Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
Governments of Botswana, Lesotho, Namibia and South Africa

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Hydro-meteorological Monitoring in the Orange-Senqu River Basin, Data and Information Sharing

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Contents

1. Background

The Orange-Senqu River basin is one of the larger river basins in southern Africa. The basin is regulated by some 30 large dams and includes several larger inter- and intra-basin water transfers. Extensive water utilisation for urban, industrial and agricultural purposes has significantly reduced natural flow, to the extent that the current flow reaching the river mouth is in the order of half of the natural flow. Future basin management in the Orange-Senqu River basin has to balance these competing water uses, and deal with increasing rates of human-induced change and the mounting concerns about the causes and consequences of this change. Differences in legal frameworks, historical backgrounds and technical capabilities of the four Basin States Botswana, Lesotho, Namibia and South Africa add to the complexity. The four basin states are strongly committed to a joint, basin-wide approach to addressing threats to the shared water resources. This led to the Agreement on the Establishment of the Orange-Senqu River Commission in 2000 (ORASECOM).

The UNDP-GEF Orange-Senqu Strategic Action Programme supporting ORASECOM compiled a Trans-boundary Diagnostic Analysis Report (TDA) of the basin. The TDA charts the main environmental threats to the basin and ascertains their root causes. The report serves as the scientific basis for a basin-wide Strategic Action Programme (SAP) and related National Action Plans (NAPs) in the four basin state. The SAP is a negotiated basin-wide planning document that provides a basin-wide framework for the implementation of a prioritised set of national and joint trans-boundary actions and investments to address water-related environmental problems in the basin. The core of the SAP and the NAPs is a portfolio of projects that are envisaged to be implemented over the coming five to ten years following the adoption of the SAP by the basin states.

This technical paper describes the state of hydro-met monitoring in the Orange-Senqu River basin, data and information exchange and sharing between the basin states and ORASECOM's facilitating role. In particular, it covers:

- A description of current hydro-metrological monitoring initiatives in the basin states, identifying the main gaps and demands for harmonisation in terms of quality assurance, procedures and standards.
- An assessment of current data and information exchange and sharing practice, given the ORASECOM mandate
- An assessment and description of the Orange-Senqu Water Information System, a data and information portal initiated by the UNDP-GEF project, with the identification of key components for its maintenance and further refinement.

The focus of this paper is on climatic and water quantity monitoring, aspects of water resource quality monitoring are covered under a separate technical paper (, Du Plessis, technical report 44, UNDP-GEF project, 2013).

2. Hydro-meteorological monitoring in the orange-Senqu River basin

Monitoring networks must be maintained on an ongoing basis and should be spatially and temporally well distributed for effective management of a river basin. World-wide, however, there is a trend to re-evaluate monitoring networks to ensure the most optimal design while minimising infrastructure maintenance costs and human resources required maintaining the network. What is of utmost importance is to identify key gauging stations and adequately maintain theses stations, which requires investment into knowledgeable human resources, improvement in operations, as well as data quality control and management. Rainfall, evaporation and surface water flow monitoring are not only important for long-term planning purposes for any water management institution but also for operational, environmental and flood monitoring purposes.

This Section will provide an overview of the current surface water and rainfall monitoring processes that the Orange-Senqu basin states are responsible for. Some limited comments will also be made regarding the evaporation information available. A high level assessment of the standards, procedures and quality assurance of the data will also be undertaken. This Section will conclude with identification of gaps and proposing the need for harmonisation of the monitoring networks.

2.1 Surface water gauging

The spatial distribution of flow and reservoir gauges is most dense in the highest runoff production areas, i.e. the Senqu, Upper Orange and Upper Vaal catchments. This is also where the longest measured flow records are found, in some places as early as 1908. The drier part, except for the lower Orange River, has typically lesser gauges. The significant size and remote location of the lower Orange River also makes monitoring stream flow difficult.

The following sections provide an overview of the current gauging networks and the data management of the four basin states as done by Crerar et al. (2011).

Botswana

There are currently no operational river gauging stations in the Botswana part of the basin. This is due to the very dry Lower Molopo and Kuruman rivers not having any significant surface water flows. All water demands in the Botswana part of the Orange-Senqu Basin is supplied by groundwater resources. Institutionally the water related monitoring is being done by a division of the Department of Water Affairs of Botswana.

The Department of Water Affairs in Botswana has only recently established a dedicated data processing and quality control unit in the Gaborone office. The unit is responsible for the processing of data and its evaluation, which is done in HYDSTRA, their hydrological database. The bulk of the data consists mainly of strip charts and gauge plate readings, with only a relatively small amount of electronic data. Processing of data is far from ideal and errors are made in the interpretation of chart data.

Some of the staff that forms the data processing unit are fairly new to the department and need extensive hydrological field and data analysis training. During the period of 2009 to 2010 several training courses were presented to the staff but IT related data corruption of the HYDSTRA system caused the system to be re-installed three times during this period.

The current process of collected data for surface water data includes manual collection by technicians and regional capturing of data in spreadsheets or A4 forms. Annually it is proposed that records is sent to the Department for capturing of data in HYDSTRA. This process is far from ideal and it was recommended that an attempt should be made to improve the data chain efficiency and build the hydrological knowledge of the staff.

Lesotho

There are a total of 95 active gauging stations in Lesotho, although only 69 stations were operational at end of 2010/11. In addition, water levels at the Katse, Mohale and Muela Dams, as well as releases from these dams are monitored by Lesotho Highlands Development Authority (LHDA) and other dams by the Water and Sewage Authority (WASA). There is a need to increase the number of operational stations. The current situation is a result of budgetary constraints and a shortage of qualified staff. There is a need to prioritise stations for rehabilitation and to programme and budget for this work (CoW, 2012).

The monitoring of surface water resources is undertaken by the Hydrology Division in the Department of Water Affairs. Data from the hydrological stations are collected by a number of technicians and given to an established data processing unit. All data is captured in HYDSTRA (Crerar et al., 2011).

Typical problems pertaining to measurement and onsite data storage experienced include:

- Vandalism;
- Run down logger batteries;
- Personnel shortages; and
- Blocked inlet systems (despite regular flushing in many cases) and other technical defects.

During 2009 and 2010 training was provided to the staff at the department on HYDSTRA and data analysis. The staff's overall knowledge of basic hydrological concepts needs to be improved. Field training is therefore essential, as it will better equip individuals in the interpretation and analysis of data and the many problems encountered. Data quality control is an area that requires improvement, as it is practically non-existent. The data processing unit carry out data updates but greatly struggle with data analysis - an area which is crucial for correct data processing (Crerar et al., 2011).

