WatERP

Water Enhanced Resource Planning

“Where water supply meets demand”

GA number: 318603

WP 2: External System Integration

D2.7: Results of Work on Standards

V1.0 31.05.2015

www.waterp-fp7.eu

Document Information

Project Number	318603	**Acronym**	WatERP
Full title	Water Enhanced Resource Planning "Where water supply meets demand"		
Project URL	http://www.waterp-fp7.eu		
Project officer	Grazyna Wojcieszko		

Deliverable	**Number**	D2.7	**Title**	Results of Work on Standards
Work Package	**Number**	WP2	**Title**	External System Integration

Date of delivery	**Contractual**	M30	**Actual**	M32
Nature	Prototype ☐ Report X Dissemination ☐ Other ☐			
Dissemination Level	Public X Consortium ☐			

Responsible Author	Andreas Abecker	**Email**	andreas.abecker@disy.net
Partner	disy	**Phone**	+49-721-16006256

Abstract (for dissemination)	A major aim of the WatERP project is to ease data and information exchange between different players and software systems in the water supply domain. In order to achieve sustainable and generally applicable project impact, it is crucial to carefully take into account the current situation with regard to standards in water data transfer and try to have maximum impact on these standardization efforts. In delivery D2.2, an activity plan for the WatERP project was devised which should guide all project activities in this direction. As a main focus, it was aimed at implementing, testing and extending the WaterML2.0 standard of the Open Geospatial Consortium (OGC). In this activity, the status and results of the so-planned activities is assessed and documented half a year before project end. Briefly, it can be said that the technical developments and pilot applications of WatERP have significantly extended the way how to work with WPS and SOS based software architectures. Complementing existing OGC approaches by a rigorous application of semantics-based methods gives them much more possibilities and flexibility. In order to do so, the WatERP Water Management Ontology has been devised and used, e.g., for supporting matchmaking orchestration in WPS-based SOAs and for adding a

	semantic layer to SOS-based measurement-data management. These results have been communicated and discussed with the OGC Hydrology Domain Working Group and they have been published to a wide audience of researchers and practitioners in geoinformatics, in hydroinformatics, and in water management.
Key words	Water data standards, OGC WaterML2.0

Glossary of terms

API - Application Programming Interface

CHE - Ebro River Hydrographic Confederation

CHy - Commission for Hydrology

CUAHSI - Consortium of Universities for the Advancement of Hydrologic Science, Inc.

DSS - Decision Support System

DWG – OGC Domain Working Group

EC - European Commission

FIPA - Foundation for Intelligent Physical Agents

GeoSPARQL – OGC standard for querying of geospatial linked data in the Semantic Web

HDWG – OGC Hydrology Domain Working Group

ICT - Information and Communication Technology

IE – OGC Interoperability Experiment

IETF - Internet Engineering Task Force

ISO - International Standards Organisation

O&M - Observation and Measurements

OASIS - Advancing Open Standards for the Information Society

OGC - Open Geospatial Consortium

PC – OGC Planning Committee

REST - REpresentational State Transfer

SAS – OGC Sensor Alert Service

SOAP - Simple Object Access Protocol

SOS – OGC Sensor Observation Service

SPS – OGC Sensor Planning Service

SSHD - Support System for Hydrologic Data

SWE – OGC Sensor Web Enablement

TC – OGC Technical Committee

URL - Uniform Resource Locator

W3C - World Wide Web Consortium

WDW – WatERP Water Data Warehouse

WfMC - Workflow Management Coalition

WFS-T - Web Feature Service - Transactional

WMO - World Meteorological Organisation

WMS – OGC Web Map Service

WNS – OGC Web Notification Services

WPS – OGC Web Processing Service

XML - eXtensible Markup Language

Executive Summary

A major aim of the WatERP project is to ease data and information exchange between different players and software systems in the water supply domain. In order to achieve sustainable and generally applicable project impact, it is crucial to carefully take into account the current situation with regard to standards in water data transfer and try to have maximum impact on this standardization effort. In WatERP deliverable D2.2, an activity plan has been devised that should guide all WatERP project activities in this direction. In this deliverable D2.7, the status and results of the planned activities is reviewed at project month 30 and the remaining tasks until project end are presented. Briefly, it can be said that the technical developments and pilot applications of WatERP have significantly extended the way how to work with WPS and SOS based software architectures. Complementing existing OGC approaches by a rigorous application of semantics-based methods gives them much more possibilities and flexibility. In order to do so, the WatERP Water Management Ontology has been devised and used, e.g., for supporting matchmaking orchestration in WPS-based SOAs and for adding a semantic layer to SOS-based measurement-data management. These results have been communicated to and discussed with the OGC Hydrology Domain Working Group and they have been published to a wide audience of researchers and practitioners in geoinformatics, in hydroinformatics, and in water management.

To understand this document the following deliverables have to be read.

Number	Title	Description
D2.2	Activity Plans for Work on Standards	Describes the planned WatERP project activities regarding impact on standards.

Table of contents

Table of figures

1. Motivation and Overview

In the water supply system, manifold players collaborate in complex ways in order to enable the stable, sustainable and high-quality provision of drinking water to the citizen. Depending on the national regulations and grown structures, these actors may comprise national, regional, or municipal public authorities, non-profit companies, private profit-oriented companies, etc. - which stand in more or less complex networks of technological, legal and business relationships among each other. Increasingly, new actors “enter” the network, for instance new scientific or commercial providers of sophisticated weather forecasts or even the general public interested in more transparent information about the usage of their tax money or interested in possible ways of saving water or saving money paid for water. Because of their different tasks and interests in the system, their different regulatory constraints, different business models and technical facilities, these actors differ much (i) with respect to the information on the water system they have, consume, and create, (ii) with respect to the way they store, manage and process information and data on the water system, and (iii) with respect to the software systems, data models and information exchange mechanisms they employ.

It is the major assumption of the WatERP project that significant improvements in the overall system can be achieved by a better exchange of information between such actors / stakeholders in the water system. Hence a major part of the technical developments within WatERP comprise software-technology for data collection and data exchange between different players, to enable better-informed decisions and novel decision-support mechanisms. In principle, a data-exchange infrastructure consists of a reference architecture, specific technical services, communication protocols, and data schemata / content models.

Obviously, the transferability of the project results to other regions, and with that, the potential impact of project results, can be leveraged by far if the WatERP approach is based to the biggest possible extent on suitable open standards, implements, evaluates and further develops them and thus contributes to the European and worldwide standardization efforts in the water area.

Hence, working with and working on water-data transfer standards is an orthogonal activity, embedded in practically all WatERP work packages and working threads. However, in order to make the contributions to standards in a more structured, consistent and planned manner and in order to monitor its progress and success better, the WatERP project workplan has foreseen two specific deliverables related to the WatERP work on standards:

- In the early phase of project set-up (project month 1 – 6), the Consortium was expected to make-up its mind with respect to standardization and decide upon the basic goals and concrete steps to achieve them regarding the standardization work. This planning led to an activity plan for the whole project duration describing what should be done with respect to standards, when and by whom for the rest of the project duration. The results of this planning process are documented in deliverable D2.2.

- In the last phase of the project, the achieved results and concrete insights of standardization work should be documented. This is done with this deliverable D.2.7.

This document is structured very simply:

- In Section 2 of this document, the WatERP activity plan from deliverable D2.2. has been overtaken, it is went through activity by activity; for each activity, the status and results are added to the original activity description. A final subsection summarizes the status of task achievement in an overview.
- In Section 3, the main technical contributions of WatERP to the water management / hydroinformatics standardization are summarized.
- In Section 4, some conclusions and last steps for achieving the WatERP standardization goals are presented.

2. Activity Plan for Work on Standards

In Deliverable D2.2. "Plan for Work on Standards", four activity areas together with a number of concrete planned activities in these areas were defined, as shown in Figure 1.

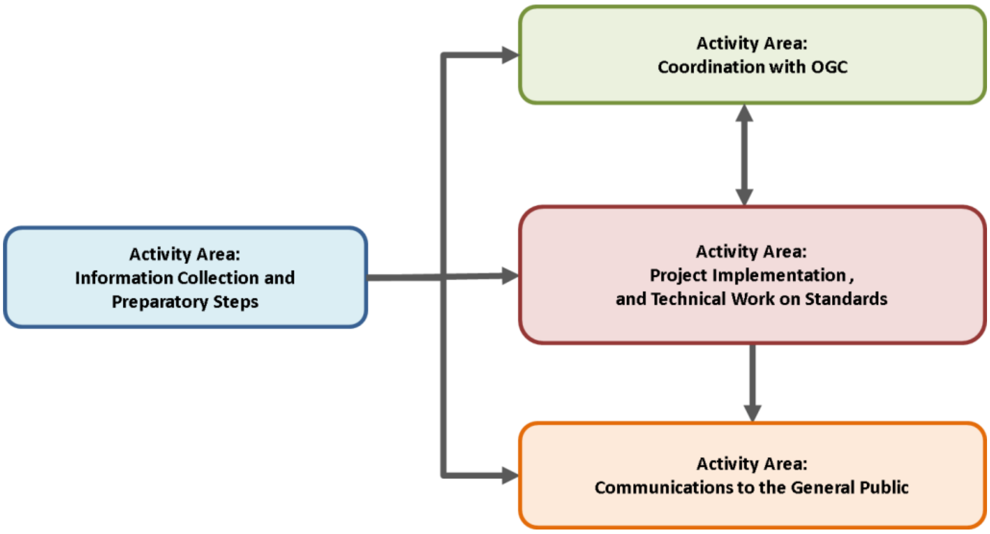

Figure 1 "Activity Areas for Work on Standards"

In the following subsections, we go through these four activity areas and review the related activities and sub-activities one by one. For each activity, we repeat the plan from D2.2 and include an additional row coloured in orange, for the actual status and results of this activity.

2.1 Information Collection and Preparatory Steps area

Before WatERP could really start to work on concrete standards, some initial steps had to be under-taken to prepare the further content-oriented work. These comprised information collection and basic decisions.

2.1.1 Fundamental decisions activity

First, basic considerations had to be taken, where to focus the standards-related activities on.

S1 – Fundamental decisions	
What	Collect and share information, assess different options and take decisions in which direction standardization work in WatERP should be focused on. Possible directions comprise information exchange and content model (de facto) standards discussed within W3C, ISO, OGC, FIPA and water-domain specific

	consortia and organizations (like CUAHSI).
Result	Decision on WatERP standardization focus
Lead partner	BDIGITAL
Contrib. partners	DISY, INCLAM, SU, ICCS
Resources	Part of work in WP1, WP2, WP3
When	M1-M3
Due date	End of Month 3
Comments	• Prerequisite for all subsequent activities with reference to standards. • When preparing report D2.2, the decision had already been taken, namely focusing on OGC data exchange standards in general, and on OGC SWE-SOS (Sensor Observation Service) in particular, together with WaterML2.0 as a content model.
Status and Results	*Activity S1 has been successfully completed.* As already stated above, it was decided to focus exclusively on contributions to the OGC-based standards for exchanging geospatial information, domain-independently as well as with a domain focus (WaterML2.0). Looking back at the time of writing this report, we consider this decision still valid and useful because OGC stands at the core of standardization regarding geodata exchange, achieving a high level of visibility and impact.

2.1.2 State of practice summary activity

Having taken the basic decisions, it was necessary to collect as complete and consistent information as possible about the considered standards, both inside and outside the WatERP project, in order to base subsequent activities on latest information and to drive them by real-world requirements. This activity comprised three sub-activities described below.

S2 – State of practice summary	
What	Assess, analyse and distribute within WatERP Consortium the state-of-the-art in the use of standards for water-data exchange.
Result	*see below in sub-activities*
Lead partner	DISY
Contrib. partners	All
Resources	Part of work in WP1, WP2
When	M1-M6

Due date	*see below in sub-activities*
Comments	This action partially prepares S1 and partially prepares all subsequent steps.
Status and Results	*This activity field has been successfully completed.* Results are described below in the associated sub-activities.

2.1.2.1 Pilot situation sub-activity

On one hand, the standards-related state-of-affairs in the two WatERP pilot sites had to be assessed.

S2-1 – State of practice summary // Pilot situation	
What	Analyze status of the two WatERP pilot sites with reference to adoption of water-data exchange standards.
Result	Part of deliverable D2.1.
Lead partner	SU
Contrib. partners	INCLAM, ACA, TZW, SWKA
Resources	Part of work in WP2
When	M1-M6
Due date	End of M6 (deliverable D2.1)
Comments	
Status and Results	*Sub-activity S2-1 has been successfully completed.* The concrete usage of water-data exchange standards in the two WatERP pilots has been assessed and documented as part of the piloting work in WP7 and WP2. Briefly, it turned out that: While in the ACA pilot, a Spatial Data Infrastructure (SDI) for water-data exchange had already been in place, using the usual OGC standards for typical geodata access and presentation (OGC WFS, OGC WMS) together with a WaterOneFlow server (which can be seen following a predecessor philosophy of WaterML2.0), in the SWKA case, practically no standards at all were used. Mostly, of course, because neither cross-organization nor organization-internal data exchange beyond the simple tool-internal usage of technical machine-operation data and economic water-allocation data (SCADA system) were practiced at all.

