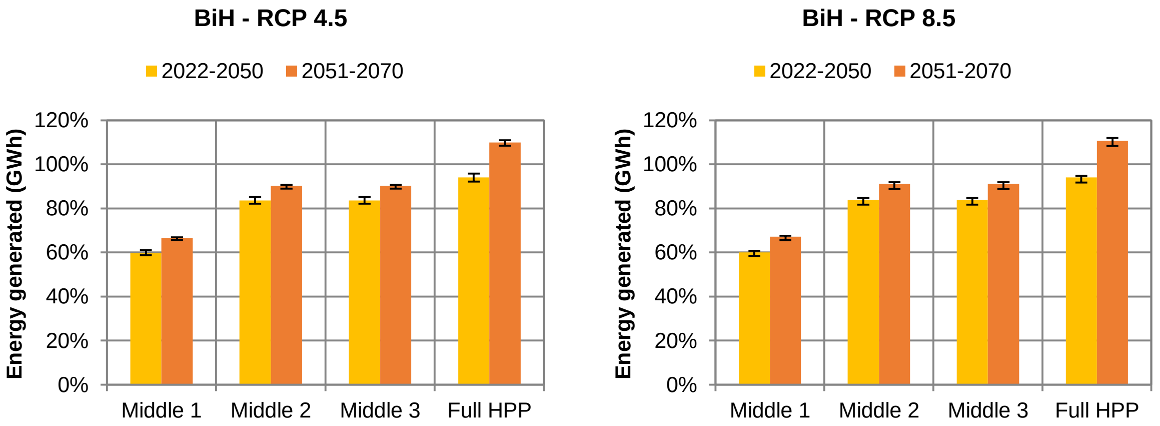


Figure K-7: Development options effect: change in average annual hydropower generation in BiH (excluding joint HPPs with Serbia) relative to Green Growth option; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

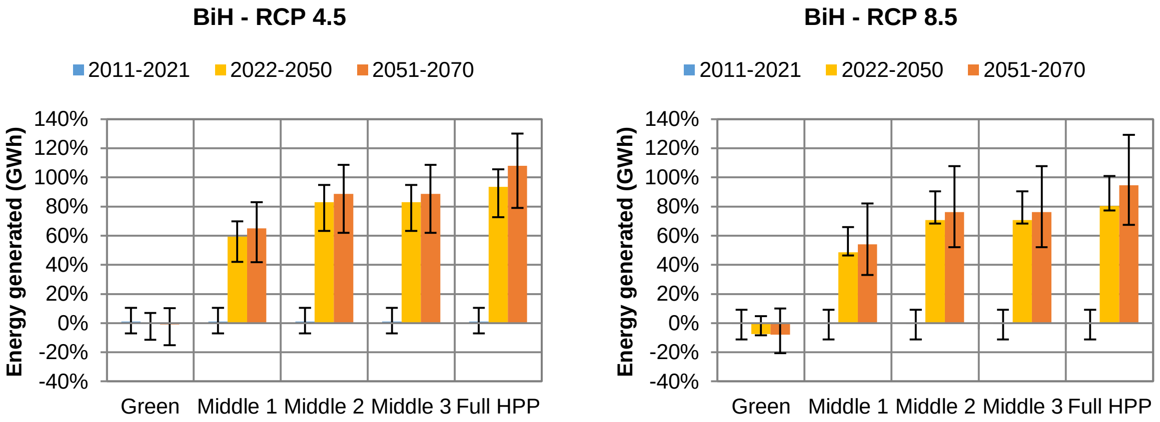


Figure K-8: Combined climate change and development options effects: change in average annual hydropower generation in BIH (excluding joint HPPs with Serbia) relative to 1961-1990; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