Namibia

Namibia operates 27 gauging stations in the Fish, Auob, Oanob, Nossob and Orange catchments, of which 8 are reservoir stations. Almost all stations are fitted with recorders and many with electronic loggers. The hydrology division also operates real-time stations at stations on the Fish (Seeheim and Ai Ais) and at Rosh Pinah on the Orange River mainstem. In general, the real-time data are not used to build historic records (Crerar et al., 2011).

The Department of Water Affairs of Namibia is responsible for the surface water and groundwater monitoring in Namibia, with NamWater also contributing towards monitoring initiatives. The monitoring institutional set-up is well-defined and has been operating for many years. Technicians, technical assistants and 'basin officers' support a chief control technician in the hydrology division with monitoring and "check and service" functions. Data from stations are downloaded during service trips, which are carried out every two or three months. These trips include the collection of charts where chart recorders are still in operation. Namibia has a well-established data processing system. Like the other basin states, they use HYDSTRA. There is, however, no internet-based system through which interested parties can access data on line. Therefore data is provided on official request only.

Problems are largely due to lack of staff and a relatively rapid staff turnover. A number of empty posts exist and a lack of capacity at senior level is also observed, which leads to quality control problems. New field technicians require training and time to build up their experience.

South Africa

The largest part of the Orange-Senqu River basin falls within South Africa and the most gauging stations is therefore also situated within South Africa. The Table 1 below provides an overview of hydrological data and water use monitoring sites in the Vaal and Orange River catchment areas within South Africa (Source: Department of Water Affairs: South Africa HYDSTRA Web Interface).

The operation and maintenance functions of hydrological monitoring stations in the Orange-Senqu River basin are managed by the Department of Water Affairs regional offices in the Northern Cape, Free State and Gauteng. Each region is fully responsible for their data and its integrity. Technicians are responsible for the maintenance of the instrumentation, be it mechanic or electronic. They also ensure that observers are correctly trained and are capable of carrying out their duties. Depending on the region, the task of data collection and data processing is mainly the responsibility of auxiliary officers. In some cases, technicians are also involved in the processing of electronic data (Crerar et al., 2011).

Table 1: Gauging stations in the South African part of the Orange-Senqu River basin

Type of monitored data	***River Basin***	***Total stations with historical data***	***Number of stations in operation in 2013***	***Total stations in operation in 2013***
Reservoir (levels, dam balances, spills and other variables)	Vaal	35	29	44
	Orange	18	15	
River flow monitoring stations	Vaal	198	84	123
	Orange	108	39	
Canals (irrigation supply and others)	Vaal	73	34	46
	Orange	21	12	
Pipelines (to treatment plants and other users)	Vaal	15	9	18
	Orange	12	9	
Eyes	Vaal	24	8	13
	Orange	13	5	
Meteorological (rainfall and/or evaporation)	Vaal	86	Unknown	138
	Orange	53	Unknown	
Total monitoring points (Excluding Meteorological)	Vaal	345	164	244
	Orange	172	80	

The staff complements of the Gauteng, Free State and Northern Cape regional offices for monitoring and data management is respectively 13, 12 and 6. During 2011 the Northern Cape hydrology unit had a vacancy rate of 72%. This situation resulted in only a limited number of key flow monitoring points being currently monitored.

Both the Gauteng and Free State regional offices have sufficient budget available to procure equipment and to replace faulty equipment. Personnel are also able to install and replace data logging devices. Gauging stations are well developed, regularly maintained, protected against vandalism and include back-up equipment.

The Northern Cape regional office does not have sufficient budget available to procure equipment and to replace faulty equipment as well as maintain their allocated sites properly. Although gauging stations are automated as far as possible the stations are not adequately protected against vandalism and approximately 10% of the sites are not safe from flooding.

Typical problems pertaining to measurement and onsite data storage experienced include: vandalism, run down logger batteries, personnel shortages and blocked inlet systems (although inlet systems are typically flushed every three months as preventative maintenance (Crerar et al., 2011).

In South Africa, data processing is undertaken in HYDSTRA, the hydrological database, by the regional offices. HYDSTRA is centralised and runs on a Citrix Server, which allows instant availability of data, not only in the head office in Pretoria but at the regional offices as well. The ownership of the data lies entirely with each region and they are totally responsible for the analysis, processing and evaluation of all their data. The vast majority of data are electronic, but mechanical data are still used, either as a backup or as a primary data source, as is the case in the Gauteng region, where vandalism is at its highest. After the processing of data, the first step in the auditing of data quality is performed in the different regions by the quality control group. The final stage of the data auditing process, for all regions, is undertaken by the audit group located at the head office in Pretoria. This group liaises with all the data groups in the different regions and alerts them of possible problems found in the data. Should errors be found in the data, the specific region will re-evaluate and correct the data before once again submitting to the audit group.

The biggest issue with quality assurance can be found in the Northern Cape, where the key problem is the lack of personnel. In the past head office has assisted this region with data processing. Unfortunately, this is no longer the case due to the lack of personnel in head office. Currently, the Gauteng regional office provides assistance with the capturing of evaporation and rainfall data.

Hydrological cycle observing system, HYCOS

The purpose behind the formulation of the SADC-HYCOS project was the contribution to regional social-economic development by providing the necessary management tools for sustainable and cost effective water resources management and environmental protection. Its main objectives were to:

- Provide the Southern Africa Development Community (SADC) with an information system for the sustainable improvement of regional integrated water resources assessment, monitoring and management for a peaceful and sustainable development of the region.
- Assist the participating countries in developing their own national capacity in these fields to allow them to fully participate in, and benefit from, the project.
- Collaborate with other national, regional and international projects and programmes, towards the modernisation, rationalisation and improvement of the efficiency, cost-effectiveness and sustainability of the water resources and related information systems in the continental part of the SADC region and at the international level.

SADC-HYCOS was established in 1998, participating countries were Angola, Botswana, the Democratic Republic of Congo, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe, Mauritius. The second phase of the project commenced in December 2005 and ended in May 2010, Madagascar and Seychelles joined the project during its second phase. No funding could be secured for a third phase of the project.