2.1.2.2 General situation sub-activity

Next, the general state-of-affairs outside the WatERP project had to be examined, in order to find existing implementations, implementation experiences, ongoing activities, etc.

S2-2 – State of practice summary // General situation	
What	Assess the current state-of-the-art regarding adoption of water-data exchange standards in water supply and water utilities.
Result	Possibly, a specific presentation at first review meeting.
Lead partner	INCLAM
Contrib. partners	SU, DISY, BDIGITAL
Resources	Part of work in WP1, WP2
When	M1-M6
Due date	M13 (first project review)
Comments	
Status and Results	*Sub-activity S2-2 has been successfully completed.* During the preparatory phase of the pilots (WP7), the domain knowledge characterization (WP1), the overall WatERP architectural design (WP2), the state-of-the-art analysis for external-systems integration (WP2), and in networking events and dissemination meetings with numerous practitioners (as part of WP8), the state-of-practice regarding the use of standards in the water-supply chain has been examined. Altogether, the results were relatively disillusioning: (a) In general, there is extremely few data exchange between organizations. Seen from the purely technical perspective (domain-independent), the OGC download and presentation services (WFS, WMS) are in practical use and represent the de-facto standard for data exchange of geodata. From the domain-specific perspective (water domain), WaterML2.0 and its predecessors are known in the scientific and practitioner communities, but (i) only among the very early adopters of technology (ii) very much focussed on the original purpose of transmitting hydrological and hydrographic data, not extending the concept towards more kinds of data and (iii) still very often using the predecessors of WaterML2.0. (b) Data exchange between different kinds of tools within organizations

	is surprisingly seldom. If it happens, the interfaces are practically always proprietary and based on the industrial protocols and data formats used by the producers of the hardware-software systems for controlling the machines in the distribution network (pumps, etc.). Altogether, the results of S2-2 confirm the observations already made in S2.1 for the two WatERP pilots which show that the pilots for the project were well selected.

2.1.2.3 WatERP-internal workshop on standards sub-activity

Having collected the manifold kinds of information in the prior two sub-activities, a project-internal workshop had to be held in order to exchange and consolidate the shared knowledge level within the project Consortium and to confirm and communicate strategic decisions for the project work on standards.

S2-3 – State of practice summary // WatERP-internal workshop on standards	
What	Run a project-internal workshop on water-data standards in order to harmonize knowledge levels within project Consortium and to consolidate basic decisions.
Result	Internal workshop on standards.
Lead partner	DISY
Contrib. partners	All
Resources	Part of work in WP8
When	M1-M6
Due date	End of M6
Comments	
Status and Results	*Sub-activity S2-3 has been successfully completed.* The half-day workshop took place as part of the Consortium meeting in Karlsruhe in March 2013. Especially between the technical partners, much background knowledge was shared and strategic directions were discussed in order to design and align future work, particularly in WP1, 2, 3 and 6. Mainly, these strategic directions were: (i) Full WatERP architecture alignment with OGC standards which are the most widespread. Where necessary and useful (because we need to add functionalities that are currently not in the scope of OGC), the OGC standards shall be extended and comple-

	mented by the respective developments from W3C (regarding Semantic Web and Linked Data representations, especially to use GeoSPARQL as a representation and querying mechanism within WP3) and from FIPA (regarding Multi-Agent Systems). (ii) This directly leads to the decision to focus on the SOS protocol and the WaterML2.0 data model for measurement-data transfer. This implies that other data-transfer approaches (e.g., from sensor suppliers) or data models (like the many WaterML2.0 predecessors) are not considered in depth. It also leads to the decision to use the very widespread 52°North open-source SOS implementation as a basis for WP2/ WP3 implementations in the area of data transmission. (iii) Further, for achieving the project goals regarding geospatial reasoning and ontology-based structuring of the system, this means that the SOS/WaterML2.0 approach must be "semantics-enabled". This has direct implications on the architecture of the WatERP Water Data Warehouse. (iv) Similarly, it was decided that OGC WPS shall be used as the basic mechanism for realizing the WatERP service-oriented architecture, but that it must be extended by a semantics-aware component (the MAS based on the Water Management Ontology) in order to achieve the necessary flexibility and extensibility. (v) In order to support all these innovative developments mentioned under (iii) and (iv), the WatERP Water Management Ontology was designed which is aligned with HY_FEATURES, SWEET, OWL-S, the W3C Semantic Sensor Network (SSN) ontology and other relevant ontologies.

2.2 Standards-based Project Implementation and Technical Work on Standards area

Having undertaken the basic decision and information-collection steps described in the activities above, the biggest part of the WatERP work on standards was the concrete technical work about implementing, using, and further extending standards models and standards-compliant software. This comprised a technical design activity (S3), the concrete doing (S4) and the reflection of and learning from the doing (S5).

2.2.1 Standards-compliant system architecture activity

Before realizing software solutions, in this activity, a careful overall software design had to be devised to be implemented, validated and evaluated later on.

S3 – Standards-compliant system architecture	
What	Basic software design decisions for data exchange and data storage in WatERP shall be done such that they adopt and support to the widest possible extent the standards identified as interesting within action items S1 and S2. The system architecture shall be designed such that it allows (1) a rigid *assessment* of existing standards' usability under the pilots´ real-world conditions and (2) a good *extensibility* with reference to all issues deemed necessary during further elaboration of pilots and technical work in WP2.
Result	Part of deliverable D3.1.
Lead partner	DISY
Contrib. partners	INCLAM, SU, BDIGITAL, ICCS
Resources	Part of work in WP2, WP3
When	M4-M6
Due date	End of M6
Comments	• Prerequisite for S4. • When preparing document D2.2, this had already been done. This led in particular to a WDW design offering an OGC SOS import interface as well as OGC WFS-T, WMS and WPS read/write interfaces. Specific interest was spent, e.g., for analysing performance issues of the SOS interface and for the question under which conditions which of the different OGC interfaces (SOS, WFS, WPS) will be the most appropriate. Further, it led to the decision for an object-relational database core the schema of which can be easily extended during the project when extending the content model of WaterML2.0.
Status and Results	*Activity S3 has been successfully completed.* As explained above, OGC standards have been overtaken as guiding technological themes for the layout of the WatERP architecture. At the time of preparing this report D2.7, these decisions still can be considered technically valid and strategically promising (with respect to practical impact and to sustainable technical decisions). Many of the details mentioned above have been taken care for in the further run of the project and will be sketched below. The extensibility

	of the WatERP architecture is definitely realized to the highest possible extent. The usability of the employed standards in our pilots has been shown so far (until project month 30) and will be further examined in the last project period (month 30 – 36).

2.2.2 Standards-compliant pilot implementations activity

After having defined the standards-oriented project software architecture, it was implemented in generic software modules (technical workpackages WP2, WP3, WP6) and applied in the two WatERP pilot cases (WP7). These implementations and pilot installations should be done such that they take-up and extend latest standards developments and allow to qualitatively and quantitatively assess major success factors and quality metrics.

S4 – Standards-compliant pilot implementations	
What	For all conceptual models (WP1), technical implementations (WP2,3,6), and pilot installations (WP7) take into account the basic decisions of S1/S3 allowing to set-up a real-world test bed of the standards to be supported. Specific aspects to be inspected in detail comprise <u>efficiency/scalability</u>, <u>expressivity</u> (is it possible to express the facts that shall be described by the data in a natural and easy manner?), <u>interoperability</u> with legacy systems and <u>extensibility</u>. Furthermore, based on the pilot requirements, identify needs for extending the standards and implement them prototypically.
Result	Parts of deliverables D3.3/D3.4 (WDW versions 2 and 3) as well as deliverables D7.3.1/D7.3.2 (pilot installations of WDW); standards aspects shall be covered in specific presentations at project reviews 2 and 3 if needed and appropriate.
Lead partner	HYDS
Contrib. partners	All
Resources	Part of work in WP1, 2, 3, 6 and WP7.
When	M6-M30
Due date	M18, M30
Comments	• S4 implements S3 and is specifically18analysed in S5. The technical developments will aim at the following objectives: • The WatERP WP2 and WP3 together with the pilot realizations in WP7 deliver more stable, comprehensive and efficient implementations of contemporary SOS-based solutions. • The pilot implementations will allow assessing their efficiency and general

	applicability. • The pilot implementations will drive suggestions and prototypical implementations of extensions of the WaterML2.0 content model (which is currently exclusively focused on time-series data about hydrological features), probably through additional domain-specific features and/or controlled vocabularies covering WatERP specific domain knowledge (water supply, water usage, …).
Status and Results	*Activity S4 has successfully been completed.* More details follow below in the descriptions of the S4-i sub-activities.

2.2.2.1 Pilot set-up sub-activity

In a first round of implementations, the technical workpackages delivered their individual standards-compliant modules, extended the standards wherever needed, integrated them in the overall WatERP software framework and installed them as part of the first version of pilot installations.

S4-1 - Standards-compliant pilot implementations // Pilot set-up	
What	Standards-compliant realization of pilot solutions; if needed, with suitable standards extensions.
Result	Parts of deliverables D3.3 (WDW version 2) as well as deliverable D7.3.1 (first version of pilot installations) where appropriate.
Lead partner	HYDS
Contrib. partners	All
Resources	Part of work in WP1, 2, 3, 6, and WP7.
When	M6-M18
Due date	M26 (review 2)
Comments	
Status and Results	*Sub-activity S4-1 is successfully completed.* The as-is-analysis and the pilot-implementation planning took into account the standards-related aspects. In particular, this meant, analysis of the WaterOneflow approach used in ACA to exchange data between ACA and its water consumers; detailed examination and modelling of all domain- and application-specific phenomena in the ACA and in the SWKA pilot needed to build the WatERP Water Management Ontology (WMO) at the conceptual and the instance level which serves as the basis for semantic metadata description in the

	SOS-based data exchange; design and implementation of the Pilot Integration Manager (PIM, WP2/3) which allows to integrate existing data management approaches into the SOS-based WatERP infra-structure.

2.2.2.2 Pilot analyses and improvements sub-activity

After having set-up the first round of pilots, these were carefully analysed with respect to standards-compliance, performance of implemented modules and extensions, potential drawbacks and gaps. The results were fed into technical development workpackages WP2, WP3, WP6 which in turn (within sub-activity S4-3) produced changed, consolidated or extended tools, integrated in a revised integrated platform (S4-3) and leading to revised/ extended pilot installations in the second round of piloting.

S4-2 - Standards-compliant pilot implementations // Pilot analyses and improvements	
What	Analysis of standards-oriented strengths and weaknesses of pilot implementations; identification and prototypical realization of necessary software changes.
Result	Parts of deliverables D3.4 (WDW versions 3) and D7.3.2 (second version of pilot implementations); standards aspects shall be covered in specific presentations at project review 3 if considered necessary and useful.
Lead partner	DISY
Contrib. partners	all
Resources	Part of work in WP1, 2, 3, 6, and WP7.
When	M13-M30
Due date	M36 (review 3)
Comments	
Status and Results	*S4-2 is successfully completed.* In general it turned out that, in order to achieve WatERP's ambitious goals with respect to flexibility and extensibility, the existing OGC based approaches are not deeply enough rooted in semantic techno-logies and that existing domain models do not cover broadly enough all phenomena relevant in the water management area. To be more concrete, several fields of necessary technical development activities have been identified: (i) Existing OGC approaches in the water area

	hardly use semantic technologies (from the technical point of view) and they focus much on hydrological and hydrographic aspects (from the content point of view). Thus it was necessary to design the WatERP Water Management Ontology (WMO) as a significant progress beyond existing work in water ontologies. (ii) Although very much academic work has been done regarding content-oriented (semantic) description of WPS processes (e.g., in the area of WPS application profiles) and regarding WPS orchestration, there is nevertheless no approach for that which is really fully automatically extensible and reconfigurable and widespread in practice. Hence, WatERP devised the Multi-Agent Systems based WPS-SOA. (iii) Although existing infrastructures for SOS implementation have already been taken up by a wider audience in academics and practice and exhibit a high level of functionality and stability, they are not designed for integration in semantics-enabled environments. Thus, a way had to be found for combining existing strengths of SOS implementations with future ontology-enabled architectures. (iv) SOS-based infrastructures are typically set up from scratch, when installing a new sensor technology. In WatERP, we use SOS also for importing data from legacy systems and software infrastructures. So, a technical support for easily integrating existing systems into our SOS-based infrastructure had to be developed.

2.2.2.3 *Standards extensions sub-activity*

The insights from piloting (sub-activity S4-2) led to requirements for extending the standards, the supporting software or the way of using them (best practices). These generic insights were collected and realized in this sub-activity before they were fed back into application in the pilots within S4-3. So, sub-activities S4-2 and S4-3 together realize a continuous improvement cycle between generic development and concrete piloting.

S4-3 - Standards-compliant pilot implementations // Standards extensions	
What	Based on the concrete pilot experiences, identify general (pilot-independent) needs for extending the standards and implement them prototypically.

