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## DRAFT WHOS Phase II Operational Plan (OP) 2024-2029

The WMO Hydrological Observing System (WHOS) development started in 2015 under the former WMO Commission for Hydrology (CHy) to promote free and unrestricted exchange of hydrological data using free open-source tools, standardized web services, data exchange protocols, WMO and other formats. The pilot phase started in 2018 in two major basins (La Plata and Arctic-HYCOS) and was extended to the Dominican Republic, Sava River Basin Commission and United Kingdom. The pilot project in the La Plata basin was one of the WIS 2.0 demonstration projects and as such was presented at the “[WIS 2.0 demonstration projects workshop](https://wmo-teams.atlassian.net/wiki/spaces/WIS2/pages/167313674/WIS+2.0+Demonstration+Projects+Workshop)” The workshop noted that all the projects aligned with the WIS 2.0 principles and demonstrated their soundness. However, the challenge of bringing together the elements and technologies presented at the workshop in a body of technical regulations defining the WIS 2.0 framework and providing the required level of interoperability between different systems was identified. The new technical regulations for WIS 2.0 are now ready to be endorsed by the second INFCOM session and adopted by the World Meteorological Congress.

WHOS is part of the one-year WIS 2.0 pilot phase which is starting at the end of 2022. During this phase the system will be made compliant with WIS 2.0 and WIGOS technical specifications and the data exchange through the WIS 2.0 framework will be implemented. At the end of the WIS 2.0 pilot phase a report on the status of interoperability and eventual gaps will be drafted by SC-IMT. The draft WHOS phase II operational plan will be modified to take into account the outcome of the WIS 2.0 pilot phase. Activities not directly related to WIS 2.0 will be performed with the view that future integration in WIS 2.0 may require modifications to the WHOS components.

The WHOS operational plan has a target of at least 50 Members expected to exchange data within WHOS by 2025, [Cg-Ext (2021](https://wmoomm.sharepoint.com/:w:/s/msteams/EdsACYkrCwRDlzR0Szu_r9QB5tNpnzUcyGnVH2YVmWpfrA)). WHOS in the La Plata basin is already in operation phase, but not yet compliant with WIS 2.0 technical specifications. However, it is being integrated with [Delft-FEWS](https://oss.deltares.nl/web/delft-fews/about-delft-fews) (Flood forecasting and Early Warning System), PROHMSAT (Hydrometeorological Forecasting and Early Warnings System in the La Plata Basin), Water quality systems among other systems in the basin.

The activities of WHOS are currently undertaken by JET-HYDMON experts who will collaborate with various SC-IMT Expert Teams in finalizing this draft WHOS Phase II Operational Plan, WHOS as WIS 2.0 pilot for implementation of hydrological data exchange within WIS2.0.

### INTRODUCTION: WHOS objectives and current achievements

1.1 WHOS Operational Plan 2024-2029 will guide the implementation of the WMO Hydrological Observing System (WHOS) Phase II within the new WMO structure from pilot phase (2018-2022) by NMHS and partner organizations at different scales (national, regional, and global). It outlines the aspects of WHOS implementation and operation by addressing three main goals:

* Goal 1: Improve the accessibility and interoperability of hydrological data published by NMHSs and Other data providers;
* Goal 2: Establish effective connection with WIGOS (and its WIGOS tools), WIS, GDPFS, and developments like MCH and OpenCDMS, for better supporting products and services such as FFGS and HydroSOS;
* Goal 3: Advance hydrological data exchange technology, ontology, standards, and tools.