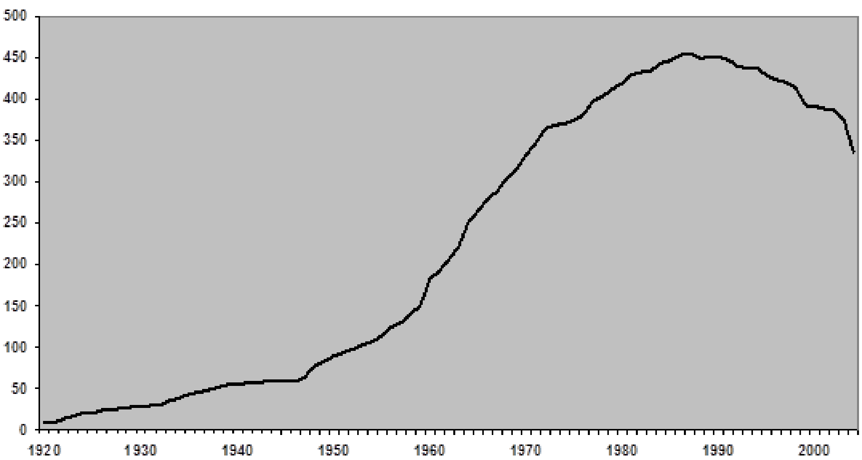
The project's focus was on capacity building, infrastructure and information management systems development. However, large staff turnover defeated the capacity building investments and non-continuous funding for the project left the ICT and measuring infrastructure open to vandalism and disrepair.

Current Orange-Senqu stream flow data density and quality

When evaluating a monitoring network it is always advisable to look at the quality and usability of the data being gathered. The density of a monitoring network is not only dependant on the number and spatial distribution of the gauges, but also if the gauges are located optimally, the data is of good enough quality and if it is monitoring the required variables for a specific user/need.

When considering the usability of flow gauging networks for the purpose of long-term and operational planning one can observe the general trend of decline in useful flow gauging stations as observed by South African Water Research Commission's Water Resources of South Africa publications (WRC, 2009). Figure 1 below provides an overview of useful flow gauges open in each year in South Africa from 1920 to 2004 (Pitman, 2012). This figure shows a rapid growth after a relatively slow start before 1960, then a flattening off to a peak of around 450 in the late 1980s. Since 1990 there has been a steady decline such that the number open in 2004 has dropped to about 350. If this trend continues into the future it will be a serious cause for concern. Although this figure only represents the decline in South African flow gauges, it is expected that a lesser severe but similar trend can be found in the other Orange-Senqu basin states.

Figure 1: Number of useful flow gauges in South Africa operational in each year.



The decline of useful monitoring flow gauging stations will cause a "planning-blindness" in the near future if the rapid decline in stations isn't based on proposed network optimization based in user needs. Instead the fear is that it is based on a rapid decline in competency and high level understanding of the importance of proper flow monitoring, especially when facing uncertain future climate conditions.

Regarding the useful flow gauges in the Orange-Senqu Basin, a recently study to update and extend the historic stream flow time series data for the entire basin revealed that of the 455 flow gauging stations that has historic flow data in Namibia (27), Lesotho (69) and South Africa (359), only 86 stations were useful during the calibration of the hydrological models (excluding the stations in the Namibian Fish). 73% of these stations were located in the high runoff areas in the Senqu, Vaal and the Upper Orange Rivers. In 2004 only 70 of these stations were still open (Haasbroek et al., 2011).

2.2 Meteorological monitoring

Rainfall in association with evaporation is the main climatic drivers for all inland water availability. There is therefore an obvious link between the monitoring of rainfall data and the estimation of available surface and groundwater in a river basin. Since rainfall is so much easier to measure than stream flow, longer and more point rainfall data records exist compared to flow measurements. Due to the relationship between rainfall and runoff hydrologist are able to extend the short period of observed stream flow data records using mathematical models. The result is realistically simulated long-term stream flow records based on long-term rainfall. The longer simulated flow is used to determine the long term variability of stream flow and the yield reliability of the basin. Without good and long record period rainfall records, proper water resource supply and operational planning is therefore not possible.

The following sections will provide an overview of the current rainfall gauging networks of the four basin states.

Botswana

The Department of Meteorological Services of Botswana monitors and analyses the country's and regional weather, providing weather forecasts, bulletins and an extensive range of meteorological and climatological data and reports. Botswana's mean annual rainfall varies between 340 and 580mm/a.

The Department has 21 climatological stations across the country of which 4 is key stations at Tshabong, Letlhakane, Maun and Sir Seretse Khama Airport, Gaborone. These stations measure meteorological parameters in the atmosphere up to height of about 20km and include evaporation data. Seven of the 21 stations (of which one is a key station) are in and around the Orange Senqu River basin.

The Meteorological Services of Botswana is divided in the following divisions:

- Climatological Division - analyses data using statistical methods and the average values of meteorological parameters for different parts of the country are published. Provides input to specialised reporting, such as agro-meteorological reports and reports of the Inter-Ministerial Drought Committee.
- Training and Research Division - coordinates departmental training and research activities. This includes recruitment of technical employees who initially undergo WMO (World Meteorological Organisation) class IV and refresher courses offered by the department.
- Field Operations Division - responsible for ensuring the continuous operation of the basic national meteorological network.
- Weather Information Services Division – collects and analyses weather data and provides weather forecasts for the general public and special reports to aviation as well as special forecasts during cases of flash floods, heat waves etc.

- Engineering Division - responsible for the up-keep, operation and maintenance of all meteorological instruments and equipment.
- Management Division - manages human resources, finance, materials, supplies and administrative information.
- Data Processing Division - responsible for electronically analysing, validating, storing and archiving of meteorological data.

Software used for quality control and management currently is WMO's CLICOM software. The department provides on-line weather forecast and bulletins but historical data can also be requested via e-mail.

Lesotho

The Lesotho Meteorological Service is responsible for all climatological monitoring in Lesotho. Lesotho's mean annual precipitation ranges between 500 and 1,200mm/a.

The service operates a network of meteorological stations across the country for weather and climate monitoring. The stations undertake routine meteorological observations of weather elements at internationally agreed time frames. The stations are divided into four categories, namely; synoptic, rainfall, climate and agro-meteorological stations.

- Synoptic stations – Four stations are fully equipped with various sensors for various climatic parameters and the stations form part of the global observational system of WMO. These stations are required to report on a 24-hour basis but they operate only day time due to staff constraints.
- Rainfall, climate and agro-meteorological stations - There are a total 90 stations across the country where 53 are exclusively rainfall stations and 37 stations are also measuring temperature. Of the 37, 8 serve as agro-meteorological purposes where air temperature, soil temperature, precipitation, evaporation and sunshine duration is also measured.