Result	Parts of deliverables D3.3/D3.4 (WDW versions 2 and 3) as well as deliverables D7.3.1/D7.3.2 (pilot installations of WDW); standards aspects shall be covered in specific presentations at project reviews 2 and 3 if considered necessary and useful.
Lead partner	INCLAM
Contrib. partners	DISY, SU, BDIGITAL
Resources	Part of work in WP2 and WP3
When	M13-M30
Due date	M36 (review 3)
Comments	
Status and Results	*Sub-activity S4-3 is successfully completed.* Based on the observations mentioned in sub-activity S4-2 the general extensions of the OGC approaches used in the project, can be summarized as follows: • The idea of OGC WPS as an interoperability protocol is extended by a MAS-based layer for identifying and orchestrating the appropriate WPS services to be employed (or, combined) for satisfying a specific informational goal. • The WatERP Water Management Ontology (WMO) has been developed and put into practice. WMO, on one hand continues the efforts to represent the WaterML2.0 concepts with a Semantic Web language. But, on the other hand, it also significantly extends the WaterML2.0 conceptual model, in particular by concepts (i) to describe human water-management decisions, (ii) to describe prognoses and forecasts, and (iii) to describe man-made water management infrastructures (distribution network, etc.). Altogether, the scope of modelled concepts has been lifted from the narrower area of hydrology and hydrography to the much more comprehensive area of water supply and water management. • Using this ontology, the WDW has been implemented as a hybrid storage which uses object-relational mechanisms for storing time-series observation data and semantic technologies for storing WMO-based metadata for observations. In this way, a se-

	mantic layer has been added to the SOS approach, while still remaining consistent with the main decisions regarding observation-data management and access. • The SOS approach for transferring observation data is – for cases where data from an already existing, not SOS-oriented, data infrastructure shall be consumed – extended by the Pilot Integration Manager for easily integrating new data sources into an SOS-based infrastructure and for doing the necessary data transformations in a systematic, supported manner. • The OGC WPS standard provides operations for service discovery, but all them are focused on syntactic issues and forget the semantics. Because service semantics is key to the orchestration process and for avoiding ambiguity; the standardization of this best practice is strongly recommended.

2.2.3 Lessons learned from piloting activity

Besides coining implementation and piloting experience into refined implementations, tools, and standards, from the time of having the first round of deployed software in the pilots, a continuous learning and reflection process started in order to draw the conclusions and lessons learned from the concrete technical work. This led to concrete insights as the basis for communicating project results outside the project Consortium (in later activities S6 and S7). The lessons learned activity has been broken down into the continuous reflection sub-activity (S5-1) and the compilation of results into a document (S5-2).

S5 – Lessons learned from piloting	
What	During the implementation and after its evaluation, the main conclusions will be drawn and generalized with reference to their usefulness and applicability beyond the scope of WatERP. This will be done as a continuous project-internal reflection process during consortium and technical meetings and will be documented in the project-internal knowledge management systems.
Result	Standards aspects will be summarized as part of D9.4/D9.5 (2nd and 3rd periodic report, M26); standards aspects shall be covered in specific presentations at project reviews 2 and 3 if considered useful and necessary.
Lead partner	BDIGITAL

Contrib. partners	INCLAM, DISY, SU
Resources	Part of work in WP2, 3, 7, 9.
When	M18-M36
Due date	M26 (review 2), M30 (D2.7), M36 (review 3)
Comments	S5 is based on S4. The insights gained here will be the basis for all external communications in the subsequent action items. The insights will, in particular, comprise i) assessments of usability/applicability of existing standards and tools; ii) suggestions for generally applicable software decisions with reference to WaterML2.0 usage; iii) suggestions for generally applicable extensions of WaterML2.0 content model.
Status and Results	*The goals of Activity S5 have already been reached. But due to their nature, S5 activities may continue until end of the project and final review.* In very general terms, the four technical development areas motivated in the results of S4-2 that led to the technical developments sketched in the results of S4-3, constitute the main lessons learned developed in the project. Along these four development paths, WatERP has delivered novel conceptual approaches and pilot implementations which are still under examination in the two pilot installations. These four development paths are also shortly summarized in the Section 3 of this document.

2.2.3.1 Continuous reflection sub-activity

Continuously monitoring the state-of-affairs with respect to standards should be done as part of project management, integrated into standard meeting and reporting procedures.

S5-1 – Lessons learned from piloting // Continuous reflection	
What	Continuous project-internal reflection process about status and issues of water-data exchange standardization within and beyond WatERP.
Result	Standards aspects will be summarized as part of D9.4/D9.5 (2nd and 3rd periodic report, M26); standards aspects shall be covered in specific presentations at project reviews 2 and 3 if considered useful and necessary.
Lead partner	BDIGITAL
Contrib. partners	INCLAM, DISY, SU
Resources	Part of work in WP2, 3, 7, 9.

When	M18-M36
Due date	M26 (review 2), M36 (review 3)
Comments	
Status and Results	*The goals of sub-activity S5-1 have already been reached. But due to their nature, S5-1 discussions may continue until end of the project and final review.* Standards-related aspects have been continuously integrated into the work procedures of consortium meetings and workpackage activities. The results of the standards-related activities shall be summarized in a dedicated section of the WatERP final report. Examples for concrete activities to implement this continuous reflection process: At the Consortium Meeting in October 2013 in Athens, standardization issues were included in Session #1.5 on external system integration and interfaces. At the Consortium meeting in April 2014 in Stafford, standardization issues were included in Session #1.3 on external system integration and interfaces. At the Consortium meeting in October 2014 in Dresden, standardization issues were discussed in a dedicated Session #1.5. At the Consortium Meeting in May 2015 in Athens, standardization issues were included in the Session #1.7 on data management. As part of the Consortium Meeting in March 2013 in Karlsruhe, a full-day consortium workshop on standardization issues was run (cp. Sub-activity S2-3). As part of the review preparations in February 2014 and March 2015 in Brussels, the Consortium summarized, assessed and reflected the status of standardization work and the planned next steps. As part of the technical work in WP1, 2 and 3, the official communications and OGC-internal discussions regarding HY_FEATURES, WaterML2.0 and O&M have been followed continuously. Specific standards-related technical aspects have been discussed on a call-by-need basis as part of the respective technical developments, mainly in the (about) bi-weekly tele-/Skype-conferences regarding PIM/WDW using SOS+ WaterML2.0 between DISY and SU, on one hand, and SU and BDIGITAL, on the other hand, but also in the work led by BDIGITAL in close cooperation with INCLAM regarding the Water Management Ontology. In this context, BDIGITAL together with

	the project partners drafted a discussion paper on the relationship between the OGC HY_FEATURES ontology and the WatERP Water Management Ontology in order to give some foundation to the communications with the OGC HDWG.

2.2.3.2 *Lessons-learned document sub-activity*

Coming closer to the end of the project and having implemented and assessed both generic software modules and pilot prototypes, the results of the work on standards will be documented in a project deliverable.

S5-2 – Lessons learned from piloting // Lessons-learned document	
What	The main conclusions will be drawn and generalized with reference to usability beyond the scope of WatERP.
Result	Deliverable D2.7.
Lead partner	DISY
Contrib. partners	BDIGITAL, INCLAM, DISY, SU
Resources	Part of work in WP2, 9.
When	M18-M30
Due date	M30 (D2.7)
Comments	
Status and Results	*This Sub-activity will be successfully completed with the acceptance of this document D2.7.*

2.3 Coordination with OGC area

So far, we have only talked about inputs for the project to be collected from the standards community and about project internal further developments, assessments and extensions of standards. But to have real impact with those activities, one needs to approach the suitable standards organizations and link the project activities with their ways of working, communicating and finding of decisions. In the case of WatERP, these steps shall be done in collaboration with the Open Geospatial Consortium (OGC) within the thread of work about WaterML2.0 performed by the OGC Hydrology Domain Working Group (HDWG). Going forward step by step, three sub-activities can be identified.

2.3.1 Coordination with OGC activity

As a continuous activity over the project duration, the contact to the OGC HDWG has to be established and maintained. This is the prerequisite for the subsequent sub-activities.

S6 – Coordination with OGC	
What	Align WatERP project work as closely as possible with standardization work in OGC Hydrology DWG and aim at maximum impact of project results within OGC water-data exchange standardization
Result	*see below in sub-activities*
Lead partner	INCLAM
Contrib. partners	DISY
Resources	Part of WP8 work.
When	M6-M36
Due date	*see below in sub-activities*
Comments	Besides this specific question to the OGC, INCLAM and DISY will keep continuous contact to the OGC Hydrology DWG, keeping them informed about WatERP project progress and staying in contact with ongoing OGC developments.
Status and Results	*This activity is still ongoing.* Details are explained in the following sub-activities. Briefly, it can be said that the WatERP developments were done in close communication with the OGC Hydrology Domain Working Group. In general, project approach and results are received with interest and positive attitude. The plan of devising and running an official OGC Interoperability Experiment based on the WatERP pilots has been cancelled due to principled as well as practical reasons. Nevertheless, the project results shall be communicated to the OGC community in the form of an OGC discussion paper.

2.3.1.1 Apply for Interoperability Experiment sub-activity

A central working instrument of HDWG in the WaterML2.0 context is running so-called interoperability experiments (IE). It is aimed at getting accepted the WatERP project pilots as such an IE.

S6-1 – Coordination with OGC // Apply for Interoperability Experiment	
What	The WatERP Consortium will approach the OGC Hydrology Domain

	Working Group and ask for accepting the WatERP project as an "OGC Interoperability Experiment (OGC IE)".
Result	Acceptance of WatERP pilots as OGC Interoperability Experiment
Lead partner	INCLAM
Contrib. partners	DISY
Resources	Part of WP8 work.
When	M6-M12
Due date	End of M12
Comments	Risk: OGC could reject our suggestion. This would lead to a lower level of "formality" and visibility of WatERP work within OGC.
Status and Results	*This sub-activity can be seen completed with some time delay.* *However, the plan to apply with WatERP pilots as an OGC Inter-operability Experiment has been cancelled.* Closer discussions with the OGC HDWG have shown a number of practical impediments of our initial plan: (i) OGC organization: Work in OGC is very much organized in specific sub-groups. For instance, WPS as a technology is treated in a different community than SOS as a technology which is again discussed in a different community than water applications. On contrary, a main characteristic of WatERP is its comprehensive approach spanning a number of complementary technologies and instantiating it in the water domain. In the development paths introduced above, we consider WPS, SOS and the water domain in an integrated manner. However, to design an acceptable OGC Interoperability experiment, we would have to discuss the MAS-Based WPS extensions with the WPS Standards Working Group, the SOS extensions (WDW, PIM) with the SOS Standards Working Group and the Water Management Ontology with the Hydrology Domain Working Group. It is not foreseen by the OGC procedures to run such cross-cutting experiments. (ii) Timing: Running an OGC IE needs a time-consuming preparation and analysis. Relevant steps should be coordinated with the OGC, ideally during an OGC TC/PC meeting. These meetings are normally run at most once a year in Europe. On the other hand, stable and consolidated, good enough project results to achieve a satisfactory level of maturity for

	running a practice-oriented IE with software close to operational solutions, installed in the production environments of the two pilots, could not be produced before project month 30. So, achieving the OGC expected quality level and running an IE during project run-time was not realistically possible. Instead, the project decided to continuously discuss preliminary results with different OGC sub-communities, with a focus on the Hydrology DWG, and finally prepare a discussion paper about the project results and insights.

Specific meeting activities with the OGC HDWG can be summarized as follows:

- June 2014: Presentation of WatERP project approach and preliminary results at the Hydrology Domain Working group's meeting during the a OGC Technical Committee Meeting in Genova (Italy). Discussion about ways of cooperation.
- August 2014: Presentation of WatERP work and use of OGC service standards (SOS, WPS, WMS, WFS), WaterML2.0, semantics and ontologies at the workshop "Standardization of Water Data Exchange: WaterML2.0 and Beyond" organized by the HDWG and the World Meteorological Organization in new York (USA).
- October 2014: WatERP researchers shared a workday with their colleagues from BfG, the German National Agency for Water, who used to chair HDWG for several years and initiated the HY_FEATURES ontology. Important experiences related to OGC standards were discussed, as well as the strategy used in WatERP to be compatible with HY_FEATURES model and, particularly, the semantic mapping implementation. Future ways of collaboration were explored and initiated which they have paid off with a formal request that two partners (BDIGITAL and INCLAM) of WatERP will participate in the definition of the HY_FEATURES standard.
- May 2015: WatERP researchers participated in the Interoperability Day in Barcelona presenting both the interoperability pilot and the OGC standards applied on the water field. This event was organized by the Foro Ibérico y Latinoamericano of the OGC and the Asociación Catalana de Tecnologías de la Información Geospacial (ACTIG).

2.3.1.2 Documentation and analysis of WatERP Interoperability Experiment sub-activity

After having run the main implementation and assessment activities within S4, and if WatERP is accepted as an OGC HDWG IE, it must produce a formal documentation of results according to OGC practices.

