Water data standards by the Hydrology Domain Working Group of WMO and OGC – from development to implementation and adoption

Tony Boston[1,7], Silvano Pecora[2], David Blodgett[3], Irina Dornblut[4], Boyan Brodaric[5] and Peter Taylor[6]

[1] Fenner School of Environment & Society, Australian National University, Linnaeus Way, Acton ACT 2601, Australia
[2] Hydrological Service, Arpae Simc, Via Garibaldi, 75, 43121 Parma, Italy
[3] U.S. Geological Survey, 8505 Research Way, Middleton, WI 53562, USA
[4] Global Runoff Data Centre (GRDC), Federal Institute of Hydrology (BfG), Am Mainzer Tor 1, 56068 Koblenz, Germany
[5] Geological Survey of Canada, Natural Resources Canada, 117 – 601 Booth St. Ottawa, ON K1A 0E8, Canada
[6] Data61, CSIRO, Hobart, TAS, Australia
[7] Corresponding author: Tony.Boston@anu.edu.au

Abstract. WaterML2 is a series of information models and encodings for the representation of water features and observations data, developed to allow the exchange of such datasets across information systems. WaterML2 consists of four parts dealing with different types of hydrological data: Part 1 (Timeseries) defines an encoding for timeseries observations enabling exchange of data such as water level or discharge; Part 2 (Ratings, Gaugings and Sections) deals with rating conversions (stage to discharge etc), gauging observations and river cross sections, which are part of most surface water monitoring programs; Part 3 (Surface Hydrology Features) is a conceptual model describing surface water hydrologic features such as rivers, lakes, catchments and drainage networks; and Part 4 (GroundWater Markup Language 2 [GWML2]) supports the description of key hydrogeological entities such as aquifers and water wells, as well as related measurements and groundwater flows.

From 2009-2018, these water data standards were developed by the Hydrology Domain Working Group (HDWG) of the World Meteorological Organization (WMO) and the Open Geospatial Consortium (OGC). The HDWG develops technical solutions and standards for exchanging data, describing the state and location of water resources both above and below the ground surface.

Implementation and adoption of WaterML2 standards is a critical next step. National Meteorological and Hydrological Services (NMHSs) in many countries have already implemented WaterML2 within their national water information systems. In May 2017, the WMO Executive Council formally adopted WaterML2: Parts 1 and 2 as official standards for use by NMHSs and within the WMO Hydrological Observing System (WHOS). Adoption of GWML2 by WMO is expected in the near future.

WHOS is a portal for accessing existing online hydrological data, drawing from the water information systems of countries around the world. WHOS is being developed in two phases. The first phase (already completed) is a map interface on the WMO website that links to those NMHSs that make their real-time and/or historical stage and discharge data freely available online. The second phase is a much more comprehensive undertaking aimed at developing a complete services-oriented framework linking hydrologic data providers and users through an information system that enables data registration, data discovery and data access. Work on phase 2 of WHOS is currently being undertaken by WMO.

1. Introduction

The goal of hydrological data collection, including precipitation measurements, water-level recordings, gaugings of discharge, groundwater monitoring or water quality sampling, is to provide a high-quality dataset that can be used in decision-making concerning all aspects of water resources management, in a wide range of operational applications as well as in research. Decisions may be made based on raw observational data, summary statistics, or model results informed by data. In all cases it is the collected data that underpin these decisions. Datasets are of great value as they are collected through a sizeable commitment of financial and human resources, generally over a long period of time. The value of datasets is even greater when they are made publicly available in a usable form to a variety of users.

In 2005, a report from the Global Climate Observing System (GCOS) addressing data exchange problems in global hydrological and atmospheric networks identified standards as a key issue. The report stated that: “There are no established international standards on the acquisition of river data, the set of required metadata, data formats, and transmission modes” [1]. The 6th edition (2008) of Volume 1 of the WMO Guide to Hydrological Practices also stated that: “There are currently no standards for data exchange formats for hydrological data” [2].

Water resource management within countries, regions and continents around the world is highly distributed with many organizations typically involved in the collection and management of water data, even within single countries. Until recently, international exchange standards for hydrological data, at a national or international scale, have been the exception rather than the rule. However, geographic features such as river basins and aquifers generally do not align with national boundaries, and 90 percent of the world’s population lives in countries that share transboundary hydrological features with their neighbours [3]. Thus, it seems obvious that data sharing among countries within transnational river basins would be of significant mutual value. In the few cases where data are currently being shared, it is typically where the parties have negotiated specific bilateral or multilateral agreements.

