Sava and Drina Rivers Corridors Integrated Development Program (SDIP)

Hydrological Study for the Sava River Basin

Terms of Reference

August 2024

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PROJECT:	SAVA AND DRINA RIVER CORRIDORS INTEGRATED DEVELOPMENT PROGRAM (SDIP)-Phase I, Part 4 – Regional Cooperation
IMPLEMENTING AGENCY:	International Sava River Basin Commission (ISRBC)
ACTIVITY:	Hydrological Study for the Sava River Basin
REFERENCE NUMBER	HR-ISRBC-343710-CS-QCBS

ABBREVIATIONS AND ACRONYMS

API	Application Programming Interface
ARSO	Slovenian Environment Agency
Data Policy	Policy on the Exchange of Hydrological and Meteorological Data and Information in the Sava River Basin
DHMZ	Croatian Meteorological and Hydrological Service
EU	European Union
FHMZ	Federal Hydrometeorological Service, Bosnia and Herzegovina
H-SAF	Satellite Application Facility on Support to Operational Hydrology and Water Management
FASRB	Framework Agreement on the Sava River Basin
FFWS	Flood Forecasting and Warning System
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HMS	Hydro-Meteorological Services
HIS	Hydrologic Information System
ISRBC	International Sava River Basin Commission
OGC	Open Geospatial Consortium
REST	Representational State Transfer
RHMZ	Republic Hydrometeorological Service of Serbia
RHMZRS	Republic Hydro-Meteorological Service of Republic of Srpska, Bosnia and Herzegovina
SOAP	Simple Object Access Protocol
SDIP	Sava and Drina Rivers Corridors Integrated Development Program
SSD	System for Spatial Data Discovery
WML	Water Markup Language
WMO	World Meteorological Organization
WMS-T	Web Map Service - Time
XML	Extensible Markup Language
ZHMS	Institute of Hydrometeorology and Seismology

1. Background

This assignment is part of the regional component of the Sava and Drina Rivers Corridors Integrated Development Program (SDIP) - Phase I, which aims to strengthen transboundary water cooperation and improve navigability and flood protection in the Sava River basin.

This assignment intends to develop the Hydrological Study of the Sava River Basin (the Study) and a web-based tool for its presentation. The last comprehensive study covering the entire basin was conducted in 1976, using data from 1926-1974. Subsequent studies and projects have focused on specific water regime characteristics that do not encompass the entire basin. The development and expected results of a joint hydrological study, based on a comprehensive basin-wide methodology, will significantly contribute to all activities of the ISRBC and the riparian countries, i.e. river basin and flood risk management, navigation safety, sediment management, droughts/low flows analysis, groundwater analysis, and climate change adaptation.

1.1. Sava River Basin and relevant characteristics

The Sava River basin covers an area of approximately 97,200 km^2. Encompassing substantial portions of Bosnia and Herzegovina, Croatia, Montenegro, Serbia, and Slovenia, the Sava River basin constitutes 12% of the Danube River basin area, making it the second-largest sub-basin of the Danube (Figure 1).

Figure 1. Location of the Sava River basin and sharing between countries

The Sava River is the largest tributary by discharge to the Danube River, with an average discharge of about 1,700 m3/s, which accounts for almost 30% of the Danube's total discharge at their confluence in Belgrade. The Sava River is formed by two mountainous streams: the Sava Dolinka and the Sava Bohinjka. From the confluence of these headwaters in Radovljica, Slovenia, the Sava River is 945 km long. It flows in a northwest-southeast direction through Slovenia, Croatia, Bosnia and Herzegovina, and Serbia. A schematic longitudinal profile of the Sava River and some of its main tributaries is shown in the following figure.

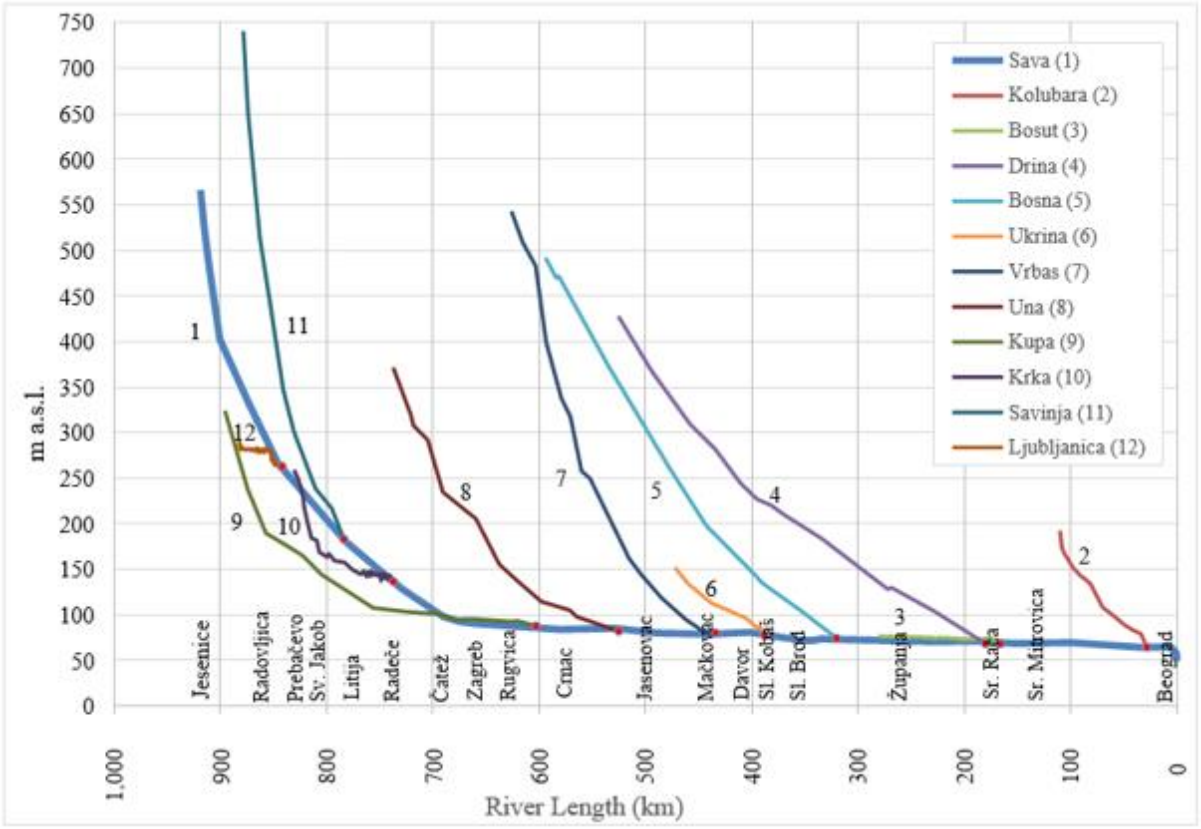

Figure 2. Schematic longitudinal profiles of the Sava River and its main tributaries

A detailed elaboration of the main characteristics of the Sava River basin is provided in the 2nd Sava River basin analysis report prepared in 2016.

1.2. Legal and regulatory framework for cooperation in the Sava River basin

In 2001, the four riparian countries of the Sava River basin (at the time, Slovenia, Croatia, Bosnia and Herzegovina, and the former Federal Republic of Yugoslavia) aiming at cooperation for sustainable basin-wide water resources management, entered into a process known as the Sava River Basin Initiative. The basic idea of the Sava Initiative was to establish an appropriate institutional framework for transboundary cooperation, to ensure sustainable use, protection, and management of water resources in the Sava River basin and ultimately enhance living conditions in the region. In 2002, the process was successfully finalized with the signing of the Framework Agreement on the Sava River Basin (FASRB). The FASRB calls for cooperation among the Parties, among others, toward three main goals: (a) establishment of an international regime of navigation on the Sava River and its navigable tributaries; (b) establishment of sustainable water management; and (c) undertaking of measures to prevent or limit hazards and reduce and eliminate adverse consequences, including those from floods, ice hazards, droughts, and incidents involving substances hazardous to water. In 2005, the ISRBC was established to facilitate the implementation of FASRB. Since then, the ISRBC has coordinated the development and implementation of joint and /or integrated plans on the management of the water resources of the Sava River basin, preparation of the development programs, establishment of integrated information systems, harmonization of the activities with national and international organizations and the development of protocols for regulating specific aspects of the FASRB implementation.

By the FASRB, the Parties recognize that the exchange of data and information within the Sava River basin is vital for the sustainable management of water resources and mitigation of water-related hazards. Additionally, the *Protocol on Flood Protection to the FASRB* states that the Parties shall, through the hydro-meteorological services and institutions responsible for flood protection, ensure the timely exchange of meteorological and hydrological data.

In 2012, the ISRBC began preparing a regulatory framework for data and information exchange in the Sava River basin, in collaboration with the World Meteorological Organization (WMO). In July 2014,

the *Policy on the Exchange of Hydrological and Meteorological Data and Information in the Sava River Basin* (Data Policy), was signed by relevant organizations of the Parties to the FASRB, and Montenegro, (national/entity hydro-meteorological services and some water/environmental agencies). The list of the signatories is provided in Annex A of the Data Policy.

1.3. Existing data collection, monitoring, management and modeling

The Data Policy was a prerequisite for establishing the Sava Hydrologic Information System (Sava HIS) in 2015. Since then, the Sava HIS, hosted by the ISRBC, has been providing tools for collecting, storing, analyzing, and reporting hydrometeorological data. The Sava HIS is supporting the Sava countries[1] in sharing and disseminating hydrologic and meteorological data, information and knowledge about water resources. The collection of observed meteorological and hydrological data is the responsibility of the relevant national organizations, mainly the hydro-meteorological services (HMSs) of the Sava countries These data and information are used for decision-making in all aspects of water resources management, including operational applications and research. Part of the Sava HIS (real-time data exchange) is available to the interested public, while some parts are only available to registered users.

The Sava HIS operates using the software infrastructure of the Sava GIS Geoportal (Sava GIS), essentially representing its distinct module. Detailed information on the Sava GIS architecture is available in the final report of the project "Establishment of the Sava GIS Core Functionalities[2]". A conceptual Sava HIS system architecture is shown in Figure 2 below.