The Meteorological Service has the following sub-divisions:

- Applications Division – Provides agro-meteorological, hydro-meteorological, disaster management and environmental meteorological information, data and advisories.
- Climatology Division - Observes and analyses Lesotho's weather and climate and provides meteorological services.
- Communications & Public Affairs Division - Communicates meteorological forecasts and other products.
- ICT Services Division – Maintains the ICT systems for the Meteorological Service including, satellite information, wireless networks, GIS, website maintenance, general maintenance and the high performance computing system.
- Weather Forecasting Division - Provides weather forecasts and warnings.

Software used for quality control and management currently is WMO's CLICOM, which is now being replaced by the more recent WMO software, CLIMSOFT. Online weather forecast and bulletins are provided and data can be requested via fax or telephone. Some of Lesotho's government departments have direct access to the database.

Namibia

Namibia Meteorological Service is the custodian of climatic information in the country. The country's mean annual precipitation varies between 10 and 700mm/a.

The Namibia Meteorological Service obtains rainfall data from rainfall-only stations operated by volunteer individuals and organizations. Currently there are about 200 rainfall stations not all maintained on an uninterrupted basis. Their databank has 700 rainfall stations records that operated at some point in time in the past. In recent studies (Haasbroek et al., 2011) a database of 397 stations with reasonable record length was obtained from the Namibia Meteorological Services. Other surface data are mainly made up of daily maximum and minimum temperature, relative humidity, atmospheric pressure and wind from 14 stations with varying record lengths. Upper air data is only available from one station in Windhoek.

The Namibia Meteorological Service provides two main functions:

- Forecasting services for aviation and general public – Provide users with data and information according to strict stipulated times according to WMO and the International Civil Aviation Organisation (ICAO) standards. This service includes public and aviation weather forecasts and related online services.
- Climate data and consultancy services – Quality control of climatic data provide to users with data analysis techniques such as statistical inferences. Publishes data summaries and media briefs on significant events.

Data bulletins and weather forecast are available online and historical data can be requested via e-mail or telephonically. The Department of Water Affairs of Namibia as well as NamWater are custodians of some additional rainfall and evaporation data observed at their reservoirs.

The South African Weather Service (SAWS) is the custodian of weather, climate and related products in South Africa. South Africa has a wide range of mean annual precipitation ranging for less than 50 to more than 1,800mm/a. SAWS has 24 offices across the country with the following observation network:

- 214 automatic weather stations
- 22 climate stations
- 233 rainfall stations, with up to 1,277 historical stations
- 73 automatic rainfall stations
- 23 sea surface temperature stations
- 2 voluntary observing ships

- 47 weather buoys, in the South Atlantic and South Indian Oceans
- Meteorological radar systems
- The Global Atmosphere Watch Station at Cape Point
- 2 Dobson ozone spectrophotometer stations in Irene and Springbok. (a third to operate at Cape Point shortly)
- A national UVB Biometer Network in Cape Town, Cape Point, Port Elizabeth, De Aar, King Shaka Airport, Pretoria and Polokwane
- 24 lightning detection sensors (additionally SAWS operates one in Swaziland)
- Air quality monitoring stations (Department of Environmental Affairs infrastructure being maintained by SAWS) and 3 new SAWS stations to be added shortly
- 11 upper-air sounding stations with Irene also conducting ozone soundings, plus the South African research vessel S.A. Agulhas II.

The South African Weather Service has a multitude of function both for the public as well as commercial services which can be summarised as follow:

- Forecasting services – Including general and specialised forecasts over different time scales, severe weather warnings, multi-hazard forecasts, aviation services and maritime forecasting services.
- Prediction and observation research – Including now casting, very short range and long range forecasting and observation research
- Climate services – Including the population, quality control and information dissemination via the Climate Monitoring System (CLIMOS), climate change research and maintenance of a South African Air Quality Information System.

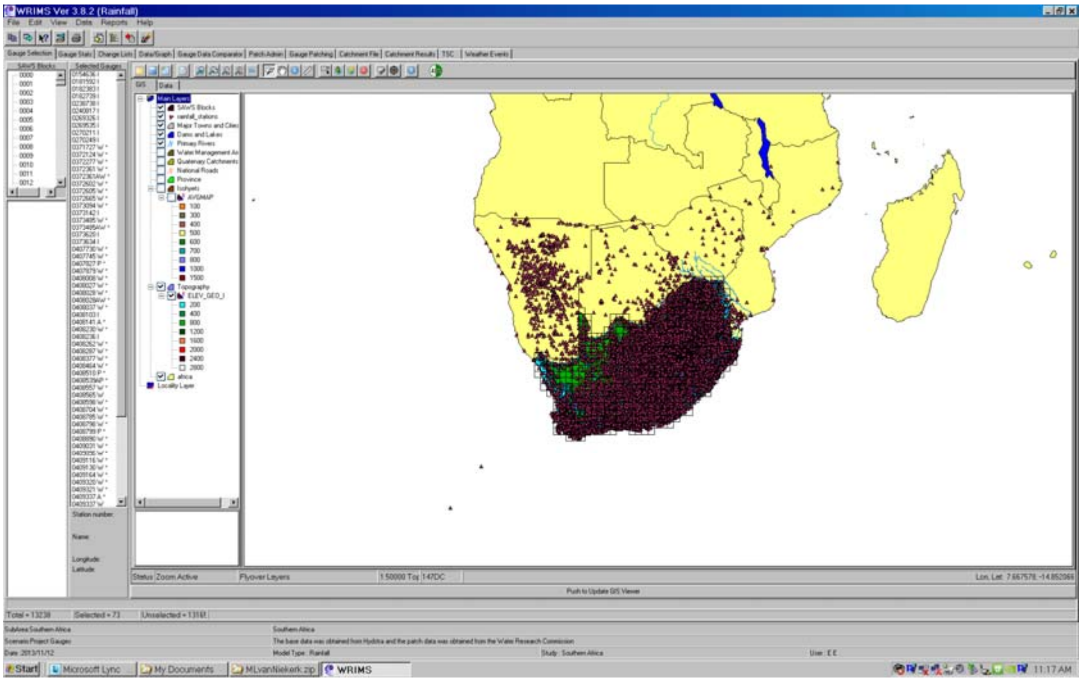
The South African Weather Service has an extensive website for dissemination of public as well as commercial services. Request for specific rainfall data can be placed via e-mail, but all historical rainfall data must be paid for.

Another resource of rainfall and agro-meteorological data in South Africa is the Agricultural Research Councils' (ARC) database. This database is not widely shared and data can be obtained with special request from the Council.

