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Time Series Management for Operational River Basin Management

TIME SERIES MANAGEMENT FOR OPERATIONAL RIVER BASIN MANAGEMENT

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ABSTRACT

The core objective of the hydrological KISTERS TSM (time-series management) suite is to manage data which is highly variable in time for river basin management (e.g. river stage and flow, climate parameters, water quality and tidal stage) in a central database. Based on the integrated data structures of the TSM suite, a variety of key functions are available. Those are automatic data collection from remote sites via telemetry or IP-based protocols, time-series graphs with sophisticated data editing and quality control tools, statistical and analysis tools, reporting and dissemination tools for electronic and paper publishing. With the automatic background time-series calculation service, an open API, the KISTERSDataProvider for external data access, and a powerful scripting language, data of the highest quality is always available. These automated processes can enable the combination with hydrological models for forecasting flooding or managing dam sites. The KISTERS TSM based hydrological information System WISKI is running successfully at hundreds of customer sites in Europe, the USA, Canada, China, and Japan with varying amounts of measuring sites (less than 5 to more than 50000).

Keywords: TSM, WISKI, SOFINET WATER, GIS, integrated water management, monitoring system, database, time series

1. KISTERS TSM (TIME SERIES MANAGEMENT)

In many technical and commercial software systems, it is necessary to acquire, process and archive mass data in the form of time series. In addition to many specialist technical aspects, rapid processing and quick data access are of the utmost importance. These demands call for specific software solutions, which up until now were typically developed independently for each application

The KISTERS TSM system is the new shared system core of all KISTERS products where time series are involved. It represents the business layer of a 3-layer architecture, and provides all services necessary for time series management and calculation to applications built upon it.

Data acquisition and integration

In order to support a more integrated approach to water management, a modern hydrological information system has to acquire and store all types of data from a wide range of parameters. Not only the commonly used parameters such as water stage and discharge, but also, for example climate parameters to allow analysis within the same system.

Typical data input sources are remote data acquisition from field data loggers, import of third party data via input files in different formats, read out of field devices, digitisation from graphical charts or manual input using the interactive time series editor.

The import process should be automated as much as possible to free staff resources from manually entering data. The WISKI data acquisition server allows the automatic collection of data from field data loggers. The Import Server can scan directories and import data files, which are saved via the TSM layer into the database. When the user digitises graphical charts, the digitised data is imported automatically afterwards, without user intervention.

Data storage

Due to the complexity of data modelling, WISKI stores data in relational database systems (RDBMS). The storage of recorded or calculated time series data is managed by the central TSM. Additional station information available and other meta data are stored in a separate sub-model. As historical data plays a fundamental role in hydrology, one of the greatest challenges is to achieve a high level of performance when dealing with large amounts of measured data; this is a key objective of the developers. Another fundamental aspect is to allow multiple users to work on the same system simultaneously. They can benefit from working on the same data whilst also preventing users from editing the same data at the same time. The TSM data model was developed to deal with large amounts of recorded data. Therefore it has all the necessary functionality to manage time series on such a level. Another important topic is time series classification. One of the major differences found, is the distinction between equidistant data (e.g. 15minute water stage values) and non-equidistant data (e.g. rainfall event data).

Data validation

Identifying abnormalities in the data is normally the first step of the validation process. As a result of malfunctioning of field sensors and other devices, or due to the maintenance of those devices, recorded data is likely to have a range of different quality that has to be corrected. To help the user locate data of poor quality, KISTERS TSM has auto validation routines. These routines can be used to apply the organizations' business rules to validate the data using predefined criteria and place remarks for user notification each time one of the criteria is violated. Examples of these quality controls are identification of gaps, maximum/minimum exceedance of thresholds, variations from to neighbouring stations or other user defined formulas and rules.

2. THE WISKI SOFTWARE PACKAGE

Data processing

The stored data can be accessed through the graphical user interface (GUI) of the WISKI hydrological workbench (Figure 1). The WISKI workbench client is developed for MS-Windows platforms. Therefore, WISKI has a modern interactive graphical time series editor, to allow graphical editing of time series.

Following the data flow through the system, WISKI is able to deliver the following processes and functionalities.