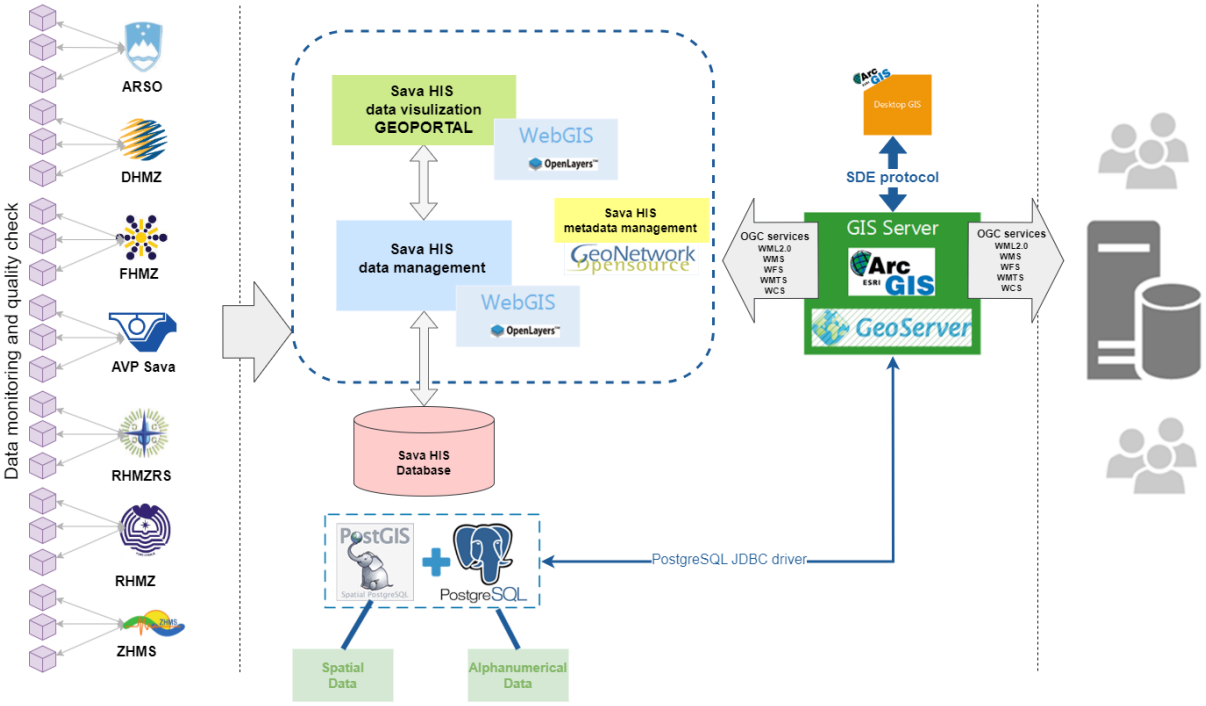

Figure 2. Conceptual Sava HIS system architecture

The Sava HIS architecture is based on open-source software (Apache Tomcat, PostgreSQL, Geoserver, GeoNetwork). It uses Open Geospatial Consortium (OGC) procedures including Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), Web Map Tile Service (WMTS) and others. A middleware Java-based application of Sava HIS is tasked with converting, migrating and storing collected data of different formats and from many sources into the database in Water ML 2.0 format. The Sava HIS system complies with the WMO Information System (WIS) and Hydrological

[1] The term "Sava countries" refers to the countries sharing the Sava River basin: Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, whose relevant institutions, listed in Section3, are the primary users of the system.

[2] Sava GIS Project Report

Observing System (WHOS) standards as a metadata management solution (i.e. GeoNetwork), supporting the OAI-PMH harvesting protocol and ISO 19115/19139 schemas.

A proprietary ArcGIS[3] software is used for spatial data exchange in an ESRI geodatabase format.

Besides retrieving and storing real-time data, the Sava HIS also contains processed hydrological and meteorological data and metadata, including daily time series and statistics from historical data (Hydrological Yearbooks) as well as monthly/yearly time series from discharge measurement data. Spatial data (x, y coordinates of the location of the measuring stations), general data and metadata about measuring stations (organization, type, identifier), and attributes of measuring data (data type, units, methods, accuracy, censoring, data quality) are also available. Since its establishment, due to the growing commitment of the involved countries, the number of stations within the Sava HIS has continuously increased. Currently, data from more than 310 hydrological and over 220 meteorological gauging stations are being collected and stored.

Table 1. Overview of the data availability in Sava HIS

Parameters	Number of stations with processed information (2000-2021)*	Number of stations with raw/not processed information (2010-2024)*
	Daily time series (including monthly and yearly statistics)	Hourly/Daily time series
Precipitation	86	146
Air temperature	86	164
Snow depth	-	57
Water level data	157	271
Discharge data	137	144
Water temperature	85	68
Susp. Sediment discharge	7	1 (turbidity)

* The period of data availability is not consistent (some of the stations do not have information for the complete period)

Further details about the stations and indicative information on data availability, which will be re-analyzed during the inception phase, can be found in Appendices A and B.

The Sava HIS is also integrated into the Sava Flood Forecasting and Warning System (Sava FFWS), where it serves as the primary tool for real-time data collection.

Regarding hydrological modeling, the USACE HEC-HMS and the Deltares WFlow hydrological models developed under the ISRBC, are operational in the Sava FFWS.

The HEC-HMS Sava model[4], covering the entire Sava River basin, consists of 235 subbasins selected to take the local hydrology into account, 174 junctions (mainly located at hydrological stations or confluences), 158 river sections and 20 major reservoirs. The model was initially calibrated on several selected periods (up to six months long), characterized by average to high flow conditions. Since the model was not calibrated for dry and low-flow episodes, it does not perform well under those conditions. During its development, the model was at one stage (WATCAP[5]) enhanced to assess the potential impacts of climate change when a huge number of meteorological inputs were analyzed and used. The model was upgraded to the new software version (v.4.11) and recalibrated to the long-term period 2010-2018. However, the lack of spatial coverage of the available rainfall and snow input still impacts the accuracy of simulation results. The HEC-HMS Sava is coupled with the HEC-RAS (v.6.4) Sava[6] hydraulic model covering the mainstream of the Sava River (downstream of Slovenia) and main tributaries in Bosnia and Herzegovina, Croatia, and Serbia.

The WFlow Sava[7] model covers a part of the Sava River basin that belongs to Bosnia and Herzegovina, Serbia and Montenegro. It is based on the HBV algorithm and integrates multiple grid layers of open-

[3] ISRBC is a part of the ESRI Nonprofit Program and has available ArcGIS licenses

[4] Sava HMS Technical Documentation (savacommission.org)

[5] WATCAP Project Report (savacommission.org)

[6] Sava RAS Technical Documentation (savacommission.org)

[7] Sava FFWS Project Report (savacommission.org)

source data, such as the Corine land use and the FAO soil maps. The distributed, grid-based Wflow is a 2-D model that has a spatial resolution of 250 m. It is divided into six sub-catchments: Sava (downstream), Una, Vrbas, Bosna, Drina and Kolubara. Additionally, the model is coupled with the RTC-Tools package for the analysis of ten major reservoirs in the basin.

These existing systems for data collection and modeling will be one of the data sources for the development of the Study. However, these systems exhibit partial incompleteness and inconsistency across data and values, which this assignment aims to address.

2. Objectives of the Assignment

The main goal of this assignment is to enhance knowledge of the water cycle dynamics and components and their spatial and temporal distribution in the Sava River basin by improving hydrological and meteorological data reliability and management in the Sava River basin, considering current climate variability and future climate change. Ultimately, this enhanced knowledge will better inform decision-making on sustainable water resources management in the Sava River basin.

The major expected outcomes of the assignment are:

1 **Hydrological Study of the Sava River Basin**

The Study should provide a reliable hydro-meteorological foundation for all information-based decisions related to sustainable water resources management in the Sava River basin. This will include the collection, compilation, collation, assessment, improvement, standardization, and validation of all data related to the water cycle in the Sava River basin, while ensuring consistency. Moreover, a methodology will be deployed to ensure completeness of time series, and conduct statistical analysis.

2 **A web-based tool for presentation and use of the Hydrological Study**

This tool should offer a uniform and consistent representation of hydrological and meteorological information for the Sava River basin.

3 **Knowledge transfer and capacity building**

This outcome will be measured by the availability of better-trained staff to use and provide information from the Study.

4 **Recommendations for future activities and developments**

Recommendations, based on the findings of this assignment, will serve as a guideline for future activities related to hydrological issues in the Sava River basin.

All activities should be performed fully aligned with the provisions of the Environmental and Social Framework (ESF) of the World Bank, and all the underlying Environmental and Social Standards (ESS) under the ESF. The results of the Study should be compared to the ESF, and all gaps should be identified. Recommendations that include ways to bridge the identified gaps should be provided.

3. Scope of Services, Tasks and Expected Deliverables

The major expected outcomes, described above, require the following sets of actions[8]:

1. Preparation of the Hydrological Study of the Sava River Basin

1.1. Development of the methodology for the preparation of the Study

In the Inception Phase, the Consultant should develop a methodology containing proposals of all elements necessary for the successful completion of the Assignment, such as criteria for the selection of relevant gauging stations, the lengths of data series, methods of calculation and analysis, the way of

[8] The list of tasks presented shall not be considered exhaustive. The tasks will be confirmed based on the Inception Report and may be further amended based on progress insights. Therefore, it is the Consultant's responsibility to proactively reassess the requested services to fulfill the stated assignment objectives.

presenting results and addressing all other aspects necessary for a comprehensive approach to the tasks. To accomplish this, the Consultant needs to develop a road map which should include the key elements, such as:

- Outline the specific tasks and activities that will be conducted as part of the Study, including data collection, analysis methods, modeling approaches, etc.
- Collate existing knowledge and data resources available for the basin of relevance to this assignment.
- Specify the types of data required for the Study, such as precipitation data, streamflow measurements, land use data, topographic maps, soil characteristics, and hydrological records.
- Assess the availability of these data and identify any gaps that need to be filled. As part of this stocktaking, assess available processed data (as well as alternatives for filling the gaps) and accessibility (including formats and services). Develop the format for an updatable data catalog indicating these data/data services with relevant brief metadata.
- Propose the required length of data series (e.g., precipitation, streamflow, water level) to ensure the relevance and reliability of the analysis.
- Define procedures and methods for collecting additional data that are not currently available. Specify data processing methods, including error corrections, data interpolation, and application of statistical methods for data analysis. Propose procedures for quality control and validation of data.
- Propose criteria for data storage, including security and archiving, as well as types of data/metadata and information to be stored.
- Propose coding conventions, and identify data that require coding (for locations, measurement units, parameters, missing data, standard methods, data quality, etc.). Review and use as much as possible existing national codes.
- Propose a timeline including milestones for each phase of the Study, from data collection and analysis to reporting and the presentation of findings.
- In collaboration with ISRBC, identify stakeholders interested in the Study outputs. Collate the relevant types of stakeholders at regional and national levels that could help input into, and benefit from, the results of this assignment. Describe how findings will be communicated to stakeholders and decision-makers.
- Evaluate potential risks and challenges that may impact the Study timeline or results. Develop contingency plans to mitigate these risks.

In performing these tasks, the Consultant should review, analyze and reassess previous relevant hydrological studies and reports prepared in the Sava countries, with a specific focus on the basin-wide study conducted in 1976.