K.1.3 Bosnia and Herzegovina / Serbia

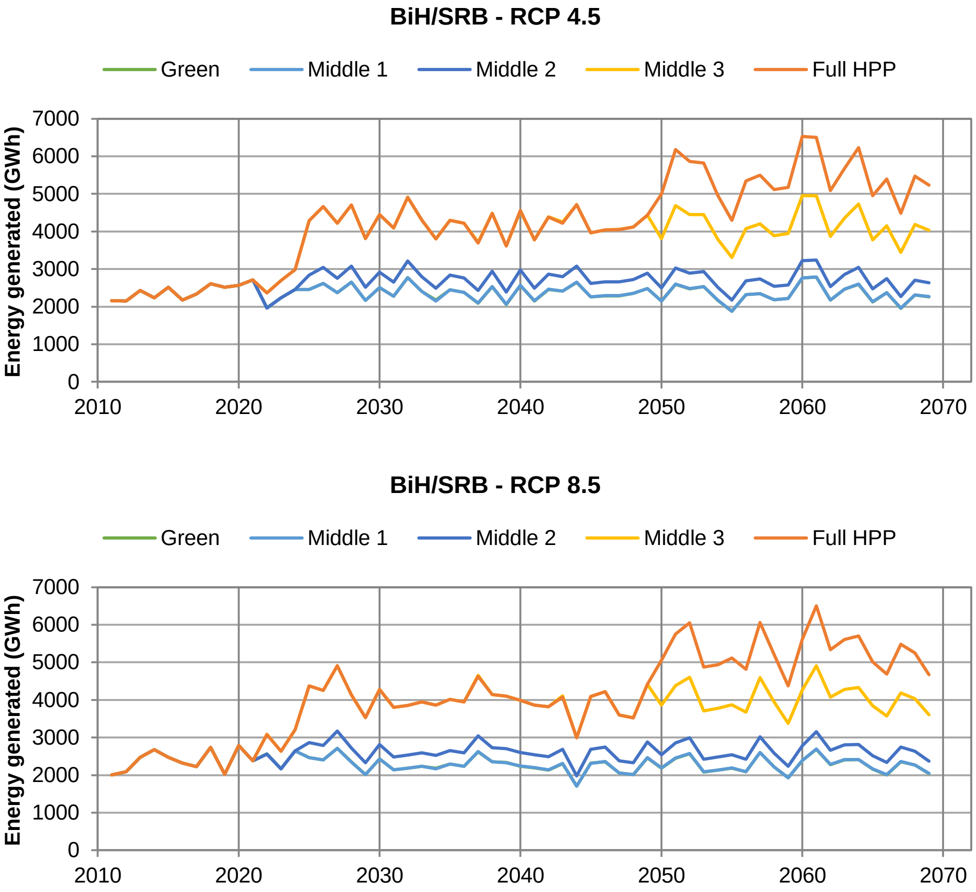


Figure K-9: Annual hydropower generation for joint HPPs in Bosnia and Herzegovina and Serbia for different development options; ensemble medians for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

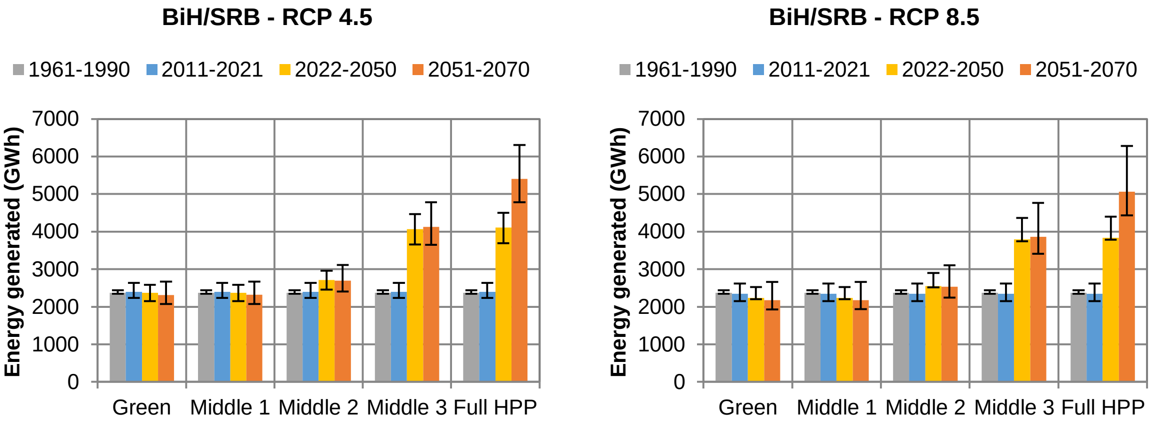


Figure K-10: Average annual hydropower generation for joint HPPs in Bosnia and Herzegovina and Serbia for different development options; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