The Department of Water Affairs and Forestry of South Africa (DWA), also has a network of rainfall stations and evaporation stations at their major dams as indicated in Table 1. DWA also gets a full copy of the updated rainfall database from SAWS each year for use in DWA research projects. The Chief Directorate Integrated Water Resources Planning also developed RainIMS. This product includes a database of all the historical rainfall data from DWA, SAWS, ARC as well as neighbouring countries and private individuals. The data was gathered during an early 2000 Water Research Commission project to create an integrated patched rainfall database. Figure 3 provides a view of the RainIMS and the stations with data that it contains. This system is used in all the

Department's planning studies to generate long-term hydrological data with and contains tools for quality control and patching of monthly rainfall data.

Figure 2: Spatial coverage of the Department of Water Affairs of South Africa RainIMS product.



Current Orange-Senqu climatic data density and quality

As for stream flow data the density of a monitoring network is not only dependant on the number and spatial distribution of the gauges, but also if the gauges are located optimally, the data is of good enough quality and if it is monitoring the required variables for a specific user/need. The South Africa Water Research Commission's Water Resources of South Africa publications (WRC, 2009) also provides a general trend of decline in useful point rainfall. Figure 3 provides an overview of useful rainfall gauges open in each year in South Africa from 1920 to 2004 (Pitman, 2012).

Figure 3: Number of useful rainfall gauges in South Africa operational in each year.

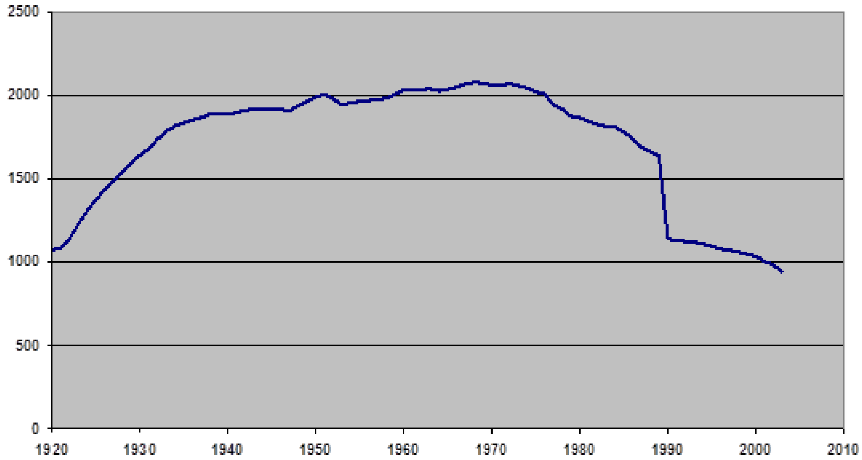


Figure 3 paints a far more serious picture than for the Figure 1 for gauging stations. South Africa is now in a similar position with the decline in numbers from a high around 1970 to only about half of that in 2004, which is roughly the same number of stations as in 1920. This is a major problem as rainfall is the primary input to any rainfall-runoff model – not only for simulating long-term runoff accurately but also for calculating irrigation, forestry and invasive alien plants estimated water demands and losses from reservoirs and wetlands. Some water management areas (WMAs) are worse off: for example WMA no. 13 (Upper Orange – the highest runoff area in the Orange-Senqu River basin) now has less than half the number of stations open than in 1920.

The recent study on updating and extending the hydrological time series database for the Orange-Senqu River basin (Haasbroek et al., 2011) also assess the number of usable rainfall stations with historically data and those who were still open in 2004.

What is of particular concern is the high runoff areas in the Orange-Senqu River basin – the Senqu and the Upper Orange areas (that generated 60% of the total natural runoff of the entire basin). Only 127 stations were found useful in the analysis of which only 35 (28%) was still open in 2004.

The Lesotho rainfall data has been a contentious issue for many years. At the time of the Lesotho Highlands Development Project planning phase, several studies were undertaken to estimate long term rainfall patterns for Lesotho using their data. None of the studies resulted in hydrology that was accepted by both South Africa and Lesotho. It was therefore decided to undertake a joint study in an effort to break the impasse. The work was carried out co-operatively by LHDA's Water Resources Division and consulting engineers acting on behalf of South African DWA. The resulting study was done in close cooperation between the two countries and approval was reached at the end of each step in the process. The study resulted in an accepted hydrological and rainfall database that stretched from 1935/36 to 1995/1996 for the entire Senqu River Basin up to the border with South Africa. The hydrology and rainfall data was subsequently extended to start in 1920.

2.3 Conclusions

The following summary conclusions can be made about the hydro-meteorological monitoring networks.

Surface water gauging

- Botswana does not have any surface water gauges in the Orange-Senqu River basin.
- In Lesotho there are currently 69 operational gauges, of which only eight were considered useful in a recent hydrological analysis of the area (Haasbroek et al., 2011). The Senqu River catchment is the highest runoff generating sub-area of the Orange-Senqu River and therefore accurate flow gauging is of great importance. Although the Lesotho Hydrology Division is functioning well and data capturing is taking place, a great need exists for data quality assurance training. There are also some major structural short comings and vandalism problems with the Lesotho flow gauges. Most of the stations are manually monitored and the data is not easily accessible.
- In Namibia there are 27 flow gauges in the Orange-Senqu area. Most of the stations are in remote places, monitoring data is mostly gathered manually. Data processing is well established but high staff turnover leads to a diminishing data quality. Although the data is stored in HYDSTRA there is no internet access to the data.
- South Africa has the largest portion of the Orange-Senqu River basin and therefore also has the greatest number of flow gauges (359 gauges of which 167 are currently opeational). Just as in the other basin states limited knowledgeable staff and vandalism are the main problems. Data collection, processing and quality assurance is the responsibility of the regional offices of the Department of Water Affairs and HYDSTRA is fully distributed to all the regions. Head office has a centralised data quality assurance and dissemination function, which is also hampered by not having enough knowledge staff. Two of the regional offices (Gauteng and Free State) have well developed and automated stations which are protected against vandalism and knowledgeable staff to maintain the stations. The Northern Cape, however, does not have budget nor personnel to maintain and monitor the flow gauges in their region. Although gauging stations are automated as far as possible in this region the stations are not adequately protected against vandalism, and the region only have a staff complement of 6 with an vacancy rate of 72% in 2011. South Africa is the only basin state that has full access to all their measured hydrological data over an easy to use web-interface to HYDSTRA.
- Although SADC-HYCOS did not succeed in obtaining further funding, several valuable lessons can be learnt from their implementation problems, particularly it's ICT approach.