Note: The development of the methodology will not be a straightforward process. The initially proposed methods will be validated by expert bodies of the ISRBC throughout the entire process, in accordance with the road map for the study. The involvement of relevant stakeholders during the methodology development should be ensured with the facilitation provided by ISRBC. The hydro-meteorological services of the Sava countries are key stakeholders in the overall implementation of the Assignment:

- Slovenian Environment Agency (ARSO) (www.arso.gov.si)
- Croatian Meteorological and Hydrological Service (DHMZ) (https://meteo.hr)
- Federal Hydrometeorological Service (FHMZ) (www.fhmzbih.gov.ba/latinica/index.php
- Republic Hydro-Meteorological Service of Republika Srpska (RHMZRS) (https://rhmzrs.com)
- Republic Hydrometeorological Service of Serbia (RHMZ), Belgrade (www.hidmet.gov.rs)
- Institute of Hydrometeorology and Seismology (ZHMS), Podgorica (www.meteo.co.me).

1.2. Collection, assessment, storing, processing and standardization of all data and other information relevant to the Assignment, including resources for the Study visualization

- Data digitalization, collection, storing:

  This task will involve the collation and development of data required for this assignment.

  - Spatial and related attribute data: Gauging station locations, digital elevation models, river catchment delineations, river networks, water bodies, land cover/land use maps, soil and soil moisture maps, erosion, flood maps, hydrogeology, aquifer boundaries, etc.).
  - Meteorological data: Rainfall, snowfall and snow cover, snow water equivalent, air temperature, evaporation, solar radiation, etc.
  - Hydrological data: Streamflow/river discharge measurements, water levels in rivers, lakes, and reservoirs, water temperature, reservoir volume, sediment load and turbidity, ice information, groundwater levels, soil moisture, etc.
  - Hydraulic data: Cross-sections of rivers and streams at selected locations, hydraulic structures (dams, weirs, etc.), stage-discharge (rating) curves, level-volume curves, etc.
  - Climate data: historical climate data time series (including related to precipitation, snow, evapotranspiration, runoff, infiltration and other aspects of the water cycle) and climate change projections and scenarios.
  - Data on historical floods and hydrological droughts: historical identification of events and hydro-meteorological characteristics (precipitation, snowmelt); selected hydrographs of events; statistical evaluation of significance; other relevant and related data.
  - Other information and data relevant to the assignment, such as water infrastructure (data on dams: year of construction/commissioning, dimensions, operator, operation rules, rehabilitation/retrofitting, services provided), socioeconomic data (incl. population distribution), water use (including information on supply and demand scenarios if available), etc.
  - All data collected should be pre-processed and, if necessary, digitized to provide input for the Study. The scope of digitalization is indicated in the appendices per data providers.
  - Develop a data catalog for the relevant data/data services.

- Data assessment, processing, validation and standardization:

  This task will involve basic data analytics required for this assignment.

  - Check data for accuracy (correctness of the data) and validity (applicability of the data to the purpose).
  - Create time series per station as a convenient sequence of validated data of hourly, daily, seasonal or annual observations of each variable. The original data must be kept while changes during the validation processes should be reflected in quality flags (e.g. original data, corrected data, reconstructed such as by interpolation, estimation or disaggregation, calculated value).
  - Increase the reliability and usefulness of data by treating data samples against spurious error and systematic error. Data should be checked for consistency (temporal and spatial) with the definitions (e.g. precipitation cannot be negative).
  - Supplement and fill in any missing data using appropriate methods and/or models (e.g. regionalization procedures and estimation at ungauged sites should be performed in combination with the modeling using the existing models HEC-HMS/RAS Sava, WFlow Sava).
  - Calculate frequency and probability distributions, analyze cycles in mean/median annual and monthly data series and perform trend analysis.

- Perform all standard statistical tests and analyses, including tests of randomness, independency, homogeneity, and stationarity as well as analysis of climate normals.
- Prepare and analyze data, including verification and definition for all related purposes and especially for the elaboration of hydrological conditions on unstudied catchments and catchments with gaps in observations.
- Detect and analyse the anthropogenic impacts on the water regime, especially on low flows and floods. Data should be transformed in a sample with and without the impact of hydropower storages, flood protection measures and other anthropogenic changes in the Sava River basin developed in the past fifty years.
- Summarize the basic analytics conducted for the Sava basin data.

➢ All identified, collected and processed data should be standardized, respecting the WMO/OGC requirements and standards (e.g. Water ML 2.0).

Note: The main data sources will include existing national information systems as well as those operating at the basin level under the coordination of the ISRBC (Sava GIS, Sava HIS, Sava FFWS). All other sources should also be taken into consideration.

Analytical treatment of data should be provided at the modern methodological level, and the mapping process should be performed digitally, all according to the WMO guides and state-of-the-art hydrological practices. In the Study, the period of over 95 years of data should be analyzed, while the last about 25 years (period from 2000) should be in focus, in order to: enhance the accuracy of statistical and probabilistic calculations, and thus the reliability of the calculation values that have rare occurrence probabilities (longer return periods); account for anthropogenic impacts, especially in the past fifty years; evaluate internal structure and representativeness of the time series; give a good insight into the possible climate change effects in the Sava River basin area.

1.3. Indicative general content of the Study and related tasks

➢ Introduction

➢ Elaboration of the agreed methodology for the Study preparation

➢ Catchment and the main tributaries[9] sub-catchments characteristics: identification of size and shape; geomorphology; climatology; hydrological and hydrodynamic conditions in the sub-catchments in terms of water quantity, quality and erosion processes, sediment transport and deposition; parameters necessary for numerical hydrological and hydraulic modeling.

➢ Hydro-meteorological investigation: description of available meteorological and hydrological data and their reliability; description of selected meteorological and hydrological stations; historical overview of the operation of gauging stations; description of the selection and adoption of time series periods analyzed.

➢ Climate characteristics: determination of climate characteristics (precipitation, snow depth, snow water equivalent and snow cover, air temperature, relative air humidity, partial water-vapour pressure, cloudiness, isolation, evaporation and evapotranspiration, wind); analysis of climate characteristics data, including derived missing data, per characteristic and per station and derived basic statistics of collected daily data, per month and per year (mean, minimum value, maximum value, standard deviation); derived monthly data and annual including their basic statistics (mean, minimum value, maximum value, standard deviation); seasonal analysis of mean monthly data, trends in seasonal analysis of climate characteristics data; trends of mean, maximum and minimum values; analysis of changes in mean annual values (harmonization); maps of mean annual data for characteristic periods.

- Snow depth data analysis per station (number of days with snow depth, water equivalent, start and end of snow depth season, duration, statistics analysis, trends); snow cover data analysis per station (periods with snow cover, duration, water equivalent, statistics of

[9] Defined by the Sava River Basin Management Plan (Table 3. page 11)

annual data of duration of snow cover; statistics of annual start and end of snow cover season); snow cover area analysis (estimation of water equivalent, annual area–duration curve: mean, minimum, maximum duration).

- Water level data analysis: derivation of basic statistics of collected daily data (mean, minimum value, maximum value, standard deviation); derivation of missing data; transformation of observed data in the past 40–50 years to 'natural values' without anthropogenic impacts; derivation of monthly data and its basic statistics (mean, minimum value, maximum value, standard deviation); derivation of annual data and its basic statistics (mean, minimum value, maximum value, standard deviation), seasonal analysis of mean monthly data, absolute minimum and maximum water level data; derivation of trends in the seasonal analysis of climate characteristics data.
- Discharge data analysis: review and outline of operation and performances of hydrological stations with basic data; review of flow measurements at gauging stations; revision, reconstruction and upgrading of rating curves; comparison and harmonization of data along the rivers; mean annual discharge series; absolute minimum and maximum discharge.
- Runoff/flow analysis at the basin level: longitudinal cross-section of the Sava River and its main tributaries with mean, maximum and minimum flows for the observation period; correlation of station data along the river; specific discharges; homogeneity and trends; anthropogenic impacts; seasonal flow analysis; runoff coefficient.
- Representative periods for definition of hydrologic characteristics: homogeneity analysis of mean annual discharge series; analysis of cycles in mean annual discharge series; trend analysis of mean annual discharge series; adoption of representative period for evaluating average runoff in the Sava River basin.
- Characteristics of average discharge: series of mean monthly and annual discharge on hydrological stations; discharge distribution within a year; duration curves of mean daily discharge; probability distribution of mean monthly and annual discharge; map of unit-area runoff for long-term annual average discharge.
- High flow regime: homogeneity and trend analysis in maximum annual discharge series; probability distribution of maximum annual discharge; probability of coincidence in peak flows on tributaries and mean stream; statistical and probabilistic analyses of flood flow hydrograph parameters (flood volume, duration, water surplus…); theoretical hydrographs of flood waves.
    - Analysis of historical floods: identification of the historical floods; selected historical floods hydrographs; analyses of historic flood hydrographs; statistical evaluation of significance (hydro-meteorological aspects) of the selected historical floods.
- Low flow regime: homogeneity and trend analysis in minimum annual discharge series; probability analyses of minimum annual discharge; probability analyses of minimum mean monthly discharge series; analyses and statistical evaluation of low flows (discharge during low-flow periods, duration of selected low-flow periods, water deficit, …); regional distribution of low flows module.
    - Analyses of historical hydrological droughts: identification of historical droughts; selection of historical drought hydrographs; evaluation of properties of historic drought hydrographs; statistical evaluation of significance (hydro-meteorological aspects) of the selected historical droughts.
- Water balance: basic water balance equation; water balance calculation procedure; partition of the catchment into the balance units; water balance calculation; preparation of maps of water balance elements; review of trends and current conditions and discussion of water balance elements according to balance units, relevant sub-catchments, and countries; water supply-demand analysis; water resource spatial and temporal distribution and its characteristics in the Sava catchment.

- Representative inland waterway parameters: high navigable water level (e.g. water level of 1 to 3% duration); low navigable water level (e.g. water level of 95% duration); navigable water level of 65% duration; minimum waterway widths (in the direction and bend) including parameters of the navigable clearance; minimum depths for certain waterway classes; prescribed vertical clearance; minimum sinuosity radius; navigation water demand; minimum and maximum discharge for navigation; navigation season (not hampered by ice); principal shallows by navigation reaches.
- Hydrogeological analysis: stations for measurement of groundwater; hydrogeological conditions; the average depth of groundwater; mean annual groundwater fluctuation; quality and groundwater protection (biological water quality, hydro-geochemistry of water, water protection and water quality trends); long-term trends in groundwater (trends that reflect the quantitative status of groundwater, i.e. water table in aquifers, springs outflow; trends that reflect the quality status of water; deep groundwater circulation (categorization of thermal and mineral waters along with a cartographic representation of the methodology to modernize and adapt to the EU and other relevant categorizations).