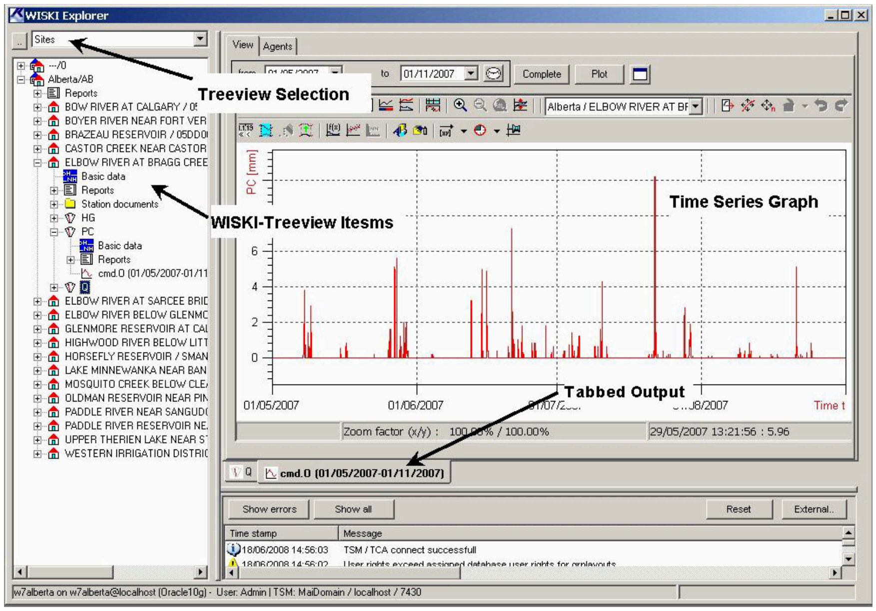

Figure 1: Graphical user interface of WISKI 7 software

Data manipulation

For editing purposes, WISKI provides efficient data editing functionality using an interactive graph or table to allow graphical editing using the computer mouse and keyboard. Examples of functions and methods to correct errors in time series are the filling of gaps with interactive linear or spline interpolation, adjusted data from neighbouring stations or regressions or e.g. vertical or horizontal stretching of the trace.

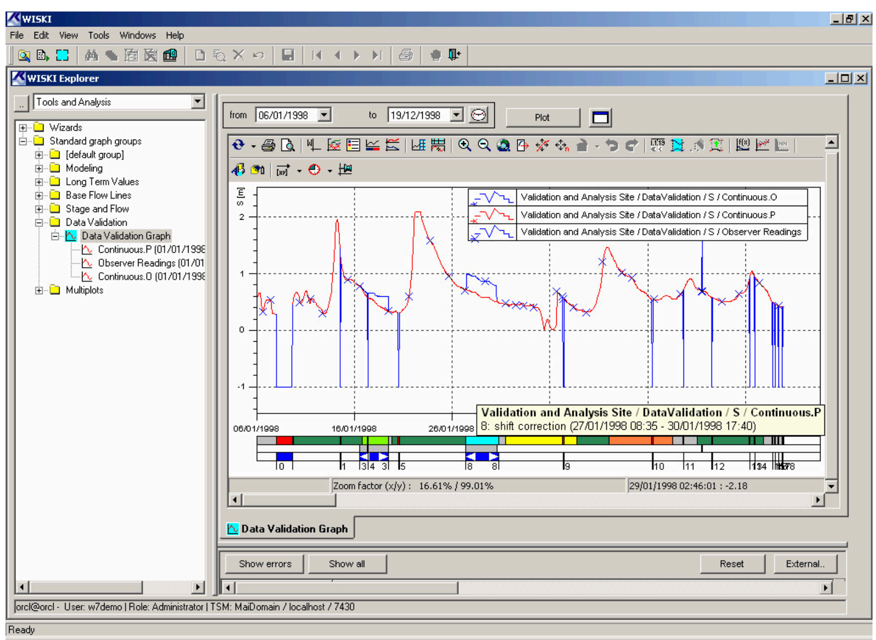

Figure 2: Interactive Data Editing in the WISKI Graph

WISKI allows 255 user-defined data quality flags to be assigned to each data value. This will identify the primary quality for example Good, Suspect, Estimated, Unchecked, Missing; ….,.. Standard remarks from a pick list and free text comments added by users can be used provide additional information about the data (figure 2).

WISKI keeps a record of who changed the data, for which period and automatically records the name of the method applied for the predefined editing functions listed above. The original data is not edited; instead a "production" time series is defined which stores a copy of the original values, which can be viewed, edited, and validated.