1.2 The plan builds on the initial WHOS implementation plan ([link](https://filecloud.wmo.int/share/s/9DESF6TPQYKIrTA8BN6mrQ)) that was endorsed by [Resolution 17 (EC-70)](https://library.wmo.int/doc_num.php?explnum_id=4981#page=70) – Implementation Plan of WMO Hydrological Observing System phase II, and the WMO Action Plan for Hydrology 2022-2030 ([link](https://www.hydroref.com/wmo/hcp/index.php)), [Resolution 4](https://library.wmo.int/doc_num.php?explnum_id=11113#page=36) (Cg‑Ext(2021)) – WMO Vision and Strategy for Hydrology and its associated Plan of Action. The action plan promotes further implementation of WHOS for sharing of operational and historical data among Members. WHOS implements open-source tools, web services and data standards like WaterML2.0 (a joint activity of WMO and OGC) for hydrological data interoperability, access, and sharing. Part 1 (Time Series), part 2 (Stream Ratings, Gaugings and Sections), part 3 (Surface Hydrology), and part 4 (Groundwater) of WaterML 2.0 standard have been adopted by WMO and OGC while part 5 on Water quality is under development. WHOS aims to address the challenges of hydrological data exchange through support and contribution to the WMO data value chain from data production to end‑user dissemination as shown in [Figure 1](#Figure1).

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**Figure 1: WHOS Data Value Chain, illustrating the pathway through which data collection activities datasets lead to value in applications that impact data users**

1.3 WHOS aims to address the challenges of hydrological data exchange through support and contribution to the WMO data value chain from data production to end-user dissemination as shown in Figure 1.

1.4 WHOS contributes to the realization of WMO Vision and Mission 2020–2030 ([*WMO Strategic Plan 2020–2023*](https://library.wmo.int/index.php?lvl=notice_display&id=21525)(WMO‑No. 1225)) alongside Long-term goals 1 and 2 as the central piece of hydrological data sharing as components of WIGOS ([*Manual on the WMO Integrated Global Observing System*](https://library.wmo.int/index.php?lvl=notice_display&id=19223)(WMO-No. 1160)). WHOS supports the work of the Water and Climate Coalition especially on data and information.

1.5 The WHOS pilots have been completed in the following regions and countries, and data are accessible through three WHOS Portal pilots using different web services ([WHOS Global](https://wde.hydro.geodab.eu/apps/water-data-explorer/) as shown in [figure 2](#Figure2), [WHOS-Plata](https://tethys.inmet.gov.br/apps/water-data-explorer/), [WHOS-Arctic](https://hydrohub.wmo.int/en/projects/Arctic-HYCOS)).

1. The La Plata Basin in South America (WHOS-Plata) shares hydrometeorological data provided by Argentina, Bolivia, Brazil, Paraguay, and Uruguay. Data are harmonized and published by WHOS-broker and accessed through WaterML 2.0.
2. The Arctic Region (WHOS-Arctic) shares hydrometeorological data provided by Canada, Finland, Denmark (for Greenland), Iceland, Norway, the Russian Federation, and the United States of America (USA). Data are harmonized by WHOS-broker and published by ArcGIS.
3. The Dominican Republic (WHOS-DR) promotes harmonized hydrometeorological data sharing through WHOS between NMS and NHS.
4. The United Kingdom National River Flow Archive (UK-NRFA) shares historical data from multiple observing institutes through WHOS.

The Sava River Basin Commission (WHOS-SAVA) data are accessible through SAVA HIS (<https://savahis.org/his>) to basin Members.

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**Figure 2:** [**Water Data Explorer interface for WHOS Global Portal**](https://wde.hydro.geodab.eu/apps/water-data-explorer/)

### WHOS INTER-RELATIONSHIPS

2.1 Introduction

2.1.1 [Figure 3](#Figure3) illustrates the interaction of various WMO Bodies, activities, and other communities with WHOS. The diagram interaction arrows are divided between different functions.

2.2 Guidance

2.2.1 INFCOM provides the overall guidance of WHOS development and implementation with support from SERCOM, HCP and Regional Associations. The work of WHOS within INFCOM will be undertaken mainly within SC-IMT and SC-ON with support from SC-ESMP. JET‑HYDMON ensures the coherence of the INFCOM hydrology experts and WHOS Technology providers in line with WMO Action Plan for Hydrology 2022-2030.

2.2.2 SERCOM through SC-HYD, provides requirements to WHOS development to be globally consistent with alert protocols and user-focused services based on principles of good practice, opportunities for all, and long-term sustainability.