This paper summarizes efforts from 2009-2018 by the WMO/OGC Hydrology Domain Working Group (HDWG)[1] to create standards for the exchange of hydrological data between information systems. The working group develops technical solutions and standards for exchanging data, describing the state and location of water resources both above and below the ground surface. The HDWG includes representatives of the WMO Commission for Hydrology and member organizations of the OGC drawn from government agencies, industry, universities and non-government organizations, with members largely from Europe, North America and Australasia.

2. WaterML2: Part 1 – Timeseries

Providing hydrological data to national and global information systems has traditionally been difficult due to the variety of monitoring methods and supporting information systems. Providing comparable information from different hydrological agencies involves understanding the way in which data are collected, stored and transmitted between information systems. To share data efficiently and

[1] Hydrology DWG. URL: http://www.opengeospatial.org/projects/groups/hydrologydwg. Accessed 5 August 2019.

effectively, standards are critical, both in monitoring methods and how data are represented, encoded and exchanged.

Development of community-agreed consistent models and exchange formats for spatial and temporal data and metadata increases interoperability between information systems. It has many practical benefits including:

- Improved efficiency and quality of information models and systems;
- Wider use and re-use of information;
- Vendor and open source support at low or no cost to users; and
- Adding new value to existing information through serendipitous uses.

Timeseries are one of the most common ways to represent observational data in hydrology. For in-situ and ex-situ measurements, hydrologists use timeseries as a data management structure allowing reporting and analysis of particular parameters through time for data collected at point locations on the Earth's surface. Often timeseries will be transformed, corrected, interpolated and extrapolated to allow accurate and continuous reporting of conditions [4].

The WaterML2: Part 1 standard [5] consists of a conceptual information model and an XML encoding for timeseries hydrological data, both based on the ISO-OGC Observations & Measurements (O&M) [6] and Geography Markup Language (GML) standards [7]. WaterML2: Part 1 is defined according to OGC's modular specification, which outlines guidelines for structuring standards to enhance modularity, ease of implementation, extension and interoperability [4].

In the development of this standard, the HDWG studied and harmonized existing encodings for hydrological timeseries data from around the world including: WaterML1.0 (USA), Water Data Transfer Format (Australia), XHydro (Germany), Time Series Data Exchange Format (UK), Sandre (France) and the Flood Early Warning System's (FEWS) published encoding used in the USA, Australia, Germany, UK, France and the Netherlands.

WaterML2: Part 1 defines an encoding for timeseries observations enabling exchange of data such as water level or discharge between information systems. The standard was extensively tested during development through a surface and groundwater interoperability experiment. WaterML2: Part 1 provides an interoperable hydrological exchange format that can be used to address a wide range of user needs. These include the exchange of data relating to:

- In-situ observations at hydrological (gauges, reservoirs) or climatological stations;
- Forecast products (probabilistic or deterministic timeseries) at forecast locations;
- Emergency or operator-oriented alerts (of threshold exceedance) and reports;
- Timeseries of planned intake and release/discharge; and
- Groundwater observations of water levels within wells.

Since it was published in 2012, WaterML2: Part 1 has been implemented using OGC standards such as the Sensor Observation Service (SOS) [8] by National Meteorological and Hydrological Services in many countries to make water level and discharge data publicly available via the Internet, as well as being adopted by major vendors of Hydrological Information Systems.

3. WaterML2: Part 2 – Ratings, gaugings and sections

To understand water resources, hydrological data and metadata sharing becomes a necessity – both within and between countries. The sharing of such data is dependent upon having both a common understanding of the underlying hydrological concepts and a defined data format for exchange.

Hydrological data analysis typically involves the use of discharge or volume data; these data are difficult and expensive to monitor in situ. It is common practice to monitor a surrogate variable, such as water level or stage, and to use computer algorithms and metadata to derive discharge and aggregated discharge data [9]. Rating tables or curves provide the metadata to enable the stage to discharge conversion.

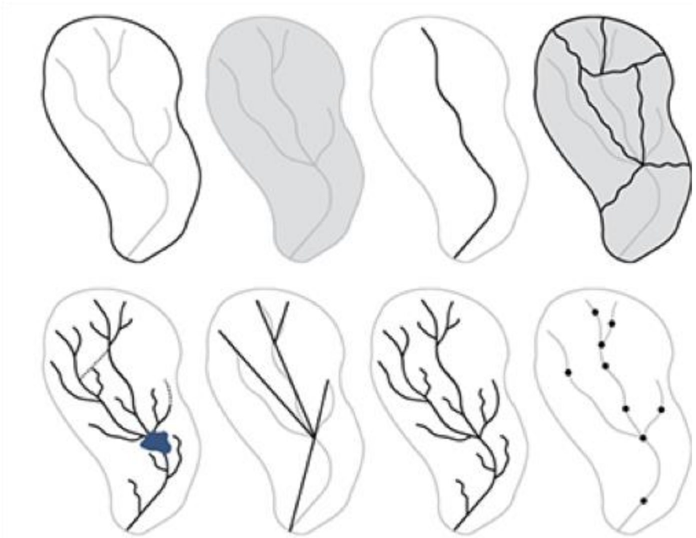
Rating tables or rating curves express a theoretical or empirical relationship between any two variables. In hydrology, the development of empirical relationships is normally through the use of field observations, including stage, stream gaugings and river cross-sectional data. The ongoing collection of information and data at stream gauging stations is used to validate and refine the relationship as river profiles change over time.