S6-2 – Documentation and analysis of WatERP Interoperability Experiment	
What	Document the WatERP implementation experiences following the guidelines of OGC.
Result	Final interoperability report for OGC
Lead partner	INCLAM
Contrib. partners	All
Resources	Part of work in WP7 and WP8
When	M19-M30
Due date	End of M30
Comments	Depending on the OGC's international meeting calendar, it is aspired to present the IE report at an official OGC conference (if there is one in Europe).
Status and Results	*Because the plan to apply for an OGC Interoperability Experiment has been given up, the IE analysis and documentation sub-activity has also been cancelled.*

2.3.1.3 WatERP OGC discussion paper sub-activity

After (possibly) having run the WatERP IE and produced the final documentation in S6-2, the results of S6-2 and of the general reflection process of S5, the most important general insights for the standardization community shall be compiled into an OGC discussion paper.

S6-3 - WatERP OGC discussion paper	
What	The ideas for extending the selected standards shall be put into an official OGC discussion paper.
Result	Discussion paper to be submitted to the OGC Hydrology Domain Working Group
Lead partner	INCLAM
Contrib. partners	DISY

Resources	Part of WP8 work
When	M31-36
Due date	End of M36
Comments	• Depending on the OGC's international meeting calendar, it is aspired to present the discussion paper at an official OGC conference (if there is one in Europe). • The paper will most probably suggest extensions to the WaterML2.0 domain-specific content model (cp. comments to S4 and S5 above).
Status and Results	*Sub-activity S6-3 is under work.* Based on the positive feedback that the WatERP project team collected in several meetings and communications with members of the OGC Hydrology Domain Working Group (HDWG), the plans have been confirmed to write an OGC discussion paper especially on the use of and extension of WaterML2.0 for exchanging data within WatERP and for designing and using the WatERP ontology. It will be investigated in how far the OGC TC/PC meeting in September 2015 in Nottingham (UK) will be a good opportunity to present the paper and discuss it with the OGC HDWG.

2.4 Communications to the General Public area

2.4.1 Communication to the general public activity

Besides the more formal communications with the standardization community through the OGC processes and communication mechanisms (S6), WatERP should also disseminate its results and should aim at an impact to the largest possible audience. To do so, a number of sub-activities concerned communications to the general public, ordered according to different communication channels.

S7- Communication to the general public	
What	Try to achieve the widest reasonable public visibility for standards-related project results.
Result	*see below in sub-activities*

Lead partner	DISY
Contrib. partners	All
Resources	Part of WP8 work
When	Within the period M13-M30
Due date	M31
Comments	
Status and Results	*This activity is under work.* But the set goals have already been reached. Details can be found in the sub-activities below. We expect standards-related project activities until the end of the project.

2.4.1.1 *WatERP whitepaper sub-activity*

As a compilation of results from project reflection (S5) and OGC communications (S6), a public whitepaper should be produced in the last project semester to transport major insights to the general public. This should be offered for free and might be submitted in a revised version to a suitable conference or journal.

S7-1- Communication to the general public// WatERP whitepaper	
What	Compile the most important project insights and generally applicable lessons learned from standardization work into a public whitepaper to be distributed through the project Web site and other communication channels.
Result	WatERP public whitepaper on standardization
Lead partner	INCLAM
Contrib. partners	DISY, SU, BDIGITAL
Resources	Part of WP8 work
When	M25-M30
Due date	M31
Comments	
Status and Results	*This sub-activity is ongoing. Its due date has been postponed to the end of the project (M36).* A free PDF version of the paper will be available through the WatERP project website. Potential targets for a journal submission comprise,

	among others: Elsevier journal on “Water Research”, the Royal Society of Chemistry’s journal on “Environmental Science: Water Research & Technology”, “Journal of Sustainable Development of Energy, Water and Environment Systems”.

2.4.1.2 *WatERP public presentations sub-activity*

As part of the project dissemination activities, also – and especially – the standards-related results should be presented at workshops and conferences.

S7-2- Communication to the general public // WatERP public presentations	
What	Give at least three presentations at public workshops/conferences about the WatERP results with respect to standardization.
Result	At least 3 presentations at suitable workshops/ conferences.
Lead partner	BDIGITAL
Contrib. partners	All
Resources	Part of WP8 work
When	Within the period M13-M36
Due date	M36
Comments	Suitable conferences may comprise: AGIT and AGILE – Int. Conferences on Geoinformatics; IWRM – Int. Conf. on Integrated Water Resources Management; HIC – Int. Conf. on Hydroinformatics; World Water Forum; EnviroInfo – Annual Int. Conf. on Environmental Informatics; ISESS – Annual Int. Symp. On Environmental Software Systems.
Status and Results	*According to the time planning of D2.2, sub-activity S7-2 is ongoing at the time of writing this document.* However, according to the goal planning, the goals are already more than fulfilled. The WatERP standards-related activities and results have been presented in manifold scientific and practice-oriented events. These events are listed below.

Here follows a list of WatERP publications and presentations with a partial or pure focus on standards:

- April 2015: Talk about "Standards und semantische Technologien für den Datenaustausch in der Wasserwirtschaft" at the conference „GIS und GDI in der Wasserversorgung" organized by the DWA (German Association of Utility Companies in the Area of Water, Waste Water and Waste) in Cologne, Germany, visited by about 60 practitioners and researchers from the water-utility domain.
- March 2015: Participation and presentation at the Interoperability Day, a Spanish national event with the aim of discussing OGC standards. It was organized by the Foro Ibérico y Latinoamericano del OGC and the Asociación Catalana de Tecnologías de la Información Geospacial (ACTIG).
- October 2014: Paper presentation "Standards and Semantics to Support Interoperable Software Solutions in the Water Distribution Chain" at the e-Challenges 2014 conferences in Belfast (Northern Ireland).
- October 2014: WatERP had several presentations and participated with several project members at the WaterIdeas Conference 2014 in Bologna (Italy) which included a Special Session of the ICT4Water project cluster and a Special Session on Smart Water Standards organized by the ICT4Water Cluster initiative. It was an audience of stakeholders, end-users and potential collaborators in partnership building for potential market/commercial exploitation of the outcomes of the project.
- September, 2014: Paper presentation "A Sensor and Semantic Data Warehouse for Integrated Water Resource Management" at the EnviroInfo-2014 conference in Oldenburg (Germany).
- August 2014: Paper presentation "Integration of Water Supply Distribution Systems by using Interoperable Standards to Make Effective Decisions" at the 11th International Conference on Hydroinformatics (HIC 2014) in New York (USA).
- July 2014: Paper presentation „Eine Software-Infrastruktur für bessere Dateninteroperabilität in der Wasserversorgung" at the AGIT-2014 conference about applied geoinformatics in Salzburg, Austria).

There are also more events scheduled already at the time of writing this document:

- July 2015: Presentation of two papers, "Data and System Interoperability in the Drinking-Water Supply Chain" and "A Generic Framework to Integrate Water Supply Distribution Systems Using Interoperable Standards" at the 36th IAHR World Congress in The Hague (The Netherlands).
- November 2015: Paper presentation "A Standards-Oriented Data Warehouse for Sensor and Semantic Data Along the Water Supply Chain" at the IWRM-2015 Conference in Karlsruhe, Germany.

2.4.1.3 WatERP public standards workshop sub-activity

In the last semester of the project, a public workshop shall be held in order to disseminate the project results with respect to standards to a broader audience.

S7-3 - WatERP public standards workshop	
What	The standards-oriented results of the WatERP project shall be presented and discussed with the general public within an open workshop.
Result	At least 1 public workshop
Lead partner	BDIGITAL
Contrib. partners	All
Resources	Part of WP8 work
When	Within the period M25-M36
Due date	M36
Comments	Period for accomplishing this sub-task has been chosen so long in order to enable finding the most appropriate conference to attach the workshop; or have enough time to prepare a stand-alone event. Suitable conferences: see above as well as conferences hosted by Consortium members like the BDIGITAL Global Congress or some TZW / DVGW Symposium.
Status and Results	*This task has been successfully completed.* However, the specific focus of this sub-activity has been changed slightly. When writing the deliverable D2.2., it was planned to have an end-user oriented workshop exclusively focussed on WatERP standardization results, at the end of the project. During the run of the project it turned out to be more useful to have continuous standards-related dissemination activities and discussions with the standards community in other, broader events. Concretely, standards issues have been presented and discussed thoroughly, in particular, (a) in the Interoperability Day organized in May 2015 by OGC in Barcelona (see S6-1), (b) in the WaterML workshop organized in August 2014 by OGC in New York (see S6-1), (c) during the DWA symposium in Cologne in April 2015 (see 7-2), and (d) during the ICT4Water cluster event in Bologna in October 2014 (see S7-2).

2.5 Overview of activity status

Figure 2 below summarizes the activities with their respective status.

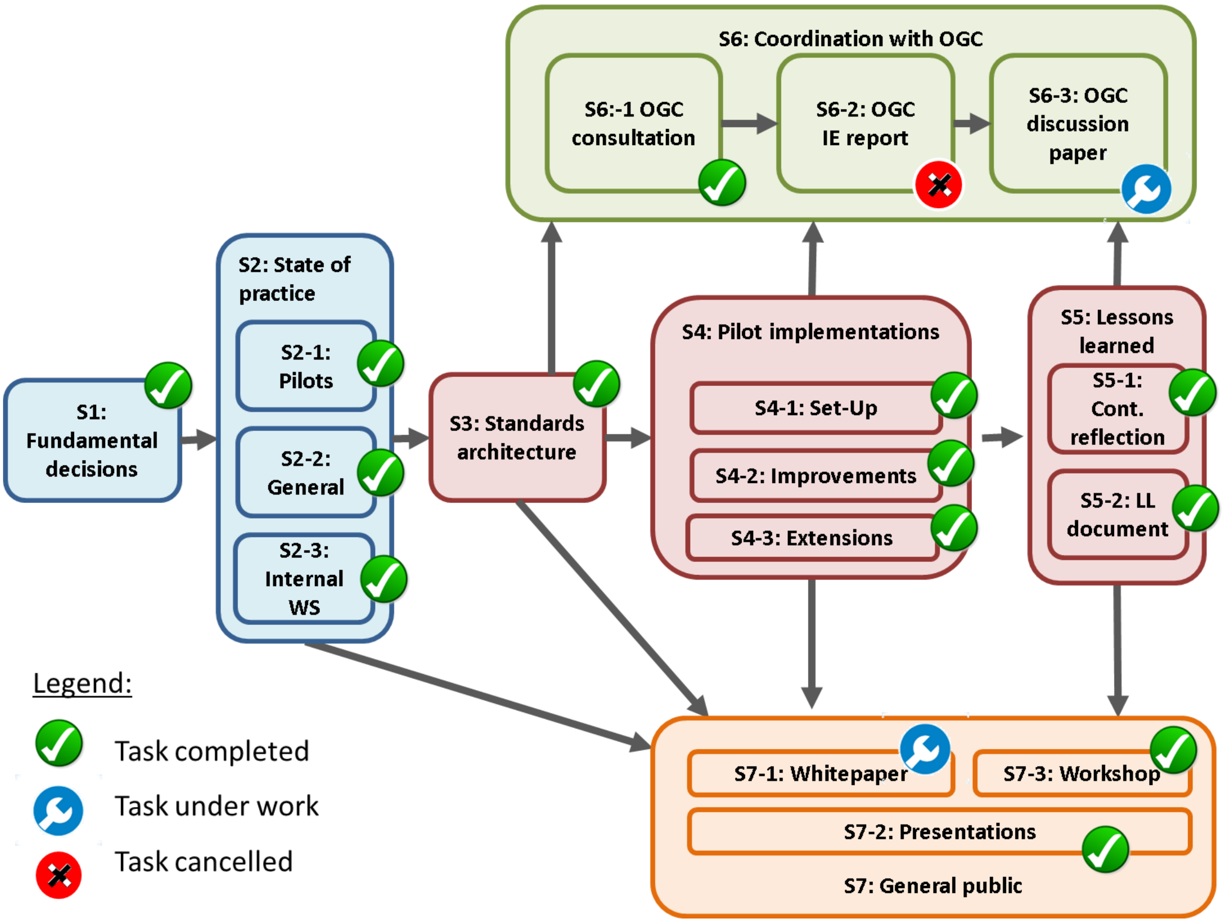

Figure 2 "Overview of Activities and Status"

3. Summary of Major Standards-Related Lessons Learned

In the following subsections, we summarize the major outcomes and lessons learned of WatERP with respect to standardization.

3.1 Service-oriented Architectures based on OGC WPS Should be Extended by Semantics-Aware Mechanisms for Service Identification and Orchestration.

Let us repeat the argumentation first presented comprehensively in [Anzaldi et al., 2014]: MAS match-making orchestration shall manage information flows and system executions towards achieving water-managers' information needs for decision-making. The MAS matchmaking process consists of fitting integrated process inputs and outputs to support decision-making in an unassisted way. It relies on the SOA architecture to discover and bind available processes published by a specific OGC WPS Server for a concrete building block.