Note: The Consultant's tasks include graphic processing and printing of the final version of the Study. The final version of the Study will be prepared in English and the six official languages of the Sava countries.

2. Development of a web-based tool for the presentation of the Study

- Propose a technical solution of a web-based tool for the presentation of the Study, based on the analysis and assessment of the current systems presenting hydrological and meteorological data and statistics in the Sava countries.
  The tool may be designed and implemented using (a) the existing ISRBC software solution, based on open-source software; (b) ESRI ArcGIS proprietary software; (c) a combination of (a) and (b); or (d) other software solution. In a case that the Consultant decides to implement the tool based on a commercial software other than ArcGIS, it will be solely responsible for acquiring the perpetual licenses.
- Develop a geodatabase for data storing, as part of or an extension of the Sava HIS database, that should cover thematic datasets resulting from the Study and include all identified and previously collected data.
- Establish a web-based tool for water data management, as a modern interactive portal, using and analyzing data and metadata, including aspects related to its system architecture, schema, software and data services platform, functionality, information flow, look and feel, navigation, help, security, hosting, deployment and roll-out. Functionalities should support the online public and private/restricted domain and should promote open data principles and enhance access to global, regional, and national good practices where possible. The basic functionality should enable users to interactively and intuitively access, analyze, and visualize information (through interactive maps, graphs, overlays, animations, and data visualization using appropriate libraries). The tool should enable:
  - transforming database scheme, data and information (different than existing in Sava HIS) in Water ML 2.0 standard information model;
  - displaying statistical analysis with a range of plotting styles (e.g. line, bar, pie, box plots) to view and use data in conjunction with existing products, tools and processes as well as enabling comparisons between different years or events;
  - displaying different types of time series plots for both raw data (Sava HIS real-time app) and the processed data and statistical analysis, including but not limited to: a simple time series plot; a time series plot with the day/month recorded maximum and minimum and the long-term average; regime bandings; comparisons to pre-selected major events, and the option for the use to select years of the user choice;
  - displaying spatial data in the form of a map with a location selector (station, sub-catchments, river segments, etc.) for searching, filtering, and displaying data in spatial

and tabular form including interpretation of information as well as spatial analytics (e.g. for a selected area, pre-defined administrative, hydrological or other areas, selected shapefiles) – incl. use of Google Earth Engine or other free cloud analytics. Public domain data and data services (related to associated hydrological themes) available from global, regional, national, and other sources for high-quality data should be analyzed and integrated;

- displaying different metadata per selected station (station catchment/drainage area, river kilometer, start/end date, total values, missing values, frequency, normal distribution, standard deviation, asymmetry and density of the probability distribution, etc.);
- ability to export data services and visualizations as images, spreadsheets/CSV where possible, deep URL links and embeds in other portals, mobile Apps, etc.;
- user and administration manuals and help tools (e.g. interactive documentation, screen-capture videos);
- data and user management, with a separate interface for user access, based on their roles and granted permissions.

➢ Test and operationalize the tool by:

- developing a prototype/pre-release to help users visualize the intended type of the tool. Utilize modern agile design sprints (incl. with virtual participation) to collate inputs for prototyping and developing alternative options for data visualization and interactive analytics.
- detailed testing, performed by the stakeholders, during each pre-release version to ensure that the developed solution satisfies the requirements defined in the functional requirements specification. Subsystem integration tests (compatibility, performance, stress and load testing) should be executed and evaluated to prove that the tool integrates properly into Sava HIS and the external services and applications. During testing, any shortcomings and bugs encountered in the system must be removed.
- conducting final testing and operationalization to ensure that it meets all technical requirements. This includes verifying its functionality within the ISRBC's IT environment, with a focus on reliability, security, multi-user access, and efficiency/performance.

Note: The existing hydrological atlases (e.g. Germany, Austria, Switzerland) as well as state-of-the-art web solutions could be used as examples for the development of the tool and for the combination of the free/public-domain services within the tool (e.g. UK Water Resources Portal, UK Reconstructed Flow Data Explorer, US Time Series Toolbox, US Climate Hydrology Assessment Tool, Google Earth Map, Google Climate Engine, ECMWF GEOGloWS Hydroviewer, World Bank Maps, World Bank Hydro Informatics Data Portal).

3. Recommendations for future studies and developments

➢ Review and update of the Data Policy: provide a proposal for an update of the document based on the findings from the Study and trends in hydrological data management.

➢ Evaluation of data monitoring systems - gap analysis and investment program: review and evaluate the spatial distribution of gauging stations (meteorological, surface and groundwater); review of data collection and processing practices (equipment, software, staff, institutional set-up); reliability assessment of the available data from the point of view of water resources evaluation; propose measures (program) for the improvement of monitoring network and data acquisition and processing, including cost estimates of investment, and operation and maintenance.

➢ Maintenance, sustainability, updating, and scaling-up plan for the tool, including technical, institutional/governance, quality management, financial, and capacity-development aspects. This should include a maintenance and user support plan for the provision (licensing, adaptation

or development of new data/analytic services or functionality) of software solutions and maintenance and user support (backups, error reporting and tracing of corrective actions, mechanism for system upgrades/bug fixes and associated documentation and release notes), and suggestions for support beyond the project duration. Also analyse the expansion of Sava HIS and the tool, including the potential improvements, for analysis of the effects of climate change within the basin.

- A roadmap for the development of high-resolution gridded precipitation and air temperature datasets based on the processed daily and hourly time-step data: analyse effects of available stations density in the Sava River basin, interpolation method, and spatial resolution on observation-based gridded datasets quality; evaluate a general relationship between mean absolute error and the percentage of stations included in the grid.

4. Training, capacity building and communication activities

4.1. Training and capacity building

The Consultant will prepare a training program proposal aligned with the project's implementation phases. The program will be refined based on the analysis of the key stakeholders, further detailed, and approved during the Inception Phase. The training sessions should cover various relevant topics and should incorporate an analysis of user experiences gathered (training evaluation).

The Consultant will organize at least 3 training sessions, each lasting 3 days. In principle, sessions will be conducted in person with an estimated attendance of 15 participants per event. The Consultant will cover the costs of travel, meals, and accommodation for training participants. Per diems may not be paid to participants when meals and accommodation are to be provided. The Consultant is also responsible for providing a suitable meeting room equipped with modern technical amenities, including excellent sound systems, quality lighting, a projector, screen, and high-speed internet. For the invited participants who will not be able to attend the training sessions in person, access should be provided through a web application, such as MS Teams, Webex, etc.

During the operational testing phase of the web-based tool, an online knowledge transfer session for all users should be organized. The main goal is to allow users to directly pose specific questions to the Consultant, facilitating the exchange of insights among users and enabling the transfer of knowledge and expertise in using the tool.

Training materials such as agendas, descriptions of specific topics, presentations, examples, etc., will be distributed to participants at least one week before each course.

Additionally, the Consultant should establish an online platform, such as SharePoint, to ensure continuous communication between users and the Consultant. This may include a forum enabling easy discussion about various topics (i.e. how to…, bugs). It may also encompass all documentation generated throughout the project implementation to keep all stakeholders updated with the latest information.

4.2. Project events

In the course of the assignment, the Consultant will organize the following events with the participation of key stakeholders:

i. Kick-off meeting during the Inception Phase (months 1-2) to present the planned project activities including the draft methodology for preparation of the Study as well as results of an initial data gathering performed and get feedback from participants.
ii. Intermediate workshop scheduled after development of a mature draft of the Study and the completion of the tool implemented installation (months 16-17) to exchange experiences with participants.
iii. Final conference scheduled after the submission of the draft Final Report (month 21) to present the Study and the tool and get feedback from participants for final adjustments before handing over.

The events will be essentially organized in a hybrid format. The Consultant should provide an adequate meeting room, equipped with modern technical equipment, which includes excellent sound systems,

quality lighting, projector, screen, and high-speed internet. The costs of refreshments and meals for in-person participants will be borne by the Consultant. The estimated number of participants attending the events in person is the following: 30 at the kick-off meeting, 30 at the intermediate workshop and 40 at the final conference.

For each event, the Consultant should prepare an agenda with background information and draft documents and presentations with critical issues to be discussed. The Consultant shall arrange translations/interpretation, moderate the events, and write the minutes highlighting findings, agreements, among others.

4.3. Communication activities

During the implementation of the assignment, the Consultant will, on an ad hoc basis, prepare appropriate materials for public release, which may include short videos, press releases, and news for the web and social media, in English and one of the official languages of the Parties to the FASRB.

Note: All stakeholders' engagement activities should continuously take into consideration the main project indicator - *enhanced monitoring/data sharing protocols and schedules developed*. The indicator should measure the progress in the development of data-sharing protocols/schedules which are harmonized and agreed upon among the riparian countries.

4. Deliverables/specific outputs

The following should be delivered to the Client:

1. Methodology for preparation of the Hydrological Study of the Sava River Basin.
2. The Hydrological Study of the Sava River Basin.
3. Installed and well-tested, integrated operational tool for presentation of the Hydrological Study of the Sava River Basin, with online access to its use. The final delivery shall include the general system documentation and a description of the installed system architecture showing how the final system has been configured.
4. Appropriately trained staff to ensure continued use after installation and delivery. All training materials delivered.
5. A report describing recommended investments which will lead to future hydrological analysis and studies as well as improvements of the tool for presentation of the Study.

The main deliverables specified in this Section will be detailed and possibly amended in the Inception Phase.

5. Reporting Requirements and Time Schedule for Deliverables

Month*	Project report	Main Deliverable	Indicator
2	Draft Inception Report		
3	Inception Report	Report	The report, including a description of the detailed approach, aimed to achieve the assignment's objectives. The draft methodology and a road map for the preparation of the Study developed. An inventory of required and available data done. Initial data gathering performed.
6	Draft Interim Report 1		
7	Interim Report 1	Study draft 0.1 Tool prerelease 0.1	The majority of the necessary data collected.

			An initial version (outline of the Study) developed. The tool design (mock-up) prepared.
11	Draft Interim Report 2		
12	Interim Report 2	Study draft 0.2 Tool prerelease 0.2	Data collection completed. The second draft of the Study developed. The initial version of the tool installed on the testing platform.
16	Draft Interim Report 3		
17	Interim Report 3	Study draft 0.3 Tool prerelease 0.3	The third draft of the Study developed. All components/functionalities of the tool implemented.
21	Draft Final Report	Study version 1.0 Tool release1.0	The final draft version of the Study developed. The tool tested and implemented on the operational platform.
23	Final Report	Study version 2.0 Tool release2.0	The final version of the Study and an operational version of the tool – delivered to the Client, along with all necessary documentation.