Working within a multi-user environment also implies being able to regulate access to the data by defining roles with corresponding access rights. This allows the hierarchy of the organization to be represented by the information system.

Derived and summary values

While validation takes place on high resolution time series, WISKI calculates the derived summary time series for further analysis and dissemination. The daily, monthly and yearly values are derived from the high resolution time series and are calculated automatically. In combination with built in reports, the user can rapidly generate these reports without exporting data to external publishing software. An internal mechanism ensures that each time the underlying high resolution time series are modified, the derived summary time series are updated automatically. This mechanism, prevents a user from publishing or exporting out of date data, and prevents them from having to keep a record of when to update derived time series.

Rating curves and data analysis

WISKI has a fully integrated rating curve editor. Based on flow measurements, and other filed collected data rating curves can be managed without having to leave the main application. Following validation of the stage data all necessary functionality is available to perform the complex task of defining the water stage/flow relationship of a river. The flow is calculated automatically, or can be triggered by opening the corresponding time series in a graph or table.

For the advanced analysis of recorded data, WISKI offers statistical analysis tools such as linear and non-linear regression analysis, statistical analysis of durations, flood and low flow frequencies, double mass plots, rain storm frequency analysis. The WISKI statistical analysis tools were developed in close collaboration with hydrologists, and are based on national and international standards, such as the United States Geological Survey, the World Meteorological Organization and ISO standards.

Data dissemination

WISKI has an open data model based on the core TSM/WISKI model. The user can add attributes and objects as required by his organisational structures and workflows. A generic C++ & Java-APIs for report generation, external data access or model integration is integrated into WISKI software. This API has the same flexibility and security in data access as the software itself.

Additionally, the easy to learn WISKI scripting language KiBasic brings flexibility to the user to add their own calculations, queries, reports, or exports into the system and interface to Excel or other software products.

WISKI standard reports, written in KiBasic, can be adopted easily to an organization's reporting requirements. Today, the Internet has become one of the key gateways for exchanging information. For this purpose a web module has been developed for WISKI for disseminating data on the Internet/Intranet using a web browser as a GUI. Moreover, WISKI supports fully automated services such as the sending of data files via FTP (file transfer protocol) or email.

Mapping and GIS integration

The display of spatially referenced information is made in several ways – following the different objectives required by the user:

- The WISKI Web provides browser based access to the data and shows maps with station locations. (Figure 3).
- Data can be published based on services like WaterOneFlow, WFS, WMS, and Oracle Spatial and may be used in all applications using this protocols
- The WISKI-ArcGIS extension retrieves information from the database and integrates it into the ArcGIS session; subsequently the whole range of ArcGIS-functionality (e.g. mapping, selections, classifications, exports…) is available (see Figure 4)
- Simple maps can be shown in the WISKI client software for navigation purposes