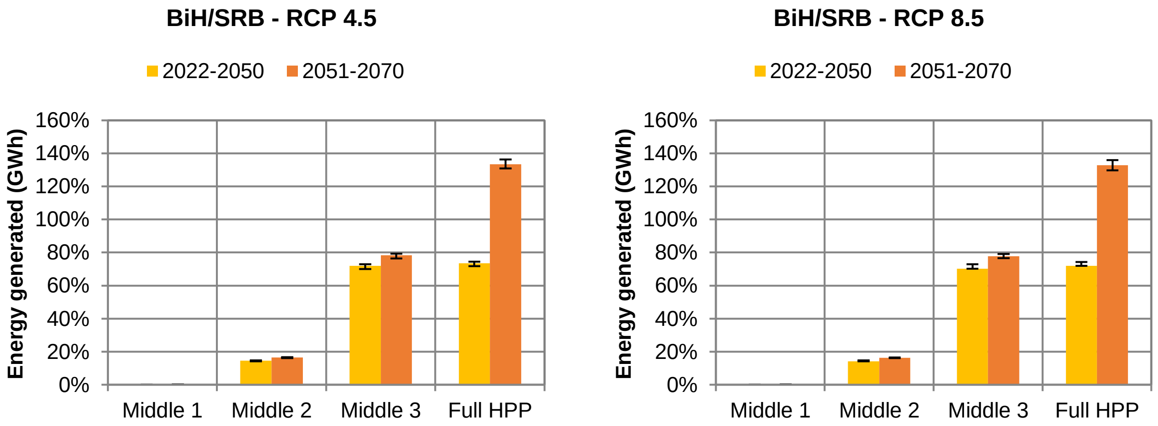


Figure K-11: Development options effect: change in average annual hydropower generation for joint HPPs in BiH and Serbia relative to Green Growth option; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

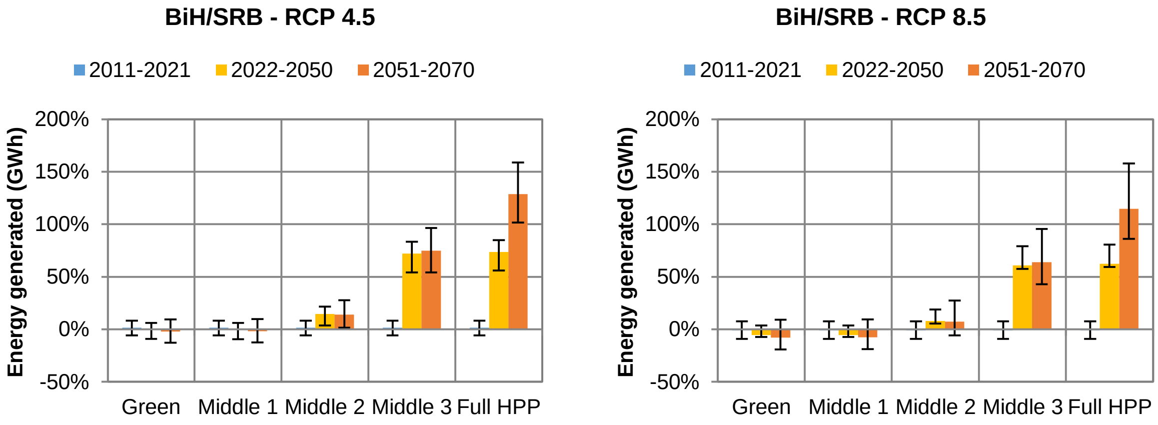


Figure K-12: Combined climate change and development options effects: change in average annual hydropower generation for joint HPPs in BIH and Serbia relative to 1961-1990; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