Meteorological monitoring networks

Quality control for rainfall data is much more standardised than flow data. All meteorological services of the basin states adhere to WMO standards at least for their key stations. This is to ensure that commercial services, i.e. supplied to aviation is adequate.

Rainfall data monitoring activities predate flow measurement in places by several decades.

Historic data sets are still mostly driven by voluntary individuals that send data to the respective meteorological services.

Botswana has 21 climate stations across the country of which seven stations are in and around the Botswana part of the Orange Senqu River Basin. Four of the stations are key climatological stations that also include observation of evaporation and atmospheric data. One of these key stations is in the Orange Senqu River basin. Botswana makes use of the WMO's CLICOM software for data storage and processing.

Lesotho has a climatological network of 94 stations. Four of the stations are full synoptic stations managed according to WMO standards, eight stations are agro-meteorological stations (observations include evaporation and other related parameters, mostly situated in the Lesotho lowlands), 37 stations measure temperature and rainfall, and 53 stations measure rainfall only. Lesotho also makes use of WMO's CLICOM, the country is currently upgrading to the newer software CLIMSOFT. The usability of the Lesotho data for hydrological purposes has long been a contentious issue – during the LHDP planning phases only 27 stations were identified as being useful, of which only ten remained active in 2004.

Namibia has approximately 200 active rainfall stations with a databank of about 700 historic stations. A total of 47 stations is situated inside or nearby the Orange-Senqu River basin and were used in previous analyses of the Fish, Molopo and Nossob catchments. Only one upper atmospheric data station is available and 14 stations measure various other parameters. It is unknown which software is used for processing and storage of data. Online weather forecasts and bulletins are available, and historic data can be requested via e-mail and telephonically.

The South African Weather Service (SAWS) has a total of 542 stations that can measure rainfall and up to 1277 historical records across the country. SAWS maintains an extensive website for dissemination of public as well as commercial services. Request for specific rainfall data can be placed via e-mail, but all historical rainfall data must be paid for. The SA Weather Service has their own software to manage their data with (CLIMOS) .Another databank of rainfall and agro-meteorological data in South Africa is the Agricultural Research Councils' database. This database is not widely shared and data can be obtained with special request from the Council. Of major concern is the dramatic decline in rainfall data. In 2004 there were less stations that was available than in 1920. In the Senqu and Upper Orange catchments only 35 stations were operational in 2004.

2.4 Gaps

Surface water gauging

The first aspect of flow gauging is the relative expensive and complex nature of flow gauges. There is a need for competent staff that can understand the problems of the gauges and maintain the gauge themselves through local suppliers. High technical staff turn-around, budget limitations, remoteness of the gauges, floods and vandalism seem to be the largest problems related to ongoing measurement of flow.

Developing a flow gauge catalogue by experienced technical staff providing:

- the type of gauge;
- known structural problems and flow calibration problems of the gauge with associated problems in the data;
- procedures for checking and fixing the stations; and
- the importance of the gauge for particular users

would help in the training for new technical staff. Very little is known about existing guidelines and standards for flow gauging data quality control. Sharing knowledge on how to detect problems with observed data and training on hydrological concepts should also be enhanced.

Regarding the software, all the basin states use HYDRSTA. A number of problems with maintaining these systems in Lesotho and Namibia have been hampering using the full potential of the software. ORASECOM could support the automated collection and distribution of data for some key stations in the Basin.

Meteorological monitoring

Measurement of rainfall is not as complex compared to flow measurements and rainfall monitoring has been ongoing for a much longer time in the basin states than flow monitoring. This has to some extent established better quality control processes. A major problem, however, is that voluntary contributions from the public are often not accurate and subject to changes in position and equipment.

Improved quality control is also partly driven by the importance of services that are delivered such as reporting to aviation, disaster management and international clients such as the WMO. Infrastructure problems also exist such as vandalism and remote locations of some stations. However, the equipment is relatively inexpensive to replace compared to flow gauging. In general the meteorological services in the basin states operate well and provide data of an acceptable quality.

Access to historical data and updating of the historical data on a periodic basis, while providing access to the general public will prove to be difficult in South Africa. The South African Weather Service has commercialised the gathering and distribution of historical and the updating of historical rainfall datasets. The other basin states, however, do not have such restriction in providing this data but obtaining the data is in many cases very difficult, sometimes only via telephonic request..

General conclusions

While higher density networks are always desirable, it is clear that budgetary constraints and a shortage of personnel to maintain such a network are some of the key obstacles. World-wide there seems to be a decline in monitoring networks and a drive to optimise existing networks. What is of great concern is the overall decrease of hydro-meteorological observations in the Orange-Senqu River basin. Although plenty of historical data exist, near future planning analyses will not be done at the same level of detail and to the same level of confidence as historical analyses. This means that we will not be able to describe or properly plan for projected climate change because we have not been measuring it adequately. It is unknown if the alarming decrease in hydro-meteorological monitoring in the Orange-Senqu River basin has been done with input from the users of the data of what data is key for decision making process.

An action plan for the maintenance of stations will have to be developed. It should include capacity building, technical assistance and the supply of automated equipment as described in the previous sections. ORASECOM could also play a facilitating role in data and information management and could also assist in attracting complementory donor funding for selected activities.

3. Data and information exchange and sharing

In this section an assessment of current data and information exchange and sharing practice is provided in the light of ORASECOM's mandate.

3.1 Current practice

Since the largest part of the Orange-Senqu River basin falls within South Africa, it is safe to say that the basin state with the greatest need for data exchange and sharing would be South Africa. Exchange and sharing of data is usually required for areas around shared borders or if one country is located upstream from another. Not only is South Africa the only basin state that shares borders with all three of the other basin states, but South Africa has a crucial relationship with Lesotho as upstream riparian as well as a key supplier of water to South Africa's economic heartland. South Africa has been doing large scale water resources planning and operational studies since the mid 1980's, including analyses for the whole Senqu catchment and the South African part of the basin. Sharing and obtaining data historically (and even today) is often tedious and sometimes impossible. With the development of the web-based HYDSTRA system for South African data, hydrological data sharing improved dramatically and all basin states have full access to all measured data on the Orange-Senqu, including flood monitoring data, river monitoring data, reservoir data, DWA's meteorological data, pipe and canal flow data. Rainfall data is however not widely available as described in the previous chapter.

To some extent the main obstacle to proper data sharing was the absence of broadband internet services until a decade ago, and for some of the basin states as recent as five years ago. With the broadband internet services becoming more and more widely available new opportunities opened.

