Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
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Basin-wide Environmental Flow Regime in the Orange-Senqu River Basin

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1. Introduction

1.1 Background

The Orange-Senqu River basin is one of the larger river basins in southern Africa, with a catchment just under one million km2 (Figure 1.1). The river rises in the water-rich highlands of Lesotho, as the Senqu River, which is augmented by the flows from, inter alia, the Malibamatso, Mashai and Sequnyane River, before crossing the border into South Africa, where its name changes to the Orange River. Shortly after entering South Africa, the Orange River is joined by the Caledon River, part of which (the Phuthiatsana, or Little Caledon, River) also originates in Lesotho. Although the mountain region of Lesotho constitutes only 5% of the total area of the Senqu/Orange catchment, it generates nearly 50% of the total run-off of the Orange-Senqu River. After the Caledon confluence, the next major confluence is with the Vaal River, which is by far the largest tributary of the Orange River, generating the bulk of the remaining 50% of the natural runoff. The lower 65 % of the catchment is arid to semi-arid in nature, with a mean annual precipitation of around 50 mm and a mean annual potential evaporation of more than 3000 mm/yr. The low rainfall in this lower part of the basin means that the mouth and estuary are highly dependent on the upper parts of the system and the underlying alluvial aquifer for freshwater inputs. Key tributaries in this area are the ephemeral Molopo River from Botswana, and the seasonal Fish River from Namibia.

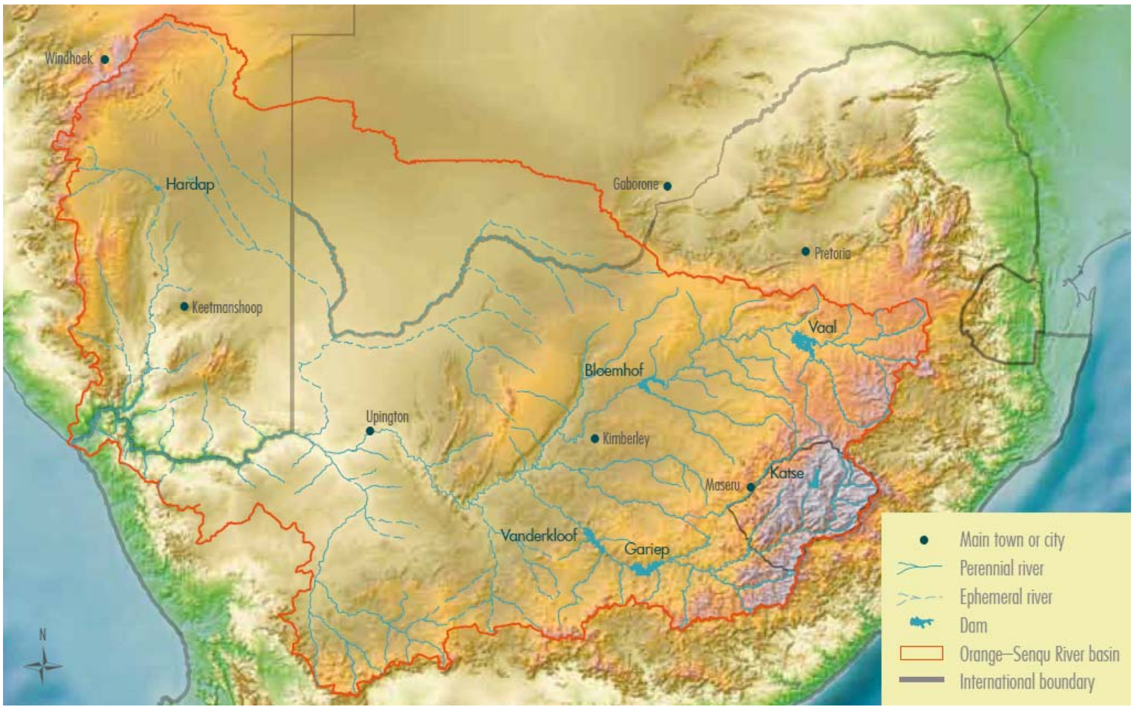


Figure 1: The Orange-Senqu River basin (from TDA, final draft, 2013).

The Orange River is heavily utilized and the anthropogenic influences on the rivers of the Basin are many and varied. The system is highly regulated with 11 major dams, and many smaller dams and diversion weirs, within its basin. As a result of the impoundments and other abstractions, it is currently estimated that the mean annual runoff (MAR) reaching the Orange-Senqu River Mouth, has been reduced to about 41% of the natural MAR (some 11 300 million m3; Rivers for Africa 2013). The reduction in volume has been accompanied by other changes to the flow regime as a result of activities such as hydropower (Senqu, Vaal, mainstem), irrigation releases from dams resulting in constant (and elevated) dry season flows, increased sediment supply from poorly-managed catchment areas (Senqu and Caledon), and poor water quality from point- and non-point sources (Vaal) and mining (mainstem and estuary).

The Orange River Estuary (28°38' S; 16°27' E) is one of only two estuaries of perennially flowing rivers on the arid west coast of southern Africa. The South African portion of the estuary was declared a RAMSAR site in 1991, mainly because of its importance for waterbirds. Namibia followed suit, and in 1995, the Orange River Estuary became one of the first transfrontier RAMSAR sites in southern Africa. However, many of the RAMSAR requirements have not been implemented, and the resultant deterioration of the mouth's general condition, in particular the saltmarsh, placed the South African portion on the Montreux Record, which lists RAMSAR Wetlands in need of urgent conservation attention.

The four riparian states are strongly committed to a joint, basin-wide approach to addressing threats to the shared water resources. This commitment led to the agreement on the establishment of the Orange-Senqu River Commission in 2000 (ORASECOM). ORASECOM acknowledges that future river basin management in the Orange-Senqu River Basin will need to balance competing water uses, and deal with the increasing rates of human-induced change and the mounting concerns about the causes and consequences of this change. One of the main aspects of this will be to ensure that sufficient water is left in the riverine ecosystem for it to continue to function in a predetermined ecological condition and provide for the people in the basin. This water is known as the Environmental Flow (EFlows; Box 1.1).

Box 1.1 Definition of EFlows

EFlows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (Hirji and Davis 2009).

The provision of water for the protection of the riverine and estuarine ecosystems, and the control of unwanted consequences of degradation, has long been recognized as a key factor in the management of the Orange Basin. In the 1970s and into the 1980s blackflies were controlled using water-flow manipulation (Myburg and Neville 2003), and in the late 1980s, the Orange River Environmental Task Group was formed to assess the EFlow requirement of the Orange River between Vanderkloof Dam (then PK le Roux Dam) and the mouth (ORETG 1990). Since then, EFlow assessments have been done for various parts of the basin (Sections 3). To our knowledge, however, only those for the Senqu sub-basin in Lesotho are being actively implemented and monitored (Section 4).

1.2 Scope of the assignment

This assignment covers:

A brief assessment of existing relevant environmental flow studies

- A summary of:
    - EFlow methodologies
    - Key findings and identification of gaps
- A summary of the state of implementation of EFlows in the four Orange-Senqu basin states
- A list of the key components of a harmonised, basin-wide EFlows implementation and monitoring regime, with an outline of key activities required to establish such a regime.

This assignment does not cover comment on or analysis of the validity of any of the results for EFlows in the Orange-Senqu Basin. These have been used as stated in the respective studies.

1.3 This report

This report starts with the identification of key components for basin-wide implementation of EFlows (Section 2). This provides the background against which the key findings and methodologies of environmental flow studies completed in the Orange-Senqu Basin are assessed (Section 3), and implementation initiatives discussed (Section 4). The key components for implementation are then re-visited in the context of work already done in the Orange-Senqu River Basin (Section 5).

2. Key components for the implementation of harmonised basin-wide EFlows

Much has been written about what is needed for EFlows implementation (e.g., Dyson et al. 2003; Postel and Richter 2003; Hirji and Davis 2009; Dollar et al. 2010; King and Pienaar 2011; Paredes-Arquiola et al. 2011; Arthington 2012), but there are few practical examples where this has been achieved at a basin scale, and fewer still where a full suite of recommendations has been applied from which to take guidance. There is, however, general agreement that the key components for successful implementation of EFlows should encompass the activities listed in Figure 2.1 (overleaf). There is also general agreement that the details will change, and/or the required activities expand, as implementation progresses.