K.1.4 Serbia

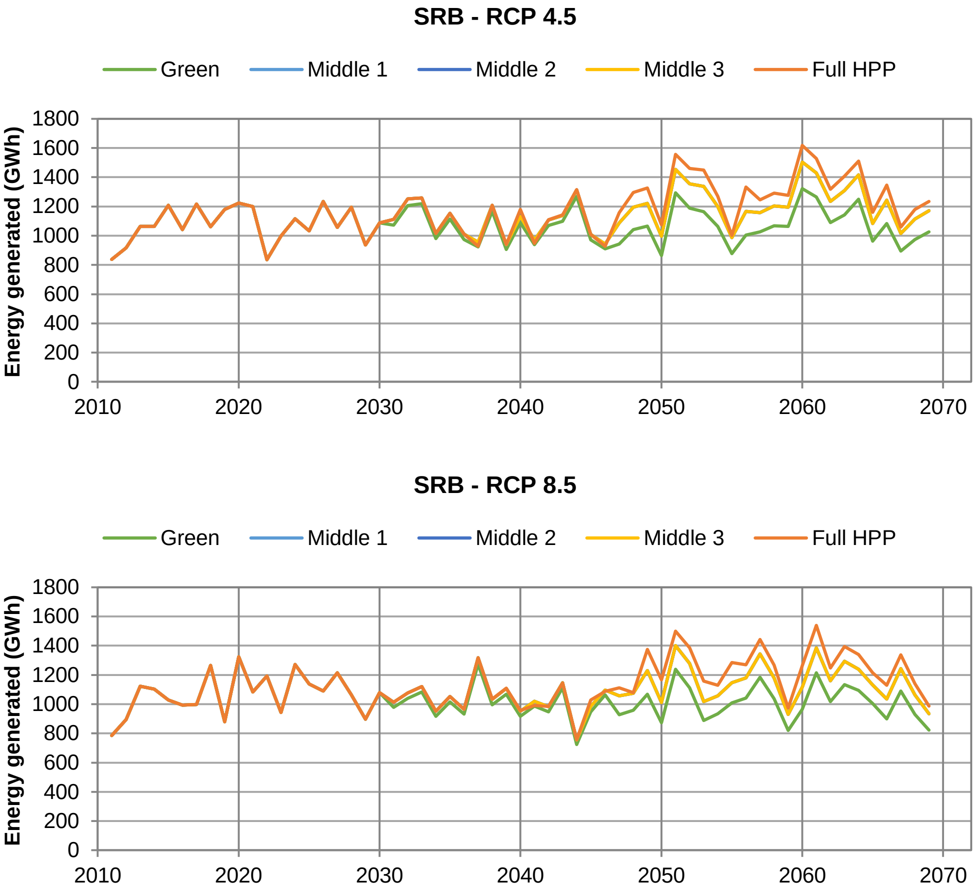


Figure K-13: Annual hydropower generation in Serbia (excluding joint HPPs with BiH) for different development options; ensemble medians for RCP 4.5 (top) and RCP 8.5 (bottom) climate scenarios.

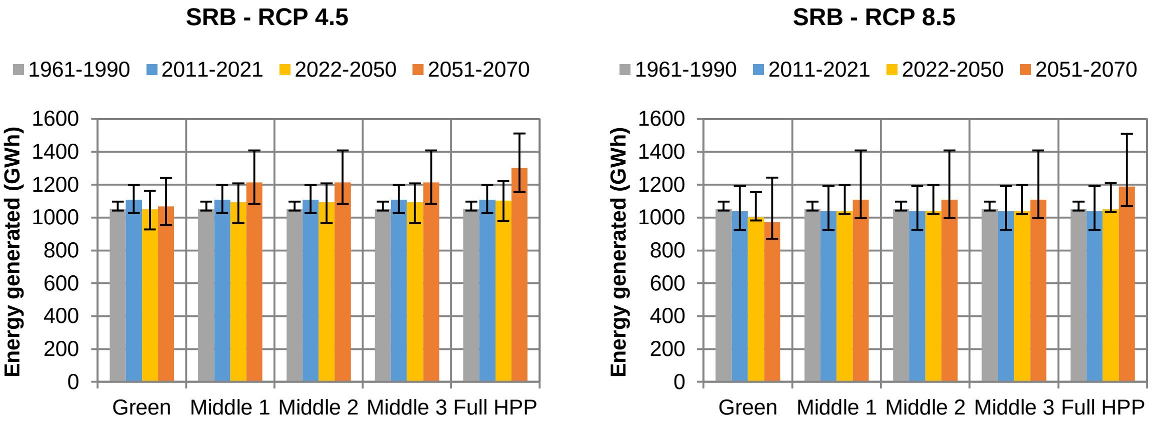


Figure K-14: Average annual hydropower generation in Serbia (excluding joint HPPs with BiH) for different development options; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) .