3.2 ORASECOM's mandate

ORASECOM provides a forum for consultation and coordination between the Basin States to promote integrated water resources management (IWRM). The IWRM approach helps to manage and develop water resources in a sustainable and balanced way, taking into account social, economic and environmental interests. Such an approach requires the standardised collection, analysis and dissemination of data and information on all aspects of the basin.

The role and responsibilities of ORASECOM relating to data and information management are laid out in the Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC Protocol, 2000) and the ORASECOM Agreement. The SADC Protocol states that *'Parties shall exchange available information and data regarding the hydrological, hydro-geological, water quality, meteorological and environmental condition of shared watercourses'*.

The ORASECOM Agreement includes three tasks related to data and information:

- Art 7.4 obliges the Parties to the Agreement to *'exchange available information and data regarding the hydrological, hydro-geological, water quality, meteorological and environmental condition of the River System.'*
- Standardisation of river monitoring: Art 5.2.5 advises the Parties to work towards *'the standardised form of collecting, processing and disseminating data or information with regards to all aspects of the River System.'*
- Notification of projects: Art 7.5 obliges: *'a Party planning any project, programme or activity with regard to the River System which may have a significant adverse effect upon anyone or more of the other Parties, or which may adversely affect such River System, shall forthwith notify the Council and provide all available data and information with regard thereto.'*

As can be seen from the previous analysis hydro-metrological data in the Orange-Senqu Basin is far from adequately exchanged amongst basin states. Furthermore, no standardised monitoring and collection of data is taking place currently, with each basin state grappling with their own infrastructure and capacity problems. Several obstacles will have to be overcome to achieve an adequate level of data and information exchange and sharing.

As would be expected, line agencies in the basin states as well as other institutions acquire and manage a large range of data and information relevant to water resources management in the Orange-Senqu River Basin. These activities should be continued and even expanded. But ORASECOM can and should play an integrative role to standardise and share data and information collected for the basin.

4. ORASECOM Water Information System

This section describes and assess the ORASECOM Water Information system, a web-based data and information portal initiated by the UNDP-GEF Project. Potential functionality as well as data and information holdings improvement to the WIS will also be discussed. Elements for the maintenance and further development of the WIS are also proposed.

4.1 Description and assessment of the WIS

The Orange-Senqu Water Information System (WIS) was designed and developed in supported of ORASECOM's data and information exchange mandate under the ORASECOM Agreement. It can be found at:

http://wis.orasecom.org

The WIS aims provides a web-based platform for the basin states, ORASECOM and the interested public to exchange and share:

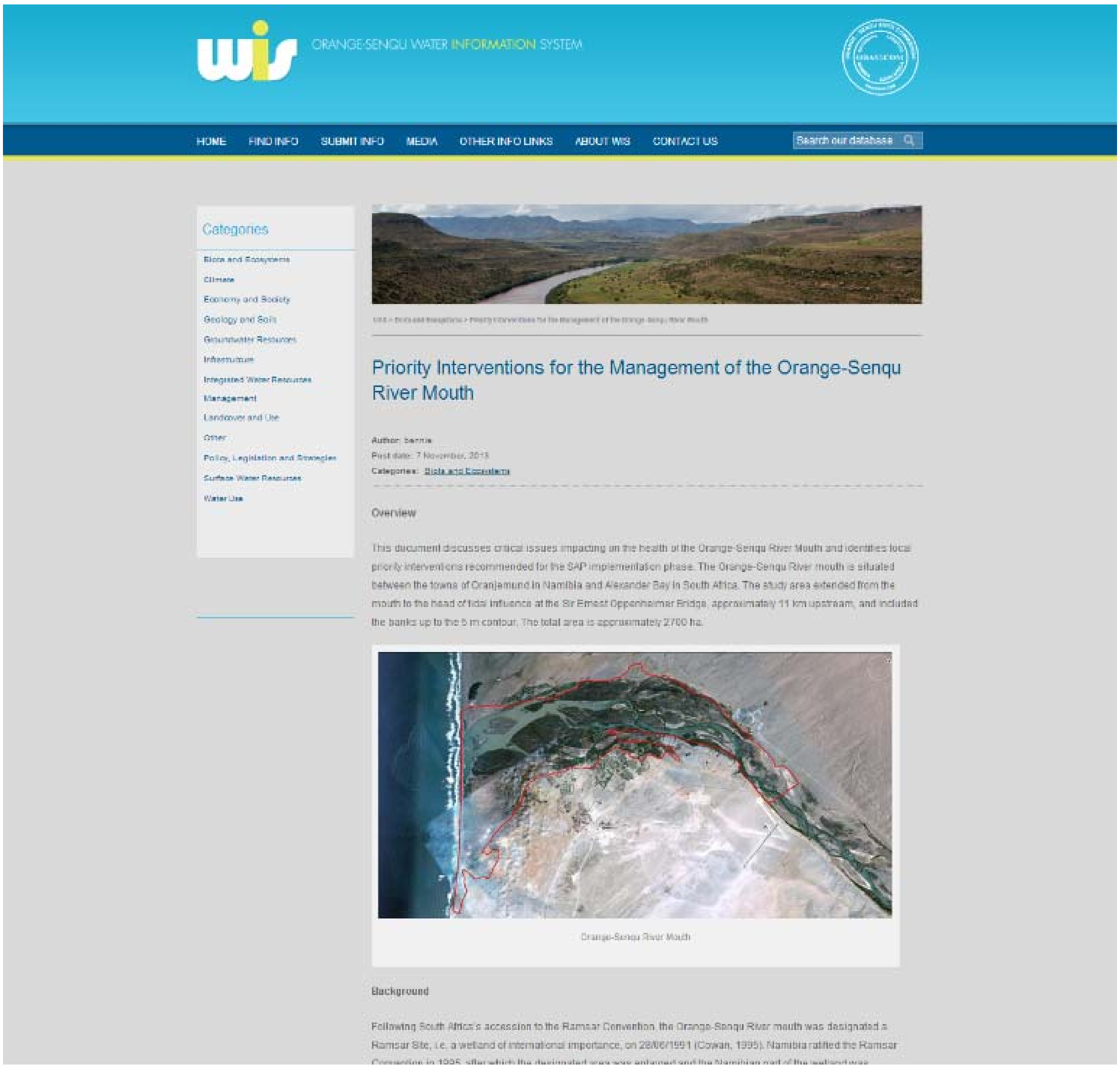
- Datasets,
- Links to related data,
- Documents,
- Media,
- Software, and
- Contact details of other information sources.

The main components of the WIS is discussed in more detail below.