One of the main challenges of EFlow implementation is the level of integration required between technical, legal, administrative and political processes, and the private and government sectors. This integration becomes increasingly important and difficult with increasing development of the basin. In basins (or sub-basins) where the demand on water resources is low relative to natural supply, implementation of EFlows can be achieved through one or two technical studies aimed at defining the EFlows, limited public participation and a simple legislation and implementation process. In basins where the demand on water resources is high relative to natural supply, however, decisions on the volume and distribution of water allocated to an EFlows often require complex technical studies that explore numerous scenarios, require difficult trade-offs, extensive public participation both during the technical work and for legislating the outcomes, and onerous policing and monitoring regimes to ensure compliance. They also require interventions that depend on people changing their perceptions and behaviour, and thus need broad governmental and societal support, coupled with a programme of technical assistance and cross-disciplinary capacity building.

The activities and outcomes presented in Figure 2.1 are arranged in three phases (Preparation, Setup, and Compliance and integration) and according to three categories. The technical work encompasses the information on the hydrology, and on the ecosystem and the people who depend on it, needed to assess options, make decisions and set targets; and the legal and administrative provisions that need to be in place before EFlows can be implemented. The technical work should be both supported by, and inform liaison with, the government(s) and other stakeholders in the basin, and by an on-going programme of capacity building across all sectors. This should be aimed at ensuring that the technical work addresses the issues of importance to government and stakeholders, that local knowledge is incorporated and valued, and that there is an understanding of and backing for EFlows. Each phase ends with a clear outcome that provides the stepping-off point for the next phase.

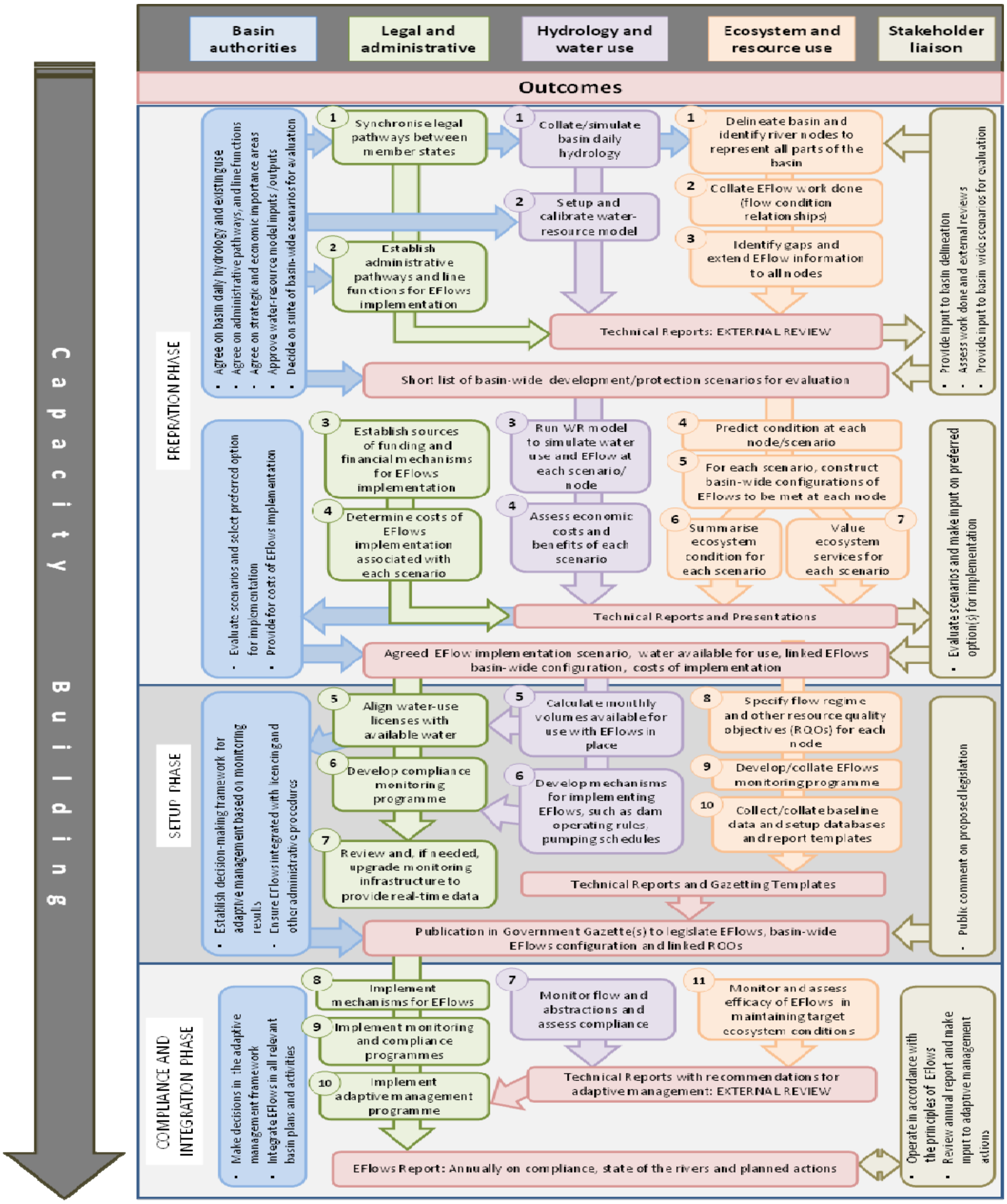


Figure 2: Key components for implementation of harmonised basin-wide EFlows

The legal and administrative, and technical activities in each of the three phases are explained below, and then discussed in the context of the Orange-Senqu River Basin in Section 5. Tasks are numbered according to Figure 2.1.

2.1 Phase 1: Preparation

The Preparation Phase is aimed at collating and organising the information, tools and agreements and, where necessary, generating additional information to fill gaps, all of which will be needed for subsequent phases. Chief among these are requirements for resolution on the administrative and legal pathways, the baseline hydrological data, the models to be used in the implementation process, delineation of the basin and the generation of EFlow data for all representative key points within the basin. Mid-way through the Preparation Phase there is agreement on a suite of basin-wide development/protection scenarios for evaluation

In the second part of the Preparation Phase the technical information on a range of development/protection scenarios is generated and the scenarios are evaluated to arrive at an agreed EFlows implementation scenario. The EFlow scenarios chosen for assessment will each provide information on the environmental, economic and social outcomes (three pillars of sustainability). This is a technical task aimed at presenting each scenario in a manner that is understandable to the stakeholders so as to facilitate discussion, and recommendations for an implementation scenario. The decision on an implementation scenario is a social and political one, informed by scientific information.

Phase 1: Legal and administrative tasks

A clear legal and administrative pathway to protect EFlows is necessary before stakeholders will commit or agencies will fund EFlow implementation. A serious attempt to manage EFlows will not occur unless clear policy decisions have been taken at the appropriate level of government (Dyson et al. 2003), and the legal and administrative requirements are clearly understood and catered for in the implementation process.

Task 1: Synchronise legal pathways between member states: It is important that the requirements of any and all legislation relevant to EFlows is understood so that the EFlow implementation activities provide the required information in the correct format, and that consultation and decision-making processes meet legal requirements. In situations where the basin is shared by more than one country, the pathways and mechanisms for legislating EFlows need to be aligned.

Task 2: Establish administrative pathways and line functions for EFlows implementation: The administrative load associated with EFlows implementation is potentially great (Figure 2.1), particularly in a situation where the basin is shared by more than one country. The administrative processes, reporting procedures and people responsible for each facet of implementation need to be clearly defined and understood.

Task 3: Establish sources of funding and financial mechanisms for EFlow implementation: Successful implementation of EFlows is directly linked to funding. Well-funded programmes are likely to be more successful as there is a clear commitment to support them, and paid specialists are employed to drive the process. Many a well-intentioned plan fails simply because it is nobody's paid job to make it work, and everyone else is too busy to do it part-time. Funds for EFlow implementation should thus be secured and realistic.

Task 4: Determine the costs of EFlow implementation associated with each scenario: The objective of this task is to ensure that authorities and stakeholders are made aware of any discrepancies in the cost of implementation of scenarios. For instance, a scenario that earmarks a sub-basin for conservation so that it can provide the EFlows required in downstream reaches may be cheaper to implement than a scenario that relies on dam releases to meet those requirements. This information should form part of the assessment of economic costs and benefits of each scenario.

Phase 1: Hydrology and water use tasks

Task 1: Collate/simulate basin daily hydrology: The objective of this task is to establish a >45-year time series of naturalized daily flows for key locations in the basin (see Ecosystem and resource use Task 1). Often, particularly in situations where the basin is shared between countries, agreement on the hydrological data sets to be used is at least as important as the accuracy of those data. Once established, the data will form the basis of any EFlow assessments, scenario evaluation, calculation of water use, licensing, operating rules and monitoring and compliance.

Task 2: Setup and calibrate basin-wide water-resource model: A basin-wide water-resource model is central to EFlows implementation and will be used in all phases. It is thus essential that it is set-up and calibrated early, and that the authorities and stakeholder have confidence in its outputs.