It is important to note that the OGC WPS standard has a lack of semantic understanding because the major goal of the XML-based standards is to achieve a syntactic and structural interoperability between different software components. Further, OGC WPS only assures that a transmitter and a receiver use the same data-exchange format, but this does not assure a right communication. For instance, consider two different processes published on an OGC WPS server: i) generate the temperature forecast; and ii) generate the demand forecast. The response produced by calling *describeProcess* when "generate the temperature forecast" process information is required produces a process description where the output is defined as text/xml mime type, UTF-8 encoding and http://www.opengis.net/waterml/2.0 schema. Furthermore, the output of the "generate the temperature forecast" function returns the result (Temperature Forecasted) encapsulated in an XML (codified in UTF-8) that also accomplish the WaterML2.0 schema. On the other hand, in the same way as the previous process, the "generate demand forecast" process defines also an output parameter with text/xml mime type, UTF-8 encoding and http://www.opengis.net/waterml/2.0. That is, the result (Demand Forecasted) is encapsulated in an XML (codified in UTF-8) which fulfills the WaterML2 schema. Therefore, from a machine-orchestration point of view both, both generated outputs are the same. Specifically, the "*temperature forecast*" process and the "*demand forecast*" process provide a text/xml document (formatted in UTF-8) that is supported by the schema *http://www.opengis.net/waterml/2.0*. WPS orchestration software is not able to distinguish between both outputs. As a conclusion, OGC WPS needs extra information with the aim of achieving the transference of processes' semantic information and a well-defined machine-interpretable format.

With the aim of minimizing this semantic lack, the OGC elaborates a Best Practices document to provide the OGC Web Services with semantic annotations (Houbie, Duchesne, & Maué, 2012), including OGC WPS. The semantic annotations establish a connection between the geospatial resource, its metadata and the ontology by extending the already existing annotations of the OGC WPS. This OGC WPS annotation extension can be implemented by using the ISO19139 structure. The experience provided by the WatERP project strengthens the idea that those semantic annotations must to be included in an OGC WPS standard because they provide machine-readable information to facilitate the automatic orchestration and understanding of the processes and parameters.

Below, a matchmaking process based on semantic annotations to orchestrate the building blocks is presented. It matches semantic and syntactic parts between two building blocks. Two building blocks are linked if the published operation that one of the building blocks can provide (via the specific OGC WPS), accomplishes both; the semantic annotations and OGC WPS definitions that are required for executing the other building block. This matchmaking is carried out by looking for capabilities using the agents network: *(i)* an agent for interacting with the user to gather water-manager requirements (OMP-Agent); *(ii)* an agent to interact with the ontological instantiation (SESAME-Agent); *(iii)* an agent to manage the SOS Servers (SOS-Agents); *(iv)* an agent to manage the building-block integration (OGCWPS-Agent); *(v)* agents to manage building blocks (DMS-Agent, DSS-Agent and hydrological forecasts agent - HF-Agent); and finally *(vi)* a Jadex agent (YellowPages-Agent) aimed at managing the registered services on the Yellow page.

The MAS matchmaking orchestration is applied in two fluxes: (i) *building block integration* is executed when a new building block (with a specific OGC WPS) is registered in the platform, and (ii) *invocation process* is initiated when the water manager asks for specific information by using the OMP (WatERP Open Management Platform).

The *building block integration* process is used for cataloguing new building block processes. It is also able to analyze if new processes have the information necessary for execution. It consists of several steps that go from adding a new specific agent to the architecture until the integrated building block can be called by the MAS (Figure 3, aX steps): When a new building block has been noticed on MAS, the MAS creates an OGC WPS-Agent that is bound with the new OGC WPS Server (step a1). The next step (a2) finds out the type of the new building block by calling the "*getCapabilities*" operation of the associated OGC WPS-Server.

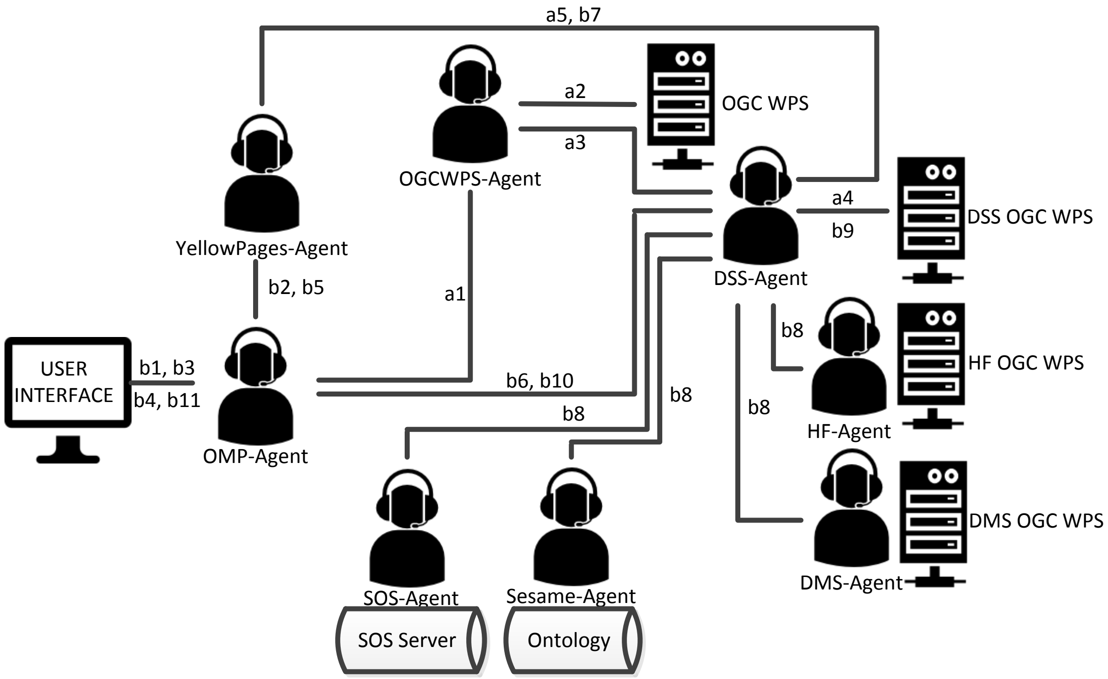

Figure 3 "Building Block Integration Process (aX steps) and Invocation Process (bY steps)"

This allows the MAS to know the type of the new block based on defined semantic annotations (DSS tools, DM tools, HF tools) in the "*ServiceIdentification*" node. After that, the OGC WPS-Agent instantiates a more specific agent (DSS-Agent, DMS-Agent, HF-Agent, etc.) to attend the building block, and delegates the responsibility of analysing the building-block processes (a3). Calling "*describeProcess*", the instantiated agent asks for the available processes that the building block can serve (a4). The returned available processes (with their inherited input/ output parameters) are checked by the specific agent by using the YellowPages-Agent (a5). It checks if the information required to execute a process is available. In case that the process requirements can be satisfied by the MAS, the specific process is registered on the YellowPages-Agent. The inclusion of a new process in the yellow pages can generate new processes that accomplish the necessary inputs to execute some required building blocks (waiting in the non-executable process). Therefore, when a new process is added in the yellow pages, the non-executed process must be reviewed. To finish the *building block* process, the defined specific agent enters a stand-by mode until its execution will be required for the MAS.

The *invocation process* provides to the water manager required information by executing building blocks. This process (Figure 5- bY steps) is performed by the interaction of the water manager with the user interface (OMP). The defined need (e.g., "*re-allocate water resources*") in the OMP is transformed into a goal in the OMP-Agent (step b1). Then, the OMP-Agent asks the YellowPages-Agent for the process(es) that can achieve this goal (b2). The YellowPages-Agent looks up published process(es) inside the Yellow pages and returns the building blocks which can fulfil the goal. Once the OMP-Agent receives the suitable processes, these are returned to the OMP (b3). The water manager selects the suitable available process. The selected process is transferred as a goal that receives the OMP-Agent (b4). Once again, the OMP-Agent asks the YellowPages-Agent for the specific agent (DSS-Agent, DMS-Agent, HF-Agent, etc.) that is responsible to execute the process (e.g., DSS-Agent) (b5). The OMP-Agent invokes this specific agent (e.g., DSS-Agent) in order to delegate the execution of the required process (b6). Later, the specific agent asks the YellowPages-Agent for agents that are able to satisfy the requirements obtained by the *"getDescription"* operation for the current process to execute (e.g., "*inflows/outflows variables and demand forecasting*" defined in an XML file) (b7). The YellowPages-Agent (b8) finds the agents (e.g., SOS-Agent and DMS-Agent) that provide the requirements and returns them to the specific agent (e.g., DSS-Agent). Then, the specific agent invokes the agents which are able to provide the required information (e.g., SOS-Agent and DMS-Agent) through the "*execute*" operation on the DMS-Agent and "*getObsevation*" on SOS-Agent case. Steps b7 and b8 can be performed again by the agents invoked (e.g., SOS-Agent and DMS-Agent) if they require extra data to provide to the initiator agent (e.g., DSS-Agent) the required answer (recursive agent invocation). When all input parameters are acquired, the initiator agent invokes the *"execute"* operation by using the gathered parameters (e.g., Inflows, Outflows and Demand Forecasting) (b9). Then, the operation is executed and the results are sent to the OMP-Agent (b10) that visualizes the operation's result into the OMP (b11).

Altogether, the MAS extension layer can be seen as a powerful extension of OGC WPS-based SOAs that considerably increases the flexibility and level of automation achievable within the SOA. Its practical viability and usefulness still has to be proven in the last piloting semester of WatERP.

Some general lessons were learnt during the development of the WatERP SOA-MAS architecture:

- OGC WPS description lacks semantic information and hence it is only focused on describing the processes syntactically.
- Semantic annotations provide machine-readable information on OGC WPS and SOS servers to discern between processes or observations allowing automatic orchestration.
- Semantic annotations open a range of new possibilities of semantic searches on OGC servers promoting the creation of open hubs of observations and processes.
- The SOA-MAS architecture enhances the flexibility and allows transparent chaining of processes and observations thus facilitating the reuse of services.

3.2 The WaterML2.0 Data Model Should be Semantically Enriched and Extended Towards More Comprehensive Coverage of the Water Management Domain.

The work on the WatERP conceptual framework in WP1 and its instantiated use in the two pilots (WP7) has motivated the broad and deep semantic layer to be used as the semantic backbone for WatERP. This represents a far-reaching continuation and extension of existing HDWG work on conceptual models and hydrological ontologies. As summarized in [Anzaldi, 2014], the relationship between the WatERP Water Management Ontology and the OGC HY_FEATURES ontology can be described as follows:

The WatERP ontology provides a common information access to support decision-making and water resource planning. This ontology represents the water domain knowledge by defining *(i)* human-made interactions and decision making in the water supply distribution chain; *(ii)* water resource availability; *(iii)* ecological, cultural and social functions of water resources and potential impacts of changes on hydrological regimes; *(iv)* current water infrastructure/assets and the economic value of water; *(v)* administrative, policy or regulatory issues of relevance; and *(vi)* sectorial use (demand) and water hierarchy. Then, the novelty of the WatERP ontology over the current state-of-the-art lies in the **incorporation of human-made interactions and decision-making processes carried out in the water domain**.

This allows alignment of water-physical objects ("*FeaturesOfInterest*") with decisional concepts. Thus, the developed ontology is able to represent the decisional correspondence (direct or indirect) between physical hydrological elements and how these decisions affect the mentioned real-world elements at different levels such as *(i)* in each step of the water supply distribution chain, *(ii)* from the interactions among functions involved in each step of the water transport from the water production data to the final user, *(iii)* from the interplay between currently separated control and optimization systems such as reservoir or hydroelectric plant decision support systems or water treatment and distribution management tools, and *(iv)* from analysis of the impact of water savings on energy savings.

This decisional correspondence between entities of the hydrological cycle is supported by the real-objects situation ("*FeaturesOfInterest*") that gathers hydrological information by an observation-and-measurement process mainly described by "*observations*", "*procedures*", "*phenomena*" and "*results*" (Figure 4). This process representation intent is to align the WatERP ontology with the OGC Observations & Measurements standard for hydrological systems providing easy information access through URIs for each term in the ontology.