2.2.3 HCP coordinates contribution of WHOS to WMO vision for Hydrology and its Action Plan while liaising with the overall hydrology community on their contributions to and the implementations of WHOS.

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**Figure 3: WHOS Inter-Relations**

2.3 Implementation

2.3.1 At the national level, Member States (NMHSs) are responsible for all activities connected with the implementation and operation of WHOS while on the regional scale, WMO Regional Associations help implement WHOS as part of their workplan lead by RHAs.

2.3.2 It is expected that WMO Centres (GDPFS (especially future GDPFS centres for hydrology), WIS, WIGOS, and Global Hydrological Data Centres) will host and maintain the WHOS DAB, Web Services, WHOS Portals, provide data centre services (data cubes and cache) and support hydrological data and information interoperability, access and sharing using the available resources.

2.3.3 Data Sharing Agreement Experts will support implementation of the WMO Unified Data Policy ([Resolution 1 (Cg-Ext(2021))](https://library.wmo.int/doc_num.php?explnum_id=11113#page=9) – WMO Unified Policy for the International Exchange of Earth System Data) by working closely with established relevant bodies within WMO to develop consensus-based data sharing agreements within their regions.

2.4 Development

2.4.1 The development of WHOS is currently coordinated by JET-HYDMON with support from other INFCOM experts, WHOS technology providers (WHOS DAB (Discovery and Access Broker) and Water Data Explorer (WDE)), collaborators, development projects and other WMO related activities. Formation of WHOS Core Development Team, WHOS communities (technology, standardization (ISO, OGC (WaterML2.0)), and user), data policy experts to further support the operation of WHOS Phase II will be critical during the operation phase.

2.4.2 The WHOS technology community, data user community, and standardization community will be open to WMO Members and partners interested in, contributing to and participating in WHOS and in line with WIS and WIGOS guides and manuals and guide to hydrological practices.

2.5 Contribution

2.5.1 WIGOS provides a number of tools such as WIGOS Station Identifier, OSCAR Surface, WIGOS Data Quality Monitoring System, and [Rolling Review of R](https://community.wmo.int/rolling-review-requirements-process)equirements that will be necessary to WHOS operation. The WHOS contributes to WIGOS by providing a metadata catalogue compatible with the WIGOS Metadata Representation (WMDR) for the registration of hydrological observing stations.

2.5.2 WHOS provides a technology to promote the integration of hydrological observational data into numerical weather and hydrological prediction systems and enhances the dissemination of the prediction results into the hydrological observing systems from GDPFS.

2.5.3 HydroHub will support WHOS capacity building especially distance learning course on interoperable data exchange in hydrology while implementing and promoting specific aspects of WHOS especially through innovative technologies for hydrological data exchange and water quality.

2.6 Support/Facilitation

2.6.1 Support, facilitation, and coordination functions needed for WHOS implementations and developments are provided by WMO Secretariat.

### WHOS IMPLEMENTATION PRINCIPLES

3.1 Implementation Principles

3.1.1 Members providing hydrological observations to WHOS shall operate in accordance with the procedures and practices set out in the *Technical Regulations* (WMO-No. 49), Volume I, [Part I](https://library.wmo.int/doc_num.php?explnum_id=10955), and in conjunction with the relevant WMO manuals and guides. In addition, it is recommended to share standards, tools and techniques, experiences and capacities acquired during WHOS implementation with the WHOS community. The implementation of WHOS is undertaken with existing national and basin-wide resources.

3.2 Implementation Steps

3.2.1 The WHOS five step implementation is expected as follows:

1. Implementation request (Request to participate in WHOS): The data provider sends a WHOS implementation request to WMO Secretariat specifying the details of focal points, web services, standards, and commitment to share data.
2. Request for Information (Request for information, formats, web services): The WMO Secretariat sends a request for more needed information to the data provider on data publishing, formats, web services among others.
3. Implementation (testing endpoints and integrating WHOS using different tools, DAB installation): Depending on the kind of web service(s) available, the installation may include configuration of a new data source for an existing accessor, developing new accessor, mapping of metadata vocabulary and setting user views.
4. Implementation testing: When a preliminary solution has been developed, the data providers and technical experts are informed to perform the testing of the new connection and provide the test results.
5. Implementation feedback: Finally, the WMO Secretariat provides brief implementation report to the data provider’s focal point describing technologies and standards used and how the requests were handled.