The focus of the WaterML2: Part 2 standard [10] is defining a common structure (information model) for representing rating tables, gauging observations and river cross sections, their associated metadata and vocabularies, as well as an XML format for the exchange of data between organizational systems. The standard provides a published, internationally agreed method for sharing ratings, gaugings and cross-sectional (termed sections) data between organizations and information systems.

4. WaterML2: Part 3 – Surface Hydrology Features [HY_Features]

Surface hydrologic features are units of hydrologic information required to convey the identity of real-world water-objects through the data processing chain from observation to water information. This standard provides a reference model defining real-world water-objects and the way they relate to each other according to the hydro-science domain. It is defined under the umbrella of the joint WMO/OGC Hydrology Domain Working Group and is intended to form the groundwork for future hydrologic feature encoding standards among other applications.

HY_Features standardizes hydrologic features such as those shown in figure 1.



- Catchment Boundary
- Catchment Area
- Flowpath
- Contained Catchments

- Cartographic Realization
- Topological Schematic
- Hydrographic Network
- Hydrometric Network

Figure 1. Example hydrologic features that can be described using WaterML2: Part 3.

The HY_Features common hydrologic feature model [11] is a formalism based on definitions published in the WMO/UNESCO International Glossary of Hydrology (WMO Series no. 385) [12]. The HY_Features model describes surface hydrologic features by defining the fundamental relationships among major components of the hydrosphere in a way that is independent from geometric representation or the scale of the described features.

The HY_Features model allows for common and stable reference definitions wherever hydrologic features and relationships are required:

- to allow identification of the target feature-of-interest of hydrologic observations;
- to assist the assimilation of data into integrated datasets or computer software on global, regional or basin scales;
- to enable information systems to link distributed data across application domains and jurisdictions; and
- to enable cross-domain services to communicate by referencing common, shared concepts promoting semantic interoperability between systems.

5. WaterML2: Part 4 – GroundWater Markup Language 2 [GWML2]

A significant portion of the global water supply can be attributed to groundwater resources. Effective management of such resources requires the collection, management and delivery of related data, but these data are distributed globally across many agencies resulting in major data heterogeneity [13]. Discovering, accessing, assessing, reformatting and using these data are thus considerable challenges for any user.

To help overcome this challenge, a group of international groundwater data providers have collaborated within the Groundwater Standards Working Group (GW SWG) of the Open Geospatial Consortium (OGC) to develop the GWML2 standard [14] for sharing groundwater data. GWML2 comprises the groundwater component of the WaterML2 suite of hydrologic data standards and consists of three data structures for groundwater features progressively optimized for data exchange with OGC protocols. Groundwater features are natural or artificial entities significant to the storage or movement of groundwater, and GWML2 includes the following features as partially illustrated in Figure 2:

- **Hydrogeological units**: basins, aquifers and their properties and spaces fillable by water;
- **Groundwater bodies**: biologic, chemical and material constituents and groundwater flow;
- **Man-made artifacts**: wells, monitoring stations, management areas and aquifer tests.

GWML2 has been successfully tested by groundwater data providers from North America, Europe and Australasia in an OGC Interoperability Experiment (GW2IE). GWML2 complements emerging standards for surface and atmospheric water features as well as hydrologic observations, to facilitate the exchange of data for the complete water cycle.