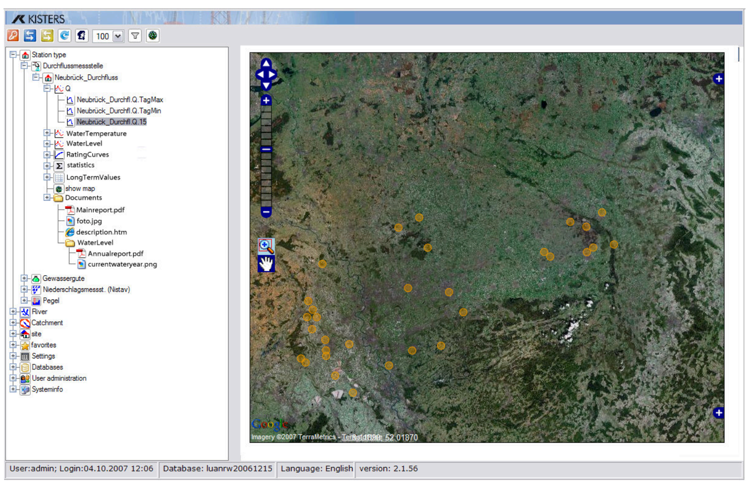

Figure 3: browser based access via WISKI Web

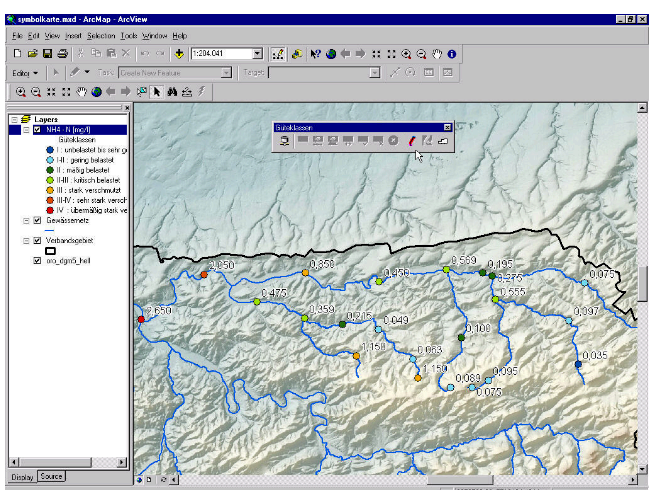

Figure 4: higher level mapping via ArcGIS Extension

3. CASE STUDY

Flood Warning Centre of Saxony-Anhalt, Germany (HVZ)

As a consequence of the flood disaster in August 2002, the German state Saxony-Anhalt decided to unitise and optimise the activities from Flood Control Centre (HWMZ) and the State Office for Flood Protection and Water Management (LHW) by combining them to form a modern Flood Warning Centre (HVZ).

The main requirements of the project have been the meta data management, forecast and scenario management, data publication, complete data management, complete redundancy, open XML based interfaces between all modules, real-time data exchange with external data. The Flood Warning Centre is divided into several areas with different functions.

Data acquisition and time series data management

A fundamental contribution to the total information management of the Flood Warning Centre is made by the observed stage, discharge and precipitation data. It is not only the data measured by the LHW Saxony-Anhalt itself which flows into the system; there is also data coming from the national river authority, the reservoir operators, the neighbouring countries and the groundwater measuring network. Data, forecasts and warning messages of the German Federal Weather Service (DWD) are also received.

Control Centre

The head office of the new control centre is in Magdeburg. Here, the Control Unit is the central communication point which retrieves and collects the observed data, weather reports and other information which might be flood-relevant. It receives flood alarms from the gauge stations as well as storm warnings and is responsible for alarming the relevant authorities and the Forecast Unit. Core component is the KISTERS HVZ-monitor, which assists the operation team as a web application in the intranet. This application clearly displays each data in- and outlet in real-time. Documents will be filtered through and taken on into the system.

The Forecast Unit creates stage forecasts based on the input data and information coming from the Control Unit. A Central Operation Team continuously analyses the flood situation. It is responsible for the coordination of the flood protection measures and prepares the flood bulletins which are published, among others, via the public platform.

The Media Publishing Unit produces its own video films, graphics and charts and additionally, it takes over productions from third parties, evaluates, processes, manages and archives them. The results of these activities can be published via the public platform.

Implementation

The functional structure described above is realized through the appropriate distribution of services within the network structure in the Flood Warning Centre. The whole data transfer between the authorities inside and outside the country happens within the TESTA-Network (Trans-European Services for Telematics between Administrations). This network was created as an enclosed network for data transfer between European national organizational units. The benefit of this is, the use of common Internet technologies, without accepting their pitfalls.

KISTERS provided the Time Series Data Management including remote call processes and communication lines for the online collection of hydrological and meteorological data, and the Control Centre itself. Additional data arrived in the HVZ-Control Centre by email as well as active and passive FTP-connections. Messages from gauge observers can be fully automatically taken over into the system by mobile phone and DTMF-entries. Also the entry over telephone answering machine with appended manual input mask is possible.

The information is distributed and monitored via the input monitor of the Control Unit in the Control Centre of the HVZ. The monitor is automatically and continuously updated via the Web application.

The Public Platform, installed as a web portal, is divided into the area of the public Internet with its own http address that can be reached directly or from the state portal for environmental information. The state's administration wide Intranet, corresponding to the extended public Internet presentation, but only accessible with a specific user account, in which the users can define and administer their own personal views and the HVZ internal Intranet that can be reached only by means of a user ID and only within the network of the Flood Warning Centre. The main difference between these areas is the amount of data (stations and observed data) and the additional functions offered to the users.

The HVZ flood warning centre is fully operative since 2002.