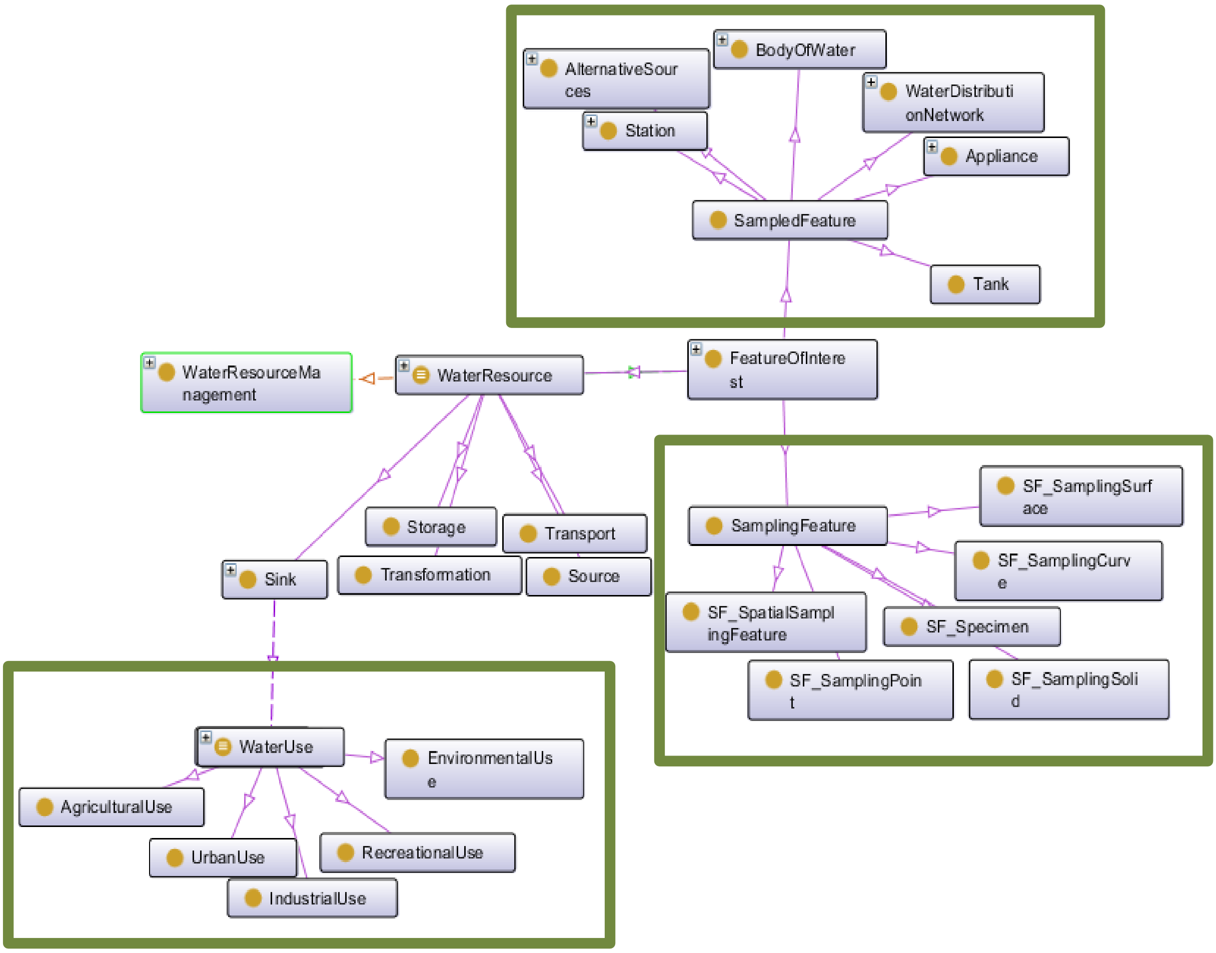

Figure 4 "Matching Supply and Demand Described by the Decision-Making Process with Real Entities"

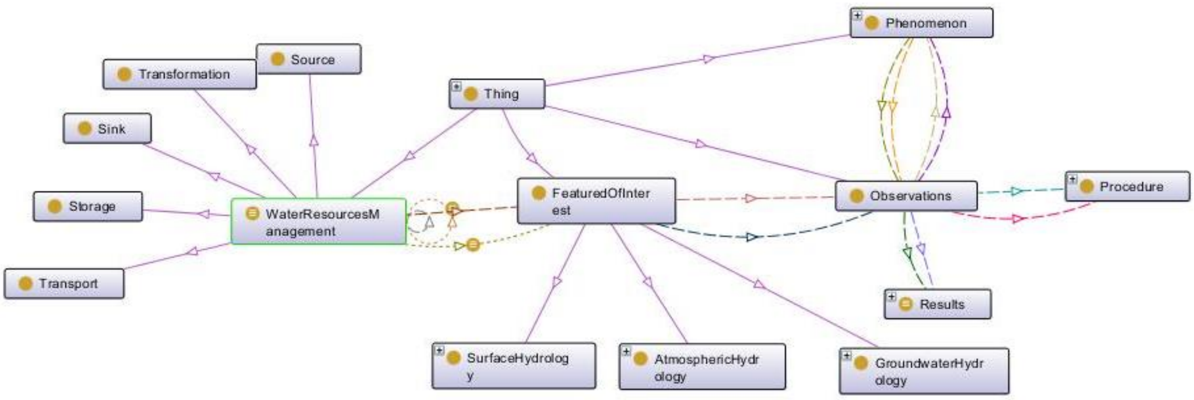

Figure 5 "Observation and Measurement Concept in the WatERP Ontology"

Furthermore, this knowledge representation supports the data-provenance concept by storing and inferring information and knowledge regarding the informational nature for each element of the water-supply distribution chain. Aligned with this concept, the WatERP ontology is able of fusing sensor information with similar nature in a certain region by applying geo-spatial reasoning. The geo-spatial reasoning is implemented by including the Geo-SPARQL ontology inside the WatERP ontology.

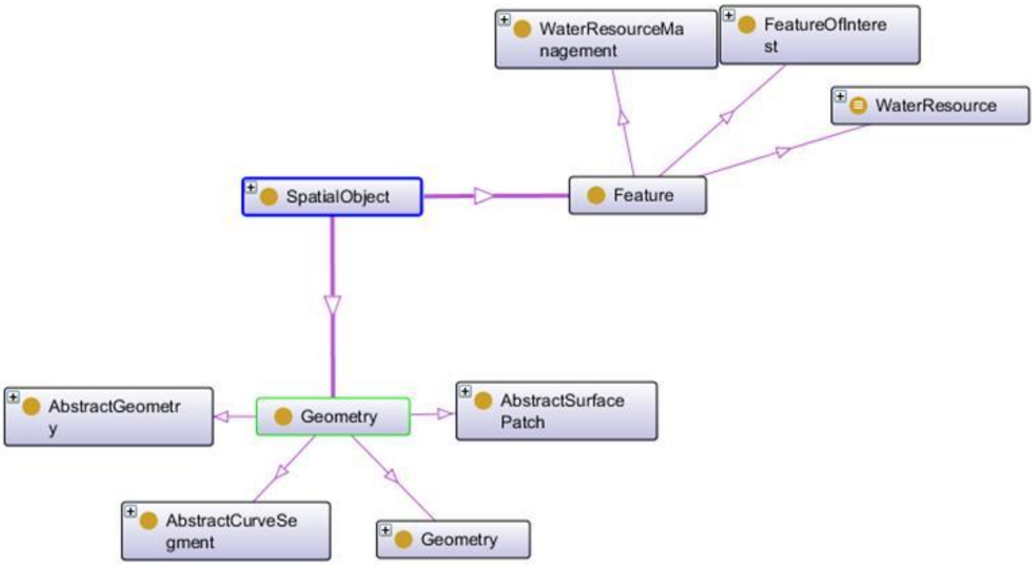

Figure 6 "GeoSPARQL Ontology in WatERP"

The WatERP ontology foresees the representation of alerts and actions in order to semantically depict the outputs generated by decision-support tools that act inside of the water-supply distribution chain under management.

Additionally, the WatERP ontology is able of fusing information from other ontologies by using standard concepts and standard terms provided by trustworthy schemas as WaterML and HY_FEATURES and ontologies such as the NASA, CUAHSI, OGC and World Wide Web Consortium (W3C) ontologies. Moreover, the WatERP ontology has been constructed following the principles of the Linked Open Data Cloud (LODC). LODC permits resources to be accessed by a URI and linked with other elements. From this, ontological information can be integrated and accessed, the terms of different vocabularies can be mapped, and data fusion supported. All of these features contribute to resolve data conflicts by integrating data from different sources into an entity.

So, the WatERP ontology contributes to interoperability by *(i)* the incorporation of standardized concepts into the ontology, *(ii)* the definition of ontological alignments with external representative water-domain ontologies to facilitate knowledge re-usability; *(iii)* the representation of human interactions to support decision-making processes in the water supply distribution chain; *(iv)* easy information access by the use of URIs to represent each ontology term; *(v)* implementation of semantics annotation recommended by OGC and *(vi)* the use of the ontology to support orchestration among services (semantic orchestration using OWL-S).

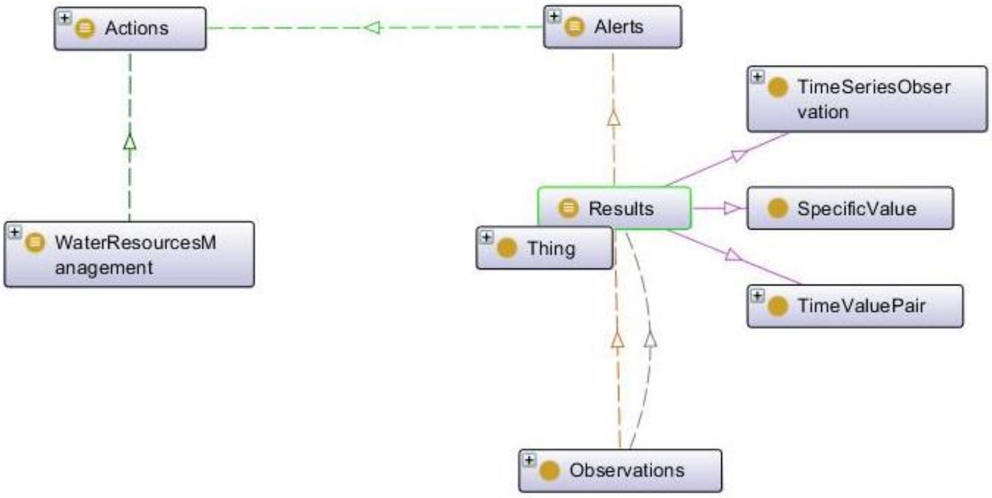

Figure 7 "WatERP Ontology Alerts"

In the context of the OGC HDWG, the HY_FEATURES[1] ontology has been devised in order to define a standard ontology for the water domain. The concept of this ontology is similar to the CUAHSI ontology which models natural paths of the water cycle. Like the CUAHSI ontology, HY_FEATURES has also included chemical, biological and physical aspects in order to depict the interaction of the water path with the environment. The improvements of HY_FEATURES over CUAHSI have been summarized as *(i)* definition of proper semantics relation between hydrologic features (called HY_FEATURE); *(ii)* creation of a mechanism for domain-specific instances (e.g., "*GF_FeaturesType*"); and *(iii)* definition of a meta-data concept inside the ontology (annotation).

Hence, the main reasons for the WatERP ontology to include the HY_FEATURE semantic model were: *(i)* improving the definitions of the WatERP ontology in a way aligned with the current developments in hydrological data exchange and hydrological data representation; *(ii)* sharing knowledge with other hydrological models in order to enhance the hydrological decision-making process; *(iii)* including multidisciplinary information (e.g., biological-chemical-cultural) that can help in making decisions for

[1] HY_Features: a Common Hydrologic Feature Model Discussion Paper

water supply and distribution; and *(iv)* reinforcing an observations and measurements concept fully compatible with the current OGC schemas such as RiverML and WaterML.

The ontological alignment of the WatERP WMO with HY_FEATURES has been performed in two stages.

The first stage was focused on annotating into the WatERP ontology the concepts to be included from HY_FEATURES. Technically, the annotations were defined under the "*alignWithHY_FEATURES*" tag. This tag was applied over the WatERP entities (e.g., "*FeaturesOfInterest*" aligned with "*HY_HydroFeature*") and relations (e.g., "*hasObservation*" aligned with "*observedProperty*").

Once the WatERP ontological resources had been annotated, the second stage was focused on materializing the alignments during the ontological population in order to define internally needed "*owl:equivalentClass*" and/or "*owl:equivalentProperty*" to let the ontology know which classes/properties have the same meaning. Furthermore, the "*owl:sameAs*" has been used to indicate which instances refer to the same individual. Then, in the reasoning and querying stage, the WatERP ontology can merge knowledge from the above mentioned ontologies in order to provide the required information for the water manager by merging external concepts and vocabularies with the WatERP ontology

As general lessons learned one can say that during the development of the WatERP ontology some areas have been identified as possible improvements of HY_FEATURES hydrological representation:

- modeling natural water paths aligned with human-engineered paths (decisional paths) in order to enhance the multi-disciplinary and multi-level management of the hydrological water cycle;
- including geo-spatial reasoning in order to support geo-SPARQL and then, provide a mechanism to fuse hydrological sensor information by region (or similar ones);
- enhancing the HY_FEATURES with the equivalent standard concepts to reinforce data provenance, data sharing and semantic interoperability across platforms that supports semantic sensor web concept; and
- using Linked Data principles in order to facilitate the comprehension and knowledge sharing of hydrological observations with other platforms such as other hydrological systems, DBPedia, Schema.org, etc.