Task 3: Run WR model to simulate water use and EFlows at each scenario/ node: The objective of this task is to simulate in-channel flows and water used for other purposes for the scenarios selected in Phase 1. The volume and timing of the in-channel flows will be used to predict the ecological condition of the rivers and estuary, and the volume and timing of the available water will inform the economic analyses.

Task 4: Assess economic costs and benefits of each scenario. This task will provide the information needed to assess the 'economic pillar' of sustainability.

Phase 1: Ecosystem and resource use tasks

Task 1: Delineate basin and identify river nodes to represent all parts of the basin: The primary objective of this task is to divide the basin into relatively homogeneous river zones in terms of biophysical characteristics and land-use and to provide the zonational context for EFlow sites to enable decisions on whether existing data (see Collate EFlow work done) can be extrapolated between sites, and whether any new EFlow assessments are required. Nodes are located along the rivers at points where the river changes, such as at main tributaries and/or where information on how the river could change is needed to help the interpretation of how this could impact the people.

Task 2: Collate EFlow work done: The objectives of this task are to identify whether EFlow assessments exist for any of the nodes identified in the delineation exercise. This information, together with a basic review of the methodologies used and the results generated by any such study (studies), will form the basis for the decisions needed in the gap analysis below. Ideally, the assessments should be in a form that defines the relationship between flow changes and aspects of the ecosystem of importance for assessing overall condition and/or of importance to one or more groups of stakeholders, so that the outcomes for various flow scenarios can be provided to aid decision making (Phase 2). EFlow assessments also provide other important contextualisation information such as the key habitats and ecological features of the river, present ecological status, recommended attainable condition and information that can inform a monitoring programme.

Task 3: Identify gaps and extend EFlow information to all nodes: EFlow assessments usually focus on one or more sites within a basin. For basin-wide implementation, these site-based assessments need to be extended across the whole basin and harmonised to ensure that they can be implemented. Depending on whether or not EFlow assessments exist for representative parts of the basin, this exercise can range from commissioning full EFlow assessments to simple extrapolation of existing EFlow information to new nodes.

Task 4: Predict condition at each node/scenario: Each scenario will result in different flow regimes at different nodes. The objective of this task is to use the completed EFlow assessments to predict the ecological condition likely to result from the flow regime at each node. This task will provide the basis for the ecological information put forward for the scenarios (the ecosystem pillar).

Task 5: For each scenario, construct basin-wide configurations of EFlows to be met at each node: EFlow basin configurations are set such that EFlows at upstream nodes will satisfy the requirements at downstream nodes. This is best done using a calibrated water resource model for the basin. In the absence of this, however, coarser-level cross-checks are possible based on monthly volumes for EFlows (e.g., Umvoto 2013).

Task 6: Summarise ecosystem condition for each scenario: The objective of this task is to summarise the basin configurations of EFlows for each scenario in terms of the overall condition of ecosystems. This is done at an appropriate scale for comparison with the economic and social information for that scenario. This task will provide the information needed to assess the 'ecosystem pillar' of sustainability.

Task 7: Value ecosystem services for each scenario: The objective of this task is to account for, and where possible value, changes in the ecosystem services that the river system naturally provides. These services include goods that may be harvested from the river ecosystem and sold, used directly, or traded, such as water, fish, wild vegetables, medicines, firewood and reeds. Regulating and cultural services should also be valued. These include flood attenuation, water purification, groundwater recharge, bank stabilisation and habitat for species of value to people. This task will provide the information needed to assess the 'social pillar' of sustainability.

Phase 1: Liaison with basin authorities and stakeholders

Buy-in from basin authorities, landowners, the business community and other stakeholders is probably the most important aspect of EFlows implementation. Implementation of EFlows may depend on people changing their perceptions and behaviour, and thus EFlows should be based on informed decisions that have broad societal support, coupled with a programme of technical support and capacity building (Dyson et al. 2003). Establishing a transparent and consultative process from the outset can enhance ownership of EFlows.

This process should include:

- Input to basin delineation from authorities and stakeholders;
- External review of all relevant existing and new technical work;
- Agreement on input and models;
- Consultation and agreement on administrative pathways, and line functions; and
- Consultation and agreement on the suite of basin-wide scenarios to be evaluated in the second part of the Preparation Phase.

Scenarios are a means of exploring possible pathways into the future. They aid discussion and negotiation on what would constitute an acceptable way forward (King et al. 2013). It is critical that the scenarios are chosen by, or in consultation with, all key stakeholders or they stand the risk of being dismissed by these parties at a later stage.

Once this has been achieved, the main responsibility of basin authorities and other stakeholders is to evaluate the EFlow scenarios and select a preferred option for implementation. A wide range of scenarios, from environmental protection to serving the needs of industries, and the effects of climate change, should be evaluated, discussed, and one scenario ultimately agreed upon as the future management pathway for the river system.

Phase 1: Outcomes

The key outcomes of the Preparation Phase are:

- Technical reports on:
    - Legal and administrative pathways
    - Basin hydrology and setting up of the water-resource model
    - Basin delineation and EFlows assessment/consolidation for representative nodes throughout the basin
- Reports from independent external reviewers on the technical reports
- Report on the extent of and feedback from stakeholder consultations
- Basin-wide agreement on hydrology and other input data
- Agreement on a suite of basin-wide development/protection scenarios for evaluation in the Scenario Phase.
- Technical reports and presentations on the various aspects of each scenario, including:
    - Funding sources and mechanisms
    - Implementation costs
    - Infrastructure
    - EFlows for representative nodes throughout the basin

    - Water available for use
    - Economic costs and benefits
    - Evaluations of ecosystem services and resource use.
- Agreement on the implementation scenario, water available for use, linked EFlows basin-wide configuration, and costs of implementation that will be the focus of the Setup Phase.

2.2 Phase 2: Setup

The Setup Phase focuses on developing the information, process and infrastructure required to legislate and operationalise the agreed EFlow implementation scenario. It ends with the legislation of Resource Quality Objectives (RQOs; including the EFlow, that is, the volume and timing of water allocated for river protection) that define the EFlow implementation scenario.

Phase 2: Legal and administrative tasks

Task 5: Align water-use licenses with available water: For EFlow implementation to succeed it is essential that the outcomes of Hydrology and Use Task 5 (done in Phase 2, see below) are used to evaluate the granting of licenses. This is particularly important in heavily allocated basins, where even slight over allocation of resources for off-stream use can result in a failure to meet EFlow targets. Aligning water-use licenses with available water can also reduce the administrative burden by identifying sub-basins that are fully- or over-allocated. If a basin is fully allocated it should be declared closed for new license applications. Over-allocated basins should also be closed, and mechanisms for clawbacks set in place (This is aligned to South African Department of Water Affairs programmes, such as compulsory licensing, which are concerned with verification and validation of water use).

Task 6: Develop compliance monitoring programme: The objective of this task is to develop a programme for monitoring river flows, abstractions, releases and diversions aimed at evaluating compliance with agreed EFlows and associated mechanisms for implementation. It should stipulate the type of data to be collected, monitoring locations, monitoring schedule, infrastructure requirements, method statements and downloading protocols, data analysis and reporting, roles and responsibilities, quality assurance measures, reporting and costings. Importantly, it should also make provisions for sanctions to be applied if and when a user is found to be non-compliant. It should be undertaken in close cooperation with Hydrology and Water Use Task 6 and Ecosystem and Resource Use Task 9, and should provide input to the review of monitoring infrastructure in Legal and Administrative Task 7.

Task 7: Review and, if needed, upgrade monitoring infrastructure to provide real-time data: The objective of this task is to review the existing monitoring and measuring infrastructure in the basin in the context of the EFlow implementation scenario, including flow gauging stations, water level gauges, and pump gauges, and where necessary upgrading it to a standard that will enable effective compliance monitoring. Real-time data are recommended as they provide almost immediate acquisition of data, which is useful in, for instance, flood forecasting required to match flood releases to rainfall, or policing of run-of-river abstractions. It also reduces the reaction time to any non-compliance.

Phase 2: Hydrology and water use tasks

Task 5: Calculate monthly volumes available for use with EFlows in place: The objective of this task is to identify the amount of water that is available for water-use allocation, if any, in different months of the year. This information is needed to inform licensing activities (Legal and Administrative Task 5). If only the water that is required to remain in the river (EFlows), and not that available for allocation, is identified, this leaves the onus on the administrators of licenses to complete complicated and difficult calculations that they may not be in a position to do, which can result in inappropriate granting of licenses and over-allocation of the water resources.