Flood Warning Centre of the DDE Dordogne, France

DDE Dordogne is a regional office of the French transportation ministry and for over 40 years has been assuming the role of flood centre for the Dordogne basin. Due to a recent reorganisation, it is now one of the 22 French flood centres. Its responsibility is to inform and to alert public organisations on flooding situations. They issue a bulletin twice a day to complete a national flood vigilance map. The Dordogne catchment is 25000 km² with 5 main sub catchments and is faced with high and medium floods. Approximately 60 stations equipped with both, a rain and a water stage gauge, are providing the data.

The acquisition is renewed by the standard hydrological telemetry system SODA operating the digital radio network. The new alarm management operates on the KISTERS WISKI alarm module, and the visualisation of hydrological and technical information is carried out Web-based in quasi real-time. All data are stored in one Oracle database. The data is dissemination to third parties like the central French flood control centre SCHAPI is scheduled not event driven. All systems run on dedicated hardware with redundant servers. Beside these core functionalities the project also includes digitising the hydrological archive (water stage + rainfall data from 1963 to today).

Data acquisition, alarm management and synoptic

The radio network has now moved to a digital network with the automatic selection of a route when a problem or failure occurs. The acquisition of hydrological and technical data is very fast, as is the management of the incoming raw data by the WISKI Alarm Manager that compare data to thresholds or to "on the fly" calculated values like flow data from stage. The preferred way to alert the operators on duty is the voice message (but not SMS). Cascading calls ensure that the alarm reaches a recipient.

The synoptic system overview is elaborated via a Web interface and it allows a quick view on the hydrological and technical situation in the catchments. Evaluation of the technical situation of the network is essential to ensure complete operation of the system.

Implementation

The WISKI system is integrated with the forecast models, the vigilance software, the hydrological server, and other related products. Every interface can be accessed directly on site or by remote access. The whole process to disseminate reports and data to third parties is fully automated. Historical data and current data are stored in one common database. Statistics can be efficiently performed to characterize flood events. Data management on hydrological data is of benefit to complete the analysis on a flooding situation. The adequate hardware was part of the project to offer a global system warranty.

The DDE flood warning centre became fully actively in 2006.

Hydrometric archive replacement project, England

The Environment Agency of England and Wales is the leading public body protecting and improving the environment in England and Wales. The Agency operates a network of hydrometric sites that measure and record river, tidal and groundwater levels, river flows, rainfall and other climate data. There are nearly 2900 permanent flow gauging and water level sites, over 6500 groundwater level monitoring sites and 4300 manual and automatic rain gauges. In addition there are historic archive records for all types of sites that are no longer used to provide current hydrometric information but are important historical records.

The Agency was using a number of third party products and Agency bespoke legacy systems to provide the previous archive functionality. They were running under MS DOS and Windows operating systems. The core part of the archive had been in use for up to ten years. There were over 500 users across the Agency, of those about 250 were ’main users’ requiring full access to the system.

The legacy archive systems required significant manual intervention, and were expensive to maintain. Archives were maintained locally at eight regional and twenty-six area offices that do not provide access to data to Agency staff based in other locations.

In May 2000 the Agency set up a project to replace the legacy systems, the guidelines for the project were to:

- Procure a Commercial-Off-The-Shelf (COTS) package, with the understanding that an element of bespoke development may be required that should not exceed more than 50% of the final product
- Maintain existing functionality and allow the development of new functionality to meet changing business needs
- Procure a next generation product that will provide a single consistent national archive that is consistent with the Agency’s IS/IT Strategy

Implementation

WISKI has been implemented as a National Database hosted at the Agency’s Host Data Centre in Leeds in 2002. The database is on a multi-processor Oracle “N” Class Server. This is connected to a shared storage area that holds the data. Citrix MetaFrame XP is being used as the operating system for WISKI; this sits on a server farm at the Host Data Centre currently. The Citrix server farm consists of 22 servers that can support 300 concurrent users. The Host Data Centre and Agency offices are connected through a Wide Area Network (WAN) . The implementation of WISKI across the Agency was organised as a staged process to ensure that each region had access to suitable training resources, time to address any problems during implementation, become familiar with WISKI before it became operational and reduce the risk of aborting implementation.

Migration of data from the Agency legacy system to the WISKI database was a significant part of the implementation with over 40 staff involved migrating and validating 143 archives. One of the biggest risks to the Agency was the permanent loss of data during the migration process that cannot be recovered.