Submitting information

Currently the WIS is populated with data and information (documents and other media, software) generated during ICP-funded studies undertaken under the auspice of ORASECOM. The aim is that the WIS will serve as the central repository of all products developed for ORASECOM. The WIS is designed in such a way that users can go through a moderated registration process where they get access to contribute information to the WIS in the form of an article. The user can provide a written description of the information that is being provided and add links and pictures and upload data files. The user can then link the article to specific categories of information and add special tags to the article for enhanced searching for the specific article.

Figure 4: Example of an article in the WIS.



After the user has submitted the article, a moderator will review and edit the article after which he will approve the article for publication on the site. The published article will be searchable under the category of information immediately and searchable after a while after the search functionality has re-indexed the site.

Finding information

The WIS allows you to either browse for certain categories of information that can be found on the site, our doing a general search for words in articles. At this stage generalised search is only available on text on the site and not content in .pdf documents uploaded.

All articles and data elements are categorised according to categories provided in Table 2.

Table 2: Categories of information in the WIS

Category	***Types of information***
Biota and ecosystems	Wetlands, environmental flow requirements, estuary, etc.
Climate	Rainfall, evaporation, temperature, wind, etc.
Economy and society	Demography, population density, economic indicators, etc.
Geology and soils	Geological data, soils, etc.
Groundwater resources	Recharge, quality, base flows, borehole yields, etc.
Infrastructure	Dams, diversions, transfer schemes, WTW/WWTW, hydro-met stations, etc.
Integrated water resources management	Systems operations, strategic planning, hydrological and systems modelling, flood and drought management, etc.
Land cover and use	Land cover and land use, in particular irrigated agriculture
Policy, legislation and Strategies	Water law, IWRM plans, water reconciliation strategies, etc.
Surface water resources	Flows, quality, floods, sedimentation, etc.
Water use	Irrigation, urban and rural demands, industrial demands, groundwater use, demand for power generation, water demand management, water conservation

This categorisation enables users to browse through all the articles that is link to this category. Alternatively the general search function can be used which not only looks at the content of the article and the selected category of the article but any tags that was specified by the user who submitted the article.

Other information that can be found on the WIS is all the publications and photo galleries as well as a list of other water related data custodians.

4.2 Further development of the WIS

Although the WIS already contributes towards sharing of data and information to all basin states, several enhancements could be considered. This section describes the proposed further developments and their potential benefits:

Improvements and promotion of the WIS

To increase the benefit of the current system, while further improvements of functionality and content are underway, the following actions are proposed:

- A more streamlined process of content contribution is designed and implemented.
- The search functionality will be improved even more to include inside-PDF searches.
- The design and development of a data-wiki:
    - A data-wiki will enable registered users to add their personally collected datasets.
    - An example the first data-wiki implementation is the storage and display of miniSASS observations conducted by participating schools under the ORASECOM River Learning Box project.
    - A second application could be the storage and summarisation of rainfall data (or other environmental observations) collected by individuals users.
    - The rainfall data-wiki will enable users to register the position of their rain meter and capture their rainfall reading over time, and import historic rainfall data into the system for the point.
    - The data-wiki will then provide the user with graphs and summaries of their data. They can also browse other user's data.
    - The advantage of having such a data-wiki is that catchment planner can use this data in their studies to fill spatial and temporal gaps in their rainfall data.
- Once these improvements have been implemented the site will have to be promoted with stakeholder to get feedback on potential key data sources that they would like to see shared as well as possible other functionality that could help water resources management and planning activities for the Basin.

Identification, obtaining and populating the WIS with further datasets

With inputs from basin states and other stakeholders a list of key datasets that should be shared on the WIS could be developed and sourced. These datasets might include the following:

- Population density figures at a resolution conducive for IWRM planning at basin to catchment levels;
- Geological and soil data;
- Comprehensive documentation on water related legislation, policies and strategies.

These datasets will have to be sourced with the help of key Basin State contacts. Thematic articles will be developed that would provide access to WIS users. Guidelines shall also be developed for all ICP-funded projects on how to upload products from their projects onto the WIS.

Identification, design and implementation of a key network of monitoring stations of basin-wide and transboundary importance

As outlined in the previous sections 2 and 3 the decline of hydro-meteorological monitoring stations in the Orange-Senqu Basin is of great concern. ORASECOM's mandate is not only to facilitate the exchange of data and information but also promote standardised monitoring practises. The following steps are proposed to support ORASECOM with their mandate:

- An assessment is required on the critical variables that need to be monitor in for effective IWRPM decision support in the future.
- The ideal and minimum gauging stations must be determined in all the basin states to support water resources planning and operations. Previous analyses will have to be consulted to see which stations were found to be critical and to have useful data.
- The status of the monitoring, data processing, archiving and data access of the key gauges should be reviewed and redefined.
- An action plan for supporting the basin states on improving the monitoring, the quality of the data and access to the data should then be developed to ensure that key stations are continuously being monitored.
- A user requirements based interface for the monitored variables will then be developed for the WIS and as access to key stations data becomes available, the data will be added to the interface. Tools will also be developed to analyse and display the data that is being monitored.
- Lastly, the system will be able to generate annual monitored data reports stating how many of the key stations were monitored during that year and make some qualitative remarks about the monitored data of that year.

References

Crerar, S; Gaspar, G & Harmse, C. 2011. Improvements of gauging network and review of existing data acquisition systems, Work Package 2: Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan, ORASECOM Document No. 005/2011, February 2011.

Du Plessis, M. 2013. Development of Basin-Wide Water Resources Quality Guidelines and Monitoring System. UNDP-GEF Technical Report 44.

Haasbroek, B; Crerar, S & Maré, M. 2011. Extension and expansion of Hydrology of the Orange-Senqu Basin, Work Package 2: Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan, ORASECOM Document No. 006/2011, April 2011.

Office of the Commission of Water, Lesotho (CoW), 2012. 1st Annual State of Water Resources Report (1 April 2010 – 31 March 2011), Lesotho Water Sector Improvement Project, Second Phase, RFP No.: LWSIPII/06/02/2011, Draft Final, 31 May 2012.

Pitman, W. 2012. Overview of Water Resources Assessment in South Africa: Current State and Future Challenges. Phalaborwa, unpublished article.

SADC, 2000. Revised Protocol on Shared Watercourses in the Southern African Development Community, Windhoek , 7 August 2000.

WRC, 2009. Water Resources of South Africa, 2005 Study. Water Research Commission of South Africa Report Number TT380/08, March 2009, Pretoria.