Task 6: Develop mechanisms for implementing EFlows, such as dam operating rules, pumping schedules: The mechanisms for implementing EFlows include active management of infrastructure, such as operating rules for dams, and restrictive management, for example through controlling the volume and timing of abstractions and diversions. A third, but also important, mechanism is land-use management, and catchment restoration and/or protection aimed at those land use activities that intercept or exacerbate overland flows. The objective of this task is to align the operation of dams, diversions and pumps, and if relevant land-use management, to meeting the agreed EFlows.

Phase 2: Ecosystem and resource use tasks

Task 8: Specify flow regime and other resource quality objectives (RQOs) for each node: RQOs are descriptive statements and attendant numerical values for a range of operational objectives associated with the EFlow implementation scenario. The descriptions are narrative and qualitative statements that describe the objectives for each river reach represented by a node. They should be meaningful to stakeholders and water managers, and give direction for whatever action is necessary to achieve the vision for the resource. The numerical limits are a quantitative measure of the RQOs that can be used for monitoring, such as an upper limit for salt concentrations or a lower population size limit for fish. Possibly the most important numerical limits, however, are the actual hydrological (EFlow) requirements for each node.

Task 9: Develop/collate EFlows monitoring programme: The EFlows monitoring programme is aimed mainly at efficacy monitoring, and should stipulate the type of data to be collected, monitoring locations, monitoring schedule, infrastructure requirements, method statements and sampling protocols, data analysis and reporting, roles and responsibilities, quality assurance measures, reporting and costings. Unlike the hydrological component of the EFlow monitoring, this component focuses in the structure and functioning of the aquatic ecosystems themselves. It should be undertaken in close cooperation with Hydrology and Water Use Task 6 and Legal and Administrative Task 6.

Task 10: Collect/collate baseline data and setup databases and report templates: The objectives of this task are to verify existing baseline data, and initiate programmes to augment the existing data and build a robust baseline dataset that will underpin the implementation of the EFlows monitoring in Phase 3. In addition, an EFlow Baseline Database should be established for the storage of baseline and compliance monitoring data and performance of basic analysis, and the templates for reporting should be designed in accordance with the expected outputs.

Phase 2: Liaison with basin authorities and stakeholders

In Phase 2, basin authorities should be tasked with establishing a decision-making framework for adaptive management (Bornmann et al. 1999) based on monitoring results. It is highly likely that potentially difficult decisions with respect to adaptive management of the condition of aquatic ecosystems in the basin will be required, and making such decisions will be far easier within an already established and agreed decision-making framework. Basin Authorities should also provide the necessary encouragement for the integration of EFlows into licencing and other administrative procedures.

In addition, stakeholders should be given an opportunity to comment on the proposed legislating of EFlows, through established gazetting processes.

Phase 2: Outcomes

The key outcomes of the Setup Phase are:

- Reports on:
    - Water available for use at a monthly time-step, and mechanisms for implementing EFlows
    - Administrative adjustments undertaken to align water-use licenses with available water
    - Upgrades to monitoring infrastructure to provide real-time data
    - Resource quality objectives (RQOs)
    - EFlows monitoring programme
    - Baseline data.
- Publication in Government Gazette(s) to legislate EFlows, basin-wide EFlows configuration and linked RQOs.

2.3 Phase 3: Compliance and integration

The Compliance and Integration Phase is an on-going phase where the monitoring and compliance programmes are effected, EFlows integrated into relevant basin activities, and adaptive management is realised.

Phase 3: Legal and administrative tasks

Task 8: Implement mechanisms for EFlows: This task entails deploying a team of officials with the job of ensuring that water users are aware of and using the implementation mechanisms designed to meet the EFlows (Hydrology and Water Use Task 6). It also entails collection and collation of suggestions and comments from the users for consideration in the adaptive management programme (Task 10).

Task 9: Implement monitoring and compliance programmes: This task entails deploying technical teams to undertake Hydrology and Water Use Task 7 and Ecosystem and Resource Use Task 11 – see below.

Task 10: Implement adaptive management programme: This task entails ensuring that the principles of adaptive management are applied in terms of consideration of management outcomes and inclusive decision-making. See Phase 3: Liaison with Basin Authorities and Stakeholders below.

Phase 3: Hydrology and water use tasks

Task 7: Monitor flow and abstractions and assess compliance: The flow and abstraction monitoring should have two main objectives: (i) to verify that the management interventions designed in Hydrology and Water Use Task 6 produce the required flow patterns at the EFlow sites, and (ii) to check user compliance with those management interventions.

Phase 3: Ecosystem and resource use tasks

Task 11: Monitor and assess efficacy of EFlows in maintaining target ecosystem conditions: The objective of the ecosystem monitoring is to assess the condition of the rivers for comparison with the baseline data sets and to provide data that can be used to assess the overall efficacy of the EFlows in meeting their stated objectives, and to provide data that can be used as motivation for adjusting the EFlows, as needed, as part of the adaptive management programme. The results should also be used to evaluate whether the parameters selected for inclusion in the Monitoring Programme are appropriate, and whether parameters should be added or subtracted.

Phase 3: Liaison with basin authorities and stakeholders

In the Compliance and Integration Phase, Basin Authorities will be required to make decisions with respect to water use, EFlow allocation and related activities in accordance with the monitoring results and the decision-making processes in the adaptive management framework. Furthermore, for them to be effective, EFlows should be seen within the context of applying IWRM in a river basin. EFlows will only ensure a healthy river if they are part of a broader package of measures, such as soil protection, pollution prevention, and protection and restoration of habitats (IUCN 2003). As such, it is imperative that the Basin Authorities actively promote the integration of EFlows into all basin-related plans and policies, such as national action plans, basin management plans, estuary and marine management plans, development plans, conservation plans and sectoral policies. Avenues for enhancing the successful implementation of EFlows should also be sought. For instance, incorporation of EFlows into existing incentives is one option for facilitating their implementation.

The annual reports should be made available to stakeholders for review and input to adaptive management decisions. Individual farmers, municipal officials, dam operators and others with direct responsibility for use or abstraction of water from the rivers, wetlands or estuary should ensure that they operate within the provisions principles of the agreed EFlows.

Phase 3: Outcomes

The key outcomes of the Compliance and Integration Phase are:

- Implementation of mechanisms for EFlows
- Implementation of monitoring and compliance programmes
- Implementation of the adaptive management programme.
- Annual:
    - Technical Reports with recommendations for adaptive management
    - Summary Reports on compliance, state of the rivers and planned actions.

3. EFlow assessments in the Orange-Senqu River basin

3.1 Previous assessments

EFlow assessments have been done for several river reaches in the Orange-Senqu Basin, and in some cases more than one study has been done for the same area. Detailed methodological differences aside, these assessments vary in terms of their basic approach and the level of detail at which they were done (see in Box 3.1; Table 3.1).

Box 3.1 Levels of detail

For the purposes of this review, the levels of detail at which the different environmental flow assessments were done have been categorised in alignment with the South African Department of Water Affairs categories: Desktop, Rapid, Intermediate and Comprehensive.

The following basic definitions apply here:

Desktop: No fieldwork. Monthly hydrological data. Assessment done using the Desktop Model (Hughes and Hannart 2003) or some other hydrological index method, such as the Tennant Method (Stalnaker and Arnette 1976). Uses monthly hydrological data.

Rapid: Limited field work (usually < ½ day), ranging from an assessment of Present Ecological Status (Rapid I) up to, and including, basic hydraulics and/or biological sampling (Rapid III). Assessment done using Desktop Model (Hughes and Hannart 2003). Uses monthly hydrological data.

Intermediate: One full field visit to collect biophysical data. Full hydraulics and biological sampling. Assessment done using Habitat Flow Stressor Response (HFSR; Hughes and Louw 2010) or DRIFT (King et al. 2003; Brown et al. 2013). Uses daily hydrological data.

Comprehensive: Two full field visits to collect biophysical data. Full hydraulics and biological sampling. Assessment done using Habitat Flow Stressor Response (HFSR; Hughes and Louw 2010) or DRIFT (Brown et al. 2013). Uses daily hydrological data.