3.3 A Water Data Warehouse Should Combine Conventional Data Management Approaches and Semantically Enriched Mechanisms.

On the one hand, we have seen that "conventional" data management approaches (PostGIS database) are useful and highly efficient for dealing with the time-series data of the O&M model employed in the WaterML2.0 approach. This object-relational database should also be kept in order to be SOS standards-compliant, to stay consistent and interoperable with other SOS infrastructures and to be able to reuse existing SOS technology (like the 52°North developments) as well as upcoming future developments in this area (e.g., using Big Data technologies). On the other hand, for opening up future application scenarios, we need more powerful representation mechanisms offered by semantic technologies which can be the basis for knowledge-based query answering or for publishing data as Linked Open Data. Hence, the WatERP Water Data Warehouse was designed as a hybrid solution combining an object-relational and a semantic storage area (cp. [Abecker et al., 2014]):

Figure 8 sketches the WDW architecture within the overall project context. At the center, we see the two separate storage areas:

- **Mass data** (time series describing sensor measurements about hydrology, network operation, meteorology, etc.) is typically highly repetitive, very simply structured, but coming in large volumes. Large amounts of this kind of data can easily and efficiently be managed with "conventional" database technologies, in our case, an *object-relational storage area* (*PostGIS* database). These data populate a data schema which is based on the structure of the OGC / ISO conceptual model "*Observations and Measurements*" and on OGC *WaterML2.0*, respectively.
- On the other hand, in order to describe all decision-relevant aspects of a water supply chain comprehensively – which might be needed to allow interoperability of formerly isolated systems responsible for specific complex tasks – one might have a need to describe more irregularly structured knowledge, **complex relationships** between objects, definitions of technical terms or interrelationships of them, or generic relationships which abstract away from specific facts (like rule-based knowledge or arithmetic relationships). For expressing such more complex issues, computer science has developed knowledge-representation languages for expert systems which have been consolidated and standardized through "Semantic Web" technologies. In the Semantic Web area, so-called triple stores have been introduced for storing and processing complex knowledge. More recently, *triple stores* have been extended towards geospatial reasoning which allows drawing logical deductions that also include also simple notions of spatial relationships and spatial deductions. For instance, sensors could be geo-referenced and the system could, if appropriately modelled, find all sensors in a given administrative district or in the state which comprises this

district; or all sensors situated on the rivers that a given public authority is responsible for. So, the second main storage area of the WatERP WDW is a triple store enabled to do geospatial reasoning (*OWLIM* triple store with *SesameAPI* together with the *uSeekM* library to add geospatial search functions and geospatial reasoning through the *GeoSPARQL* query mechanism).

All sensor-data and measurement transmissions follow the **OGC SOS protocol** with **WaterML2.0 as data schema**. The internal organization of the mass-data storage also implements a simplified and tailor-made data schema based on the OGC WaterML2.0 data specification. For implementation, we employed the 52°North SOS Server.[2] All data sources are linked to the WDW through SOS – except for the meteorological forecasts where we considered WFS/WFS-T more suited for representing the structure of the data.

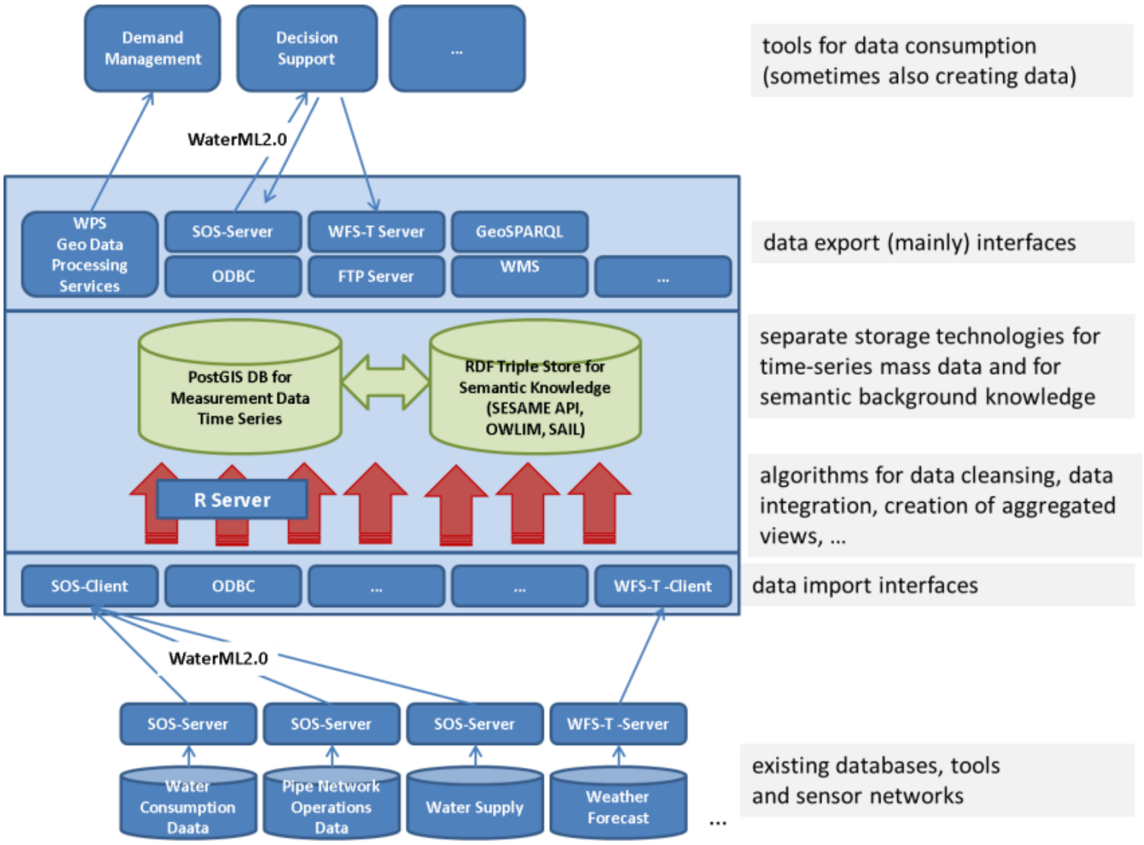

Figure 8 "Simplified Architecture of WatERP Water Data Warehouse"

---

2 http://52north.org/communities/sensorweb/sos/

The incorporation of a semantic knowledge base follows the current trend to empower modern software solutions by knowledge-based components, to increase interoperability through ontologies and to provide data with *Semantic Web* methods according to the *Linked Open Data* paradigm. However, a complete “semantification” (representation, storage and processing of all aspects with Semantic Web methods and tools) of all data in WatERP seemed not feasible and promising to us, especially regarding the measurement data. Instead, the time-series data and the semantic knowledge complement each other and could together be exploited for powerful analyses and queries about the considered water supply system. For instance, the structured relationships in the triple store might be used to logically describe a water-distribution network and its geospatial aspects, as well as some background knowledge, for instance, about measurement methods for assessing water quality. Then, specific water-quality measurements could continuously be fed as time series into the PostGIS database. The metadata for measurements would have references into the knowledge base. This allows making complex queries which combine time-series sensor data and semantic background knowledge. For instance, one could ask for all measurements made in a certain geographic area and using an analytical sensor technology with certain characteristics; or, about all sensor data from a certain point on in the water supply chain which make statements about a certain group of related chemical or biological pollutants. Analysing the answers could help to find upstream dischargers responsible for a contamination and take appropriate counter-measures, or it could help to identify endangered spots further downstream and take suitable protection or purification measures.

It should be noted that, as a side-effect of this architecture, the simultaneous evaluation of quantitative, measurement-data based and qualitative, knowledge-based conditions in *one* query cannot be done within the WDW framework. So, if one would like to find, for example, all sensor observations coming from a certain administrative area (spatial reasoning) and made with a certain type of sensor technology (structural reasoning) which are above a certain threshold (sensor value), this would have to be implemented as a query agent outside the WDW that merges the query results of the SOS sensor-data query and the logic-based query. This is a little bit ugly, but is the price for having some architectural clarity in the overall system layout. Of course, in a post-project exploitation phase of project results, if considered necessary or useful, this kind of queries could also be moved towards the inner area of the WDW if one would plan to commercialize the WDW stand-alone without the WPS/SOA-based agent infrastructure around.

To draw some general conclusions, the OGC SOS protocol with the WaterML2.0 data format together with widespread software modules for its implementation turned out to be a powerful and stable infrastructure in our experience – which can serve many more purposes than the transmission of measurement data only. During the WP3 work, one minor problem of the 52°North SOS Server was discovered which is documented in the WP3 deliverables: If one would try to send as one large package a huge number of observations (> 1 Million) with the full WaterML2.0 metadata, the server would probably crash. But, of course, dividing the database into smaller packages or loading as a CSV file already helps here. The combination of conventional mass-data storage with a triple store for semantic facts about observation metadata allows keeping the strong performance of the former while gaining the expressive and deductive power of the latter. This seems to be an interesting architectural perspective for smoothly extending existing SOS infrastructures towards more semantically enabled solutions.

3.4 In Order to Use SOS Mechanisms for Exchanging and Storing Manifold Kinds of Data One Should Also Provide Automated Support for Integrating Legacy Systems.

The “normal” way of using SOS and WaterML2.0 is that a newly installed sensor network is equipped with data-transmission software which is designed from scratch to follow the SOS paradigm. In WatERP we discovered that many more kinds of data (machine-operation data, water-consumption data, demand-forecast data, planning data, etc.) can be processed following the O&M time-series paradigm even if they are no observational data in the narrower sense. This has the effect that also software systems and databases must be integrated into the architecture that exist already, maintain their own, not O&M or WaterML2.0 based database and have their own interfaces. In order to easily integrate such existing software systems into WatERP infrastructures, WP2 realized the Pilot Integration Manager (PIM) software. Following [Hussein et al., 2015], we shortly describe its approach:

Three steps are considered to integrate existing data from clients namely (1) the data access, (2) the data mapping, and (3) the data export:

(1) Data Access

The first step is to identify the data sources for any particular client which might require:

- Reading the data from a single or multiple databases;
- File parsing;
- Calling web services where format and protocol can highly differ;
- Screen scraping or embedding legacy code into the integration module;
- A mix of the access mechanisms above.

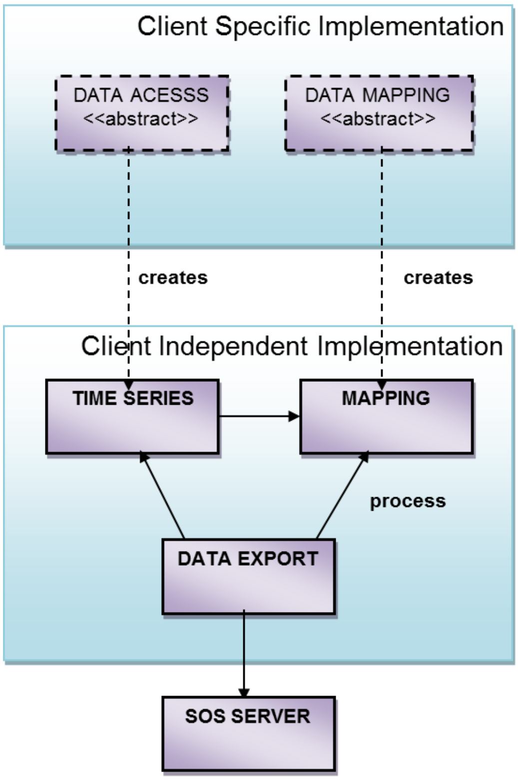

Figure 9"General Module Design of Pilot Integration Manager"

Consequently, the general integration module design must enable the data-access layer to be highly flexible. There is a possibility that interface implementation steps for one client can be used for other clients if they share same infrastructure to make their observation results available.

(2) Data Mapping

The second step is to map client's data with WaterML2.0 applying the following strategies:

- The data required to map WaterML2.0 documents might be available from client data source but it will have to be transformed through the integration manager ;
- If not all the data is provided from client's data sources then the integration manager should provide this data.

The implementation of data mapping depends on the data supplied by the data access module. In consequence, for the general PIM design, the same level of flexibility is required for both data access and data mapping modules.

(3) Data Export

In this final step the data is transformed into a WaterML2.0 document and exported to the SOS server for observations registration and storage. At this point the results of data access and data mapping consist of the same set of information for each client. The generation of WaterML2.0 as it is based on data mapping and interaction with SOS server is identical for each client. Unlike data access and mapping which are highly client-dependent modules, data export is independent of the client's specific implementation.

Figure 10 shows the general module design of the PIM. Data access and data mapping are abstract but have to populate the time series and mapping information using a predefined structure. The data export which consumes the data is independent of the actual client context as the client specifics have no influence on the export processing.