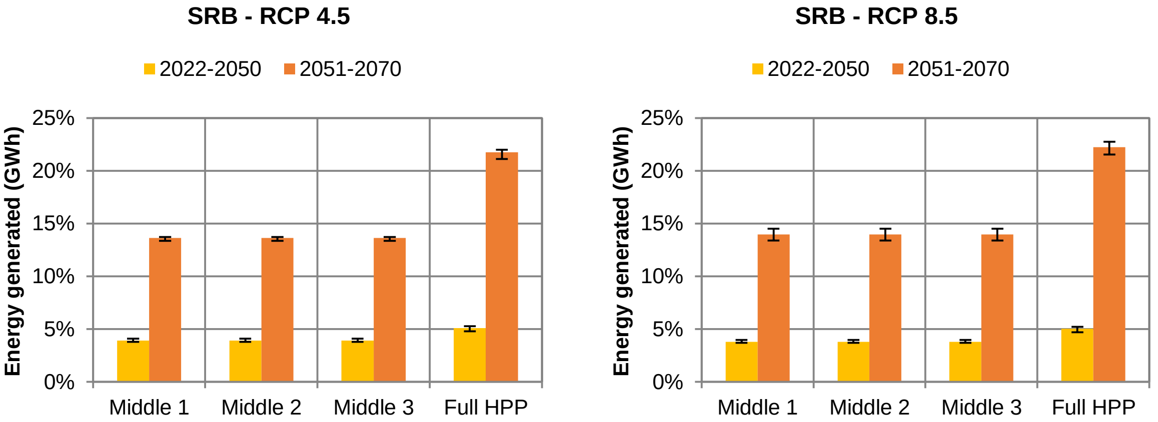


Figure K-15: Development options effect: change in average annual hydropower generation in Serbia (excluding joint HPPs with BiH) relative to Green Growth option; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

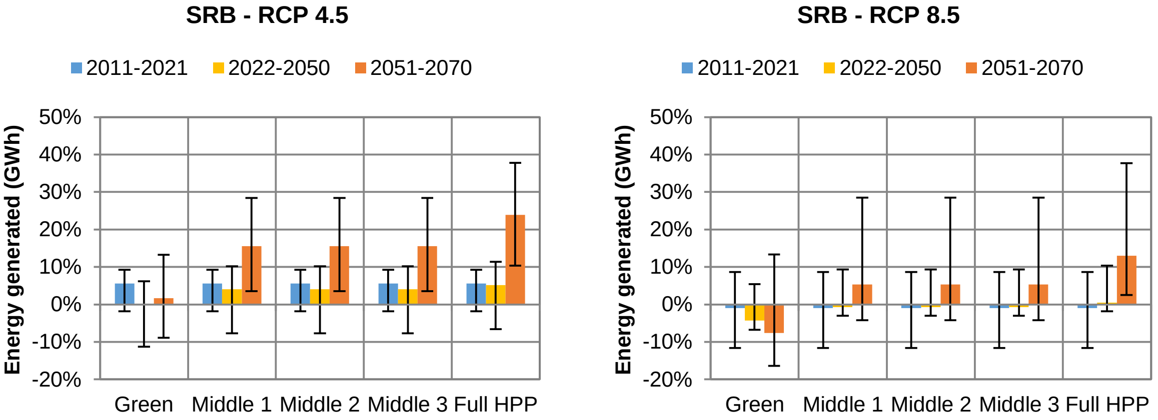


Figure K-16: Combined climate change and development options effects: change in average annual hydropower generation in Serbia (excluding joint HPPs with BiH) relative to 1961-1990; ensemble medians with ranges of results from different climate models for RCP 4.5 (left) and RCP 8.5 (right) climate scenarios.