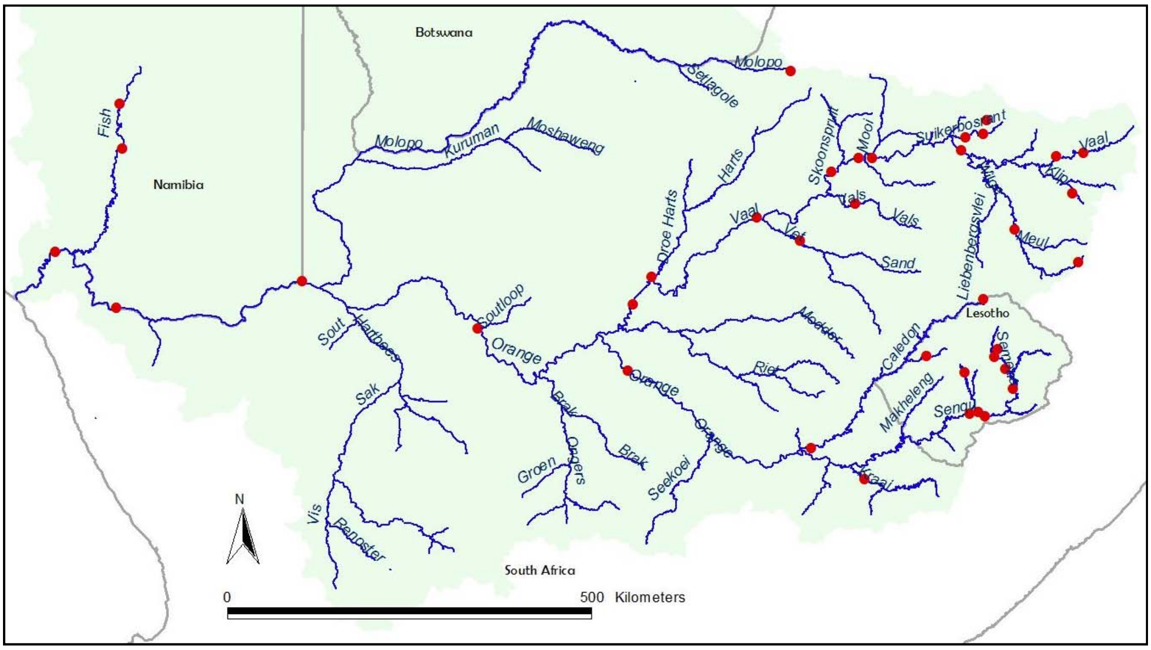
Desktop and rapid assessments in the basin were done mostly using the Desktop Model (Hughes and Hannart 2003) with the exception of some early work on the lower Orange River (ORETG 1990; Venter and Van Veelen 1996), which used a desktop version of (what became) the Building Block Method (King and Louw 1998), and the EFlows for Polihali Dam on the upper Senqu, which used DRIFT. Most of these have been superseded by more detailed studies. In fact, the amount of more-detailed EFlows work done in the Orange-Senqu River basin makes redundant most if not all of the desktop-level assessments done to date. The reasons for this are explained in Section 3.2.

Table 3 1 Relevant EFlow assessments for rivers in the Orange-Senqu River basin.

Sub-basin	*Period*	*Rivers*	*Method*	*Level of detail*	*Delineation*	*Number of sites*	*Key references*
Senqu	1997-2002	Matsoku, Malibamatso, Senqu, Senqunyane	DRIFT(1)	Comprehensive	Yes	7	Metsi (2000), LHDA (2003)
	2002	Nqoe	Treaty provision (Article 7(10): 100% of natural flow of Nquoe River from Muela	N/A	No	1	LHDA (2002)
	2006-2007	Senqu	DRIFT(1)	Rapid	No	1	Brown et al. (2008)
	2013-	Senqu	Not yet decided	Intermediate	Unknown	unknown	ongoing
Caledon	2005-2006	Phuthiatsana	DRIFT(1)	Intermediate	No	1	Southern Waters (2006).adjusted for updated hydrology in metholong authority (2012)
	2008-2010	Caledon	HFSR	Intermediate	Yes	3	Louw and Koekemoer (2010)
	2008-2010	Kraai	HFSR	Intermediate	Yes	1	Louw and Koekemoer (2010)
Vaal	2009-2012	Upper Vaal	Desktop model	Rapid	Yes	5	DWA (2012)
	2009-2012	Upper Vaal	HFSR	Intermediate	Yes	6	DWA (2012)
	2007-2011	Mid-Vaal	HFSR	Intermediate	Yes	4	DWA (2009)
	2007-2011	Lower Vaal	HFSR	Intermediate	Yes	4	DWA (2009)
Molopo	2008-2010	Molopo	Flow management	Intermediate	Yes	1	Louw and Koekemoer (2010)
Fish	2010-2013	Fish	HFSR	Intermediate	Yes	2	Rivers for Africa (2013a)
Orange	2008-2013	Orange	HFSR	Intermediate	Yes	5	Louw and Koekemoer (2010), Rivers for Africa (2013b)

Table 3.1 lists the most relevant studies done for rivers in the basin, and the locations of the EFlow sites are illustrated in Figure 3.1.

Figure 3: Map showing the location of the Eflow sites



3.2 EFlow methodologies applied

The three main methods used for EFlow assessment for the rivers in the Orange-Senqu River Basin are (Table 3.2):

- For intermediate and comprehensive studies; DRIFT (King et al. 2003) and Habitat-Flow Stressor Response (Hughes and Louw 2010),
- For desktop and rapid assessments; the Desktop Model (Hughes and Hannart 2003).

HFSR and DRIFT(1) are similar in terms of the information they require, and the outputs they provide. They differ in terms of the detailed ecological information used to evaluate the implications of different flows for the riverine ecosystem. It is unclear whether the results of the two methods are comparable in terms of their predicted impacts associated with flow change because there are no studies where they have been applied simultaneously. However, broad level evaluations suggest that they produce comparable outputs.

There is a broad regional differentiation in the intermediate and comprehensive studies with the DRIFT(1) methodology being applied in Lesotho, and the HFSR being applied in South Africa and Namibia. Both HFSR and DRIFT focus on developing relationships between different aspects of the riverine ecosystem and flow and can thus be used, within reason, to explore alternative flow scenarios. This is important in the context of the key activities provided in Section 2, which are underpinned by the evaluation of possible EFlow scenarios. That said, there are some qualifications with respect to the applications of both DRIFT and HFSR in the Orange-Senqu Basin, and, given these, it is likely that the evaluation of any additional scenarios will require some input from the original team leaders.

The DRIFT(1) assessments for the Senqu Basin (excl. those for the upper Senqu at Polihali) were done in the late 1990s, and represent the first ever application of the DRIFT methodology. The original (1998) DRIFT databases are unwieldy and difficult to use, however, these were updated in 2005 using the original relationships. The updated databases are similar to those used for the Upper Senqu (Consult 4/Seed 2008) and the Phuthiatsana (SMEC 2006; MA 2012). All of the databases are somewhat dated relative to the most recent DRIFT(2) applications but are able to provide an indication of the ecosystem response to new flow scenarios.

HFSR was used to assess the environmental flow requirements for sites in the Vaal Basin (2007-2011), the Upper Orange and Caledon Rivers (2008-2010), and the lower Orange and Fish Rivers (2011-2013). The Client (South African DWA) reportedly had some concerns about the original applications of the HFSR in the middle and lower Vaal catchment (DWA 2009), but these were subsequently corrected (DWA 2011). All of the HFSR applications are relatively recent (2010-onwards), and are all able to provide an indication of the ecosystem response to new flow scenarios.

Some of the sites in the Vaal Basin and upper Orange River were not suitable for application of HFSR, and rapid assessments using the Desktop Model were done instead. The Desktop model cannot be used for assessing scenarios, but once calibrated, is able to provide flow regimes to meet a range of ecological conditions. These can, in turn, be checked against scenario flow regimes to see which comes closest. Possibly one of the most valuable features of the Desktop Model is the IFR Edit component that allows the Desktop Model to be calibrated using data from comprehensive or intermediate environmental flow assessments at similar sites in the basin. This makes the Desktop invaluable for extrapolating environmental flow data from one part of the river system to another.

Table 3 2 Comparative summary of process and outputs of EFlow methodologies used for the river.

Considerations	*HFSR*	*DRIFT(1)*	*Desktop*
Software	Flow Stressor Response model within SPATSIM	Excel databases	Desktop Model within SPATSIM
Hydrology	Daily data	Daily data	Monthly data in WR90 format
Low flows	Stress indices set for fish and macroinvertebrates	Response curves linking biophysical indicators to flow change	Pro-rata distribution of MAR in accordance with results of detailed Eflow assessments at similar sites
High flows	Predictions of change in indicators linked to occurrence of floods of different magnitude		
Output	Ecological categories	Ecological categories, plus predicted changes in abundance of indicators	Ecological categories
	Annual volume of EFlows	Annual volume of EFlows	Annual volume of EFlows
	Monthly discharge and volume lowflows for maintenance and drought	Monthly flow duration curves (discharge) and volume for lowflows	Monthly lowflows for maintenance and drought
	Timing, duration, peak and volume of intra-annual floods	Timing, duration, peak and volume for intra-annual and inter-annual floods	Monthly volume for intra-annual floods
Can be used to evaluate flow scenarios?	Yes	Yes	Limited
Can be used to extrapolate EFlows?	No	Limited	Yes

3.3 EFlows assessment for the estuary

The impact of reduced freshwater inflows on the condition of the Orange-Senqu River Estuary has been part of various assessments over the years. However, it was not until recently that a more detailed EFlow assessment was done for the estuary (CSIR 2013). It involved:

- Development and implementation of a baseline monitoring programme covering flow-related biophysical parameters
- Assessment of non-flow related impacts
- Description of the Present Ecological State
- Determination of EFlows for maintaining a range of ecological conditions
- Recommendations on attainable and satisfactory EFlow outcomes for the estuary
- Design of a long-term monitoring programme.