* from the commencement of the assignment

Each report shall consist of a narrative section and a financial section. The financial section must contain details of the time inputs of the experts and the provision for expenditure verification. Draft reports must be provided along with the corresponding invoice to the ISRBC (e-mail: isrbc@savacommission.org). The Consultant shall present the final version within 21 days from the date it receives the comments from the ISRBC. The approved reports will serve as the basis for payments.

Reports shall be provided in English with summaries in one of the official languages of the Parties to the FASRB. Three printed copies of the final report should be submitted. All documents, i.e. (draft) reports, records of informative data, spatial information such as maps, and training material are to be made available in electronic form. Each version of a complete web-based tool (prerelease 0.1 to release 2.0) should be installed and available at the ISRBC IT infrastructure, and release 2.0 should also be prepared and submitted on digital media.

In addition to the aforementioned reports, the Consultant is obligated to prepare brief periodic progress reports, generally on a monthly basis. Periodic reports shall be prepared in English.

Note: As the stakeholders' network is rather complex (e.g. representatives of five countries and various sectors), the inception phase is crucial for the assignment, planned for three months. During this phase, the stakeholder list may be updated. The requested outputs and services will be (re)analyzed, confirmed by the key stakeholders and afterwards approved by the coordinating body to be established by the ISRBC.

6. Logistics, Team Composition & Qualification Requirements

6.1. Logistic Requirements

To ensure the smooth execution of the assignment, the Consultant will:

- Establish one or more offices in the Sava countries, including all equipment necessary for the project, which will remain the Consultant's property at the end of the assignment.
- Establish a mechanism to ensure continuous and unrestricted communication with the ISRBC, as well as with relevant stakeholders in the countries of the Sava River basin.
- Support the ISRBC in the establishment of a project coordination platform respecting the existing cooperating structure among the participating countries established under the ISRBC.
- Organize meetings in and among countries and/or between sectors (with the support of the ISRBC when and where necessary) and prepare for each meeting the following: (i) agenda, (ii)

a brief description of critical issues to be discussed, (iii) minutes, including agreed actions, deadlines, and responsibilities.

Note: The Consultant's team needs to possess adequate proficiency in the official languages of the FASRB Parties to ensure fluid communication and engagement with national entities in the countries of the Sava River basin during the contract implementation.

6.2. Consultant Qualification

- The core business of the Consultant should encompass the development of hydrological and meteorological studies and the configuring of web-based tools for the presentation of spatial and alphanumerical information and analysis with demonstrated evidence of at least fifteen (15) years of general experience in implementing similar types of projects. Experience with projects funded by donors such as the World Bank and other IFIs, the EU or similar entities will be considered as an added advantage.
- The Consultant must provide evidence of at least three (3) successfully completed contracts similar to this Assignment in the last ten (10) years, demonstrating a proven record of scope, complexity, and value. References for the listed assignments should be provided. Previous assignments of a similar nature in the region will be considered as an added advantage.
- The Consultant must demonstrate solid technical and managerial capabilities of the firm providing only the structure of the organization, general qualifications, and availability of appropriate skilled key experts[10].

The shortlisting criteria are:

a) Overall experience relevant to the assignment –	*35*
b) Similar contracts to demonstrate specific experience –	*50*
c) Firm Organization and availability of key experts –	*15*
Total weight:	*100 points*

6.3. Team Composition

The Consultant will ensure that appropriately qualified experts for each of the tasks described in Section 3. (scope of services for each activity) and the necessary equipment are available to complete the activities required and to achieve the overall and specific objectives of this project in terms of time, costs, and quality.

For this assignment, the Consultant should field a well-balanced team of international and local key experts with the following aggregate abilities, by specialist position:

Key Expert 1: Technical Team Leader - TTL

- Education: Advanced university degree (master's or equivalent) in water resources engineering/management/science; an advanced university degree in another discipline may be accepted in lieu if it is pertinent to the requirements of the assignment and in combination with relevant professional experience.
- Professional Experience: At least 15 years of extensive practical experience in similar projects including development of hydrological and meteorological studies.
- Project Management: Documented experience in leading international and multidisciplinary technical projects, including planning, budgeting, scheduling, and resource allocation.
- Language: Excellent command of written and spoken English.

Key Expert 2: Senior hydrologic expert

- Education: Advanced university degree (master's or equivalent) in water resources engineering/management/science; an advanced university degree in another discipline may be

[10] *No need to provide CVs of key experts. The key and non-key experts will be evaluated at next stages of procurement procedure.*

accepted in lieu if it is pertinent to the requirements of the assignment and in combination with relevant professional experience.

- Professional Experience: At least 15 years of extensive experience which includes: data consistency checking; statistical analysis of hydrological and hydrometeorological long-term data and stochastic/random variables and extremes; water balance studies, advanced hydrological modeling and environment flow assessment, flood frequency analysis, low flows and droughts, etc., with a proven track record of successful related projects.
- Language: Excellent command of written and spoken English.

Key Expert 3: Senior water resources expert

- Education: Advanced university degree (master's or equivalent) in water resources engineering/management/science; an advanced university degree in another discipline may be accepted in lieu if it is pertinent to the requirements of the assignment and in combination with relevant professional experience.
- Professional Experience: At least 15 years of extensive experience relevant for the assignment which includes analysis of water balance, hydrological and meteorological long-term data, climate change, water quality, sediment management, groundwater, etc., with a proven track record of successful related projects.
- Language: Excellent command of written and spoken English.

Key Expert 4: Senior data processing expert

- Education: Advanced university degree (master's or equivalent) in data processing related discipline; an advanced university degree in another discipline may be accepted in lieu if it is pertinent to the requirements of the assignment and in combination with relevant professional experience.
- Professional Experience and Skills: At least 10 years of extensive experience relevant for the assignment which includes: in-depth knowledge of data management and organizing long-term data for analysis, filling gaps in the time series, assessing and interpreting statistical data, etc., with a proven track record of successful related projects. Proficiency in statistical analysis tools, GIS, programming languages commonly used in data processing, such as R, Python, MATLAB, HydPy, C++, as well as software for data management, such as HEC-DSS.
- Language: Excellent command of written and spoken English.

Key expert 5: Senior IT expert

- Education: Advanced university degree (master's or equivalent) in computer science, information technology, software engineering; an advanced university degree in another discipline may be accepted in lieu if it is pertinent to the requirements of the assignment and in combination with relevant professional experience.
- Professional Experience and Skills: At least 10 years of extensive experience in IT project management, software development, and system integration with a proven track record of successfully implementing IT solutions for complex projects, preferably in the domain of hydrology or water resources management and knowledge of OGC standards and open APIs. Proficiency in programming languages such as Java, Python, C++, or JavaScript; Web Programming Skills; working knowledge of PostgreSQL/PostGIS, ArcGIS Online. In-depth knowledge of the Apache Tomcat platform's architecture, functionalities, and capabilities.
- Language: Excellent command of written and spoken English.

<u>Pool of other international and national experts, such as:</u>

- Hydrologist(s)
- Meteorologist(s);
- Climatologist(s);
- Hydrogeologist(s);
- Hydrologic modeler(s);
- Data management specialist(s);
- Water resources management specialist(s);

- Inland navigation expert(s);
- IT specialist(s): database architect/developer; system integrator, network engineer, cyber security expert, etc.
- Stakeholder involvement/Public communications expert.

Special requirements

The Consultant should ensure that the consortium brings in substantial local expertise to address the specific needs of the Sava countries and secure future support from consultants based in the Sava River basin. The list of non-key experts shall be approved with the approval of the Inception Report, i.e., when the scope and set-up of the assignment will be (re)defined and approved by the ISRBC coordinating body.

Estimated input per expert

Experts	Number of days
K1- Technical Team Leader - TTL	120
K2 - Senior hydrological expert	95
K3 - Senior water resources expert	85
K4 - Senior data processing expert	85
K5 - Senior IT expert	85
Non-key experts	590
TOTAL	**1060**

7. Client's Input and Counterpart Personnel

The work on the assignment will be overseen and coordinated by the ISRBC. The HMSs from all participating countries will be involved through the ISRBC. These organizations will be actively engaged throughout the assignment period and will assist in the collection of data and other relevant information. Although the collection of data is the responsibility of the Consultant, the ISRBC and the HMSs will facilitate communication with other potential data providers in the riparian countries (e.g. national relevant authorities responsible for water management, inland navigation, as well as reservoir operators and water utilities, academic institutions, and engineering companies practicing hydrological investigations).

Additionally, the ISRBC shall:

- Establish and facilitate the work of the project coordination platform.
- Facilitate contacts with the stakeholders and assist in the collection and valorization of comments when necessary.
- Provide support in organizing project events and training courses.
- Make available all Sava HIS data.
- Make available all publications of interest in electronic form.
- Make available all internally upgraded hydrological models.
- Provide related GIS data in its native format.

8. Working languages

The working language would be English.

9. Duration of the Assignment

The requested services are to be rendered within a maximum of **23 months.** The intended commencement date is March 2025, but the actual date will be defined with the Contract signature. The Consultant will perform the services in line with a detailed schedule submitted as part of the proposal, subject to changes during negotiations to accommodate the Client's comments and requirements and during the inception phase period.

10.Selection process

The Consultant will be selected under the provisions of the World Bank Procurement Regulations for IPF Borrowers (Procurement Regulations), in investment project financing Goods, Works, Non-Consulting and Consulting Services November 2020, based on the method of Quality and Cost Based Selection (QCBS) Lump Sum Contract.