K.2 Flow requirements

Table K-1: Flow requirement quantitative coverage for the "Green Growth" scenario: ensemble medians under RCP 4.5 and RCP 8.5 climate scenarios.

Node	River	RCP 4.5				RCP 8.5		
		1961-1990	2011-2021	2022-2050	2051-2070	2011-2021	2022-2050	2051-2070
Ak. Bajina Basta EF	Drina	1	1	1	1	1	1	1
Ak. Krusevo EF	Piva	1	1	1	1	1	1	1
Ak. Otilovici EF	Ćehotina	1	1	1	1	1	1	1
Ak. Potpec EF	Lim	1	1	1	1	1	1	1
Ak. Radoinja EF	Uvac	1	1	1	1	1	1	1
Ak. Ribnica EF	Crni Rzav	1	1	1	1	1	1	1
Ak. Snijeznica EF	Janja	1	1	1	1	1	1	1
Ak. Visegrad EF	Drina	1	1	1	1	1	1	1
Ak. Zaovine EF	Rzav	1	1	1	1	1	1	1
Ak. Zvornik EF	Drina	1	1	1	1	1	1	1
Bistrica EF	Bistrica	0.9695	0.9621	0.9608	0.9300	0.9682	0.9614	0.9375
Donja Tara EF	Tara	0.9851	0.9720	0.9636	0.9353	0.9776	0.9629	0.9272
Donji Jadar EF	Jadar	1.0000	1.0000	1.0000	0.9989	1.0000	1.0000	0.9993
Gornja Tara EF	Tara	0.9997	0.9495	0.9330	0.9254	0.9422	0.9222	0.9137
Gornji Jadar EF	Jadar	0.9991	1.0000	1.0000	0.9978	1.0000	0.9996	0.9973
Gornji Lim EF	Lim	0.9602	0.9514	0.9327	0.9023	0.9528	0.9275	0.8903

Table K-2: Flow requirement quantitative coverage for the "Middle 1" scenario: ensemble medians under RCP 4.5 and RCP 8.5 climate scenarios (nodes below reservoirs are given in bold type).

Node	River		RCP 4.5			RCP 8.5		
		1961-1990	2011-2021	2022-2050	2051-2070	2011-2021	2022-2050	2051-2070
Ak. Bajina Basta EF	Drina	1	1	1	1	1	1	1
Ak. Buk Bijela EF	Drina			1	1		1	1
Ak. Foca EF	Drina			1	1		1	1
Ak. Krusevo EF	Piva	1	1	1	1	1	1	1
Ak. Mrsovo EF	Lim			1	1		1	1
Ak. Otilovici EF	Ćehotina	1	1	1	1	1	1	1
Ak. Potpec EF	Lim	1	1	1	1	1	1	1
Ak. Radoinja EF	Uvac	1	1	1	1	1	1	1
Ak. Ribnica EF	Crni Rzav	1	1	1	1	1	1	1
Ak. Snijeznica EF	Janja	1	1	1	1	1	1	1
Ak. Visegrad EF	Drina	1	1	1	1	1	1	1
Ak. Zaovine EF	Rzav	1	1	1	1	1	1	1
Ak. Zvornik EF	Drina	1	1	1	1	1	1	1
HE Brodarevo 1 EF	Lim			0.9926	0.9707		0.9735	0.9715
HE Rekovici EF	Lim			1	1		1	1
HE Ustikolina EF	Drina			1	1		1	1
Bistrica EF	Bistrica	0.9695	0.9621	0.9608	0.9300	0.9682	0.9614	0.9375
Donja Tara EF	Tara	0.9851	0.9720	0.9636	0.9353	0.9776	0.9629	0.9272
Donji Jadar EF	Jadar	1.0000	1.0000	1.0000	0.9989	1.0000	1.0000	0.9993
Gornja Tara EF	Tara	0.9997	0.9495	0.9330	0.9254	0.9422	0.9222	0.9137
Gornji Jadar EF	Jadar	0.9991	1.0000	1.0000	0.9978	1.0000	0.9996	0.9973
Gornji Lim EF	Lim	0.9602	0.9514	0.9327	0.9023	0.9528	0.9275	0.8903

Table K-3: Flow requirement quantitative coverage for the "Middle 2" scenario: ensemble medians under RCP 4.5 and RCP 8.5 climate scenarios (nodes below reservoirs are given in bold type).