The method used does allow for the evaluation of additional scenarios, but may require additional specialist input.

3.4 EFlows assessments on other systems

Little or no EFlow work has been done on the other major systems in the Orange-Senqu Basin. A flow management plan was provided for the Molopo Wetland as part of the Middle Orange River assessments (see Table 3.1), and some work has been done on high-altitude wetlands in Lesotho (ORASECOM, 2008a and 2008b).

3.5 Key findings

The natural MAR (nMAR), PES (see definitions in Table 3.3), recommended/target ecological condition, annual volume allocated to EFlows to maintain the target ecological condition and that volume expressed as a percentage of nMAR for the EFlow assessments in the Orange-Senqu Basin are presented in Table 3.4. Their locations are illustrated in Figure 3.2.

There are key volumetric mismatches, even at the level of annual volumes, which would need to be resolved before implementation. For instance, EFR 05, on the Orange River immediately upstream of the estuary requires 14% of nMAR to maintain its ecological condition, whereas as the estuary requirement is 39.50%.

These mismatches are likely to be more marked at a monthly or daily (required for floods) level of resolution.

Table 3 3 Definitions of the Present Ecological State (PES) categories (after Kleynhans 1996).

Ecological Category	*PES % score*	*Description of the habitat*
A	90-100%	Still in a Reference Condition.
B	80-90%	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
C	60-80%	Moderately modified from the Reference Condition. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	40-60%	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	20-40%	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-20%	Critically / Extremely modified from the Reference Condition. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

Table 3 4 Key findings from EFlow assessments in the Orange-Senqu River basin.

Senqu sub-basin

River	*Tributary*	*Tributary*	*Site*	*Method*	*nMAR (MCM)*	*PES*	*Target EC*	*EFlow (MCM)*	*EFlow as % of nMAR*	*x_coord*	*y_ccoord*
Senqu			Polihali	DRIFT(1)	730	C	D	136	18.63%		
		Matsoku	IFR 1	DRIFT(1)	87	A	C	34.8	40.00%	28.56417	29.25583
	Malibamatso		IFR 2	DRIFT(1)	576	B	D	88.1	15.30%	28.52556	
	Malibamatso		IFR 3	DRIFT(1)	774	B	C	224.46	29.00%	28.65536	29.49861
Senqu			IFR 4	DRIFT(1)	1572	B	B	Dependent on IFR 3	28.75528	29.73889	
Senqu			IFR 5	DRIFT(1)	1924	B	B	Dependent on IFR 3	28.40778	30.06556	
	Senqunyane		IFR 7	DRIFT(1)	355	B	D	78.1	22.00%	28.15417	
Senqu			IFR 6	DRIFT(1)	3330	B	B	Dependent on IFR 3 and 7	28.32008	30.01623	

Caledon sub-basin

River	*Tributary*	*Tributary*	*Site*	*Method*	*nMAR (MCM)*	*PES*	*Target EC*	*EFlow (MCM)*	*EFlow as % of nMAR*	*x_coord*	*y_ccoord*
		Nqoe	IFR 11	N/A	5	B	B	4.8	100.00%		
		Phuthiatsana	EF Site 1	DRIFT(1)	73	C/D	C/D	15.39	21.09%	27.68707	29.33586
		Kraai	EFR07	HSFR	683	C	C	135	19.78%	26.92056	
	Caledon		EFR06	HSFR	1348	C	C	259.9	19.28%	26.27088	30.4523
Orange			EFR01	N/A	6737	C	C	None	24.00927	29.516	

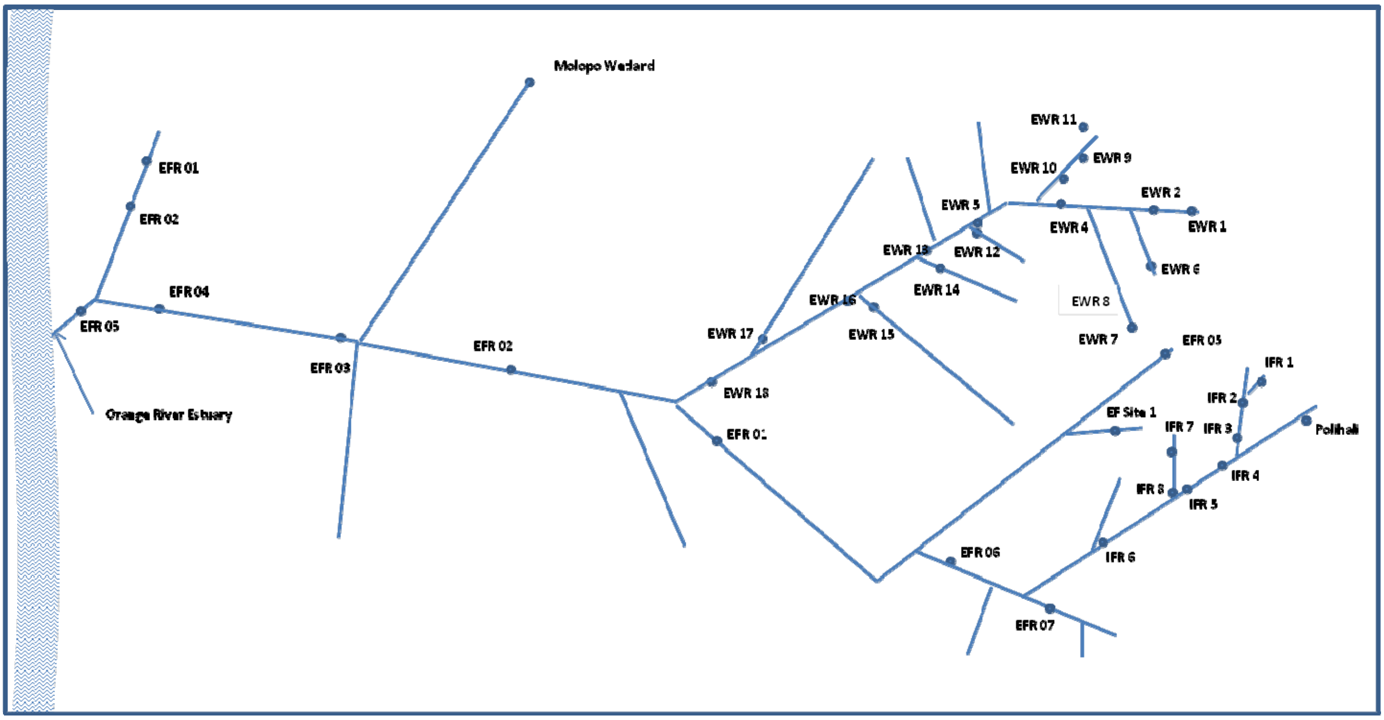
Vaal sub-basin

River	*Tributary*	*Tributary*	*Site*	*Method*	*nMAR (MCM)*	*PES*	*Target EC*	*EFlow (MCM)*	*EFlow as % of nMAR*	*x_coord*	*y_ccoord*
	Vaal		EWR 1	Desktop	332	B/C	B	130.92	39.40%	29.61384	26.8728
	Vaal		EWR 2	HSFR	458	C	C	62.27	13.61%	29.27929	
		Klip	EWR 6	HSFR	95	B/C	B/C	25.3	26.54%	29.48503	27.36166
	Vaal		EWR 3	HSFR	858	C	C	122.67	14.30%	8.72971	26.99087
		Wilge	EWR 7	HSFR	23	A/B	C	10.77	45.89%	29.55827	28.20185
		Wilge	EWR 8	HSFR	474	C	C	64.45	13.59%	28.76778	
	Vaal		EWR 4	Desktop	1977	C	B/C	None	28.1123		26.84262
		Suiker-bosrand	EWR 9	HSFR	31	C	B/C	10.85	34.65%	28.38197	26.6467
		Suiker-bosrand	EWR 10	Desktop	149	C/D	C/D	61.35	41.10%	28.16798	26.68137
		Blesbok-spruit	EWR 11	Desktop	29	D	D	6.18	21.21%	28.42488	26.47892
	Vaal		EWR 5	Desktop	2288	C/D	C	-	-	27.01367	26.93243
	Vaal		EWR 12	HSFR	2546	D	D	832.79	32.70%	26.85025	26.93615
	Vaal		EWR 13	HSFR	2654	C/D	C/D	859.82	32.39%	26.52185	27.10413
		Vals	EWR 14	HSFR	146	C/D	C/D	24.85	17.05%	26.8132	27.48685
		Vet	EWR 15	HSFR	413	C/D	C/D	46.1	11.16%	26.12569	27.93482
	Vaal		EWR 16	HSFR	1699	D	D	422.24	24.85%	25.59564	27.65541
		Harts	EWR 17	HSFR	148	D	D	107.2	72.51%	24.30305	28.37694
	Vaal		EWR 18	HSFR	3347	C	C	257.39	7.69%	24.07578	28.70758
	Vaal		EWR 19	HSFR	404	C	2	171.1	42.37%		