APPENDIX A – List of hydrological stations

No	Stations	Period of the data available per parameter				Data Provider
		P1	P2	P3	P4	
1	Radovljica + Radovljica I	1926-2022	1910-2022	1896-2022	n/a	ARSO
2	Šentjakob	1952-2022	1926-2022	1969-2022	1954-1994	ARSO
176	Litija I + Litija	1936-2022	1895-2022	1896-2022	n/a	ARSO
10	Suha + Suha I	1952-2022	1926-2022	1953-2022	1973-2022	ARSO
22	Rakovec I + Rakovec	1952-2022	1926-2022	2015-2022	1978-2006	ARSO
21	Metlika	1954-2022	1926-2022	1953-2022	n/a	ARSO
12	Moste + Moste I	1952-2022	1924-2022	1953-2022	n/a	ARSO
13	Nazarje	1933-2022	1926-2022	1953-2022	n/a	ARSO
16	Veliko Širje + Veliko Širje I	1955-2022	1955-2022	1968-2022	1955-2022	ARSO
19	Podbočje	1947-2022	1926-2022	1953-2022	1978-1987	ARSO
5	Čatež + Čatež I	1955-2022	1926-2022	1977-2022	n/a	ARSO
189	Medno	1968-2022	1978-2022	1997-2022	1997-2002	ARSO
4	Hrastnik	1993-2022	1993-2022	1997-2022	1997-2022	ARSO
7	Blejski most	1959-2022	1963-2022	2010-2022	n/a	ARSO
9	Bodešče	1954-2022	1951-2022	2013-2022	n/a	ARSO
192	Kranj I + Kranj II	1956-2022	1957-2022	1990-2022	n/a	ARSO
193	Kamnik + Kamnik I	1954-2022	1926-2022	1954-2022	n/a	ARSO
	Podbukovje + Podbukovje I	1959-2022	1959-2022	1968-2022	n/a	ARSO
191	Petrina	1952-2022	1952-2022	2016-2022	n/a	ARSO
23	Jesenice II	1999-2022	2000-2022	n/a	n/a	DHMZ
25	Podsused	1900-2022	1949-2022	1980-1986	1979-2022	DHMZ
27	Zagreb	1900-2022	1926-2022	1948-2022		DHMZ
28	Rugvica	1901-2022	1926-2016	1948-1995	1978-2022	DHMZ
30	Crnac	1949-2022	1955-2022	1966-2022		DHMZ
35	Jasenovac	1900-2022	1926-2022	1966-1990	1978-2022	DHMZ
36	Stara Gradiška	1900-2022	1937-2022	1964-1991	1963-1991	DHMZ
37	Mačkovac	1951-2022	1951-2022	n/a	n/a	DHMZ
38	Davor	1921-1981; 1958-2022	1926-1960; 1958-2022	1984-1991	n/a	DHMZ
39	Slavonski Kobaš	1900-2022	1926-2022	n/a	n/a	DHMZ
40	Slavonski Brod	1900-2022	1926-2022	1956-2022	1960-2022	DHMZ
41	Slavonski Šamac	1900-2022	n/a	n/a	n/a	DHMZ
42	Županja	1900-2022	1929-2022	n/a	n/a	DHMZ
45	Zelenjak	1957-2022	1958-2022	1964-2022		DHMZ
48	Kupljenovo	1964-2022	1964-2022	n/a	1980-2022	DHMZ
51	Brodarci	1957-2022	1982-2022	n/a	n/a	DHMZ
52	Karlovac at Kupa	1926-2022	n/a	1948-1995	n/a	DHMZ
53	Jamnička Kiselica	1948-2022	1948-2022	n/a	n/a	DHMZ
55	Farkašić	1965-2022	1965-2022	1969-1986	n/a	DHMZ
71	Kostajnica	1900-2023	1926-2023	1968-1991	1967-1991	DHMZ
72	Hrvatska Dubica	1900-2023	1980-2013	n/a	n/a	DHMZ
84	Pleternica	1946-2021	1946-2013	n/a	n/a	DHMZ
82	Frkljevci	1995-2022	1999-2022	n/a	n/a	DHMZ
66	Glina	1946-2022	1952-2019	1972-1973	n/a	DHMZ
43	Gunja	2011-2022	2011-2022	n/a	n/a	DHMZ
49	Hrvatsko	1949-2022	1949-2022	1964-2004	1963-2022	DHMZ
62	Karlovac at Korana	1951-2022	n/a	1984-2012	n/a	DHMZ
232	Koretići	1980-2022	1980-2022	1981-2012	n/a	DHMZ
239	Lipovac	2009-2022	n/a	n/a	n/a	DHMZ
240	Ljubanj	1989-2022	n/a	n/a	n/a	DHMZ
24	Medsave	1950-2022	n/a	n/a	n/a	DHMZ
57	Stative Donje	1946-2022	1946-2022	1957-2022		DHMZ
93	Martin Brod-downstream	1948-1990 2004-2023	1953-1990 2004-2023	n/a	n/a	FHMZ
97	Kralje	1968-1990 2002-2023	1961-1990 2002-2023	2005-2023		FHMZ
100	Bosanska Otoka	2004-2023	2004-2023	n/a	n/a	FHMZ
103	Rmanj Manastir	1948-1990 2006-2023	1961-1990 2006-2023	2006-2023		FHMZ
106	Ključ	1957-1990 2005-2023	1961-1990 2005-2023	n/a	n/a	FHMZ
107	Sanski Most	1945-1990 2001-2023	1952-1990 2001-2023	2001-2023		FHMZ
110	Daljan	1959-1990 2005-2023	1959-1990 2005-2023	n/a	n/a	FHMZ
111	Kozluk	1924-1990 2004-2023	1959-1990 2004-2023	n/a	n/a	FHMZ
121	Reljevo	1904-1990 1998-2023	1951-1990 1998-2023	n/a	n/a	FHMZ

No	Stations	Period of the data available per parameter				Data Provider
		P1	P2	P3	P4	
125	Raspotočje	1963-1990 2001-2023	1961-1990 2001-2023	n/a	n/a	FHMZ
128	Zavidovići at Bosna	1957-1990 2001-2023	1961-1990 2001-2023	n/a	n/a	FHMZ
129	Maglaj	1971-1990 2001-2023	1961-1990 2001-2023	n/a	n/a	FHMZ
133	Ilidža	2001-2023	2001-2023	n/a	n/a	FHMZ
134	Sarajevo-Čumurija	1923-1990 2003-2023	1951-1990 2003-2023	n/a	n/a	FHMZ
135	Merdani	1959-1975 1979-1990 2001-2021	1961-1990 2001-2021	n/a	n/a	FHMZ
136	Olovo	1923-1968 1968-1990 2001-2023	1961-1990 2001-2023	n/a	n/a	FHMZ
137	Zavidovići at Krivaja	1957-1990 2001-2023	1961-1990 2001-2023	n/a	n/a	FHMZ
138	Kaloševići	1971-1990 2006-2023	1961-1990 2006-2023	n/a	n/a	FHMZ
147	Goražde			n/a	n/a	FHMZ
142	Karanovac	1969-1990 2003-2023	1951-1990 2003-2023	n/a	n/a	FHMZ
144	Srebrenik	1968-1986 2004-2023	1968-1986 2004-2023	n/a	n/a	FHMZ
89	Svilaj	2004-2023	2006-2007	n/a	n/a	FHMZ
104	Drvar	1927-1990 2005-2023	1961-1990 2005-2023	n/a	n/a	FHMZ
123	Visoko at Bosna	1961-1989 2008-2016 2016-2023	1961-1989 2008-2023	n/a	n/a	FHMZ
299	Visoko at Fojnica	1960-1990 2006-2023	1963-1988 2006-2023	n/a	n/a	FHMZ
141	Modrac	1957-1990 2002-2023	1961-1990 2002-2023	n/a	n/a	FHMZ
87	Gradiška	1994-2023	n/a	n/a	n/a	RHMZRS
88	Srbac	1997-2023	n/a	n/a	n/a	RHMZRS
101	Novi Grad-upstream	1967-1986; 2020-2023	n/a	n/a	n/a	RHMZRS
102	Novi Grad-downstream	1949-1991; 1993-2003	1960-2023	2006-2023	n/a	RHMZRS
108	Prijedor	1949-1989; 1994-2023	1959-2023	2006-2023	n/a	RHMZRS
105	Donji Ribnik	2007-2014; 2018-2023	n/a	n/a	n/a	RHMZRS
112	Banja Luka	1921-2023	1958-2023	n/a	n/a	RHMZRS
113	Delibašino Selo	1925-2023	1962-2023	1998-2023	n/a	RHMZRS
130	Doboj	1961-2023	1961-2023	1997-2023	n/a	RHMZRS
115	Vrbanja	1925-2023	1961-2023	n/a	n/a	RHMZRS
146	Foča-downstream	1923-1990; 2000-2014	n/a	n/a	n/a	RHMZRS
180	Bočac	1959-1990; 2015-2023	1961-1973; 1984-1986	n/a	n/a	RHMZRS
114	Razboj	n/a	n/a	n/a	n/a	RHMZRS
	Volari	1960-1990; 2006-2023	1960-1986; 2006-2023	n/a	n/a	RHMZRS
116	Viseći most	n/a	n/a	n/a	n/a	RHMZRS
117	Prljača	n/a	n/a	n/a	n/a	RHMZRS
131	Modriča	1965-1990	n/a	n/a	n/a	RHMZRS
	Stanić Rijeka	1965-1990; 2020-2023	n/a	n/a	n/a	RHMZRS
145	Bastasi	1923-1990	1959-1990	n/a	n/a	RHMZRS
149	Rudo	1949-1979; 2020-2023	n/a	n/a	n/a	RHMZRS
150	Ćehotina	1923-1990	1965-1990	n/a	n/a	RHMZRS
151	Drinjača	1967-1990	1980-1986	n/a	n/a	RHMZRS
152	Jamena	1980-2023	2006-2023	2004-2023	n/a	RHMZ
153	Sremska Mitrovica	1920-2023	1926-2023	1948-2023	2004-2007 (P)&(Cs) 1958-1978 2017 (C)	RHMZ
154	Šabac	1922-2023	1990-2002	1949-2023	1993-2002 (P) 1993-2001 (Cs)	RHMZ

No	Stations	Period of the data available per parameter				Data Provider
		P1	P2	P3	P4	
					1958-1962 (C) 1986-2002 (C)	
155	Beljin	1949-2023	n/a	2016-2023	n/a	RHMZ
156	Beograd	1920-2023	n/a	n/a	- (P) 1993 - (Cs) 1958-1998 (C)	RHMZ
157	Bajina Bašta	1926-2023	1926-2023	1964-2023	n/a	RHMZ
158	Radalj/ Kozluk	1976-2023/ 1956-1979	1979-2023/ 1964-1978	1976-2023/ 1964-1979	1984-2003 (P) 1984-2001 - (Cs) 1984-2002 (C)	RHMZ
159	Brodarevo	1935-1940; 1959-2023	1961-2023	n/a	n/a	RHMZ
160	Prijepolje at Lim	1924-2023	1925-2023	1973-2023	1968-2007 (P) 1968-2001 (Cs) 1963-2002 (C)	RHMZ
161	Priboj	1959-2023	1962-2023	2019-2023	n/a	RHMZ
169	Čedovo	1959-2023	1959-2023	2019-2023	n/a	RHMZ
170	Lešnica at Jadar	1926-2023	1960-2023	1972-2014	n/a	RHMZ
162	Batrovci	1983-2023	n/a	1993-2002	n/a	RHMZ
164	Valjevo	1951-2023	1957-2023	n/a	n/a	RHMZ
165	Slovac	1953-2016; 2020-2023	1954-2016; 2020-2021	1959-2005	1959-1992 (P) 1991-1992 (Cs) 1958-1992 (C)	RHMZ
167	Draževac	1946-2023	1951-2023	1968-2007; 2020-2023	1991 (P) 1991-2001 (Cs) 1958-1966 (C) 1991-2002 (C)	RHMZ
172	Bogovađa	1951-2023	1955-2023	n/a	n/a	RHMZ
171	Ćemanov Most	1970-2023	1971-2023	2020-2023	n/a	RHMZ
166	Beli Brod	1950-2023	1959-2023	1985-2015; 2020-2023	1986-2007 (P) 1986-2001 (Cs) 1986-2001 (C)	RHMZ
	Zavlaka	1959-2023	1960-2023	2019-2022	n/a	RHMZ
175	Bijelo Polje	n/i	n/i	n/i	n/i	ZHMS
174	Trebaljevo	n/i	n/i	n/i	n/i	ZHMS
	Crna Poljana	n/i	n/i	n/i	n/i	ZHMS
	Gornja Bijela	n/i	n/i	n/i	n/i	ZHMS
	Gradac	n/i	n/i	n/i	n/i	ZHMS
204	Pljevlja	n/i	n/i	n/i	n/i	ZHMS

n/a – information provided by the HMSs that data are not available. This information should be checked during the implementation.
n/i – no information provided by the HMSs. The information should be collected during the implementation.