Node	River		RCP 4.5			RCP 8.5		
		1961-1990	2011-2021	2022-2050	2051-2070	2011-2021	2022-2050	2051-2070
Ak. Bajina Basta EF	Drina	1	1	1	1	1	1	1
Ak. Buk Bijela EF	Drina			1	1		1	1
Ak. Foca EF	Drina			1	1		1	1
Ak. Krusevo EF	Piva	1	1	1	1	1	1	1
Ak. Mrsovo EF	Lim			1	1		1	1
Ak. Otilovici EF	Ćehotina	1	1	1	1	1	1	1
Ak. Potpec EF	Lim	1	1	1	1	1	1	1
Ak. Radoinja EF	Uvac	1	1	1	1	1	1	1
Ak. Ribnica EF	Crni Rzav	1	1	1	1	1	1	1
Ak. Snijeznica EF	Janja	1	1	1	1	1	1	1
Ak. Visegrad EF	Drina	1	1	1	1	1	1	1
Ak. Zaovine EF	Rzav	1	1	1	1	1	1	1
Ak. Zvornik EF	Drina	1	1	1	1	1	1	1
HE Brodarevo 1 EF	Lim			0.9926	0.9707		0.9735	0.9715
HE Dubravica EF	Drina			1	1		1	1
HE Gorazde EF	Drina			1	1		1	1
HE Paunci EF	Drina			1	1		1	1
HE Rekovici EF	Lim			1	1		1	1
HE Ustikolina EF	Drina			1	1		1	1
Bistrica EF	Bistrica	0.9695	0.9621	0.9608	0.9300	0.9682	0.9614	0.9375
Donja Tara EF	Tara	0.9851	0.9720	0.9636	0.9353	0.9776	0.9629	0.9272
Donji Jadar EF	Jadar	1.0000	1.0000	1.0000	0.9989	1	1	0.9993
Gornja Tara EF	Tara	0.9997	0.9495	0.9330	0.9254	0.9422	0.9222	0.9137
Gornji Jadar EF	Jadar	0.9991	1.0000	1.0000	0.9978	1	0.9996	0.9973
Gornji Lim EF	Lim	0.9602	0.9514	0.9327	0.9023	0.9528	0.9275	0.8903

Table K-4: Flow requirement quantitative coverage for the "Middle 3" scenario: ensemble medians under RCP 4.5 and RCP 8.5 climate scenarios (nodes below reservoirs are given in bold type).

Node	River		RCP 4.5			RCP 8.5		
		1961-1990	2011-2021	2022-2050	2051-2070	2011-2021	2022-2050	2051-2070
Ak. Bajina Basta EF	Drina	1	1	1	1	1	1	1
Ak. Buk Bijela EF	Drina			1	1		1	1
Ak. Foca EF	Drina			1	1		1	1
Ak. Kozluk EF	Drina			1	1		1	1
Ak. Krusevo EF	Piva	1	1	1	1	1	1	1
Ak. Mrsovo EF	Lim			1	1		1	1
Ak. Otilovici EF	Ćehotina	1	1	1	1	1	1	1
Ak. Potpec EF	Lim	1	1	1	1	1	1	1
Ak. Radoinja EF	Uvac	1	1	1	1	1	1	1
Ak. Ribnica EF	Crni Rzav	1	1	1	1	1	1	1
Ak. Snijeznica EF	Janja	1	1	1	1	1	1	1
Ak. Visegrad EF	Drina	1	1	1	1	1	1	1
Ak. Zaovine EF	Rzav	1	1	1	1	1	1	1
Ak. Zvornik EF	Drina	1	1	1	1	1	1	1
HE Brodarevo 1 EF	Lim			0.9926	0.9707		0.9735	0.9715
HE Dubravica EF	Drina			1	1		1	1
HE Gorazde EF	Drina			1	1		1	1
HE Paunci EF	Drina			1	1		1	1
HE Rekovici EF	Lim			1	1		1	1
HE Rogacica EF	Drina			1	1		1	1
HE Tegare EF	Drina			1	1		1	1
HE Ustikolina EF	Drina			1	1		1	1
Bistrica EF	Bistrica	0.9695	0.9621	0.9608	0.9300	0.9682	0.9614	0.9375
Donja Tara EF	Tara	0.9851	0.9720	0.9636	0.9353	0.9776	0.9629	0.9272
Donji Jadar EF	Jadar	1.0000	1.0000	1.0000	0.9989	1	1	0.9993
Gornja Tara EF	Tara	0.9997	0.9495	0.9330	0.9254	0.9422	0.9222	0.9137
Gornji Jadar EF	Jadar	0.9991	1.0000	1.0000	0.9978	1	0.9996	0.9973
Gornji Lim EF	Lim	0.9602	0.9514	0.9327	0.9023	0.9528	0.9275	0.8903