Orange sub-basin

River	*Tributary*	*Tributary*	*Site*	*Method*	*nMAR (MCM)*	*PES*	*Target EC*	*EFlow (MCM)*	*EFlow as % of nMAR*	*x_coord*	*y_ccoord*
Orange			EFR02	HSFR	10573	C	C	1797	17.00%	22.16225	29.0055
Orange			EFR03	HSFR	10513	C	B	2341	22.27%	19.9983	28.4287
Orange			EFR04	HSFR	10335	C	B/C	1478.9	14.31%	17.71696	28.7553
	Molopo		EFR08	Flow Plan	10	C	B/C	3.53	34.17%	26.01592	25.8812
	Fish		EFR 01	HSFR	-	B/C	B	Flood requirements for Hardap Dam	24.00927	29.516	
	Fish		EFR 02	HSFR	613	B/C	B/C	245.20	40.00%	22.16225	29.0055
Orange			EFR 05	HSFR	11373	B/C	B	1667.32	14.66%	28.3875	28.6508
Orange	Estuary	Estuary	Estuary	Estuary	11373	D	C	4469.77	39.50%		

Figure 4: Schematics of the locations of EFlow sites listed in Table 3.4



4. Current state of implementation of Eflows

The state of implementation of EFlows for the sub-basins in the four basin states is summarised in Table 4.1. A distinction is drawn between active implementation (including monitoring) of EFlows, and situations where the recommended environmental flow is lower than the present-day (2010/11) flows in the river, which means that the EFlows are being met even if they are not being actively implemented.

Table 4 1 Summary of the state of implementation of EFlows for the sub-basins.

Sub-basin	*Rivers*	*Implementation and monitoring of EFlows?*	*EFlows met by flows at 2010/11*
Senqu	Malibamatso	Yes	Yes
	Matsoku	Yes	Yes
	Senqu	Yes	Yes
	Senqunyane	Yes	Yes
	Nqoe	Yes	Yes
Caledon	Phuthiatsana	From 2013	Yes
	Caledon	No	?
	Kraai	No	?
Val	Upper Vaal	No	Variable
	Mid-Vaal	No	Yes
	Lower Vaal	No	Yes
Molopo	Molopo	No	Yes
Fish	Fish	No	Yes
Orange	Orange	No	Yes
Estuary	Estuary	No	Yes
	Marine	No	Yes

4.1 Botswana

The Molopo sub-basin falls within the borders of Botswana. No information was found relating to the implementation of EFlows in the Molopo River.

4.2 Lesotho

The Senqu, Nqoe and Hololo and Phuthiatsana sub-basins fall within the borders of Lesotho.

Flow in the Senqu River is controlled by the infrastructure of the Lesotho Highlands Water Project, which currently comprises Katse Dam on the Malibamatso River, Matsoku Weir on the Matsoku River and Mohale Dam on the Senqunyane River. Construction is also underway for supporting infrastructure for a fourth dam, Polihali, on the upper Senqu River near Mhot. Flow in the Nqoe and Hololo Rivers is controlled by the Muela Hydropower Plant, which also forms part of the Lesotho Highlands Project.

In 2003, the Lesotho Highlands Develop Authority published an IFR Policy (LHDA 2003), which stipulated target conditions and associated EFlow requirements for nine river reaches (including Nqoe and Hololo Rivers), operating rules for EFlow releases from Katse and Mohale Dams, monitoring of both compliance to and efficacy of EFlow releases and provision for compensation payments to affected downstream communities. Implementation of the requirements of the IFR Policy began in 2003 and has continued since. Monitoring has also been on-going, if somewhat sporadic at times, with independent updates being conducted every 5 years or so (Southern Waters 2006; Afridev 2012 - ongoing). LHDA's implementation of its IFR Policy also passed an independent audit in 2005 (INR 2007). Polihali Dam is not covered by the existing IFR Policy (LHDA 2003).

From December 2013, flow in the Phuthiatsana River will be controlled by Metolong Dam. Metolong Authority, who are responsible for dam construction, have drafted an EF Policy (MA 2013), which stipulates the EFlows requirements at a downstream EFlow site, operating rules for EFlow releases from Metolong Dam, and monitoring of both compliance to and efficacy of EFlow releases. They also commissioned the collection of two-years of baseline hydrological, water quality and ecological data downstream of the Metolong Dam (Aurecon 2013) prior to closure. All indications are that the EF Policy will be endorsed and implemented following closure of Metolong Dam in December 2013.

4.3 Namibia

The Fish and Nossob sub-basins fall within the borders of Namibia. EFlows are being implemented in the Nossob River.

4.4 South Africa

The Vaal and Caledon sub-basins, and the Orange River mainstem, fall within the borders of South Africa. Implementation of EFlows (the Reserve) requires one of two legal steps following the Reserve assessment (DWAF 1998):

- If a Classification process has not been conducted in the basin/sub-basin of concern, the target category and the EWR required to meet it must be signed off by the Director of

Water Affairs or her representative. This is then known as a Preliminary Reserve, which denotes that it was signed off without having gone through a Classification Process (see Section 4.4).

- If a Classification process has been concluded in the basin, the agreed target categories and their EWRs and the Resource Quality Objectives are published in the Government Gazette and, pending public comment, are thereafter written into law.

Classification has been concluded for the Vaal sub-basin (DWA 2011), but the results have not yet been gazetted. However, the scenarios considered as part of the classification did not differ significantly from the present day operation of the system, and the recommendation was to set the Reserve at the present-day (2011) operation of the system. This would mean that, by definition, the Reserve is being met by present-day flows.

Classification has not yet been done for the Caledon and Orange Rivers.

In the next chapter, the overall situation for the Orange-Senqu Basin is evaluated.

5. Progress made towards EFlows implementation

This section is an evaluation of the EFlow-related work done in the Orange-Senqu Basin in the context of the key activities outlined in Section 2. Given the nature of the ToR, this evaluation is more detailed for the Ecosystem and Resource Use Tasks, but effort has been made to ensure that the information provided for the other tasks is as comprehensive as possible within the constraints of this review. General progress is summarised in Table 5.1.

Table 5.1 Summary of progress towards EFlow implementation.

Task No.	*Legal and administrative*	*Progress*	*Hydrology and water use*	*Progress*	*EFlows*
1	Synchronise legal pathways between member states	Not done	Collate/simulate basin daily hydrology	Done but may need revision	Delineate basin and identify river nodes to represent all parts of the basin
2	Establish national and basin administrative pathways and define line functions for EF implementation	Not done	Setup and calibrate water resource model	Done but may need revision	Collate EFlow work done (flow condition relationships)
3	Establish sources of funding and financial mechanisms for EF implementation	Not done	Run WR model		
4	Determine costs of EFlows implementation associated with each scenario	Not done	Assess economic costs and benefits of each scenario	Not done at basin level	Predict condition at each node/scenario
5	Align water-use licenses with available water	Not done	Calculate monthly volumes available for use with EFlows in place	Not done for EFlow implementation scenario	For each scenario, construct one or more basin-wide configurations of Eflows that must be met at each node
6	Develop compliance monitoring programme	Not done at basin level	Develop mechanisms for implementing environmental flows, such as dam operating rules, pumping schedules		Summarise ecosystem condition for each scenario

Task No.	*Legal and administrative*	*Progress*	*Hydrology and water use*	*Progress*	*EFlows*
7	Review and, if needed, upgrade monitoring infrastructure to provide real-time data	Not done at basin level	Monitor flow and abstractions and assess compliance	Senqu only	Value ecosystem services for each scenario
8	Implement mechanisms for EFlows	Senqu only			Specify flow regime and other resource quality objectives (RQOs) for each node
9	Implement monitoring and compliance programmes	Senqu only			Develop/collate EFlows monitoring programme
10	Implement adaptive management programme	Senqu only			Collect/collate baseline data and setup databases and report templates
11					Monitor and assess efficacy of EFlows in maintaining target ecosystem conditions

5.1 Phase 1: Preparation

In the Senqu Sub-basin, scenarios formed the basis for protracted negotiations between the Lesotho Highlands Development Authority, the World Bank, and the governments of Lesotho and South Africa, which led to agreements on the volume of water to be released from Phase 1 LHWP dams, the timing of releases, and the compensation payments to be made to people living downstream. We are unsure of the process for Phase 2 LHWP (Polihali Dam). In The Vaal Sub-basin, development and operational scenarios formed the basis of the Classification Process (see Section 4.4). ORASECOM has also recently commissioned a basin-wide scenario assessment, the details of which are not available at this time.