### WORKPLAN, MONITORING AND RISK ASSESSMENT

4.1 Work Plan

The implementation of the WHOS will be guided by the needs of Members and other WHOS users, which will be adopted, as appropriate by WHOS expert or task team. A summary of the expected timelines is given in [Table 1](#Table1).

**Table 1: Activities and Deliverables**

| **Tasks/Activities** | **Deliverables** | **Time** |
| --- | --- | --- |
| WHOS-WIS Pilot | Report on hydrological data exchange within WIS2.0 | 2023 |
| Identify functionalities from WMO centres, including evolving role of the three global data Centres to help Members to share and rescue their data | New role definition adopted by INFCOM-3 | 2024 |
| Establishment of the key units that will coordinate, support and lead the implementation of WHOS | * New WHOS Web page launched * WHOS Core Technical development team, WHOS Communities, WHOS experts are established | 2023  2024 |
| WHOS-WIGOS integration | * WSI for hydrological stations adopted and pilot Hydrological stations registered in OSCAR/Surface * WIGOS metadata code lists revised and expanded: Metadata records for WHOS datasets in OSCAR/Surface * WMO ontology registry updated with potential contribution of GTN-H | 2025  2025  2026 |
| Develop WHOS Technical Guide/Manual | Technical Guide Approved by INFCOM-3 | 2024 |
| Sharing of data from recognized centennial/reference (GBON-hydrology and Data Centers) stations in hydrology | WHOS improved to promote implementation of the GBON for hydrology | 2027 |
| WHOS – operational data exchange | At least 50 members are sharing data through WHOS | 2025 |
| Capacity building on Interoperable Hydrological Data Exchange, WHOS DAB, WDE, WaterML2.0 | One training conducted in each WMO Regional Association | 2027 |
| Implementation of WMO Unified Data Policy at Members’ level to enhance data sharing | Number of Members providing core data by 2027 | 2027 |
| Supporting WaterML-WQ development | * WaterMl2.0 part 4 adopted as WMO standard * WHOS interconnection to GEMS/IIWQ established | 2026  2027 |

4.2 Monitoring and Risk Assessment

The implementation of WHOS phase II operational plan will be regularly monitored and evaluated using quantitative and objective methodology wherever possible using relevant tools. The KPIs with targets and evaluation tools are provided in [Table 2](#Table2) and the risk assessment and mitigation is shown in [Table 3](#Table3).

**Table 2: Key Performance Indicators**

| **KPI** | **Base line** | **Mid-Target** | **Final Target** | **Tool** |
| --- | --- | --- | --- | --- |
|  | 2023-2025 | 2025-2027 | 2027-2031 |  |
| Number of basin organizations participating in WHOS | 4 | 6 | 8 | WHOS portal |
| Number of Members publishing their data through WHOS Portals | 55 | 65 | 89 | WDQMS/WHOS Portal |
| Number of NMHS staff with expertise in WHOS technologies | 40 | 80 | 120 | Database of WHOS experts |
| Number of countries exchanging data within WIS2.0 framework | 10 | 30 | 50 | WIS Architecture |
| Number of WIGOS metadata records displayed in WHOS | 10 | 20 | 30 | OSCAR/Surface/WHOS portal |
| Number of Members providing water quality data through WHOS | 15 | 30 | 40 | WHOS Web portal |