Table K-5: Flow requirement quantitative coverage for the "Full HPP" scenario: ensemble medians under RCP 4.5 and RCP 8.5 climate scenarios (nodes below reservoirs are given in bold type).

River	Node		RCP 4.5			RCP 8.5		
		1961-1990	2011-2021	2022-2050	2051-2070	2011-2021	2022-2050	2051-2070
Ak. Andrijevica EF	Lim			1	0.9965		1	0.9948
Ak. Bajina Basta EF	Drina	1	1	1	1	1	1	1
Ak. Brodarevo 2 EF	Lim			1	0.9971		1	0.9954
Ak. Buk Bijela EF	Drina			1	1		1	1
Ak. Foca EF	Drina			1	1		1	1
Ak. Kozluk EF	Drina			1	1		1	1
Ak. Krusevo EF	Piva	1	1	1	1	1	1	1
Ak. Lukin Vir EF	Lim			1	0.9962		1	0.9942
Ak. Mrsovo EF	Lim			1	1		1	1
Ak. Otilovici EF	Ćehotina	1	1	1	1	1	1	1
Ak. Potpec EF	Lim	1	1	1	1	1	1	1
Ak. Radoinja EF	Uvac	1	1	1	1	1	1	1
Ak. Ribnica EF	Crni Rzav	1	1	1	1	1	1	1
Ak. Snijeznica EF	Janja	1	1	1	1	1	1	1
Ak. Sutjeska EF	Sutjeska			1	1		1	1
Ak. Vikoc EF	Ćehotina			1	1		1	1
Ak. Visegrad EF	Drina	1	1	1	1	1	1	1
Ak. Zaovine EF	Rzav	1	1	1	1	1	1	1
Ak. Zvornik EF	Drina	1	1	1	1	1	1	1
HE Brodarevo 1 EF	Lim			1	0.9970		1	0.9951
HE Drina 1 EF	Drina			1	1		1	1
HE Drina 2 EF	Drina			1	1		1	1
HE Drina 3 EF	Drina			1	1		1	1
HE Dubravica EF	Drina			1	1		1	1
HE Gorazde EF	Drina			1	1		1	1
HE Paunci EF	Drina			1	1		1	1
HE Rekovici EF	Lim			1	1		1	1
HE Rogacica EF	Drina			1	1		1	1
HE Tegare EF	Drina			1	1		1	1
HE Ustikolina EF	Drina			1	1		1	1
Bistrica EF	Bistrica	0.9695	0.9621	0.9608	0.9300	0.9682	0.9614	0.9375
Donja Tara EF	Tara	0.9851	0.9720	0.9636	0.9353	0.9776	0.9629	0.9272
Donji Jadar EF	Jadar	1.0000	1.0000	1.0000	0.9989	1	1	0.9993
Gornja Tara EF	Tara	0.9997	0.9495	0.9330	0.9254	0.9422	0.9222	0.9137
Gornji Jadar EF	Jadar	0.9991	1.0000	1.0000	0.9978	1	0.9996	0.9973
Gornji Lim EF	Lim	0.9602	0.9514	0.9327	0.9023	0.9528	0.9275	0.8903