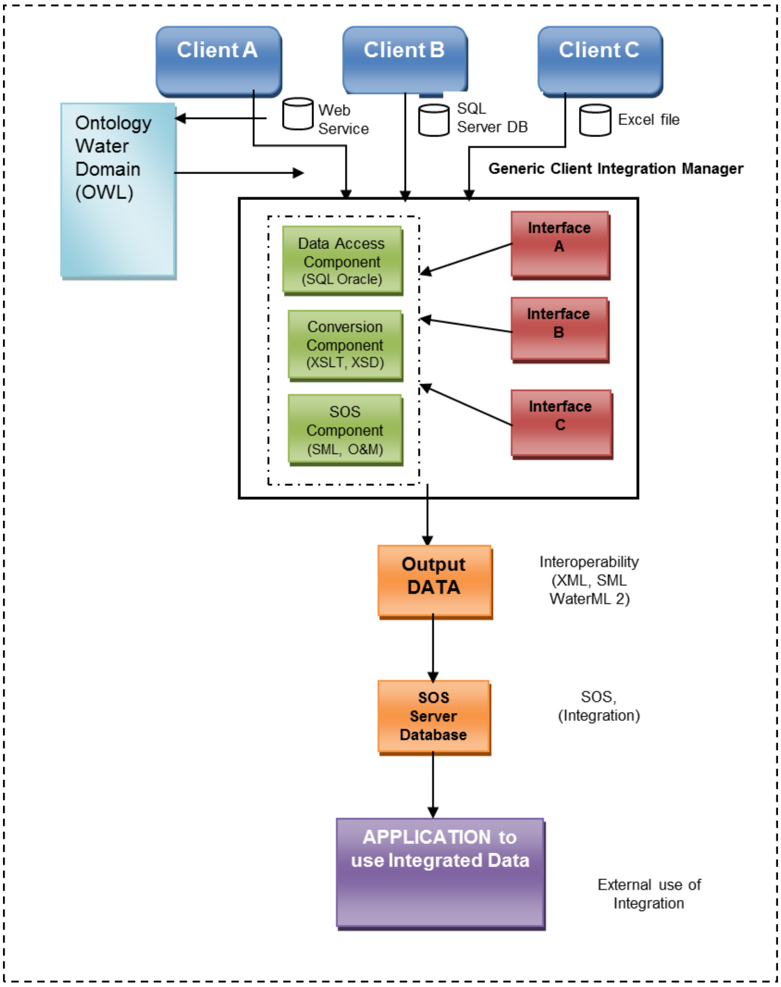

Figure 10 "Generic Integration Framework"

Figure 10 illustrates the implementation of the generic integration framework. The clients provide their data in the form of a Database, Excel file or Web Service etc. An ontology is built for each client data using software such as Protégé to map client's terminology and develop the knowledge base. The framework consists of a generic Client Integration Manager Application which is the heart of the framework. Each of its components performs a specific task. The Database component deals with the reading and manipulating of data from the data source, XSLT and XSD components are responsible for providing stylesheets and schema files, respectively, to conversion components to transform data into required formats. The SOS component generates files to register sensors and insert observations into the SOS server. These components are based on some common reusable code base, but do contain own processes. Each client has an interface to use these components according to the requirements. Each interface has its own data access and conversion components. The integration manager uses the ontology in the conversion component to overcome semantic heterogeneity. This way in case of an update in data format or data resource at any client side will make necessary an update in that client's interface only. For each client XML data files are generated in the form of WaterML2.0, SML and O&M which goes into the SOS server database. These provide means of interoperability and can be used by any application in the water distribution chain. The framework should be easy to maintain in order to include new procedures or new concepts when a client's new needs emerge or new client participates in the framework. A change at one client site should not affect other client sites. Ontologies should be clarified and understandable by all clients.

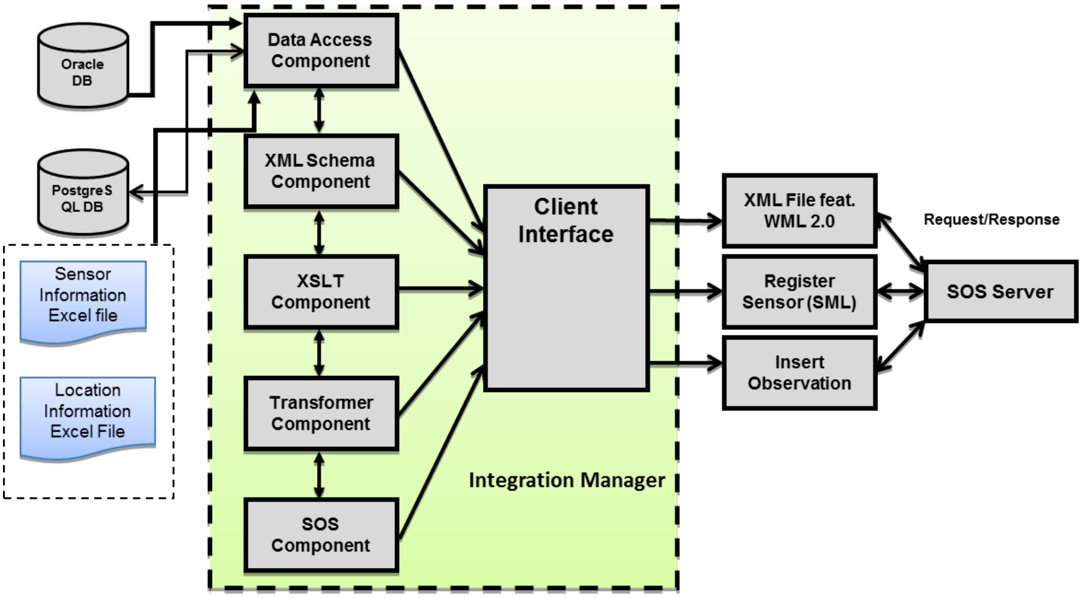

Figure 11 "Example Client's Integration through the Framework"

The application and instantiation of the generic integration framework for a specific client is explained in the following (Figure 11):

Data Access

The Client has time-series data in an Oracle Database and sensor information and location data in Excel sheets. The data-access component of the integration manager takes the sensor and location data from the Excel sheets and stores them inside the PostGreSQL database. A PostgreSQL database is used because it allows the PostGIS extension which is used to store spatial data. In the next step the data-access component retrieves the sensor data from the PostGreSQL database and matches the, with the time-series data from the Oracle database.

Data Mapping

The XML schema Component works with the data-access component through the client interface for data mapping. When data is mapped the XSLT wrapper works with the Transformer component through an interface layer to transform the data into the required standardized document.

Data Export

In the last step, the interface layer uses the SOS component to export data mainly in three forms: 1) a WaterML2.0 document to insert time-series data; 2) Register Sensor request in the form of SML to register sensor; 3) Insert Observation document in the form of O&M to insert observational data. The exported data is transferred through the interface layer with the help of the SOS component to the SOS server.

To conclude, the description above should have given an impression how one can implement automated support for integrating legacy data into the WatERP SOS-based environment. Of course, many steps will always remain application–specific and must be done manually. Nevertheless, the framework gives some guidance and reusable code. There are also the counterparts implemented in the WDW infrastructure which will then easily import the created data, create new sensors in the sensor database and create the semantic objects for representing observation metadata. Altogether, the Pilot Integration Manager is a useful tool to complete a fully SOS-based WatERP architecture and couple existing software solutions to it.

4. Conclusions and Next Steps

Acknowledging the fact that the impact of a project like WatERP which is to a huge extent about enabling and fostering software system interoperability, can be increased by far by leveraging and further developing widespread water-data standards, it was decided to coordinate the project's standards-related activities centrally and first make an activities plan and then continuously measure against this plan the project progress and the project success in terms of standards-impact.

In a first analysis phase it turned out the most important and most promising area for WatERP to become active is the OGC water-data exchange standard WaterML2.0 as a content model together with OGC SOS plus related services like OGC WFS/WFS-T and OGC WPS as a communication protocol.

The deliverable D2.2 presented the WatERP activities plan for work on standards which contains activities in four main areas. In this deliverable D2.7, status and results of these planned activities have been reviewed six months before the end of the project. Following the four activity areas defined in D2.2., the results can be summarized as follows:

(i) **Preliminary steps and decisions** have been fully completed, mainly corroborating and refining the ideas already foreseen at the time of writing D2.2. Referring water-standards, the pilot analysis demonstrate existent heterogeneity in the water domain where ACA is based on standards such as OGC WFS and OGC WMS to geodata access and presentation as well as WaterOneFlow to publish observations and WaterML1.0 as data exchange format. Instead, Instead, SWKA is based on no standard solutions. On the other hand, the analysis of the state-of-the-art in water standards allows to know where the market is headed which is focused on OGC standards. Finally, these results together with ideas how OGC standards should to be used in the WatERP project, were presented in a project-internal workshop

(ii) **Standards-based project design and implementation** has practically been completed successfully. The only still open point (at the time of writing this report) is the finalization of all reflection processes about the remaining months of piloting and pilot evaluations that may lead to final insights to be communicated in the final review, the final reports and/or the final whitepapers, documents, and communications to the OGC. The most remarkable conclusions and highlights referring this step are:

- Extensive uses of standards based on the OGC stack were applied in the WatERP architecture.
- Pilot implementations based on OGC standards were realized that show how to integrate legacy systems.
- Current OGC standards were enhanced with semantic technologies in order to increase their potential and cover not only syntactic interoperability.

- The development of hybrid storage solutions showed how object-relational mechanisms can be empowered by semantic technologies.
- A semantic representation of WaterML2 concepts was developed.
- A semantic representation of human water-management decisions was developed.
- A semantic representation of man-made water management infrastructures was developed.
- A MAS responsible for orchestrating OGC WPS services is the basis for creating a hybrid and flexible service-oriented architecture (SOA-MAS).

(iii) **Communications with OGC:** the contact to the OGC standardization communities has been established, in particular to the Hydrology Domain Working Group working on WaterML2.0 and the HY_FEATURES ontology. Moreover, these contacts with the OGC have enabled the WatERP project participating in several OGC acts such as: (i) OGC Technical Committee Meeting in Genova; (ii) “Standardization of Water Data Exchange: WaterML2.0 and Beyond” workshop in New York; (iii) Interoperability Day in Barcelona. Finally, referring the established contacts, WatERP project partners have been invited to take part in the definition of the future standard HY_FEATURES. In contrast to the original plan, the idea of running and documenting an OGC Interoperability Experiment based on the two WatERP pilots has been given up, due to practical (timing) and principled (OGC working and organization structures) reasons. The remaining open task for the last six project months is the creation of an OGC discussion paper about the project approach and results.

(iv) **Communications to the general public:** The WatERP approach and intermediate results have already been widely disseminated, to academic audiences and to practitioners. In the last project semester, this work will be finalized by writing a comprehensive WatERP whitepaper on standards and by a public workshop on standards-related project results.

The major lessons learned from the WatERP implementation have been summarized in the design decisions and software developments explained in the different Subsections of Section 3:

- Service-oriented Architectures based on OGC WPS Should be Extended by Semantics-Aware Mechanisms for Service Identification and Orchestration.
- The WaterML2.0 Data Model Should be Semantically Enriched and Extended Towards More Comprehensive Coverage of the Water Management Domain.
- A Water Data Warehouse Should Combine Conventional Data Management Approaches and Semantically Enriched Mechanisms.
- In Order to Use SOS Mechanisms for Exchanging and Storing Manifold Kinds of Data One Should Also Provide Automated Support for Integrating Legacy Systems.

Much more detail on the concrete technical achievements behind these lessons learned can be found in the respective deliverables of workpackages WP1, WP2, and WP3.

Summing up, we can say that the WatERP results considerably extend and renovate the OGC approaches in many relevant and innovative directions. This has been communicated to many interested parties and found much interest, by practitioners and academics. We are sure that this will have concrete impact on the OGC standards and the ways how to use them in the water management practice in the near and mid-term future.

Nevertheless, many discussions with practitioners and technical people from the water management area also showed that such technological further developments may be *necessary* for achieving interoperability in the water sector, but that they are by far not *sufficient*. First, it should be noted that technical means for interoperability are only a technological tool – but to achieve that a technological tool is also used in practice, one needs to establish a non-technological incentive systems which makes the tool application useful or unavoidable, e.g., because of economic or regulatory reasons. Without concrete such incentives, tools like the WatERP developments will by far not achieve the impact they could achieve in principle. Second, it turned out that from the perspective of geodata and hydrological/hydrographic data exchange, settling upon OGC standards completely made sense. However, in the area of water utilities, OGC is still very seldom used. In order to become more important there, one would have to close the gap to commercial de facto standards from machine-control software providers (like Siemens), maybe to commercial sensor suppliers, or maybe even to data-exchange standards for economic data (ERP data, SCADA). Lastly, it should be noted that since a couple of years the EC asks its member states to implement the INSPIRE directive which also includes data models about the water sector. For the utilities, this had practically no impact yet on their daily work. But if one would really try to seriously implement INSPIRE in the water sector, this would also have to be aligned with the WatERP Water Management Ontology.

5. References

A. Abecker, T. Brauer, B. Magoutas, G. Mentzas, N. Papageorgiou, M. Quenzer (2014): A Sensor and Semantic Data Warehouse for Integrated Water Resource Management. In: Proceedings of the 28th EnviroInfo 2014 Conference, Oldenburg, Germany, September 10-12, 2014.

G. Anzaldi (2014): WatERP Ontology Summary & HY-FEATURES Relation. WatERP internal discussion paper. Barcelona, July 2014.

G. Anzaldi, W. Wu, A. Abecker, E. Rubión, A. Corchero, A. Hussain, M. Quenzer (2014): Integration of Water Supply Distribution Systems By Using Interoperable Standards to Make effective Decisions. In: 11th International Conference on Hydroinformatics - HIC 2014, New York City, USA.

A. Hussein, W. Wu et al. (2015): A Generic Framework to Integrate Water Supply Distribution Systems Using Interoperable Standards. In: E-proceedings of the 36th IAHR World Congress, 28 June – 3 July, 2015, The Hague, the Netherlands.