**Table 3: Risk Assessment and Mitigation**

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| --- | --- | --- | --- |
| **Number** | **Assumptions** | **Risk** | **Mitigation** |
| 1 | WHOS Technologies address the needs of WMO community | * Weak links between WHOS experts and WHOS Communities or users | * Establish feedback mechanics between WHOS communities and WHOS experts * Sign contract with WHOS technology developers * Get right experts to support WHOS (TT-WHOS) |
| 2 | WMO Members’ data policies promote WHOS implementation (ready to implement WMO Unified Data Policy) | * Strategies and policies not favouring WHOS implementation * Members’ policies do not promote free and unrestricted data exchange | * Promote WHOS for sharing hydrological data within WMO Unified Data Policy * Conduct more webinars, training and WHOS demonstrations |
| 3 | Available adequate resources for WHOS operation | * Limited funding and resources for implementation of WHOS activities | * Encourage Members and/ or basin institutions to commit and fundraise for resources needed to implement WHOS * Raise awareness with NHA, RHAs and install mechanisms within RA bodies e.g., establishment of Regional WHOS expert groups |
| 5 | WHOS fully integrated within WIS2.0 framework | * WIS2.0 architecture does not fully address requirements for Hydrological data exchange | * Establish good collaboration between WHOS experts, Hydrology experts and other SCT-IMT experts |
| 6 | WIGOS and WHOS fully integrated to support hydrology | * WIGOS tools not designed for integration of hydrological observation network | * Adequate representation of hydrology experts in SC-ON (WIGOS) * Identify RWCs supporting hydrology stations |

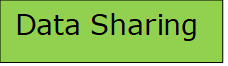
### WHOS TECHNOLOGY AND DEVELOPMENTS

5.1 Introduction

WHOS is supported by several standardized open-source tools, web services and standards having the support of the scientific community.

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**Figure 4: WHOS as A Data Sharing Tool**

5.2 Tools and Web Services

5.2.1 DAB (Discovery and Access Broker)  
The DAB provides **framework** for the **mediation and harmonization** supporting data discovery and access layer technology for WHOS.

5.2.2 WHOS implements many standardized and/or customized Web services that have been developed and are being maintained by different communities as provided in the list below:

* DAB Timeseries API
* Unidata THREDDS service
* CUAHSI WaterML 1.0/ CUAHSI WOF HydroServer
* USGS Water Services
* ESRI Feature Service
* OAIPMH (Dublin Core, ISO 19139, WIGOS Metadata models)
* OGC (Open Geospatial Consortium) SOS (Sensor Observation Service)
* WaterOneFlow HIS Central Catalog service

5.2.3 WHOS technologies are also supported by free online tools that have been developed, tested and/or being maintained by large scientific and research communities to promote hydrological data interoperability, access and sharing as listed below:

* ESRI ArcGIS Online
* Geonetwork
* Water Data Explorer (WDE)
* Met Data Explorer supports
* WaterML library
* Node.js WaterML client
* WCF Data Service template plugin
* 52North Helgoland
* USGS GWIS

5.3 Further Developments

WHOS will provide a solid platform for sharing and exchanging data, products between different systems that may be using different technologies by implementing developed standards, web services and emerging technologies like AI, Neural networks, machine learning and big data. Several initiatives and tasks need to be undertaken to fulfil the objectives of WHOS in line with the emerging technologies and increased demand for interoperability among different hydrometeorological data, information, and service providers:

* Integration of WHOS as part of the Earth Systems approach connecting hydrology domain with other domains providing related hydrological data (more data sets);
* Support the implementation of RBON and GBON, WMO Unified Data Policy as the hydrological component of WIGOS and WIS2.0;
* Optimization of communication between WHOS web services, the database systems, user and data provider web services including other integrated models;
* Fully open-source system of systems maintained and developed by a community at national, regional, basin and global levels with focus to user needs;
* Development of APIs for WHOS system integration with early warning systems, flood forecasting systems, WMO Global Data Centres, GDPFS-Hydrological Centers, WIS2.0 in A box, WIGOS Tools, HydroSOS and other data portals;
* Intelligent online digital support assistant, and user-friendly interfaces;
* Machine Learning techniques for user interface views including mobile devices and Personal digital assistants;
* Advanced AI based discovery, access, brokering, caching and retrieval techniques supporting WMO community and in line with WMO relevant guides;
* Implementation of Big data integration, analytics, and processing;
* Expanding Metadata to accommodate all data types of the hydrological cycle (e.g. water quality, soil moisture).

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