Digitalization:
ARSO – most of data are available in digital form, while for the specific data the digitalization is ongoing.
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FHMZ – data after 1951 available in digital form, while data for the earlier periods are available in the scanned copies.
RHMZRS – data after 1961 available in digital form, while data for the earlier periods are available in the scanned copies.
RHMZ – all data are available in digital form.
ZHMS – all data are available in digital form.

Examples of documentation to be digitalized: https://www.fhmzbih.gov.ba/latinica/HIDRO/godisnjaci.php

Note:
Some data sets may be incomplete. The micro-locations of the stations changed during the measurement period, which is evident from the name of the station (extension to the name I or II).

Parameter		Temporal Resolution	Units
P1	Water Level	Daily / Hourly	cm
P2	River Discharge	Daily / Hourly	$m^3 s^{-1}$
P3	Water Temperature	Daily / Hourly	^oC
P4	Suspended Sediment Discharge	Daily	$kg s^{-1}$

NOTE:
A list of stations for analysis of groundwater, river ice conditions and other specific parameters will be defined during the inception phase of the project.

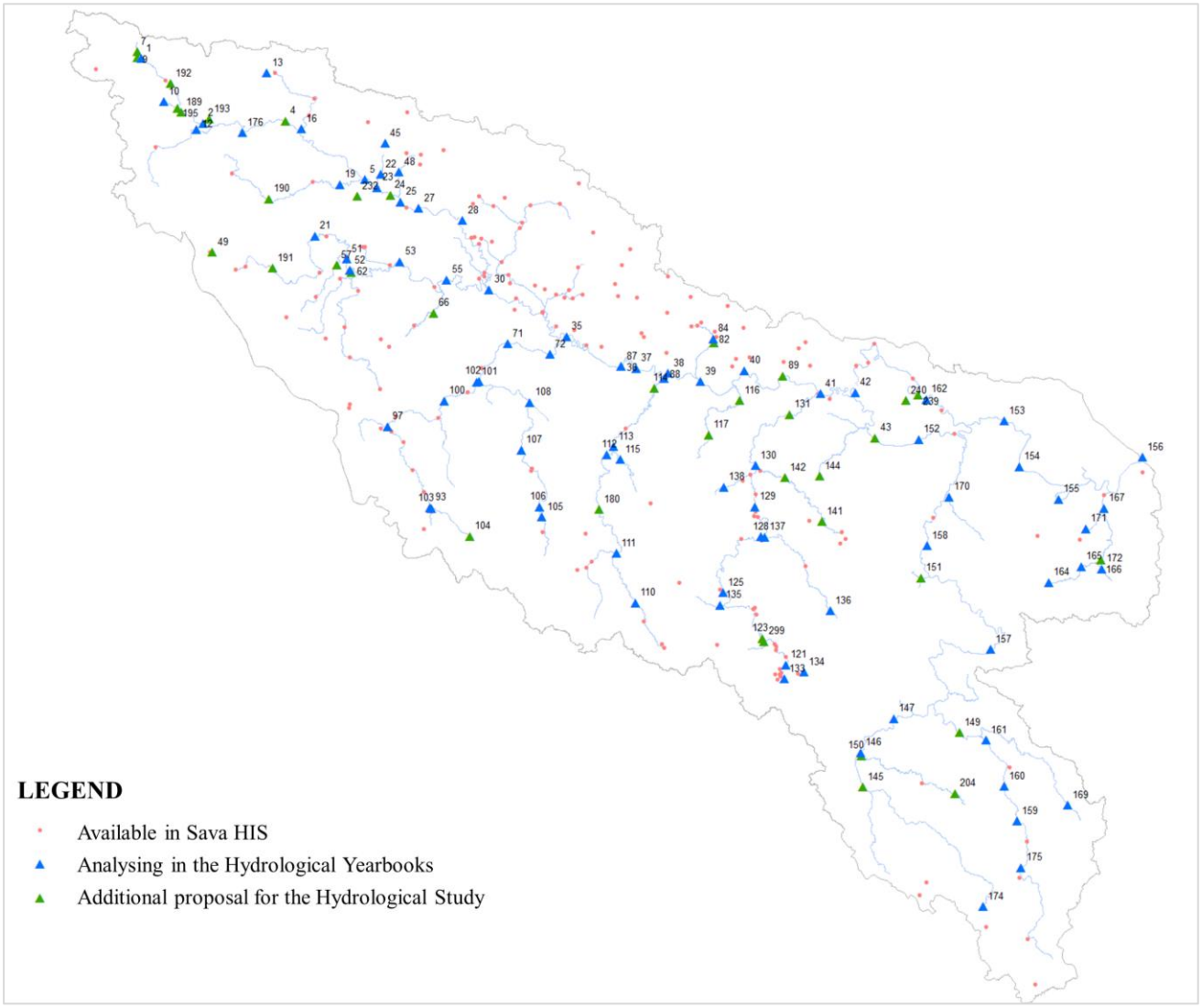

Figure A1: Overview of hydrological stations (corresponds with the list of stations)

APPENDIX B – List of meteorological stations

No	Stations	Period of the data available per parameter			Data Provider
		P1	P2	P3	
1	Ljubljana-Bežigrad	1948-2024	1948-2024	1948-2024	ARSO
2	Lesce	1979-2024	1979-2024	1979-2016	ARSO
3	Krvavec	1952-2024	1952-2024	1952-2022	ARSO
4	Celje-Medlog	1948-2024	1948-2024	1948-2024	ARSO
5	Novo mesto	1952-2024	1952-2024	1952-2024	ARSO
6	Podčetrtek-Atomske Toplice	2001-2024	2001-2024	n/a	ARSO
8	Lisca	1985-2024	1985-2024	1985-2015	ARSO
9	Rateče	1948-2024	1948-2024	1948-2015	ARSO
10	Kredarica	1955-2024	1955-2024	1955-2024	ARSO
11	Vogel	1983-2024	1983-2024	1983-2024	ARSO
12	Postojna	1950-2024	1950-2024	1950-2024	ARSO
86	Boršt pri Gorenji vasi	2005-2024	2005-2024	n/a	ARSO
87	Cerklje - letališče	2006-2024	2006-2024	2006-2024	ARSO
90	Iskrba	1997-2024	1997-2024	n/a	ARSO
91	Letališče JP Ljubljana	1964-2024	1964-2024	1964-2024	ARSO
92	Litija	2015-2024	2015-2024	n/a	ARSO
93	Malkovec	1957-2024	1957-2024	1957-2024	ARSO
129	Babno Polje	1950-1990, 2004-2024	1950-1990, 2004-2024	1950-1990, 2004-2024	ARSO
131	Velenje	1961-2005, 2016-2024	1961-2005, 2016-2024	1961-2005	ARSO
132	Metlika	1982-2024	1982-2024	1982-2017	ARSO
143	Bohinjska Češnjica	2003-2024	2003-2024	2003-2024	ARSO
151	Blegoš	2017-2024	2017-2024	n/a	ARSO
165	Ratitovec	2017-2024	2017-2024	n/a	ARSO
166	Logatec	2014-2024	2014-2024	n/a	ARSO
170	Kranj	2014-2024	2014-2024	n/a	ARSO
173	Jezersko	2016-2024	2016-2024	n/a	ARSO
176	Logarska dolina	2017-2024	2017-2024	n/a	ARSO
177	Velike Lašče	2016-2024	2016-2024	n/a	ARSO
178	Gornji Grad	2016-2024	2016-2024	n/a	ARSO
179	Marinča vas	2017-2024	2017-2024	n/a	ARSO
47	Puntijarka	1959-2024	1959-2024	1959-2024	DHMZ
48	Zagreb Grič	1862-2024	1862-2024	1895-2024	DHMZ
49	Slavonski Brod	1963-2024	1963-2024	1963-2024	DHMZ
50	Krapina	1994-2024	1994-2024	1994-2024	DHMZ
51	Parg	1951-2024	1951-2024	1951-2024	DHMZ
52	Karlovac	1949-2024	1949-2024	1949-2024	DHMZ
53	Sisak	1949-2024	1949-2024	1949-2024	DHMZ
54	Ogulin	1949-2024	1949-2024	1949-2024	DHMZ
55	Križevci	1961-2024	1961-2024	1961-2024	DHMZ
56	Daruvar	1978-2024	1978-2024	1978-2024	DHMZ
57	Gradište-Županja	1981-2024	1981-2024	1981-2024	DHMZ
48	Zagreb-Maksimir	1927-2024	1926-2024	1933-2024	DHMZ
58	Stružec	1981-2024*	1981-2024*	1981-2024*	DHMZ
59	Zvečevo	1988-2024*	1989-2024*	1987-2024*	DHMZ
61	Bjelovar	1949-2024	1949-2024	1949-2024	DHMZ
62	Bosiljevo	1981-2024	1981-2024	1981-2024	DHMZ
63	Čazma	1981-2024*	1981-2024*	1981-2024*	DHMZ
64	Delnice	1981-2024*	1981-2024*	1981-2024*	DHMZ
65	Hrvatska Kostajnica	1981-2024*	1981-2024*	1981-2024*	DHMZ
67	Plaški	1960-2024*	1960-2024*	1960-2024*	DHMZ
68	Slunj Poligon	1956-2024*	1956-2024*	1956-2024*	DHMZ
69	Topusko	1981-2019*	1981-2019*	1981-2019*	DHMZ
71	Novska	1981-2024*	1981-2024*	1981-2024*	DHMZ
101	Goli Vrh	2016-2024*	2016-2024*	n/a	DHMZ
107	Kutjevo-Vidim	2003-2024*	2004-2024*	2004-2024*	DHMZ
110	Pisarovina	1981-2024*	1981-2024	1981-2024	DHMZ
112	Plitvička Jezera	1986-2022*	1986-2022*	1986-2022*	DHMZ
113	Prijeboj	2011-2024**	2011-2024**	n/a	DHMZ
17	Bihać	1892-2023	1892-2023	1960-2023	FHMZ
17	Bihać II	2005-2023	2005-2023	n/a	FHMZ
19	Drvar	2005-2023	2005-2023	n/a	FHMZ
22	Lušci Palanka	2005-2023	2005-2023	n/a	FHMZ