WISKI, as the central hydrometric archive of England and Wales is operational and has been in production since 2005. Northern Ireland (since 1999) and Scotland (2007) host their own WISKI-based solutions.

Grand Canal Project, China

The Grand Canal of China, known as the Peking-Hangzhou Grand Canal is the longest ancient canal or artificial river in the world. It passes through the cities of Beijing and Tianjin and the provinces. The length of the Grand Canal is about 1770 km. Its greatest height is reached in the mountains of Shandong, at a summit of about 42 m. The focus area of the project is at the southern end of the Grand Canal which is located closed to Hangzhou, capital of Zhejiang Province and one of China's seven ancient national capitals.

The General Hydrological Station of Hangzhou (GHS of Hangzhou) received a project in 2006, through which it should be possible, to obtain the flow values immediately (e.g.: within one minute). Since the Grand Canal in Hangzhou is tidally influenced, the relationship is very complicated. GHS of Hangzhou wanted to use ADCP to measure the velocity of the flow and store it every three minutes. But how can the velocity be converted into flow?

GHS of Hangzhou has the data of water level, which is stored on a one-hourly time grid. This data is converted to a three minute time level in WISKI. After that flow is calculated based on data from ADCP and converted water level in WISKI.

Moreover, the amount of water, daily, monthly report etc. are also accomplished at the same time.

Data acquisition and implementation

The sensors by Sontec that measures water level and flow from six monitoring points send data through SODA into WISKI.

Teganuma project, Japan

This project has been forwarded by Tokyo University and a consortium including Nippon Software Knowledge Corp (NSK) and KISTERS as a pilot project. Teganuma-lake which is located north east of Tokyo was one of the most polluted lakes/marshes in Japan for more than 20 years because of domestic wastewater. Various investigations, researche projects and measurements by public authorities and researchers were done and water quality in the Teganuma-lake had somewhat improved. However, recently the rate of this improvement has slowed down because of increasing population in this basin. Therefore, Professor Guangwei, Tokyo University, proposed an online monitoring system to understand the fundamental mechanism of water pollution of the lake.

The project was processed as follows:

- Assessment and combination of existing monitoring programs
- Improvement and standardization of monitoring programs
- Shared management of water quantity and quality data
- Combined water quantity and quality data analysis
- Assessment and improvement of water body status
- Presentation of results

For this project, three workshops have been already taken place at the Tokyo University and various public authorities, organisations and inhabitants were invited.

Data Acquisition and implementation

An integrated system which consists of SOFINET WATER by NSK and WISKI Water Quality module (WQM) by KISTERS was chosen for the project. SOFINET WATER is a SCADA system experienced with more than 700 water plants for 18 years in Japan. WQM is an established software package which is already applied in many present member states of the European community.

Professor Guangwei selected the most effective monitoring point based on past measured data and his statistics method and a sensor from YSI/Nanotech Inc. is set to measure 9 water quality parameters: DO, pH, ORP, turbidity, Chlorophyll, temperature, conductivity, salt, T-N. This measured data is initially sent to SOFINET WATER every hour, and the data format is configured and then formatted data is imported in WISKI. This architecture makes the database tolerant to various accidents because data are saved in both of the databases of SOFINET WATER and WISKI. When one database has problem, the database can be recovered from the other database.

GIS and web function, which enables various stakeholders to browse the database and to input further data, will be integrated in the future.

4. SUMMARY

The five case studies from Germany, France, England, China and Japan were presented in this paper. The focus point for each case study was different, however, there are five following common focus points:

- Central data management with a total system from data logger to reports
- Realisation of automatic working process and data management
- Requirement of a real time monitoring system
- Easy to use but including special functions of water management
- User friendly interface

The KISTERS TSM based hydrological information System WISKI has adequately fulfilled these requirements. WISKI was developed continuously through various projects in different countries.

The WISKI system should provide a reliable and flexible archive enabling a central, consolidated source of information. It can provide a modern software platform with sufficient flexibility to encompass future business change and data demands. Its implementation within different authorities reduces costs for support and maintenance, frees up staff resources to improve data quality, undertake more comprehensive analysis and to convert data into information for managing the environment.

On all levels of data quality assurance, WISKI provides ideas, strategies or tools to increase the quality of the data and information. However, due to the never ending process of increasing quality, continuous discussion on this topic is needed.

ACKNOWLEDGMENTS

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