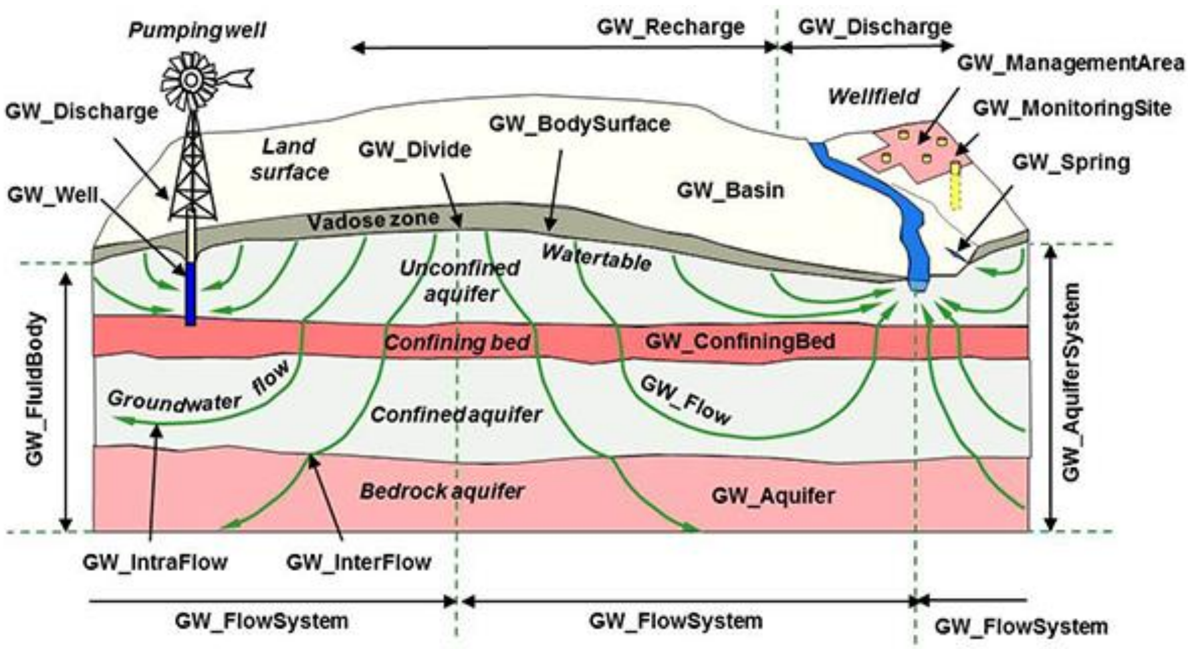


Figure 2. A partial view of GWML2. Labels prefixed with "GW_" denote GWML2 components.

6. WMO Hydrological Observing System (WHOS)

Through policies such as resolution 25, adopted by the Thirteenth Congress in 1999, WMO Members are committed to broadening and enhancing, whenever possible, the free and unrestricted international exchange of hydrological data and products. The work of the WMO/OGC Hydrology Domain Working Group is highly relevant to achieving the goals of resolution 25 through development of international standards that support data sharing.

Through the cooperation of member countries from around the world, WMO operates a number of observing systems, coordinated through WIGOS (WMO Integrated Global Observing System), which support the global sharing of meteorological, climatological and hydrological data. The WMO Hydrological Observing System (WHOS), the hydrological component of WIGOS, is conceived as a portal for accessing existing online near real-time and historical data, drawing from the water information systems of countries that make their data freely and openly available.

WHOS is being developed in two phases. The first phase, already completed, is the publication of a map interface on the WMO website that links to those National Meteorological and Hydrological Services (NMHSs) that make their real-time and/or historical stage and discharge data available online[2]. The second phase, currently in development, is a much more comprehensive undertaking aimed at developing a complete services-oriented framework linking hydrologic data providers and users through a hydrologic information system that enables data registration, data discovery and data access. The scope of WHOS is defined as a multi-scale (local, national, regional and global) registry of hydrological data and information services catalogued using the standards and procedures of OGC and WMO.

WHOS is being designed to offer services that support the operational needs of NMHSs as well as the broader scientific needs of the international hydrological community. WHOS will support storage of hydrological observations, publication on the Internet via web-services, federation (combining) with hydrological data published by multiple hydrological agencies, and search across the various data holdings within a network. These advanced data access and analysis capabilities are provided through the use of web services using standardized data formats and service types, such as standards and procedures of OGC and WMO.

When fully implemented, the WMO Hydrological Observing System will fulfill the long-sought goal of hydrologists and water resources specialists to have simple access to hydrological data from those NMHSs around the world that make their data freely and openly available. The WaterML2 suite of standards are critical to our ability to build WHOS supporting the free and open exchange of hydrological data.

In May 2017, the WMO Executive Council formally adopted WaterML2: Parts 1 and 2 as official standards for use by NMHSs and within WHOS. Future WMO adoption of the WaterML2: Parts 3 and 4 standards is expected. Using WaterML2 and OGC's interoperability standards, the linking of local, national, regional and global water information systems is now possible, providing quality hydrological data that can be used in decision-making for all aspects of water resources management.

7. Conclusion

Ten years of successful collaboration between WMO and OGC in hydrology and informatics has resulted in the WaterML2 suite of standards that support increased hydrological data sharing and exchange, with the promise of improved management of our precious water resources.

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