Note: The hydrology and water use, ecosystem and resource tasks as envisaged here are essentially those that comprise the South African Classification Process (DWAF 2006). Thus, the tool and procedures developed for Classification would be applicable. Importantly though, the classification process has been completed for the Vaal sub-basin, and for several other basins in South Africa, which means (i) much of the information needed is already available for a portion of the Orange-Senqu Basin, and (ii) additional work in the Orange-Senqu Basin should take note of lessons learnt in the classification processes completed to date.

Phase 1: Legal and administrative tasks

Task 1: Synchronise legal pathways between member state: This has not been done at a basin level.

Task 2: Establish administrative pathways and line functions for EFlows implementation: This has not been done at a basin level.

Task 3: Establish sources of funding and financial mechanisms for EFlows implementation: This has not been done at a basin level.

Task 4: Determine costs of EFlows implementation associated with each scenario: This has not been done at a basin level.

Phase 1: Hydrology and water use tasks

Task 1: Collate/simulate basin daily hydrology: This task has been completed for individual sub-basins, but these may need to be revisited and updated for the basin as a whole.

Task 2: Setup and calibrate water- resource model: This task has been completed for individual sub-basins, but these may need to be revisited and updated for the basin as a whole.

Task 3: Run WR model to simulate water use and EFlow at each scenario/node: This has not been done at a basin level.

Task 4: Assess economic costs and benefits of each scenario: This has not been done at a basin level.

Phase 1: Ecosystem and resource use tasks

Task 1: Delineate basin and identify river nodes to represent all parts of the basin: Delineation exercises have been completed for all of the main sub-basins, and in each of the studies the EFlow sites assessed were chosen on the basis of the results of the delineation. It may however be necessary to collate and synthesise these to create a cohesive basin-wide delineation to identify river nodes.

Task 2: Collate EFlow work done (flow-condition relationships): Relevant EFlow studies done in the Orange-Senqu Basin are summarised in Sections 3.1 and 3.5. For the most part these assessments were based on methods that define flow-condition relationships and can be used to assess scenarios.

Task 3: Identify gaps and extend EFlow information to all nodes: It is highly unlikely that any additional river EFlow assessments will be required, as long as the existing sites/data are of an acceptable quality. The existing sites more than adequately cover the basin, and would be sufficient to be able to extrapolate to other nodes if needed. Possible exceptions to this are the ephemeral and seasonal tributaries in the middle reaches of the Orange River.

Task 4: Predict condition at each node/scenario: This is dependent on the outcome of Phase 1 and, as such, has not yet been done for the basin as a whole.

Task 5: For each scenario, construct basin-wide configurations of EFlows to be met at each node: This has not been done for the Orange-Senqu River. The rapid review of the results of the EFlow assessments presented in Section 3.5 suggests that there are some serious volumetric mismatches between upstream and downstream sites and that this task should be afforded high priority.

Task 6: Summarise ecosystem condition for each scenario: This is dependent on the outcome of Phase 1 and, as such, has not yet been done for the basin as a whole.

Task 7: Value ecosystem services for each scenario: The EFlow assessment for the Senqu Sub-basin included detailed predictions of change in the value of ecosystem services with different flow scenarios (although the monitoring results to date indicate that some aspects have not responded as predicted). Similar analyses have not been done for the remainder of the Orange-Senqu Basin. It remains a contentious undertaking but is nonetheless an important component of scenario evaluations as it attempts to convey some of the losses in value associated with ecosystem decline.

5.2 Phase 2: Setup

Phase 2: Legal and administrative tasks

Task 5: Align water-use licenses with available water: This has not been done at a basin level.

Task 6: Develop compliance monitoring programme: This has not been done at a basin level.

Task 7: Review and, if needed, upgrade monitoring infrastructure to provide real-time data: This has not been done at a basin level.

Phase 2: Hydrology and water use tasks

Task 5: Calculate monthly volumes of water available for use with EFlows in place: Calculations of monthly volumes available for use formed part of some of the scenarios investigated during the various EFlow assessments, but this task would need to be redone, at a basin level, on the basis of the agreed EFlow implementation scenario.

Task 6: Develop mechanisms for implementing EFlows, such as dam operating rules, pumping schedules: The operating rules for several dams include consideration of EFlows, but these would need to be updated and synchronised to meet the EFlow implementation scenario. There are also diversion and pumping rules for many users, but these would need to be extended to other users and aligned to EFlows.

Phase 2: Ecosystem and resource use tasks

Task 8: Specify flow regime and other resource quality objectives (RQOs) for each node: This has been done for the Senqu and Vaal Sub-basins, but not for other parts of the basin.

Task 9: Develop/collate EFlows monitoring programme: EFlow monitoring programmes have been developed for the river in the Senqu and Vaal sub-basins and for other individual rivers in the basin, such as the Phuthiatsana River in the Caledon Sub-Basin. Recently a long-term monitoring programme (in collaboration with the South African Environmental Observation Network) was also designed to assess the efficacy of EFlows and other management interventions for the estuary. Depending on how the implementation of EFlows is organised in the basin (see Section 0), the EFlows monitoring programmes may require extension to other parts of the basin and synthesising to fit into a basin-wide programme.

Task 10: Collect/collate baseline data and setup databases and report templates: Baseline databases are available for the Senqu sub-basin and the Phuthiatsana River, and a baseline data collection programme was recently developed and implemented at the estuary. There have also been varying levels of data collected in other sub-basins, which could contribute towards a useful baseline data set. Depending on how the implementation of EFlows is organised in the basin (see Section 0), the datasets and report templates may require some adjustments to fit into a basin-wide programme.

5.3 Phase 3: Compliance and integration

The state of implementation of EFlows in the basin states, which covers many of the activities in this phase, is discussed in Section 4.

Phase 3: Legal and administrative tasks

Task 8: Implement mechanisms for EFlows: In the Senqu Sub-basin, all LHWP dams make EFlow releases in accordance with a set of operating rules that are summarized in the IFR Policy. In the Vaal Sub-basin, the recent Classification Process reportedly (Delana Louw, RfA, pers. comm.) concluded that the Reserve (EFlows) would be set at 2011 flow (i.e., Present Day flows at the time of the study), which presumably means that the operating and pumping rules that apply there are sufficient to meet the requirements for the EFlows, although this assumption requires verification. The extent to which mechanisms for EFlows have been implemented in the remaining parts of the basin is not obvious. To our knowledge, mechanisms for EFlows have not been implemented in the Caledon sub-basin, although this will change for the Phuthiatsana River once Metolong Dam is completed. There have been some attempts to implement dam operating rules to provide EFlows for the lower Orange River, but it is not clear that these have been successful, and there is no implementation in the remainder of the basin.

Task 9: Implement monitoring and compliance programmes: In the Senqu Sub-basin, a compliance and monitoring programme has been underway since 2003, with independent updates being conducted every 5 years (see Section 4.3). To the best of our knowledge there are no other ongoing EFlow compliance and monitoring programmes in the basin.

Task 10: Implement adaptive management programme: Adaptive management underlies the EFlow implementation in the Senqu Sub-basin. After nearly 10 years of EFlow implementation in the Senqu sub-basin, LHWA has recently commissioned a review of the EFlows based on an assessment of the extent to which they have achieved the ecological targets set in its IFR Policy

(LHDA 2003). To our knowledge there are no other ongoing EFlow adaptive management programmes in the basin.

Phase 3: Hydrology and water use tasks

Task 7: Monitor flow and abstractions and assess compliance: As mentioned above, a compliance and monitoring programme has been underway in the Senqu Sub-basin, since 2003. Although flow monitoring, and some abstraction monitoring, is also ongoing in most of the other sub-basins, this is not targeted specifically towards assessing compliance with EFlows.

Phase 3: Ecosystem and resource use tasks

Task 11: Monitor and assess efficacy of EFlows in maintaining target ecosystem conditions: As mentioned above, a compliance and monitoring programme has been underway in the Senqu Sub-basin, since 2003, with independent updates being conducted every 5 years (see Section 4.3).

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