No	Stations	Period of the data available per parameter			Data Provider
		P1	P2	P3	
23	Sanski Most	1892-1940 1945-1992 1996-2023	1892-1940 1945-1992 1996-2023	1960-2023	FHMZ
23	Sanski Most II	2005-2023	2005-2023	n/a	FHMZ
25	Bugojno	1892-2023	1892-2023	n/a	FHMZ
26	Jajce	1892-1940 1945-1992 2001-2023	1892-1940 1945-1992 2001-2023	1960-2023	FHMZ
30	Bjelašnica	1895-1990 2001-2023	1895-1990 2001-2023	1960-1990 2001-2023	FHMZ
31	Sarajevo-Bjelave	1892-2023	1892-2023	1960-2023	FHMZ
32	Zenica	1925-2023	1925-2023	1960-2023	FHMZ
34	Olovo	2005-2023	2005-2023	n/a	FHMZ
35	Tuzla	1910-2023	1910-2023	1960-2023	FHMZ
16	Gradačac	1953-2023	1953-2023	1960-2023	FHMZ
42	Velika Kladuša	2005-2023	2005-2023	n/a	FHMZ
44	Bosanska Krupa	2006-2023	2006-2023	n/a	FHMZ
45	Cazin	2004-2023	2004-2023	n/a	FHMZ
192	Rmanj Manastir	2005-2023	2005-2023	n/a	FHMZ
189	Bosanski Petrovac	2005-2023	2005-2023	n/a	FHMZ
190	Ključ	2004-2023	2004-2023	n/a	FHMZ
162	Gornji Vakuf	2008-2016	2008-2016	n/a	FHMZ
162	Gornji Vakuf II	2016-2023	2016-2023	n/a	FHMZ
159	Borova Ravan	2016-2023	2016-2023	n/a	FHMZ
157	Rat	2016-2023	2016-2023	n/a	FHMZ
164	Šeherdžik	2016-2023	2016-2023	n/a	FHMZ
191	Fojnica	2006-2023	2006-2023	n/a	FHMZ
194	Karanovac	2003-2023	2003-2023	n/a	FHMZ
46	Zavidovići	2004-2023	2004-2023	n/a	FHMZ
	Ivan Sedlo	1892-1940; 1945-1992; 2001-2023	1892-1940; 1945-1992; 2001-2023	1960-1991; 2001-2023	FHMZ
154	Kupres	2016-2023	2016-2023	n/a	FHMZ
195	Bila	2016-2023	2016-2023	n/a	FHMZ
14	Gradiška	1961-1987; 2003-2024	1961-1987; 2003-2024	1961-1987; 2003-2024	RHMZRS
15	Srbac	1961-1975; 2003.2024	1961-1975; 2003.2024	1961-1975; 2003.2024	RHMZRS
18	Novi Grad	1961-1991; 2002-2024	1961-1991; 2002-2024	1961-1991; 2002-2024	RHMZRS
20	Drinić	1961-1990; 2007-2024	1961-1990; 2007-2024	1961-1990; 2007-2024	RHMZRS
21	Ribnik	2000-2024	2000-2024	2000-2024	RHMZRS
24	Prijedor	1961-1989*; 1995-2024	1961-1989*; 1995-2024	1961-1989*; 1995-2024	RHMZRS
27	Banja Luka	1961-2024	1961-2024	1961-2024	RHMZRS
28	Mrkonjić Grad	1961-1991*; 1999-2024	1961-1991*; 1999-2024	1961-1991*; 1999-2024	RHMZRS
29	Šipovo	1965-1991*; 2006-2024	1965-1991*; 2006-2024	1965-1991*; 2006-2024	RHMZRS
33	Doboj	1961-1991; 1997-2024	1961-1991; 1997-2024	1961-1991; 1997-2024	RHMZRS
36	Foča	1961-1991*; 2006-2024	1961-1991*; 2006-2024	1961-1991*; 2006-2024	RHMZRS
37	Višegrad	1961-1991; 2002-2024	1961-1991; 2002-2024	1961-1991; 2002-2024	RHMZRS
38	Sokolac	1961-2024*	1961-2024*	1961-2024*	RHMZRS
39	Han Pijesak	1961-1991; 2006-2024	1961-1991; 2006-2024	1961-1991; 2006-2024	RHMZRS
40	Bijeljina	1961-1991; 1997-2024	1961-1991; 1997-2024	1961-1991; 1997-2024	RHMZRS
41	Čemerno	1961-1991; 2001-2024	1961-1991; 2001-2024	1961-1991; 2001-2024	RHMZRS
72	Sremska Mitrovica	1923-2023	1949-2023	1949-2023	RHMZ
73	Zlatibor	1941-2023	1950-2023	1950-2023	RHMZ
74	Loznica	1923-2023	1952-2023	1952-2023	RHMZ
75	Sjenica	1925-2023	1946-2023	1946-2023	RHMZ
76	Valjevo	1923-2023	1949-2023	1949-2023	RHMZ

No	Stations	Period of the data available per parameter			Data Provider
		P1	P2	P3	
77	Beograd-Vračar	1887-2023	1887-2023	1948-2023	RHMZ
78	Krupanj	1926-2023	1961-2023	1961-2023	RHMZ
79	Bajina Bašta	1926-2015; 2019-2023	1961-2015; 2019-2023	1961-2015	RHMZ
123	Štavica	1956-2023	n/a	1992-2023	RHMZ
125	Velika Ivanca	1953-2023	n/a	1992-2017	RHMZ
80	Berane	n/i	n/i	n/i	ZHMS
81	Bijelo Polje	n/i	n/i	n/i	ZHMS
82	Kolašin	n/i	n/i	n/i	ZHMS
83	Žabljak	n/i	n/i	n/i	ZHMS
84	Pljevlja	n/i	n/i	n/i	ZHMS

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n/i – no information provided by the HMSs. The information should be collected during the implementation.

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Examples of documentation to be digitalized: https://www.fhmzbih.gov.ba/latinica/KLIMA/godisnjaci.php

Note: Some data sets may be incomplete (* incomplete series; ** unreliable data).

Parameter		Temporal Resolution	Units
P1	Precipitation	Daily (Total) / Hourly	mm
P2	Air Temperature	Daily (Mean) / Hourly	^{o}C
P3	Snow Depth	Current Snow (Daily Total)	cm

NOTE:
List of stations for analysis of relative humidity, wind speed and direction, evaporation, solar radiation, sunshine, atmospheric pressure and other specific parameters will be defined during the inception phase of the project.

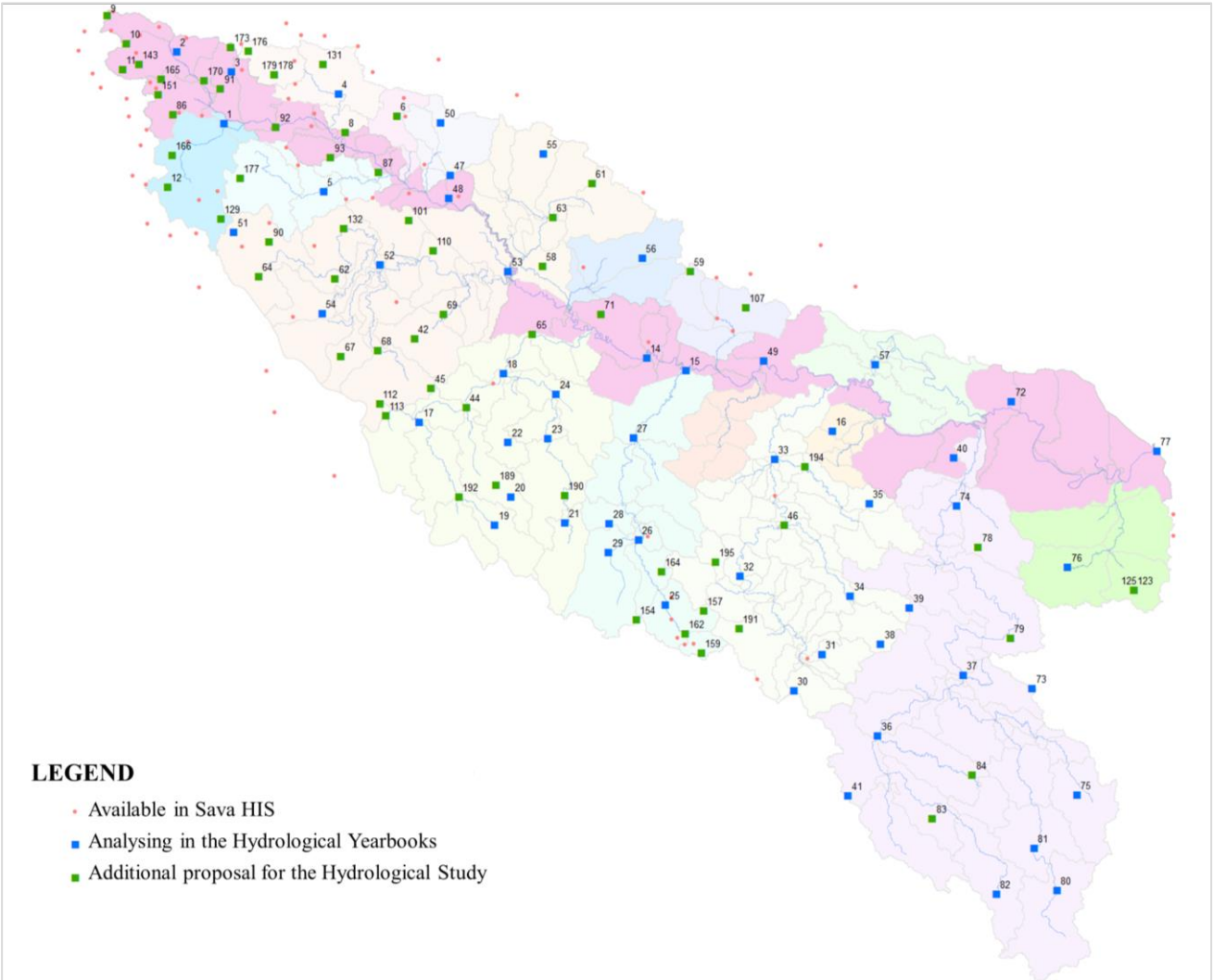

Figure B1: Overview of meteorological stations (corresponds with the list of stations)